COASTAL RESILIENCE PARTNERSHIP
SOUTHEAST PALM BEACH COUNTY

MULTI-JURISDICTIONAL CLIMATE CHANGE VULNERABILITY ASSESSMENT

FINAL PROJECT REPORT

Prepared for the Cities of Boca Raton, Boynton Beach, Delray Beach, and Lake Worth Beach, the Towns of Highland Beach, Lantana, and Ocean Ridge, and Palm Beach County

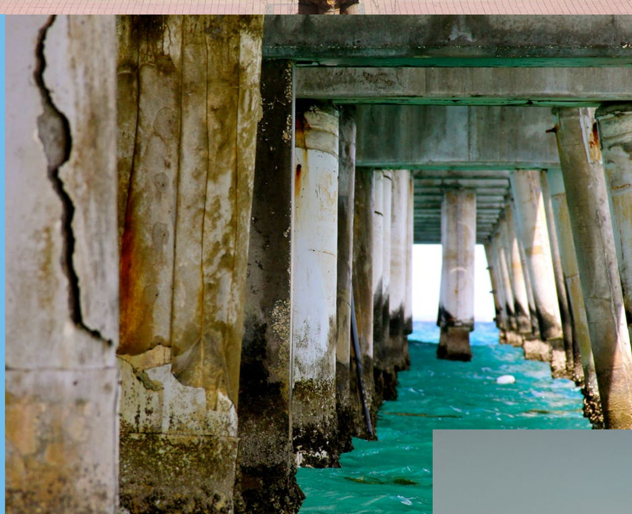
This report was funded in part, through a grant agreement from the Florida Department of Environmental Protection, Florida Resilient Coastlines Program, by a grant provided by the Florida Coastal Office. The views, statements, findings, conclusions, and recommendations expressed herein are those of the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

July 2021, Version 1.1

COASTAL RESILIENCE PARTNERSHIP
SOUTHEAST PALM BEACH COUNTY

Climate Change Vulnerability Assessment

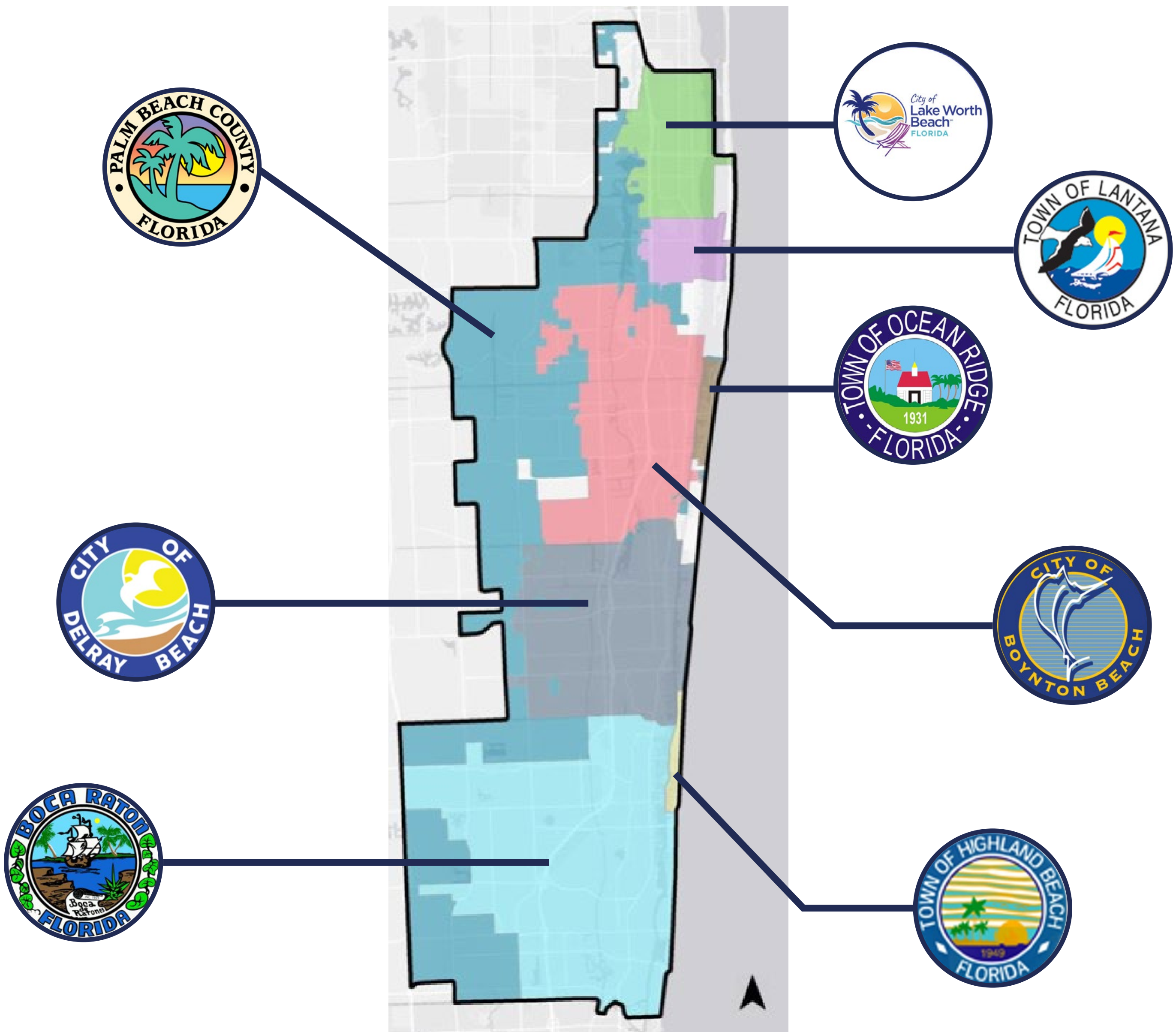
Executive Summary



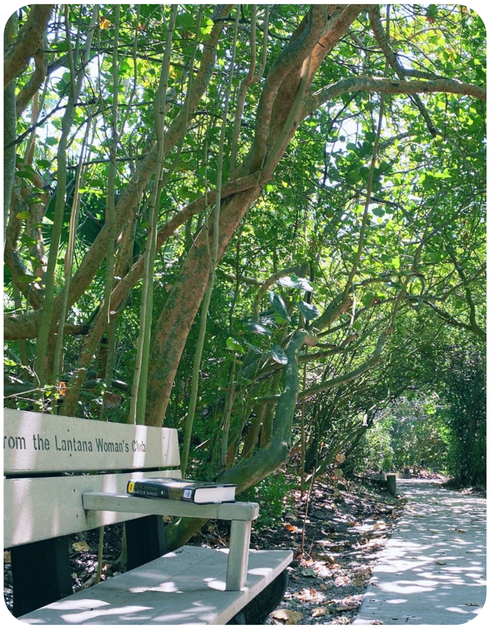
Welcome to the Coastal Resilience Partnership of Southeast Palm Beach County

The Coastal Resilience Partnership of Southeast Palm Beach County Climate Change Vulnerability Assessment is a comprehensive multi-threat assessment geared towards evaluating critical questions related to climate change throughout the southeastern portion of Palm Beach County.

COASTAL RESILