CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

RS&H

City of Hallandale Beach Vulnerability and Adaptation Plan

June 30, 2020
RS&H No.: 301-0068-000

Prepared by RS&H, Inc. at the direction of the City of Hallandale Beach

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RS&H

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February 28, 2020
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1. SUMMARY

This document provides an inventory of the hazard data gathered for the vulnerability assessment. Four types of flooding-related hazards are considered in the vulnerability assessment: Federal Emergency Management Agency (FEMA) flood zones, storm surge, sea level rise and high tide flooding. For each of these hazards, we use the most up-to-date nationally available datasets from federal sources. No additional modeling is performed by FernLeaf Interactive.

1.1 FEMA FLOOD ZONES

In coastal areas like Hallandale Beach, FEMA Flood Zones represent a combination of rainfall-induced and storm surge flooding.

The assessment uses the most recent floodway, wave action, 100-year and 500- year floodplains developed by FEMA to support the the National Flood Insurance Program (National Flood Hazard Layer (NFHL) Id 12011C; effective on 8/18/2014).

Depth grids are not available for FEMA flood zones.

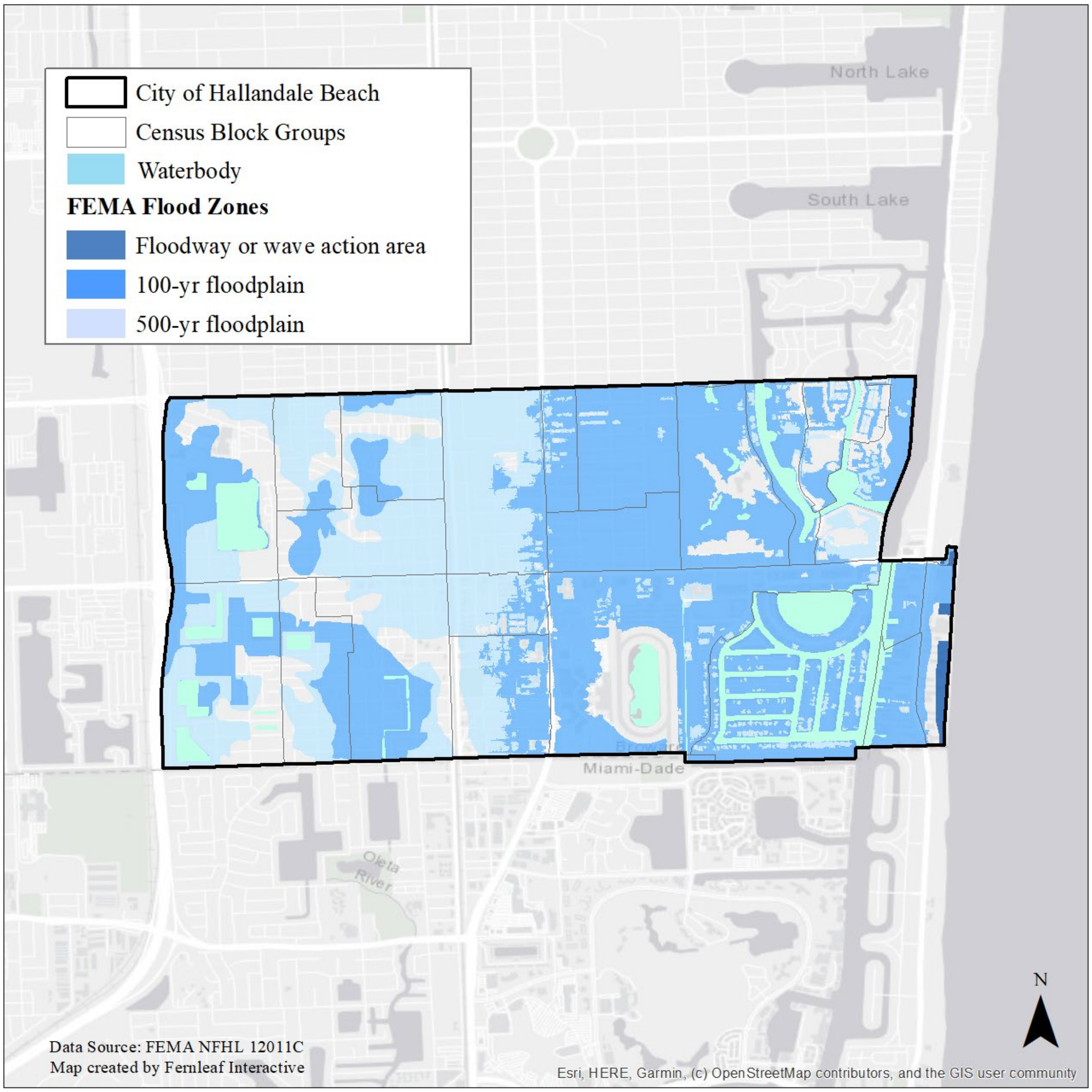

FIGURE 1: CITY OF HALLANDALE BEACH FEMA FLOOD ZONES

1.2 STORM SURGE FLOODING

Flooding caused by an abnormal rise in tide from a severe storm (e.g. a hurricane) over and above the usual, astronomical tide.

The assessment uses the Sea Lake and Overland Surge from Hurricanes (SLOSH) Maximum of the Maximum Enveloped of Water (MOM) layer for hurricane categories 1-5, developed by the National Oceanic Atmospheric Administration (NOAA) National Weather Service's National Hurricane Center. This layer represents a "worst case" scenario of flooding resulting from an "ideal" storm. Figure 2 shows storm surge inundation for Category 1, Category 2-3 and Category 4-5 storms.

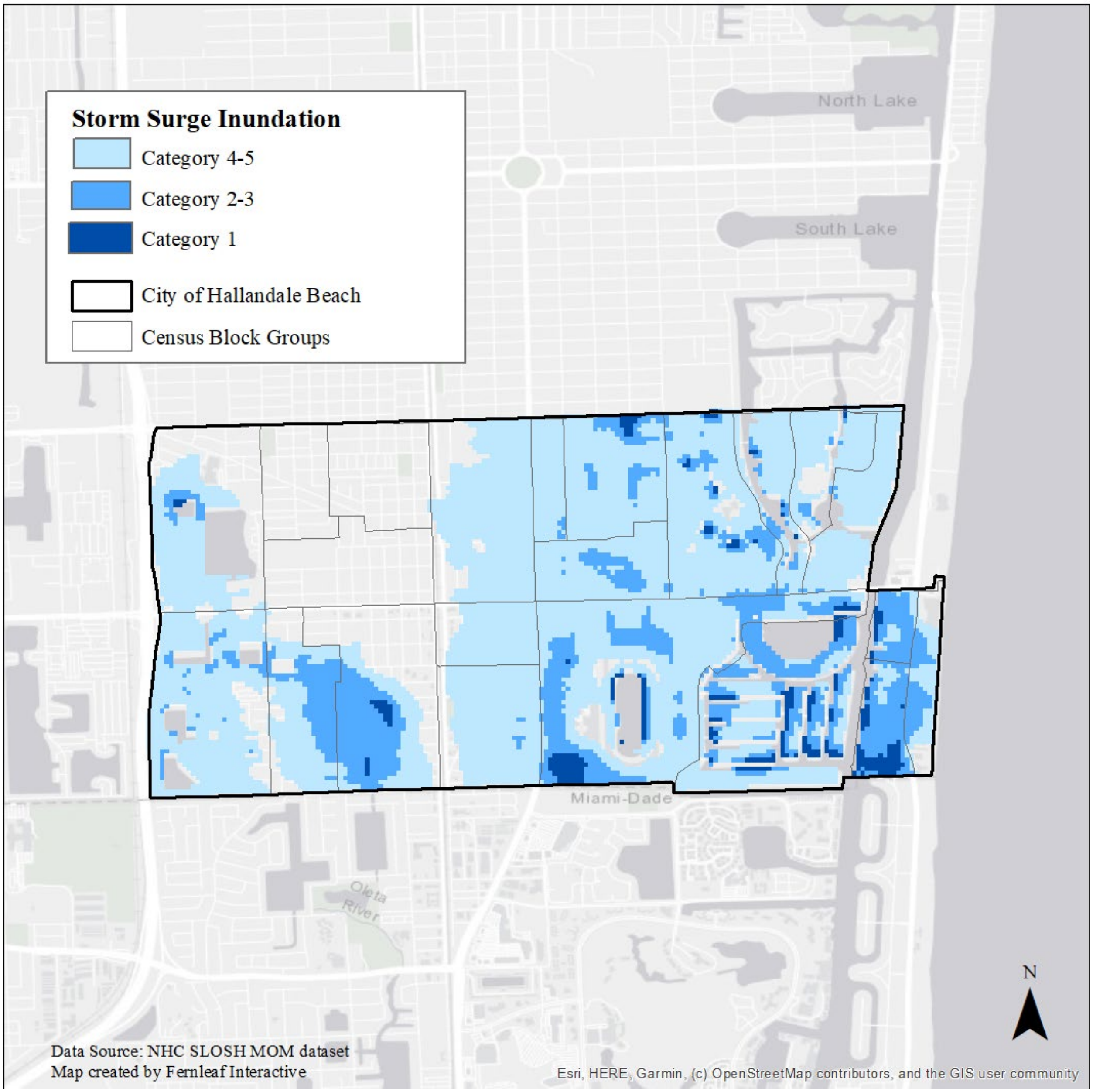

FIGURE 2: CITY OF HALLANDALE BEACH STORM SURGE INUNDATION BY HURRICANE CATEGORY

Figures 3 – 5 show inundation depth grids for Category 1 – 5 storms, respectively.

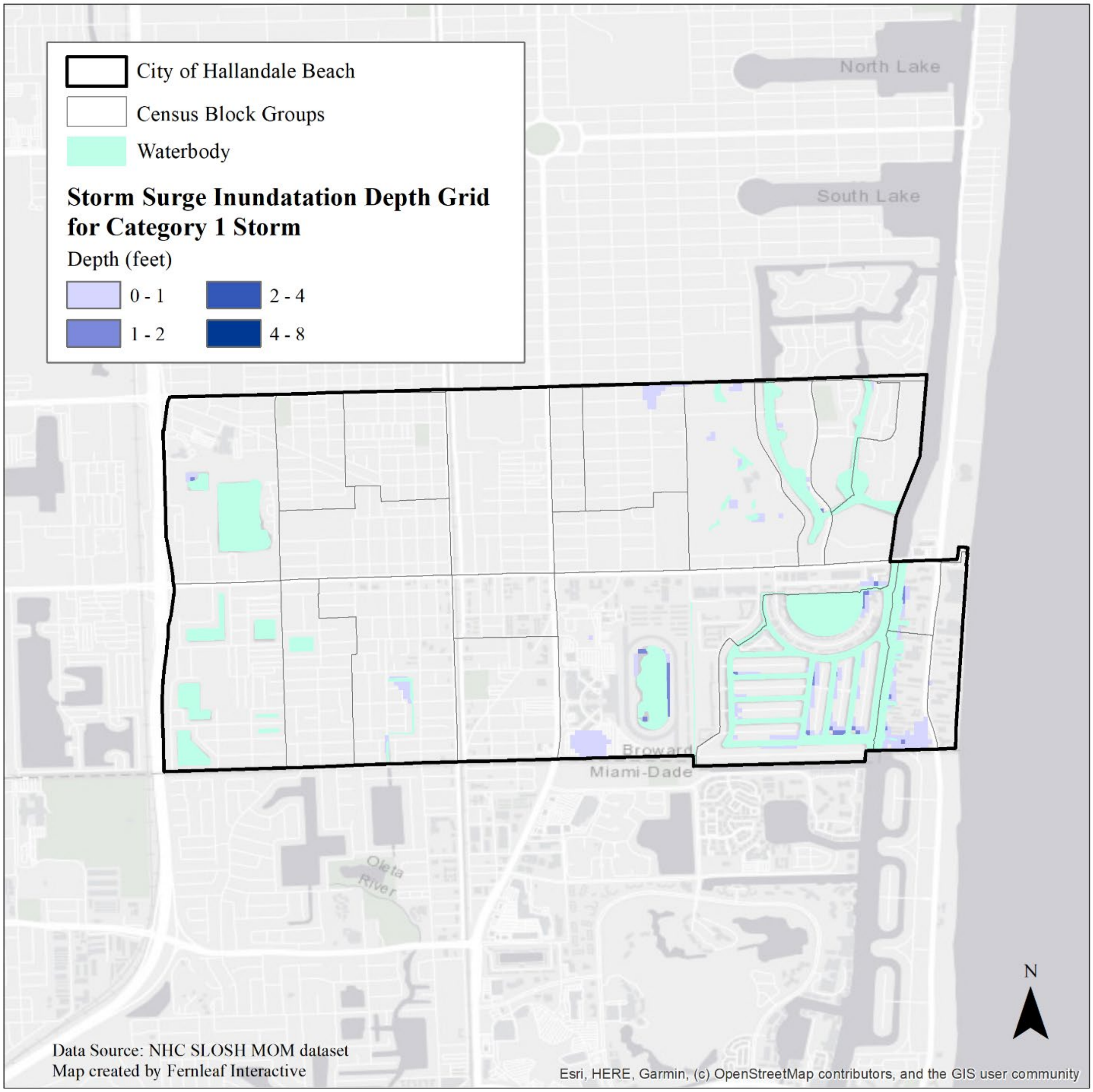

FIGURE 3: STORM SURGE INNUNDATION DEPTH GRID, CATEGORY 1 STORM

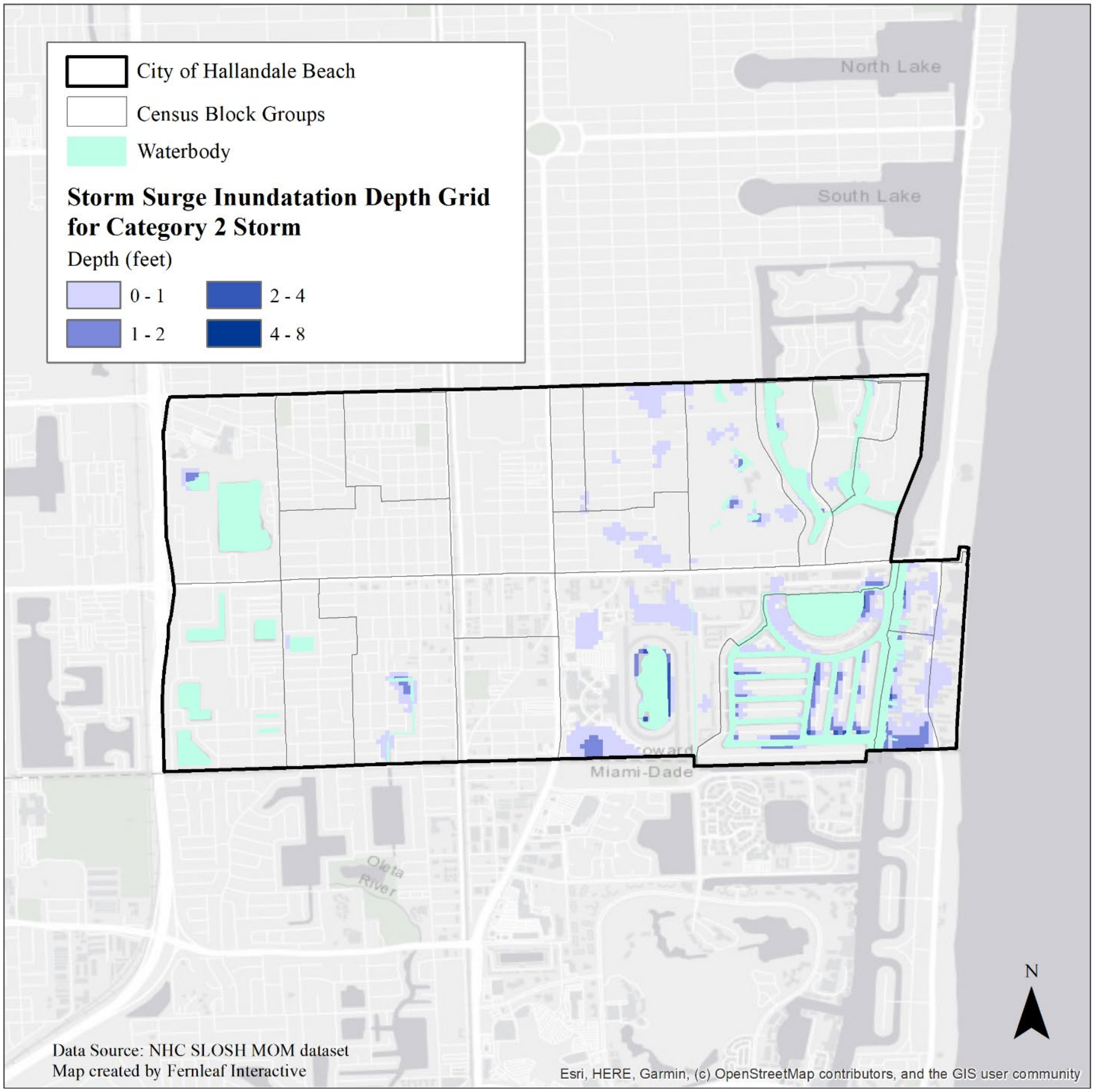

FIGURE 4: STORM SURGE INNUNDATION DEPTH GRID, CATEGORY 2 STORM

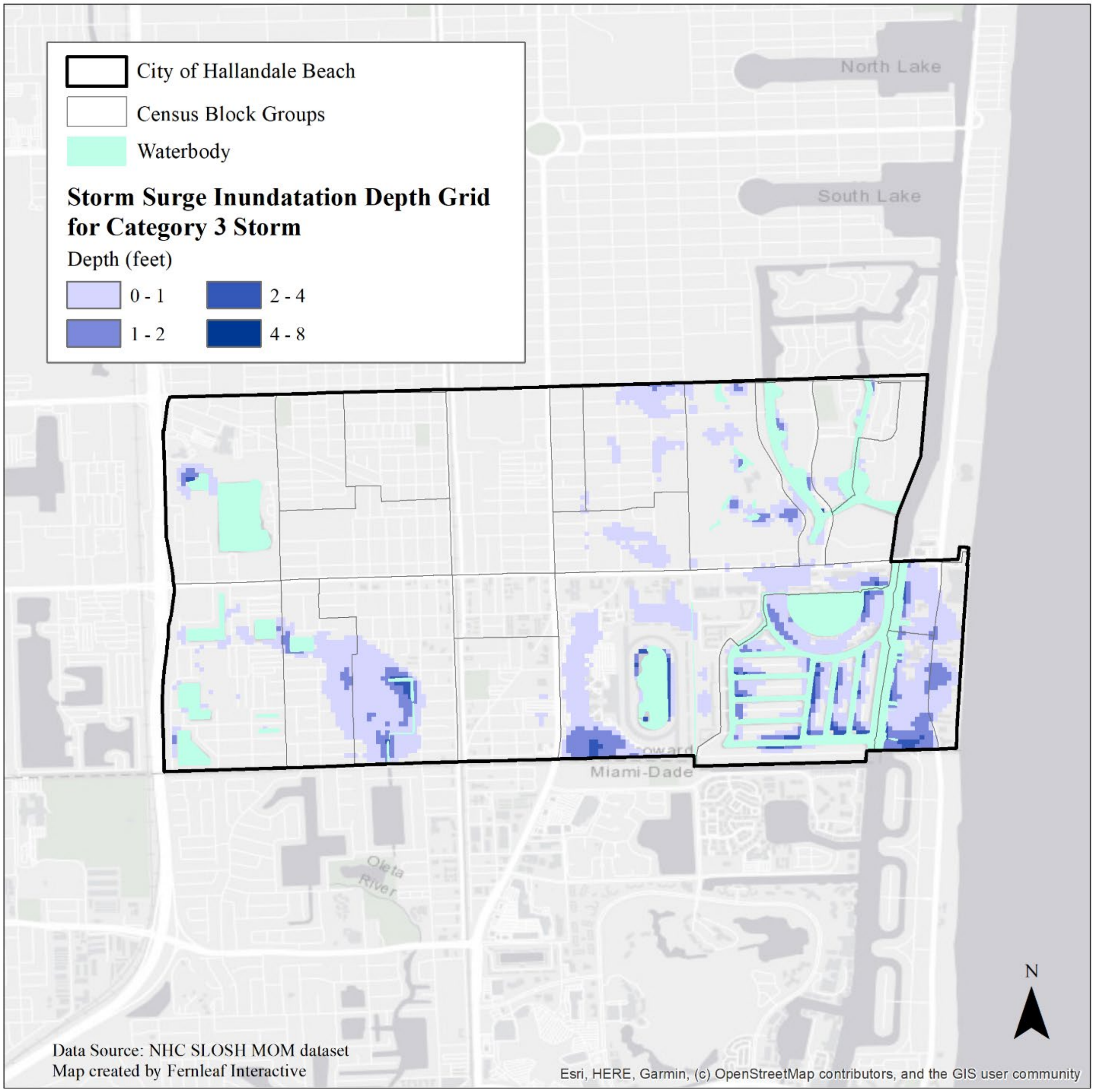

FIGURE 5: STORM SURGE INNUNDATION DEPTH GRID, CATEGORY 3 STORM

FIGURE 6: STORM SURGE INNUNDATION DEPTH GRID, CATEGORY 4 STORM

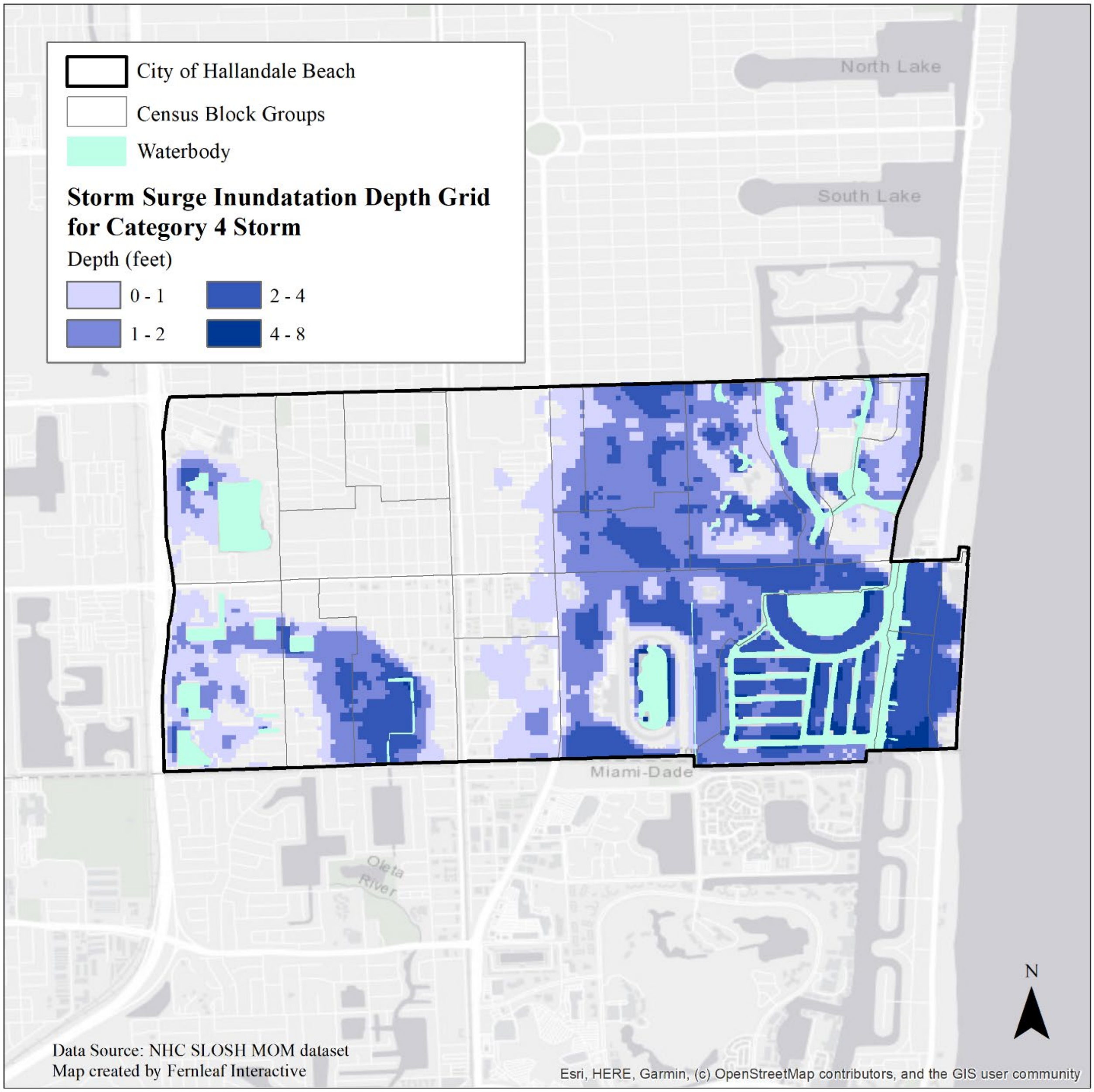

FIGURE 7: STORM SURGE INNUNDATION DEPTH GRID, CATEGORY 5 STORM

1.4 SEA LEVEL RISE

The relative rise of the local mean sea level over time. Sea level rise can cause permanent inundation as well as an increase in frequency and severity of future tidal flooding.

The assessment uses the NOAA Sea Level Rise Viewer dataset, including inundation extents for up to 10 feet mapped using a "modified bath-tub approach". Based on the 2019 SLR curves developed by the SE Florida Regional Climate Change Compact and the City's feedback, we chose two sets of sea level rise levels for the analysis: 1, 2 and 3 ft for the near-term and 2, 4 and 5 ft for medium/long- term.

Depth grids are not available for sea level rise.

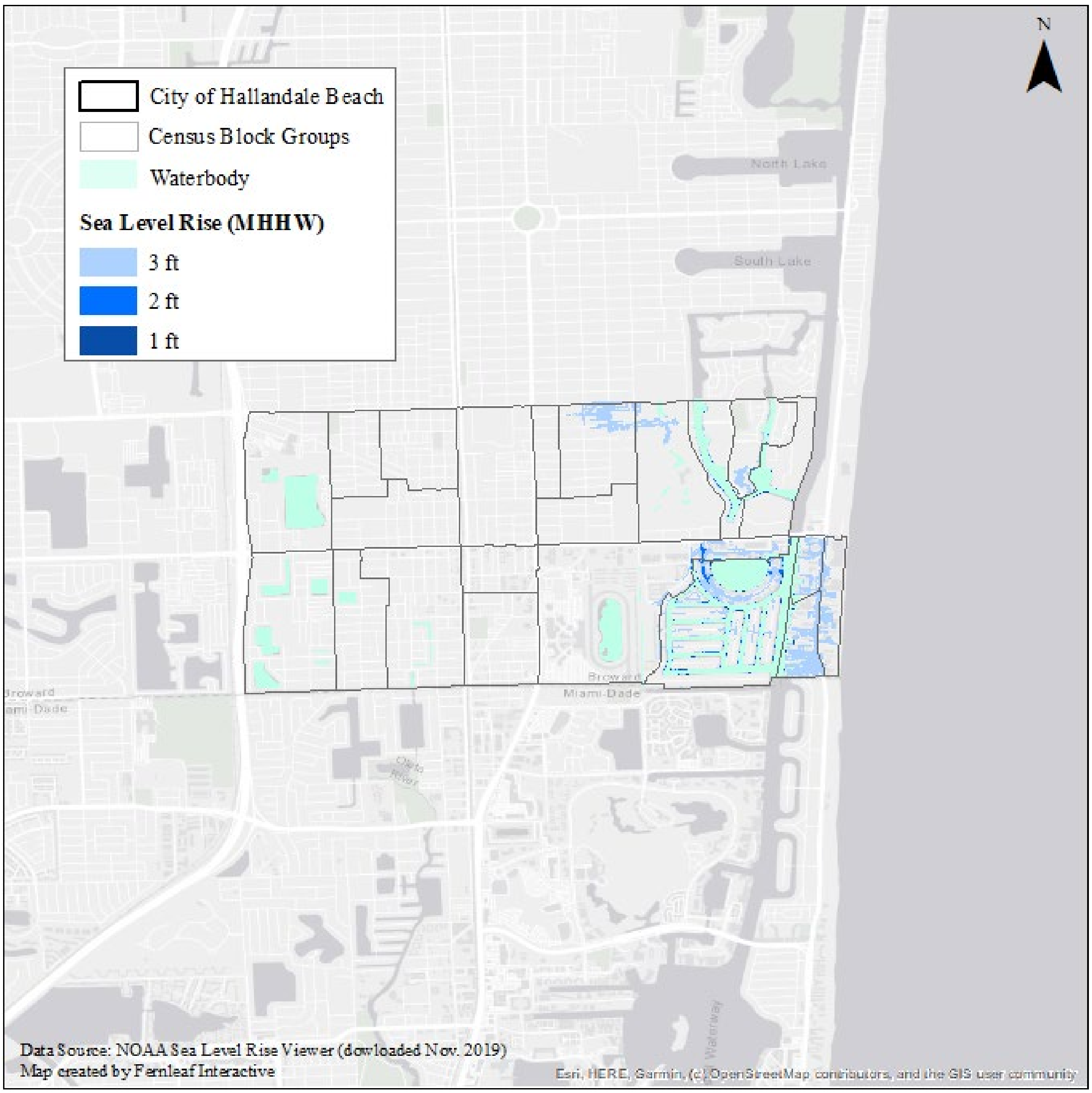

FIGURE 8: CITY OF HALLANDALE BEACH NEAR-TERM 1, 2- AND 3-FOOT SEA LEVEL RISE INUNDATION EXTENTS

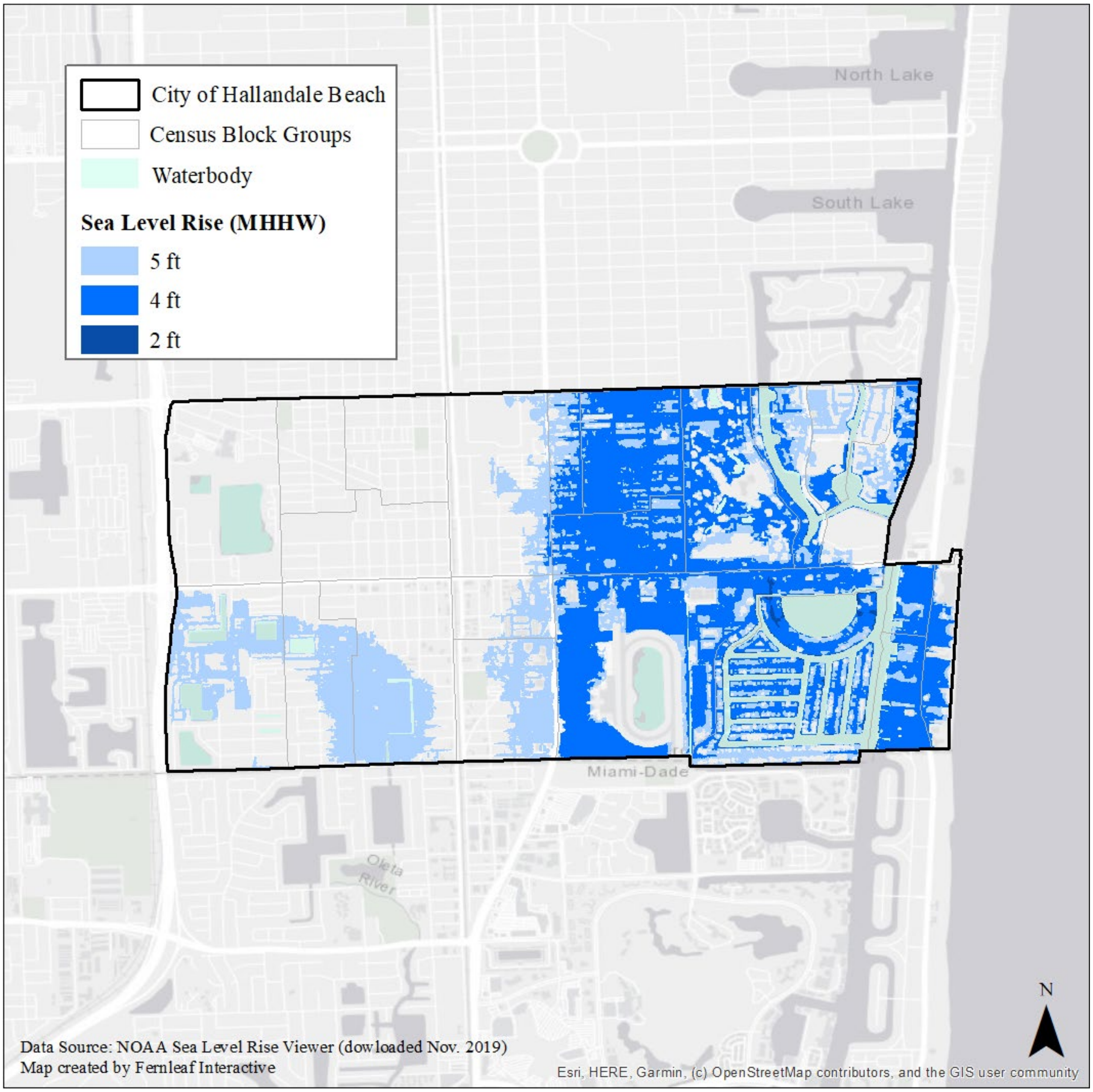

FIGURE 9: CITY OF HALLANDALE BEACH MID- TO LONG-TERM 2, 4- AND 5-FOOT SEA-LEVEL RISE INUNDATION EXTENTS

1.5 TIDAL FLOODING

Tidal flooding is flooding of the low-lying land along the coastline from a high tide that is not associated with a major storm. Tidal flooding is also referred to as “high tide”, “sunny day”, or ”nuisance” flooding.

The assessment uses the “High Tide Flooding” layer produced by NOAA.

Depth grids are not available for tidal flooding.

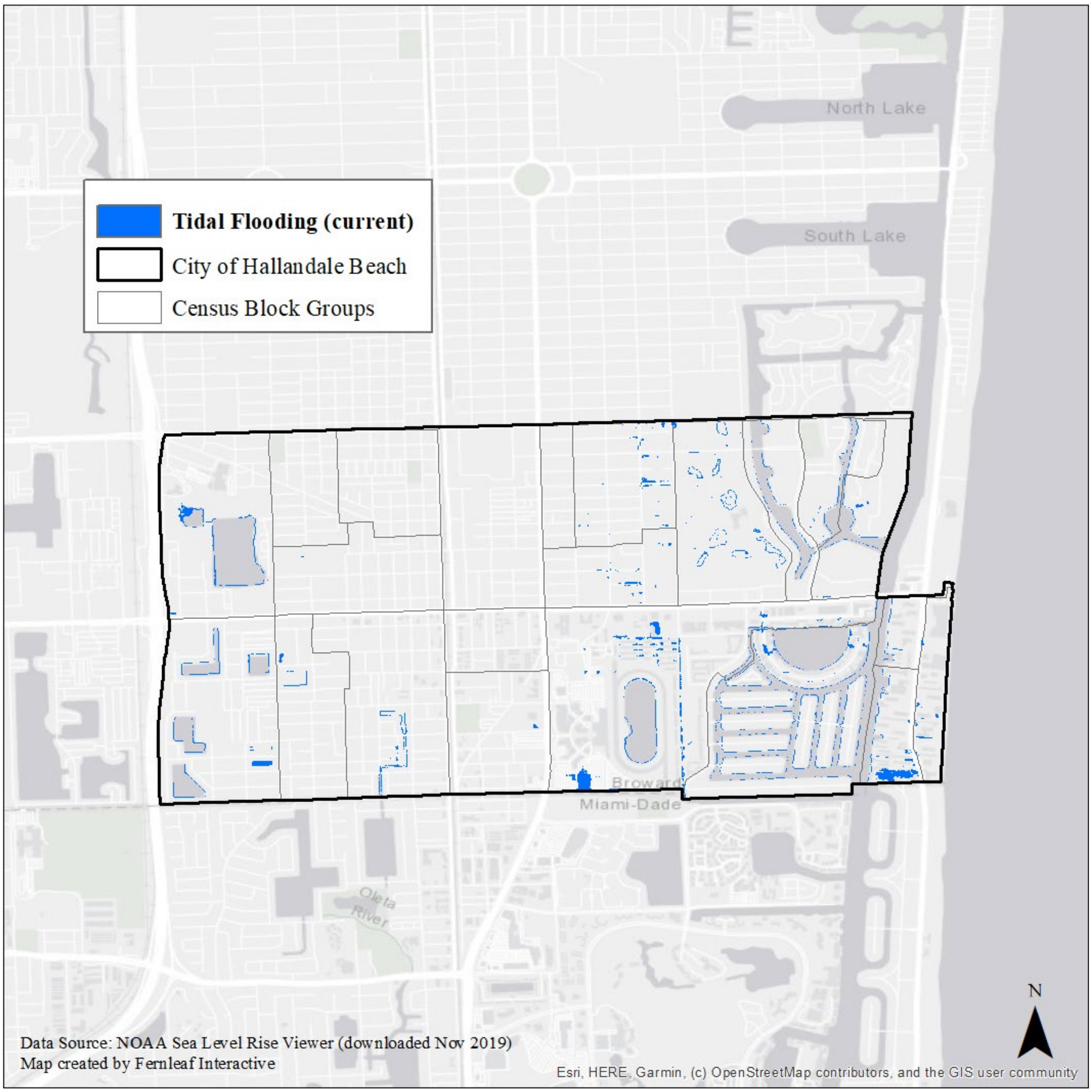

FIGURE 10: CITY OF HALLANDALE BEACH CURRENT TIDAL FLOODING

2. FLOOD AREA AND FREQUENCY

AccelAdapt uses a parcel-based rather than an area-based methodology. However, flood area extents were calculated for the flood types included in the analysis and displayed in AccelAdapt. This allowed the percentage of the total City area affected to be calculated.

The frequency of the various flood types is discussed in terms of recurrence intervals, where it makes sense to do so. Some flood types, such as sea level rise contribute to increased frequency of other flood types, such as storm surge and tidal flooding. Projections of changes in frequency of most flood types are subject to uncertainty.

1.6 FLOOD AREA

Flood areas were calculated in acreage and as a percentage of the total area of the City for each of the flood layers mapped, including FEMA Flood Zones, Storm Surge, Near-term Sea Level Rise, Mid/Long-term Sea Level Rise, and Tidal Flooding. Flood area calculations were performed using Geographical Information Systems (GIS) software and should be regarded as approximate. GIS-based area calculations vary in accuracy depending on the map projection used, with equal-area projections providing the best results. An Albers Equal Area map projection was used to perform flood area calculations.

1.6.1 FEMA Flood Zones

FEMA identifies areas on its Flood Insurance Rate Maps as Special Flood Hazard Areas (SFHA) if there is a 1% or greater risk that they will be flooded in any given year. A flood with a 1% annual probability is also called a 100-year flood, or a base flood. For the purposes of this study flood with a 100-year and 500-year return probability were considered. Note that FEMA flood zones include heavy or extreme precipitation among the various factors used in determining the flood area.

Approximately 83.5% of the City’s area is located in a SHFA. Table 1: City Area within FlooD ZoneS below shows acreage and percentage of total City area located in the 100-year and 500-year flood zones.

TABLE 1: CITY AREA WITHIN FLOOD ZONES

Type of Flooding	Description	Area Inundated (Acres)	Percent of Total City Area
FEMA SFHA	100-year	1545.1	54.92%
	500-year	804.2	28.58%

1.6.3 Storm Surge

Storms surge flooding was modeled for Category 1 through 5 hurricanes. The analysis uses the SLOSH MOMs to model an ideal storm under a worst-case scenario. Table 2 shows area inundated in acres and percent of total City area for each depth range of flooding under each hurricane category rating.

TABLE 2: CITY AREA SUBJECT TO STORM SURGE BY HURRICANE CATEGORY

Type of Flooding	Depth of inundation (Feet)	Area Inundated (Acres)	Percent of Total City Area
Storm Surge, Category 1	0-1'	81.8	2.91%
	1-2'	10.0	0.36%
Storm Surge, Category 2	0-1'	230.0	8.17%
	1-2'	50.3	1.79%
	2-3'	6.4	0.23%
Storm Surge, Category 3	0-1'	454.1	16.14%
	1-2'	121.6	4.32%
	2-3'	26.7	0.95%
	3-4'	0.7	0.02%
Storm Surge, Category 4	0-1'	551.1	19.59%
	1-2'	678.3	24.11%
	2-3'	417.9	14.85%
	3-4'	161.0	5.72%
	4-5'	38.5	1.37%
	5-6'	6.7	0.24%
Storm Surge, Category 5	0-1'	315.8	11.22%
	1-2'	451.9	16.06%
	2-3'	607.1	21.58%
	3-4'	636.3	22.61%
	4-5'	270.0	9.60%
	5-6'	75.8	2.70%
	6-7'	20.5	0.73%
	7-8'	0.9	0.03%

1.6.4 Sea Level Rise

Sea level rise flooding was modeled for two scenarios, near-term and mid/long-term. Table 3shows area inundated in acres and percent of total City area for each depth range of flooding under each sea level rise scenario.

TABLE 3: CITY AREA INNUNDATED BY SEA LEVEL RISE, NEAR-TERM AND MID/LONG-TERM

Type of Flooding	Depth of inundation (Feet)	Area Inundated (Acres)	Percent of Total City Area
Sea Level Rise, Near Term	0-1'	116.5	4.14%
	1-2'	11.9	0.42%
	2-3'	154.1	5.48%
Sea Level Rise, Mid/Long Term	0-1'	594.7	21.14%
	1-2'	658.6	23.41%
	2-3'	165.1	5.87%

1.6.5 Tidal Flooding

Tidal flooding uses NOAA's "High Tide Flooding" layer. This is current condition tidal flooding, i.e. it does not project future tidal flooding conditions. The layer does not show flood depths, rather it indicates whether an area is inundated. Table 4 shows the area in acres and percentage of the City as a whole inundated by current condition tidal flooding, as well as the area and percentage of the City unaffected.

TABLE 4: CITY AREA SUBJECT TO CURRENT CONDITION TIDAL FLOODING

Type of Flooding	Description	Area Inundated (Acres)	Percent of Total City Area
Tidal Flooding (Current Condition)	Inundated	65.5	2.33%
	Not Inundated	2,748.1	97.67%

1.7 FLOOD FREQUENCY

Flood frequencies are best represented through annual probabilities of occurrence for floods of a given magnitude. Climate change will have the effect of decreasing the recurrence intervals for many types of flooding.

1.7.1 FEMA Flood Zones

In coastal areas such as the City, FEMA Flood Zones include flooding related to both extreme precipitation and storm surge. See the Task 3 Memo, "Future Precipitation Analysis" for discussion of climate projections regarding the frequency of extreme precipitation events. Frequency of storm surge flooding is discussed in Section 1.2.2, below.

FEMA flood zones are characterized by the probable frequency of flooding occurring over a given time period. A 100-year flood has a 1% and a 500-year flood has a 0.2% chance of occurring annually.

Flooding related to precipitation occurs when urban drainage systems are overwhelmed by storm water as a result of an extreme rainfall event. Storm surge flooding results in unusually high tides associated with a severe storm, such as a tropical depression or hurricane.

Flood hazards are subject to frequent change due to changes in weather patterns, erosion, and development. FEMA does not update flood maps on a regular schedule, but on an as-needed basis as flood hazard change. Flood maps are not forward-looking, but are based on current conditions.

1.7.2 Storm Surge

The frequency of storm surge inundation events is related to several factors: the frequency and intensity of hurricanes and other severe storms, and sea level rise. As sea level rises, the base tidal level will increase, resulting in higher storm surge elevations.

The September 2018 Coastal Storm Surge Risk Assessment produced for Broward County, indicates higher sea levels along the Broward coastline will result in increased risk of flooding due to both storm surge and high tide events. Additionally, climate change may contribute to higher frequencies of tropical storms, and related storm surge events (RMS Coastal Storm Surge Risk Assessment, Risk Management Solutions, September 2018).

The report found that for nearby Fort Lauderdale and Hollywood beaches, the storm surge height would increase linearly at approximately the same rate as sea level, i.e. a one foot increase in sea level would also result in a one foot increase in storm surge. The data shows that the recurrent interval for a storm surge of a given depth would decrease by approximately 50% corresponding to each foot of sea level rise. For instance, under current conditions an 8.8 foot storm surge would be expected to occur at the city of Hollywood's North Beach every 500 years. However, with one foot of sea level rise, the probability of occurrence drops to once every 250 years, at two feet once every 100 years, and at 3 feet once every 50 years. This approximate rule is likely also valid for the City of Hallandale Beach.

1.7.3 Sea Level Rise

Sea level rise flooding was modeled for two scenarios (near-term and mid/long-term) based on the Southeast Florida Regional Climate Change Compact's 2019 projections. Sea level rise is projected to be a steady, gradual increase that results in permanent flooding. It is not subject to variations in frequency over relevant timescales.

The projection indicates:

- Short term, by 2040, sea level is projected to rise 10 to 17 inches (0.8 to 1.4 feet) above 2000 mean sea level.
- Mid/Long term, by 2070, sea level is projected to rise 21 to 54 inches (1.75 to 4.5 feet) above 2000 mean sea level.

1.7.4 Tidal Flooding

The assessment is based on NOAA's "High Tide Flooding" layer which represents current tidal flooding and does not project future changes. Like storm surge, tidal flooding will increase as a result of increasing sea level. The National Climate Assessment states that, "By 2050, many Southeast cities are projected to experience more than 30 days of high tide flooding regardless of [emissions] scenario." (Carter, L., et. al., 2018: Southeast Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 743–808. doi: 10.7930/NCA4.2018.CH19)

NOAA projects that the nearby Virginia Key tidal gauge will experience about 30 days of tidal flooding per year by 2100, based on a low emissions scenario and a derived high tide level of 0.53 meters. (NOAA Technical Report NOS CO-OPS 086: Patterns and Projections of High Tide Flooding along the U.S. Coastline Using a Common Impact Threshold, NOAA Center for Operational Oceanographic Products and Services, February 2018).

However, under an intermediate-low scenario, tidal flooding would be nearly 200 days per year by 2100, while intermediate, intermediate high, and high scenarios would see 200 days of flooding per year by 2055, 2045 and 2035, respectively. At intermediate scenarios and above, the location is flooded year-round from 2070 onwards. Figure 6 shows projected number of days per year for tidal flooding at Virginia Key for various emissions scenarios.

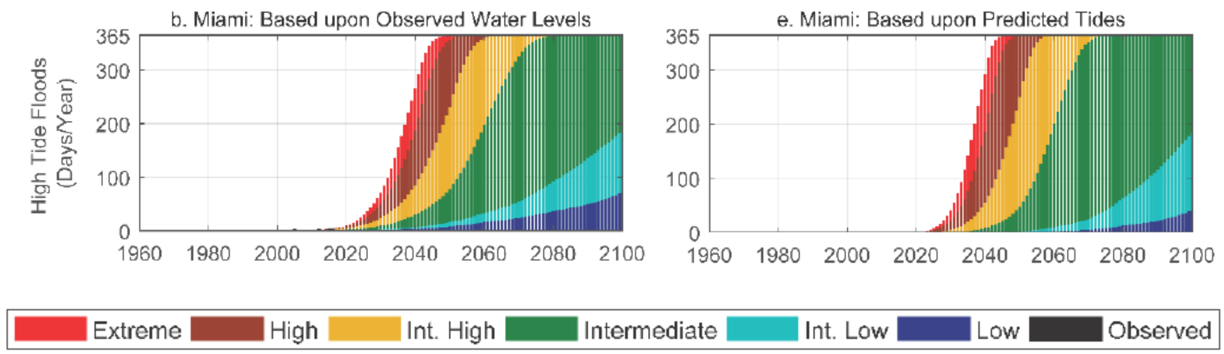

FIGURE 11: PROJECTED TIDAL FLOODING FREQUENCIES AT VIRGINIA KEY, MIAMI (SOURCE: NOAA

3. TECHNICAL DOCUMENTATION: FLOOD HAZARD DATA

This document provides information about the geospatial hazard data gathered for the vulnerability assessment. Four types of flooding-related hazards are considered in the vulnerability assessment:

- Federal Emergency Management Agency (FEMA) flood zones,
- Storm surge,
- Sea level rise, and
- Tidal flooding

For each of these hazards, we downloaded the most up-to-date nationally available datasets from federal sources (see details below). Links to further technical documentation from various federal agencies are also provided below. No additional flood modeling was performed by FernLeaf Interactive. Rather, the team conducted extensive spatial analysis using this geospatial hazard data as well as other existing data provided by the City of Hallandale Beach, such as property parcel GIS data and the location of city facilities.

This analysis was conducted in four stages:

1. Asset (parcel) data normalization and categorization
2. Spatial relation of individual assets to each hazard layer
3. Application of asset-scale vulnerability and risk rulesets
4. Aggregation of vulnerable and at-risk assets to census tracts

Further details about the assessment approach for each flood hazard are included in the Technical Documentation for Task 2.

1.8 FEMA FLOOD ZONES

In coastal areas like Hallandale Beach, FEMA Flood Zones represent a combination of rainfall-induced and storm surge flooding.

Dataset Used: The assessment uses the most recent floodway, wave action, 100-year and 500-year floodplains developed by FEMA to support the National Flood Insurance Program (National Flood Hazard Layer (NFHL) Id 12011C; effective on 8/18/2014).

FEMA technical documentation: https://www.fema.gov/media-library-data/1556727977591-8b087b84083bda804143de635df0d5d6/FIRM_Database_Technical_Reference_Feb_2019.pdf

1.9 STORM SURGE FLOODING

Flooding caused by an abnormal rise in tide from a severe storm (e.g. a hurricane) over and above the usual, astronomical tide.

Dataset Used: The assessment uses the Sea Lake and Overland Surge from Hurricanes (SLOSH) Maximum of the Maximum Enveloped of Water (MOM) layer for hurricane categories 1-5, developed by the National Oceanic Atmospheric Administration (NOAA) National Weather Service's National Hurricane Center. This dataset represents the scale of potential "near worst case" flooding from hypothetical "ideal" storms.

NOAA Storm Surge Technical Documentation: https://www.nhc.noaa.gov/surge/slosh.php#MODELING

1.10 SEA LEVEL RISE

The relative rise of the local mean sea level over time. Sea level rise can cause permanent inundation as well as an increase in frequency and severity of future tidal flooding.

Dataset Used: NOAA Sea Level Rise Viewer dataset includes inundation extents for up to 10 ft that were mapped using a "modified bath-tub approach". Based on the 2019 SLR curves developed by the SE Florida Regional Climate Change Compact and the City's feedback, we chose two sets of sea level rise levels for the analysis: 1 and 2 ft for the near-term and 2, 4 and 5 ft for medium to long- term.

NOAA Sea Level Rise Technical Documentation: https://coast.noaa.gov/data/digitalcoast/pdf/slr-inundation-methods.pdf

1.11 TIDAL FLOODING

Tidal flooding is flooding of the low-lying land along the coastline from a high tide that is not associated with a major storm. Tidal flooding is also referred to as "high tide", "sunny day", or "nuisance" flooding.

Dataset Used: The "High Tide Flooding" layer produced by NOAA for its Sea Level Rise Viewer is used to assess vulnerability and risk to current high tide flooding.

NOAA Technical Documentation: https://coast.noaa.gov/data/digitalcoast/pdf/slr-high-tide-flooding.pdf

CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 2: FLOOD VULNERABILITY / LOSS ASSESSMENTS

RS&H

City of Hallandale Beach Vulnerability and Adaptation Plan

TASK 2: FLOOD VULNERABILITY / LOSS ASSESSMENTS

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RS&H No.: 301-0068-000

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TABLE OF CONTENTS

1. SUMMARY

This document includes flood exposure assessment and economic loss analysis for commercial and city-owned building assets.

GIS imagery of asset risk and vulnerability for each of four flood conditions are provided in Section 2: Flood Vulnerability. This section also includes tables and short discussions of vulnerabilities, highlighting key at risk assets.

Estimated direct and indirect economic losses for both existing and future conditions, including loss by return period / annualized loss for each flood type are summarized in Section 3: Potential Economic Loss. Economic loss estimates are based on impacts to building stock / essential facilities. This section also includes summary of demographic effects associated with economic losses and existing and future flood scenarios.

Technical Documentation is provided in Section 4, including a description of asset vulnerability GIS layers.

Further flood vulnerability and associated estimates of potential economic loss is available via the AccelAdapt tool, a web-based geospatial database developed for Hallandale Beach as part of project deliverables (See Appendix).

2. FLOOD VULNERABILITY

This section uses GIS imagery and tabular summaries to describe current and future risk and vulnerability in the City of Hallandale Beach to four types of flooding-related hazards: FEMA flood zones, storm surge, sea level rise (2 time horizons) and tidal flooding. FEMA flood zones, storm surge and tidal flooding represent current conditions. Sea level rise is a future condition. The scope for this analysis is limited to commercial and city-owned properties. A similar assessment for residential properties would provide additional insight into comprehensive asset vulnerabilities in the city.

The maps below show the distribution of commercial and city-owned properties across the City of Hallandale Beach aggregated for each census block group. Commercial property includes non-residential properties that serve businesses, organizations and industries. They typically support commerce, jobs, and tourism in the community. The assessment used the 2018 parcel data from the Department of Revenue.

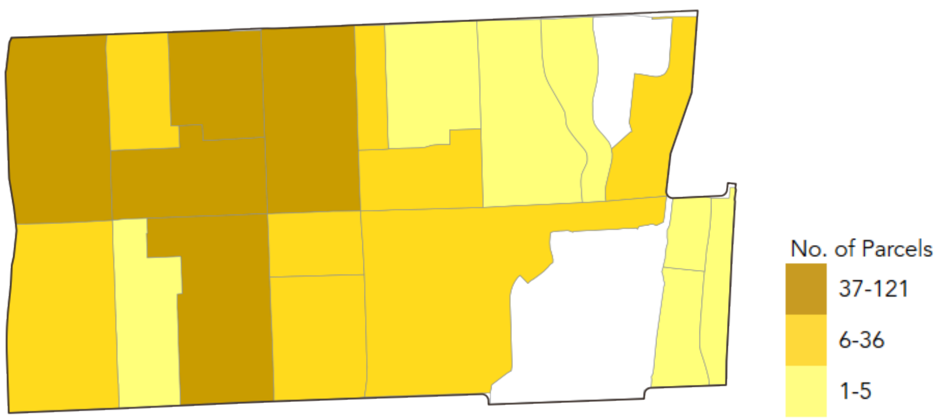


FIGURE 1: COUNT OF COMMERCIAL PARCELS BY CENSUS BLOCK GROUP

City-owned property includes City of Hallandale Beach facilities (n= 21) such as parks, fire stations, and city hall as well as other city-owned parcels.

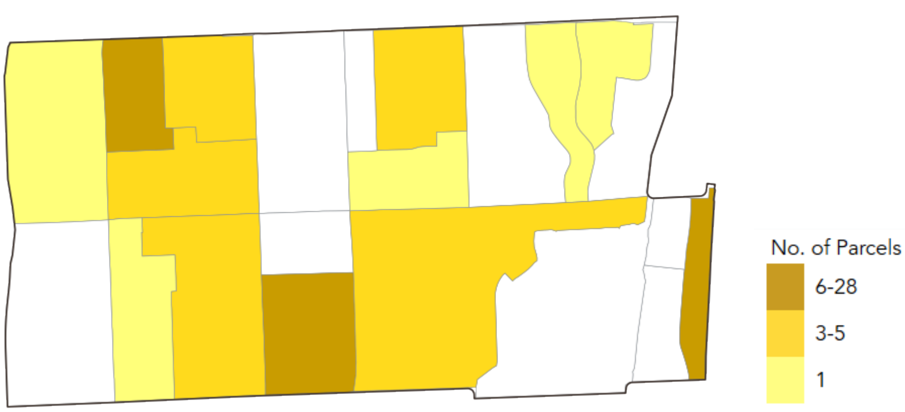


FIGURE 2: COUNT OF CITY-OWNED PARCELS BY CENSUS BLOCK GROUP

2.1 FEMA FLOOD ZONES

In coastal areas like Hallandale Beach, FEMA Flood Zones represent a combination of rainfall-induced and storm surge flooding. The assessment used the most recent floodway, wave action, 100-year and 500-year floodplains developed by FEMA to support the National Flood Insurance Program (National Flood Hazard Layer (NFHL) Id 12011C; effective on 8/18/2014).

2.1.1 Commercial Property

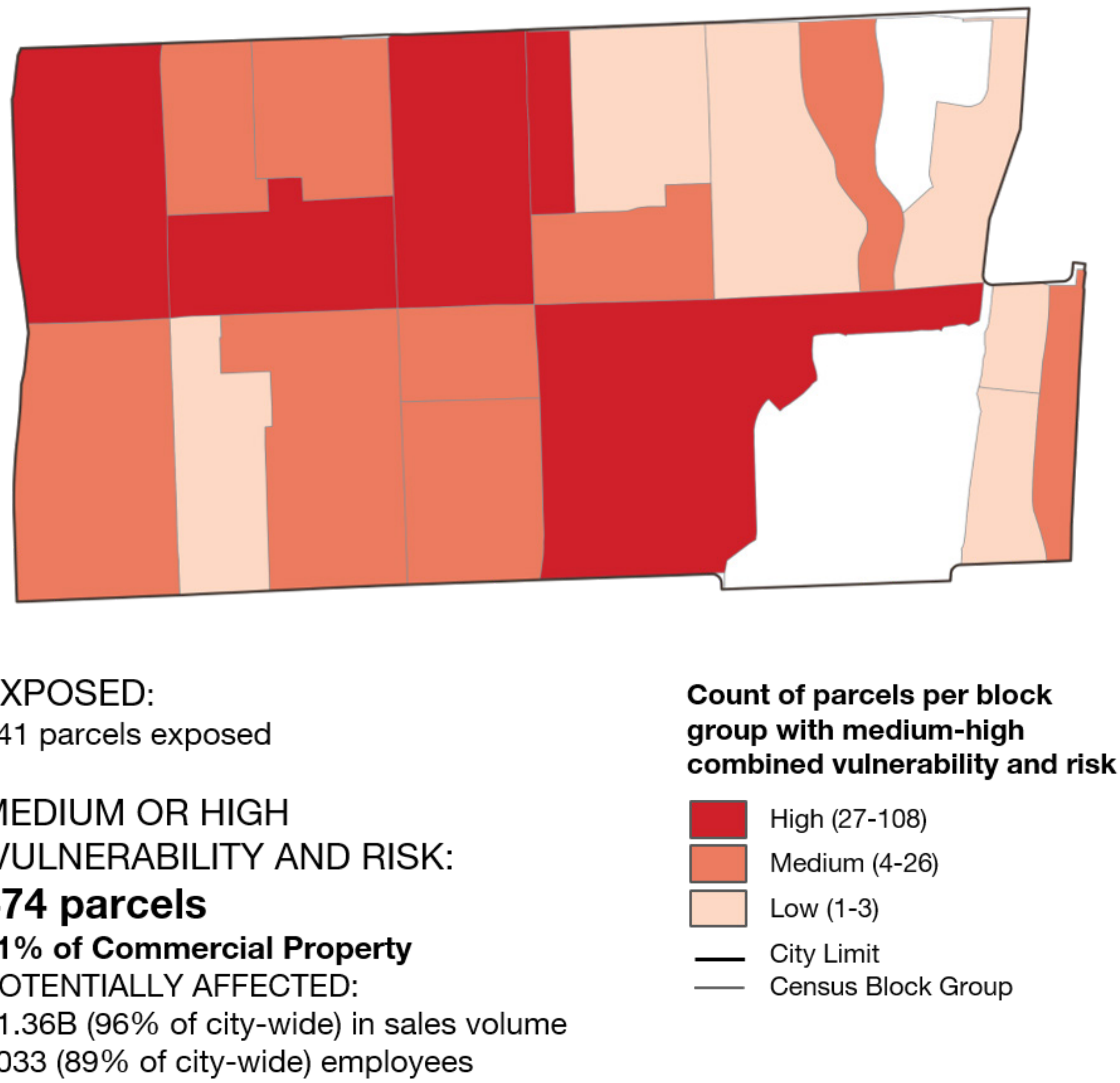
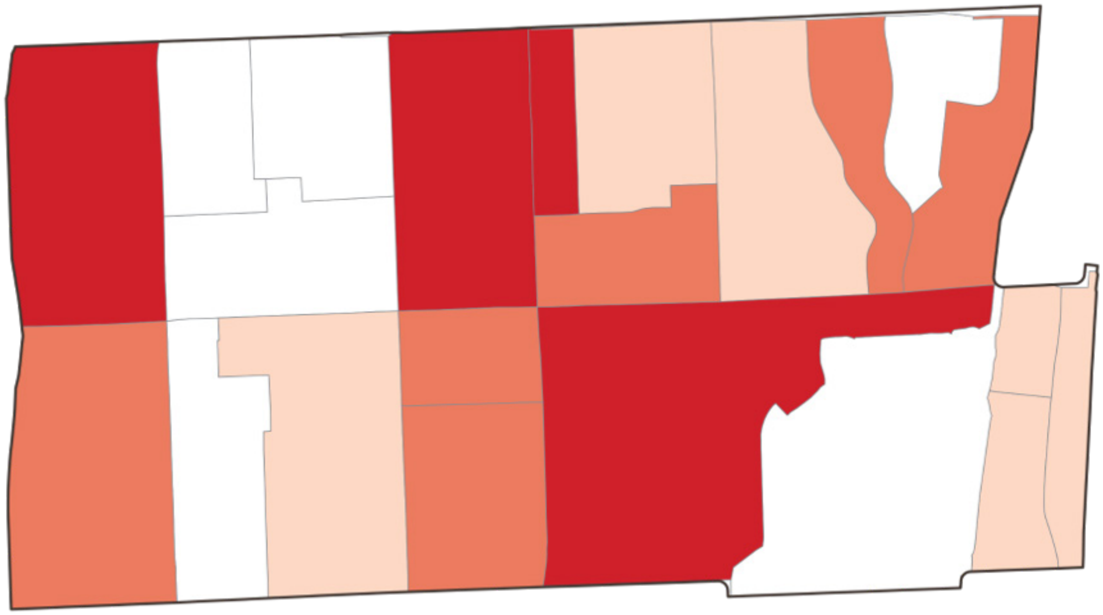


FIGURE 3:FEMA FLOOD ZONE VULNERABILITY AND RISK ASSESMENT FOR COMMERCIAL PROPERTY

2.1.2 City-owned Property



EXPOSED:
343 parcels exposed

MEDIUM OR HIGH
VULNERABILITY AND RISK:
275 parcels
47% of Commercial Property
POTENTIALLY AFFECTED:
$933.1M (66% of city-wide) in sales volume
5180 (66% of city-wide) employees

Count of parcels per block group with medium-high combined vulnerability and risk

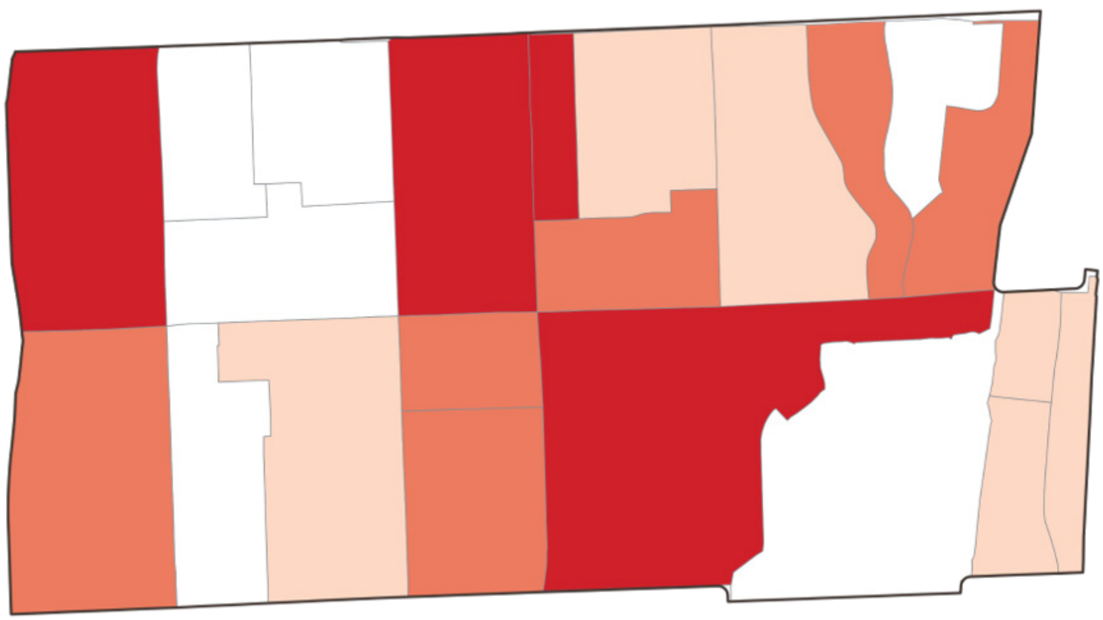
- High (21-85)
- Medium (2-20)
- Low (1)
- City Limit
- Census Block Group

FIGURE 4: FEMA FLOOD ZONE VULNERABILITY AND RISK ASSESMENT FOR CITY-OWNED PROPERTY

2.2 STORM SURGE

Storm surge is flooding caused by an abnormal rise in tide from a severe storm (e.g. a hurricane) over and above the usual, astronomical tide. The assessment used the Sea Lake and Overland Surge from Hurricanes (SLOSH) Maximum of the Maximum Enveloped of Water (MOM) layer for hurricane categories 1-5, developed by the National Oceanic Atmospheric Administration (NOAA) National Weather Service's National Hurricane Center. This dataset represents the scale of potential "near worst case" flooding from hypothetical "ideal" storms.

2.2.1 Commercial Property



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Count of parcels per block group with medium-high combined vulnerability and risk

High (21-85)
Medium (2-20)
Low (1)
City Limit
Census Block Group

FIGURE 5:STORM SURGE VULNERABILITY AND RISK ASSESMENT FOR COMMERCIAL PROPERTY

2.2.2 City-owned Property

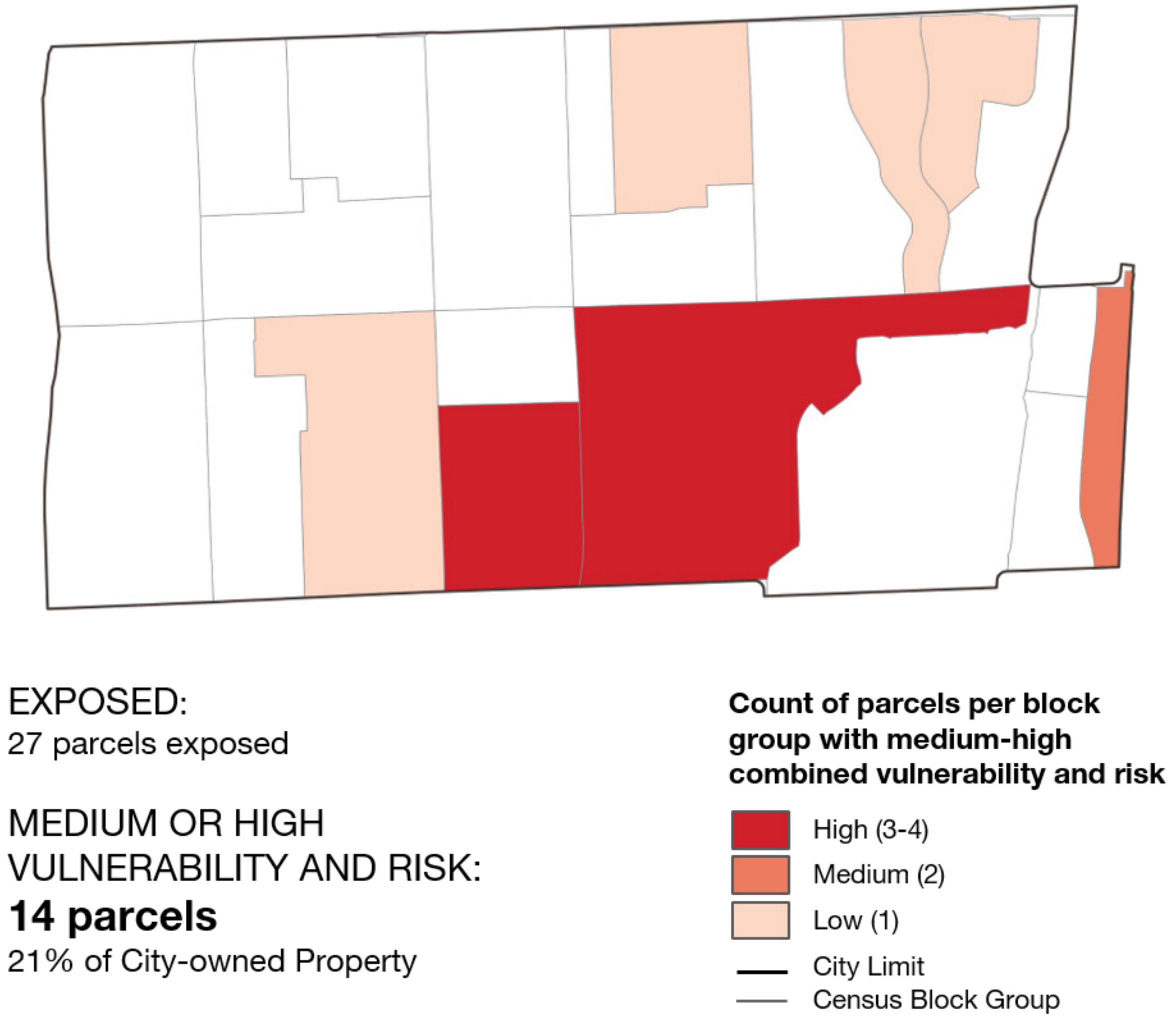


FIGURE 6: STORM SURGE VULNERABILITY AND RISK ASSESMENT FOR CITY-OWNED PROPERTY

2.3 SEA-LEVEL RISE (MID/LONG-TERM)

The relative rise of the local mean sea level over time can cause permanent inundation as well as an increase in frequency and severity of future tidal flooding. In this assessment, vulnerability and risk of permanent inundation from SLR in the mid/long-term (roughly, 2070s-2080s) is assessed for 2, 4, and 5 ft over current Mean Higher High Water (MHHW) using the NOAA Sea Level Rise Viewer dataset. These levels were chosen based on 2019 SLR curves developed by the SE Florida Regional Climate Change Compact.

2.3.1 Commercial Property

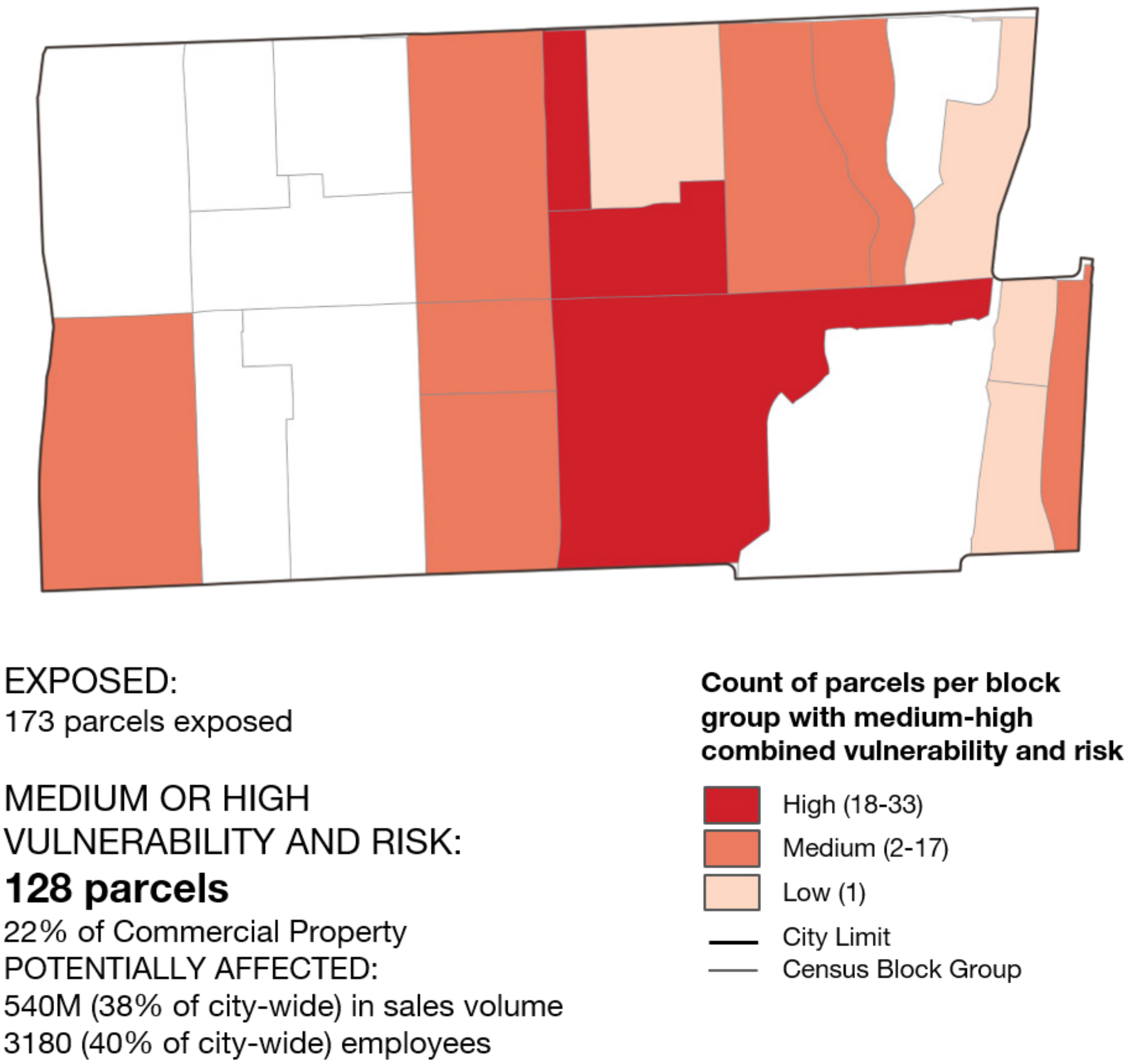


FIGURE 7: SEA LEVEL RISE (MID/LONG-TERM VULNERABILITY AND RISK ASSESMENT FOR COMMERCIAL PROPERTY

2.3.2 City-owned Property

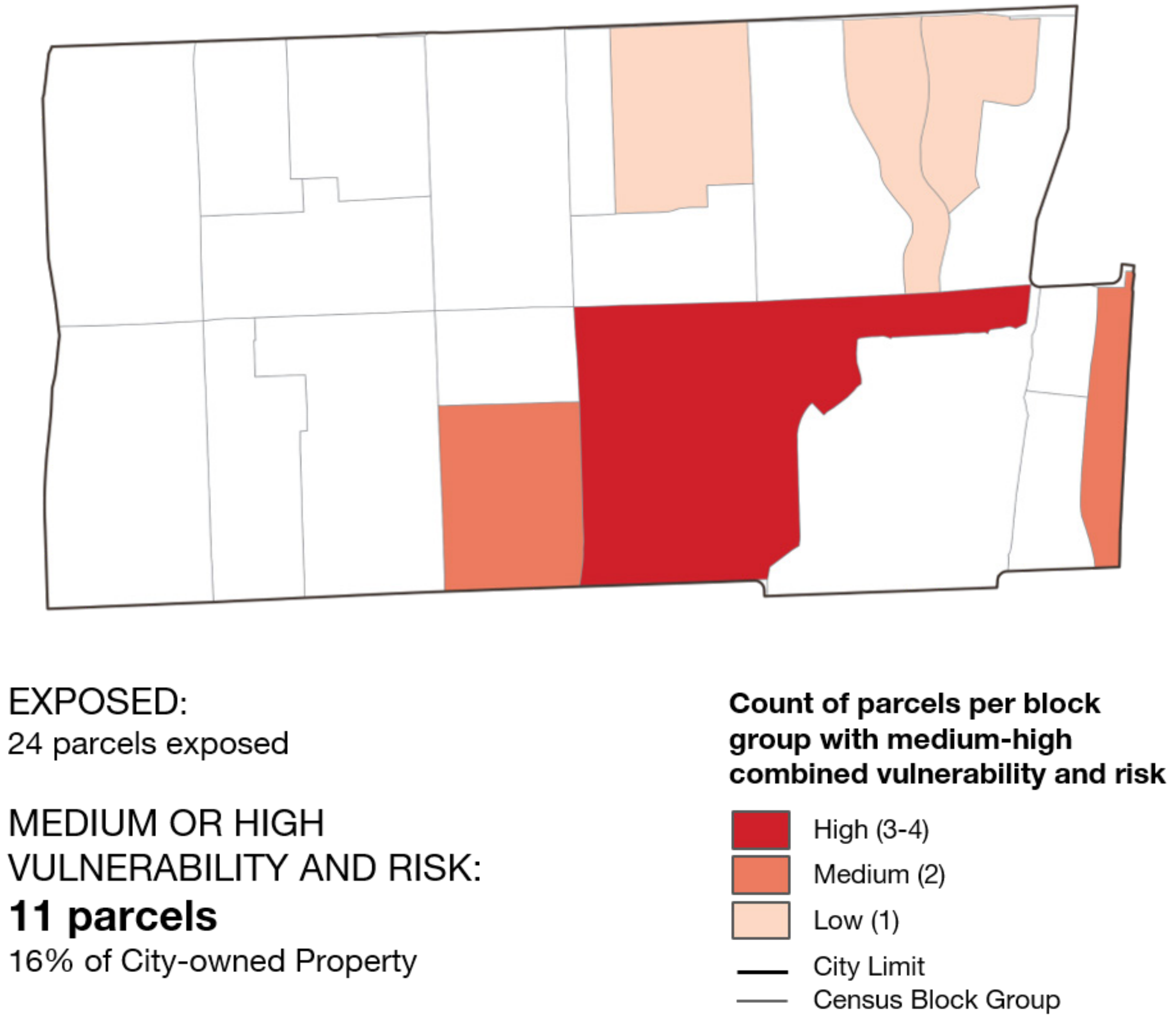
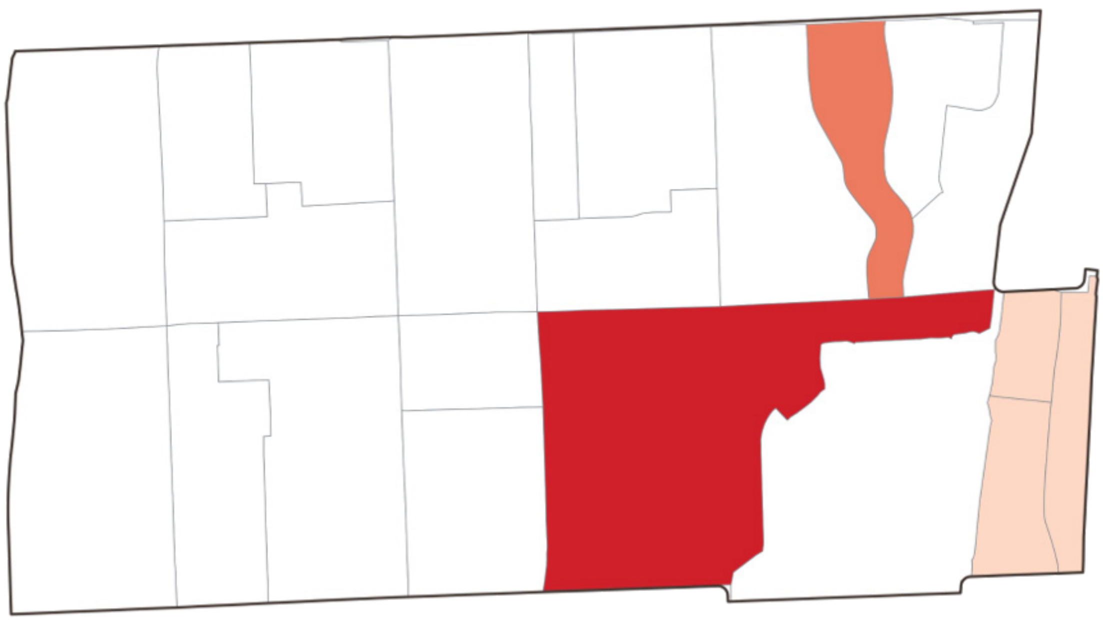


FIGURE 8: SEA LEVEL RISE (MID/LONG-TERM VULNERABILITY AND RISK ASSESMENT FOR CITY-OWNED PROPERTY

2.4 SEA-LEVEL RISE (SHORT TERM)

The relative rise of the local mean sea level over time can cause permanent inundation as well as an increase in frequency and severity of future tidal flooding. In this assessment, vulnerability and risk of permanent inundation from SLR in the short--term (r2030s-2040s) is assessed for 1, 2 and 3 ft over current Mean Higher High Water (MHHW) using the NOAA Sea Level Rise Viewer dataset. These levels were chosen based on 2019 SLR curves developed by the SE Florida Regional Climate Change Compact.

2.4.1 Commercial Property



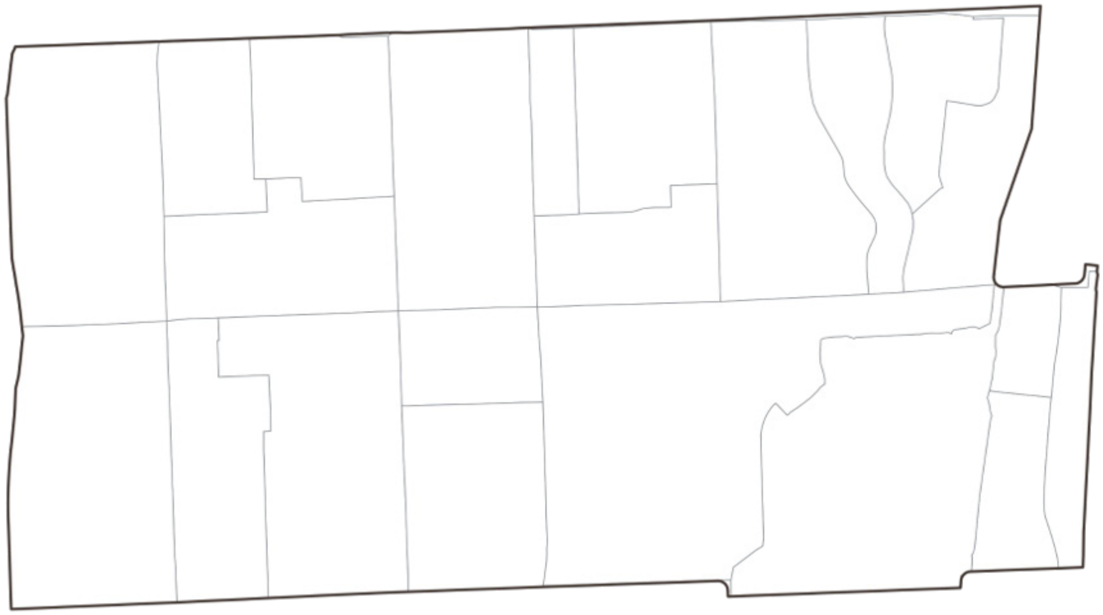
EXPOSED:
24 parcels exposed

MEDIUM OR HIGH VULNERABILITY AND RISK:
12 parcels
2% of Commercial Property
POTENTIALLY AFFECTED:
$91.6M (6% of city-wide) in sales volume
472 (6% of city-wide) employees

Count of parcels per block group with medium-high combined vulnerability and risk

High (5)
Medium (2-4)
Low (1)
City Limit
Census Block Group

2.4.2 City-Owned Property



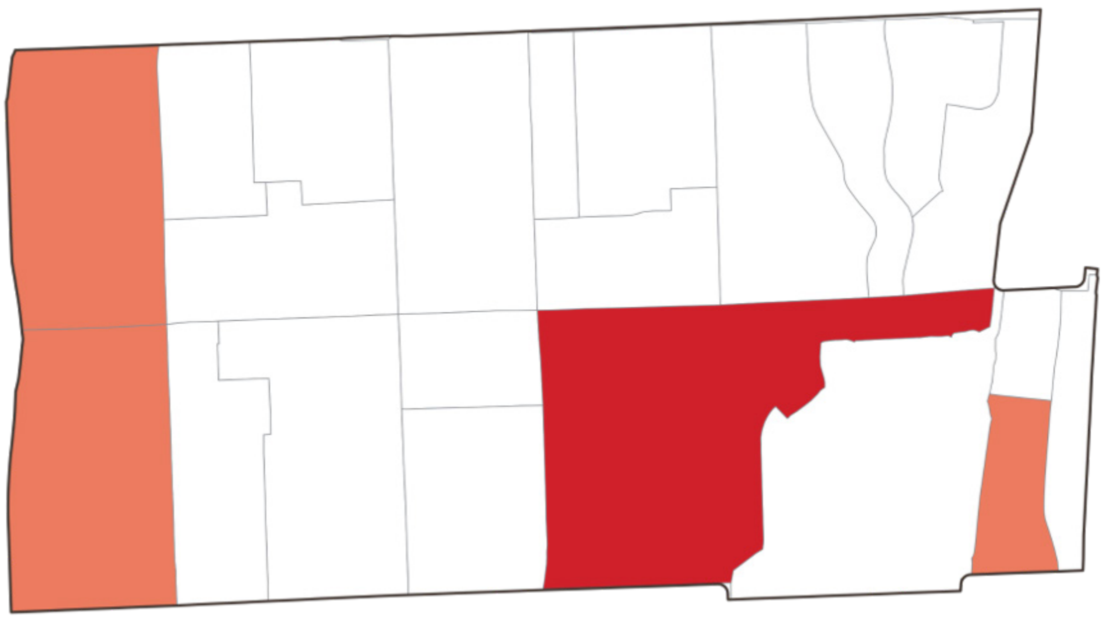
EXPOSED:
6 parcels exposed

MEDIUM OR HIGH
VULNERABILITY AND RISK:
0 parcels
0% of City-owned Property

2.5 TIDAL FLOODING (CURRENT)

Tidal flooding is flooding of the low-lying land along the coastline from a high tide that is not associated with a major storm. Tidal flooding is also referred to as “high tide”, “sunny day”, or “nuisance” flooding. We use the ‘High Tide Flooding’ layer produced by NOAA for the Sea Level Rise Viewer. While this assessment is for current tidal flooding, the frequency and intensity of tidal flooding will increase with rising sea levels. Note that around some inland bodies of water (e.g. lakes, ponds) this dataset shows tidal flooding where, in our opinion, it is not in fact likely to occur.

2.5.1 Commercial Property



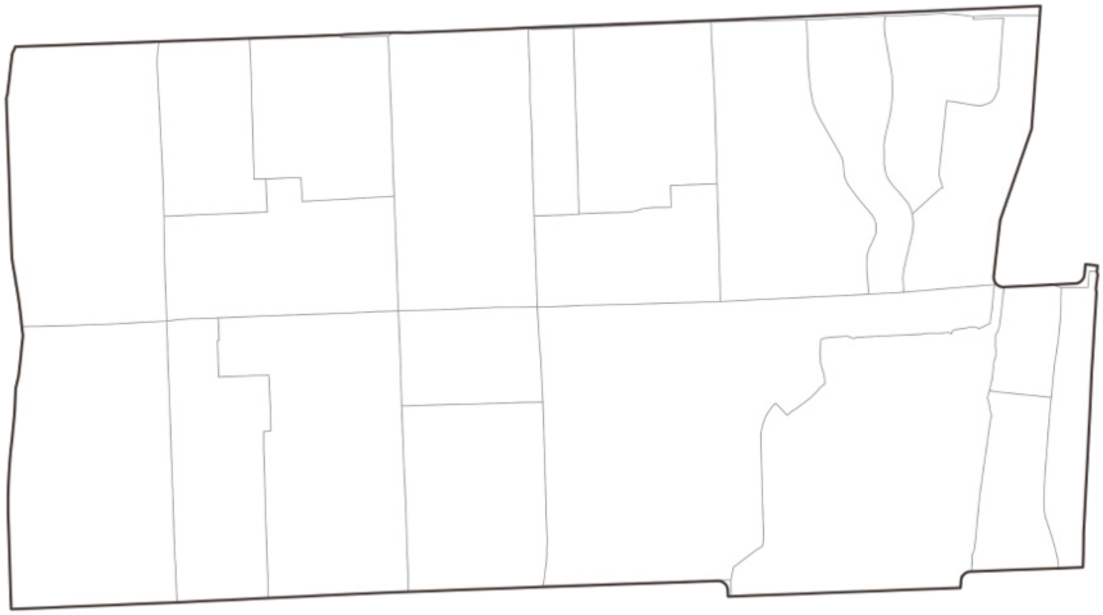
EXPOSED:
29 parcels exposed

MEDIUM OR HIGH VULNERABILITY AND RISK:
5 parcels
<1% of Commercial Property
POTENTIALLY AFFECTED:
$50.4M (4% of city-wide) in sales volume
186 (2% of city-wide) employees

Count of parcels per block group with medium-high combined vulnerability and risk

High (2)
Medium (1)
City Limit
Census Block Group

2.5.2 City-owned Property



EXPOSED:
9 parcels exposed

MEDIUM OR HIGH
VULNERABILITY AND RISK:
0 parcels
0 of City-owned Property

3. POTENTIAL ECONOMIC LOSS

This section summarizes estimated direct and indirect economic losses for both existing and future conditions, including loss by return period / annualized loss for each flood type. Economic loss estimates are based on impacts to building stock / essential facilities. This section also includes summary of demographic effects associated with economic losses and existing and future flood scenarios.

3.1 EXISTING AND FUTURE FLOOD HAZARDS

In this assessment we include both existing and future flood hazards summarized in Table 1.

TABLE 1: FLOOD HAZARD TIME HORIZONS

Flood Hazard	Time Horizon
FEMA Flood Zones (floodplain inundation)	Current
Storm Surge	Current
Sea Level Rise (short-term)	2040-2050s
Sea Level Rise (mid/long-term)	2060-2070s
Tidal Flooding	Current

3.2 BUILDING STOCK AND ESSENTIAL FACILITIES

This section summarizes the extent of potential direct (total property value) and indirect (sales volume, employees) economic losses that could occur due to flooding-related hazards. This information also provides insight to the potential for losses related to ability to provide critical services. Table 2 provides a summary of potential economic losses associated with assets with high or medium combined vulnerability and risk.

TABLE 2: POTENTIAL DIRECT EXISTING AND FUTURE LOSS PROFILE SUMMARY OF COMMERICAL AND CITY-OWNED PROPERTY

Asset Type	Vulnerability/ Loss Metric	Total Citywide Assets	FEMA Flood Zones (floodplain inundation)	Storm Surge	Sea Level Rise (short-term)	Sea Level Rise (mid/long-term)	Tidal Flooding (current)
Commercial	No. of Properties	585	474 (81%)	273 (47%)	12 (2%)	128 (22%)	5 (1%)
	Total property value	$1.63B	$1.57B (96%)	$1.14B (70%)	$486M (30%)	$1.24B (76%)	$160M (10%)
	Annual Sales Volume	1,420M	1,363M (96%)	933M (66%)	92M (6%)	540M (38%)	50M (4%)
	Employees	7,868	7,033	5,180	472	3,180	186
City-Owned Facilities	No. of Properties	68	21 (31%)	14 (21%)	0	11 (16%)	0
	Total property value	$102M	$78M (77%)	$57M (56%)	0	$48M (48%)	0

In Table 2, the Total Citywide Assets column summarizes the total number of assets citywide, providing a baseline against which to evaluate potential losses. For each flood type, the 'No. of Properties' gives the number and percentage of total assets at medium or high combined vulnerability and risk. In addition, the 'Total Property Value' summarizes potential direct economic losses and 'Annual Sales Volume' and 'Employees' summarizes vulnerable indirect economic activity.

Table 3 shows the total building value that is exposed to floodplain inundation. The values are specified by the two flood return intervals included in FEMA dataset: 1) 100-year or 1%-annual-chance and 2) 500-year or 0.2%-annual-chance.

TABLE 3 POTENTIAL TOTAL AND ANNUALIZED LOSSES BY RETURN PERIOD

Asset Type	100-year flood			500-year flood event		
	No. of Properties	Potential Total Loss (Building Value)	Potential Annualized Loss (Building Value)	No. of Properties	Potential Total Loss (Building Value)	Potential Annualized Loss (Building Value)
Commercial	215	$1356.2M	$135.6M	474	$1574.6M	$31.5M
City-owned	12	$33.3M	$3.3M	19	$61.1M	$1.2M

The No. of Properties column in Table 3 gives the count of parcels with buildings that are exposed to flooding. Exposed parcels that do not include buildings within the floodplain are not included in this tabulation. Note that the loss estimates use total building values regardless of level or amount of building exposure.

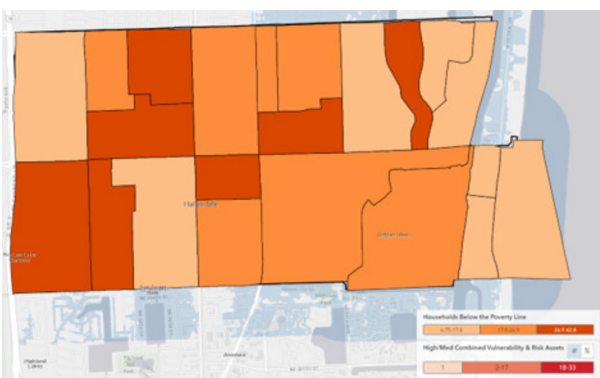
3.3 DEMOGRAPHICS

At the census block group level, the assessment cross references potential loss profiles with several demographic criteria for each flood type. Table 4 summarizes the demographic criteria included in the assessment.

TABLE 4: DEMOGRAPHIC CRITERIA INCLUDED IN LOSS PROFILE ASESSMENT

Demographic Criterion
Percent African American Population
Percent of Population Younger than 18 or Older than 64
Workers Relying on Public Transportation
Percent of Population with at least a High School Diploma
Percent of Population with a College Degree
Households Below the Poverty Line
Households Above the Poverty Line
Percent of Households Receiving SNAP Benefits
Median Household Income

Figure 9 provides an example of demographic data and economic data available in AccelAdapt tool (also see Appendix). The image on the left shows the number of households below the poverty line in the City aggregated by block groups (calculated from the American Community Survey dataset). The image on the left shows the number of employees that could be potentially affected by sea level rise in the mid/long term.



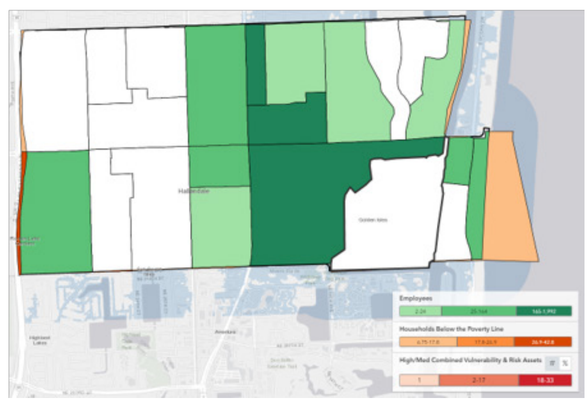


FIGURE 9: COMPARISION OF NUMBER OF HOUSEHOLDS BELOW THE POVERTY LINE (LEFT) AND THE NUMBER OF EMPLOYEES AFFECTED BY SEA LEVEL RISE (MID/LONG-TERM)

4. TECHNICAL DOCUMENTATION

This section describes the methodology of the assessment of vulnerability and risk of commercial and city-owned property in the City of Hallandale Beach to four types of flooding-related hazards: FEMA flood zones, storm surge, sea level rise (2 time horizons) and tidal flooding.

4.1 ASSESSMENT APPROACH

This assessment was performed at the asset-level in a data-driven pipeline and full results are provided to the City using a specialized tool, AccelAdapt, which allows interactive interrogation of vulnerability and risk (results are also made available in the form of GIS layers).

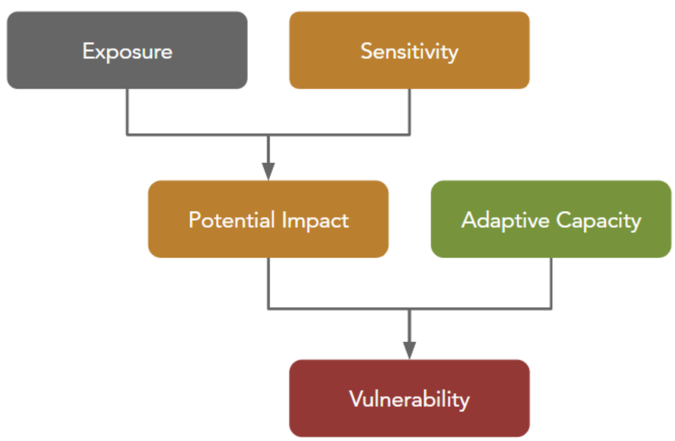
The assessment approach combined multi-criteria decision analysis and spatial analysis.[1] This involved developing criteria, or rules, that were used to assign to assets specific ordinal classifications of *high*, *medium*, and *low* for each of the variables described below. The classifications were then combined using a matrix approach to determine levels of vulnerability, risk, and combined vulnerability and risk.[2]

4.1.1 Vulnerability

Vulnerability describes the susceptibility of exposed assets based on the two core concepts described above: (1) potential impact—the degree to which an asset is affected; and (2) adaptive capacity—the ability the asset has to cope with a potential impact.

4.1.1.1.1 Potential Impact

Potential impact is the degree to which an exposed asset (asset that is in harm's way) is potentially negatively affected by a climate-related threat. The level at which an exposed asset is negatively affected is also referred to as the asset's *sensitivity*. Assets that are not exposed have no potential impact; thus, they are not vulnerable, or at risk. Exposed assets were evaluated for levels of sensitivity, which were used in determining levels of potential impact.



4.1.1.1.2 Adaptive Capacity

Adaptive capacity considers how an asset can cope with a threat event or impact. An asset with adaptive capacity can withstand an impact with minimal disruption or loss. Measures of adaptive capacity can

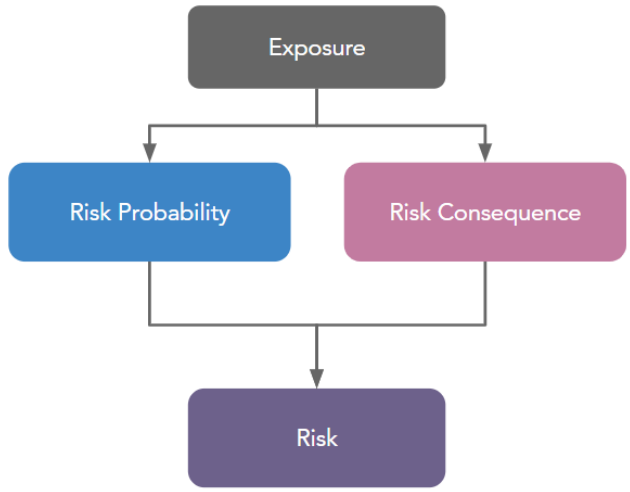
[1] Malczewski, Jacek, and Claus Rinner. *Multicriteria Decision Analysis in Geographic Information Science.* Springer-Verlag, 2015.
[2] EPA Office of Water, Climate Ready Estuaries. *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans.* U.S. Environmental Protection Agency, 2014. [https://www.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf]

include physical elements, conditions, or designs in place that help an asset absorb an impact. Exposed assets were evaluated for indicators of adaptive capacity and classified accordingly.

Levels of potential impact and adaptive capacity are then combined to inform vulnerability. Assets with low potential impact and high adaptive capacity are the least vulnerable. Assets with high potential impact and low adaptive capacity are the most vulnerable.

4.1.1.2 Risk Scoping

Just as potential impact and adaptive capacity combine to determine vulnerability, risk probability and risk consequence combine to give us an assessment of risk scoping.



4.1.1.2.1 Risk Probability

Probabilities were determined for each threat using annualized likelihoods of threat occurrence or relative levels based on known risk factors. For example, for FEMA Flooding, the floodway, 100-year, and 500-year flood hazard zones were used to evaluate different probabilities of flooding for each asset.

4.1.1.2.2 Risk Consequence

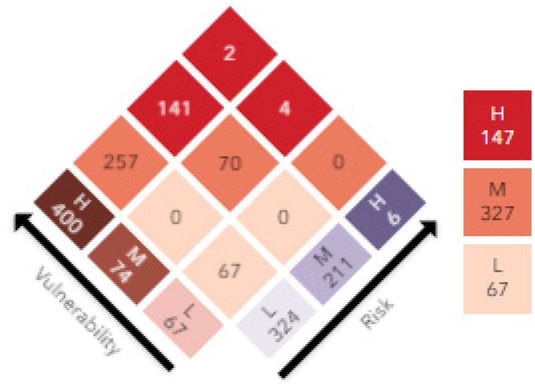
Risk consequence refers to negative outcomes or critical thresholds that indicate varying levels of significance if a threat were to occur. For example, assets with affected structures or a higher monetary value may have a greater negative consequence than assets with no affected structures or that have a lower monetary value.

Levels of risk probability and risk consequence are then combined to inform risk scoping. For example, a parcel with an exposed high-value building in the 10-year flood hazard zone would have a high risk classification, while a parcel in the 100-year flood hazard zone without an exposed building would have a low risk classification.

It is important to note that this step provides the scope of risk rather than estimating loss

4.1.1.3 Combined Vulnerability and Risk

Vulnerability considers how an asset might be impacted and its ability to cope if a given threat event were to occur, and risk considers the probability of the threat occurring and the general consequence of the threat (without considering factors that make it susceptible). Combining these concepts allows decision makers to evaluate which assets are most susceptible and most likely to be impacted and consider options according to different levels of risk threshold.



The matrix shown here features the combination of vulnerability and risk for Commercial Property and FEMA Flood Zones. High-vulnerability and high-risk parcels are in the top-most cell. Those that have low vulnerability and low risk are in the bottom-most cell.

4.1.1.4 Aggregation of Vulnerability and Risk

In order to focus on the most vulnerable and risk assets, the assets with either medium or high combined vulnerability and risk are mapped at the census block group scale as shown in the map below of commercial property and FEMA flood zones. In the matrix above, these are the cells (i.e., parcels) with the two darkest shades of red.

4.1.1.5 High-Level Summary of Assessment Ruleset Components

The table below summarizes the type of criteria ("rulesets") used for each climate stressor considered in the assessment. Rulesets have been developed for criteria including exposure, vulnerability and risk. More specific information about the various criteria is available in the AccelAdapt tool (See Appendix).

TABLE 5: ASSESSMENT RULESETS BY CLIMATE STRESSOR

Hazard	Exposure[3]	Risk		Vulnerability	
		Probability	Consequence	Potential Impact	Adaptive Capacity
FEMA Flood Zones	Any FEMA flood zone (floodway, and 100-yr and 500-yr)	Levels of flood probability (floodway, 100-yr, 500-yr)	Property value	Criticality of asset based on type and use	Base flood elevation (BFE)
Storm Surge	Inundation for Cat 1-5	Levels of Storm Category (1, 2-3, 4-5).	Property value	Criticality of asset based on type and use	Base flood elevation (BFE)
Sea Level Rise (mid/long-term)	Up to NOAA 5 ft SLR	Levels of SLR (2, 4, 5)	Property value	Criticality of asset based on type and use	Base flood elevation (BFE)
Sea Level Rise (short-term)	Up to NOAA 3 ft SLR	Levels of SLR (1, 2, 3)	Property value	Criticality of asset based on type and use	Base flood elevation (BFE)
Tidal Flooding (current)	NOAA high tide extent (impact threshold)			Criticality of asset based on type and use	Base flood elevation (BFE)

For commercial properties that have high or medium vulnerability and risk, we also estimate the economic activity that could be potentially affected by each flooding hazard. Specifically, we look at sales volume and jobs associated with the property using data provided by ESRI Business Analyst.

4.2 ASSET VULNERABILITY GIS LAYERS

This section records the metadata of GIS layers produced as the end-result of the vulnerability assessment. Specifically, it provides details about the format in which the vulnerability scores for commercial and city-owned assets for each flooding hazard is available in the GIS outputs delivered as part of this study. Assessment output is available in two layers: 1) Data aggregated at census block group level and 2) Parcel level data. These data are used within the AccelAdapt tool (see Appendix) for Hallandale Beach and made available for download as feature services.

4.2.1 Census Block Group Aggregation Dataset

This GIS layer summarizes the assessment within census block group boundaries. The output dataset (Census Block Group Aggregation Data) provides the assessment summaries in a format that is best suited

[3] Details about the threat datasets are available as part of Task 1 documentation

to be viewed using definition or attribute queries. Table 3 lists the attributes of the dataset along with some description and example data values:

TABLE 6: GIS DATASET ATTRIBUTES

GEOID	Census block group ID	ID string
MODULE	The unique asset-threat pair associated with the metric	string
ASSET	Assessment asset category	city_owned commercial
THREAT	Assessment threat	flood storm_surge sea_level_rise_2040 sea_level_rise_2070 high_tide_flood
VARIABLE	Variable type / theme	asset exposed vulnerability combined _vulnerability_risk
VAR_UNIT	Variable subtype / specific unit	count improvement_value
VAL	Count of total for "asset" and "exposed" variables; count of medium or high for "combined_vulnerability_risk" and "vulnerability"	[number]
HML_H	Count of high	[number]
HML_M	Count of medium	[number]
HML_L	Count of low	[number]

Values from multiple columns in the dataset may need to be selected in or order to select individual map variables or asset-threat pairs. For example, to view the residential property/flooding high or medium combined vulnerability and risk map as seen in the default view in AccelAdapt, the following selection or definition query would need to be made:

MODULE = residential_flood
VARIABLE = combined _vulnerability_risk

Then, the resulting selection or definition query could be symbolized using the VAL column (which is a total of HML_H + HML_M for "combined_vulnerability_risk", as described above).

4.2.2 Parcel/Asset Dataset

The GIS layer contains attributes that identify the parcel asset categories and specify parcel-level values of vulnerability and risk components. The output dataset (Parcels) has the following attributes (Table 4)

TABLE 7: OUTPUT DATASET ATTRIBUTES

Attribute	Description	Data Type
PARCEL	Unique parcel ID	number
TAGS	Comma separated list of asset categories parcel belongs to	string
VAL	Total parcel value in dollars	number
VAL_LAND	Parcel land value in dollars	number
VAL_IMPRV	Parcel improvement value in dollars	number
YR_BLD	Year built of structure on parcel (min year if multiple structures)	number
CBG_GEOID	ID of the census block group parcel is within	string

4.2.3 Parcel-level assessment variables

The following column attributes include the components of the vulnerability and risk assessment. These column names can be deciphered using the following replacement pattern of THREAT_VARIABLE. For example, FLD_VR is the parcel-level variable for flooding and combined vulnerability and risk. Below is a list of the THREAT and VARIABLE abbreviations:

TABLE 8 PARCEL-LEVEL ASSESSMENT VARIABLES

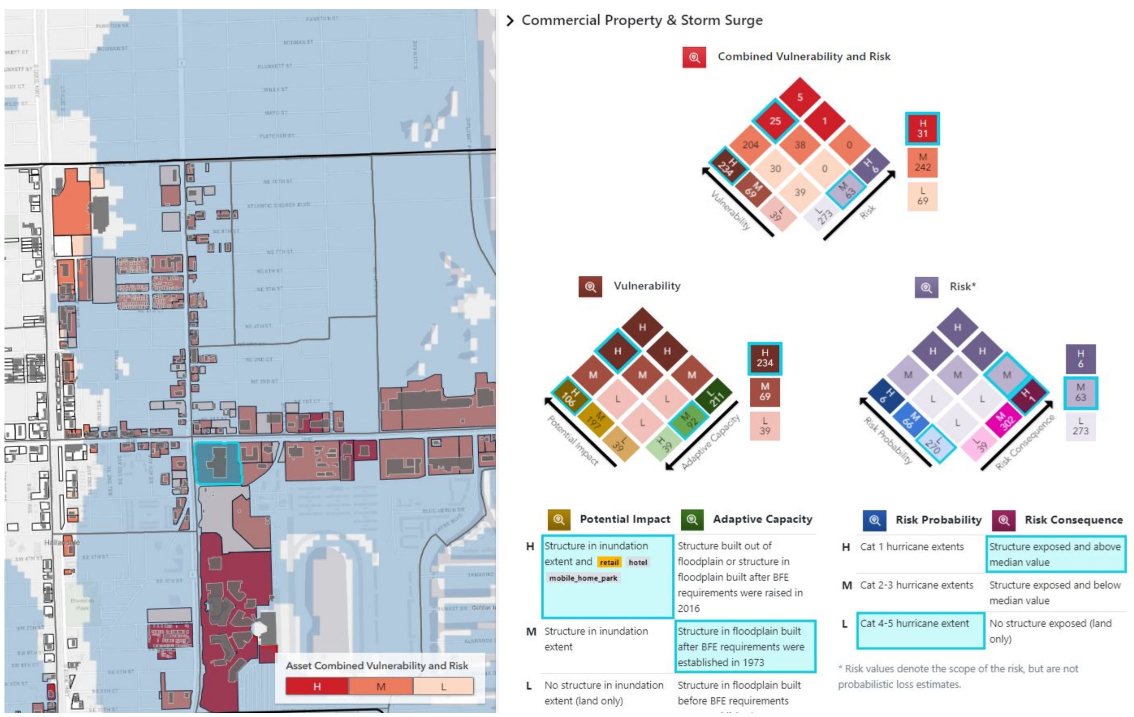
Threat	Variables		
FLD = flooding HTF = high tide flooding STS = storm surge S40 = near-term SLR S70 = mid/long-term SLR	EX	Exposure	[0=None, 1=Yes]
	EX_BLD	Building exposure	[0=None, 1 =Yes]
	P	Parcel threat probability	threat-specific/relative likelihood
	P_BLD	Building threat probability	threat-specific/relative likelihood
	PI	Potential impact	[0 = None, 1=Low, 2=Med, 3=High]
	AC	Adaptive capacity	[0 = None, 1=High, 2=Med, 3=Low]
	AC_C	Adaptive capacity desc.	commentary
	V	Vulnerability	[0 = None, 1=Low, 2=Med, 3=High]
	RP	Risk probability	[0 = None, 1=Low, 2=Med, 3=High]
	RC	Risk consequence	[0 = None, 1=Low, 2=Med, 3=High]
	R	Risk	[0 = None, 1=Low, 2=Med, 3=High]
	VR	Combined vulnerability & risk	[0 = None, 1=Low, 2=Med, 3=High]

5. APPENDIX: OTHER INFORMATION AVAILABLE IN AccelAdapt

AccelAdapt is designed to provide assessment information at multiple scales in an interactive and transparent manner. Key AccelAdapt features are highlighted here to document the full extent of information that is available to the City of Hallandale Beach.

Asset-level View

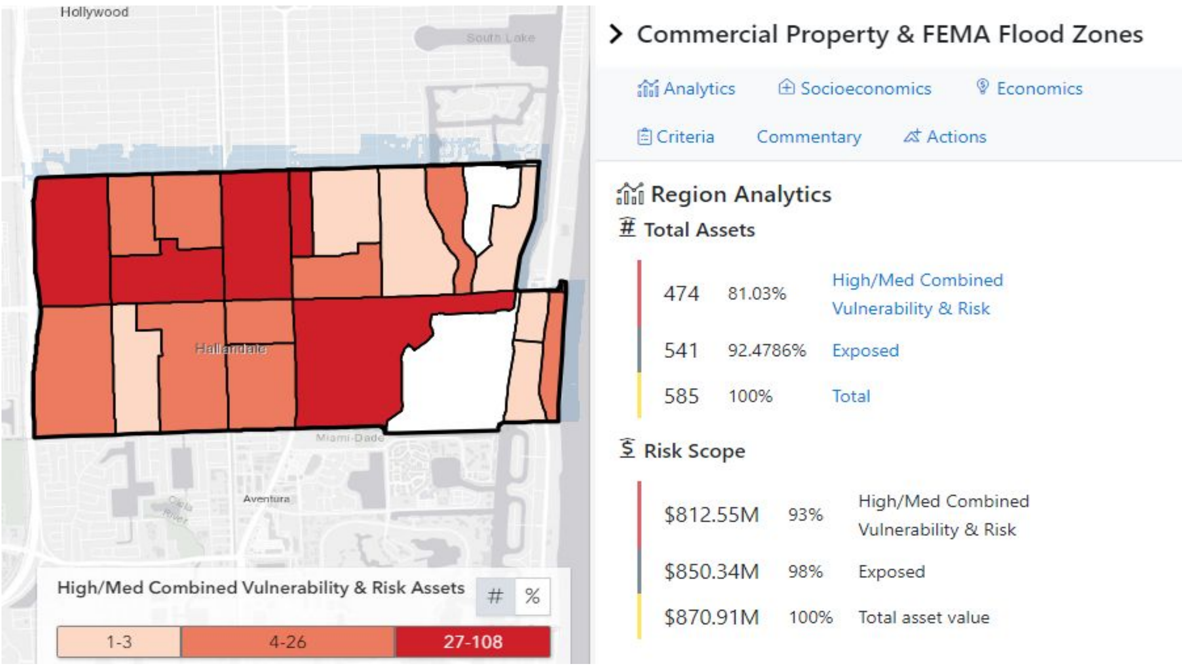
Analysis is conducted and made available at the asset scale. Rulesets for the four components of vulnerability are available on the right. When a parcel is highlighted in this view, the corresponding factors (4 in total) that contribute to its classification as having high, medium or low combined vulnerability and risk get highlighted in the rulesets. The matrices on the right also include the total number of assets in the city for each category of vulnerability and risk and their individual components.



In addition to combined vulnerability and risk, the asset-level view is also available for each component individually: adaptive capacity, potential impact, risk probability, risk consequence, vulnerability and risk.

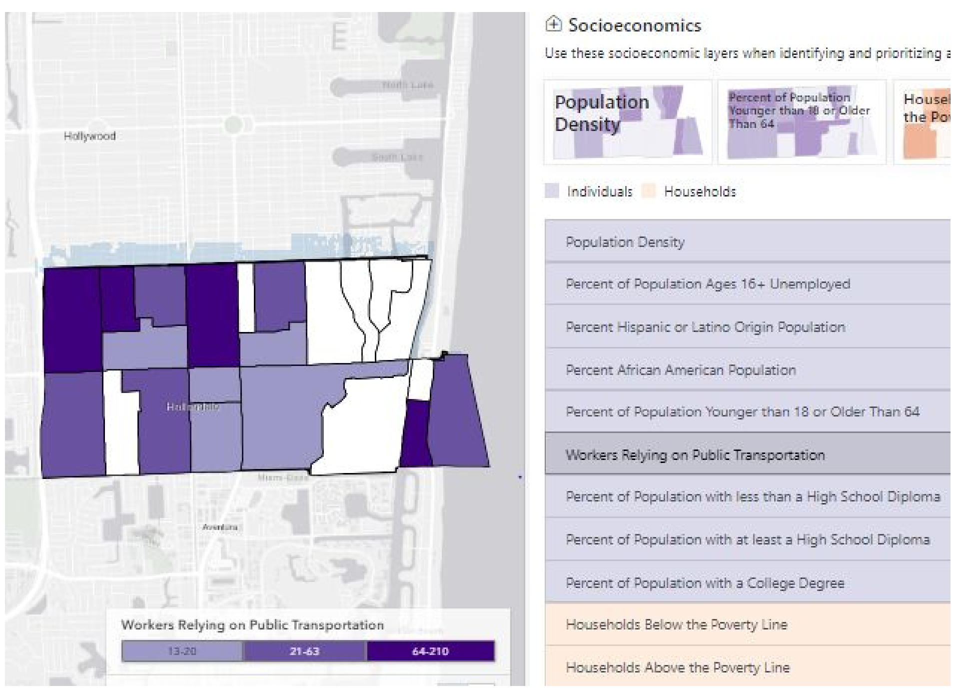
City-wide View

The asset-specific information is aggregated to census block groups in the city-wide view to enable comparison across neighborhoods. Specifically, the colors denote the number or percentage of assets in a block group at high or medium combined vulnerability and risk.



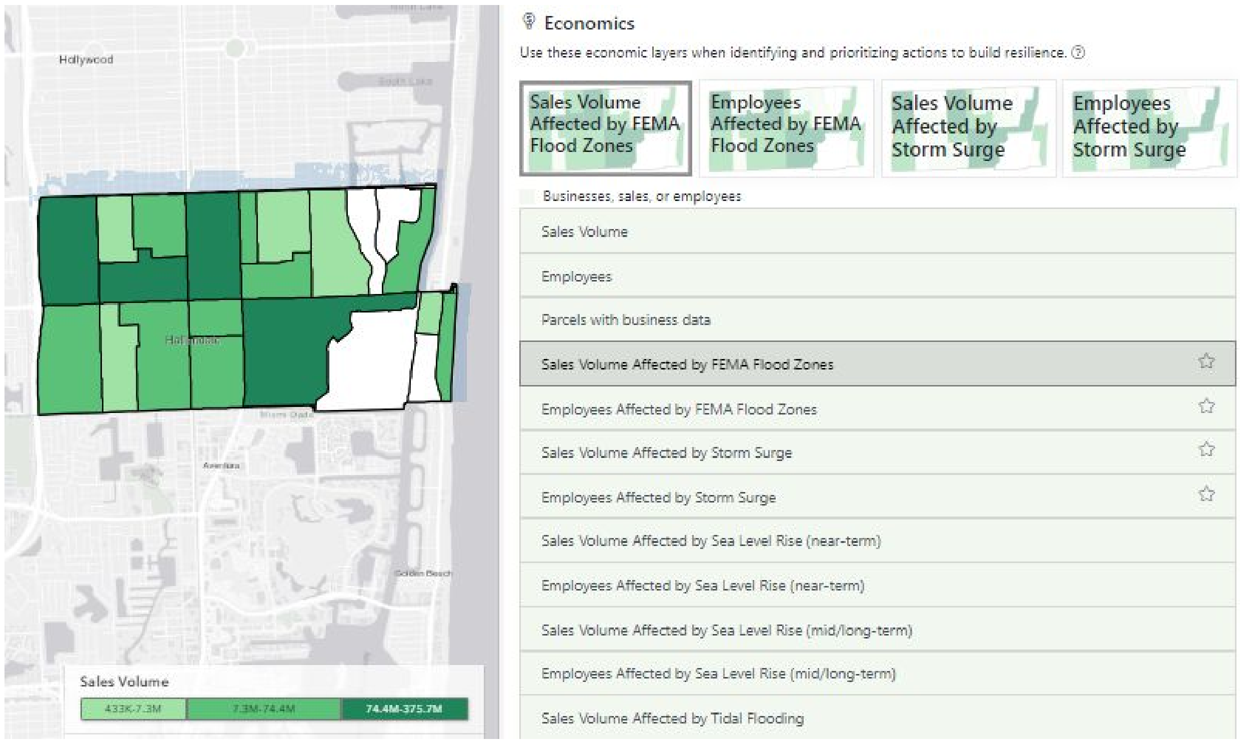
Socioeconomic Variables

AccelAdapt includes several socioeconomic variables for households and individuals from the American Community Survey dataset. These variables are aggregated at the block group scale. Many of these variables can be used as indicators of social vulnerability.



Economic Analysis

The Economics section of AccelAdapt shows the sales volume and number of jobs associated with properties that have high or medium combined vulnerability and risk for each threat. These numbers are a measure of the economic activity that could be *potentially affected* by a threat rather than estimates of loss.



CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 3: FUTURE PRECIPITATION ANALYSIS

RS&H

City of Hallandale Beach Vulnerability and Adaptation Plan

TASK 3: FUTURE PRECIPITATION ANALYSIS

February 28, 2020
RS&H No.: 301-0068-000

Prepared by RS&H, Inc. at the direction of the City of Hallandale Beach

RS&H

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1. OVERVIEW OF CLIMATE EFFECTS ON PRECIPITATION

Precipitation patterns are expected to change as the climate changes. Precipitation projections agree that rainfall will become more intense globally when it does occur[i]. This pattern may lead to periods of drought interspersed with intense rainfall and flooding. Typically, extreme precipitation events are defined as those in the top 1% of all days with precipitation. In the Southeast, extreme precipitation events have increased by 18% since 1901 (**Error! Reference source not found.**).

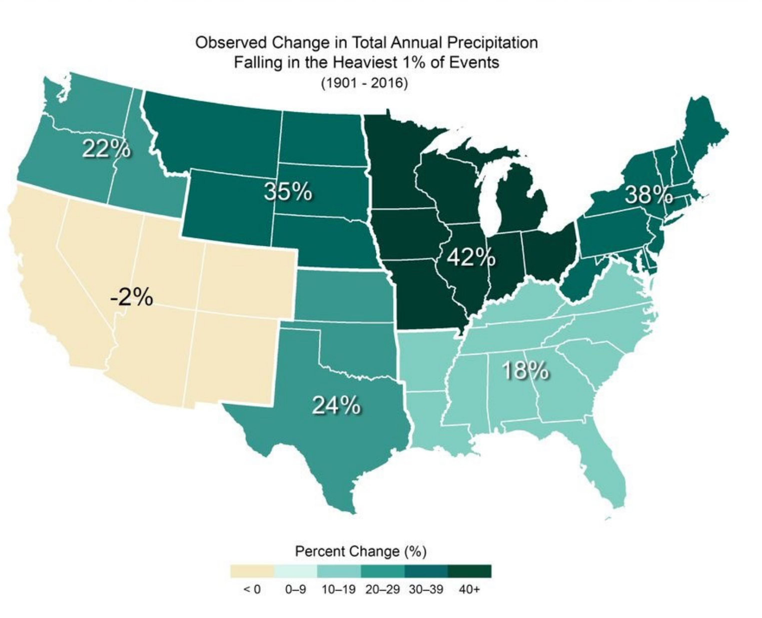

FIGURE 1: OBSERVED CHANGE IN HEAVY PRECIPITATION 1901-2016. SOURCE: U.S. GLOBAL CHANGE RESEARCH PROGRAM

Temperature and precipitation are closely linked. Higher temperatures increase evaporation and can contribute to drought in some cases. However, as the air warms, it can also hold more water vapor. Air can hold about 7% more moisture for every 1 degree C increase in temperature.[ii] Together, these changes can lead to more extreme and variable precipitation.

The severity of a flood event related to precipitation depends on the total amount and intensity of precipitation as well as soil moisture conditions, the extent of impervious surfaces, performance of stormwater systems and tailwater conditions holding back discharges to receiving waters. Sea level rise may compound these effects as the water table rises and tailwater conditions increase and there is less capacity to store stormwater in the ground.

This is of concern because the majority of the land area of the City of Hallandale Beach is located in a FEMA Special Flood Hazard Area (**Error! Reference source not found.**). Most of the City's area has either a 1% or 0.2% annual chance of flooding. The City has a history of loss claims for flood damage and has more than 420 repetitive loss properties

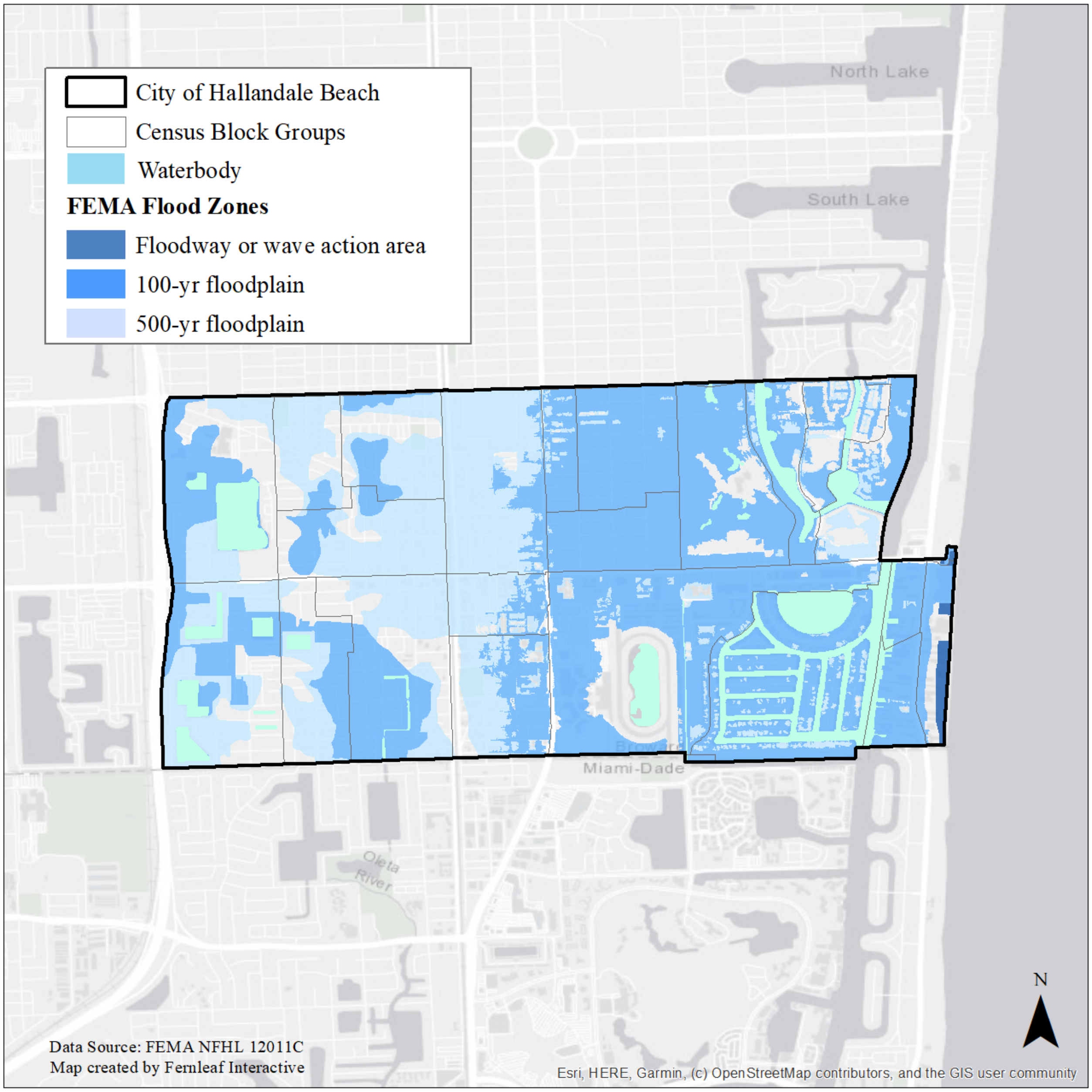

FIGURE 2: CITY OF HALLANDALE BEACH FEMA FLOOD ZONES BASELINE CONDITIONS

To understand how climate change may affect precipitation in the City, it is useful to establish a baseline by looking at historic occurrences and variability of extreme events. Other aspects of a baseline include recent extreme precipitation events in the City, and how Hallandale Beach tracks such events. Also included in the baseline is the City's level of service (LOS) standards for stormwater management systems.

2. PRECIPITATION BASELINE

Statewide, Florida averages about 54 inches of precipitation annually. The number of extreme precipitation events in the state is highly variable, with the highest 5-year average since 1900 occurring between 2010-2014 (Figure 3).

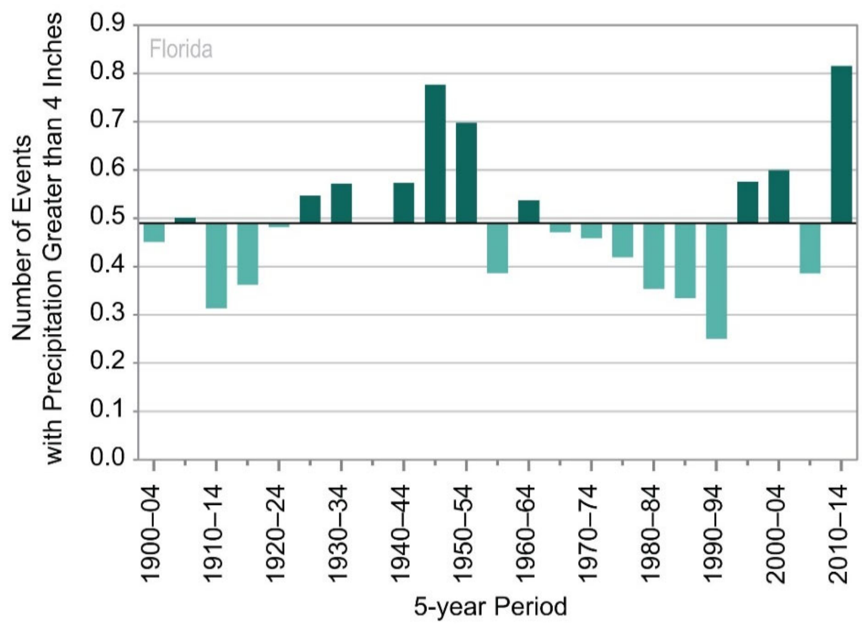

FIGURE 3: FLORIDA OBSERVED EXTREME PRECIPITATION EVENTS, NOAA STATE SUMMARY

Figure 3, from NOAA's state climate summary for Florida, shows "the observed number of extreme precipitation events (annual number of events with greater than 4 inches divided by the number of long-term stations) for 1950–2014, averaged over 5-year periods; these values are averages from 12 long-term reporting stations. The dark horizontal lines represent the long-term average. Significant variability is observed over the recorded 5-year periods. A record number of such events occurred during the most recent 5-year period (2010–2014) with an average of about 0.8 events per station per year. "

Total annual precipitation is projected to increase in Hallandale Beach and has been increasing in recent decades. Broward County averaged slightly higher annual rainfall than Florida as a whole with about 57.19 inches from 1895 to 2000 (Figure 4).[iii] NOAA data shows a very slight increasing trend of 0.04 inches per decade for the county during that period. Annual precipitation in Broward is highly variable with more than 88 inches recorded in 1948 and as little as 37 inches in 1957.

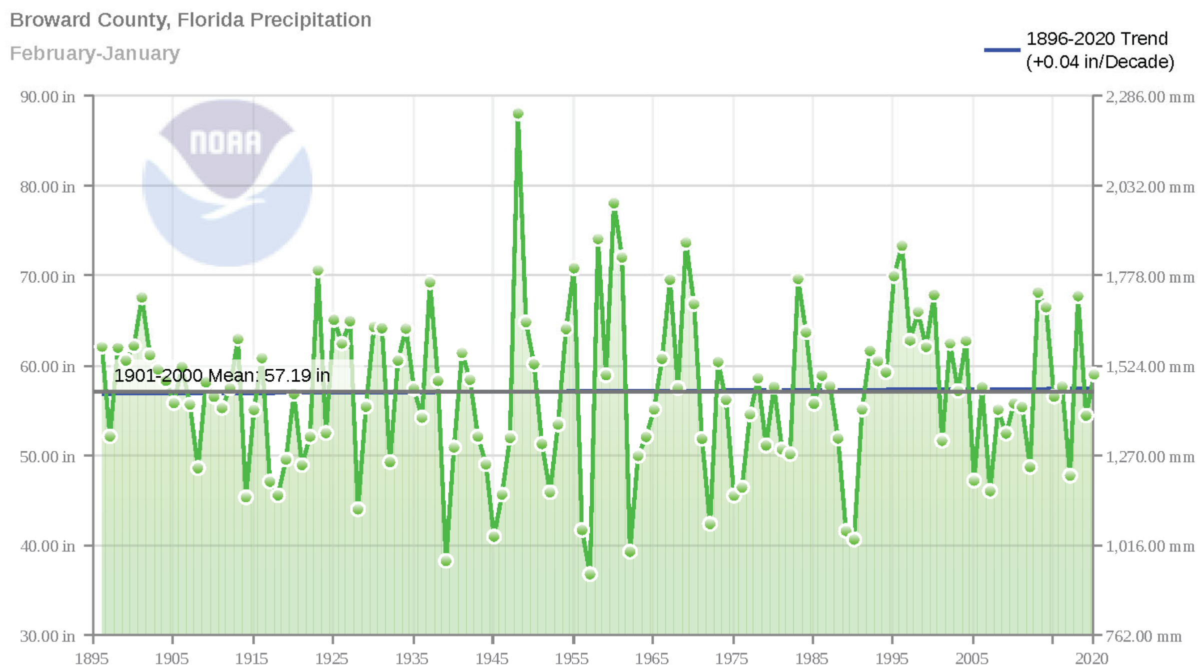

FIGURE 4: AVERAGE ANNUAL PRECIPITATION IN BROWARD COUNTY. SOURCE: NOAA

In southeast Florida, precipitation is seasonally variable, with the highest average monthly rainfall typically occurring during the warmer months between May and October. NOAA does not provide annual average rainfall data at the city level for Hallandale Beach. However, it is likely very close to the Broward county average.

2.1 NOAA PRECIPITATION FREQUENCY ESTIMATES

NOAA 90% confidence interval data for precipitation depths in inches provides values that can be utilized as a design criterion for critical infrastructure. This method is based on historical weather station observations and does not incorporate climate change predictions. It is a good basis for understanding the historical statistical frequency of precipitation events of various accumulations for Hallandale Beach.

NOAA Atlas 14 Volume 9 contains precipitation frequency estimates for the six southeastern states of Alabama, Arkansas, Florida, Georgia, Louisiana, and Mississippi. This information is also available in a searchable format through the agency's Precipitation Frequency Data Server. The data for Hallandale Beach is presented by duration of the precipitation event (vertical axis), average return interval (ARI) in years (horizontal axis) and amount in inches as measured by a precipitation gauge (Table 1).

TABLE 1: NOAA PRECIPITATION FREQUENCY ESTIMATES FOR HALLANDALE BEACH (AT UPPER 90% CONFIDENCE INTERVAL) BY DURATION AND ARI (YEARS)

Duration	1	2	5	10	25	50	100	200	500	1000
5-min	0.696	0.806	0.99	1.15	1.4	1.6	1.82	2.06	2.38	2.62
10-min	1.02	1.18	1.45	1.68	2.06	2.34	2.66	3.02	3.49	3.84
15-min	1.24	1.44	1.77	2.05	2.51	2.85	3.25	3.68	4.25	4.68
30-min	1.96	2.29	2.83	3.29	4.05	4.62	5.27	5.98	6.92	7.64
60-min	2.68	3.09	3.82	4.48	5.66	6.56	7.62	8.82	10.5	11.8
2-hr	3.38	3.87	4.78	5.63	7.23	8.45	9.91	11.6	14	15.8
3-hr	3.76	4.3	5.32	6.31	8.27	9.76	11.6	13.7	16.7	19
6-hr	4.36	5.04	6.36	7.65	10.2	12.2	14.6	17.4	21.4	24.5
12-hr	4.9	5.85	7.6	9.25	12.4	14.8	17.7	21	25.7	29.3
24-hr	5.49	6.71	8.89	10.9	14.5	17.3	20.5	24.2	29.5	33.4
2-day	6.35	7.69	10.1	12.3	16.3	19.3	22.8	26.9	32.5	36.8
3-day	7.08	8.39	10.8	12.9	17	20	23.7	27.8	33.7	38.1
4-day	7.74	9	11.3	13.4	17.5	20.5	24.2	28.3	34.3	38.8
7-day	9.4	10.6	12.7	14.8	18.8	21.8	25.4	29.6	35.5	40
10-day	10.8	12	14.3	16.4	20.4	23.5	27.2	31.4	37.4	41.9
20-day	14.3	16.2	19.3	22	26.7	30.2	34.3	38.8	44.9	49.5
30-day	17.2	19.6	23.5	26.7	31.9	35.8	40.2	44.9	51	55.7
45-day	20.8	23.8	28.5	32.4	38	42.3	47	51.8	57.8	62.3
60-day	23.9	27.3	32.6	36.9	42.8	47.4	52.1	57	62.7	67

2.2 HISTORIC PRECIPITATION EVENTS AND ASSOCIATED FLOODING IN THE CITY

Flooding has been a recurring problem in the City due to its low elevation, with much of the City located in a FEMA Special Hazard Flood Area. Many historical floods have been associated with an extreme precipitation event. During storms and hurricanes, flooding is often associated with several factors in conjunction, for example by storm surge together with heavy rainfall.

Broward County's Enhanced Local Mitigation Strategy (ELMS) lists 22 historical flood events that occurred in the county from 1994 to 2011, with nearly $500 million in associated property damage. The ELMS lists National Flood Insurance Program (NFIP) payments of $10.5 and $22.6 million in Hallandale Beach for 2009 and 2011, respectively[iv].

The City of Hallandale Beach does not currently track or maintain an internal database of flood events due to extreme precipitation. Examples of historical flooding from extreme precipitation that affected Hallandale Beach can be found in NOAA's Storm Events database, which lists three recent events involving flooding due to extreme precipitation for the "Hallandale Beach" search term[v]. For example, on December 17, 2009, heavy rains caused severe flooding southeastern Broward and northeastern Miami-Dade counties, affecting Hallandale Beach. Up to 14 inches of rain in just six hours was recorded in nearby North Miami Beach.[vi] Table 2 shows details of this extreme precipitation event and others in the NOAA database.

TABLE 2: PRECIPITATION-CAUSED FLOODING EVENTS FOR HALLANDALE BEACH FROM NOAA STORM EVENTS DATABASE

Date	Location Affected	Description of Event	Cause
6/7/2013	Portions of Hallandale Beach near the Intracoastal Waterway	Severe Flooding	Heavy rain up to 9 inches associated with Tropical Storm Andrea
04/30/2012	Hallandale Beach, specific location not recorded	Roof collapsed on a home, resulting in injury to resident	Heavy rain (2 inches in 12 hour period) and winds to 40 mph
12/17/2009	Hallandale Beach, specific location not recorded	Streets and parking lots under several feet of water	Heavy rain associated with a warm front, up to 14 inches

The most recent extreme precipitation event in the City occurred on December 23, 2019. Southeastern Broward County and Northeastern Miami-Dade County received between 8 and 12 inches of rainfall during the early morning. The heavy rainfall affected several communities in the area including Hallandale Beach, Fort Lauderdale, Hollywood and Dania Beach. Localized flooding rendered roads impassable, damaged automobiles, and caused the Fort Lauderdale-Hollywood (FLL) International Airport to close for several hours (Figure 5[vii]

In Hallandale Beach, the worst flooding occurred in the area between Hallandale Beach Boulevard and Atlantic Shores, and between Federal and NE 14th Avenue. News reports indicated a City pump stopped working, possibly as a result of wells being overwhelmed by the heavy precipitation.[viii] The City did not provide an estimate of damages associated with this event.

FIGURE 5: DECEMBER 23, 2019 FLOODING IN HALLANDALE BEACH. PHOTO PROVIDED BY THE CITY.

2.3 COMMUNITY FLOODING COMPLAINTS DATABASE

The City maintains a database of complaints related to flooding received from residents. The City provided data on 37 flooding-related complaints over a four-year period, from September 2015 to October 2019. The complaints are not organized by the cause of flooding. There appears to be an increasing trend in the number of complaints per year, from 7 in 2015 to 16 in 2019 (**Error! Reference source not found.**). With only five years in the database, a longer time period would help validate this trend.

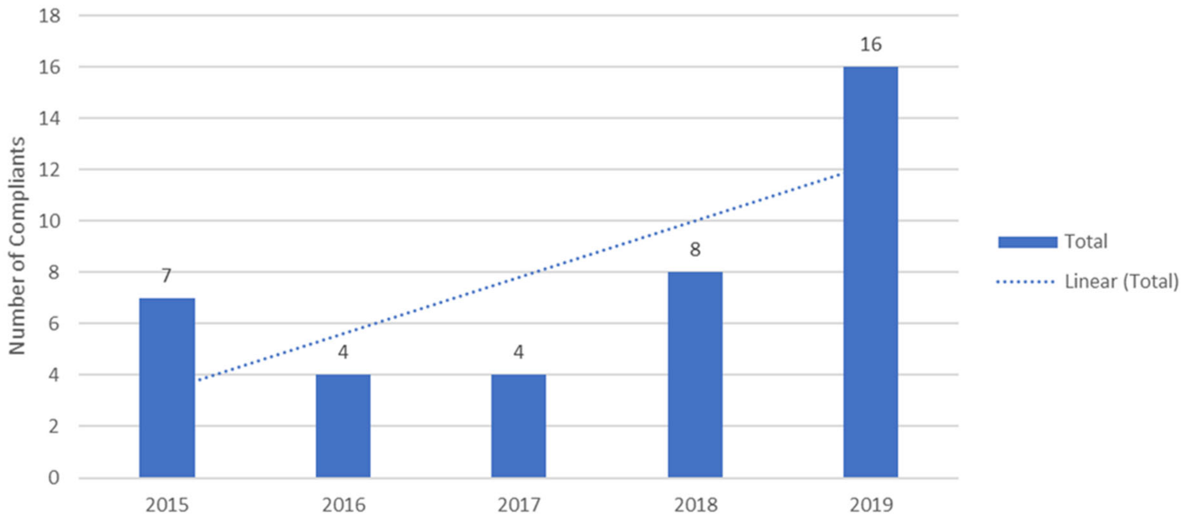

FIGURE 6: TREND IN NUMBER OF FLOODING COMPLAINTS OVER TIME, CITY OF HALLANDALE BEACH

The database includes the date each complaint was created and the date it was completed. There is no field to distinguish the cause of flooding, such as tidal flooding, precipitation events, or other causes, such as a broken water main. The database includes the date the City closed the compliant, but not a description of the City's response. Analysis of the number of days between creation and closing of the complaints shows an average 21-day response time from the City.

2.4 STORMWATER INFRASTRUCTURE DESIGN STANDARDS AND INVESTMENTS

The City's Comprehensive Plan establishes LOS standards for stormwater management. These have not changed since the previous 2007 Comprehensive Plan. For new development, the LOS is based on a design storm with a 5-year frequency, one-hour duration, and 3.3 total inches of rainfall. For existing development, the LOS is to meet the Florida Building Code drainage standards.

The City's 2007 Floodplain Management and Hazard Mitigation Plan discusses investments made to reduce flooding by implementing mitigation projects. From 2001 to publication, the City completed drainage improvement projects in areas subject to repetitive flood losses. In all, around $45 million was spent or earmarked for stormwater drainage improvements over the six-year period. The Plan indicates most of the projects were successful at reducing flooding, at least in the short term (**Error! Reference source not found.**).

TABLE 3: DRAINAGE IMPROVEMENT PROJECTS FROM 2007 HAZARD MITIGATION PLAN

Location	Description	Approximate Cost to the City
Ansin Boulevard, Northwest Quadrant	Pumps and piping installed to pump water from Chaves Lake to the C-10 Canal	$11 million
Southwest Quadrant	Capital improvement projects to enhance stormwater drainage, funded through Community Development Block Grants	$1.5 million
West of US 1	Projects to address drainage deficiencies	$3 million
Northeast Quadrant	Community Redevelopment Agency Drainage Improvements	$2.8 million

While more recent data on City investments in stormwater infrastructure improvements was not available, information from the 2007 Plan indicates the City's expenditures on improving drainage have been considerable. The next update to the Floodplain Management and Hazard Mitigation Plan will occur in 2021.

3. FUTURE CONDITIONS

Long-term climatic projections of future precipitation amount, intensity and frequency are a developing area of science. Such predictions are currently uncertain and may have a "low" or "moderate" confidence level, in contrast to climate impacts that are now more certain, such as sea level rise. Uncertainty rises as projections move from larger (global, national, regional) to smaller (state, local) geographic scales. County or city level projections are not available.

Generally, Hallandale Beach is likely to experience an increase in the frequency of extreme precipitation events, along with longer periods of drought and slightly less annual rainfall overall, in line with national and regional projections. These projections have a medium confidence level.

3.1 GLOBAL, NATIONAL AND REGIONAL PROJECTIONS

The IPCC Fifth Assessment Synthesis Report[ix] indicates it is "very likely" that extreme precipitation events over most mid-latitude land masses will become more intense and more frequent as global temperature increase. All of the continental United States falls into the mid-latitude region, which includes Earth's subtropical and temperate zones.

The report also states that in many mid-latitude wet regions, average annual precipitation will likely increase under the RCP8.5 scenario (**Error! Reference source not found.**). According to IPCC projections, by the last two decades of this century average annual precipitation could increase from 0 to 10% in Florida, compared to historical averages. However, as discussed below, some national and state-level projections show an overall decrease in annual precipitation for south Florida. The discrepancy is due to the uncertainty inherent in climate change projections related to precipitation.

In the context of flood damages, extreme precipitation events are more of a concern than total average annual precipitation. According to the Fourth National Climate Assessment, extreme precipitation events in the United States are already occurring and are expected to increase with climate change, increasing the risk of severe flooding. The report notes that infrastructure is not typically designed to account for a changing climate. In the Southeast region, "the combined effects of extreme rainfall events and rising sea level are increasing flood frequencies, making coastal and low-lying regions highly vulnerable to climate change impacts."[x]

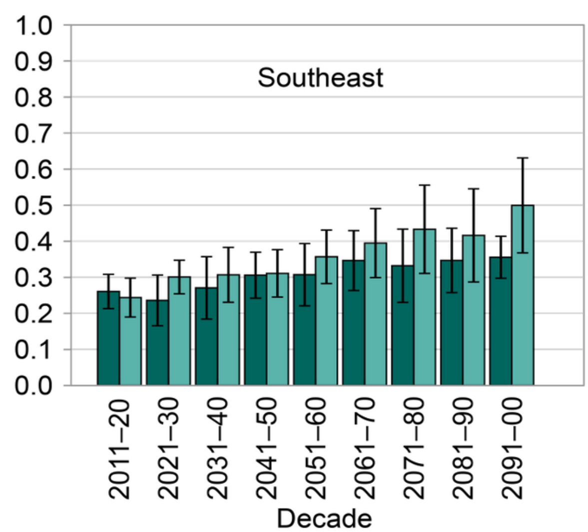

FIGURE 7: SOUTHEAST REGION EXTREME PRECIPITATION FREQUENCY FOR LOW AND HIGH CLIMATE SCENARIOS.

Extreme precipitation events in the Southeast are projected to increase in frequency during this century (Figure 7).[xi] The Figure shows projected changes in the 20-year return period amount for daily precipitation using downscaled climate projection data under both low (RCP4.5, low) and high (RCP8.5, high) scenarios. The chart aggregates average results from 16 and 14 different climate models for the low and high scenarios, respectively. The models used follow the CMIP5 protocol, endorsed by the World Climate Research Program. The low scenario shows increases of around 10% by mid-century and up to 14% by late century. The high scenario shows larger increases of around 20% by late century. The vertical axis shows the average frequency for the historical reference period (0.2), so the chart values should be interpreted relative to the historical average value.

3.2 STATE AND LOCAL PROJECTIONS

In contrast to the IPCC's projected increase in Florida, NOAA projections show annual precipitation averages in the state may decrease by the middle of this century by between 5 and 10%. [xii]

While changes in the total amount of precipitation are uncertain, NOAA and CMIP5 models generally agree that an increase in the intensity of rainfall is expected in Florida due to climate change. The result may be periods of drought interspersed with less frequent, but more intense precipitation events. This pattern has the potential to overwhelm stormwater systems that are designed to receive less runoff in any one storm.

Broward County's ELMS report indicates the county can be expected to experience future floods ranging in depth from 6 inches to 2 feet with maximum depths of up to 8 feet associated with thunderstorms, tropical storms and hurricanes. This estimate includes flooding associated with heavy rainfall, a high water table, and storm surge events. It also notes that, "the impacts of climate change and the attendant sea level rise will have considerable impact on future flood conditions" and that flooding in the county may be affected by "a potential 10% increase in overall precipitation" but also notes that, "some experts have projected a 10% decrease."

3.3 PRECIPITATION ASSOCIATED WITH HURRICANES

Hurricanes are a threat in Florida coastal communities. Broward County has had 17 hurricane disaster declarations since 1965. The flooding associated with hurricanes is be a major cause of property loss, injury and loss of life. Flooding can occur due to storm surge but can also be caused by extreme precipitation associated with these storms, or by a combination of factors.

As the climate warms, the atmosphere can hold more moisture. This can result in hurricanes releasing more extreme precipitation. The destructive potential of heavy rainfall associated with hurricanes can be seen in the flooding caused by hurricane Harvey in 2017, which dropped over 60 inches of rain in Nederland, Texas, and 36 to 48 inches in the Houston metropolitan area. Climate models on average show a 10 to 15% increase in rainfall rates for hurricanes, averaged within about 100 km of the storm, under a two-degree Celsius warming scenario[xiii].

4. IMPLICATIONS FOR HALLANDALE BEACH

While projections of future climatic changes to precipitation patterns are uncertain, there is no doubt that extreme precipitation events have the potential to cause destructive flooding in the City, impacting City infrastructure, residences, businesses, streets and vehicles. If these events become more severe and/or more frequent as projected by most climate models, the City should expect more destructive flooding unless it takes proactive mitigation measures.

Because much of the City is in a FEMA Special Flood Hazard zone, heavy rainfall has the potential to result in flooding. This has occurred repeatedly in the historical record, resulting in considerable property losses. The City has made significant capital investments in improving stormwater infrastructure with positive results. However, future changes in precipitation patterns may mean that even areas that have benefitted from these improvements could suffer flooding if design conditions are exceeded. This was seen in the December 2017 flood event when the volume of stormwater exceeded the capacity of pumps, causing one pump to go offline during the storm. The result was significant flooding of City neighborhoods, causing blocked streets and damaged cars and buildings.

Hallandale Beach's 2014 Vulnerability to Sea Level Rise Assessment Report only considers the effects of sea level rise and does not consider precipitation changes associated with climate change. Further study may be needed to fully understand the interaction and combined effect of potential climate impacts related to flooding in the City (precipitation, elevation of the water table, sea level rise and storm surge).

4.1 POTENTIAL IMPACTS TO THE COMMUNITY

Flooding can cause acute impacts such as property damage, injuries or loss of life. It can also contribute to longer term impacts such as financial hardship, loss of business income, secondary health impacts related to pollution, waterborne disease and sanitary sewer spills, and disruption of infrastructure. Transportation routes may be blocked, including critical evacuation routes. Residents may be subject to financial stress if they suffer damages, or if their flood insurance becomes unavailable or rates increase as a result of recurring or significant losses in the community. All of these impacts can also cause psychological stress for people who are affected. Vulnerable residents such as those who are elderly, young, disabled, minority and low-income may be more adversely affected or have a harder time recovering from a flood event.

4.2 POTENTIAL IMPACTS TO CITY INFRASTRUCTURE

Flooding can damage infrastructure such as facilities, roads, parks, drainage systems, water and wastewater systems, and power distribution. Damaged infrastructure can result in considerable costs to the City. Floods can also deposit debris that will require cleanup and removal, as well as spread pollutants from contaminated sites, resulting in a need for expensive remediation. Severe or recurrent flooding can anger residents, limit tourism, and potentially affect the tax base if people or businesses relocate as a result.

Floods can also impact the City's stormwater management system. Systems in coastal areas may require gravity to move water, and can back up when outfalls are submerged by flooding. Flooding can also block pipes by forcing debris into them. If saltwater is introduced into the system, it can corrode piping, valves and other components.

5. PRELIMINARY RECOMMENDATIONS

RS&H has identified number of recommendations for the City to consider that will mitigate the risk posed by flooding from extreme precipitation events.

This report presents only a high-level assessment of risk from climate-related changes in extreme precipitation. Further analysis would be needed to evaluate the vulnerability of specific infrastructure or facilities, community impacts, and thresholds where impacts would occur. It is also necessary to monitor emerging science and projections on the topic, since uncertainty exists regarding climate impacts.

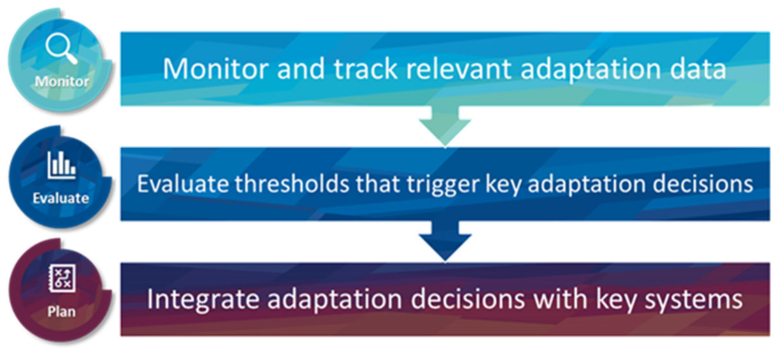

FIGURE 8: ADAPTIVE MANAGEMENT PLANNING APPROACH

For this reason, RS&H recommends an Adaptive Management planning approach (Figure 8). Adaptive Management is a systematic approach to managing uncertainty through flexible decision making informed by data. It can be used as a framework for addressing vulnerabilities, starting with the development of initial actions to mitigate climate change effects. Informed by adaptive management, the initial actions developed in this plan are classified into three categories, Monitor, Evaluate, and Plan.

5.1 MONITOR

- Monitor emerging science / projections related to extreme precipitation events. Currently, there is uncertainty related to projections of changes in total annual rainfall, and the degree to which extreme precipitation will increase. The City should monitor both changes in historical data and emerging science that may clarify projections.

- Coordinate with regional partners such as Broward County, the Florida Department of Transportation, the Florida Department of Environmental Protection, and the South Florida Water Management District on analysis of regional drainage conditions and needs and identification of critical facilities

- Maintain an internal database of flooding incidents and locations that includes flooding as result of precipitation events as well as other causes (i.e. water main leaks, tidal flooding, etc.). The City should record the cause of flooding as well as weather details about the event, such as the total rainfall, duration of event, etc. In addition, the database should include information about the location and extent of flooding, damages, and costs of the City's response. This will allow high-hazard areas to be identified and help track changes in the frequency and severity of events. Identify vulnerable populations ahead of time who may need assistance during a flood event.

» Conduct outreach to encourage these residents to register in the Vulnerable Population Registry. Conduct pre-planning to ensure the City can contact, locate, and assist them in the event of a flood.

» Monitor flood events and notify residents when they pose a threat. This is consistent with the 2018 Floodplain Management and Hazard Mitigation Plan Evaluation Report recommendation to have a flood monitoring system that can provide real-time information to residents.

» Update the resident flood complaints database to include the cause of flooding (i.e. sunny day/high tide flooding, rainfall event, storm surge, etc.) Establish a goal for response times to resident complaints. Also include in the database a field to capture the nature of the City's response to each complaint.

5.2 EVALUATE

» Conduct a benchmarking study to see how other communities are planning for extreme precipitation events and improving their stormwater systems. Benchmarking involves investigation of best management practices that peer cities have implemented and found effective and evaluating them for applicability to the City.

» Follow NOAA recommendations to identify the thresholds or failure points at which vulnerable stormwater systems may be compromised by flooding. Once these critical thresholds have been identified, they can be used to inform designs for future upgrades of the system.

» Evaluate and if necessary, update Level of Service (LOS) standards for stormwater systems in new development Identify thresholds for failure of critical stormwater system components (for instance, the level at which outfalls are submerged and cease to work) and incorporate this information into planning and upgrade projects.

» Evaluate options to improve stormwater management systems in existing developments and update them to perform under expected future conditions.

» Consider system-wide drainage impacts when approving new development. NOAA and others recommend considering the entire watershed when approving projects that will affect drainage, and looking at the issue holistically instead of as a series of isolated projects. This approach can help reduce flood risk and ensure that approved developments are not negatively impacting other parts of the stormwater management system.

5.3 PLAN

- Implement the flood risk mitigation actions included in the 2018 Floodplain Management and Hazard Mitigation Plan Evaluation Report.[xiv]

- Include resiliency projects in the 2021 update to Floodplain Management and Hazard Mitigation Plan. Projects included in this plan may be eligible for federal funding under the Hazard Mitigation Grant Program.

- Conduct education and outreach to ensure community members are informed about flood risks and that they have a personal disaster plan in place to deal with flood events. Note this recommendation is consistent with the 2018 Floodplain Management and Hazard Mitigation Plan Evaluation Report recommendation to include flood-related information in Building Division Community Education Forums.

- Promote and/or incentivize the use of flood insurance to protect vulnerable homes and businesses.

- Use flood prone areas for open spaces, parks, parking lots, or other uses that can be designed to flood in a storm and provide temporary storage for excess runoff. By designing certain areas to flood, stormwater can be diverted from the overall system so it can effectively deal with an extreme precipitation event.

- Continue to regularly maintain the stormwater system with a goal of reducing Inflow and Infiltration (I&I), removing blockages and debris, and ensuring force mains, pumps, and other components are in good condition and will not fail in a storm.

- Require Low Impact Development (LID) for all City projects and requiring or incentivize LID practices in new developments. LID is development designed to maximize green space and promote natural stormwater management through the use of plants and permeable materials to minimize stormwater runoff velocity and temperature, and reduce pollution. Examples of LID practices include the use of bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. Note this recommendation is consistent with the 2018 Floodplain Management and Hazard Mitigation Plan Evaluation Report recommendation to continue to encourage percolation-oriented drainage. As noted in the City's Sustainability Action Plan, proposed amendments to the City's Comprehensive Plan (New Policy 2.2.5 in the Coastal Management Element) stipulate that the City shall incorporate LID into all new public projects within FEMA flood zones and the Coastal High Hazard Areaxv.

- Implement the stormwater-related policies and objectives identified in the 2018 update to the City's Comprehensive Plan. Continue to include goals, objectives, and policies related to anticipated climate change impacts related to precipitation and flooding in future Comprehensive Plan updates.

- Many of these initiatives would also help to improve the City's National Flood Insurance Program (NFIP) Community Rating System (CRS) classification. The City's 2018 Sustainability Action Plan recommended improving the CRS score. If the City were able to improve the CRS score from Class 5 to Class 4, avoided insurance costs to the community could exceed $12.8 million in net present value over a ten-year period.

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CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 4: QUALITATIVE ASSESSMENT OF GROUNDWATER CHANGES

RS&H

CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 4: QUALITATIVE ASSESSMENT OF GROUNDWATER CHANGES

February 28, 2020
RS&H No.: 301-0068-000

Prepared by RS&H, Inc. at the direction of the City of Hallandale Beach

RS&H

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1. GROUNDWATER CHANGES OVERVIEW

Groundwater will be impacted by climate change as a consequence of sea level rise. The porous karst topography underlying Florida's coast allows water to flow through it. This has two primary effects: it allows the groundwater table to rise at approximately the same rate as sea level, and it leads to saltwater intrusion as sea water mixes with the groundwater. Although sea walls or other barriers could be constructed to hold back ocean waters, the permeable karst allows sea water to flow underneath the barrier.

Projections of future groundwater impacts due to climate change show the water table in Hallandale Beach may rise by approximately one foot by the 2060's. This will have implications for drainage and flooding in the City as well as increasing the rate and severity of saltwater intrusion. To prepare for this threat the City should evaluate the problem, monitor groundwater conditions, emerging science and climate projections related to the issue, and plan to improve the resilience of the community and its infrastructure.

1.1 GROUNDWATER TABLE

As the groundwater table rises, it reduces the capacity of the land to hold excess stormwater and runoff, contributing to flooding. Higher sea levels will cause less gradient for gravity control of stormwater. This may necessitate pumping to maintain pressure and flow towards the ocean. Pumping increases energy use and introduces new vulnerabilities into the City's stormwater management system.

Groundwater quality can also be compromised through exposure to contaminants which were previously isolated from the aquifer. Soil and water contaminants on brownfield sites that were previously isolated from groundwater could contact it once groundwater levels are elevated. A higher water table can impact infrastructure such as underground tanks, pipes, electrical conduits and building foundations. It can also affect vegetation. The growth of some plant species can be impaired by a high water table and poor drainage.

1.2 SALTWATER INTRUSION

Saltwater intrusion occurs when seawater moves into groundwater aquifers, contaminating freshwater resources (Figure 1). To prevent this, water managers need to maintain the groundwater table at a sufficiently high level to maintain pressure and flow towards the sea. As the sea water level increases, the flow of groundwater towards the ocean could be reversed if adequate pressure is not maintained.

Withdrawals from wellfields contribute to the saltwater intrusion problem. A 2012 U.S. Geological Survey (USGS) study in Pompano Beach found that groundwater withdrawals over several decades were the primary cause of saltwater intrusion into the city's wellfield, with sea level rise a secondary cause. As sea level rise continues in coming decades, it may become a primary cause of the problem, however limiting withdrawals can slow the rate of saltwater intrusion.[i]

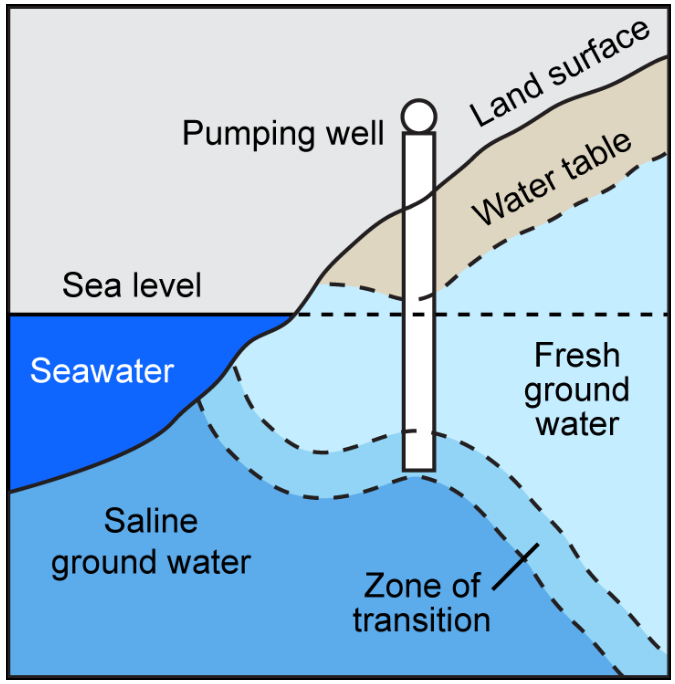

FIGURE 1: SALTWATER INTRUSION PROCESS, U.S. EPA

High temperatures related to climate change may lead to increased evaporation, contributing to drought. Drought conditions can potentially lead to over-pumping and depletion of groundwater from the aquifer as water consumption continues but groundwater supplies are not being replenished by rainfall. In times of drought, the risk of saltwater intrusion may increase if there is not sufficient groundwater pressure to hold back the rising sea.[ii] In an era of climate change, the complex relationships between temperature, sea level rise and groundwater increase the difficulty and importance of effectively managing groundwater resources for the future.

2. BASELINE CONDITIONS

Baseline conditions for groundwater in the City are defined by historical aquifer data, groundwater elevations, and observed changes over time. They also include the City's present stormwater management system, locations of the City's wellfield and the saltwater interface, and adaptation actions the City and surrounding municipalities have taken in response to groundwater changes.

2.1 BISCAYNE AQUIFER

Hallandale Beach, like most other municipalities in Broward county, draws its potable water supply from the Biscayne aquifer, which serves millions of residents in Broward, Miami-Dade, and portions of Palm Beach counties.

The Biscayne is a surficial aquifer. Surficial aquifers are located near the surface and are principally recharged by precipitation. As a result, groundwater levels can be affected by periods of drought or excessive rainfall, and by the rate of pumping to serve wells and water systems.[iii] Since the aquifer is close to the land surface, groundwater quality can easily be affected by contamination from anthropogenic sources. These may include leaking storage tanks from dry cleaners and gas stations, transportation spills and other sources.

The Biscayne is an unconfined coastal aquifer that is directly connected to the ocean. Because saltwater is denser than freshwater, groundwater typically floats above the saltwater in the transition zones where the two meet[iv]. There is also some mixing that occurs in the transition zone, making groundwater brackish in this location. The position of the saltwater interface has moved further inland in Broward County as a result of sea level rise. Globally, sea levels have increased about eight inches on average since 1900.

2.2 HISTORICAL GROUNDWATER ELEVATIONS AND OBSERVED CHANGES

The U.S. Geological Survey (USGS) maintains a national network of groundwater monitoring wells that measure the depth of water below land surface (BLS) in feet, along with other parameters. The closest wells for which data was available are located just north of the City in Hollywood, Florida. Data for two wells located in Hollywood (G-2035 and G-2441) show that the depth of groundwater is decreasing overtime as rising sea levels cause it to rise closer to the land surface.[v]

Figure 2 shows the trend in depth to water BLS for Well G-2035. About a six inch rise in the groundwater table has been observed in this well from 1977 to 2020. Similarly, a gradual increase in groundwater elevations has been observed at many monitoring wells throughout Broward County. The County has stated that as much as one foot of groundwater rise has been observed in some of its wells over the past twenty years[vi].

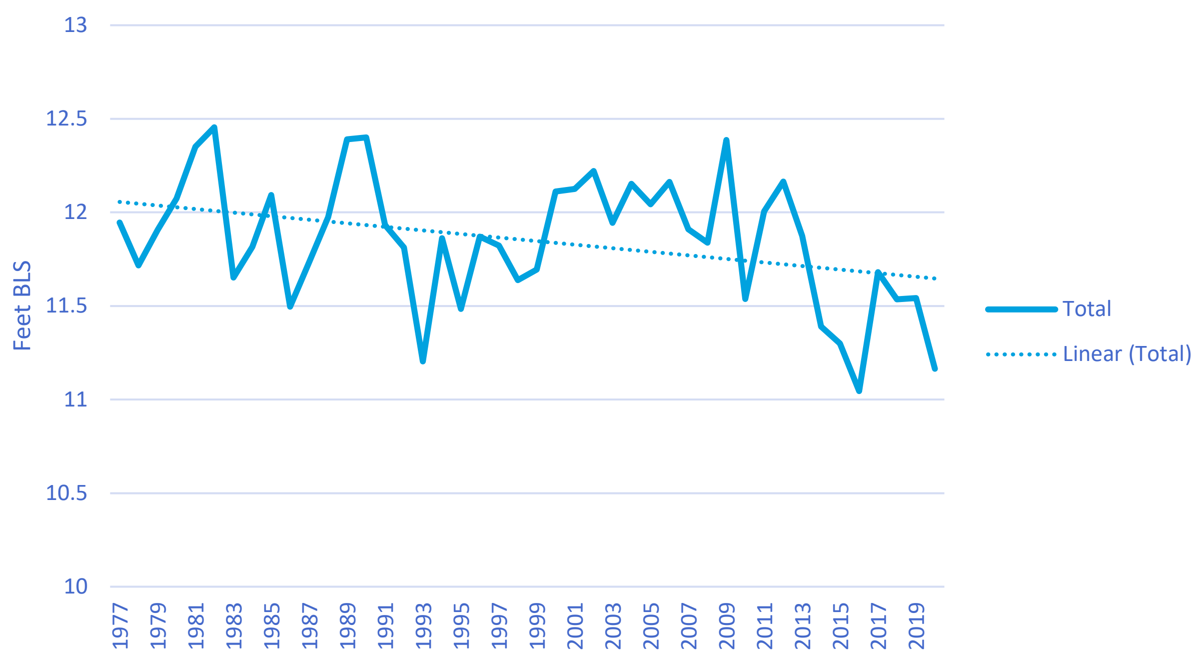

FIGURE 2: USGS GROUNDWATER MONITORING WELL G-2035, HOLLYWOOD FLORIDA, DEPTH TO GROUNDWATER

Broward County publishes groundwater surface maps for the County that are used for evaluating applications for surface water management licenses. The County's "Antecedent Conditions" map was published in 2000, and can be used as a baseline for understanding historic groundwater elevations in the County (Figure 3). This map was used to determine average ground water levels when calculating a design event for projects in permit applications to the county.[vii] It measured groundwater depths using the 1988 North American Vertical Datum (NAVD) for orthometric height, so measurements do not necessarily correspond exactly to BLS measurements. It shows the water table is deeper below the ground surface in the northern part of the county, and closer to the surface in the south and east.

Hallandale Beach is located in the southeastern portion of the county, bordering the Atlantic Ocean and Miami-Dade County. The City is located in a shallow coastal groundwater region where average groundwater depth contours have historically been around two feet NAVD or less.

As a result of the low surface elevations and high water table in the southeastern part of Broward County there are only gradual gradients available for gravity drainage of stormwater towards the ocean. The mean elevation in Hallandale Beach is 5.11 feet above mean sea level (MSL). Approximately 30% of the City is below three feet in elevation, and about 59% is below five feet. Because groundwater is so near the surface, there is relatively little storage for excess stormwater, leading to a risk of flooding. A network of canals and drainage control structures are used to keep developed land dry.

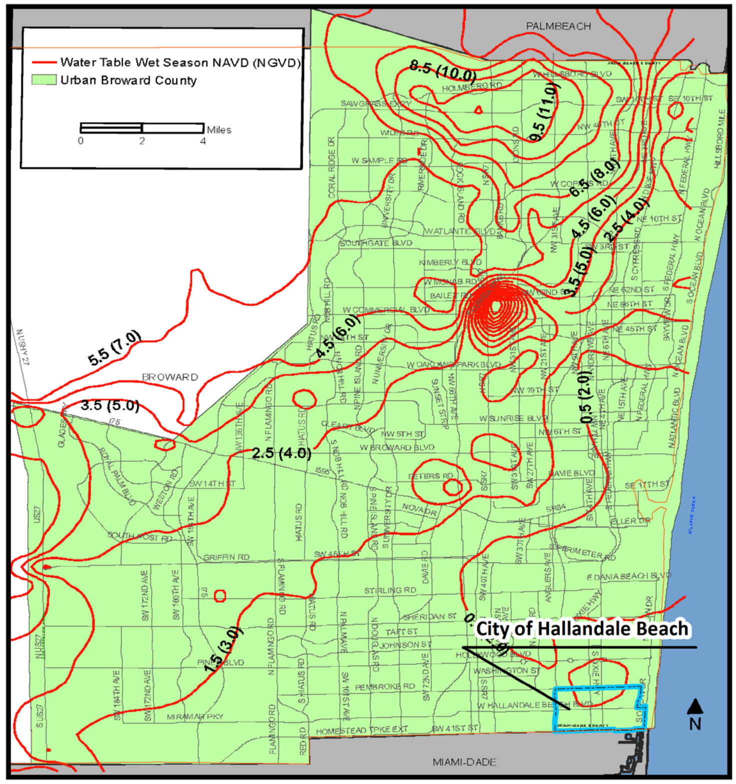

FIGURE 3: WATER TABLE DEPTH (FEET NAVD), 2000

2.3 STORMWATER DRAINAGE SYSTEM

The City is predominantly flat in elevation and has no distinct drainage basins. Large areas of the City are located in a FEMA Special Hazard Flood zones and have more than a 1% annual chance of flooding. As a result of development, much of the City is covered in impervious surfaces. The City has two systems for controlling stormwater: a positive drain system that flows to canals and other waterbodies, and a system of French drains that feed perforated pipes and dry wells to allow runoff to permeate the ground[viii]. Past improvements to the stormwater system have been largely successful in reducing nuisance flooding and ponding in the City following precipitation events. Parts of this system depend on pumps which can sometimes fail due to mechanical problems or loss of power.

2.4 LOCATION OF THE CITY'S WELLFIELD AND WATER SUPPLY

The City's wellfield is located in the northwest quadrant, within City limits. Groundwater is sourced from three wells approximately 100 feet deep.

The City also sources water from Broward County's South Regional Well Field, located in Brian Piccolo Park in southwestern Broward County. The City has a purchase agreement with the City of North Miami Beach to purchase water during emergencies. The two cities have interconnected water mains.[ix]

2.5 LOCATION OF THE SALTWATER INTERFACE

Figure 4 shows the location of the saltwater interface near the City's remaining production wells. By 2012, groundwater had become salty in about 83% of the City's area. The saltwater interface made up 4% of the City's area, and the area of lowest saltwater intrusion, located west of 8th Avenue, was about 12% of the City.

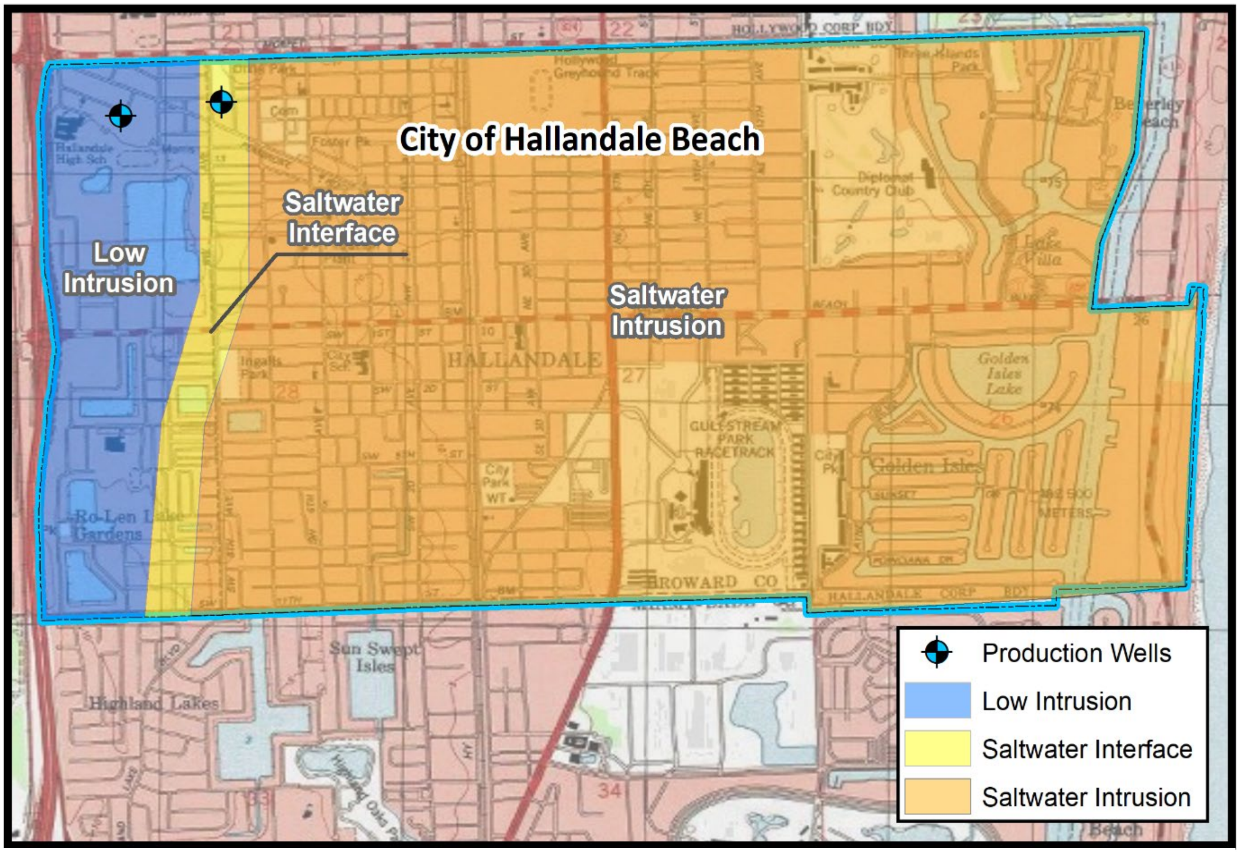

FIGURE 4: LOCATION OF THE SALTWATER INTERFACE

2.6 STATUS OF THE CITY'S WELLFIELD

The South Florida Water Management District (SFWMD) permits the City of Hallandale Beach to withdraw water from the Biscayne aquifer to supply its public water system. The City's Water Use Permit (WUP) is No. 06-00138-W. One of the conditions of the City's WUP requires the City to cease pumping if chloride concentrations exceed 150 mg/l in production wells and notify the SFWMD.

Excessive withdrawal of the groundwater resource to serve the City's water system could increase the rate at which the saltwater interface migrates westward. The SFWMD originally limited the City's wellfield pumping rate to 3.5 million gallons per day (MGD).[x] Since 2007, SFWMD has limited capacity to 3.0 million gallons per day. The City is able to source another 6.2 MGD through an agreement with Broward County.[ix]

The USGS maintains a network of monitoring wells within the City limits that measure salinity (chloride levels). The City provided RS&H with chloride measurement data in part per million (ppm) for wells G-

1435, G-2294, G-2409, G-2410, G-2477, G-2478, G-2965. Based on 2018 data, these wells show high chloride concentrations in the range of 4000 – 9750 ppm, with the exception of wells G-2409 and G-2477 which average around 50 and 35 ppm, respectively. Five of the seven monitoring wells show chloride concentrations much higher than the SFWMD's limit for production wells. The wells show gradually increasing chloride concentrations over time from 2014 to 2018.[xi]

The City began investigating the possibility of moving the wellfield westward in 2008. By 2011, the City had abandoned six of its eight production wells for drinking water because they had become saline.[xii] In August 2013, the City Commission abandoned the plan to move the wellfield westward in favor of a strategy to continue to use the City's wellfield, supplemented with supply from the County's wellfield.[xiii] At this time, only Well PW-8 is still in service. Well PW-7 is used as a standby well when PW-8 is not operational.[xiv]

2.7 ADAPTATION ACTIONS

The City has been proactive in addressing the threats posed by rising groundwater elevations and saltwater intrusion. Adaptation actions to help manage stormwater drainage and saltwater intrusion risks poses to the City's water supply fall into a few general categories:[xv]

- Monitoring
- Water Conservation
- Wellfield Protection
- Wellfield Relocation
- Alternative Water Supplies
- Improved Stormwater Management

2.7.1 Monitoring

To measure increasing chloride concentrations and groundwater levels, the City implemented a network of saltwater monitoring wells (SWMW)s that tracks the location and depth of the saltwater interface. Three SWMWs were completed in 2016, two in the southwestern and one in the northwestern quadrants of the City.[vii]

2.7.2 Water Conservation

Water conservation is one of the most cost-effective responses to the saltwater intrusion threat. By using less water, the City can slow the rate of pumping from its wellfield, which slows the rate of saltwater intrusion. The City has a number of water conservation initiatives.

Hallandale Beach implemented a Water Conservation Plan under SFWMD guidance. Conservation initiatives included in the plan include outreach events to educate residents about water conservation, and giveaways of low flow/low flush fixtures and retrofits.

The City has educated residents through public workshops for the Sustainability Action Plan, Green Fest, the Water and Energy Conservation Workshop, the Rain Barrel and Native Plant Workshop, and other events. Additionally, the City's website contains information and resources on water conservation.

Hallandale Beach has also adopted ordinances on landscaping irrigation, Florida-friendly landscaping, and automatic irrigation controls that save water. Florida-friendly landscaping promotes the conservation of water by the use of site adapted plants and efficient watering methods. The City participates in Broward County's Naturescape irrigation audit program. It has also installed drought tolerant landscaping and efficient fixtures to save water at City facilities.

2.7.3 Wellfield Protection

A feasibility study completed by the City in 2013 considered a salinity barrier which would inject reclaimed water near the City's wellfield to provide increased hydrostatic pressure, with the objective of reversing salinization of the wellfield. The project would also potentially provide a way to dispose of reuse water currently discharged to ocean outfalls. In 2012, the City studied a wellfield revitalization strategy designed to preserve the existing wellfield by developing a salinity barrier. A drainage well system was slated for completion in 2013.[x]

2.7.4 Alternative Water Supplies

The City completed a reverse osmosis membrane filtration plant in 2008. The plant has the capacity to add additional nanofiltration or reverse osmosis filtration capability. It allows the City to strain out some of the saline elements within saltwater that have infiltrated its production wells.[xii]

The City has also secured water supplies through its purchase agreements with Broward County and North Miami Beach.

2.7.5 Improved Stormwater Management

The City of Hallandale Beach has prioritized groundwater recharge in an effort to slow down the rate of saltwater intrusion. By ordinance, "new development is required to provide on-site drainage improvements sufficient that the stormwater developed by a storm up to 5 year intensity is retained on-site and recharged to the aquifer." The City has also installed large-diameter drainage wells east of U.S. 1 to reduce flood risk and help recharge the aquifer.[xxi]

2.8 ADAPTATION ACTIONS TAKEN BY PEER CITIES IN THE REGION

Other Cities in the region are also affected by saltwater intrusion and have been taking action in response to the problem. The cities of Pompano Beach and Hollywood have opened well fields to the west of their borders so they can continue to supply uncontaminated groundwater to their residents.

Another option is desalinization plants. As of 2009 there were more than thirty desalinization plants operating in the SFWMD's service area. Many of these plants draw brackish water from the Floridan aquifer, beneath the Biscayne. Up to 65 to 85% of this water can be recovered, or purified. The portion of the water that is not recovered, called concentrate, typically must be disposed of in injection wells, adding to the cost of treatment.[xvi]

People often associate desalinization with making sea water potable. While it is also possible to desalinate sea water, typically only 30%-60% can be recovered, more energy is required, and more concentrate must be disposed of, making this option much more expensive than desalinating brackish water.

Along with Hallandale Beach, the cities of Hollywood and Deerfield Beach are among those that have invested in reverse-osmosis desalinization technology.[xvii] The primary drawback of this type of treatment is cost. Treatment facilities, operations and maintenance, and concentrate disposal all involve higher costs than pumping water from a non-saline groundwater source. Ultimately, the higher costs end up being passed along to utility customers. However, there is a decreasing trend in desalination costs as technology improves. Reverse osmosis systems typically cost less to operate than competing desalinization technologies, because less energy use is required.[xviii]

3. FUTURE CONDITIONS

In 2017, Broward County developed a new Future Conditions groundwater map (Figure 5) for permitting development. It projects future average wet season groundwater elevations based on expected changes in sea level and precipitation as a result of climate change. The average is based on model outputs for the months of May through October over the period of 2060-2069. By the year 2070 Broward County expects 41% of the county's coastal wellfields will be impacted by saltwater intrusion.[xi]

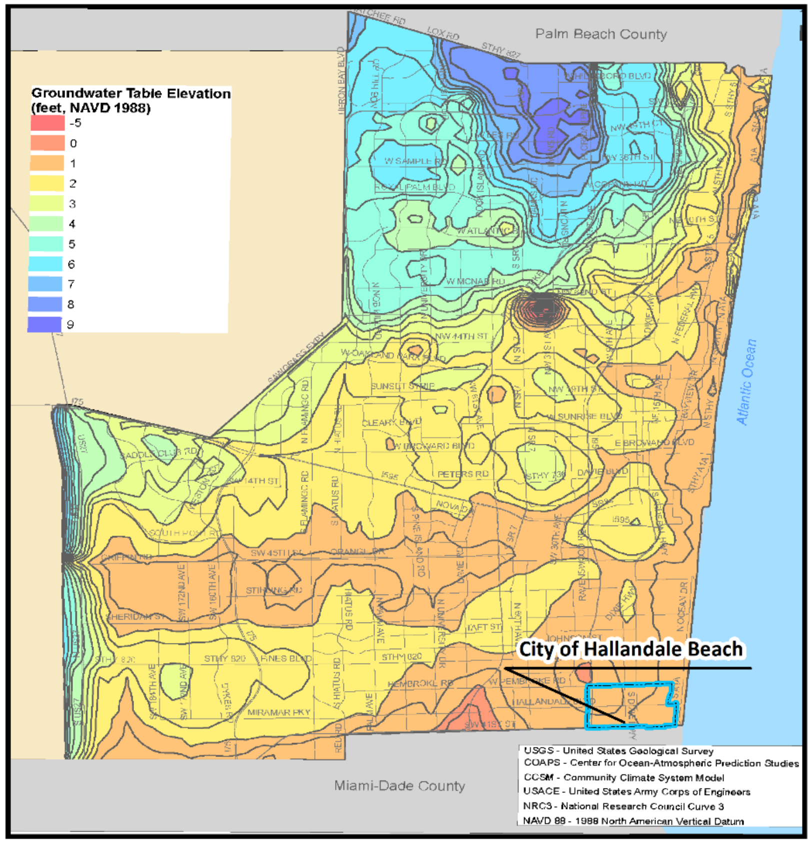

FIGURE 5: BROWARD COUNTY FUTURE GROUNDWATER ELEVATION

The map fosters development designed for conditions experienced during the project lifecycle, rather than past conditions that are no longer applicable. The County states "the map will be used for determining the average wet season ground water levels for use in calculating a design event for new applications for a surface water management license, applications for major redevelopment of existing sites, and applications for major modifications to existing surface water management licenses submitted after June 30, 2017." USGS developed the models used to project future groundwater conditions. They include the Broward County Inundation Model and the Broward County Northern Variable Density model.[1]

Broward's Future Groundwater Conditions map shows the groundwater table in Hallandale beach will be approximately one foot NAVD across the City by the 2060's. In other words, the water table will be approximately one foot higher than it is now, and only one foot below the surface, on average. However, there may be minor variations between different parts of the City that are not captured at the resolution of the Broward map.

[1] The future precipitation pattern is based on the Center for Ocean-Atmospheric Prediction Studies (COAPS) downscaled Community Climate System Model (CCSM) global model and represents an increase of 9% rainfall from the base case of 1990-1999 (53.4 inches per year to 58.2 inches per year). Sea level rise was based on the United States Army Corps of Engineers (USACE) National Research Council Curve 3 (NRC3) curve which equates to an increase of 26.6 (2060) to 33.9 inches (2070) from 1992 levels. Final results are presented in 1988 North American Vertical Datum (NAVD 88).

4. IMPLICATIONS FOR HALLANDALE BEACH

The impacts of sea level rise on groundwater elevations and water quality will have significant implications for the City. Addressing these impacts may require capital investments, public education, and potentially relocating some facilities. Implications can generally be categorized as related to drainage or flooding, and saltwater intrusion.

4.1 DRAINAGE IMPLICATIONS

In areas where groundwater is already close to the surface, such as Hallandale Beach, rising sea levels will exacerbate the expected flooding, potentially doubling it.[xix] Even before this stage is reached, elevated groundwater levels will reduce infiltration and storage of stormwater, worsening flooding during precipitation events.

Higher groundwater may affect some plant species, impairing growth of those adapted to well-drained soils. This issue may be compounded if groundwater becomes saline, as discussed in the next section.

Since infrastructure such as sewer and stormwater systems were designed for historical groundwater levels, elevated levels can cause these systems to fail. Some infrastructure can also be corroded or otherwise damaged by immersion, particularly in salty groundwater.[xx] Buried pipes may also be subjected to uplift as the water table rises, potentially altering slopes necessary for drainage. Stormwater outfalls may be inundated by rising sea levels, or groundwater levels, causing the system to back up. If wastewater systems fail, sewage overflow may affect natural ecosystems and human health.[xxi]

4.2 SALTWATER INTRUSION IMPLICATIONS

Saltwater intrusion is a long-standing issue in Hallandale Beach. The observed migration of the saltwater interface to the west is of concern since it limits the amount of water the City can withdraw, and may eventually necessitate abandonment of the City's production wells. This would require the City to develop or procure an alternative water supply, likely at greater cost than the existing system.

As the effects of sea level rise and saltwater intrusion become more pronounced, other cities in the region will be affected. Together with growing demand, this may reduce supply of water from outside the City boundaries, further increasing costs.

Vegetation may be affected by saltwater intrusion, leading to poor growth or mortality of species that are not salt-tolerant. Increasing salinity of the groundwater table may affect trees and other vegetation that take up groundwater through their roots.

5. PRELIMINARY RECOMMENDATIONS

RS&H has identified preliminary recommendations for the City to consider that will help to mitigate the risk posed by rising groundwater levels and saltwater intrusion. This report presents only a high-level assessment of risk from climate-related changes to groundwater as a result of sea level rise. Further analysis will be needed to evaluate the vulnerability of specific infrastructure or facilities, community impacts, and thresholds where impacts would occur. It is also necessary to monitor emerging science and projections on the topic, since uncertainty exists with regard to climate impacts.

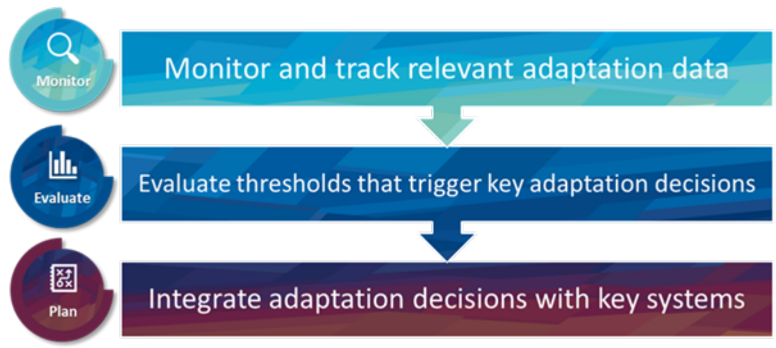

FIGURE 6: ADAPTIVE MANAGEMENT PLANNING APPROACH

For this reason, RS&H recommends an Adaptive Management planning approach (Figure 6). Adaptive Management is a systematic approach to managing uncertainty through flexible decision making informed by data. It can be used as a framework for addressing vulnerabilities, starting with the development of initial actions to mitigate climate change effects. Informed by adaptive management, the initial actions developed in this plan are classified into three categories, Monitor, Evaluate, and Plan.

5.1 MONITOR

» Monitor emerging climate and sea level rise projections. Sea level projections are subject to change due to improved scientific understanding and changes in emissions rates. Under current emissions trajectories, the trend has been for sea level rise projections to be revised upwards.

» Monitor emerging science related to the impacts of sea level rise on groundwater, including saltwater intrusion.

» Coordinate with regional partners such as Broward County, the Florida Department of Transportation, the Florida Department of Environmental Protection, the South Florida Water Management District, and other municipalities in the region on analysis of groundwater conditions and adaptation options.

» Partner with local universities to encourage collaboration and scientific research that improves understanding of groundwater and saltwater intrusion issues and adaptive responses.

5.2 EVALUATE

» Evaluate existing development and identify means to promote retrofits of existing infrastructure to conform to LID. LID is development designed to maximize green space and promote natural stormwater management through the use of plants and permeable materials to minimize stormwater runoff velocity and temperature, and reduce pollution. Examples of LID practices include the use of bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements.

» Study the implications of Broward's Future Conditions Average Wet Season Groundwater Elevation Map (showing the water table at approximately one foot NAVD by 2060-2069) for future private development/redevelopment.

» Conduct outreach to the development community to educate and inform them about the implications of Broward's Future Conditions Average Wet Season Groundwater Elevation Map and permitting requirements.

» Assess the City's Stormwater Management System and begin planning now for how the system will operate at the groundwater conditions shown in the Future Conditions Average Wet Season Groundwater Elevation Map, including needed upgrades. Update city stormwater master plan and review potential for flooding of existing facilities. Conduct an assessment of critical infrastructure and operations within the City and determine how it may be adversely impacted by sea level rise (groundwater elevations) and more extreme precipitation events. Identify means to harden stormwater system, improve pumping and recharge capabilities to promote freshwater.

» Assess the City's Wastewater Management System and begin planning for the system to operate at the groundwater conditions shown in the Future Conditions Average Wet Season Groundwater Elevation Map to prevent the possibility of sanitary sewer overflows or unpermitted releases in flood events.

» Study how public health may be affected by future groundwater elevations as a result of water quality impacts, wastewater spills, and mosquito-borne illnesses.

» Assess contaminated sites in the City to determine how they will be impacted by the rising groundwater table and how to prevent them from contaminating the groundwater resource.

5.3 PLAN

» Implement the Low Impact Development (LID) recommendations identified in the City's 2018 Sustainability Action plan.

- Because many types of infrastructure have a life of up to 50 years or longer, the City should immediately begin using Broward's Future Conditions Average Wet Season Groundwater Elevation Map when planning or conducting engineering studies for development of city-owned properties, facility construction and renovation, stormwater system upgrades, and other City projects.

- Advocate for FDEP to update the regional stormwater management rule, the "SFWMD Environmental Resource Permit Applicant's Handbook – Volume II", consistent with the recommendation of the Southeast Florida Regional Climate Collaborative (SFRCC). The SFRCC asks members to "advocate for rule changes that integrate potential future climate conditions and stormwater harvesting initiatives in permitting criteria at all levels", including average wet season groundwater elevations; unified sea level rise projections; and intensity, duration, and frequency curves."

- Conduct public outreach and education on how the rising water table and saltwater intrusion issue may affect landscaping and vegetation in the City. Encourage use of drought-tolerant, poor-drainage tolerant and salt-tolerant species in appropriate areas.

- Consider conducting a study of future groundwater / saltwater intrusions in the City that would provide higher resolution than the Broward Future Conditions Average Wet Season Groundwater Elevation Map, which shows the entire City at a one foot contour.

In addition to the recommendations listed above, RS&H recommends the City implement the Policies and Objectives related to this issue that were included in the 2018 update to its Comprehensive Plan.[viii] These adaptation measures are detailed in Table 1, below.

TABLE 1: GROUNDWATER / SALTWATER INTRUSION ADAPTATION ACTIONS FROM THE 2018 COMPREHENSIVE PLAN

Adaptation Category	Comprehensive Plan Element	Policy / Objective	Description
Monitoring	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 4.3.6	Work in conjunction with the South Florida Water Management District to coordinate the monitoring of the saltwater front along the Southeast Broward County coast.
Water Conservation	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 4.3.7	Develop and implement a program to curtail excess water use during excessively dry periods. In addition, the City will implement a plan to promote the use of water-efficient appliances and continue to coordinate efforts for water resource conservation with the SFWMD.
Water Supply	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Objective 2.2	Pursue new treated water interconnections with neighboring utilities, especially the City of Hollywood.
	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Objective 2.3	Implement projects to meet future water supply needs, including possible utilization of reverse osmosis technology.
Wastewater Reclamation	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 4.3.3	Study the possibility of the cost effective use of wastewater reuse for City irrigation needs.
	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 4.3.5	Study the viability of using greywater on large irrigation areas.
	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 4.3.8	Work with private parties, SFWMD, FDEP, City of Hollywood, and Broward County in evaluating and implementing a wastewater reuse program within Hallandale Beach.
Stormwater Management	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Objective 5.1	Continue to encourage aquifer recharge opportunities through enforcement of minimum pervious area requirements of the Hallandale Beach Zoning and Land Development Code at time of development review.
	Sewer Stormwater, Water and Groundwater Aquifer Recharge Element	Policy 5.1.1	Require on-site stormwater detention such that past development runoff rates and quantities do not change from predevelopment values. Detention methods will provide a direct means of aquifer recharge. All aspects of stormwater management will include the use of Best Management Practices.
	Coastal Management Element	Policy 2.3.4	Consider the effect of sea level rise when repairing and improving the stormwater management system. The City shall utilize the unified sea level-rise projections established by the Southeast Florida Regional Climate Change Compact.

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CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 5: PROJECTED CHANGES IN SHORELINE

RS&H

City of Hallandale Beach Vulnerability and Adaptation Plan

TASK 5: PROJECTED CHANGES IN SHORELINE

February 28, 2020
RS&H No.: 301-0068-000

Prepared by RS&H, Inc. at the direction of the City of Hallandale Beach

RS&H

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1. SHORELINE CHANGE OVERVIEW

Climate change will threaten coastal areas in a variety of ways. Beyond threats of increased frequency or intensity of storm events, coastal areas can expect to be impacted by rising sea levels, increases in precipitation, and warmer ocean temperatures. Rising sea level poses a particular threat to the resiliency of Florida beaches and has the potential to contribute to shoreline recession throughout the state.

Shoreline recession (also referred to as coastal erosion) is the process by which local sea level rise, strong wave action, and coastal flooding wear down rocks, soils and/or sands along the coast. Typically, this is experienced during storms and other natural events. The adverse effects of climate change can exacerbate this process via sea level rise[i]. This is of concern to the City of Hallandale Beach, where the City's beaches provide recreation opportunities for residents and are an important draw for tourism.

Since 1986, the Florida Department of Environmental Protection (FDEP)has been identifying and monitoring beaches that are critically eroding and in danger of critically eroding. As of 2019, the State identified approximately 420 miles of critically eroded beach, including beaches located in Broward County.[ii] Table 1illustrates the status of Broward County's beaches. Beach segments are delineated by the use of numerical Reference Monument landmarks, denoted by the letter "R". Hallandale Beach's shoreline is among those listed in critical erosion condition, located from R124-128 of the R86-R128 segment.

TABLE 1: LOCATIONS OF CRITICALLY AND NON-CRITICALLY ERODED BEACHES ADAPTED FROM FDEP CRITICALLY ERODED BEACHES

Eroding Shoreline	Erosion Condition	Critically Eroded Beach *(miles)*	Non-Critically Eroded Beach *(miles)*
R6-R23	Critical	3.2	0
R25-R77	Critical	10.0	0
R86-R128*	Critical	8.1	0

Source: Adapted from FDEP Table 1, Locations of critically eroded beach and inlet shoreline, and non-critically eroded beach and inlet shoreline, in Florida east coast counties, as of June 2019.

The effects of shoreline recession result in both environmental and economic losses. In the United States, coastal erosion is responsible for approximately $500 million per year in damages to structures and loss of land. Mitigation efforts by the federal government, such as beach nourishment and erosion control measures cost an average of $150 million every year. Additionally, the United States is experiencing an average loss of 80,000 acres of coastal wetlands annually.[ii] Despite the cost, these expenditures are deemed necessary to protect the high economic, social and environmental value of shorelines to communities like Hallandale Beach.

2. BASELINE CONDITIONS

To understand how climate change may affect sea level rise and lead to shoreline recession, it is useful to establish a baseline by looking at historic averages and variability. Other aspects of a baseline include recent storm events in the City that caused erosion, and how Hallandale Beach has tracked and reacted to these events.

2.1 EXISTING CONDITIONS AND OBSERVED CHANGES – SEA LEVEL

Changes in local sea level result from a combination of global, regional, and local change. At a global scale, global sea level has risen about 7 to 8 inches since 1900, with approximately 3 inches occurring since 1993. These changes are mainly due to melting of glaciers and ice sheets and thermal expansion of water as it warms.[iii]

In low-lying areas of the Southeast, National Oceanic and Atmospheric Administration (NOAA) tide gauges have shown as much as 1 to 3 feet of local relative sea level rise over the past 100 years. As a result of rising sea levels, many areas in the Southeast now experience high tide coastal flooding. Annual occurrences of high tide coastal flooding have increased 5- to 10 fold since the 1960s[iv]. Many cities in the Southeast are projected to experience more than 30 days of high tide flooding by 2050.

The closest NOAA tide gauge to Hallandale Beach which tracks sea level trend is located at Virginia Key, Miami. From 1920 to 2020, the gauge shows a relative sea level trend of 2.92 millimeters (mm) per year with a 95% confidence interval of +/- 0.22 mm per year, which is equivalent to a change of 0.96 feet in 100 years (Figure 1).

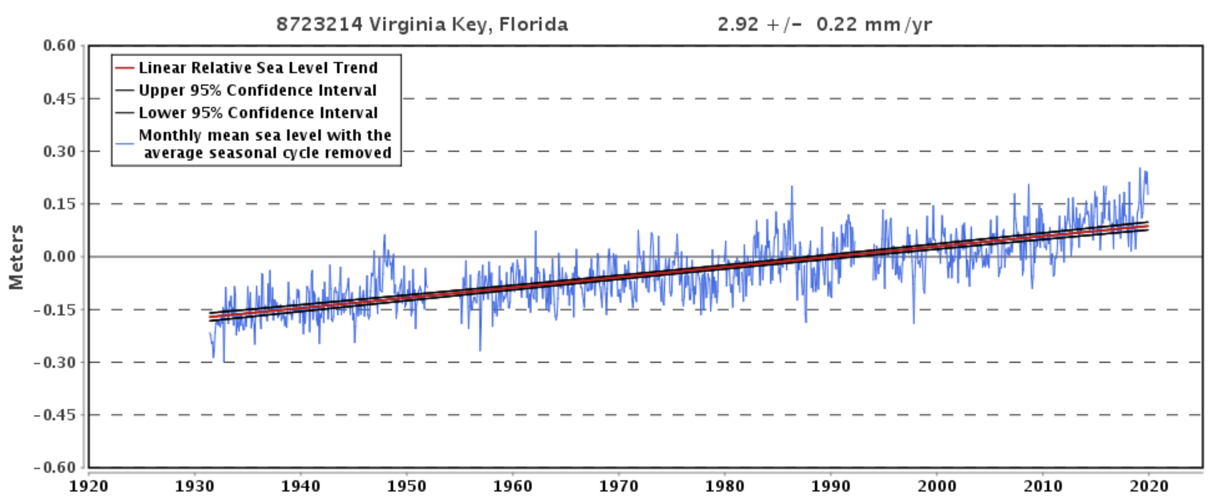

FIGURE 1: SEA LEVEL TREND AS MEASURED AT VIRGINIA KEY, MIAMI

2.2 EXISTING CONDITIONS AND OBSERVED CHANGES – SHORELINE RECESSION

Broward County, Florida completed a Beach Management Study in September 2015 for Segment III of their beaches. This document is the most detailed source of information for existing and historical shoreline conditions of Hallandale Beach. Segment III is the southernmost portion of the Broward County Atlantic Ocean coastline between the Port Everglades south jetty and the Miami-Dade County line (Reference Monument R85-R128). Due to the direct and indirect influence of the Port Everglades Inlet and its associated jetties, as well as the Federal navigation channel, the Segment III shoreline has the highest sand loss rates in Broward County. Figure 2 provides an overview of the Segment III management areas. Note that Hallandale Beach is located between R124 and R128 and is comprised of approximately 4,350 feet of the Segment III beaches.

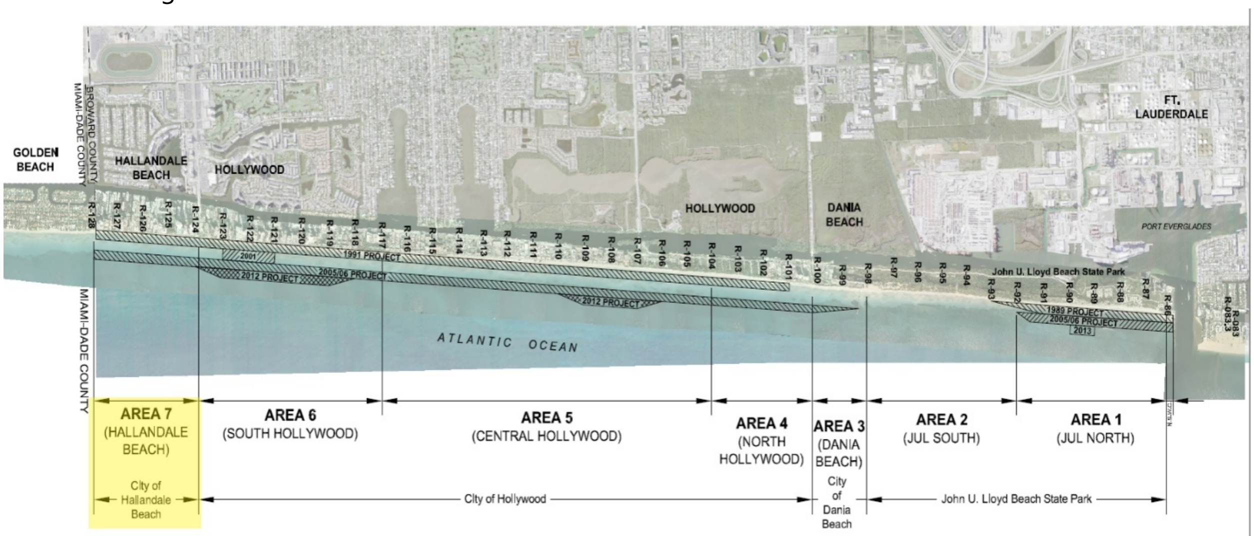

FIGURE 2: HALLANDALE BEACH SEGMENT BETWEEN R124 AND R128

2.2.1 Beach Width

To measure the extent of shoreline recession, beach widths and shoreline volume change area are analyzed. Beach width is defined as the distance between the seaward limit of development and the Mean High Water Line (MHWL).

There are two definitions of minimum beach width relevant to Hallandale Beach. The first is the Federal beach width or Erosion Control Line (ECL). It was determined using Federal shore protection project planning guidelines.

For Hallandale Beach, the design width is 50 feet seaward of the ECL, as shown in Figure 3.

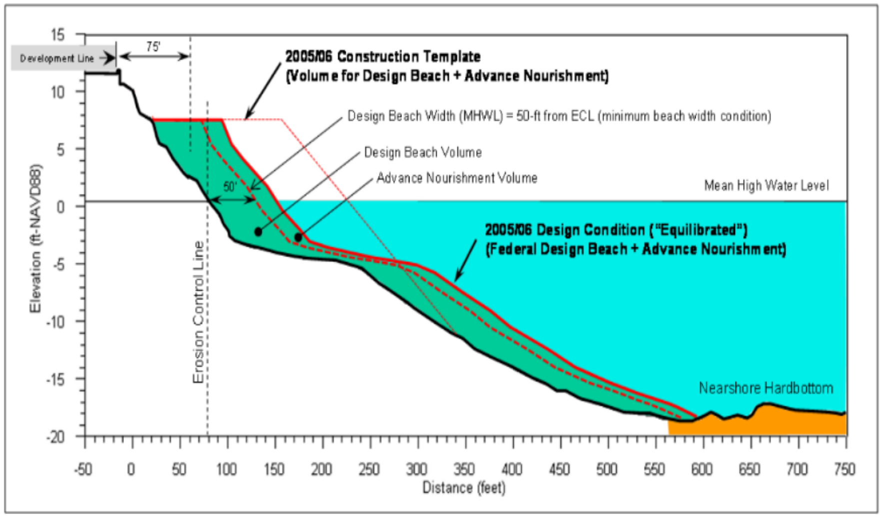

FIGURE 3: TYPICAL FEDERAL DESIGN AND CONSTRUCTION BEACH PROFILE DEFINITIONS

As a general measure to protect beaches from storms and to maintain recreational beach areas and habitats, Broward County has adopted a second definition of beach width. The County's "Environmental Benchmark" establishes a minimum beach width of 75 feet measured from the seaward development to the MHWL. Beach widths narrower than 75 feet are considered critically eroded.

The 2015 Beach Management Study for Segment III documented the MHWL under four different conditions:

- The Federally authorized design MHWL
- The existing MHWL, which was the average shoreline position measured between April 2011 and July 2013
- The historic MHWL, which consisted of the average shoreline position between October 1993 and July 2013
- The minimum MHWL, computed as the landward most occurrence of MHWL at each R-monument between October 1993 and July 2013

The results of this analysis for Hallandale Beach (R124-128) is summarized in Table 2.

TABLE 2: BEACH WIDTHS FOR THE CITY OF HALLANDALE BEACH

Monument	Federally Authorized Design Beach	*Beach Width (Feet)* Existing *(2011/2013)*	Average Position *(1993 to 2013)*	Most Landward Position *(1993 to 2013)*
R124	76.9	136.2	126.1	51.4
R125	87.1	135.4	131.1	83.3
R126	49.8	119.4	119.1	86.6
R127	57.1	88.7	102.9	49.1
R128	93.0	108.0	124.5	100.4

Source: Broward County Segment III Beach Management Study, 2015

Most of Hallandale's beach widths are within the Environmental Benchmark set by the County, with a few exceptions. During the 2011-2013 period, there were instances where R124 and R127 were narrower than the 75-foot County benchmark.

2.2.2 Shoreline Change

The 2015 Beach Management Study for Segment III analyzed beach profile surveys completed since 1993 to compute average annual MHWL change rates along the shorelines in Broward County. The study calculated the estimated change in shoreline for two periods. The values listed for the first period (1993 to 2013) represent values without beach renourishment projects to understand what conditions may have been in the event that the beach fill in 2006 was not completed. This provides a best guest estimation of a shoreline change had the County not completed beach renourishment project. The second values listed for the second period includes the effects of the 2006 and 2012 projects. Change rates for Hallandale Beach are summarized in Table 3.

TABLE 3: HALLANDALE BEACH AVERAGE ANNUAL RATE OF CHANGE

Monument	*MHWL Rate of Change (ft/yr)* 1993-2013 *(Fill Removed as Practical)*	2006-2013
R124	-9.0	-13.5
R125	-5.3	-7.9
R126	-5.6	-10.6
R127	-5.0	-5.9
R128	-2.1	-4.3

Source: Broward County Segment III Beach Management Study, 2015

Compared to the rest of the County, shoreline recession rates were high in Hallandale Beach and these highest rates were reflected in the 2006-2013 period. Although the highest rate of shoreline change in the study was located in Dania Beach (-33.7 feet per year), Hallandale Beach, specifically at R124 and R126, has had the second and third highest rates of shoreline change at -13.5 feet per year and -10.6 feet per year respectively.

2.2.3 Beach Volume Change

Beach volume changes calculated in the Broward County Segment III Beach Management Study were based upon a quantitative comparison of beach profile conditions at beach monitoring areas along the Segment III shoreline and are calculated from the seaward face of a bulkhead or vegetation line to the seaward limit of the active beach system. The numbers presented in the report do not include the effects of the 2005/06 or the 2012 renourishment projects to capture the volume changes in the absence of beach fill placement. Two time periods are represented in the table: a long-term average annual volume change, 1993 to 2013, and the most recent post-construction period, 2006 to 2013. The average sectional volumetric change rates for Hallandale Beach are included in Table 4.

TABLE 4: HALLANDALE BEACH AVERAGE ANNUAL VOLUMETRIC RATE OF CHANGE

Monument	*Sectional Volume Change Rate (cy/ft/yr)* 1993-2013	2006-2013
R124	-3.9	-5.0
R125	-0.3	-0.3
R126	-0.6	-2.7
R127	-2.0	-0.4
R128	-0.4	1.0

Source: Broward County Segment III Beach Management Study, 2015

Compared to the rest of the County, Hallandale Beach, specifically R126, has some of the highest rates of erosion. The highest rate of erosion in Segment III was -5.1 feet per year in Dania Beach, however, R124 was a close second with -5.0 feet per year[v].

2.2.4 Storm Events

Besides sea level rise, storm events are a large contributor to the erosion of the City's beaches. The National Climatic Data Center indicates that Broward County was affected by 11 major climatological incidents that resulted in beach erosion from 1998 to 2016. The Broward County Emergency Management Local Mitigation Strategy, dated 2017, noted the following significant storm events that added to the erosion of the shoreline:

- Tropical Storm Mitch (November 1998)
- Hurricane Floyd (September 1999)
- Coastal Flooding from Hurricane Michelle (November 2001)
- Hurricane Frances (September 2004)
- Hurricane Jeanne (September 2004)
- Nor'easter (2004)
- Hurricane Katrina (August 2005)[vi]

More recently, Hurricane Irma made landfall in September 2017 in areas of South Florida. As a major hurricane, Irma brought significant storm surge on both sides of the coast in South Florida. Although Broward County had minor beach erosion conditions as a result of the storm, beach renourishment measures have occurred throughout the county to address lost sand on the beaches [vii].

2.3 BEACH RENOURISHMENT PROGRAM

The beaches in Broward County provide significant support to the local economy through development, recreation and tourism. For over 50-years, the County has managed beaches with help from state and federal agencies by completing beach nourishment projects, enhancing natural dunes, and providing attention to regional sediment management.

Beach renourishment is a method to retain and rebuild eroding beaches. It has been the preferred method of protecting receding shorelines in South Florida and consists of bringing in beach-quality sand from borrow areas or upland sand mines and placing them along the coastline to restore eroding beaches.

2.3.1 Historic Beach Renourishment

Segment III has made significant efforts to improve beach conditions since the 1960s with the authorization of the Broward County Federal Shore Protection Project. To proactively address shoreline recession, a locally funded 0.8-mile restoration project began along Hallandale Beach in 1971. Since then, Broward County has actively worked to improve, manage, and maintain the Segment III shoreline through restoration and nourishment efforts. Approximately 7.2 million cubic yards of sand has been placed onto Segment III beaches. Table 5 adapted from the Segment III Beach Management Study, lists the history of beach nourishment and sand placement[viii].

TABLE 5: HISTORIC BEACH NOURISHMENT IN SEGMENT III - PROJECTS

Year	Project	Location (Reference Monument)	Project Length (miles)	Sand Quantity (cubic yards)
1971	Hallandale	R124-R128	0.75	360,00
1976	John U. Lloyd Beach SP	South Jetty to R93	1.5	1,090,000
1979	Hollywood/Hallandale	R101-R128	5.2	2,000,000
1989	John U. Lloyd Beach SP	South Jetty to R93	1.6	604,000
1991	Hollywood/Hallandale	R101-R128	5.2	1,100,000
2001	Hollywood (Diplomat)	R121-R123	0.5	25,000
2005	Hollywood/Hallandale John U. Lloyd Beach SP	R98.3-R128 South Jetty to R92	6.8	1,300,000 550,000
2012	Southern Hollywood	R119-R124	0.75	69,000
2013	John U. Lloyd Beach (Beach Disposal)	R87-R90	0.75	116,000

Source: Broward County, Segment III Beach Management Study (2015)

As of 2013, approximately $78.22 million has been spent to maintain the shorelines of the Segment III beaches. Of this amount, about 55% ($41.5 million) was paid by the U.S. Army Corp of Engineers. The remaining amount is paid by non-federal cost-share partners (i.e. State, County, and shorefront communities). Broward County paid approximately $8.95 million since 2013.[viii] Table 6 lists the approximate costs for the beach renourishment program since 2013.

TABLE 6: HISTORIC BEACH NOURISHMENT IN SEGMENT III - COSTS

Year	Project	Location (Reference Monument)	Sponsor	Total Cost (M)	Federal Share (M)	State Share (M)	County Share (M)	City Share (M)
1971	Hallandale	R124-R128	Hallandale	$0.78	$0	$0.59	$0.15	$0.04
1976	John U. Lloyd Beach SP	South Jetty to R93	Broward	$2.96	$1.97	$0.85	$0.15	-
1979	Hollywood/Hallandale	R101-R128	Broward	$7.83	$3.33	$2.82	$0.88	$0.80
1989	John U. Lloyd Beach SP	South Jetty to R93	Broward	$5.68	$3.97	$1.71	-	-
1991	Hollywood/Hallandale	R101-R128	Broward	$9.47	$4.17	$3.88	$1.07	$0.35
2001	Hollywood (Diplomat)	R121-R123	Hollywood	$1.00	-	$0.50	-	

Year	Project	Location (Reference Monument)	Sponsor	Total Cost (M)	Federal Share (M)	State Share (M)	County Share (M)	City Share (M)
2005	Hollywood/Hallandale	R98.3-R128	Broward	$44.5	$26.6	$10.1	$5.7	$2.1
	John U. Lloyd Beach SP	South Jetty to R92						
2012	Southern Hollywood	R119-R124	Hollywood	$3.50	-	$1.75	-	$1.75
2013	John U. Lloyd Beach (Beach Disposal)	R87-R90	USACE	$2.50	$1.50	-	$1.0	-

Source: Broward County, Segment III Beach Management Study (2015)

2.3.2 Recent Beach Renourishment

Following the aftermath of Hurricane Irma, the U.S. Army Corp of Engineers approved plans to spend $9.7 million for beach restoration in the southern portion of Broward County. The program would truck in approximately 123,000 cubic yards of sand to replenish sand lost during the store. Not only would this project load more sand on areas where the shorelines have eroded, it will enable critical storm surge protection. [ix]

Currently, Broward County is in the pre-permitting, engineering, and design phase for implementation of the Segment III projects that incorporates recommendations from the 2015 Beach Management Plan. According to Broward County's website, the County anticipates construction to begin in late 2021.

The City of Hallandale Beach is currently in the process of codifying Section 2-109 "Beach Preservation Advisory Board". This City Commission finds it necessary to establish a board that will study and recommend policies and programs that address beach erosion, dunes, shorelines, cleanliness and improve natural resources. If signed, this ordinance will establish a committee of engaged residents and experts on the issues of erosion, resiliency, and dune and shoreline preservation.

3. FUTURE CONDITIONS

The future of shoreline recession in southeast Florida is dependent on the scale of future predicted climate changes. Because beaches and dune systems are integral components of the coastal system and represent valuable natural resources, they are integral to resilience to future climate impacts.

The Intergovernmental Panel on Climate Change (IPCC) has very high confidence that coastal systems and low-lying areas like Hallandale Beach will increasingly experience the adverse effects of coastal erosion due to sea level rise. Sea Level Rise Projections

Locally, the Southeast Florida Regional Climate Change Compact (SFRCCC) adopted a unified sea level rise projection for the Southeast Florida region that includes Broward County and Hallandale Beach.
The unified sea level rise projections are as follows:

- Short term: 10 to 21 inches of sea level rise by 2040
- Mid-term: 21 to 54 inches of sea level rise by 2070
- Long-term: 40 to 136 inches of sea level rise by 2120

Sea level rise projections based on the emission scenarios are shown in Figure 5.

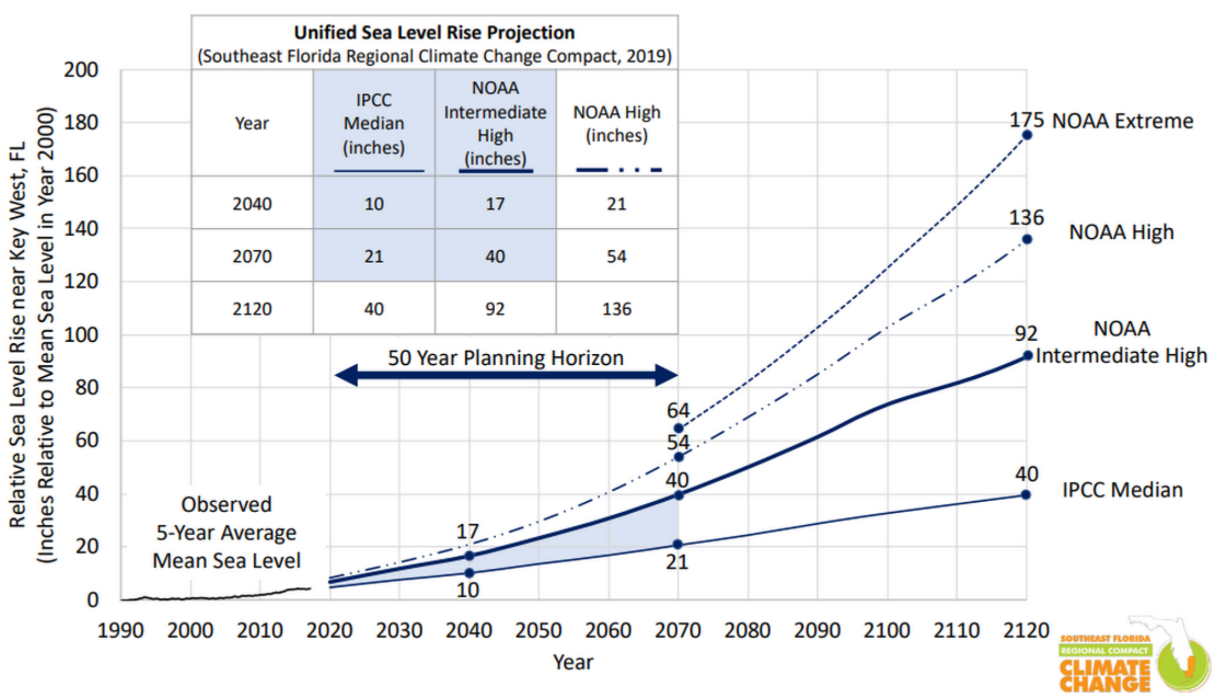

FIGURE 4: SFRCCC UNIFIED SEA LEVEL RISE PROJECTION

Source: Southeast Florida Regional Climate Change Compact, 2019

Sea level rise is an estimate of future events and is based on emissions scenarios and other drivers of global warming. As time passes, sea level rise projections may be revised based on improved scientific understanding or a change in global emissions pathways. Using the current adopted SFRCC unified sea level projection can assist Hallandale Beach in future adaptation to sea level rise.

3.1 STORM SURGE, EROSION, AND SHORELINE RECESSION

Future changes in sea level rise will also affect the intensity and scale of storm surges from tropical storms. Higher sea levels can cause storm surges to travel farther inland than in the past, causing damage to shorelines and increasing coastal erosion. The combined impacts of these events in the Southeast region have the potential to cost up to $60 billion per year by 2050[x]. Although there is high confidence that storm surges will be larger, the scale, intensity, and frequency of these events are still uncertain.

There is limited information on the rate of future shoreline recession in Hallandale Beach due to the high degree of variability in shoreline recession along the State of Florida's coasts. There are some areas in Florida with rapid erosion rates, such as Hallandale Beach, and some with net gain in sand over time.[xi] The Segment III Beach Management Study attempted to quantify the amount of sand loss for Hallandale Beach by quantifying an annual sand demand. The sand demand is assumed to be equivalent to the amount of sand lost form the beach profile due to erosion conditions on an average annual basis. The study concluded that Hallandale Beach will require approximately 11,000 cubic yards of sand per year to offset the gross loss rate.

Historically, the County's beach management program has benefited from the use of beach compatible sand located offshore of Broward County in close proximity to locations where fill is required. However, as the program has repeatedly drawn resources from these borrow areas, the supply of beach compatible sand locate in close proximity will likely not meet future projected demands for renourishment. As such, the County will likely require the use of more remote and costly sand resources in the future.

Broward County and Hallandale Beach have been experiencing erosion along the coastline for years and that trend is expected to continue. Climate scientists generally agree that future erosion is considered "likely." As most beaches in this are have been actively eroding, Broward County and Hallandale Beach can expect to continue to engage in beach renourishment projects every 10-12 years.[xii]

4. IMPLICATIONS FOR HALLANDALE BEACH

The implications of shoreline recession for Hallandale Beach include environmental, social and economic impacts on the City.

The beaches in Broward County and the City of Hallandale Beach provide critical nesting grounds for threatened and endangered sea turtles and are important habitats for shore birds and other wildlife.[xiii] Additionally, the beaches are a significant employment center for the City and County. They provide recreational opportunities for residents. Attracting more than 12.8 million visitors annually, the County's beaches contribute more than $6 billion to the local economy each year. The beaches also provide protection for more than $4 billion dollars of shoreline property, structures and infrastructure. Should these beaches continue to erode and the shorelines recess, the City can expect to lose a significant amount of economic activity.

While there are no local projections of increasing rates of shoreline recession as a result of sea level rise, it is clear that as this trend accelerates the beaches will be affected. In the short term, this may result in higher costs contributed by the City to beach renourishment programs. In the mid to long term, inundation of the City's beaches by rising seas could lead to legal complications between public beach access and landowners who property becomes part of the new shoreline. These challenges are likely to be faced by all local governments in Broward County.

5. PRELIMINARY RECOMMENDATIONS

RS&H has identified preliminary recommendations for the City to consider that will help to mitigate the risk posed by shoreline recession. This report presents only a high-level assessment of risk from climate-related changes to shorelines as a result of sea level rise. Further analysis will be needed to evaluate the vulnerability of specific infrastructure or facilities, community impacts, and thresholds where impacts would occur. It is also necessary to monitor emerging science and projections on the topic, since uncertainty exists regarding climate impacts.

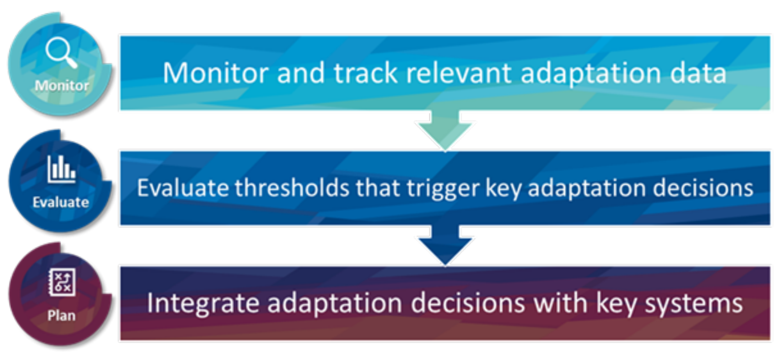

FIGURE 6: ADAPTIVE MANAGEMENT PLANNING APPROACH

For this reason, RS&H recommends an Adaptive Management planning approach (Figure 6). Adaptive Management is a systematic approach to managing uncertainty through flexible decision making informed by data. It can be used as a framework for addressing vulnerabilities, starting with the development of initial actions to mitigate climate change effects. Informed by adaptive management, the initial actions developed in this plan are classified into three categories, Monitor, Evaluate, and Plan.

5.1 MONITOR

- Monitor emerging climate and sea level rise projections. Sea level projections are subject to change due to improved scientific understanding and changes in emissions rates. Under current emissions trajectories, the trend has been for sea level rise projections to be revised upwards.

- Monitor rate of shoreline recession by tracking historic and modern shorelines using tools such as ArcGIS, NOAA CUSP, etc. In addition to monitoring the geographical shoreline change, monitor the amount of sand fill to Hallandale's beaches.

- Monitor emerging science related to the impacts of sea level rise on shoreline recession, including effects as a result of storm events and storm surge.

- Coordinate with regional partners such as Broward County, the Florida Department of Transportation, the Florida Department of Environmental Protection, the Southeast Florida Regional Climate Change Compact and other municipalities in the region on analysis of shoreline recession and adaptation strategies.

- Monitor coastal development to ensure future developments do not encroach on Federally Authorized Design Beach or Environmental Benchmark lines.

- Partner with local universities to encourage collaboration and scientific research that improves understanding of sea level rise and shoreline recession issues.

5.2 EVALUATE

- Evaluate existing development patterns and identify means to promote resilient coastal development.

- Assess the City's existing Beach Renourishment Plan and begin planning now for the program to adapt to increased demand for sand from borrow areas that are further away than those accessed historically. Evaluate if existing infrastructure is sufficient to handle an increased demand. Assess if funding will be available to support these future conditions.

- Evaluate the potential to use local, reclaimed dredge material for beach renourishment to cut down on costs for sand and greenhouse gas emissions associated with transportation. A project in St. Lucie County, Florida was able to use material from the Intracoastal Waterway dredged for a project to improve navigation to replenish a critically eroded section of the county's beach, resulting in over $8.7

million in cost savings.

- Assess the feasibility of implementing living shorelines in the City in some locations. Living shorelines stabilize coastlines using natural materials such as rocks, sand and vegetation. They may have aesthetic as well as shoreline protection benefits and unlike sea walls or other hardscape structures, they can grow over time. They may also cost less than infrastructure solutions.

- Study the legal implications of shoreline recession and determine how the City will respond to property rights disputes that may result if the shoreline moves landward as a result of sea level rise.

5.3 PLAN

- Develop and implement the Dune Protection Plan identified in the City's Sustainability Action Plan. The plan will address the design of the dune system and effective erosion control measures, recommend dune vegetation and planting guidelines, identify impacts to wildlife, and include an implementation plan and budget for improving the dune system.

- Pursue mangrove restoration projects proposed in the 2018 Sustainability Action Plan. Mangroves have many important benefits, ranging from aesthetics to wildlife habitat and flood control. They also resist erosion and wave action, helping to stabilize shorelines. This City has proposed planting mangroves at the corners of the Golden Isles Bridges, along Layne Boulevard south of Church Street, and along the seawall north of the marina on the west side of Three Islands Boulevard.

- Conduct education and outreach to the development community to inform them about the implications of a receding shoreline.

- Participate in the Shoreline Resilience Working Group, a SRFCCC subcommittee coordinated by the Nature Conservancy which brings together experts from the regions' counties, municipalities, non-profit organizations, academic institutions and the for-profit private sector who have an interest in promoting nature-based solutions to coastal protection.

In addition to the recommendations listed above, RS&H recommends the City implement the Policies and Objectives related to this issue that were included in the 2018 update to its Comprehensive Plan.[xiv] These adaptation measures are detailed in Table 7 below.

TABLE 7: SHORELINE RECESSION ADAPTATION ACTIONS FROM THE 2018 COMPREHENSIVE PLAN

Adaptation Category	Comprehensive Plan Element	Policy / Objective	Description
Coastal Protection	Coastal Management Element	Policy 1.1.1	Review potential impacts of development plans on public facilities within the City's Coastal area.
	Coastal Management Element	Policy 1.1.2	Restrict construction or redevelopment in areas controlled by State Coastal Control Lines.
	Coastal Management Element	Policy 1.4.1	Participate in Federal, State, and County Renourishment Programs to replace beach sand deposits lost to erosion.
	Coastal Management Element	Objective 1.4	Coordinate with Broward County's DEP in protecting and enhancing dunes and coastal biological communities.
Local Coordination	Coastal Management Element	Objective 1.1	Work in conjunction with Broward County Department of Environmental Protection (DEP) to protect and conserve coastal resources.
	Coastal Management Element	Policy 1.1.2	Coordinate with representatives of all local coastal governments within two miles of the boundaries of the Hallandale Beach coastal area to discuss plans and strategies to protect coastal resources.
	Coastal Management Element	Objective 2.3	Cooperate with Broward County, the Broward County Planning Council, the Southeast Florida Regional Climate Change Compact, and other agencies.
Climate Change Monitoring	Coastal Management Elements	Policy 2.3.1	Identify potential adverse impacts and map areas vulnerable to impacts.
	Coastal Management Elements	Policy 2.3.2	Develop and Adaptation Action Area for low lying coastal zones.

6. REFERENCES

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CITY OF HALLANDALE BEACH VULNERABILITY AND ADAPTATION PLAN

TASK 6: INITIAL STRATEGY DEVELOPMENT AND EVALUATION

RS&H

City of Hallandale Beach Vulnerability and Adaptation Plan

TASK 6: INITIAL STRATEGY DEVELOPMENT AND EVALUATION

June 30, 2020
RS&H No.: 301-0068-000

Prepared by RS&H, Inc. at the direction of the City of Hallandale Beach

RS&H

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1. STRATEGY DEVELOPMENT OVERVIEW

After identifying vulnerabilities related to flood, precipitation, groundwater changes and shoreline recession (See Tasks 1-5), the next step for the City of Hallandale Beach is to identify and prioritize actions to increase resilience. Task 6 documents actionable adaptation projects. The projects were developed through a collaborative process with City staff and designed to reduce exposure to some of its most significant vulnerabilities.

This task included a collaborative workshop designed to build resilience planning capacity within the City. Attendees reviewed the City's vulnerabilities (See Task 1-5). They were introduced to an adaptive management approach to resilience. Participants also engaged in exercises to develop and prioritize potential adaptation strategies. At the conclusion of the workshop, more than twenty potential adaptation strategies had been identified for further analysis and evaluation.

These strategies and others identified by RS&H were further refined through collaboration with the City's Green Initiatives Coordinator. Ten adaptation projects for City infrastructure were selected for analysis and further development.

Section 4, "Selected Adaptation projects" presents these ten projects along with their potential cost and benefits from a resilience and triple-bottom line sustainability perspective. They are informed by the vulnerabilities identified in Task 1-5, existing planning documents such as the City's Hazard Mitigation plan and Sustainability Action Plan, and by consultation with City staff. Detailed project sheets were developed for each project that explain the project name, location, objective, scope, cost/benefit assumptions, quantification of costs and qualification of benefits. Estimated costs are provided as a range with a low and high estimate for each project.

Finally, the recommendations section includes general policy propositions as well as a preliminary implementation strategy, including budget and schedule. Projects are divided into two implementation periods: short term (1 to 5 years) and long term (6 to 20 years). Estimated costs for the six short term projects range from $2.3 to $8.7 million, while estimated costs for four long term projects range from $127 to $173 million. The schedule shows a recommended implementation order for the projects based on their cost, ease of implementation and overall resilience benefits.

2. COLLABORATIVE WORKSHOP

A collaborative workshop was held with the City on March 18th, 2020. Originally planned to be held in person, the workshop was conducted as an online teleconference meeting due to safety requirements related to the COVID-19 pandemic. Polling and survey tools were used to increase engagement and attendee feedback in the online environment.

The workshop was attended by leaders from across the City's functional areas (Table 1). The objectives of the workshop were to review the Vulnerability Assessment (Task 1-5), educate attendees about the identified vulnerabilities and their implications for Hallandale Beach, introduce the adaptive management approach for resilience planning, and allow them to select and prioritize potential adaptation strategies. The workshop included several exercises or break-out sessions where participants were encouraged to provide feedback and input. Attendees contributed to a list of potential adaptation strategies and an initial round of prioritization for further development.

TABLE 1: COLLABORATIVE WORKSHOP ATTENDEES

Attendee Name	Title
Alyssa Jones-Wood	Green Initiatives Coordinator
Keven Klopp	Assistant City Manager
Peter Kunen	Assistant Director PW /City Engineer
Mary Francis Jeannot	Assistant Director of Public Works/Administration
Matthew Davis	GIS Coordinator
Aqeel Abdool-Ghany	Assistant City Engineer
Bob Williams	Assistant Director of Parks, Recreation, and Open Spaces
Jeffrey Odoms	Assistant Director of Public Works – Utility Operations

2.1 VULNERABILITIES AND IMPLICATIONS

The workshop began with a review of the Vulnerability Assessment (Tasks 1-5). Attendees were familiarized with the scope of the project and introduced to the findings related to flood hazard and vulnerability, future precipitation, groundwater changes, and changes in shoreline. These findings are detailed in Task 1-5 memos.

After reviewing the vulnerabilities, the group discussed their implications for the City of Hallandale Beach. Examples were presented for both the community and City government for flood impacts (including precipitation), groundwater impacts, and shoreline recession. Table 2 shows selected primary and secondary implications of climate vulnerabilities to the community and City government presented during the workshop.

TABLE 2: IMPLICATIONS OF CLIMATE VULNERABILITIES TO THE COMMUNITY AND CITY GOVERNMENT

Vulnerability	Community Implications	City Government Implications
Flooding (FEMA, Surge, SLR, Precipitation)	» Primary: property damage, injuries, fatalities » Secondary: financial hardship, health impacts, pollution, blocked transportation routes	» Primary: damages to infrastructure, potential to spread pollution from contaminated sites, service interruptions (police, fire, etc.) » Secondary: cleanup, repairs, remediation, adaptation actions, complaints from residents and businesses, impacts to tourism, impacts to tax base
Groundwater	» Primary: reduced infiltration and storage of stormwater, flooding, saltwater intrusion, impacts to vegetation » Secondary: damage to building foundations and buried utilities, water borne illnesses, wastewater releases	» Primary: impacts to stormwater systems, damage to underground utilities, saltwater intrusion affecting production wells, parks, etc. » Secondary: costs for alternative water supply / desalinization, improvements to stormwater system, hardening utilities
Shoreline Recession	» Primary: accelerated erosion of beaches, beaches could become narrower, impacts to sea turtles and other wildlife » Secondary: impacts to property values, impacts to tourism, loss of dune protection, loss of economic activity	» Primary: accelerated erosion of beaches » Secondary: increased costs for beach renourishment, potential legal issues, potential impacts to tax base

2.2 ADAPTIVE MANAGEMENT APPROACH

Following the discussion of implications, attendees were introduced to an Adaptive Management approach to resilience (Figure 1). This is a systematic approach to managing uncertainty through flexible decision making informed by data. It recognizes that resilience planning is an iterative process that must be continuously revisited as climate projections and data change. Adaptive Management classifies resilience actions into three categories: Monitor, Evaluate, and Plan. Participants were given examples of each category and discussed how the three categories of actions could be integrated into City planning documents, policies, and existing and future programs and projects.

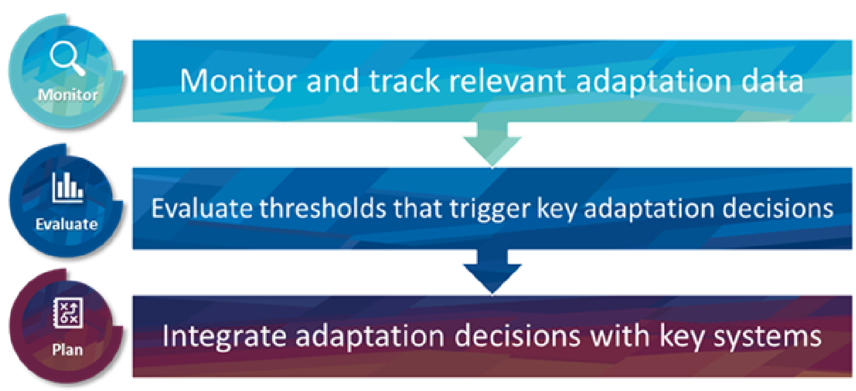

FIGURE 1: ADAPTIVE MANAGEMENT APPROACH

2.3 POTENTIAL STRATEGIES EXERCISE

Attendees then participated in a brainstorming exercise to come up with potential adaptation strategies. They were initially presented with examples of adaptation strategies the City had already implemented and a selection of proposed strategy ideas. Once familiar with the examples, they were challenged to come up with their own ideas. Online polling software was used to capture participant responses. The exercise resulted in more than twenty ideas for potential strategies. The strategies ranged from infrastructure hardening to policy changes such as including flood vulnerability in criteria for budgetary decisions.

2.4 PRIORITIZATION EXERCISE

In the final exercise, attendees prioritized the list of potential adaptation strategies. Attendees were familiarized with a prioritization process that includes:

- » Evaluating costs, benefits, and organizational capacity to accomplish each strategy
- » Ranking the expected value of each strategy
- » Integrating the highest-value strategies into a plan

Participants were then given criteria for ranking strategies that included adaptive capacity; economic, environmental, and social benefit; and feasibility. After a discussion of the criteria, they were asked to subjectively rank potential strategies using these criteria via an online survey application. The results of this exercise were used to identify strategies for further development.

3. ADAPTATION STRATEGIES

Following the collaborative workshop, results of the prioritization exercise were converted into numerical scores that were used to rank strategies. Strategies with highest aggregate values for adaptive capacity; economic, environmental, and social benefit; and feasibility were prioritized. Projects were also organized into short- and long-term categories, with short term defined as being feasible within one to five years and long term define as 6 to 20 years. RS&H also added some additional strategies that have proved valuable in similar South Florida communities.

The strategies presented are only a starting point for the City's adaptation planning efforts. Because the vulnerability assessment did not include residential properties or transportation infrastructure, few strategies related to these areas were developed. Such strategies should be considered when these sectors are added to the City's vulnerability assessment. The intent of this activity is to give the City a starting point for adapting to its most pressing vulnerabilities, not to provide an exhaustive list of possible options. Through participating in the collaborative workshop, City staff have developed skills and a familiarity with the adaptation planning process that will allow them to develop additional strategies in the future.

3.1 SHORT TERM

Short term adaptation strategies are presented in Table 3. They are prioritized from greatest to least resilience benefit based on the criteria established in the prioritization exercise.

TABLE 3: SHORT TERM ADAPTATION STRATEGIES

Priority	Strategy	Description
1	Lift station rehabilitation*	Rehabilitate / refurbish one or more lift stations to harden it to flood risks
2	Flood vulnerability criteria in CIP	Include water level rise vulnerability as an evaluation criterion in Capital Improvement Plan (CIP) and/or budget allocation process
3	Salt-tolerant landscape code	Change landscape code to require only salt-tolerant native species in high SLR and surge risk areas
4	Check valves for stormwater outfalls*	Install check valves to prevent backflow in all stormwater outfalls
5	Resilient beach access*	Pilot a resilient design for beach access points through the dunes
6	Adaptation action areas	Designate one or more Adaptation Action Areas within the City
7	Resilience office	Expand the Green Initiatives Coordinator position to a small office of Climate Change, Sustainability, and Resilience
8	County seawall ordinance	Adopt the Broward county seawall ordinance earlier than within the required two years
9	City cemetery adaptation*	Suspend ground burial and build a mausoleum to improve flood resilience at the city cemetery
10	Marina seawall rehabilitation*	Raise the City marina seawall, with the option of a hybrid living shoreline approach with mangroves contained within planter boxes.
11	Low impact development (LID) at City streets*	Develop a pilot LID project to improve stormwater controls and flood resilience for city streets

*These strategies were selected for further development and analysis

3.2 LONG TERM

Long term adaptation strategies are presented in Table 4. They are prioritized from greatest to least resilience benefit based on the criteria established in the prioritization exercise (adaptive capacity; economic, environmental, and social benefit; and feasibility).

TABLE 4: LONG TERM ADAPTATION STRATEGIES

Priority	Strategy	Description
1	Dune restoration	Restore dunes to provide additional storm protection
2	Lift station capacity	Evaluate existing lift stations to make sure they can handle future demand
3	Resilience Hub*	Establish a resilience hub to coordinate resilience activities and community outreach
4	Coastal development resilience	Perform an assessment of the resilience of existing coastal development in view of increasing erosion and flood concerns
5	Vulnerable low-income housing improvements*	Provide financial assistance for low-income homes in the flood zones to raise critical components (mechanical, electrical, HVAC) above flood elevation
6	Increase capacity of stormwater system	Increase the capacity of the City's stormwater system to handle larger volumes through a variety of improvements
7	Raise critical roads and bridges*	Elevate critical roads and bridges to reduce flood risk and maintain access
8	Relocate critical facilities*	Relocate critical government facilities to areas with less flood risk
9	Restrict development in at-risk areas	Restrict/disallow new development in areas that will be inundated
10	Low impact development (LID) near bridges	Develop a program to install LID features near bridges

*These strategies were selected for further development and analysis

3.3 OPPORTUNITIES FOR COLLABORATION

Resilience is a concern throughout the state and especially in south Florida, not just in Hallandale Beach. Many opportunities exist to collaborate and share best practices with other city and county governments, state agencies, academic institutions, non-profits, and other organizations. In fact, the project itself is the result of a collaboration between the City and the Florida Department of Environmental Protection (FDEP) Office of Resilience and Coastal Protection and its Florida Resilient Coastlines Program.

In particular, the Southeast Florida Climate Compact (SEFLCC) and Broward County are partners for collaboration. The SEFLCC works to develop local and regional responses to climate change vulnerabilities and its Regional Climate Action Plan (RCAP) includes policy initiatives, potential actions, and best practices to improve resilience. The City is a Municipal Partner of the SEFLCC, and the City's Green Initiatives Coordinator is actively involved in SEFLCC activities. Broward County is a statewide leader in resiliency planning and coordinates climate resiliency planning strategies through its Environmental Planning and Community Resilience Division. The County provides a wealth of information related to climate adaptation through its website and events, as well as producing relevant science and policy documents.

Broward County has several current and upcoming initiatives that will affect the City of Hallandale Beach. This includes the new sea wall ordinance which requires four and five feet NAVD by 2035 and 2050 respectively, and which must be adopted by local governments within two years. In addition, the County is updating its priority planning map for higher sea level rise projections and its groundwater table map, both of which will affect development in Hallandale Beach. The county is also developing a 2-stage process for a countywide resilience plan that will include basin level analysis, critical infrastructure and services, mitigation strategies, planning level cost estimates, redevelopment strategies, priority capital improvements and quantified risk reduction.

Other south Florida municipalities are also potential collaboration partners. Many of them have done extensive adaptation planning and can provide best management practices as well as valuable case studies. In particular, the City of Miami Beach and the city of Fort Lauderdale have successfully implemented many adaptation strategies. Information from both cities was used to develop the selected adaptation projects described in the following section.

4. SELECTED ADAPTATION PROJECTS

RS&H worked with the City's Green Initiatives Coordinator to select ten adaptation strategies for further development into potential projects. Basis for selection included the City's interest in pursuing the strategy and the ease of integrating it into planned activities. Other selection criteria included suitability for cost/benefit analysis, availability of supporting data, and availability of potential grant funding. Detailed project proposals were developed for the selected strategies, cost estimates were developed, and benefits were estimated or qualitatively described.

4.1 COST / BENEFIT ANALYSIS METHODOLOGY

Conceptual level cost estimates were developed for the ten selected projects. These rough order of magnitude (ROM) estimates were developed for planning purposes and should not be viewed as an accurate representation of actual planning, design, construction, and operational costs. Further project definition is required to develop detailed project level cost estimates that consider site specifics and design details and should be developed prior to procurement and construction of the projects.

The cost and benefit assumptions for each project are detailed in the project descriptions in the next section. In most cases, costs are based on case studies of similar projects or cost estimating data. Where appropriate, operations and maintenance costs over the infrastructure life cycle are included. Where such future costs are estimated, their present value is shown using the City's 2.5% discount rate. In many cases contingencies to account for significant uncertainties related to design, engineering or traffic management were included. Costs are provided as a range with a low and high estimate for each project.

The economic benefits of resilience projects are more difficult to estimate than costs and are not provided for many of the projects. Benefits may be direct, indirect, or induced. Direct benefits result in financial returns or avoided costs to the project owner of the asset. Indirect benefits are realized by other entities who do not own asset but may be affected by it. An example would be avoiding loss of access to a business district from flooding due to Low Impact Development (LID) improvements. In this case, businesses in the district benefit indirectly through avoided loss of income. Induced benefits flow from economic activity not directly related to the project but which may still benefit the community. For example, the LID improvements may result in an increase in property values.

Direct economic benefits of resilience projects to the City government include avoided physical damages, repair and replacement costs and reductions in operations and maintenance expenses. In most cases, more detailed design and site information will be needed to adequately estimate these benefits. Adaptation projects can result in savings for many years after they have been implemented. For example, elevating a flood prone structure may avoid repetitive flood damages that would otherwise have occurred many times over the facility's lifespan. Due to the variability of weather events, it may be challenging to determine how many times such damage might have occurred over a given period in the absence of the adaptation. The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4 - $6 for every $1 invested in hazard mitigation.

Indirect benefits of resilience projects include a wide range of positive results to the City government or the community, such as avoided travel disruptions/delays, reduction in vehicle operating/freight costs from detours, minimized/avoided injury costs, avoided impacts to businesses, impacts to the City's tax base, impacts to properties, reduced insurance premiums, increased property values, tourism revenue, and impacts to water quality and pollution, among others. Most of these items are difficult to quantify economically without an extensive study beyond the scope of this project.

Project benefits should not be thought of in only economic terms. Most adaptation projects have a wide range of social, environmental and resilience benefits as well. These benefits may be difficult or impossible to quantify but are still valuable. For instance, the LID project included here could provide additional green space to the City creating a more attractive space for residents and visitors to enjoy walking along the street. The project descriptions briefly describe these qualitative benefits where appropriate.

4.2 PROJECT DESCRIPTIONS

Detailed project sheets were created for ten potential adaptation projects selected to meet the City's needs. The project sheets include the project name, location, objective, scope, cost/benefit assumptions, and estimates of costs and benefits. Estimated costs are provided as a range with a low and high estimate for each project. Total costs for all ten projects range from $129 to $182 million. Table 5 shows the ten selected projects and their estimated cost ranges. Project sheets for each project are provided on the following pages.

TABLE 5: SELECTED ADAPTATION PROJECTS WITH COST ESTIMATE RANGES

Project Name	Cost Estimate (low)	Cost Estimate (high)
2000 S. Ocean Dr. Resilient Dune Access	$12,000	$16,000
Egret Lift Station Rehabilitation	$46,000	$681,000
Marina Seawall Rehabilitation	$129,000	$1,845,000
Resilience Hub	$6,054,000	$7,870,000
Vulnerable Low-income Housing Improvements	$2,400,000	$17,500,000
Raise Critical Roads and Bridges	$104,094,000	$126,000,000
Relocate Municipal Complex	$14,200,000	$21,800,000
City Cemetery Mausoleum	$501,000	$540,000
Check Valves for Stormwater Outfalls	$928,000	$1,206,000
Northeast 12th Avenue Low Impact Development	$658,000	$4,410,000
Total	*$129,022,000*	*$181,868,000*

Based on meta-research published by the National Institute of Building Sciences, these projects could result in a net benefit of $387 to $546 million to the City and community.

Project Name: 2000 S. Ocean Dr. Resilient Dune Access
Location: 2000 S. Ocean Drive

Objective: Improve the resiliency of the City's Beach Access points, beginning with a demonstration project at 2000. S. Ocean Drive, the site of a planned 64-unit residential development. The project will be designed to reduce coastal erosion by altering the design of the beach access. Pedestrian pathways through the dunes will be designed with a diagonal or curved shape and at an oblique angle to the direction of the prevailing winds, which typically blow in an easterly direction. The angled pathway will slow or prevent dune erosion due to wind as well as storm surge / wave runup.

Scope: The City will need to either procure professional services for site design and construction of dune and beach access, or provide those services using City staff. The City will need to specify and approve the resilient design, but no additional actions will be needed to implement it. The City may wish to pursue grant funding through the Broward County Environmental Planning and Community Resilience Division (EPCRD) dune grant program or FDEP to cover any additional construction costs. The City may also wish to consider changes to standard operating procedures that could improve the resilience of the beach access points. For instance, the City of Jacksonville Beach has begun temporarily filling in beach access routes through the dunes with sand prior to approaching hurricanes. This practice has successfully prevented storm surge from penetrating past the dunes during recent storms, reducing dune erosion and protecting nearby properties.

Cost Assumptions: Incremental costs for this project are estimated at $12,000 to $16,000 assuming the resilient design adds 15 feet to the length of the beach access pathway. The high estimate includes a 30% contingency. The estimate assumes the beach access pathway is constructed of an engineered composite material on concrete pilings at grade, with railings on both sides. The project assumes the angled beach access design will add about 50% to the shortest-path distance to the beach (which is approximately 30 feet). Some of the additional cost could be offset through use of grant funding through the Broward Dune Restoration Program or FDEP Beach Management Funding Assistance. Costs could also be reduced by using volunteer labor through organizations such as the Youth Environmental Alliance (YEA) to develop/maintain the beach access pathways.

Benefit Assumptions: Direct benefits may include reduced dune maintenance/restoration costs following storm events. Replacement cost for sand lost from dunes during storm events is estimated at $25 per cubic yard (CY). The angled design is intended to reduce loss of sand due to wind and water erosion. If 500 CY of sand were retained over five years compared to a conventional design, the project might break-even based on cost savings for sand replacement. Indirect benefits are related to the increased protection the resilient beach access may provide. They include avoided lost access to government fees / taxes, reduced insurance premiums, increased property values and maintaining tourism revenues. These benefits are difficult to quantify and are not estimated.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types: Construction, operations and management.
Low Estimate: $12,000
High Estimate: $16,000
Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name: Egret Lift Station Rehabilitation

Location: Egret Drive and Poinsetta Drive

Objective: To improve the resiliency and reduce the failure rate of the Egret Drive lift station (lift station #1) by elevating and hardening critical infrastructure at the station to reduce flood and storm risks. The existing lift station is a triplex design with 2-60 HP pumps and 1-200 HP pump. The City plans to upgrade it to include 3-200 HP pumps. City staff recommend elevation of electrical equipment, the use of corrosion-resistant materials, and adding a grinder station that can process solid materials to reduce pump wear as part of the upgrade. These resilient design features will add an incremental cost to the planned upgrade, but will reduce the risk of failure under flood and storm conditions and/or power outages. Other typical strategies to improve lift station resilience to flooding include: elevating equipment above critical flood elevations, utilizing submersible pumps, encasing electrical equipment in watertight housings, sealing structures with water-tight windows and doors, and providing backup emergency power generation. In addition, per Florida Administrative code, lift stations should have protection from lighting strikes and voltage surges.

No-cost resilience strategies related to operational changes are also available. In 2017 RS&H evaluated failure modes that led to unpermitted sanitary overflows that occurred during hurricanes Hermine and Matthew at seven Florida utilities. For lift stations, the most common cause of an unpermitted release was a failure of backup power. In many cases, automatic transfer switches failed to engage or protective relays on Variable Frequency Drive pump motors tripped, leaving equipment unenergized while City staff were sheltering from the hurricanes and unable to respond. An effective, no-cost solution was to provide an adequate supply of fuel and manually transfer the lift stations to run off emergency generators in advance of the storm.

Scope: Develop a resilient design specification for this and future lift station projects. Procure design/engineering services and require project design to conform to specified resiliency performance targets. After construction, commission or otherwise verify system components and performance. Develop an implementation and operation plan that incorporates standard operating procedures designed to reduce flood/storm risks. Include resilient design specification in future lift station rehabilitation/replacement/new construction projects as they come up.

Cost Assumptions: Total estimated costs for just the resiliency upgrades to Egret Lift station range from $46,000 (low estimate) to $681,000 (high estimate). These are incremental costs for resiliency upgrades only, in addition to the $2.26 million the City has estimated for improvements to modernize and increase the capacity of the facility. Exact costs will need to be estimated following an engineering survey and design of the proposed improvements. Low estimate costs are derived from the average projected cost for resiliency upgrades to wastewater pump stations in the Waterford, CT Sewer Pump Station Assessment and Adaptation Report. High estimate costs are derived from the average projected cost for resiliency upgrades to wastewater pump stations in the Los Angeles OneWater Plan. Costs include design/engineering fees estimated at 10% of construction costs. Low estimate costs include installing flood doors and panels, raising electrical equipment and transformers, raising vent and fill pipes, anchoring fuel tanks, replacing hatches, relocating chemical feed pumps. installing watertight manhole covers, concrete repairs, and waterproof membrane coating. High estimate costs include low estimate improvements plus raising generator pads and installing bollards or berms to protect against storm surge wave damage.

Benefit Assumptions: Direct potential benefits include avoided repair/replacement costs for the facility if it were flooded, and avoided fines and environmental fees if a flood or storm caused an unpermitted release. The LA OneWater plan estimated an average $4.1 million replacement cost for wastewater pumping stations. Environmental fines can also be significant. The City of Sarasota reached a consent agreement with FDEP for 83 spills of 630 million gallons of wastewater between May 2018 and September 2019 that resulted in $25.4 million in fines to the city, or more than $24 per gallon. Other indirect potential benefits (not estimated) include avoided impacts to surrounding properties, reduced insurance premiums, avoided pollution of waterbodies and avoided public health risks.The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types: Design, Construction.

Low Estimate: $46,000

High Estimate: $681,000

Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name: Marina Seawall Rehabilitation
Location: 101 Three Islands Boulevard

Objective: To improve flood resilience of the City Marina by raising the existing seawall. A Broward County land use amendment passed March 31, 2020 requires seawalls be raised to 5 feet NAVD to protect against a King Tide in 2060 plus a 20-year return interval storm surge. The Sea Level Scenario Sketch Planning Tool shows the land elevation at the marina is approximately 3 feet NAVD. Assuming the existing seawall extends roughly level with the ground surface, a minimum additional seawall height of 2 feet above ground level would be required to meet this requirement. Two options were analyzed. For option one, a concrete cap would be added to the existing seawall raising it to 5 feet NAVD. For option 2, the existing seawall would be demolished, and a new, higher concrete seawall would be constructed in its place, raising it to 5 feet NAVD. As an additional option the City could evaluate the feasibility of adding mangroves planted within rock or cement planters along 120 feet of the north end of the seawall near the Three Islands Blvd bridge. Containing the mangroves within planters may prevent them from interfering with navigation. The City would need to evaluate potential impacts of this project on nearby/adjacent private properties. The City would also need to evaluate the need to refurbish or replace existing docks at the marina as part of the project and estimate associated costs for this task.

Scope: Plan the project, conduct a site survey, obtain funding, procure design and construction services.

Cost Assumptions: Conceptual estimated costs range from $129,000 to $1,845,000. Estimates include construction material and labor costs and assume an additional 10% for design/engineering costs. The high estimate assumes replacement of the existing seawall and includes demolition of the existing structure. Estimated costs do not include stormwater drainage improvements, grading/earthwork, landscaping, additional site work, or O&M. The existing docks would likely need to be rebuilt or replaced, but these costs are not included due to a lack of available information. Costs do not include land acquisition because the City already owns the site. A site survey would need to be conducted and detailed engineering level cost estimate would need to be developed prior to construction. Costs are derived from RS Means and the City of Ft. Lauderdale. The option to add mangrove planters, if determined to be feasible, would add another $24,000-$75,000, based on comparable projects at the towns of Palm Beach and Lantana.

Benefit Assumptions: Direct benefits of the improved seawall would include protecting the site, including Fire Rescue Station #3 and Marina structures, from storm damage and king tide flooding. Building improvements on site had a just market value of $402,710 in 2019. Indirect potential benefits derive from decreased flood risk at the marina and are not estimated. They include reduction in physical damages and repair costs due to storm damage and overtopping, minimized cost of potential injury, impacts of lost access to businesses, impacts to adjoining properties, reduced insurance premiums, increased property value, and avoided disruption of tourism revenues. While indirect, these potential benefits could be quite large. For example, the "value of a statistical life" is estimated by Federal agencies as between $6-9 million. If the seawall is responsible for avoiding one resident death, it could be cost-effective from a social perspective.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types: Design, Construction, Reconstruction / rehabilitation.
Low Estimate: $129,000
High Estimate: $1,845,000
Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced

econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name:	Resilience Hub
Location:	Chaves Lake Park

Objective:

Build and operate a Resilience Hub at Chaves Lake Park. Resilience Hubs are community-serving facilities augmented to support residents and coordinate resource distribution and services before, during, or after a natural hazard event. They are used year-round as neighborhood centers for community-building activities. According to the Urban Sustainability Directors Network, "Resilience Hubs can equitably enhance community resilience while reducing GHG emissions and improving local quality of life. They are a smart local investment with the potential to reduce burden on local emergency response teams, improve access to health improvement initiatives, foster greater community cohesion, and increase the effectiveness of community-centered institutions and programs. Current plans for the park include a restroom facility and a public use room. These could be expanded into a Resilience Hub.

Scope:

This project requires conceptual planning, including establishing a project team, building partnerships, setting goals, and establishing the project performance requirements. Once complete, the City must procure professional services for building design and construction. An operating plan also must be developed, including staffing and programming.

Cost Assumptions:

Project estimated lifecycle costs are $6,054,000 to 7,870,000. The estimate does not include land acquisition, because it assumes the City will build the Hub on land it already owns (Chaves Lake Park). Upfront costs include design and construction, estimated at $2.34M. Long-term operations and maintenance costs are estimated at $3.7M. This is the present value of 40 years of O&M at $8 per square foot and a discount rate of 3%. O&M costs do not include staffing and programming expenses since these variables are unknown at this time.

Benefit Assumptions:

Potential benefits are indirect and are not quantified. These may include minimized cost of potential injury to citizens, avoided lost access to government fees / taxes, reduced insurance premiums and increased property values. While indirect, these potential benefits could be quite large. For example, the "value of a statistical life" is estimated by Federal agencies as between $6-$9 million. If the hub is responsible for avoiding one resident death, it could be cost-effective from a social perspective.

Cost Estimate:

The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types:	Land acquisition, Design, Construction, Operations and management.
Low Estimate:	$6,054,000
High Estimate:	$7,870,000
Benefit Estimate	The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name:	Vulnerable Low-income Housing Improvements
Location:	City-wide
Objective:	The objective of this project is to offer grants and technical assistance to low-income homeowners for flood mitigation measures for properties in the floodplain.
Scope:	This project considers providing assistance to low-income homeowners for dry flood proofing. Wet floodproofing is not likely applicable to most homes in Hallandale Beach due to method of construction (i.e. slab on grade), with the exception of elevating service equipment, which should be considered as an eligible measure under the program. Elevation may only be cost-effective when reconstructing a home. Flood mitigation retrofits like relocation are not likely to be cost-effective. The program would require additional planning. Foremost is the need to conduct a parcel-based vulnerability assessment of residential properties in Hallandale Beach. For this concept, the number of households below the poverty line in Hallandale Beach is used as proxy. A parcel-based analysis would identify the number of residential structures vulnerable to climate change stressors. In addition, program details, including eligibility, approved flood control measures, program terms and conditions, funding sources and budget forecasts, among other considerations, must be developed. A similar program has been administered by Charlotte-Mecklenburg County Storm Water Services department. The "retroFIT" program provides financial grants reimbursing 75 to 95 percent of qualified floodproofing projects for homeowners enrolled in the County's Low Income / Disabled Veteran Homestead Exclusion program.
Cost Assumptions:	Total costs are estimated to range from $2.4M to $17.5M over a 10 year period. These estimates assume annual program costs ranging from $280,000 to $2M. Annual costs assume a total of 3,773 low income households are vulnerable to flood damage in the City. Since nearly all of the City is within the 500 year flood plain and all census tracts have some exposure to the 100 year flood, the cost estimates assume that all household below the poverty line would be eligible for the program. The actual number of homes is likely lower. A parcel-based residential property vulnerability assessment is required to refine this estimate. The cost of dry floodproofing for these homes may range from $9,000 to $26,000 per home, with the City's program reimbursing 75% to 95% of qualifying expenses. A program participation rate of 1% to 2% is assumed based on the nationwide experience of whole building energy efficiency retrofit programs, which are used as a proxy for participation in this program. An additional 10% of total grant value is assumed for program administration.
Benefit Assumptions:	Since this is a grant program, direct benefits accrue to the property owner, rather than the City. Indirect benefits include minimized costs of potential injury, impacts of lost access to government fees / taxes, avoided impacts to properties, reduced insurance premiums, and increased property values. A study of flood protection in Miami Beach found that it is cost-effective for homeowners, a finding supported by FEMA.
Cost Estimate:	The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.
Cost Types:	Operations and management
Low Estimate:	$2,400,000
High Estimate:	$17,500,000
Benefit Estimate:	The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name:	Raise Critical Roads and Bridges
Location:	Multiple

Objective: Improve flood resilience in the Golden Isles neighborhood by raising bridges. There are nine bridges totaling 1,067 feet in length, (0.20 miles). The existing 2-lane bridges average around 120 feet in length (including approaches), are about 25 feet wide, and sit on concrete pilings with a reinforced concrete span. Raising the bridges will protect them from flood damage, ensure continued access to the area, and allow boats to continue to pass underneath as sea levels rise.

Scope: Conduct an engineering feasibility study to determine if bridges can be raised or must be demolished and replaced. Assuming they are demolished and replaced, develop conceptual project design and cost estimates. Develop plan to manage traffic and provide access during bidge demolition/construction activities. Secure funding. Procure professional services for design and construction. Develop and implement an operations and maintenance plan.

Cost Assumptions: Detailed engineering surveys would be needed to determine the feasibility of elevating existing bridges, and costs for this work would be highly site specific and depend on the condition of the existing structure and other details. Conceptual level costs to demolish and replace the existing bridges are better defined and were used in this estimate. Total estimated costs range from $8.2 to $10 million per bridge. When Management of Traffic (MOT) costs are included, the total to replace all nine bridges ranges from $104 million (low estimate) to $126 million (high estimate). A feasibility study will need to be done to determine what engineering options are available and develop a detailed engineering cost estimate based on the selected design. Since every bridge is different, it is difficult to model costs using comparable projects.

Three sources were used to develop a range of potential costs. The lowest estimate, $8.2 million per bridge, is based on 2017 FHWA average costs for 20 bridge projects completed in the state of Florida. The 2017 FDOT Structure Design Guidelines suggests the cost could be $9 million per bridge. The high estimate costs are modeled on the City of Miami Beach West Avenue Bridge, which is similar in type and span to Golden Isles Bridges but with additional lanes. This project included a prefabricated bridge span, street and pedestrian lighting, signing and pavement markings, utility relocation and drainage improvements at a cost of $10 million under a design build contract.

Management of traffic (MOT) can add 40% or more to estimated project costs in some cases. Since some parts of the Golden Isles are only accessible by a single bridge, contingencies must be made to guarantee continued access to residents during demolition and construction, which could significantly increase total costs. A 40% MOT contingency is added to each estimate.

Benefit Assumptions: Potential benefits are indirect and are not quantified. These may include reduction in physical damages and/or repair costs due to SLR and storm surge flooding, reduction in travel time and vehicle operating costs due to detours, avoided lost access to government fees / taxes, reduced insurance premiums and increased property values.

While difficult to quantify, potential benefits could be significant. A business case analysis for the City of Miami Beach's Stormwater Resiliency Program found that for every 1 foot in elevation nearby roads were raised, residential housing values in Miami Beach neighborhoods increased between 4.9 and 14.1 percent. Using this benchmark and conservative estimates of the value of residential housing stock in the project area, a 5% increase in housing values in Golden Isles could translate into more than $20 million in increased property value and associated increases in City tax revenues.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types:	Design, Construction, Travel delay (i.e. for residents).
Low Estimate:	$104,094,000
High Estimate:	$126,000,000
Benefit Estimate:	The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name: Relocate Municipal Complex
Location: 400 South Federal Highway

Objective: The Municipal Complex is located in a FEMA flood zone vulnerable to extreme precipitation and storm surge, conditions exacerbated by projected sea level rise. The objective of this project is to relocate the existing Municipal Complex (City Hall and Police Station) in the future to a new location west of US 1. By relocating the Complex, the City can reduce the chances of flood damage at the facility and potential disruption of essential services to the community. Relocating the facility would allow sustainable and resilient design features to be included in the new facility. This project does not contemplate relocating the Municipal Complex in the near-term. Rather, it provides context for mid- to long-term planning for relocation as the building nears the end of its useful life.

Scope: This project requires conceptual planning, including establishing a project team, setting goals, and establishing the project performance requirements. This phase of effort would include evaluating the optimal time to relocate the complex, given its age, condition, operating requirements, and its relative vulnerability to flooding and storm events over time. Land acquisition and associated due diligence is likely required. Once complete, the City must procure professional services for building design and construction. This project assumes that the new municipal complex will be constructed to high performance and sustainable design standards. An operating plan also must be developed, including staffing and programming. The City must also establish and execute a plan for moving departments from the current location to the new facility once ready for occupancy.

Cost Assumptions: Project estimated costs range from $14.3 to $21.8 million. The estimate includes land acquisition, design, and construction. Long-term operations and maintenance costs are not included since they are already incurred by the present municipal complex; no incremental O&M costs are assumed. O&M costs do not include staffing and programming expenses since these variables are unknown at this time.

Benefit Assumptions: Potential benefits are direct and indirect and are not quantified. Direct benefits are contingent upon avoiding physical damages and repair costs from future flooding or storm events. The municipal complex is 26 years old. Annual O&M costs tend to accelerate with age and could be significantly decreased by a new facility. Indirect benefits include may include minimized cost of potential injury and reduced insurance premiums. Outside the context of climate change vulnerability, additional benefits could include increased productivity of staff, enhanced quality of service to residents, local employment during construction, as well as other benefits associated with redevelopment of a potential site on the west side of the City.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types: Land acquisition, Design, Construction.
Low Estimate: $14,200,000
High Estimate: $21,800,000
Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name: City Cemetery Mausoleum
Location: 809 NW 7th Avenue

Objective: Cemeteries are vulnerable to damage from flooding events, such as storm surge. This vulnerability is exacerbated by climate change. The City has been considering adding a community mausoleum to its cemetery. Mausoleums are free standing buildings enclosing crypts and / or columbariums with niches for cremated remains. Such facilities are considered more ecologically friendly than in-ground burials since they save on space. A mausoleum also provides an opportunity for incorporating resilient design. This objective of this project is to incorporate additional freeboard (i.e. elevation above the base flood level) into a future mausoleum design.

Scope: Since the majority of the Cemetery is within the 500 year floodplain, where flood insurance is recommended by not required, flood resistant design and construction (ASCE 24) does not apply. However, flood risk is changing over time as a result of climate change. To mitigate vulnerability, FEMA recommends building at least 3 feet above the base flood level. Final finished floor elevation will be determined in conjunction with further site evaluation and concept planning. A project team must be established to set goals and establish the project performance requirements. The project assumes that land acquisition is not required, since the mausoleum would be built on the current cemetery property. Once complete, the City must procure professional services for building design and construction. An operating plan also must be developed, including staffing and programming.

Cost Assumptions: The City has independently obtained a quote for design and construction of one 360 crypt mausoleum with 320 niches. The estimate ranges from $495,000 and $510,000. This estimate does not include sitework or permitting. To build an additional 3 feet of freeboard may cost an additional 0.25 to 1.5 percent of total construction cost per foot. A 30% contingency has been applied to this unit cost, resulting in an incremental cost of $4,000 to $23,000 and a total cost of $501,000 to $540,000. Lifecycle operations and maintenance costs are not included in this estimate since they are assumed to be minimal relative to existing cemetery operations.

Benefit Assumptions: Potential benefits are direct and indirect and are not quantified. Direct benefits are contingent upon avoiding physical damages and repair costs from future flooding or storm events. U.S. cemeteries have been damaged from flooding as result of extreme precipitation and storm events in recent years. Unfortunately, damage to existing cemetery internments is essentially impossible to mitigate short of relocation, which is likely not feasible. A mausoleum would therefore be beneficial as an alternative to future in-ground burials. The mausoleum may also reduce O&M costs and increase potential revenues on a per square foot basis. Indirect benefits include avoiding loss of use of the cemetery and any associated revenue. In addition, a resilient mausoleum could reduce insurance premiums. Insurance premiums are generally lower for elevated structures.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types: Design, Construction.
Low Estimate: $501,000
High Estimate: $540,000
Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name:	Check Valves for Stormwater Outfalls
Location:	Stormwater outfalls (exact locations to be determined)

Objective: The objective of this project is to install inline tidal check valves at the City's stormwater outfalls. The check valves will prevent sea water from backing up into the City's stormwater system during king tides and other events when the outfalls are below the water level, helping to prevent flooding.

Scope: The City has already completed four check valve installations. Nine remaining outfalls could be retrofit. The project assumes nine installations using Tideflex valves or similar, and that the City hires outside design services. The exact outfalls targeted for check valve retrofits, specifications and other project details will be determined at a later date by the City's stormwater design consultant/engineering staff. Valve installation includes associated basin improvements, incidental expenses, and life-cycle maintenance costs. The project requires determining the exact project scope and details, securing funding; procurement of professional services; engineering design and specification; and construction.

Cost Assumptions: Total cost of installation for nine check valves, including design, outfall basin improvements and life-cycle maintenance costs, was estimated between $928,000 and $1.2 million. Costs were estimated based on the average cost the City provided for four 15″ to 16" tidal valves already installed (assumed to be material only) and costs derived from Ft. Lauderdale's check valve installation program. Design costs were estimated at 10% of retrofit costs. Material cost of check valves varies by size but was estimated at $3,200 each. Installation costs including outfall basin improvements was estimated at $22,500. Incidental costs to replace landscaping surface features etc. were estimated at $1,000 per installation. Maintenance costs were estimated at $4,000 per year for each valve based on average costs from Ft. Lauderdale. Maintenance costs are included for the typical lifespan of the check valves, which is assumed to be 25 years, based on information from Ft. Lauderdale. At a 2.5% discount rate, the present value of valve maintenance costs over their lifecycle is $73,698 each and $663,278 for all nine.

Benefit Assumptions: Direct benefits include potential reduction in damages and repair costs due to flooding events related to king tides, sea level rise and storm surge. These benefits are not estimated because a flood-reduction model and flood cost estimation model (such as Hazus) is required. Lower maintenance costs are another potential benefit. Case studies suggest inline check valves may have lower annual maintenance costs that gate or flapper type check valves that they replace. The project may also have numerous indirect benefits related to flood reduction, including: reduction in travel time costs from detours, reduction in vehicle operating costs from detours, reduction in pedestrian hazards, reduction in disruptions to freight movement, minimized cost of potential injury, minimized impacts of lost access to businesses, avoided loss of tax revenue, avoided impacts to properties, avoided impacts to landscaping from salt water exposure, reduced insurance premiums, maintenance of property values and tourism revenues, and water quality/pollution control improvements.

Cost Estimate: The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types:	Design, Construction, Maintenance.
Low Estimate:	$928,000
High Estimate:	$1,206,000

Benefit Estimate: The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

Project Name:	Northeast 12th Avenue Low Impact Development
Location:	Northeast 12th Avenue between Atlantic Shores Boulevard and Hallandale Beach Boulevard

Objective:

The objective of this project is to improve stormwater drainage, reduce flood risk, and realize social and environmental benefits by incorporating Low Impact Design (LID) features into improvements along a six-tenths of a mile stretch of Northeast 12th Avenue between Atlantic Shores Blvd and Hallandale Beach Blvd. LID is development designed to maximize green space and promote natural stormwater management through the use of plants and permeable materials to minimize stormwater runoff velocity, temperature and associated pollution.

Scope:

This project considers a range of LID options. The low cost option would include rain garden features with native plants to attenuate stormwater flows, covering 40% of the length of the project corridor along both sides of the road and assumed to be 8 feet wide or less. Incremental costs are estimated for LID features only and not for additional improvements. The high cost option is modelled on the City of Chicago's Pilsen Sustainable Streetscape project, which uses a variety of green infrastructure elements to increase infiltration of stormwater and reduce flooding. These features include bioswales, rain gardens, permeable pavements and other stormwater management measures that divert up to 80 percent of the typical average annual rainfall away from the combined sewer system. High albedo (reflection) pavement surfaces reduce urban heat island effects and drought tolerant, native vegetation increases landscape and tree canopy cover to shade the right of way and provide additional stormwater filtration. This project requires further conceptual planning, including setting goals and establishing the project performance requirements. The City must procure professional services for site design and construction. The City must also establish a plan for maintenance of the LID improvements.

Cost Assumptions:

Total costs range between $658,000 to $4.41 million, depending on project complexity and number and type of LID options included. Design, construction, and maintenance costs can vary widely depending on the exact LID components specified. The low estimate includes rain gardens installed along the project corridor and lifetime maintenance for the LID features for 37 years. The project assumes LID features are an added component to an existing design, and costs are calculated only for the additional LID components. The project assumes improvements fall within existing rights-of-way; no land acquisition costs are included. Project construction cost is estimated at $341,688 based on a $16.05 per sf unit cost. The design cost is estimated at 10% of the construction cost at $34,169. The present value of lifetime incremental maintenance costs for the LID components compared to conventional hardscape is estimated at $282,045. The high estimate is based on total project costs for the Chicago Pilsen Sustainable Streetscape, including design. Lifetime incremental maintenance costs are not included for this option.

Benefit Assumptions:

Reduction in physical damages, reduction in repair costs, minimized cost of potential injury, impacts to properties, insurance premiums, property values, tourism revenues ,traffic calming, water quality.

Cost Estimate:

The Cost types below provide a qualitative assessment of the costs that may be associated with this project. Low and high cost estimates are based on these cost types. Estimates are AACE Class 4, denoting schematic or conceptual design and are meant for use in further study or feasibility assessments. Further project definition may be required for budget authorization and procurement.

Cost Types:	Design, Construction, Maintenance.
Low Estimate:	$658,000
High Estimate:	$4,410,000
Benefit Estimate:	The National Institute of Building Sciences Natural Hazard Mitigation Saves: 2017 Interim Report estimates a return of $4-6 for every $1 invested in hazard mitigation. Resilience benefits can be direct, indirect and / or induced. Quantification of benefits on a project-specific basis derive from advanced econometric techniques which require further project definition. The benefit assumptions noted above provide a qualitative assessment of the benefits that may be associated with this project.

5. RECOMMENDATIONS

5.1 POLICY RECOMMENDATIONS

RS&H has identified number of recommendations for the City to consider that would improve resiliency. The Task 3, 4, and 5 memos include specific recommendations that address vulnerabilities related to extreme precipitation, groundwater changes and shoreline recession. Rather than reproduce those here, this section focuses on general recommendations to advance the City's adaptation program and ideas that emerged from the collaborative workshop. The recommendations are organized using the adaptive management framework categories: Monitor, Evaluate, and Plan.

5.1.1 Monitor

- Monitor emerging climate science and temperature, sea level rise, precipitation, groundwater, and shoreline projections.
- Monitor flood events and at-risk locations in the city.
- Monitor emerging adaptation best practices and technology.
- Monitor vulnerable populations in the city.
- Develop local datasets needed for adaptation planning, such as building footprints and elevations, stormwater system vulnerabilities / elevations, at risk-transportation networks, etc.
- Coordinate adaptation planning with Broward county, particularly regarding the sea wall ordinance and upcoming priority planning and groundwater maps and countywide resilience plan.
- Coordinate with SEFLCC, nearby municipalities and other regional partners.
- To better monitor vulnerabilities and manage adaptation actions within the City, expand the Green Initiatives Coordinator position to an office of Climate Change, Sustainability, and Resilience.
- Conduct outreach and education to promote the City's adaptation program and receive vital community input.

5.1.2 Evaluate

- Assess options to safely shelter vulnerable populations in the event of a severe storm event during the COVID-19 pandemic.
- Evaluate potential climate change impacts on vulnerable populations in the City and develop a plan to engage them to ensure the City's adaptation actions are implemented in an equitable way.
- Conduct a study to further quantify benefits of proposed adaptation projects in economic terms, including indirect and induced benefits.
- Develop project-level budgetary cost estimates for proposed adaptation projects based on preliminary design details.

- Evaluate the projects included in this assessment with respect to present and emerging funding opportunities for pre-disaster mitigation projects, such as FEMA's Building Resilient Infrastructure and Communities (BRIC) program.
- Conduct flood-risk vulnerability assessments of the City's residential properties and transportation infrastructure.
- Conduct a vulnerability assessment that considers the effects of temperature increases, vector borne illness, and other climate impacts not addressed in recent vulnerability assessments.
- Evaluate the feasibility of changing the landscape code to require salt-tolerant native species in areas at risk of saltwater intrusion due to groundwater changes, sea level rise, nuisance flooding and storm surge.
- Evaluate opportunities to restore dunes to provide additional storm protection.
- Evaluate existing lift stations to make sure they can handle future demand and develop resilient design standard for future lift station construction and rehabilitation.
- Assess the resilience of existing coastal development in view of increasing erosion and flood concerns.
- Assess options to restrict or disallow new development in areas that will be inundated.
- Evaluate the City's vulnerabilities to non-climate related risks such as epidemic disease, cybercrime, terrorism, and associated economic disruptions.

5.1.3 Plan

- Develop a capital plan for the adaptation projects included in this document.
- Adopt Adaptation Action Areas for the City to prioritize adaptation planning in vulnerable areas and as an avenue to pursue grant funding.
- Adopt the Broward county seawall ordinance and develop a program to assist property owners with compliance.
- Include sea level rise / flood vulnerability as an evaluation criterion in Capital Improvement Plan (CIP) and/or budget allocation process
- Develop a program to install LID features and living shorelines near bridges
- Develop design standards for city facilities and infrastructure that take climate resilience into account
- Plan to update the City's vulnerability assessment at regular intervals

5.2 PRELIMINARY WORK PLAN

This Plan contains ten adaptation projects designed to improve the City's resilience to climate vulnerabilities related to flood risk, sea level rise, groundwater elevation, extreme precipitation, and shoreline recession. The next step is to budget, schedule and commit to realizing these projects. This section includes a preliminary budget and outlines an implementation schedule for the ten projects.

5.2.1 Budget

The ROM cost estimate for all ten adaptation projects ranges from $129 to $182 million. However, greater than 95% of this cost is associated with the long term projects: Resilience Hub, Vulnerable Low-income Housing Improvements, Raise Critical Roads and Bridges and Relocate Municipal Complex. In particular, Raise Critical Roads and Bridges is by far the most expensive of the ten projects and accounts for over 70% of the total cost.

RS&H recommends the City begin by implementing lower cost projects in the short term while finding the funding available to implement longer term projects. This would result in estimated costs of $2.3 to $8.7 million in the short term, while still producing substantial resilience benefits. Table 6 shows total costs for the six short term projects.

TABLE 6: SHORT TERM PROJECTS AND COSTS

Project Name	Cost Estimate (low)	Cost Estimate (high)
2000 S. Ocean Dr. Resilient Dune Access	$12,000	$16,000
Egret Lift Station Rehabilitation	$46,000	$681,000
Marina Seawall Rehabilitation	$129,000	$1,845,000
City Cemetery Mausoleum	$501,000	$540,000
Check Valves for Stormwater Outfalls	$928,000	$1,206,000
Northeast 12th Avenue Low Impact Development	$658,000	$4,410,000
Total	*$2,274,000*	*$8,698,000*

The City could begin planning the long-term projects while implementing the short-term ones, including sourcing grant funds to build/relocate facilities, improve vulnerable low-income housing, and raise the Golden Isles bridges. The long-term projects may cost between $127 and $173 million. Table 7 shows total costs for the four long term projects.

TABLE 7: LONG TERM PROJECTS AND COSTS

Project Name	Cost Estimate (low)	Cost Estimate (high)
Resilience Hub	$6,054,000	$7,870,000
Vulnerable Low-income Housing Improvements	$2,400,000	$17,500,000
Raise Critical Roads and Bridges	$104,094,000	$126,000,000
Relocate Municipal Complex	$14,200,000	$21,800,000
Total	*$126,748,000*	*$173,170,000*

5.2.2 Schedule

The City needs to perform due diligence, site assessments, preliminary design, and project-level cost estimates to move forward with the proposed adaptation projects. Once these steps are complete, the City should integrate them into its capital improvement plan and budgetary process and begin scheduling them for implementation.

Some projects already in the planning stages can benefit from added resilience features, such as integrating LID into Northeast 12th Avenue improvements and rehabilitating the Egret Lift Station. The City has already begun implementing adaptation actions such as check valves in stormwater outfalls. These short-term projects make sense to do early since they are related to existing or planned activities.

The 2000 S. Ocean Drive Dune Access is a low-cost project that only requires some design changes to implement, so it is also a good short-term candidate. The City already plans to refurbish the City Marina seawall and should evaluate raising it and incorporating living shoreline features as it moves ahead with the project.

In the longer term, Hallandale Beach should consider the feasibility of establishing a program for low income housing resilience supported by an assessment of the vulnerability of residential properties and the City's transportation infrastructure. The City may also include resilient design it its requirements as it considers the long-term plan for its cemetery, including developing a mausoleum. It should also evaluate the viability of Resilience Hub as plans to develop Chaves Lake Park progress. The planning process for these projects may start in the short term but implementation will probably happen more than five years from now. Relocating the municipal complex is something that should be considered now as the building enters the latter half of its useful life. This will be an expensive project that will require extensive planning. Similarly, raising the Golden Isles bridges is costly and complex. The requirements to maintain access to the islands and need to establish funding for the project mean that while planning may start in the short or midterm, it will likely be implemented further into the future.

Figure 2 shows a preliminary implementation schedule to use as a starting point for these decisions. Time is shown on the horizontal axis, while the vertical axis shows cumulative resilience benefit and colors correspond to relative project costs.

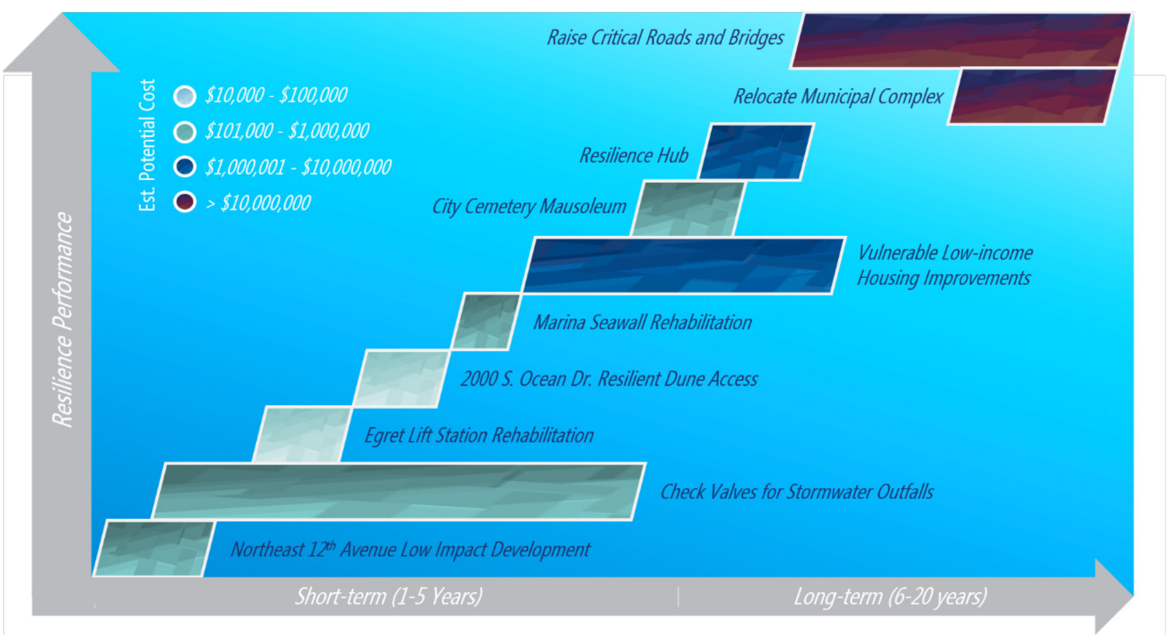

FIGURE 2: PRELIMINARY IMPLEMENTATION SCHEDULE

6. APPENDIX

6.1 COLLABORATIVE WORKSHOP MEETING AGENDA

3125 W Commercial Blvd
Suite 130
Fort Lauderdale, FL 33309

O 954-474-3005
F 954-474-3006
rsandh.com

MEETING AGNEDA

Project Number: 3010068000

Meeting Date: March 18, 2020

Meeting Place: Teleconference

Participants: Alyssa Jones-Wood, Greg Chavarria, Keven Klopp, James Sylvain, Peter Kunen, Vanessa Leroy, Cathie Schanz, Robert Williams, Miguel Nunez, Jeffrey Odoms, Mary Francis Jeannot, Aqeel Abdool-Ghany, Charles Casimir, Anthony Melvn, Matthew Davis

Subject: Hallandale Beach Vulnerability & Adaptation Action Plan Virtual Collaborative Workshop

1. Introduction	1:00 – 1:05
2. Review Vulnerability Assessment	1:05 – 2:20
3. Implications for Hallandale Beach	2:20 – 2:50
4. Adaptation Strategies	2:50 – 3:40
5. Potential Strategies Exercise	3:40 – 4:10
6. Prioritizing Adaptation Strategies	4:10 – 4:25
7. Prioritization Exercise	4:25 – 4:55
8. Next Steps	4:55 – 5:00
9. Adjourn	5:00

6.2 COLLABORATIVE WORKSHOP SIGN IN SHEET

RS&H

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PROCESS SELECTION OF PREFERRED STRATEGIES

A collaborative process was utilized to identify preferred strategies for increasing the City's Resilience. The process began with a workshop held with staff on March 18th, 2020. It was attended by leaders from across the City's functional areas (Table 1).

TABLE 1: COLLABORATIVE WORKSHOP ATTENDEES

Attendee Name	Title
Alyssa Jones-Wood	Green Initiatives Coordinator
Keven Klopp	Assistant City Manager
Peter Kunen	Assistant Director PW /City Engineer
Mary Francis Jeannot	Assistant Director of Public Works/Administration
Matthew Davis	GIS Coordinator
Aqeel Abdool-Ghany	Assistant City Engineer
Bob Williams	Assistant Director of Parks, Recreation, and Open Spaces
Jeffrey Odoms	Assistant Director of Public Works – Utility Operations

Attendees participated in a brainstorming exercise to come up with potential adaptation strategies. They were initially presented with examples of adaptation strategies the City had already implemented and a selection of proposed strategy ideas. Once familiar with examples, they were challenged to come up with new ideas. The exercise resulted in more than twenty potential strategies. The strategies ranged from infrastructure hardening to policy changes such as including flood vulnerability in criteria for budgetary decisions.

Attendees prioritized the list of potential adaptation strategies based on criteria. Criteria included adaptive capacity; economic, environmental, and social benefit; and feasibility. After a discussion of the criteria, they were asked to subjectively rank potential strategies using these criteria via an online survey application.

Following the collaborative workshop, results of the prioritization exercise were converted into numerical scores that were used to rank strategies. Strategies with highest aggregate values for adaptive capacity; economic, environmental, and social benefit; and feasibility were prioritized. Projects were also organized into short- and long-term categories, with short term defined as being feasible within one to five years and long term define as 6 to 20 years. RS&H also added some additional strategies that have proved valuable in similar South Florida communities.

RS&H worked with the City's Green Initiatives Coordinator to select ten adaptation strategies for further development into potential projects. Basis for selection included the City's interest in pursuing the strategy and the ease of integrating it into planned activities. Other selection criteria included suitability for cost/benefit analysis, availability of supporting data, and availability of potential grant funding. Detailed project proposals were developed for the selected strategies, cost estimates were developed, and benefits were estimated or qualitatively described.

6.3 COLLABORATIVE WORKSHOP MEETING NOTES

6.4 PROCESS SELECTION OF PREFERRED STRATEGIES

RS&H

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Suite 130
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MEETING NOTES:

Project Number: 301-0068-000
Meeting Date: June 23, 2020
Meeting Place: Online / Virtual
Participants: Alyssa Jones-Wood, Green Initiatives Coordinator
Keven Klopp, Assistant City Manager
Peter Kunen, Assistant Director PW /City Engineer
Mary Francis Jeannot, Assistant Director of Public Works/Administration
Matthew Davis, GIS Coordinator
Aqeel Abdool-Ghany, Assistant City Engineer
Bob Williams, Assistant Director of Parks, Recreation, and Open Spaces
Jeffery Odoms, Assistant Director of Public Works – Utility Operations

Presenters: Ben Moore, Sustainability Leader at RS&H
Nathan Stinnette, Sustainability and Resilience Specialist at RS&H
Aashka Patel, Resilience Specialist at NEMAC + FernLeaf

Subject: Hallandale Beach Vulnerability Assessment and Adaptation Plan Collaborative Workshop

Following are the minutes of this meeting (please review and advise of any changes):

Introduction – *Ben Moore introduced the consultant project team and gave an overview of the scope of the project*

Review Vulnerability Assessment Findings - *Project team presented findings of the Vulnerability Assessment (Tasks 1-5)*

Implications for Hallandale Beach – *Project team presented the implications of vulnerability findings for the City for flooding (FEMA flood zones, storm surge, SLR, precipitation), groundwater impacts and shoreline recession.*

Adaptation Strategies: *Project team introduced the Adaptive Management Concept – Monitor, Evaluate and Plan*

Potential Strategies Exercise – *Project team led an exercise to brainstorm adaptation project ideas using an online polling application*

The group came up with the following ideas:

- Dune restoration
- Relocate critical facilities

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- Change landscape code to require salt-tolerant native species
- Suspend ground burial at the cemetery in favor of mausoleums
- Install backflow preventers for EVERY stormwater outfall, even large ones
- Restrict new development in areas that could be inundated
- Increase capacity of the stormwater system
- Assess stormwater system for future precipitation conditions
- Raise critical roads and bridges for continued access to Golden Isles neighborhood
- Expand the Green Initiatives Coordinator position to an office on climate change and resilience
- Provide financial assistance for low-income homes in the flood zones to raise critical components (mechanical, electrical, HVAC) above flood zone
- Include water level rise vulnerability as an evaluation criterion in CIP/budget allocation process

Prioritizing Adaptation Strategies – *Project team presented a methodology for prioritizing adaptation strategies and some potential prioritization criteria.*

Prioritization Exercise – *Project team led the group in a prioritization exercise where they scored the ideas they had previously brainstormed for adaptive capacity, economic, environmental, and social benefit, and feasibility. An online survey application was used to capture the results.*

<u>Notes on group discussion on initial prioritization of project ideas:</u>

Jeff – How can we make sure resilience is addressed in the project capital approval process?

Ben – Could you identify a lift station that would benefit from evaluation of more long-term design concept?

Jeff- Probably could pull one together with Aqeel and Peter – Egret lift station will be rehabbed in the next year or two.

Alyssa- Regarding dune restoration, I have been doing some research on "resilience dunes" – they are shaped so less sand is lost and more is gained. You redesign the shape of the beach access. Miami Beach pioneered this. It involves planting at a particular angle.

Kevin – They are going to redo the 2000 S Ocean Beach access design – it is supposed to be a model for other beach accesses in the City.

Bob – There are condos on the beach that do that – the angled system prevents sand from blowing into their properties. The City has an issue where sand at S. Beach continually blows into the park. It could help with beach erosion and hurricane cleanup.

Alyssa - Raising the marina seawall would take space away from other social uses such as docking boats, etc.) so I rated it low on social benefit. Things described as "assess" or "study" were not rated as highly for Triple Bottom Line benefits as actual projects, but could be rated higher if turned into projects.

Next Steps – *Ben Moore presented upcoming steps and deliverables for the project*

Adjourn

6.5 DEFINITION AND OVERVIEW OF METRICS AND SCORING PROCESS

RS&H

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PROCESS SELECTION OF PREFERRED STRATEGIES

A collaborative process was utilized to identify preferred strategies for increasing the City's Resilience. The process began with a workshop held with staff on March 18th, 2020. It was attended by leaders from across the City's functional areas (Table 1).

TABLE 1: COLLABORATIVE WORKSHOP ATTENDEES

Attendee Name	Title
Alyssa Jones-Wood	Green Initiatives Coordinator
Keven Klopp	Assistant City Manager
Peter Kunen	Assistant Director PW /City Engineer
Mary Francis Jeannot	Assistant Director of Public Works/Administration
Matthew Davis	GIS Coordinator
Aqeel Abdool-Ghany	Assistant City Engineer
Bob Williams	Assistant Director of Parks, Recreation, and Open Spaces
Jeffrey Odoms	Assistant Director of Public Works – Utility Operations

Attendees participated in a brainstorming exercise to come up with potential adaptation strategies. They were initially presented with examples of adaptation strategies the City had already implemented and a selection of proposed strategy ideas. Once familiar with examples, they were challenged to come up with new ideas. The exercise resulted in more than twenty potential strategies. The strategies ranged from infrastructure hardening to policy changes such as including flood vulnerability in criteria for budgetary decisions.

Attendees prioritized the list of potential adaptation strategies based on criteria. Criteria included adaptive capacity; economic, environmental, and social benefit; and feasibility. After a discussion of the criteria, they were asked to subjectively rank potential strategies using these criteria via an online survey application.

Following the collaborative workshop, results of the prioritization exercise were converted into numerical scores that were used to rank strategies. Strategies with highest aggregate values for adaptive capacity; economic, environmental, and social benefit; and feasibility were prioritized. Projects were also organized into short- and long-term categories, with short term defined as being feasible within one to five years and long term define as 6 to 20 years. RS&H also added some additional strategies that have proved valuable in similar South Florida communities.

RS&H worked with the City's Green Initiatives Coordinator to select ten adaptation strategies for further development into potential projects. Basis for selection included the City's interest in pursuing the strategy and the ease of integrating it into planned activities. Other selection criteria included suitability for cost/benefit analysis, availability of supporting data, and availability of potential grant funding. Detailed project proposals were developed for the selected strategies, cost estimates were developed, and benefits were estimated or qualitatively described.

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DEFINITION & OVERVIEW OF METRICS AND SCORING PROCESS

A collaborative process was utilized to identify preferred strategies for increasing the City's Resilience.

The process began with a workshop held with staff on March 18th, 2020. It was attended by eight leaders from across the City's functional areas (Table 1).

Attendees participated in a brainstorming exercise to come up with potential adaptation strategies. Attendees prioritized the list of potential adaptation strategies based on five criteria. Criteria included adaptive capacity; economic, environmental, and social benefit; and feasibility.

- Adaptive capacity is the ability to accommodate expected climate stress (e.g. flooding). This ability reduces risk of damage due to climate change and determines the City's vulnerability. Potential adaptation strategies were evaluated for low, medium, and high adaptive capacity.

- Economic benefit is one of three sustainability criteria, based on the triple bottom line concept. It measures the degree to which a potential adaptation strategy avoids direct or indirect costs (e.g. physical damages, repair, operations and maintenance, disruption of business activity, loss of revenues, property values, etc.). Adaptation measures can have very positive (high), moderate (medium), low or negative (low) economic benefit.

- Environmental benefit is the second of three sustainability criteria, based on the triple bottom line concept. It measures the degree to which a potential adaptation strategy improves air, water and/or soil quality, habitat, biodiversity, etc. Adaptation measures can have very positive (high), moderate (medium), low or negative (low) environmental benefit.

- Social benefit is the third of three sustainability criteria, based on the triple bottom line concept. It measures the degree to which a potential adaptation strategy improves health, safety, quality of life, etc. Adaptation measures can have very positive (high), moderate (medium), low or negative (low) social benefit.

- Feasibility considers the barriers to implementation. Barriers can be technical, administrative, political, legal, fiscal, etc. Potential adaptation strategies with high feasibility have relatively few barriers, while low feasibility strategies have one or more barriers that may make implementation difficult.

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The eight workshop attendees subjectively ranked potential strategies according to the five criteria. For each criterion, they evaluated the potential impact. Low, medium, and high impact corresponded to a score of 1, 2 and 3, respectively. Because there were eight evaluators, the maximum score for each criterion was 24 and the maximum score for a strategy was 120. Table 1 summarizes the criteria and how they were score.

TABLE 1: PRIORITIZATION METRICS AND SCORING

Criteria	Potential Impact			Evaluators	Max Score
	Low	Medium	High		
Adaptive Capacity	1	2	3	8	24
Economic Benefit	1	2	3	8	24
Environmental Benefit	1	2	3	8	24
Social Benefit	1	2	3	8	24
Feasibility	1	2	3	8	24

Projects were prioritized based on the percent of total points possible points achieved. The results were summarized in a scoring matrix (Appendix 6).

Projects were also organized into short- and long-term categories, with short term defined as being feasible within one to five years and long term define as 6 to 20 years.

RS&H also added some additional strategies that have proved valuable in similar South Florida communities.

RS&H worked with the City's Green Initiatives Coordinator to select ten adaptation strategies for further development into potential projects. Basis for selection included the City's interest in pursuing the strategy and the ease of integrating it into planned activities. Other selection criteria included suitability for cost/benefit analysis, availability of supporting data, and availability of potential grant funding. Detailed project proposals were developed for the selected strategies, cost estimates were developed, and benefits were estimated or qualitatively described.

6.6 SCORING MATRIX

Hallandale Beach Vulnerability and Adaptation Plan

Scoring Matrix

ID	Inititives	Rank	Include in Cost Estimation?	% of Total Points	Adaptive Capacity	Economic Benefit	Environmental Benefit	Social Benefit	Feasibility
2	Egret lift station rehabilitation	1	Yes	83%	21	19	19	20	20
10	Include water level rise vulnerability as an evaluation criterion in CIP/budget allocation process	1	No	83%	20	19	21	18	21
19	change in landscape code to require only salt-tolerant native species in high SLR and surge risk areas	3	No	82%	19	17	22	19	21
20	Dune restoration	4	No	81%	20	16	22	19	20
5	we might want to look at our existing lift stations to handle new Storm water demand	5	No	78%	18	20	17	18	21
7	Establish Resilience Hub(s)	5	Yes	78%	20	17	16	20	21
8	Do an assessment of the sustainability (in terms of time) of existing coastal development with increasing erosion and flood concerns.	5	No	78%	18	17	21	18	20
11	Provide financial assistance for low-income homes in the flood zones to raise critical components (mechanical, electrical, ac) above flood zone	5	Yes	78%	22	19	15	22	16
18	backflow preventers in EVERY stormwater outfall, even very large ones	5	Yes	78%	21	21	16	15	21
13	Increase capacity of stormdrain system	10	No	77%	18	20	18	19	17
14	Assess the current stormwater system for future precipitation conditions	11	No	75%	18	17	17	17	21
1	2000 S. Ocean Beach access design (dune blowout)	12	Yes	73%	20	14	17	17	19
6	Designate 1 or more Adaptation Action Areas	12	No	73%	17	15	18	18	19
9	Expand the Green Initiatives Coordinator position to a small office of Climate Change, Sustainability, and Resilience	14	No	71%	16	16	19	15	19
12	Raise critical roads/bridges for continued access to Golden Isles, 3 Islands, and the neighborhood just west of 3 islands	15	Yes	68%	18	16	12	19	16
3	Adopt the County Seawall ordinance earlier than within 2 years	16	No	65%	18	13	15	14	18
15	Relocate critical facilities to less vulnerable areas	17	Yes	64%	16	20	12	18	11
17	For the cemetery: Suspend ground burial and build mausoleum	17	Yes	64%	18	16	12	17	14
16	Restrict or not allow any new development in areas that we know will be inundated	19	No	63%	16	13	17	14	15
4	Raising our Marina seawall and including a hybrid shoreline approach with mangrove planting seaward of the seawall	20	Yes	60%	14	16	18	11	13
21	LID at Urban Streets	-	Yes	-	-	-	-	-	-
22	LID Near Bridges	-	No	-	-	-	-	-	-
23	Beach Nourishment	-	No	-	-	-	-	-	-
24	Electrical Improvements	-	No	-	-	-	-	-	-
25	Seawall replacement / maintenance	-	No	-	-	-	-	-	-

6.7 COLLABORATIVE WORKSHOP SLIDE DECK

HALLANDALE BEACH VULNERABILITY & ADAPTATION ACTION PLAN

VIRTUAL COLLABORATIVE WORKSHOP

March 18, 2020

HELLO!

BEN MOORE, AICP, LEED AP O+M

PROJECT MANAGER

RS&H

AASHKA PATEL

TASK MANAGER

NEMAC + FERNLEAF

NATHAN STINNETTE, CSP, ENV-SP

ASSISTANT PROJECT MANAGER

RS&H

Alyssa Jones-Wood
Greg Chavarria
Keven Klopp
James Sylvain
Peter Kunen
Vanessa Leroy
Cathie Schanz
Robert Williams
Miguel Nunez
Jeffrey Odoms
Mary Francis Jeannot
Aqeel Abdool-Ghany
Charles Casimir
Anthony Melvn
Matthew Davis

TODAY'S AGENDA

1. Introduction	1:00 – 1:05
2. Review Vulnerability Assessment	1:05 – 2:20
3. Implications for Hallandale Beach	2:20 – 2:50
4. Adaptation Strategies	2:50 – 3:40
5. **Potential Strategies Exercise**	3:40 – 4:10
6. Prioritizing Adaptation Strategies	4:10 – 4:25
7. **Prioritization Exercise**	4:25 – 4:55
8. Next Steps	4:55 – 5:00
9. Adjourn	5:00

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Introduction

INTRODUCTION

- Sustainability Action Plan, 2018
  - Natural Resources & Resiliency Goal: Complete a Vulnerability Assessment & Adaptation Action Plan by 2022
- FDEP Resilient Coastlines Program Grant, 2019
- Vulnerability Assessment & Adaptation Action Plan (VAAP), 2019 – 2020:
  - Assess Vulnerabilities (Flood, Precipitation, Groundwater, Shoreline Changes)
  - Develop Initial Adaptation Strategies

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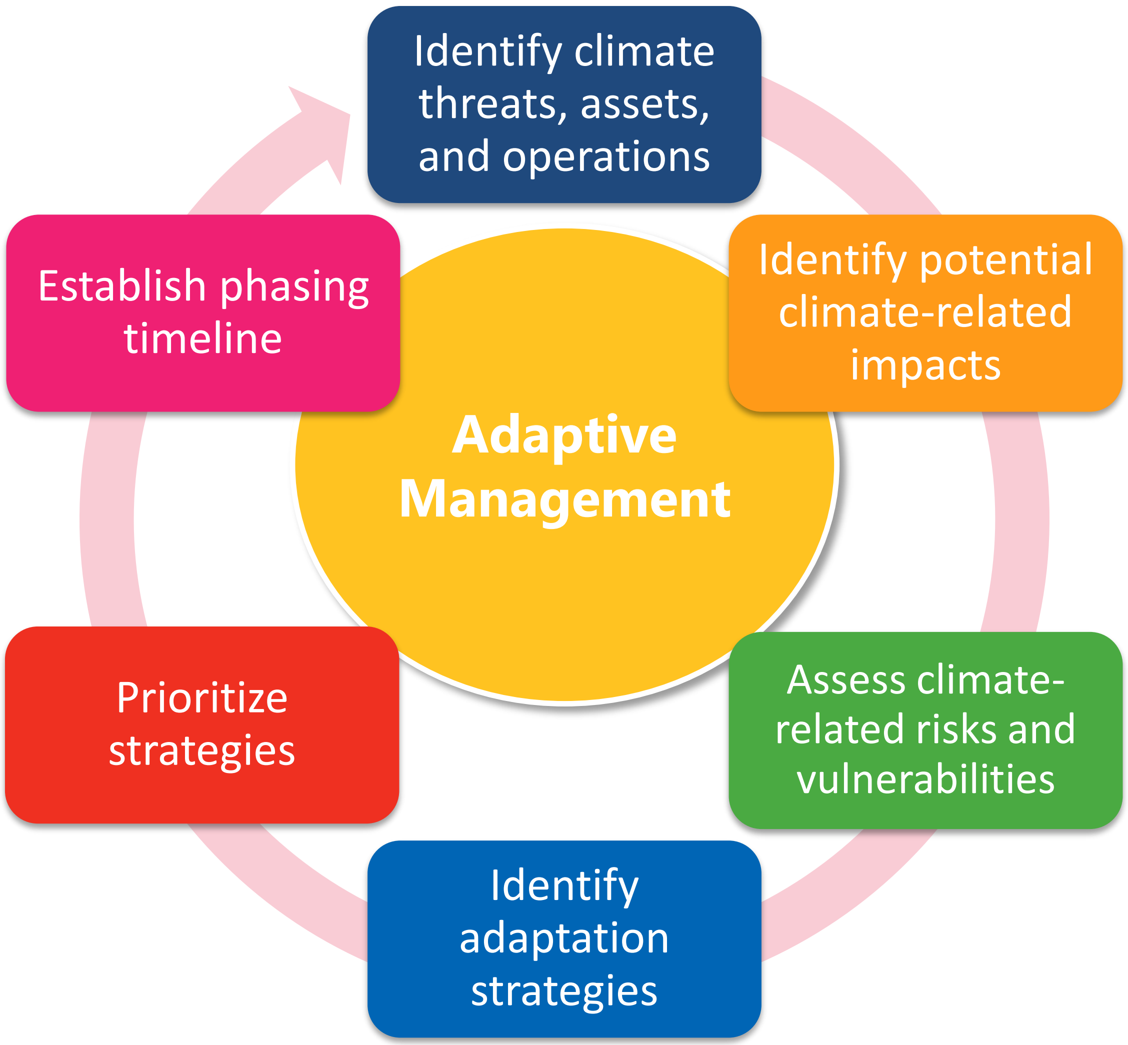
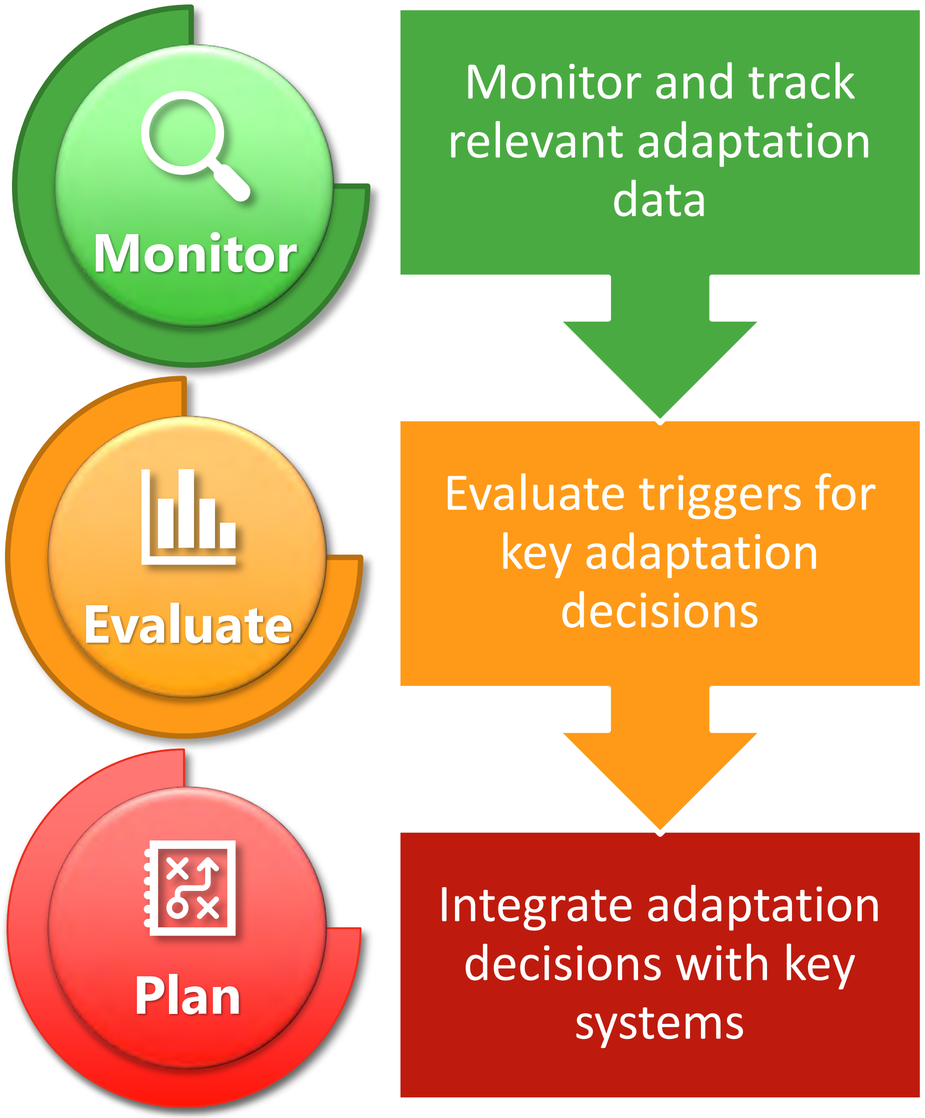
INTRODUCTION





INTRODUCTION

- Areas for Further Study:
  - Residential Sector
  - Socio-economics / Vulnerable Populations
  - Local Datasets: Building Footprints & Elevations, Stormwater, transportation networks
  - Outreach and education
  - Other Climate Stressors: Temperature and Humidity
  - Additional non-Climate Stressors: Vector-borne disease (e.g. Corona Virus), Terrorism, Cyber-security, etc.

What do you think of when you hear the word "Resiliency?"

Start the presentation to see live content. Still no live content? Install the app or get help at **PollEv.com/app**

Vulnerability

REVIEW VULNERABILITY ASSESSMENT

- Flood Hazard Mapping
- Flood Vulnerability / Loss Assessments
- Future Precipitation Analysis
- Qualitative Assessment of Groundwater Changes
- Projected Changes in Shoreline

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FLOOD HAZARD MAPPING

- The vulnerability assessment considers 4 types of flood-related hazards:
  - FEMA flood zones
  - Storm surge
  - Sea level rise
  - High tide flooding
- Two types of property
  - City-owned
  - Commercial

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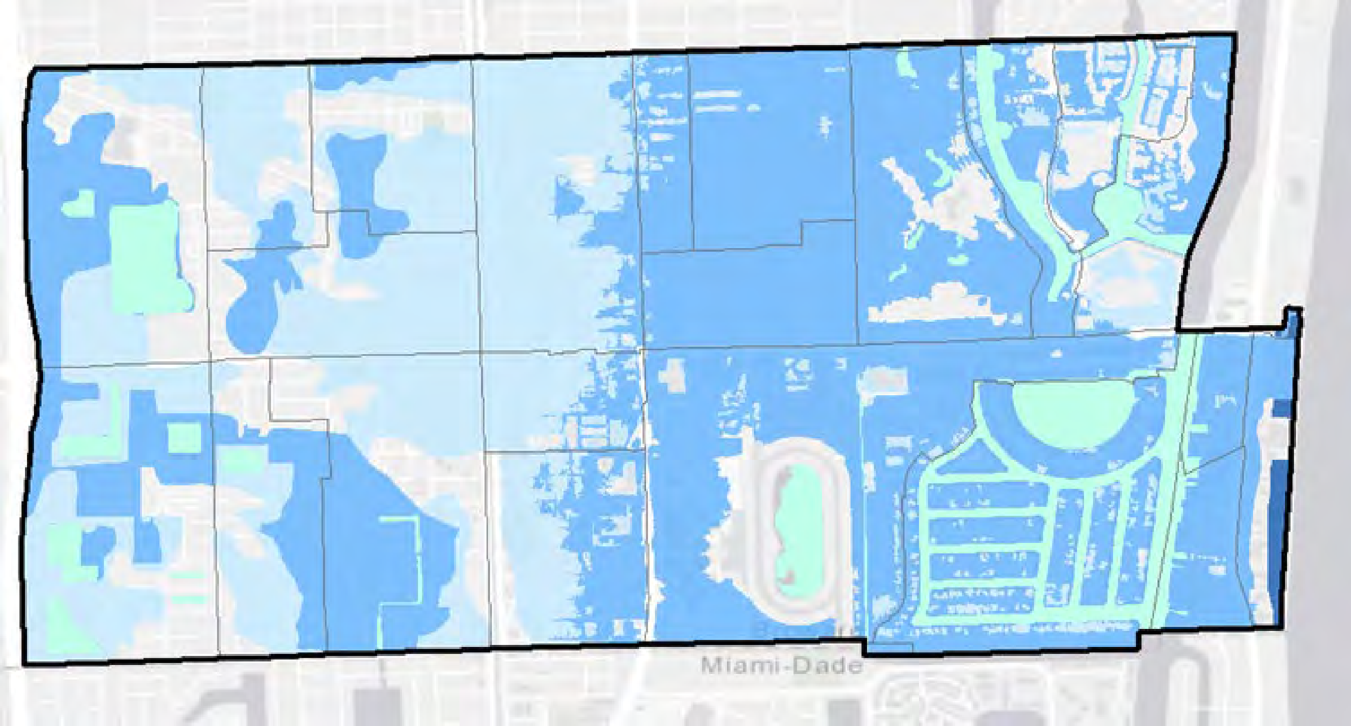
FLOOD HAZARD MAPPING

- Majority of City is located in a FEMA Special Flood Hazard Area with 1% or 0.2% annual chance of flooding



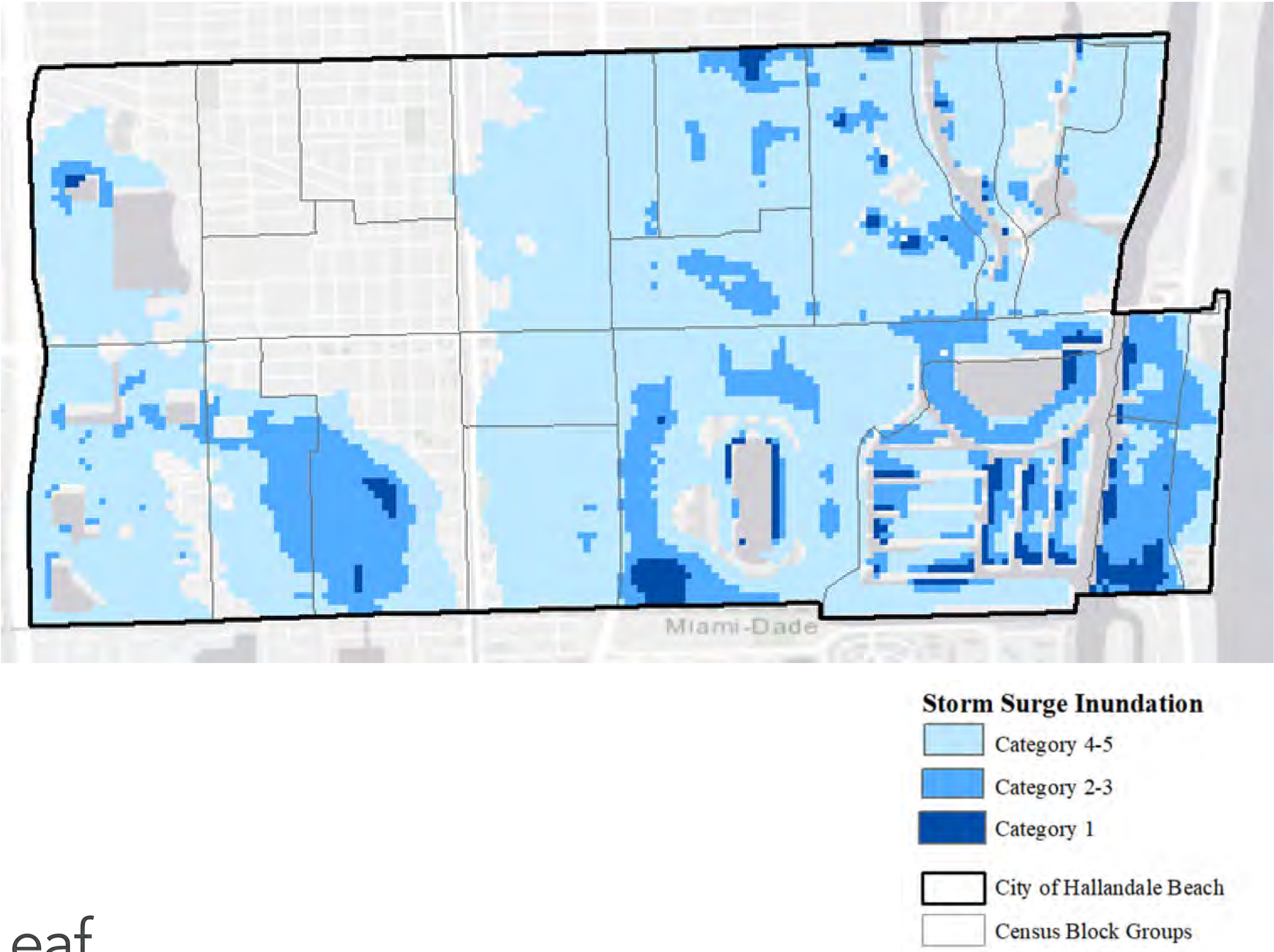
City of Hallandale Beach
Census Block Groups
Waterbody

FEMA Flood Zones

Floodway or wave action area
100-yr floodplain
500-yr floodplain

FLOOD HAZARD MAPPING

- Storm Surge – SLOSH Flood Model
  - Maximum of the Maximum Envelope of Water (MOM) layer for hurricane categories 1-5
  - Worst case flood scenario resulting from an "ideal" storm



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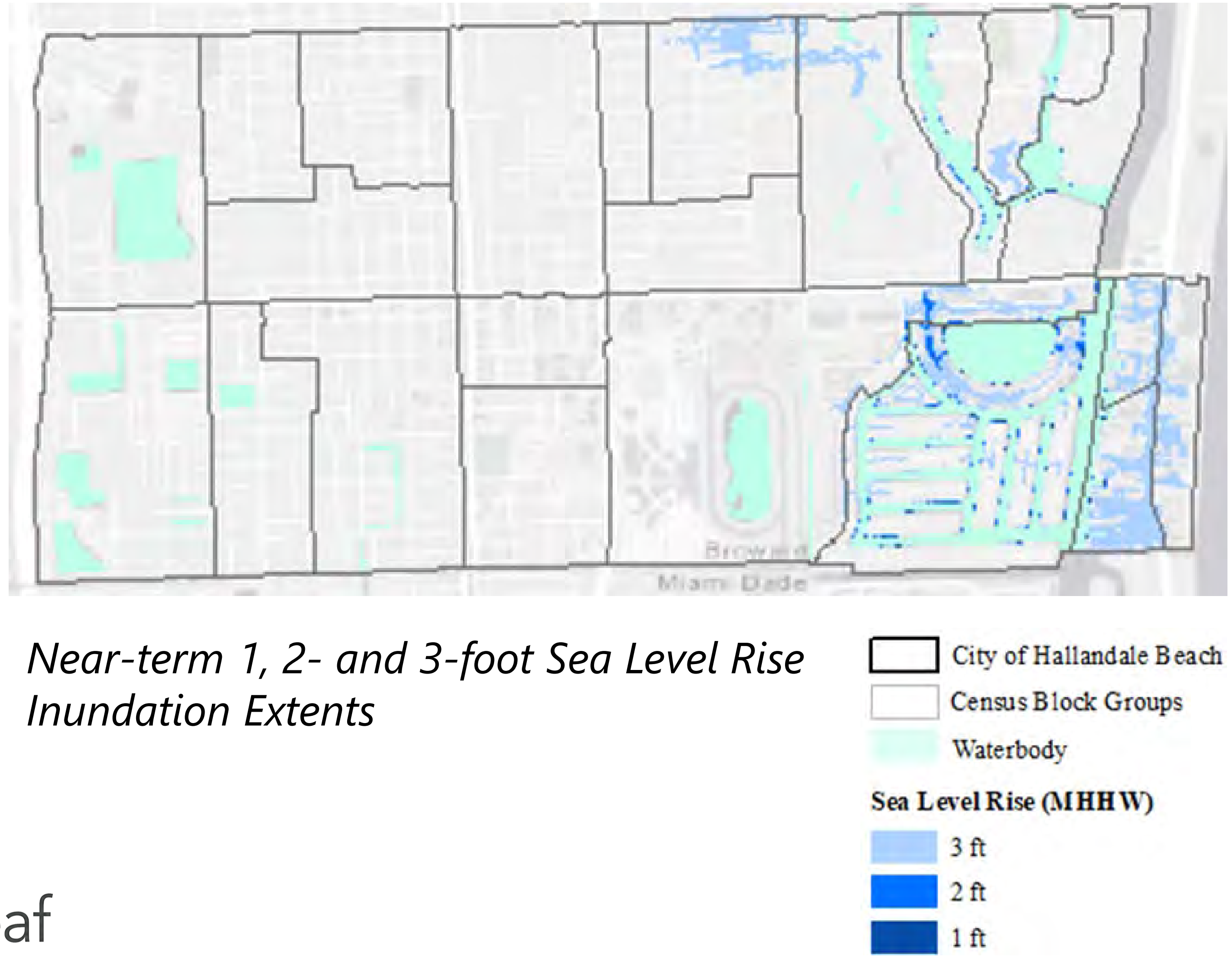
FLOOD HAZARD MAPPING

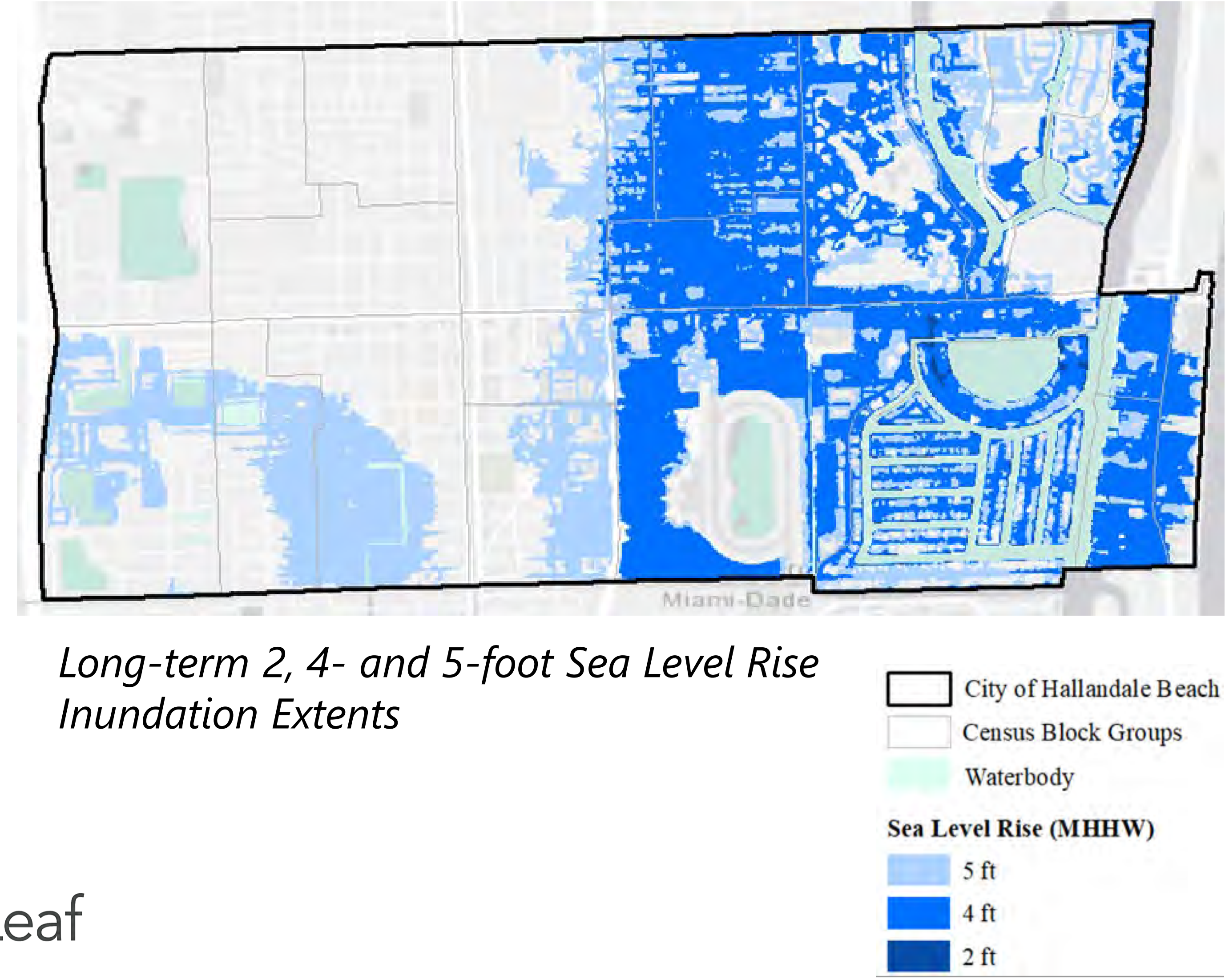
- The assessment uses the NOAA Sea Level Rise Viewer dataset
- Sea Level Rise modeled for:
  - Near-term (1,2,3 feet of SLR)
  - Medium/Long-term (2,4,5 feet of SLR)



Near-term 1, 2- and 3-foot Sea Level Rise Inundation Extents

FLOOD HAZARD MAPPING

- The assessment uses the NOAA Sea Level Rise Viewer dataset
- Sea Level Rise modeled for:
  - Near-term (1,2,3 feet of SLR)
  - Medium/Long-term (2,4,5 feet of SLR)



Long-term 2, 4- and 5-foot Sea Level Rise Inundation Extents

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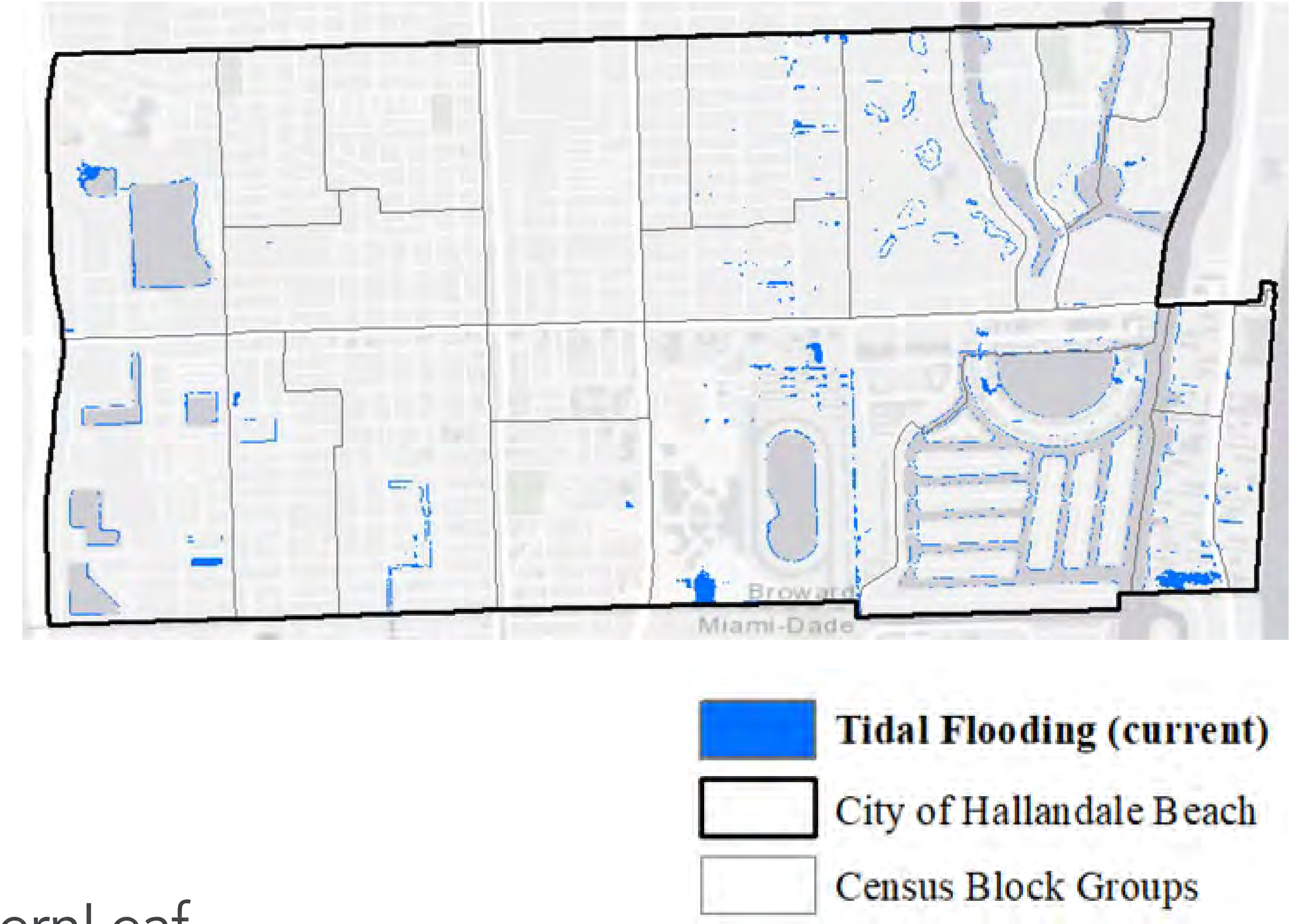
FLOOD HAZARD MAPPING

- "Tidal flooding" is flooding of low-lying land along the coastline from a high tide that is not associated with a major storm.
- The assessment uses NOAA's "High Tide Flooding" layer



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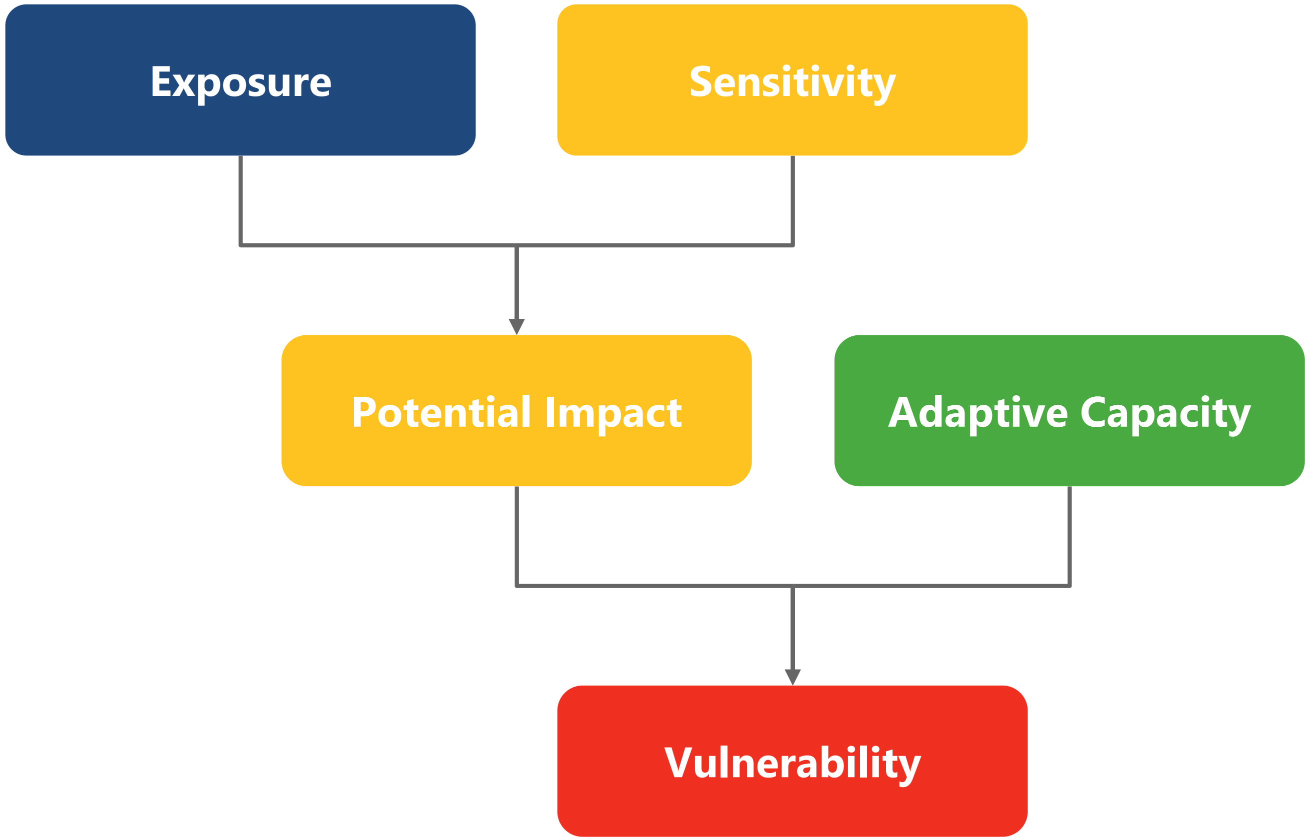
FLOOD VULNERABILITY / LOSS ASSESSMENT

- Assessment Approach
  - Moving beyond simply considering what is in harm's way

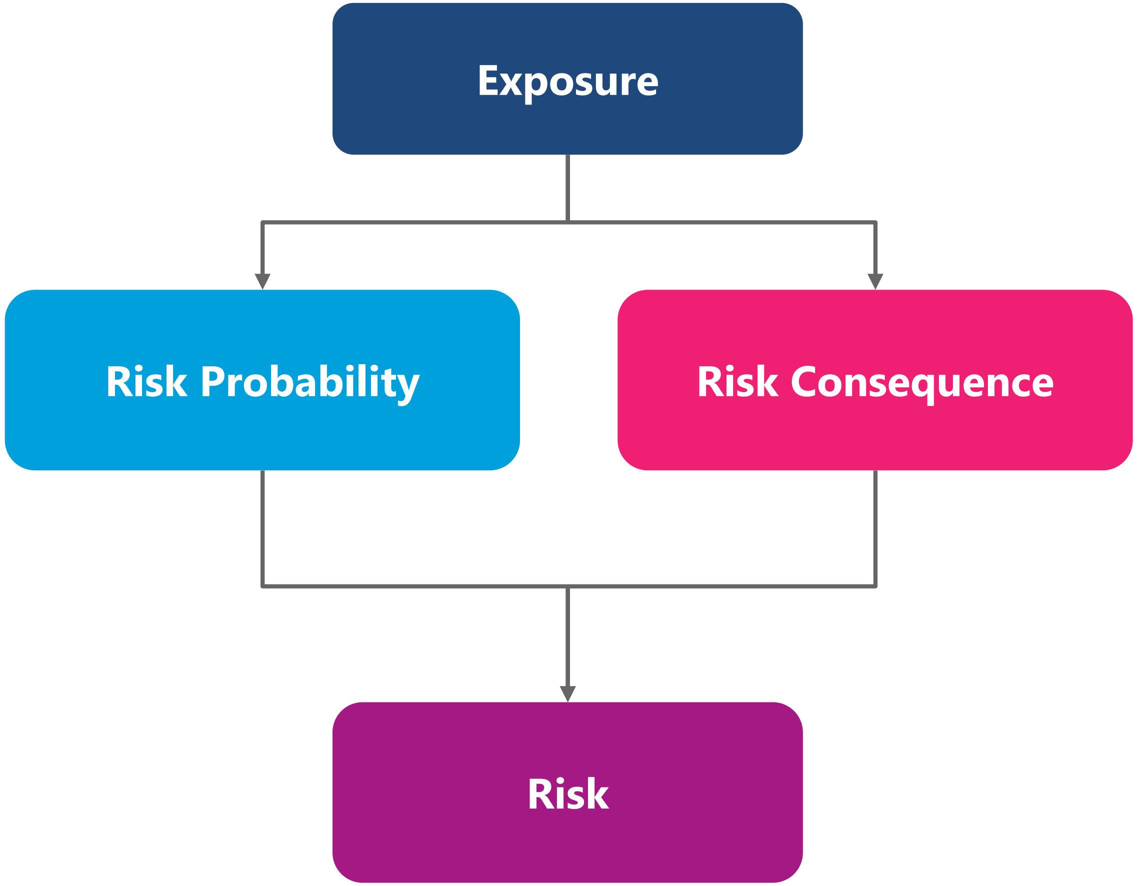
FLOOD VULNERABILITY / LOSS ASSESSMENT

- Asset Vulnerability
  - Understanding the susceptibility of societal assets.
  - Sensitivity: the degree to which assets are affected by a threat
  - Adaptive Capacity: the ability to cope with impacts



FLOOD VULNERABILITY / LOSS ASSESSMENT

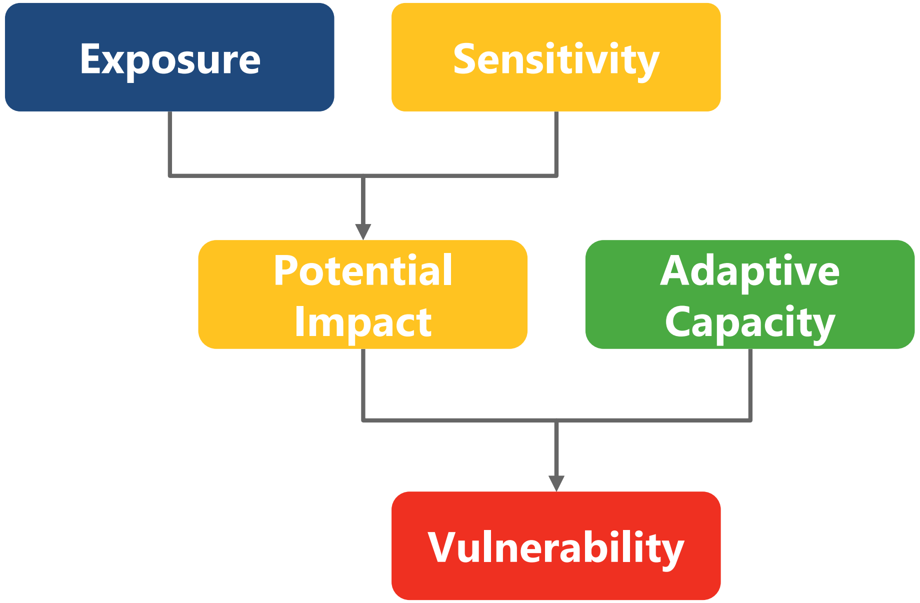
- Risk Scoping
  - Understanding the probability and negative outcome of threats.
  - Probability: the likelihood of a threat or hazard event occurring
  - Consequence: the negative outcome of a threat or hazard event



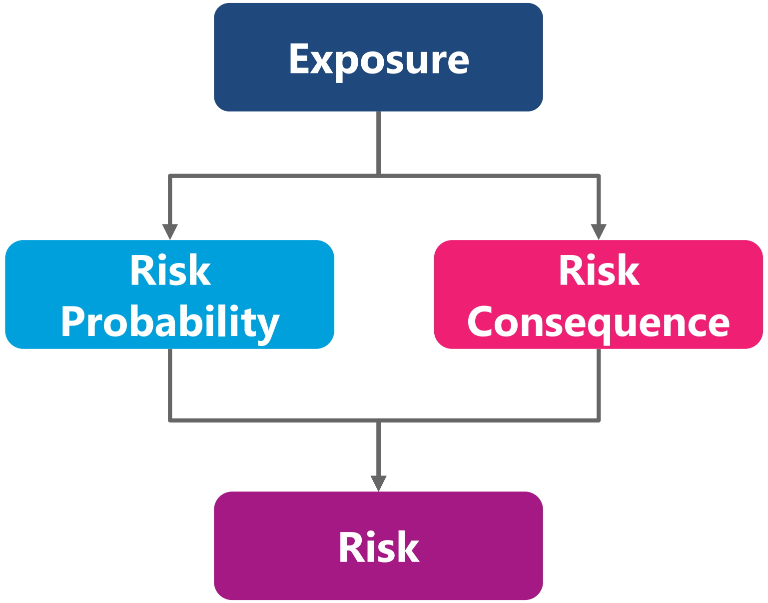
FLOOD VULNERABILITY / LOSS ASSESSMENT

« Assessment Criteria

– Parcel location
– Parcel use type
– Parcel built date



– Parcel location
– Relative likelihood of threat
– Parcel property value



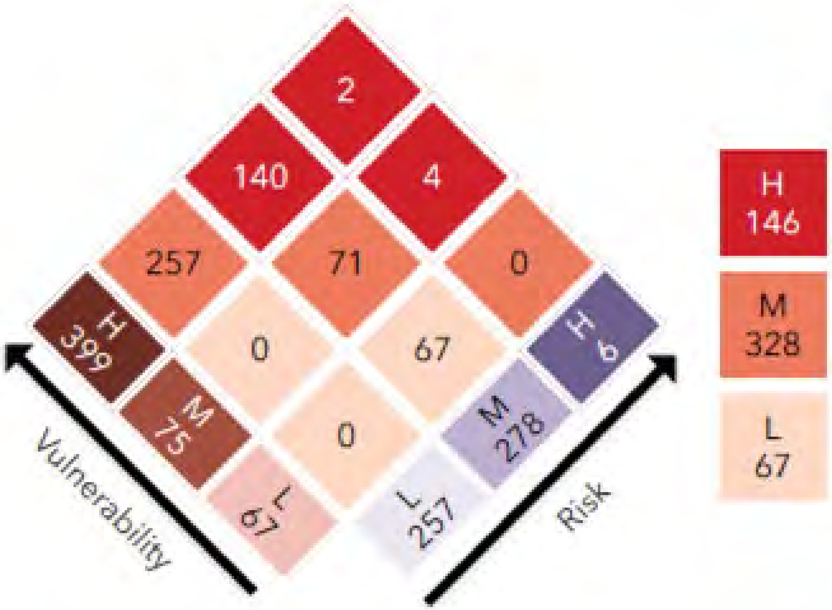
FLOOD VULNERABILITY / LOSS ASSESSMENT

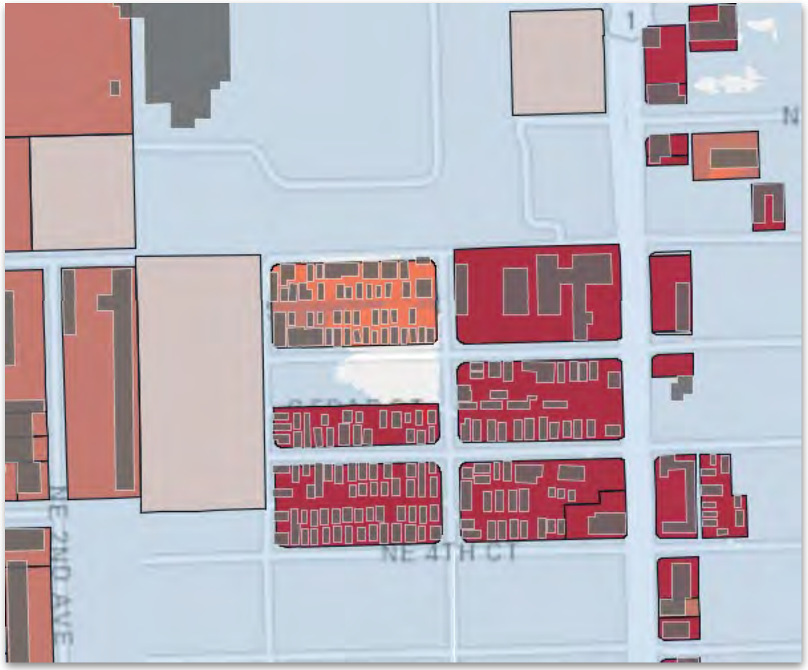
- Assessment Rulesets
  - Example: Commercial Property, FEMA Flood Zones

	Potential Impact	Adaptive Capacity	Risk Probability	Risk Consequence
High	Structure in inundation extent and business related (retail, restaurant, hotel)	Structure built out of floodplain or structure in floodplain above BFE	In floodway, wave action zone	Structure exposed and above median value
Medium	Structure in inundation extent	Structure in floodplain built at BFE	In 100-yr inundation extent	Structure exposed and below median value
Low	No structure in inundation extent (land only)	Structure in floodplain built before flood ordinance (no BFE requirement)	In 500-yr inundation extent	No structure exposed (land only)

FLOOD VULNERABILITY / LOSS ASSESSMENT

« Combining Vulnerability & Risk

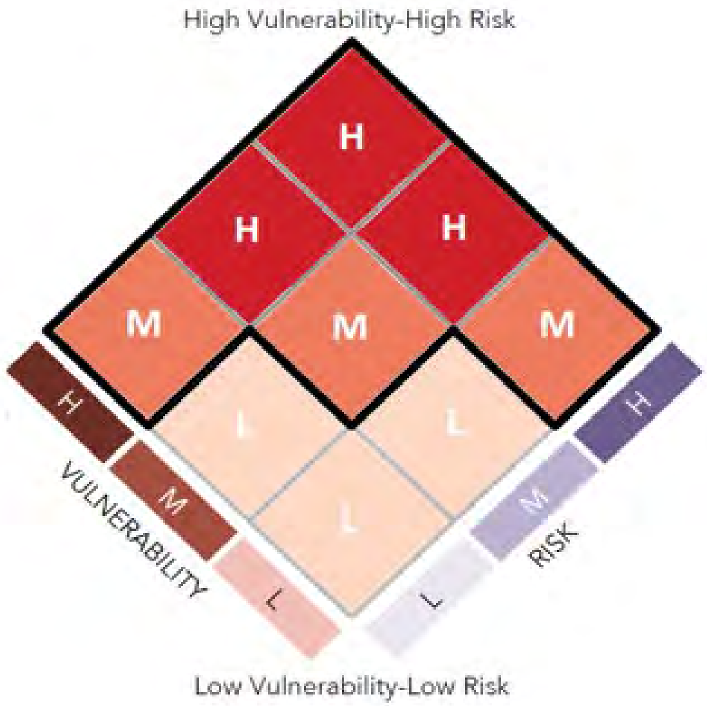


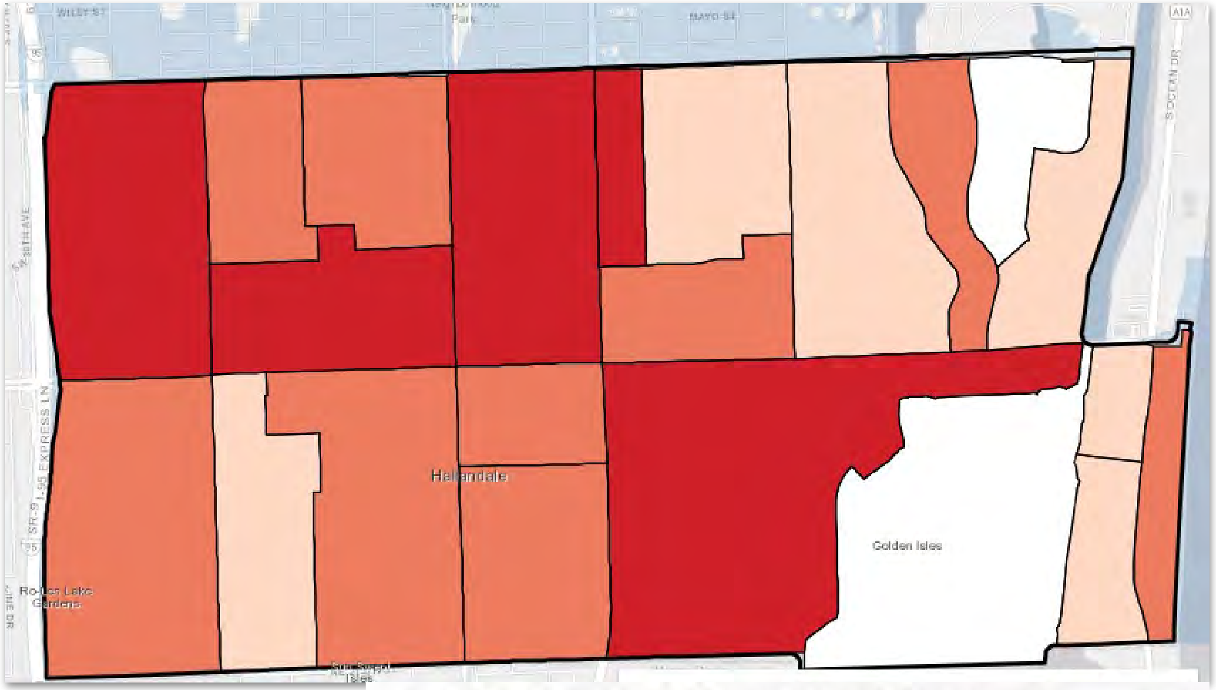


Example: Commercial Property and FEMA Flood Zones

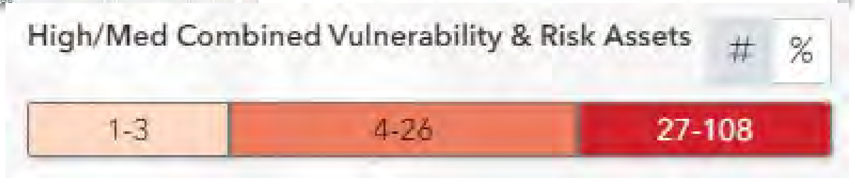
FLOOD VULNERABILITY / LOSS ASSESSMENT

« Aggregation to Block Groups



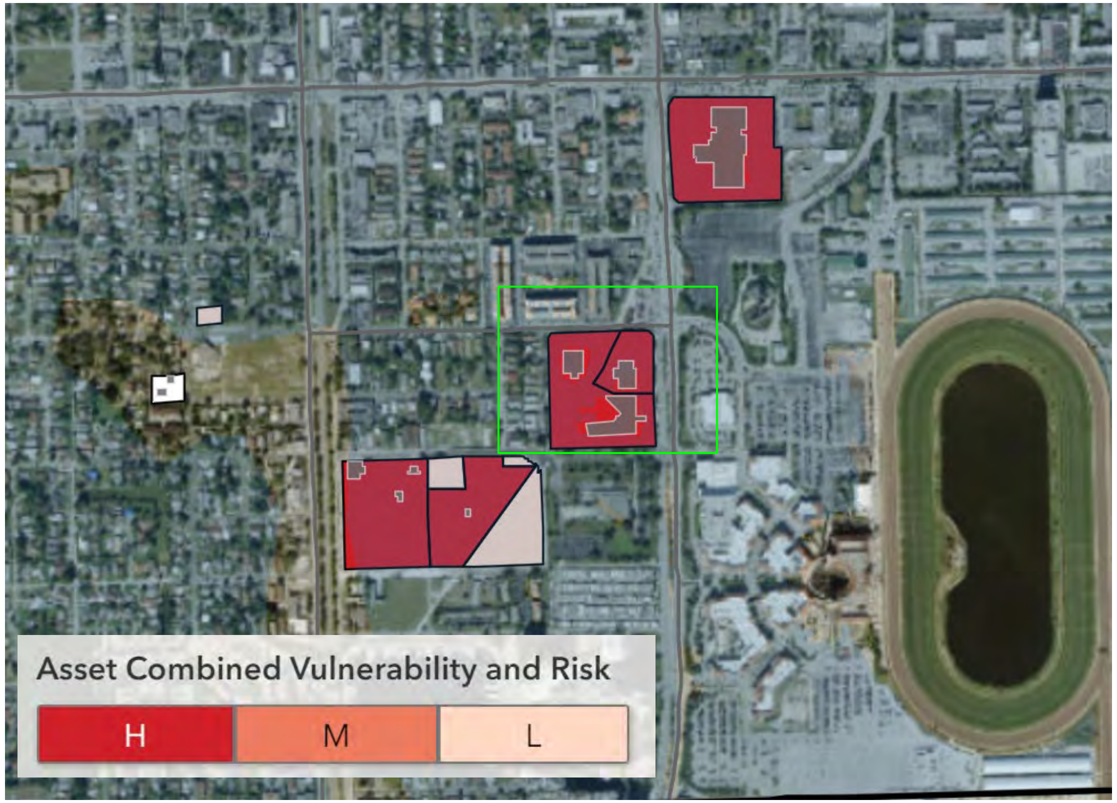


Example: Commercial Property and FEMA Flood Zones



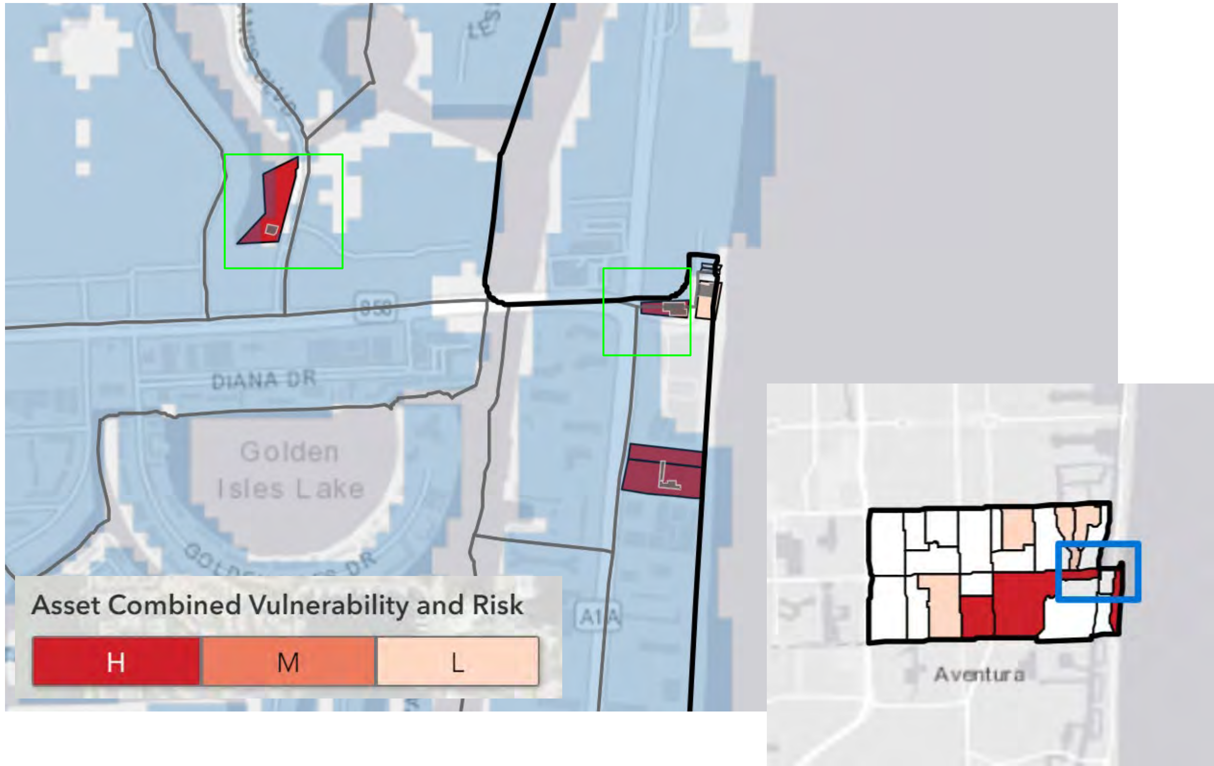
FLOOD VULNERABILITY / LOSS ASSESSMENT

- Selected Findings: Municipal Complex
  - Highly vulnerable to
    - FEMA flood zones
    - Storm surge
    - Mid/long term SLR



FLOOD VULNERABILITY / LOSS ASSESSMENT

« Selected Findings: Fire Stations / Emergency Service



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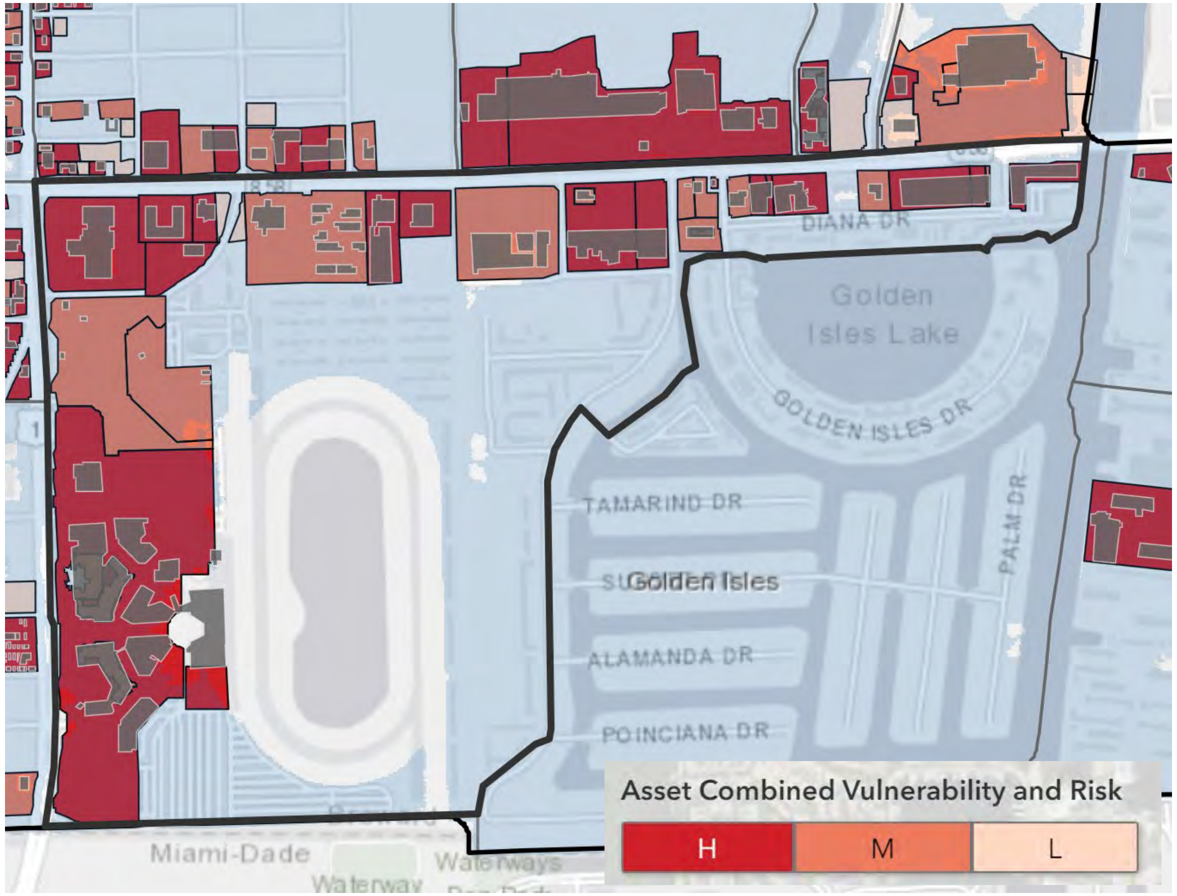
FLOOD VULNERABILITY / LOSS ASSESSMENT

- Selected Findings: Commercial Property
  - FEMA Flood Zones
  - Storm Surge
  - SLR Mid / Long Term

 # Assets

34	94.44%	High/Med Combined Vulnerability & Risk
36	100%	Exposed
36	100%	Total



Example: Commercial Property and FEMA Flood Zones

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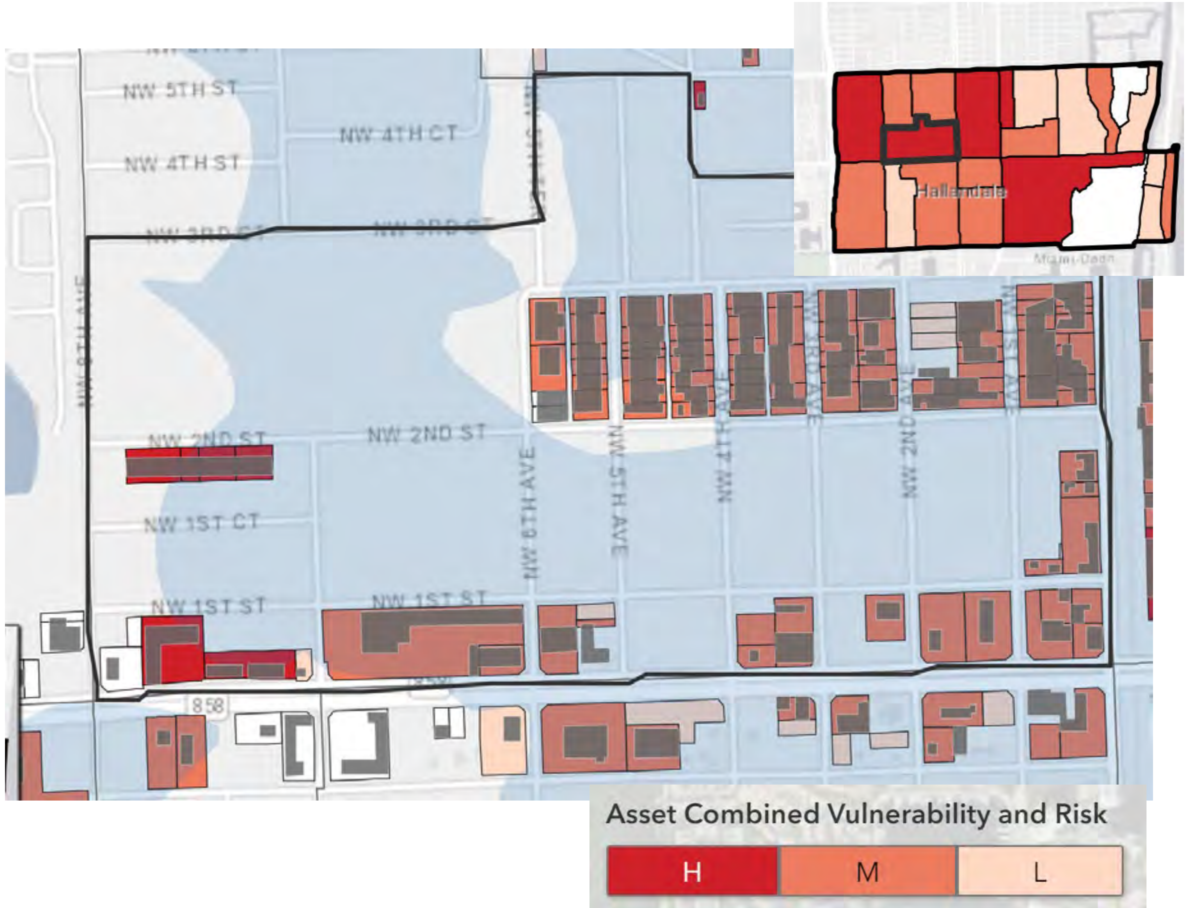
FLOOD VULNERABILITY / LOSS ASSESSMENT

- Selected Findings: Commercial Property
  - High: FEMA Flood Zones
  - Low: Storm Surge

Assets

91	90.1%	High/Med Combined Vulnerability & Risk
97	96.04%	Exposed
101	100%	Total



Example: Commercial Property and FEMA Flood Zones

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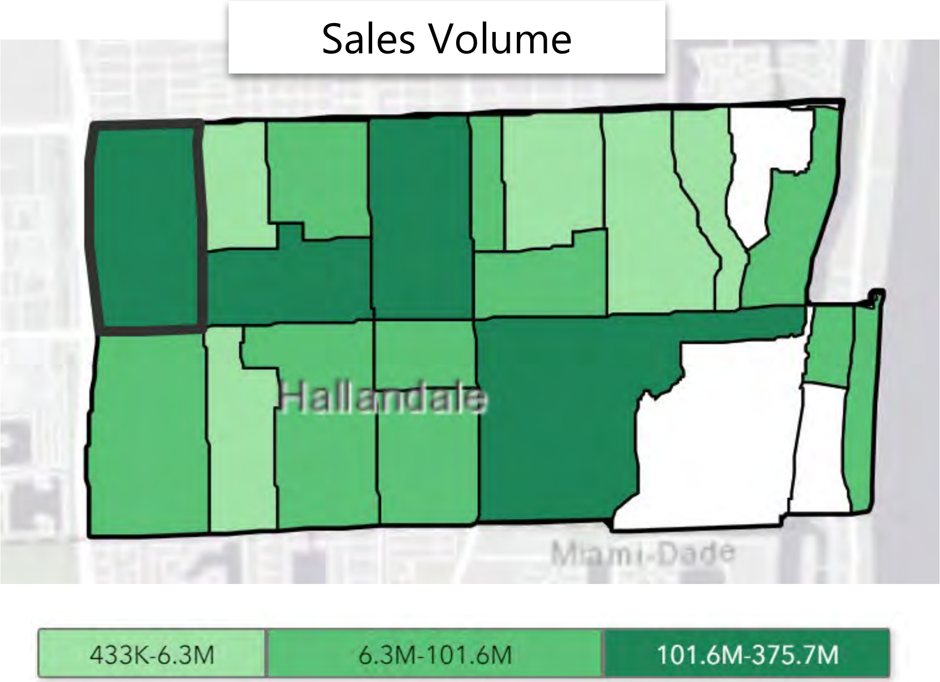
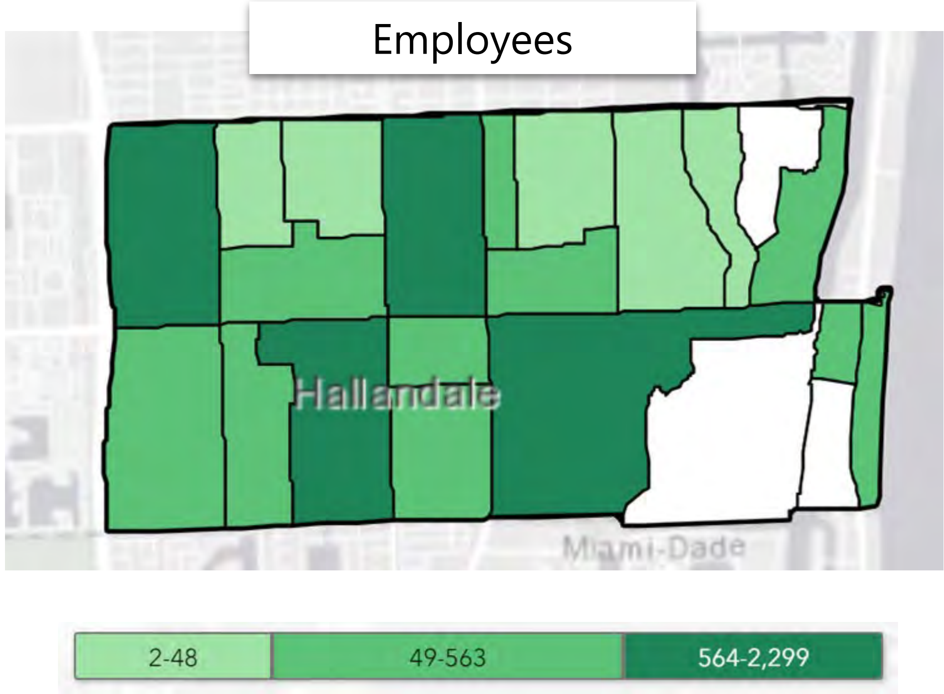
FLOOD VULNERABILITY / LOSS ASSESSMENT

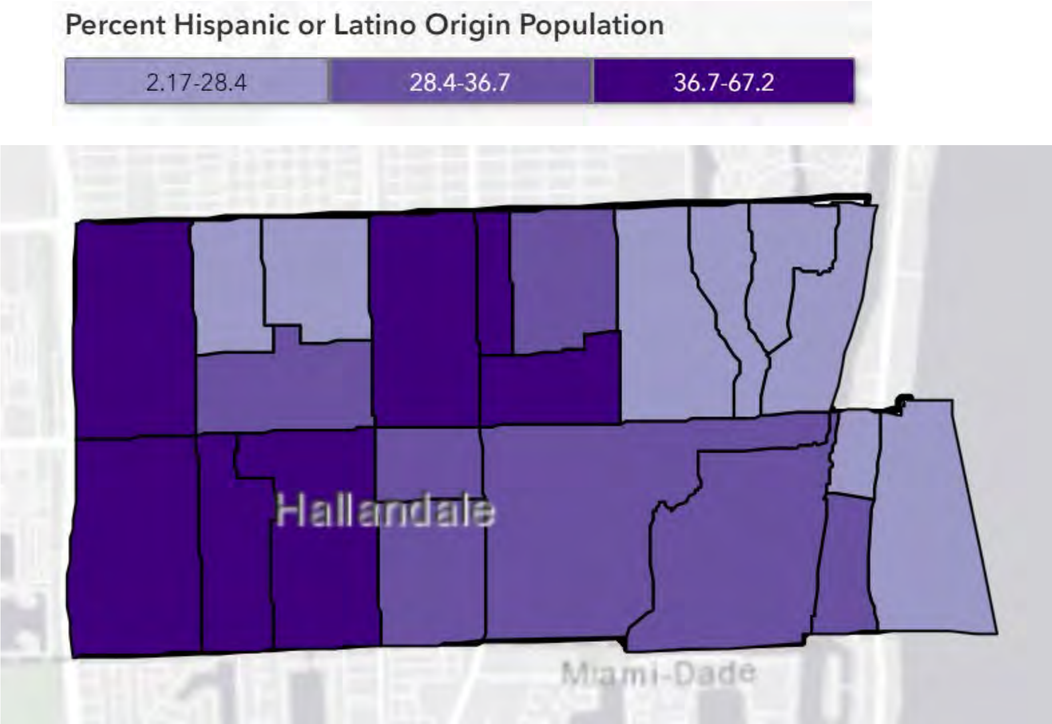
« Additional Context

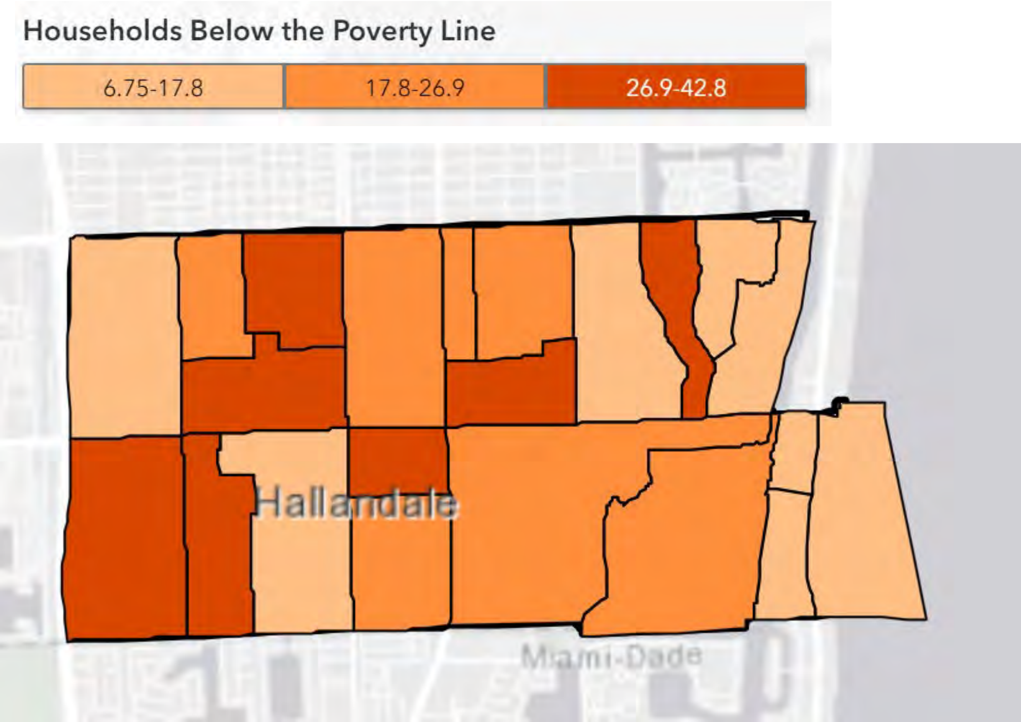




FLOOD VULNERABILITY / LOSS ASSESSMENT

« Additional Context





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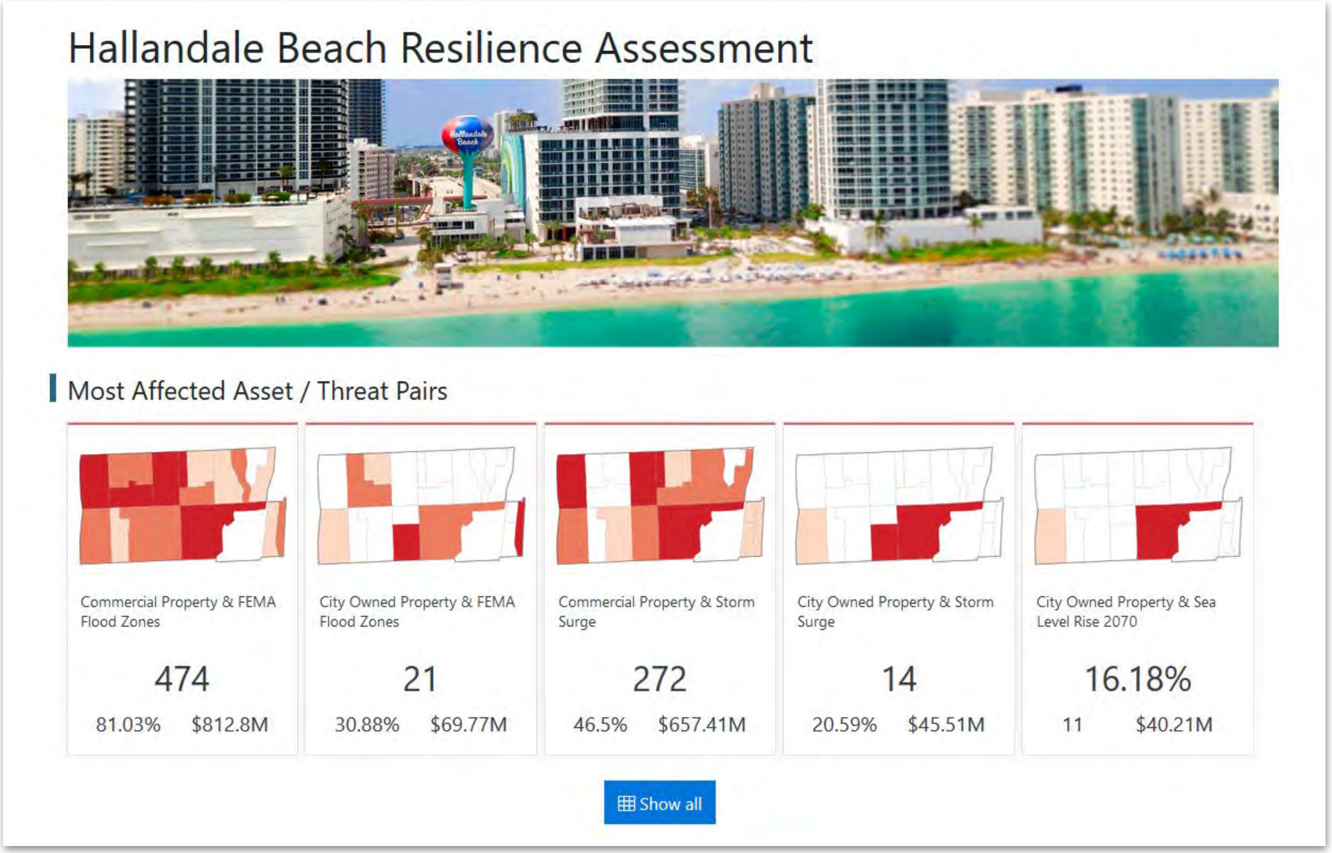
FLOOD VULNERABILITY / LOSS ASSESSMENT

- https://hallandalebeach.acceladapt.com



FLOOD VULNERABILITY / LOSS ASSESSMENT

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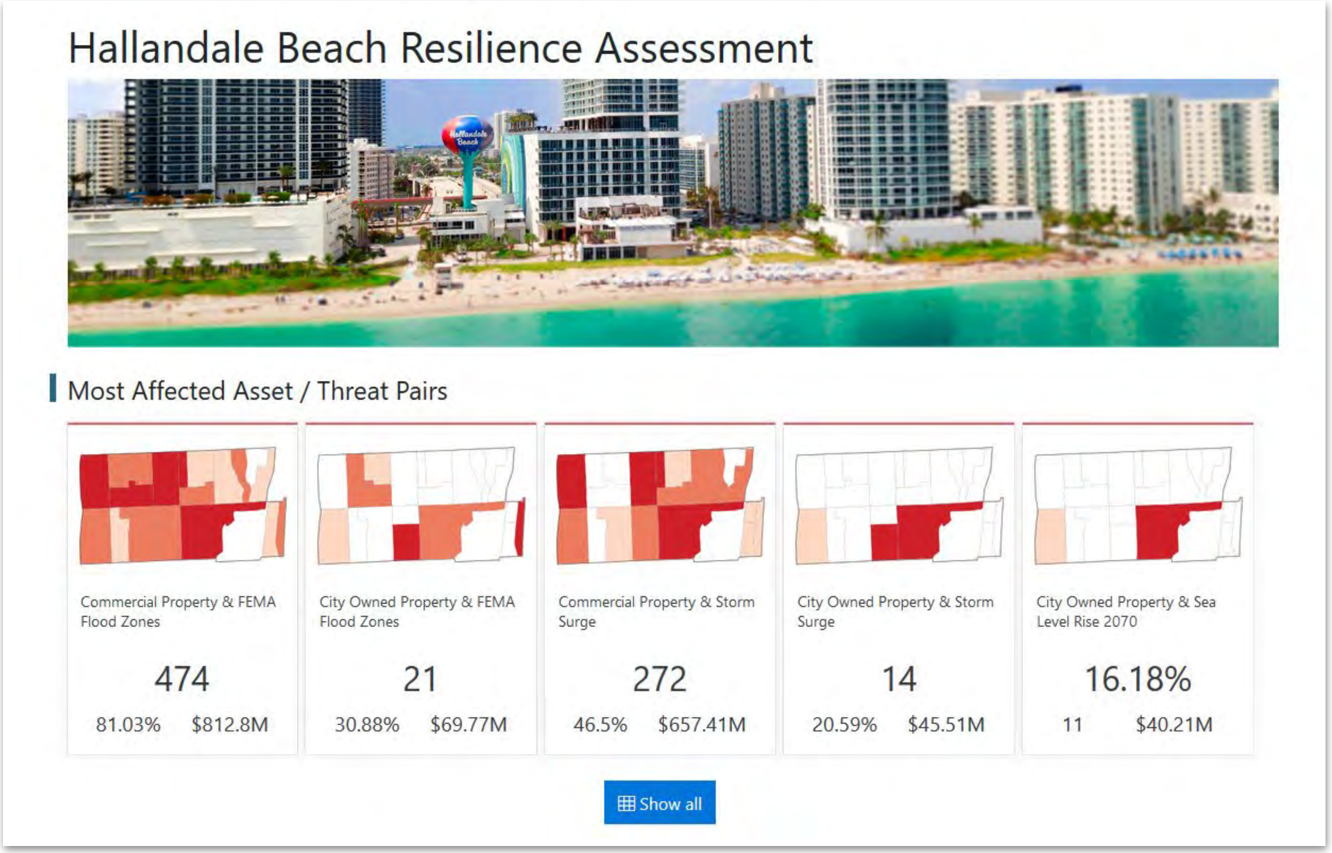

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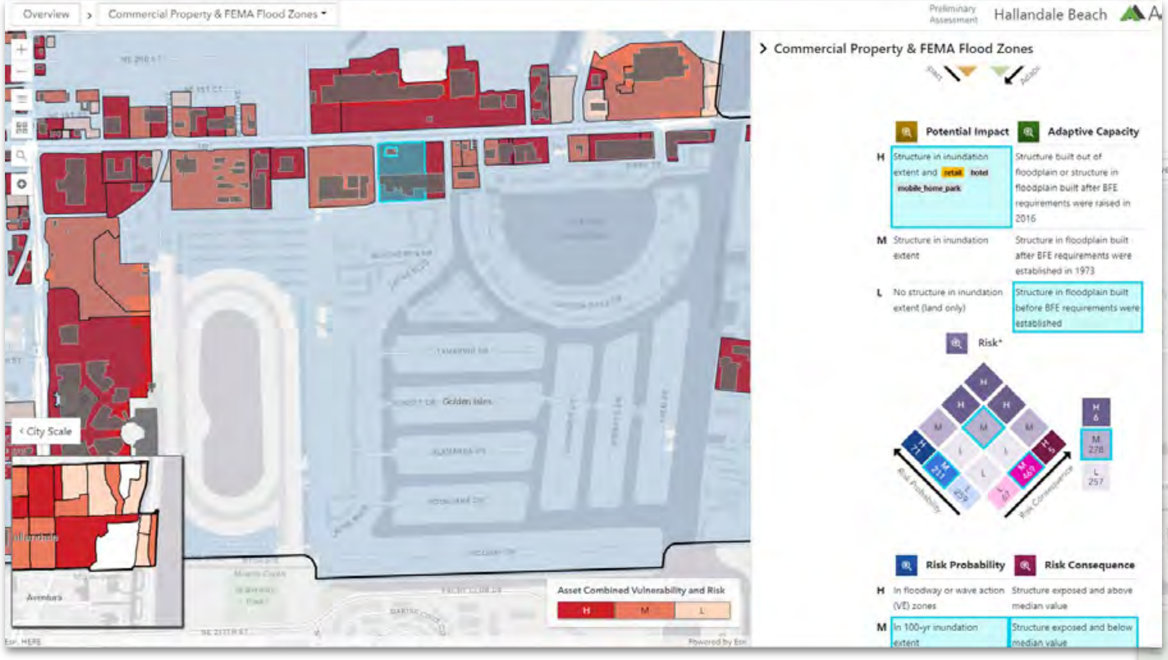
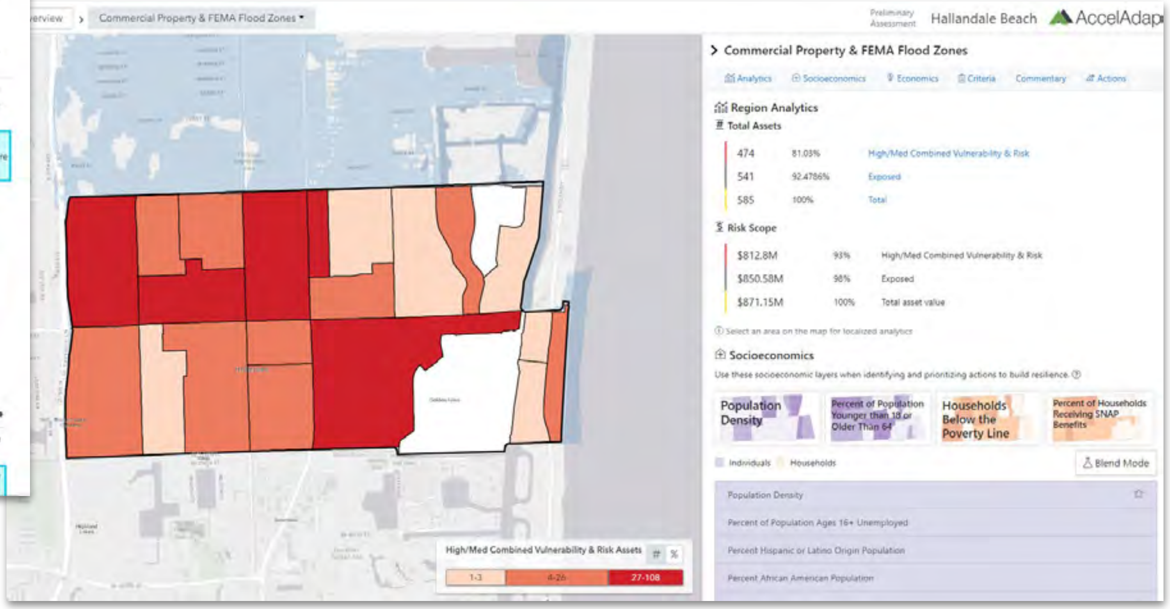
FLOOD VULNERABILITY / LOSS ASSESSMENT

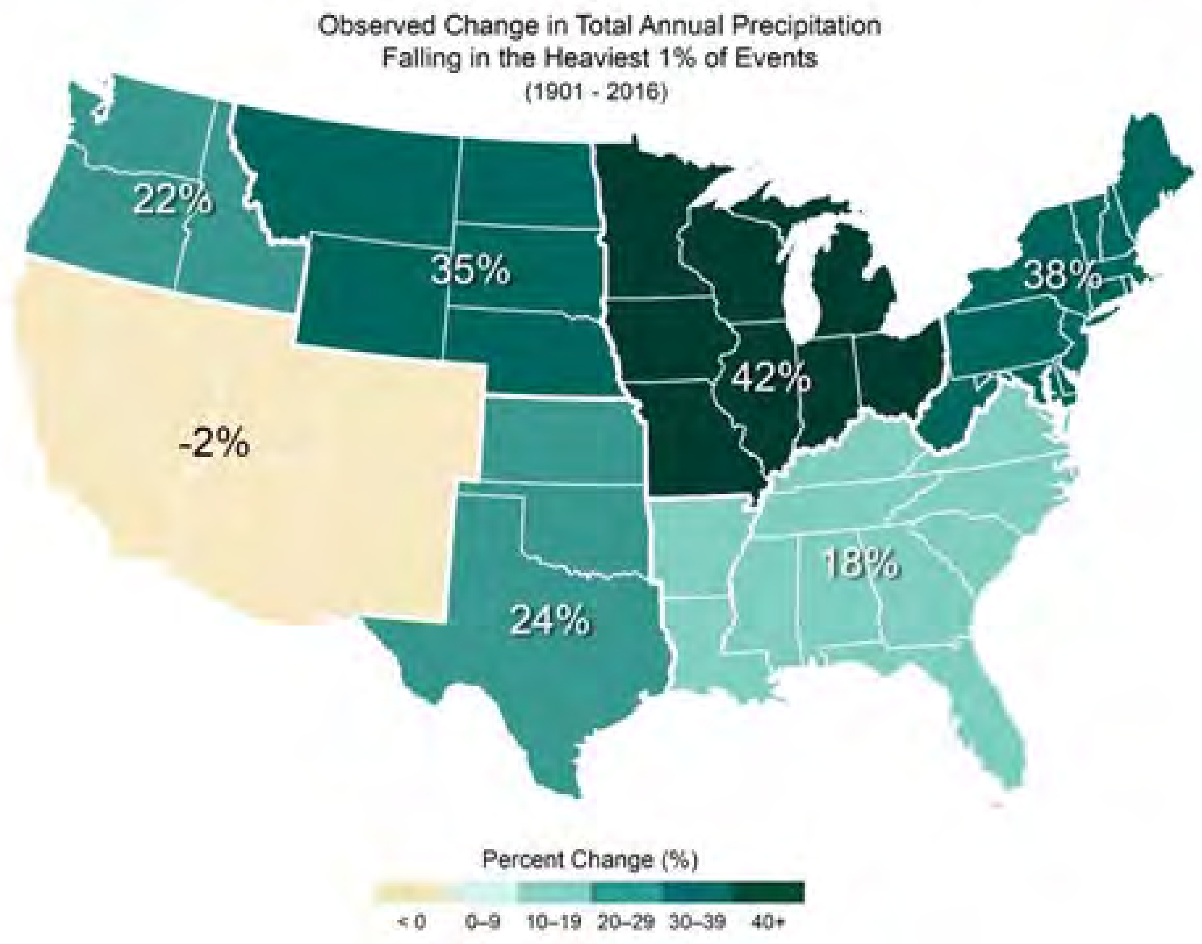
« City-wide View, Block-group level summaries, Socio-economic data, parcel views with rulesets





FUTURE PRECIPITATION ANALYSIS

- Extreme precipitation events are those in the top 1% of all days with precipitation
- 18% increase in SE since 1901
- Warmer air holds more water vapor



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FUTURE PRECIPITATION ANALYSIS

- Infrastructure was designed using *historical* precipitation conditions
- It may not be designed to deal with *future* precipitation conditions
- Increasing frequency of extreme precipitation events will increase flood frequency

	ARI (Years)							
Duration	*1*	*5*	*10*	*25*	*50*	*100*	*500*	*1000*
6-hr	4.36	6.36	7.65	10.2	12.2	14.6	21.4	24.5
12-hr	4.9	7.6	9.25	12.4	14.8	17.7	25.7	29.3
24-hr	5.49	8.89	10.9	14.5	17.3	20.5	29.5	33.4
2-day	6.35	10.1	12.3	16.3	19.3	22.8	32.5	36.8
3-day	7.08	10.8	12.9	17	20	23.7	33.7	38.1
4-day	7.74	11.3	13.4	17.5	20.5	24.2	34.3	38.8
7-day	9.4	12.7	14.8	18.8	21.8	25.4	35.5	40
10-day	10.8	14.3	16.4	20.4	23.5	27.2	37.4	41.9

NOAA Precipitation Frequency Estimates for Hallandale Beach

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FUTURE PRECIPITATION ANALYSIS

- Broward ELMS
  - 22 flood events from 1994-2011
  - $500 million in property damage
- Hallandale Beach, 12/27/2019
  - 14 inches of rain in 6 hours (100-year event)
  - Stormwater system overwhelmed
- City complaints database shows increasing trend over time

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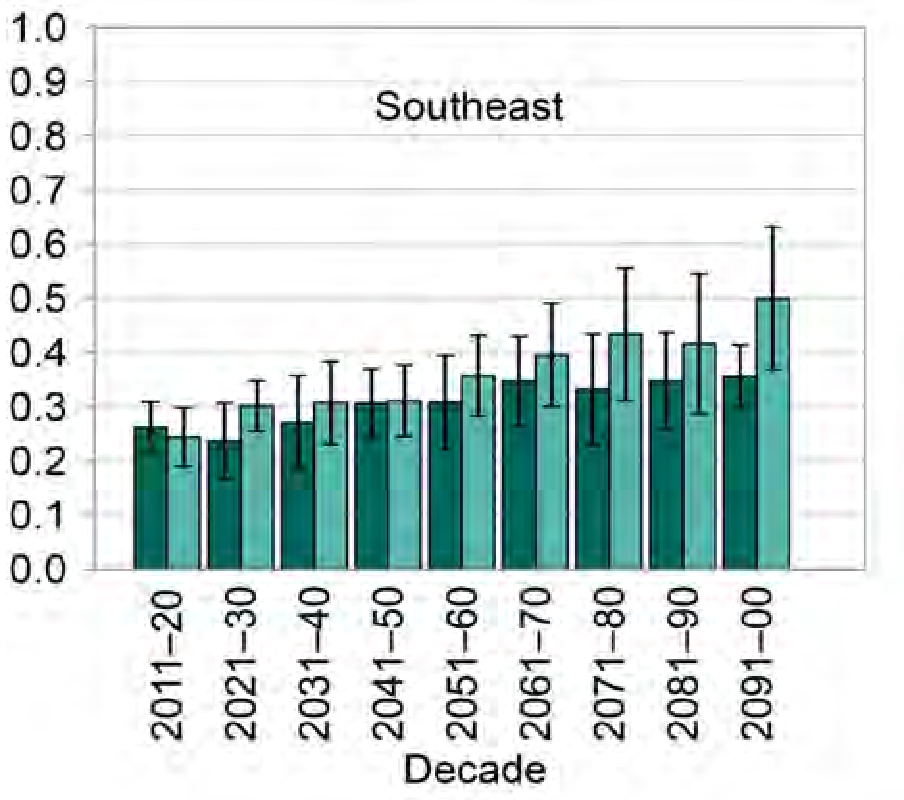
FUTURE PRECIPITATION ANALYSIS

- More frequent extreme precipitation events, more periods of drought, slightly less total annual rainfall.
- National Climate Assessment 20-year return value
  - 10% by mid-century (low scenario)
  - 14% (low) or 20% (high) by late-century
- Hurricane Precipitation
  - 10-15% increase in precipitation (NOAA)



Southeast region extreme precipitation frequency for low and high climate scenarios.

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GROUNDWATER CHANGES

- Sea Level Rise will affect the groundwater table in the City
- The two main effects will be:
  - Saltwater Intrusion
  - Elevated Water Table (closer to land surface)

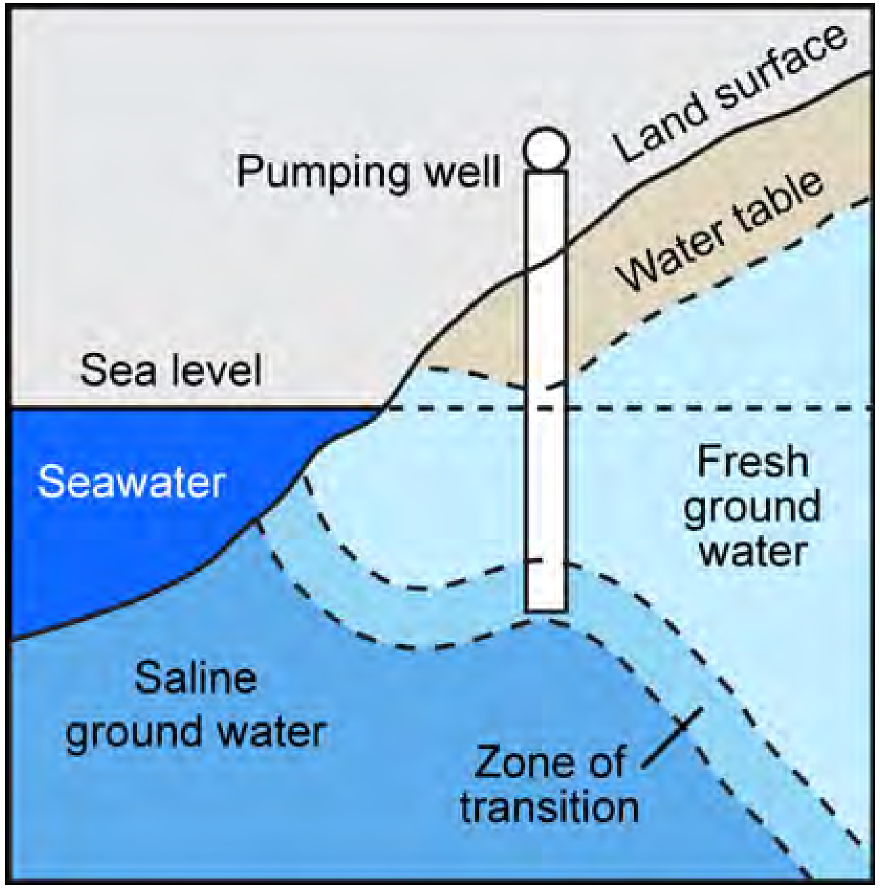

FIGURE 1: SALTWATER INTRUSION PROCESS, U.S. EPA

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GROUNDWATER CHANGES

- The groundwater (GW) table has already risen about 6” since the 1970’s
- Broward Water Table contour map shows GW depth about 2’ in the City
- Sea Level Rise will continue to affect the GW table in the City

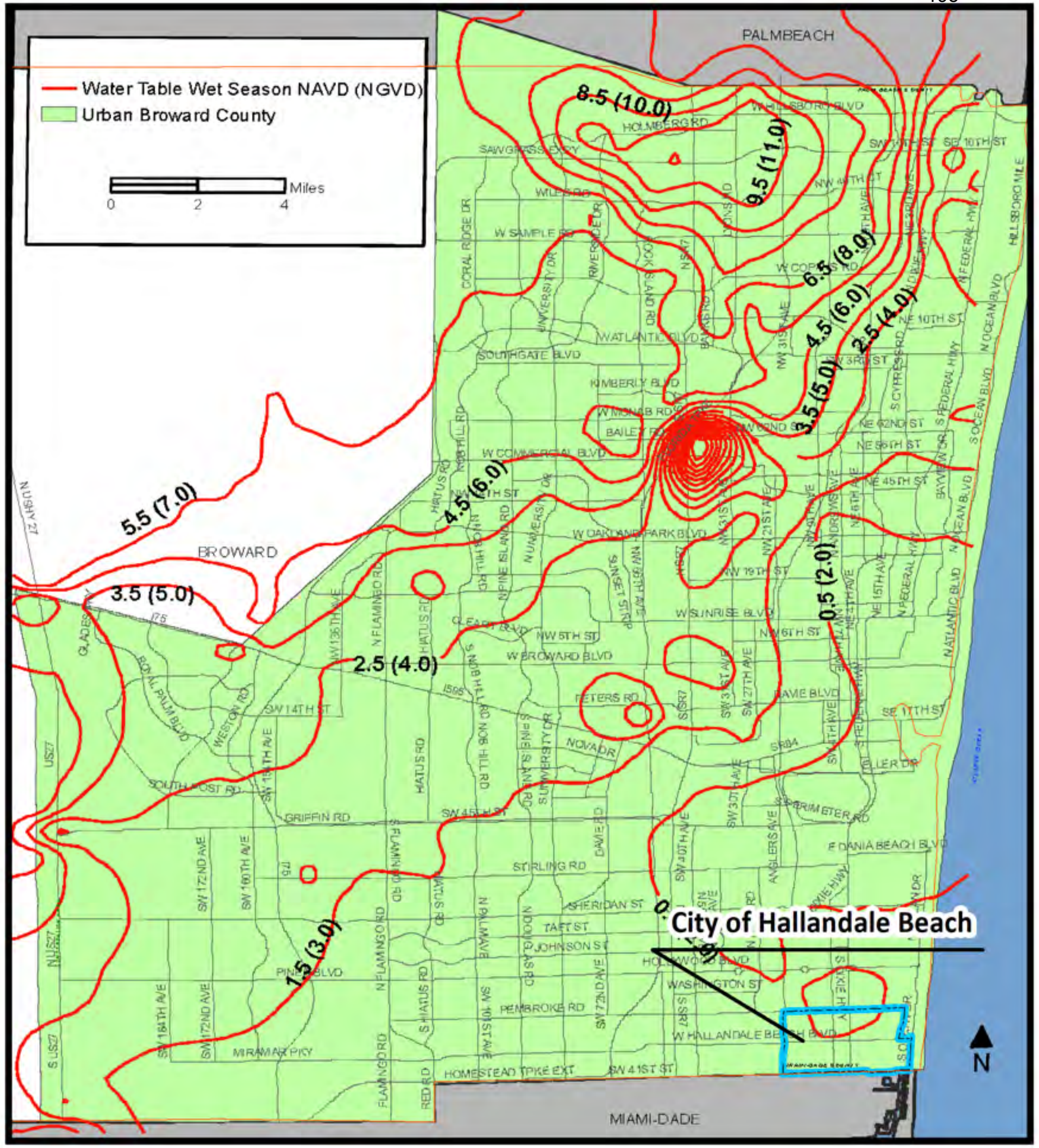

FIGURE 3: WATER TABLE DEPTH (FEET NAVD), 2000

GROUNDWATER CHANGES

- Saltwater intrusion has been experienced in Broward for ~30 years
- Sea level rise and withdrawals from the wellfield accelerate saltwater intrusion
- 6 of City's 8 production wells have been abandoned due to salinity

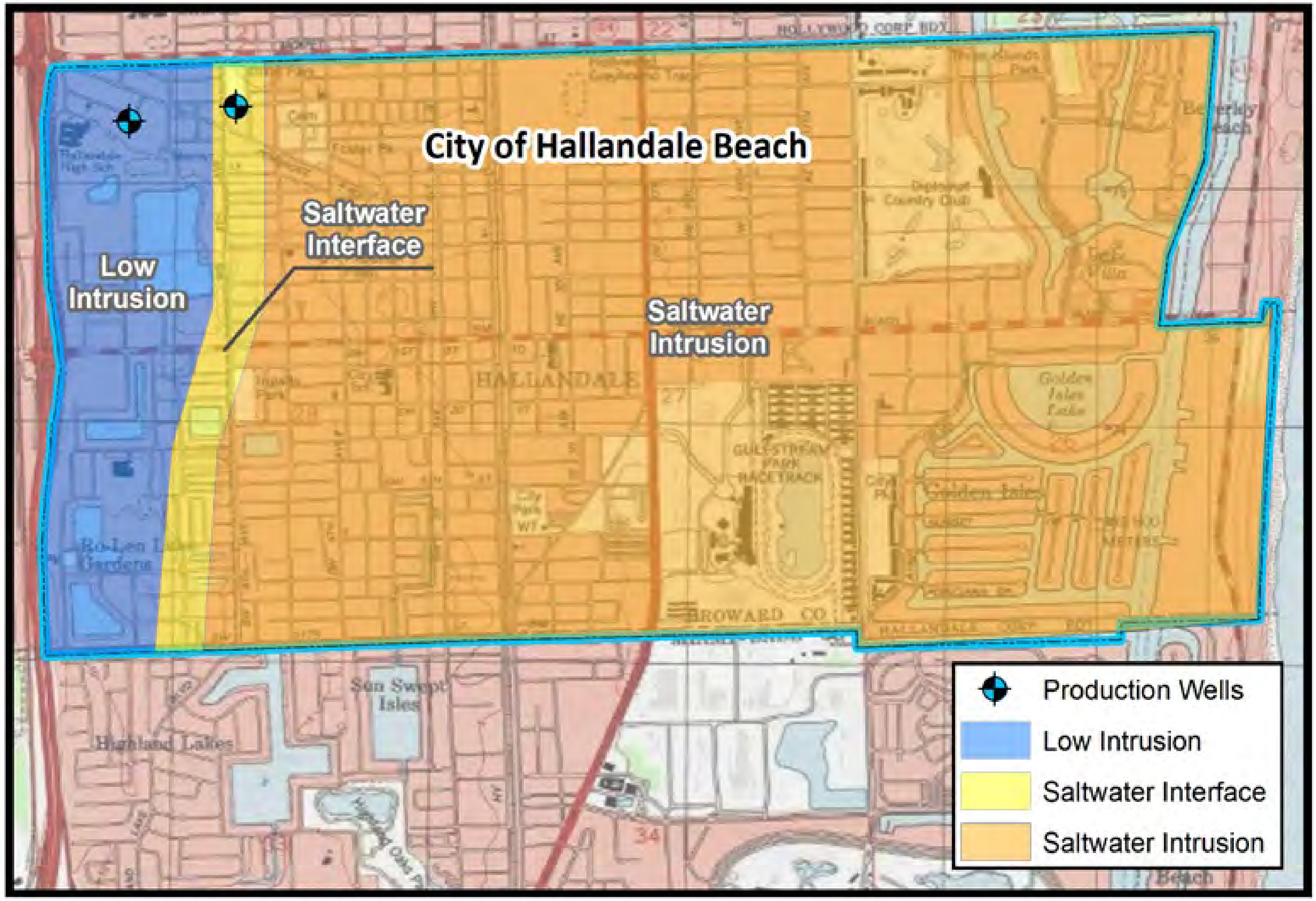

FIGURE 1: LOCATION OF THE SALTWATER INTERFACE

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GROUNDWATER CHANGES

- Broward developed a Future GW Conditions Map in 2017
- By 2070 41% of coastal wellfields will be impacted by saltwater intrusion
- By 2060's water table will be approximately 1 foot higher than it is now

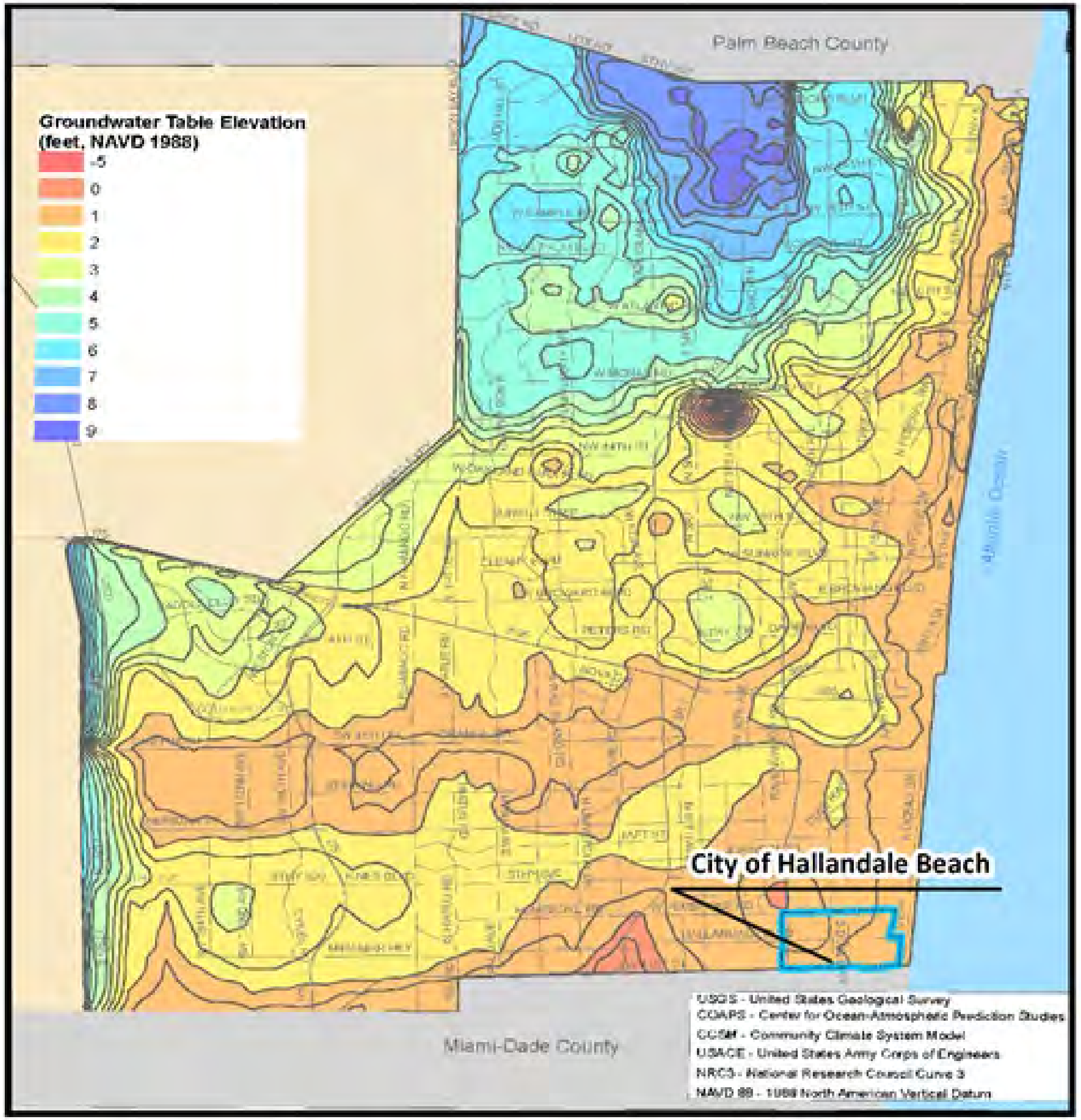

FIGURE 1: BROWARD COUNTY FUTURE GROUNDWATER ELEVATION

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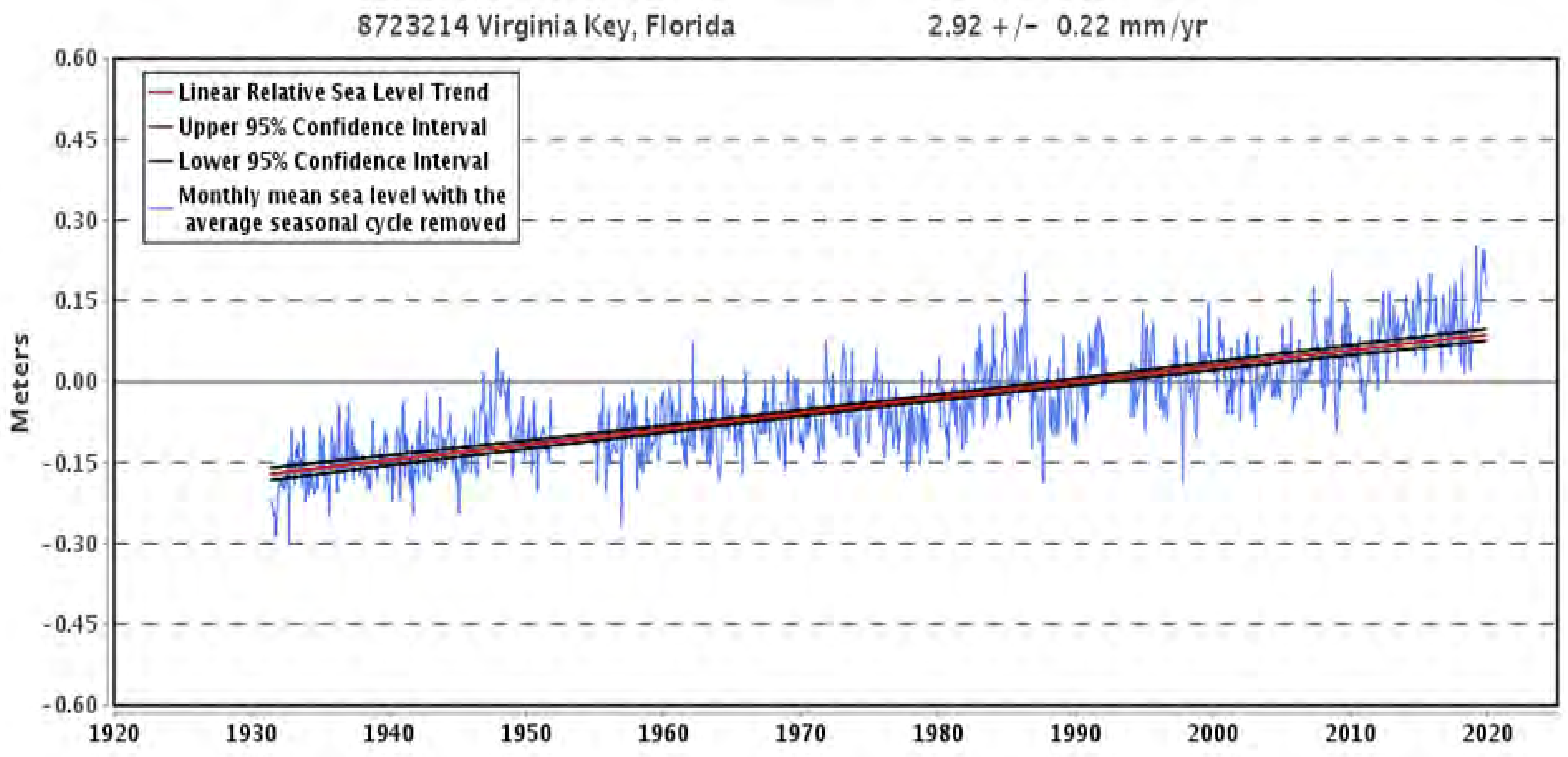
PROJECTED CHANGES IN SHORELINE

- Sea Level Rise contributes to coastal erosion and shoreline recession
- Sea Level has risen almost a foot in 100 years
- Hallandale Beach's shoreline is in critical erosion condition



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PROJECTED CHANGES IN SHORELINE

- Located between R124 and R128
- Comprised of ~4,350 of shoreline
- Compared BC, recession rate is high; accelerated since 2006-2013
- R124 segment had 5 ft of erosion per year, 2006-2013
- Beach will require ~11,000 cy of sand per year to offset the gross loss rate*.

*Segment III Beach Management Study

PROJECTED CHANGES IN SHORELINE

- The Segment III beach renourishment program cost $78 million since 1978.
- Cost shared btw. City, County, & state / federal partners
- Southern Hollywood’s 2012 project cost $3.5m; city paying 50%

PROJECTED CHANGES IN SHORELINE

- Hallandale is considering establishing a Beach Preservation Advisory Board
- The Board will "study and recommend policies and programs that address beach erosion, dunes, shorelines, cleanliness and improve natural resources"

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PROJECTED CHANGES IN SHORELINE

- There is limited information on the rate of future shoreline recession
- SLR will accelerate the rate of coastal erosion
- Availability of sand may be an issue for future renourishment projects
- Frequency, volume and cost of renourishment projects will likely increase

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Implications

IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Flooding (FEMA, Surge, SLR, Precipitation)
  - Community Implications
    - Primary effects
      - Property damage
      - Injuries
      - Fatalities
    - Secondary effects
      - Financial hardship
      - Health impacts
      - Pollution
      - Blocked transportation and evacuation routes

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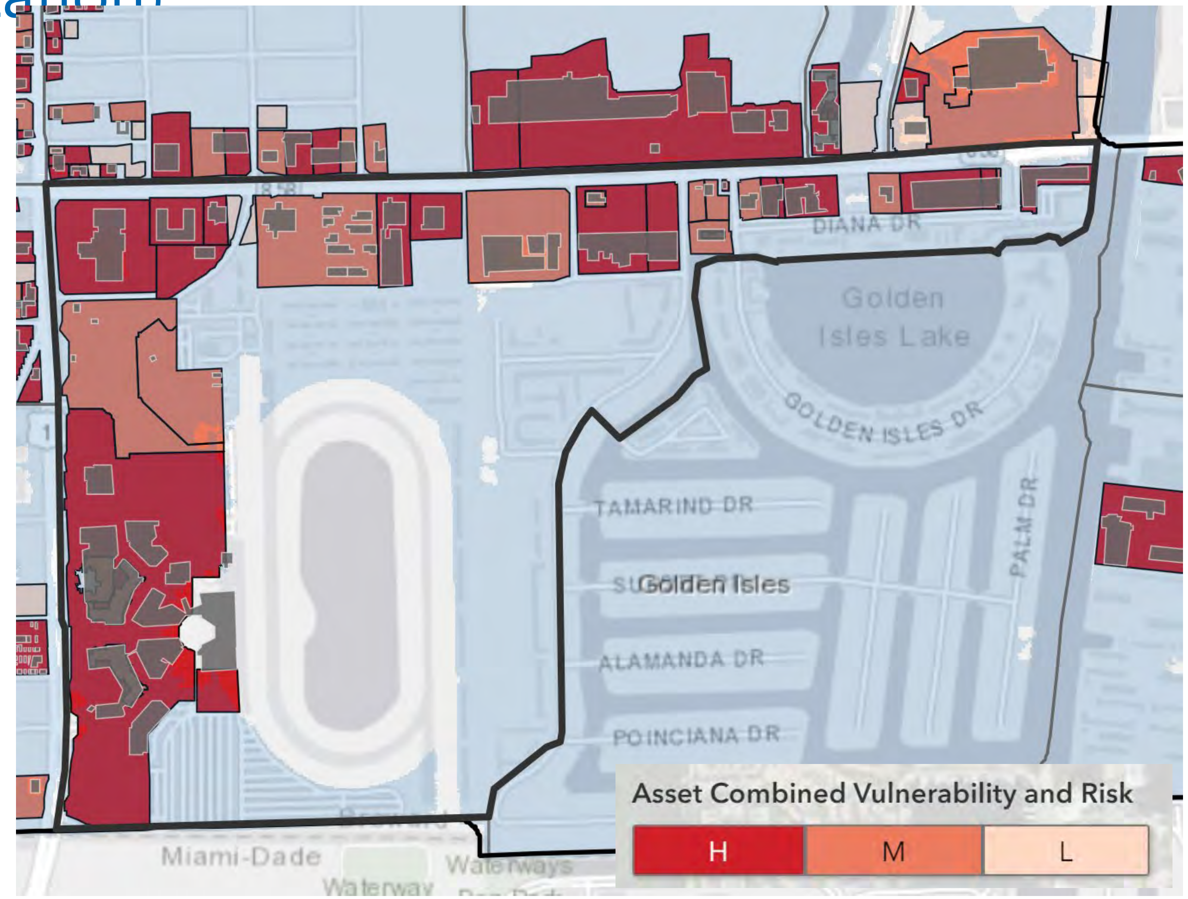
IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Flooding (FEMA, Surge, SLR, Precipitation)
  - Local Government Implications
    - Primary
      - Damages to roads, facilities, parks, drainage systems, utilities
      - Potential to spread pollutants for contaminated sites
      - Service interruptions (police, fire, etc.)
    - Secondary
      - Monetary costs for cleanup, repairs, remediation, adaptation actions
      - Complaints from residents and businesses
      - Impacts to tourism
      - Impacts to tax base if people relocate

IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- « Flooding (FEMA, Surge, SLR, Precipitation)
  - – Local Government Implications
    - Municipal Complex
    - Bluesten Park Development
    - Fire Stations
  - – Community Implications
    - Commercial assets
      - – HB Boulevard
      - – Federal Highway
    - Risk of gentrification
    - Service economy disruption



Example: Commercial Property and FEMA Flood Zones

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IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Groundwater
  - Community Implications
    - Primary effects
      - Reduced infiltration and storage of stormwater
        - Flooding
      - Accelerated saltwater intrusion impacts
        - Effects on vegetation
    - Secondary effects
      - Damage to building foundations and buried utilities
      - Potential health impacts
        - Water borne illnesses
        - Wastewater releases

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IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Groundwater
  - Local Government Implications
    - Primary
      - Impacts to stormwater systems
      - Damage to underground utilities
      - Saltwater intrusion affecting production wells, parks, etc.
    - Secondary
      - Monetary costs for:
        - Alternative water supply / desalinization
        - Improvements to stormwater system
        - Hardening of utilities

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IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Shoreline Recession
  - Community Implications
    - Primary effects
      - Accelerated erosion of beaches
      - Beaches could become narrower, steeper, less attractive
      - Impacts to sea turtles and other wildlife
    - Secondary effects
      - Impacts to property values
      - Impacts to tourism
      - Loss of dune protection
      - Loss of economic activity

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IMPLICATIONS FOR THE CITY OF HALLANDALE BEACH

- Shoreline Recession
  - Local Government Implications
    - Primary
      - Accelerated erosion of beaches
    - Secondary
      - Increased costs for Beach Renourishment
        - Availability of suitable fill
      - Potential legal issues
      - Potential impacts to tax base

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Know that you know some of the implications of Climate Change at Hallandale Beach, how are you feeling?

Start the presentation to see live content. Still no live content? Install the app or get help at **PollEv.com/app**

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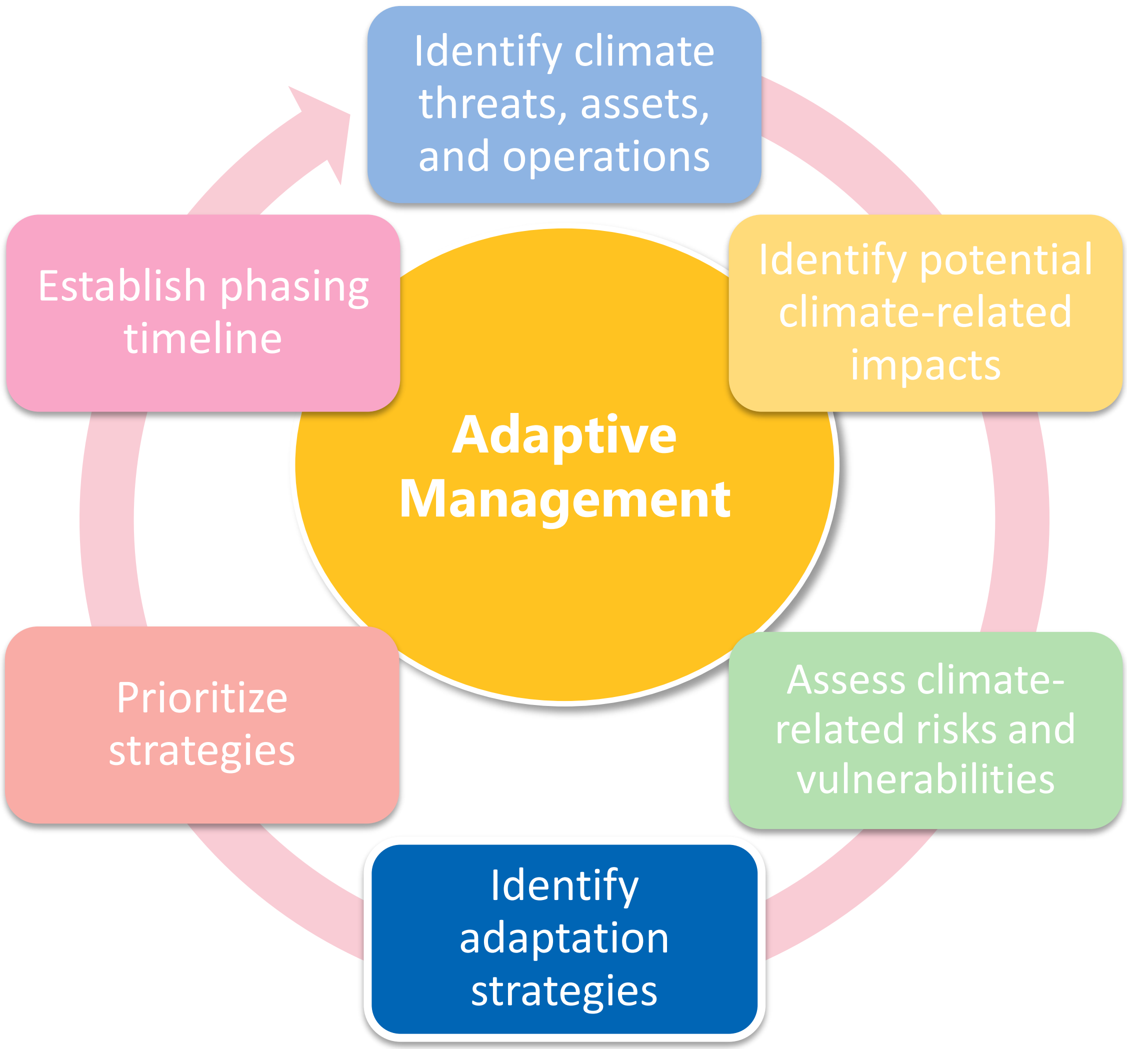
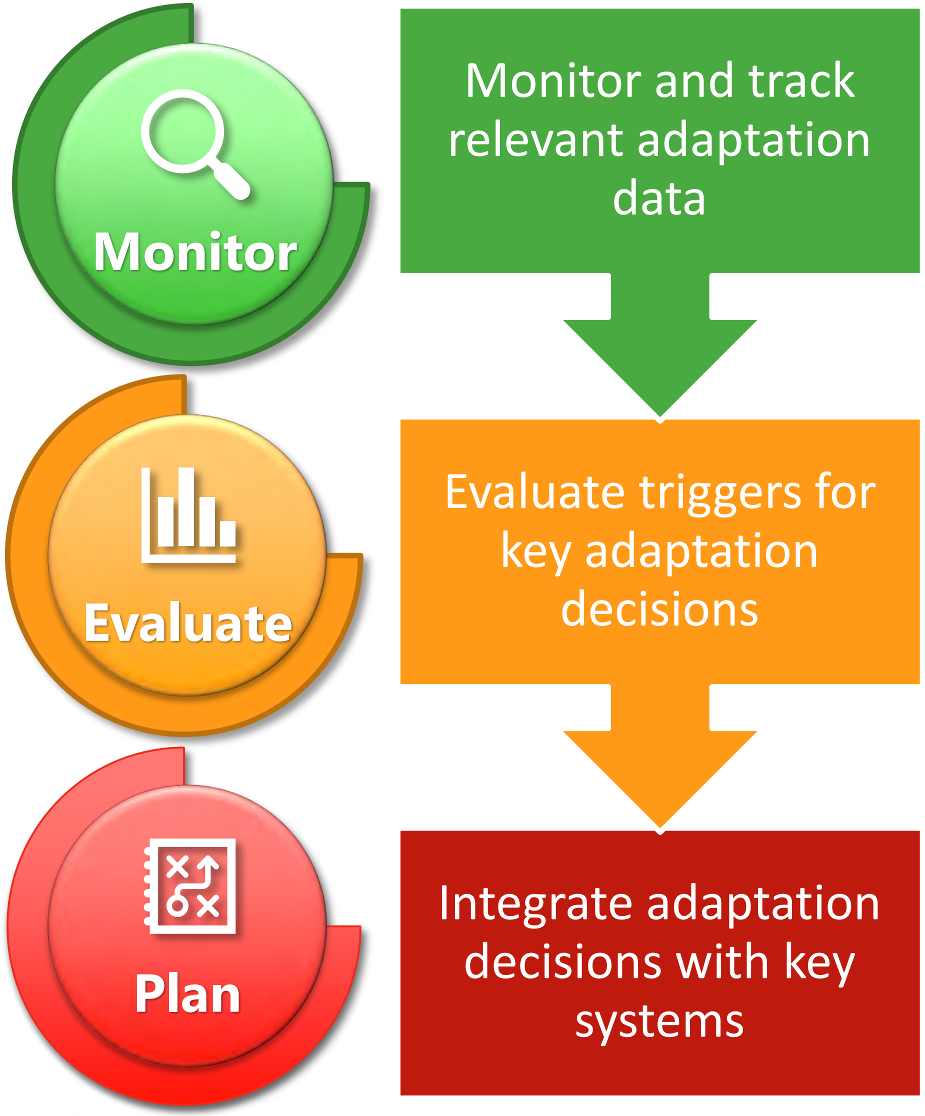
Adaptation

ADAPTATION STRATEGIES





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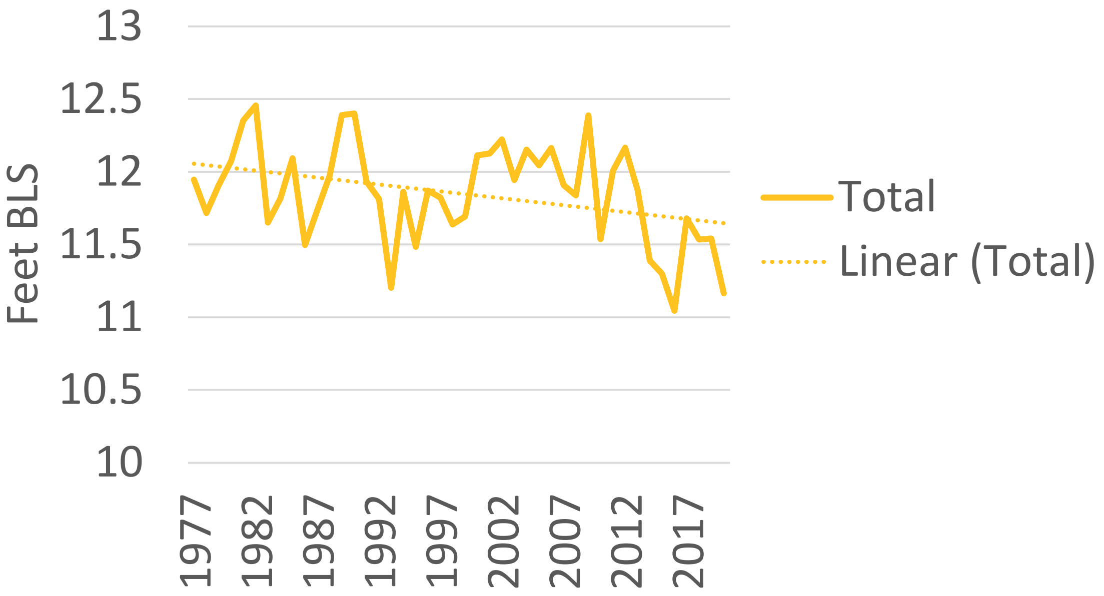
ADAPTATION STRATEGIES

- Monitor emerging science and projections
- Monitor conditions in the City
  - SLR
  - Extreme rainfall events / Flooding
  - Saltwater Intrusion
  - Beach Erosion
- Coordinate and share information
  - Regional Partners (Cities & Counties)
  - Universities
  - Stakeholder Groups



USGS GW WELL G-2035, DEPTH TO GROUNDWATER

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ADAPTATION STRATEGIES

- Identify thresholds
  - Failure points
  - Points to initiate Adaptation Actions
- Evaluate standards
  - LOS, Design
- Evaluate options
  - Policy changes
  - Technical solutions

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ADAPTATION STRATEGIES

- Develop adaptation strategies and projects
- Integrate adaptation strategies into planning documents
  - Floodplain Management and Hazard Mitigation Plan (2021)
  - Comprehensive Plan
  - Strategic Plan
- Integrate resilience into policies
  - Internal Policies and Procedures
  - Community-wide through ordinance
    - E.g. Land Development & Zoning Regulations

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ADAPTATION STRATEGIES

- Prior / Current Adaptation Strategies
  - Monitor
    - Flooding Complaints Database
    - Saltwater Intrusion (monitoring wells)
    - Coordination with SEFLCC, Broward County, others
  - Evaluate
    - Saltwater intrusion threshold (>150 mg/l chloride)
    - Options for alternative water supply
      - Move wellfield, purchase from other jurisdictions, desalinization
  - Plan
    - 2018 SAP
      - CRS, Dune Restoration Program
    - Vulnerability Assessment and Adaptation Plan

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ADAPTATION STRATEGIES

- Selected Potential Adaptation Strategies
  - Monitor
    - Develop a flood monitoring system with the ability to warn residents
    - Encourage residents to register in the Vulnerable Population Registry
  - Evaluate
    - Assess how City's Stormwater System will function with a one-foot increase in groundwater elevation
    - Assess how contaminated sites will be impacted by rising groundwater
    - Inform developers about Broward Future Conditions GW map
  - Plan
    - Develop requirements to integrate LID into new development
    - Use Future Conditions GW map when planning infrastructure

Adaptation Strategies Brainstorming Exercise

What are your ideas for potential adaptation strategies at Hallandale Beach?

Top

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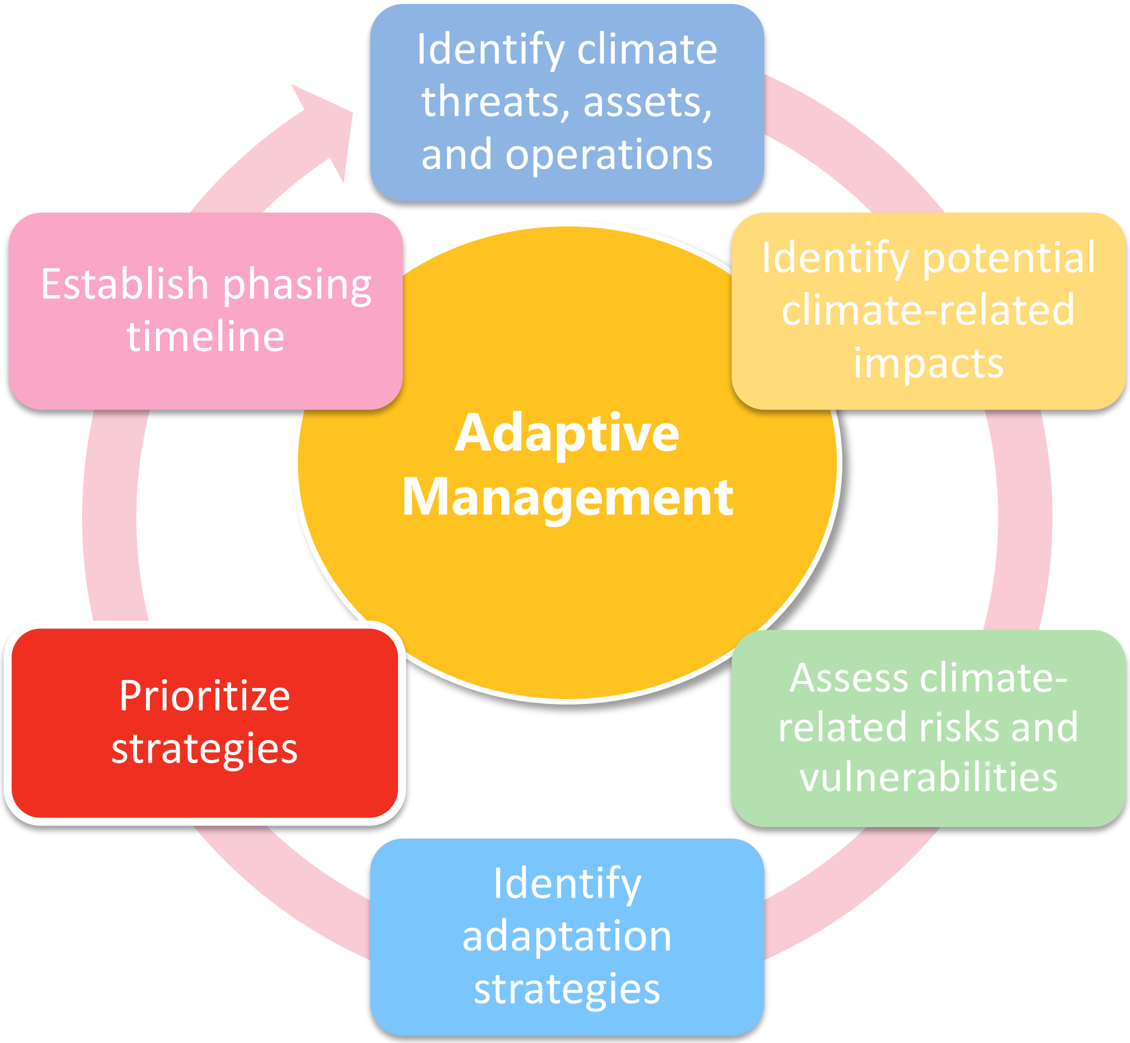
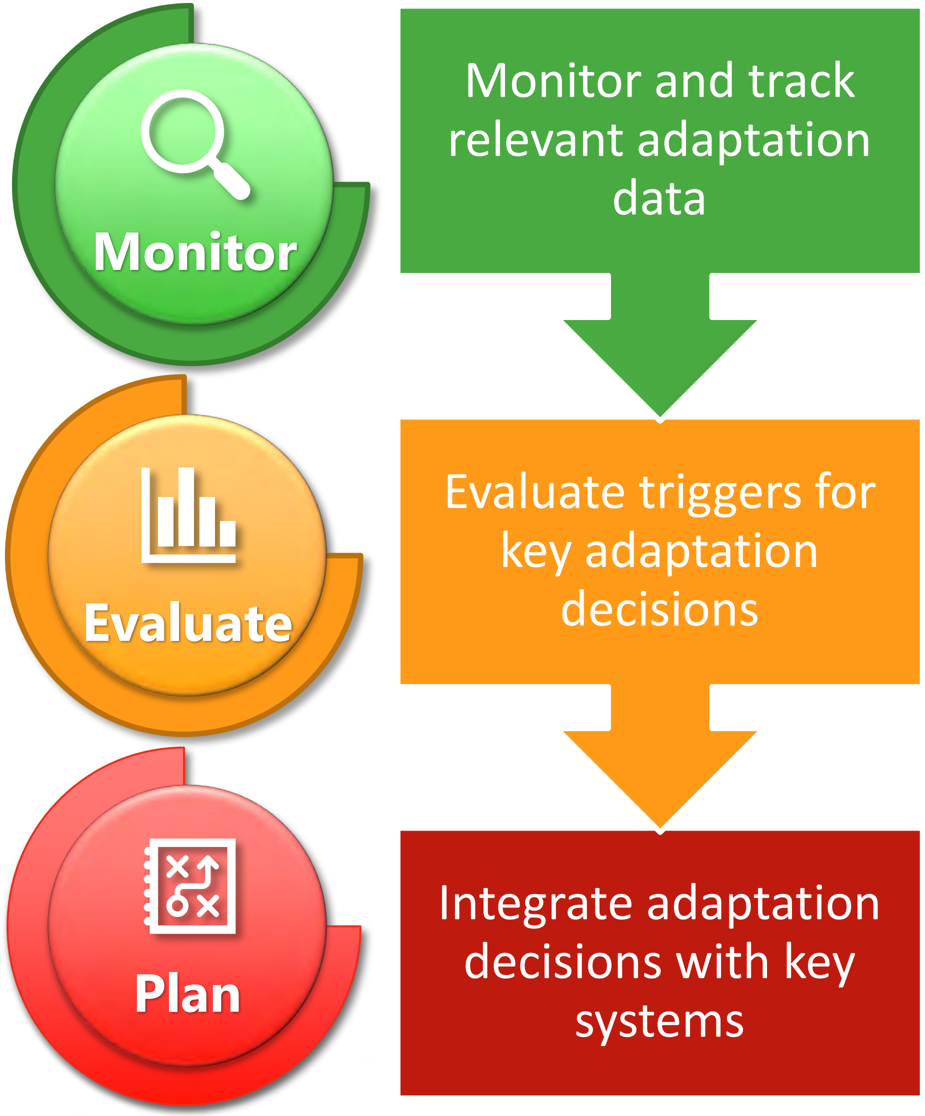
Prioritization

PRIORITIZING ADAPTATION STRATEGIES





PRIORITIZING ADAPTATION STRATEGIES

Evaluate costs, benefits, and your team's capacity to accomplish each action.

Rank the expected value of each action.

Integrate the highest-value actions into a plan.

PRIORITIZING ADAPTATION STRATEGIES

Adaptive Capacity

Economic Benefit

Environmental Benefit

Social Benefit

Feasibility

PRIORITIZING ADAPTATION STRATEGIES

« Adaptive Capacity
- What vulnerabilities does this address?
  - Does it address more than one?
  - What is the adaptation benefit for each?
- Is the strategy a flexible solution?
  - Does it allow you to adjust to changing conditions?
  - How long will it last?
  - Will it lock us into something undesirable?

FORT JEFFERSON, DRY TORTUGAS

RS&H

PRIORITIZING ADAPTATION STRATEGIES

- Economic Benefit
  - How much does it cost?
    - What is the capital cost?
    - What are the lifecycle & O&M costs?
    - How do costs compare to benefits?
    - Is it worth it?
  - What are the benefits to the community?
    - Direct
    - Indirect
    - Induced benefits

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PRIORITIZING ADAPTATION STRATEGIES

« Environmental Benefit
- Air Quality
- Water Quality
- Pollution Prevention
- Ecosystem Services
- Biodiversity
- Resource Use & Conservation
- Carbon Footprint

LIVING SHORELINE, PANAMA CITY, FL

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PRIORITIZING ADAPTATION STRATEGIES

- Social Benefit
  - Property Protection
    - Protect homes and businesses
  - Equity
    - Are stakeholders consulted?
    - Does it improve equity?
    - Are there any negative impacts on vulnerable populations?
  - Health & Safety Benefits
    - Will it improve health or safety?

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PRIORITIZING ADAPTATION STRATEGIES

- Feasibility
  - Political
    - How much political capital is needed?
    - Will the public support the strategy?
  - Cultural
    - Is it culturally acceptable?
  - Technical
    - Does the technology exist?
    - Is it proven or unproven?
  - Temporal
    - Can it be done in time?

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Prioritization Exercise

PRIORITIZATION EXERCISE

- Instructions
  - Click the link: https://www.surveymonkey.com/r/HB_VAAP
  - Rate each category low, medium or high

We will use your rankings to calculate an overall score for each proposed strategy

Strategy	Adaptive Capacity	Economic Benefit	Environmental Benefit	Social Benefit	Feasibility
Develop Flood Warning System	Medium	High	Low	High	High
…					
…					
…					

After considering Hallandale Beach's climate change vulnerabilities and how it might adapt in response, how are you feeling?

Next Steps

NEXT STEPS

- This Week:
  - Complete Potential Initiatives Prioritization Survey
- Next Two Weeks:
  - RS&H to gather supplemental information on priority initiatives
- Next Month:
  - RS&H to develop concept level cost / benefit analysis of top 10 initiatives
- End of April
  - Draft VAAP
- May
  - Final VAAP

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Adjourn

Thank you!

6.8 PROJECT WORKSHEETS

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	1. 2000 S. Ocean Dr. Resilient Dune Access
Location:	2000 S. Ocean Drive

2. Project Description

a. Objective:	Improve the resiliency of the City's Beach Access points, beginning with a demonstration project at 2000. S. Ocean Drive, the site of a planned 64-unit residential development. The project will be designed to reduce coastal erosion by altering the design of the beach access. Pedestrian pathways through the dunes will be designed with a diagonal or curved shape and at an oblique angle to the direction of the prevailing winds, which typically blow in an easterly direction. The angled pathway will slow or prevent dune erosion due to wind as well as storm surge / wave runup during severe storm events.
b. Scope	The City will already need to either procure professional services for site design and construction of dune and beach access, or provide those services using City staff. The City will need to specify and approve the resilient design, but no additional actions will be needed to implement it. The City may wish to pursue grant funding through the Broward County Environmental Planning and Community Resilience Division (EPCRD) dune grant program or FDEP to cover any additional construction costs. The City may also wish to consider changes to standard operating procedures that could improve the resilience of the beach access points. For instance, the City of Jacksonville Beach has begun temporarily filling in beach access routes through the dunes with sand prior to approaching hurricanes. This practice has successfully prevented storm surge from penetrating past the dunes during recent storms, reducing dune erosion and protecting nearby properties.
c. Cost(s):	Incremental costs for this project are estimated at $12,000 to $16,000 assuming the resilient design adds 15 feet to the length of the beach access pathway. The high estimate includes a 30% contingency. The estimate assumes the beach access pathway is constructed of an engineered composite material on concrete pilings at grade, with railings on both sides. The project assumes the angled beach access design will add about 50% to the shortest-path distance to the beach (which is approximately 30 feet). Some of the additional cost could be offset through use of grant funding through the Broward Dune Restoration Program or FDEP Beach Management Funding Assistance. Costs could also be reduced by using volunteer labor through organizations such as the Youth Environmental Alliance (YEA) to develop/maintain the beach access pathways.
d. Potential Benefit(s):	Direct benefits may include reduced dune maintenance/restoration costs following storm events. Replacement cost for sand lost from dunes during storm events is estimated at $25 per cubic yard (CY). The angled design is intended to reduce loss of sand due to wind and water erosion. If 500 CY of sand were retained over five years compared to a conventional design, the project might break-even based on cost savings for sand replacement. Indirect benefits are related to the increased protection the resilient beach access may provide. They include avoided lost access to government fees / taxes, reduced insurance premiums, increased property values and maintaining tourism revenues. These benefits are difficult to quantify and are not estimated.

3. Project Estimated Costs:

Total (Low): $12,000
Total (High): $16,000
Summary: Construction, Operations and management.
Type:
1 Construction
2 Operations and management

4. Project Potential Benefits

Reduction in repair costs, Impacts to properties, Insurance premiums, Property Values , Tourism revenues.

Summary:
Type:
1 Reduction in repair costs
2 Impacts to properties
3 Insurance premiums
4 Property Values
5 Tourism revenues

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total (low)	$ 12,000.00	
Total (high)	$ 16,000.00	

Contigency

% of total	30%	

Extra length of access path	15	feet
Width of access path	8	feet
Area of Access Path	120	square feet
Typical Cost boardwalk on g	$ 70.00	per sf
Typical Cost railings	$ 100.00	per lf

Boardwalk cost	$ 8,400.00	
Railing Cost	$ 3,000.00	
Total Path cost	$ 11,400.00	

Source of boardwalk costs:
S:\P\3010068.000 Hallandale VAAP\I Drawings and Design Data\Task 6. Initial Strategy Devlopment\Projects\1 Dune
https://www.permatrak.com/news-events/bid/97419/boardwalk-construction-estimates-how-much-does-a-boardwalk-cost

Benefits

Reduction in repair costs	$ 25.00	per CY sand replaced
	500	CY lost sand avoided, assumed every 5 years
	$ 12,500.00	avoided restoration cost every 5 years
	$ 2,500.00	avoided restoration cost annually
Impacts to properties		
Insurance premiums		
Property Values		
Tourism revenues		

Source for sand replacement costs:
S:\P\3010068.000 Hallandale VAAP\I Drawings and Design Data\Task 6. Initial Strategy Devlopment\Projects\1 Dune

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name: 2. Egret Lift Station Rehabilitation
Location: Egret Drive and Poinsetta Drive

2. Project Description

a. Objective: To improve the resiliency and reduce the failure rate of the Egret Drive lift station (lift station #1) by elevating and hardening critical infrastructure at the station to reduce flood and storm risks. The existing lift station is a triplex design with 2-60 HP pumps and 1-200 HP pump. The City plans to upgrade it to include 3-200 HP pumps. City staff recommend elevation of electrical equipment, the use of corrosion-resistant materials, and adding a grinder station that can process solid materials to reduce pump wear as part of the upgrade. These resilient design features will add an incremental cost to the planned upgrade, but will reduce the risk of failure under flood and storm conditions and/or power outages. Other typical strategies to improve lift station resilience to flooding include: elevating equipment above critical flood elevations, utilizing submersible pumps, encasing electrical equipment in watertight housings, sealing structures with water-tight windows and doors, and providing backup emergency power generation. In addition, per Florida Administrative code, lift station should have protection from lighting strikes and voltage surges.

No-cost resilience strategies related to operational changes are also available. In 2017 RS&H evaluated failure modes that led to unpermitted sanitary overflows that occurred during hurricanes Hermine and Matthew at seven Florida utilities. For lift stations, the most common cause of an unpermitted release was a failure of backup power. In many cases, automatic transfer switches failed to engage or protective relays on Variable Frequency Drive pump motors tripped, leaving equipment unenergized while City staff were sheltering from the hurricanes and unable to respond. An effective, no-cost solution was to provide an adequate supply of fuel and manually transfer the lift stations to run off emergency generators in advance of the storm.

b. Scope: Develop a resilient design specification for this and future lift station projects. Procure design/engineering services and require project design to conform to specified resiliency performance targets. After construction, commission or otherwise verify system components and performance. Develop an implementation and operation plan that incorporates standard operating procedures designed to reduce flood/storm risks. Include resilient design specification in future lift station rehabilitation/replacement/new construction projects as they come up.

c. Cost(s): Total estimated costs for just the resiliency upgrades to Egret Lift station range from $46,000 (low estimate) to $681,000 (high estimate). These are incremental costs for resiliency upgrades only, in addition to the $2.26 million the City has estimated for improvements to modernize and increase the capacity of the facility. Exact costs will need to be estimated following an engineering survey and design of the proposed improvements. Low estimate costs are derived from the average projected cost for resiliency upgrades to wastewater pump stations in the Waterford, CT Sewer Pump Station Assessment and Adaptation Report. High estimate costs are derived from the average projected cost for resiliency upgrades to wastewater pump stations in the Los Angeles OneWater Plan. Costs include design/engineering fees estimated at 10% of construction costs. Low estimate costs include installing flood doors and panels, raising electrical equipment and transformers, raising vent and fill pipes, anchoring fuel tanks, replacing hatches, relocating chemical feed pumps. installing watertight manhole covers, concrete repairs, and waterproof membrane coating. High estimate costs include low estimate improvements plus raising generator pads and installing bollards or berms to protect against storm surge wave damage.

d. Potential Benefit(s): Direct potential benefits include avoided repair/replacement costs for the facility if it were flooded, and avoided fines and environmental fees if a flood or storm caused an unpermitted release. The LA OneWater plan estimated an average $4.1 million replacement cost for wastewater pumping stations. Environmental fines can also be significant. The City of Sarasota reached a consent agreement with FDEP for 83 spills of 630 million gallons of wastewater between May 2018 and September 2019 that resulted in $25.4 million in fines to the city, or more than $24 per gallon. Other indirect potential benefits (not estimated) include avoided impacts to surrounding properties, reduced insurance premiums, avoided pollution of waterbodies and avoided public health risks.

3. Project Estimated Costs:

Total (Low):	$		46,000
Total (High):	$		681,000
Summary:	Design, Construction.		
Type:			
	1	Design	
	2	Construction	
	3		
	4		
	5		

4. Project Potential Benefits — Reduction in physical damages, Reduction in repair costs, Avoided Environmental Fines & Costs, Impacts to propert

Summary: Reduction in physical damages, Reduction in repair costs, Avoided Environmental Fines & Costs, Impacts to properties, Insurance premiums, Avoided pollution of waterbodies, Avoided public health risks.

Type:

1. Reduction in physical damages
2. Reduction in repair costs
3. Avoided Environmental Fines & Costs
4. Impacts to properties
5. Insurance premiums
6. Avoided pollution of waterbodies
7. Avoided public health risks

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total (High)	$	681,000	
Total (Low)	$	46,000	
Design / Engineering		10%	of Construction Costs
High Estimate Design Cost	$	61,880	
Low Estimate Design Cost	$	4,144	
Construction High Estimate (i)	$	618,800	
Construction Low Estimate (ii)	$	41,438	

(i) Derived from average cost of WW Pump station resilience upgrades in LAOneWater Plan — Source: S:\P\3010068.000 Hallandale VAAP\I Drawings and Design Data\Task 6. Initial Strategy Devlopment\Projects\2 Egret Lift Station\OneWaterLA_WW_SW Assessment.pdf

(ii) Derived from average cost of WW Pump station resilience upgrades in Waterford CT Adaptation report — Source: "S:\P\3010068.000 Hallandale VAAP\I Drawings and Design Data\Task 6. Initial Strategy Devlopment\Projects\2 Egret Lift Station\Waterford-CT-Sewer Pump Station Adaptation Report.pdf"

Benefits

Reduction in physical damages
Reduction in repair costs
Avoided Environmental Fines & Costs
Impacts to properties
Insurance premiums
Avoided pollution of waterbodies
Avoided public health risks

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	4. Marina Seawall Rehabilitation
Location:	101 Three Islands Boulevard

2. Project Description

a. Objective:	To improve flood resilience of the City Marina by raising the existing seawall. A Broward County land use amendment passed March 31, 2020 requires seawalls be raised to 5 feet NAVD to protect against a King Tide in 2060 plus a 20-year return interval storm surge. The Sea Level Scenario Sketch Planning Tool shows the land elevation at the marina is approximately 3 feet NAVD. Assuming the existing seawall extends roughly level with the ground surface, a minimum additional seawall height of 2 feet above ground level would be required to meet this requirement. Two options were analyzed. For option one, a concrete cap would be added to the existing seawall raising it to 5 feet NAVD. For option 2, the existing seawall would be demolished, and a new, higher concrete seawall would be constructed in its place, raising it to 5 feet NAVD. As an additional option the City could evaluate the feasibility of adding mangroves planted within rock or cement planters along 120 feet of the north end of the seawall near the Three Islands Blvd bridge. Containing the mangroves within planters may prevent them from interfering with navigation. The City would need to evaluate potential impacts of this project on nearby/adjacent private properties. The City would also need to evaluate the need to refurbish or replace existing docks at the marina as part of the project and estimate associated costs for this task.
b. Scope	Plan the project, conduct a site survey, obtain funding, procure design services, and procure construction services.
c. Cost(s):	Conceptual estimated costs range from $129,000 to $1,845,000. Estimates include construction material and labor costs and assume an additional 10% for design/engineering costs. The high estimate assumes replacement of the existing seawall and includes demolition of the existing structure. Estimated costs do not include stormwater drainage improvements, grading/earthwork, landscaping, additional site work, or O&M. The existing docks would likely need to be rebuilt or replaced, but these costs are not included due to a lack of available information. Costs do not include land acquisition because the City already owns the site. A site survey would need to be conducted and detailed engineering level cost estimate would need to be developed prior to construction. Costs are derived from RS Means and the City of Ft. Lauderdale. The option to add mangrove planters, if determined to be feasible, would add another $24,000-$75,000, based on comparable projects at the towns of Palm Beach and Lantana.
d. Potential Benefit(s):	Direct benefits of the improved seawall would include protecting the site, including Fire Rescue Station #3 and Marina structures, from storm damage and king tide flooding. Building improvements on site had a Just Market Value of $402,710 in 2019. Indirect potential benefits derive from decreased flood risk at the marina and are not estimated. They include reduction in physical damages and repair costs due to storm damage and overtopping, minimized cost of potential injury, impacts of lost access to businesses, impacts to adjoining properties, reduced insurance premiums, increased property value, and avoided disruption of tourism revenues. While indirect, these potential benefits could be quite large. For example, the "value of a statistical life" is estimated by Federal agencies as between $6 - $9 million. If the seawall is responsible for avoiding one resident death, it could be cost-effective from a social perspective. If selected, the mangrove planter option could provide protection of the seawall and improved water quality and aesthetics.

3. Project Estimated Costs:

Total (Low):		$129,000
Total (High):		$1,845,000
Summary:		Design, Construction, Reconstruction / rehabilitation, , .
Type:		
	1	Design
	2	Construction
	3	Reconstruction / rehabilitation

4. Project Potential Benefits

Summary:		Reduction in physical damages, Reduction in repair costs, Minimized cost of potential injury, Impacts of lost access to businesses, Tourism revenues.
Type:		
	1	Reduction in physical damages
	2	Reduction in repair costs
	3	Minimized cost of potential injury
	4	Impacts of lost access to businesses
	5	Impacts to properties
	6	Insurance premiums
	7	Property Values
	8	Tourism revenues

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total (low)	$129,000
Total (high)	$1,845,000

Land Acquisition

Total cost: $0

The City already owns the land required for this project (Parcel#5142 23 12 0030 at 101 3 Islands BLvd)

Construction

Elevate / Replace Seawall

Seawall thickness (existing)	1.5	feet
Seawall height (existing)	10	feet
Seawall Length	780	linear feet (LF)
Seawall volume	11,700	CF

Unit Costs

SW Option 1 Low - Cap to rais	$150.00	per LF (Source: Ft Lauderdale Sea Wall Ordinance FAQ)
SW Option 2 High - New Seaw	$2,150.00	per LF (Source: RS Means)
SW Option 2 High - Existing S	$226.50	per LF (Source: RS Means)
CF to CY unit conversion	0.037037	

Demolition Cost (option 2 only $98,150

Construction Cost

Option 1 Low cost	$117,000
Option 2 High cost	$1,677,000

Source: Broward Proposed Minimum SW Height Policy Presentation, validated with RSMeans

Design Cost

Design Cost % of constructior	10%
Option 1	$11,700
Option 2	$167,700

Plant Mangroves		
Mangrove Length	120	Linear Feet
Living Shoreline High Cost	$625.00	per lf
Low end of range	$200	per lf
High end of range	$75,000	
Low end of range	$24,000.00	
Source: London Living Shoreline Document (provided by City)		
Mangrove Planter Costs		
Town of Palm Beach	$400,000	per 2000 lf, Rock berm 8-10 feet from seawall, lined with filter fabric and fill, red mangroves planted 3' on center
	$200	per lf
Lantana	$20,000	per 32 lf, 4 feet wide mangrove planter
	$625	per lf

Benefits

Reduction in physical damages
Reduction in repair costs
Minimized cost of potential injury
Impacts of lost access to businesses
Impacts to properties
Insurance premiums
Property Values
Tourism revenues

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	7. Resilience Hub
Location:	Chaves Lake Park

2. Project Description

a. Objective:	Build and operate a Resilience Hub at Chaves Lake Park. Resilience Hubs are community-serving facilities augmented to support residents and coordinate resource distribution and services before, during, or after a natural hazard event. They are used year-round as neighborhood centers for community-building activities. According to the Urban Sustainability Directors Network, "Resilience Hubs can equitably enhance community resilience while reducing GHG emissions and improving local quality of life. They are a smart local investment with the potential to reduce burden on local emergency response teams, improve access to health improvement initiatives, foster greater community cohesion, and increase the effectiveness of community-centered institutions and programs. Current plans for the park include a restroom facility and a public use room. These could be expanded into the Resilience Hub.
b. Scope	This project requires conceptual planning, including establishing a project team, building partnerships, setting goals, and establishing the project performance requirements. Once complete, the City must procure professional services for building design and construction. An operating plan also must be developed, including staffing and programming.
c. Cost(s):	Project estimated lifecycle costs are $6,054,000 to 7,870,000. The estimate does not include land acquisition, because it assumes the City will build the Hub on land it already owns (Chaves Lake Park). Upfront costs include design and construction, estimated at $2.34M. Long-term operations and maintenance costs are estimated at $3.7M. This is the present value of 40 years of O&M at $8 per square foot and a discount rate of 3%. O&M costs do not include staffing and programming expenses since these variables are unknown at this time.
d. Potential Benefit(s):	Potential benefits are indirect and are not quantified. These may include minimized cost of potential injury to citizens, avoided lost access to government fees / taxes, reduced insurance premiums and increased property values. While indirect, these potential benefits could be quite large. For example, the "value of a statistical life" is estimated by Federal agencies as between $6 - $9 million. If the hub is responsible for avoiding one resident death, it could be cost-effective from a social perspective.

3. Project Estimated Costs:

Total (Low): $6,054,000
Total (High): $7,870,000
Summary: Design, Construction, Operations and management, .
Type:
1 Design
2 Construction
3 Operations and management

4. Project Potential Benefits

Summary: Minimized cost of potential injury, Impacts of lost access to government fees / taxes, Insurance premiums, Property Values , .
Type:
1 Minimized cost of potential injury
2 Impacts of lost access to government fees / taxes
3 Insurance premiums
4 Property Values

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total (low)	$6,054,000
Total (high)	$7,870,000

Contigency
% of total construction cost: 30%
Design
% of total construction cost: 10%
Total cost: $214,000.00
This project assumes 10% of total construction cost for engineering.
Land Acquisition
Total cost: $0
This project assumes that the City already owns the land required for this project as part of Chaves Lake redevelopment.
Construction
Total cost: $2,140,000
Cost per Square foot: $115.53
Floor Area: 20,000
Assume 20,000 square foot community center with full kitchen. Hallandale Beach's Cultural Community Center, Foster Park and OB Johnson are similar, existing buildings with floor areas of 12,500, 10,200, and 41,984, respectively.
Source: RSMeans
Operations and Management

Total:	$3,700,000	
Discount Rate	3.0%	
Annual O&M cost:	$160,000	$/year
Annual O&M cost:	$8.0	$/sf
Building Life	40	years

Source: BOMA, https://facilityexecutive.com/2016/07/boma-2016-experience-exchange-reports/

Benefits

Minimized cost of potential injury
Impacts of lost access to government fees / taxes
Insurance premiums
Property Values

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name: 11. Vulnerable Low-income Housing Improvements
Location: City-wide

2. Project Description

a. Objective: The objective of this project is to offer grants and technical assistance to low-income homeowners for flood mitigation measures for properties in the floodplain.

b. Scope: This project considers providing assistance to low-income homeowners for dry flood proofing. Wet floodproofing is not likely applicable to most homes in Hallandale Beach due to method of construction (i.e. slab on grade), with the exception of elevating service equipment, which should be considered as an eligible measure under the program. Elevation may only be cost-effective when reconstructing a home. Flood mitigation retrofits like relocation are not likely to be cost-effective. The program would require additional planning. Foremost is the need to conduct a parcel-based vulnerability assessment of residential properties in Hallandale Beach. For this concept, the number of households below the poverty line in Hallandale Beach is used as proxy. A parcel-based analysis would identify the number of residential structures vulnerable to climate change stressors. In addition, program details, including eligibility, approved flood control measures, program terms and conditions, funding sources and budget forecasts, among other considerations, must be developed. A similar program has been administered by Charlotte-Mecklenburg County Storm Water Services department. The "retroFIT" program provides financial grants reimbursing 75 to 95 percent of qualified floodproofing projects for homeowners enrolled in the County's Low Income / Disabled Veteran Homestead Exclusion program.

c. Cost(s): Total costs are estimated to range from $2.4M to $17.5M over a 10 year period. These estimates assume annual program costs ranging from $280,000 to $2M. Annual costs assume a total of 3,773 low income households are vulnerable to flood damage in the City. Since nearly all of the City is within the 500 year flood plain and all census tracts have some exposure to the 100 year flood, the cost estimates assume that all household below the poverty line would be eligible for the program. The actual number of homes is likely lower. A parcel-based residential property vulnerability assessment is required to refine this estimate. The cost of dry floodproofing for these homes may range from $9,000 to $26,000 per home, with the City's program reimbursing 75% to 95% of qualifying expenses. A program participation rate of 1% to 2% is assumed based on the nationwide experience of whole building energy efficiency retrofit programs, which are used as a proxy for participation in this program. An additional 10% of total grant value is assumed for program administration.

d. Potential Benefit(s): Since this is a grant program, direct benefits accrue to the property owner, rather than the City. Indirect benefits include minimized costs of potential injury, impacts of lost access to government fees / taxes, avoided impacts to properties, reduced insurance premiums, and increased property values. A study of flood protection in Miami Beach found that it is cost-effective for homeowners, a finding supported by FEMA.

3. Project Estimated Costs:

Total (Low):		$2,400,000
Total (High):		$17,500,000
Summary:		Operations and management
Type:		
	1	Operations and management

4. Project Potential Benefits

Summary:		Minimized cost of potential injury, Impacts of lost access to government fees / taxes, Impacts to properties, Insurance premiums, .
Type:		
	1	Minimized cost of potential injury
	2	Impacts of lost access to government fees / taxes
	3	Impacts to properties
	4	Insurance premiums

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total

Total (low)	$2,400,000	
Total (high)	$17,500,000	
Discount Rate	3%	
Project Life	10	years
Administration (low)	$25,468	
Administration (High)	$186,386	
Program Administration	10%	of annual grant total
Annual grants (Low)	$254,678	
Annual grants (High)	$1,863,862	
Annual Participation Rates (	1%	of total households below the poverty line
Annual Participation Rates (	2%	of total households below the poverty line

Source: ACEEE. (2015). Expanding the Energy Efficiency Pie: Serving More Customers, Saving More Energy Through High Program Participation

Grant Reimbursement (low)	75%	of total dry flood proofing project costs
Grant Reimbursement (high	95%	of total dry flood proofing project costs

Source: Charlotte Mecklenburg Bounty RetroFIT Program Policy Document

Dry Flood Proofing (low)	$9,000	per residential building
Dry Flood Proofing (high)	$26,000	per residential building

Source: Aerts, J. (2018) A Review of Cost Estimates for Flood Adaptation. Water.

# of vulnerable low income	3773	households below the poverty line in Hallandale Beach

Source: AccelAdapt, American Community Survey

Benefits

Minimized cost of potential injury
Impacts of lost access to government fees / taxes
Impacts to properties
Insurance premiums
Property Values

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	12. Raise Critical Roads and Bridges
Location:	Multiple

2. Project Description

a. Objective:	Improve flood resilience in the Golden Isles neighborhood by raising bridges. There are nine bridges totaling 1,067 feet in length, (0.20 miles). The existing 2-lane bridges average around 120 feet in length (including approaches), are about 25 feet wide, and sit on concrete pilings with a reinforced concrete span. Raising the bridges will protect them from flood damage, ensure continued access to the area, and allow boats to continue to pass underneath as sea levels rise.
b. Scope	Conduct an engineering feasibility study to determine if bridges can be raised or must be demolished and replaced. Assuming they are demolished and replaced, develop conceptual project design and cost estimates. Develop plan to manage traffic and provide access during bridge demolition/construction activities. Secure funding. Procure professional services for design and construction. Develop and implement an operations and maintenance plan.
c. Cost(s):	Detailed engineering surveys would be needed to determine the feasibility of elevating existing bridges, and costs for this work would be highly site specific and depend on the condition of the existing structure and other details. Conceptual level costs to demolish and replace the existing bridges are better defined and were used in this estimate. Total estimated costs range from \$8.2 to \$10 million per bridge When Management of Traffic (MOT) costs are included, the total to replace all nine bridges ranges from \$104 million (low estimate) to \$126 million (high estimate). A feasibility study will need to be done to determine what engineering options are available and develop a detailed engineering cost estimate based on the selected design. Since every bridge is different, it is difficult to model costs using comparable projects. Three sources were used to develop a range of potential costs. The lowest estimate, \$8.2 million per bridge, is based on 2017 FHWA average costs for 20 bridge projects completed in the state of Florida. The 2017 FDOT Structure Design Guidelines suggest the cost could be \$9 million per bridge,. The high estimate costs are modeled on the City of Miami Beach West Avenue Bridge, which is similar in type and span to Golden Isles Bridges but with additional lanes. This project included a prefabricated bridge span, street and pedestrian lighting, signing and pavement markings, utility relocation and drainage improvements at a cost of \$10 million under a design build contract. Management of traffic (MOT) can add 40% or more to estimated project costs in some cases. Since some parts of the Golden Isles are only accessible by a single bridge, contingencies must be made to guarantee continued access to residents during demolition and construction, which could significantly increase total costs. A 40% MOT contingency is added to each estimate.
d. Potential Benefit(s):	Potential benefits are indirect and are not quantified. These may include reduction in physical damages and/or repair costs due to SLR and storm surge flooding, reduction in travel time and vehicle operating costs due to detours, avoided lost access to government fees / taxes, reduced insurance premiums and increased property values. While difficult to quantify, potential benefits could be significant. A business case analysis for the City of Miami Beach's Stormwater Resiliency Program found that for every 1 foot in elevation nearby roads were raised, residential housing values in Miami Beach neighborhoods increased between 4.9 and 14.1 percent. Using this benchmark and conservative estimates of the value of residential housing stock in the project area, a 5% increase in housing values in Golden Isles could translate into more than \$20 million in increased property value and associated increases in City tax revenues.

3. Project Estimated Costs:

Total (Low):	$104,094,000
Total (High):	$126,000,000
Summary:	Design, Construction, Travel delay (i.e. for residents).
Type:	

1 Design
2 Construction
3 Travel delay (i.e. for residents)

4. Project Potential Benefits

Summary: Reduction in physical damages, Reduction in repair costs, Reduction in travel time costs from detours, Reduction in vehicle operating costs from detours, Impacts of lost access to government fees / taxes, Insurance premiums, Property Values .

Type:

1 Reduction in physical damages
2 Reduction in repair costs
3 Reduction in travel time costs from detours
4 Reduction in vehicle operating costs from detours
5 Impacts of lost access to government fees / taxes
6 Insurance premiums
7 Property Values

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total FHWA 2017 (low)	$	104,094,000	
Total CoMB Case Study (high)	$	126,000,000	
Total FDOT 2017 (alternate)	$	113,567,000	
Management of Traffic Contingency (		40%	
Management of Traffic (MOT) - FHWA 2017	$	29,741,034	
Management of Traffic (MOT) - CoMB Case Study	$	36,000,000	
Management of Traffic (MOT) - FDOT 2017	$	32,447,729	
Number of bridges		9	
Roadway length of bridges		0.2	miles
Area of Each bridge (including approach)		5700	sf
CoMB Case study cost	$	10,000,000	per bridge
FHWA 2017 Bridge replacement cost	$	8,261,398	per bridge
Per SF	$	118	sf
FDOT Structures manual 2017 Cost	$	9,013,258	per bridge

Source 1: https://www.fhwa.dot.gov/bridge/nbi/sd2017.cfm
Source 2: FDOT Structures Manual Vol 1
Source 3: City of Miami Beach West Avenue Bridge (Bergeron website)

Benefits

Reduction in physical damages
Reduction in repair costs
Reduction in travel time costs from detours
Reduction in vehicle operating costs from detours
Impacts of lost access to government fees / taxes
Insurance premiums
Property Values

Median residential listing price in Golden Isles	$200,000
Homes/units	2000
Existing housing stock value	$400,000,000
Value of a 5% increase in housing value	$20,000,000

Source:	Business case analysis for the City of Miami Beach's Stormwater Resiliency Program

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	15. Relocate Municipal Complex
Location:	400 South Federal Highway

2. Project Description

a. Objective:	The Municipal Complex is located in a FEMA flood zone vulnerable to extreme precipitation and storm surge, conditions exacerbated by projected sea level rise. The objective of this project is to relocate the existing Municipal Complex (City Hall and Police Station) in the future to a new location west of US 1. By relocating the Complex, the City can reduce the chances of flood damage at the facility and potential disruption of essential services to the community. Relocating the facility would allow sustainable and resilient design features to be included in the new facility. This project does not contemplate relocating the Municipal Complex in the near-term. Rather, it provides context for mid- to long-term planning for relocation as the building nears the end of its useful life.
b. Scope	This project requires conceptual planning, including establishing a project team, setting goals, and establishing the project performance requirements. This phase of effort would include evaluating the optimal time to relocate the complex, given its age, condition, operating requirements, and its relative vulnerability to flooding and storm events over time. Land acquisition and associated due diligence is likely required. Once complete, the City must procure professional services for building design and construction. This project assumes that the new municipal complex will be constructed to high performance and sustainable design standards. An operating plan also must be developed, including staffing and programming. The City must also establish and execute a plan for moving departments from the current location to the new facility once ready for occupancy.
c. Cost(s):	Project estimated costs range from $14.2 to $21.8 million. The estimate includes land acquisition, design, and construction. Long-term operations and maintenance costs are not included since they are already incurred by the present municipal complex; no incremental O&M costs are assumed. O&M costs do not include staffing and programming expenses since these variables are unknown at this time.
d. Potential Benefit(s):	Potential benefits are direct and indirect and are not quantified. Direct benefits are contingent upon avoiding physical damages and repair costs from future flooding or storm events. The municipal complex is 26 years old. Annual O&M costs tend to accelerate with age and could be significantly decreased by a new facility. Indirect benefits include may include minimized cost of potential injury and reduced insurance premiums. Outside the context of climate change vulnerability, additional benefits could include increased productivity of staff, enhanced quality of service to residents, local employment during construction, as well as other benefits associated with redevelopment of a potential site on the west side of the City.

3. Project Estimated Costs:

Total (Low):	$14,200,000	
Total (High):	$21,800,000	
Summary:	Land acquisition, Design, Construction, , .	
Type:		
	1	Land acquisition
	2	Design
	3	Construction

4. Project Potential Benefits

Summary:	Reduction in physical damages, Reduction in repair costs, Reduction in operations and management, Minimized cost of potential injury, .	
Type:		
	1	Reduction in physical damages
	2	Reduction in repair costs
	3	Reduction in operations and management
	4	Minimized cost of potential injury
	5	Insurance premiums

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total

Total (low)	$14,200,000
Total (high)	$21,800,000

Design

% of total construction cost:	10%
Total Cost High:	$1,853,800
Total cost low:	$1,184,480

This project assumes 10% of total construction cost for engineering.

Land Acquisition

Total Cost High:	$1,397,500
Total cost low:	$1,075,000
Contingency:	30%
Unit Cost	$215,000
Land Area	5

Construction

Total Cost High:	$18,538,000
Total cost Low:	$11,844,805
Police Station Total High	$8,199,500
Police Station Total Low	$5,835,135
Police Station $/sf High	$310
Police Station $/sf Low	$221
Police Station Floor Area	26,450
City Hall Total High	$10,338,500
City Hall Total Low	$6,009,670
City Hall $/sf High	$310
City Hall $/sf Low	$180
City Hall Floor Area	33,350
Current Facility Floor Area	53,500

$ / sf source high: City of Homestead: 83,841 sq ft, LEED Silver, Cat 5 hurricane, construction cost: $25,500,000

$ / sf source low: RSMeans

Operations and Management

Total annualized cost:	$0	
Discount Rate	3%	
Annual Incremental O&M cost:	$0	$/year
Annual Incremental O&M cost:	$0.0	$/sf
Building Life	40	years

Source: BOMA, https://facilityexecutive.com/2016/07/boma-2016-experience-exchange-reports/

Benefits

Reduction in physical damages
Reduction in repair costs
Reduction in operations and management
Minimized cost of potential injury
Insurance premiums

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name:	17. City Cemetery Mausoleum
Location:	809 NW 7th Avenue

2. Project Description

a. Objective:	Cemeteries are vulnerable to damage from flooding events, such as storm surge. This vulnerability is exacerbated by climate change. The City has been considering adding a community mausoleum to its cemetery. Mausoleums are free standing buildings enclosing crypts and / or columbariums with niches for cremated remains. Such facilities are considered more ecologically friendly than in-ground burials since they save on space. A mausoleum also provides an opportunity for incorporating resilient design. This objective of this project is to incorporate additional freeboard (i.e. elevation above the base flood level) into a future mausoleum design.
b. Scope	Since the majority of the Cemetery is within the 500 year floodplain, where flood insurance is recommended by not required, flood resistant design and construction (ASCE 24) does not apply. However, flood risk is changing over time as a result of climate change. To mitigate vulnerability, FEMA recommends building at least 3 feet above the base flood level. Final finished floor elevation will be determined in conjunction with further site evaluation and concept planning. A project team must be established to set goals and establish the project performance requirements. The project assumes that land acquisition is not required, since the mausoleum would be built on the current cemetery property. Once complete, the City must procure professional services for building design and construction. An operating plan also must be developed, including staffing and programming.
c. Cost(s):	The City has independently obtained a quote for design and construction of one 360 crypt mausoleum with 320 niches. The estimate ranges from \$495,000 and \$510,000. This estimate does not include sitework or permitting. To build an additional 3 feet of freeboard may cost an additional 0.25 to 1.5 percent of total construction cost per foot. A 30% contingency has been applied to this unit cost, resulting in an incremental cost of \$4,000 to \$23,000 and a total cost of \$501,000 to \$540,000. Lifecycle operations and maintenance costs are not included in this estimate since they are assumed to be minimal relative to existing cemetery operations.
d. Potential Benefit(s):	Potential benefits are direct and indirect and are not quantified. Direct benefits are contingent upon avoiding physical damages and repair costs from future flooding or storm events. U.S. cemeteries have been damaged from flooding as result of extreme precipitation and storm events in recent years. Unfortunately, damage to existing cemetery internments is essentially impossible to mitigate short of relocation, which is likely not feasible. A mausoleum would therefore be beneficial as an alternative to future in-ground burials. The mausoleum may also reduce O&M costs and increase potential revenues on a per square foot basis. Indirect benefits include avoiding loss of use of the cemetery and any associated revenue. In addition, a resilient mausoleum could reduce insurance premiums. Insurance premiums are generally lower for elevated structures.

3. Project Estimated Costs:

Total (Low):		$501,000
Total (High):		$540,000
Summary:		Design, Construction, , , .
Type:		
	1	Design
	2	Construction
	3	
	4	
	5	

4. Project Potential Benefits

Summary:		Reduction in physical damages, Reduction in repair costs, Reduction in operations and management, Impacts of lost access to government fees / taxes, .
Type:		
	1	Reduction in physical damages
	2	Reduction in repair costs
	3	Reduction in operations and management
	4	Impacts of lost access to government fees / taxes

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total (low)	$ 501,000	
Total (high)	$ 540,000	

Contigency

% of total construction cost	30%	

Design & Construction:

Incremental cost (low)	$ 4,000.00	
Incremental Cost (high)	$ 23,000.00	
Freeboard Cost (low)	0.25%	of total construction cost, per foot of freeboard
Feeboard Cost (low)	1.50%	of total construction cost, per foot of freeboard

Source: FEMA, Building Higher in Flood Zones: "Up-front costs are...0.25 to 1.5% of total construction cost for each foot of freeboard."

Flood zone	X	
ASCE 24-05 requirement	0	feet
Freeboard	3	feet
Total Freeboard	3	feet

Source: FEMA, Designing for Flood Levels above the BFE recommends freeboard required by ASCE 24-05 plus three feet for residential buildings

Low base quote:	$ 495,000
High base quote:	$ 510,000

Source: City of Hallandale Beach, email provided by Mary Francis Jeannot. Quote by Ingram Construction Company for mausoleum with 360 crypts and 320 niches.
Assume low / base design and construction to NFIP standards w/ additional freeboard

Benefits

Reduction in physical damages
Reduction in repair costs
Reduction in operations and management
Impacts of lost access to government fees / taxes
Insurance premiums

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name: 18. Check Valves for Stormwater Outfalls
Location: Stormwater outfalls (exact locations TBD)

2. Project Description

a. Objective: The objective of this project is to Install inline tidal check valves at the City's stormwater outfalls. The check valves will prevent sea water from backing up into the City's stormwater system during king tides and other events when the outfalls are below the water level, helping to prevent flooding.

b. Scope The City has already completed four check valve installations. Nine remaining outfalls could be retrofit. The project assumes nine installations using Tideflex valves or similar. The project assumes the City hires outside design services. The exact outfalls targeted for check valve retrofits, specifications and other project details will be determined at a later date by the City's stormwater design consultant/engineering staff. Valve installation includes associated basin improvements, incidental expenses, and life-cycle maintenance costs. The project requires determining the exact project scope and details, securing funding; procurement of professional services; engineering design and specification; and construction.

c. Cost(s): Total cost of installation for nine check valves, including design, outfall basin improvements and life-cycle maintenance costs, was estimated between $928,000 and $1.2 million. Costs were estimated based on the average cost the City provided for four 15 to 16" tidal valves already installed (assumed to be material only) and costs derived from Ft. Lauderdale's check valve installation program. Design costs were estimated at 10% of retrofit costs. Material cost of check valves varies by size but was estimated at $3,200 each. Installation costs including outfall basin improvements was estimated at $22,500. Incidental costs to replace landscaping surface features etc. were estimated at $1,000 per installation. Maintenance costs were estimated at $4,000 per year for each valve based on average costs from Ft. Lauderdale. Maintenance costs are included for the typical lifespan of the check valves, which is assumed to be 25 years, based on information from Ft. Lauderdale. At a 2.5% discount rate, the present value of valve maintenance costs over their lifecycle is $73,698 each and $663,278 for all nine.

d. Potential Benefit(s): Direct benefits include potential reduction in damages and repair costs due to flooding events related to king tides, sea level rise and storm surge. These benefits are not estimated because a flood-reduction model and flood cost estimation model (such as Hazus) is required. Lower maintenance costs are another potential benefit. Case studies suggest inline check valves may have lower annual maintenance costs that gate or flapper type check valves that they replace.

The project may also have numerous indirect benefits related to flood reduction, including: reduction in travel time costs from detours, reduction in vehicle operating costs from detours, reduction in pedestrian hazards, reduction in disruptions to freight movement, minimized cost of potential injury, minimized impacts of lost access to businesses, avoided loss of tax revenue, avoided impacts to properties, avoided impacts to Landscaping from salt water exposure, reduced insurance premiums, maintenance of property values and tourism revenues, and water quality/pollution control improvements.

3. Project Estimated Costs:

Total (Low): $928,000
Total (High): $1,206,000
Summary: Design, Construction, Maintenance, , .
Type:

1 Design
2 Construction
3 Maintenance

4. Project Potential Benefits

Reduction in vehicle operating costs from detours, Reduction in pedestrian hazards, Reduction in distruptions to freight movement, Minimized cost of potential injury, Impacts of lost access to businesses, Impacts of lost access to government fees / taxes, Impacts to properties, Impacts to Landscaping from salt water, Insurance premiums, Property Values , Tourism revenues, Water Quality/Pollution Control Improvement.

Summary:
Type:

1 Reduction in physical damages
2 Reduction in repair costs
3 Reduction in operations and management
4 Reduction in travel time costs from detours
5 Reduction in vehicle operating costs from detours
6 Reduction in pedestrian hazards
7 Reduction in distruptions to freight movement
8 Minimized cost of potential injury
9 Impacts of lost access to businesses
10 Impacts of lost access to government fees / taxes
11 Impacts to properties
12 Impacts to Landscaping from salt water
13 Insurance premiums
14 Property Values
15 Tourism revenues
16 Water Quality/Pollution Control Improvement

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total Cost - Low	$928,000
Total Cost - High	$1,206,000
Retrofit Cost (all 9 valves)	$240,300
PV of 25-year maintenance cost (all)	$663,278
Design Cost (10% of construction cost)	$24,030.0
Contigency (30%)	$278,400
Retrofit Cost	
Number of Outfalls included	9
Typical size of outfall pipe	16"
Valve Cost per ea. (i)	$3,200
Installation & Outfall Improvements (ii)	$22,500
Incidental Costs	$1,000
Total Retrofit Cost (ea.)	$26,700
Annual Maintenance Cost	$4,000
Discount Rate	2.5%
Lifespan of Check Valves in years	25
Present Value of maintenance cost over valve lifespan	$73,698

Source of Cost Data and Tideflex valve lifespan: Ft Lauderdale Tidal Valve Presentation
https://fsa.memberclicks.net/assets/MemberServices/Conference/AC17/05%20-%20Diaz.pdf

Benefits

Reduction in physical damages
Reduction in repair costs
Reduction in operations anc Notes:
Reduction in travel time costs from detours
Reduction in vehicle operating costs from detours
Reduction in pedestrian hazards
Reduction in distruptions to freight movement
Minimized cost of potential injury
Impacts of lost access to businesses
Impacts of lost access to government fees / taxes
Impacts to properties
Impacts to Landscaping from salt water
Insurance premiums
Property Values
Tourism revenues
Water Quality/Pollution Control Improvement

City of Hallandale Beach Vulnerability Assessment and Action Plan
Adaptation Project Summary

1. Project Identification

Project Name: 21. Northeast 12th Avenue Low Impact Development

Location: Northeast 12th Avenue between Atlantic Shores Boulevard and Hallandale Beach Boulevard

2. Project Description

a. Objective: The objective of this project is to improve stormwater drainage, reduce flood risk, and realize social and environmental benefits by incorporating Low Impact Design (LID) features into improvements along a six-tenths of a mile stretch of Northeast 12th Avenue between Atlantic Shores Blvd and Hallandale Beach Blvd. LID is development designed to maximize green space and promote natural stormwater management through the use of plants and permeable materials to minimize stormwater runoff velocity, temperature and associated pollution.

b. Scope This project considers a range of LID options. The low cost option would include rain garden features with native plants to attenuate stormwater flows. These features would cover 40% of the length of the project corridor along both sides of the road and are assumed to be 8 feet wide or less. Incremental costs are estimated for the LID features only and not for additional improvements to the roadway. The higher cost option is modelled on the City of Chicago's Pilsen Sustainable Streetscape project, which uses a variety of green infrastructure elements to increase infiltration of stormwater and reduce flooding of the roadway. These features include bioswales, rain gardens, permeable pavements and other stormwater management measures that divert up to 80 percent of the typical average annual rainfall away from the combined sewer system. High albedo (reflection) pavement surfaces reduce urban heat island effects and drought tolerant, native vegetation increases landscape and tree canopy cover to shade the right of way and provide additional stormwater filtration. This project requires further conceptual planning, including setting goals and establishing the project performance requirements. The City must procure professional services for site design and construction. The City must also establish a plan for maintenance of the LID improvements.

c. Cost(s): Total costs range between $658,000 to $4.41 million, depending on project complexity and number and type of LID options included. Design, construction, and maintenance costs can vary widely depending on the exact LID components specified. The low estimate includes rain gardens installed along the project corridor and lifetime maintenance for the LID features for 37 years. The project assumes LID features are an added component to an existing design, and costs are calculated only for the additional LID components. The project assumes improvements fall within existing rights-of-way; no land acquisition costs are included. Project construction cost is estimated at $341,688 based on a $16.05 per sf unit cost. The design cost is estimated at 10% of the construction cost at $34,169. The present value of lifetime incremental maintenance costs for the LID components compared to conventional hardscape is estimated at $282,045. The high estimate is based on total project costs for the Chicago Pilsen Sustainable Streetscape, including design. Lifetime incremental maintenance costs are not included for this option. No land acquisition costs are included.

d. Potential Benefit(s): Reduction in physical damages, Reduction in repair costs, Minimized cost of potential injury, Impacts to properties, Insurance premiums,Property Values ,Tourism revenues,Traffic calming ,Water quality improvement.

3. Project Estimated Costs:

Total (Low): $658,000
Total (High): $4,410,000
Summary: Design, Construction, Maintenance, , .
Type:

1 Design
2 Construction
3 Maintenance

4. Project Potential Benefits

Summary: Reduction in physical damages, Reduction in repair costs, Minimized cost of potential injury, Impacts to properties, Insurance premiums, Property Values , Tourism revenues, Traffic calming , Water quality improvement.
Type:

1 Reduction in physical damages
2 Reduction in repair costs
3 Minimized cost of potential injury
4 Impacts to properties
5 Insurance premiums
6 Property Values
7 Tourism revenues
8 Traffic calming
9 Water quality improvement

All costs and benefits are evaluted relative to the no-adaptation / business-as-usual option

Costs

Total		
A. Chicago Pilsen model (High)	$4,410,000	
B. Rain Garden Boxes (Low)	$658,000	
Design Costs	10%	Percent of construction costs
A. Chicago Pilsen model	Already Included	
B. Rain Garden Boxes	$34,169	
Cost Basis	0.63	Project length (miles)
A. Chicago Pilsen Project	$7,000,000	per mile
B. Rain Garden	$16.05	per sf
Rain Garden coverage percentage	40%	% coverage (both sides of road)
Construction Cost		
A. Chicago Pilsen model cost	$4,410,000	
B. Rain Garden (area)	21,289	sf (Note: Feet in a mile times project length in miles times 2 (both sides of road) times 8' width of boxes times 40% covereage)
B. Rain Garden (cost)	$341,688	
Incremental Maintenance over project life		
A. Chicago Pilsen model	Not Estimated	
B. Rain Garden		
Conventional Hardscape Maintenance cost (per sf/year)	$ 0.057	
Rain Garden Maintenance Cost (per sf/yea	$ 0.610	
Rain Garden Incremental Maintenance Cost (per sf/year)	$ 0.553	Note: Incremental cost vs. conventional. Since LID is an added feature, incremental cost is the same as the LID maintenance cost
B. Rain Garden (per year, project)	$11,773	
Project Life	37	years
Discount Rate	2.50%	
Present Value, Rain Garden Maintenance	$282,045	
Source for maintenance values	https://greenvalues.cnt.org/national/cost_detail.php	

Benefits

Reduction in physical damages
Reduction in repair costs
Minimized cost of potential injury
Impacts to properties
Insurance premiums
Property Values
Tourism revenues
Traffic calming
Water quality improvement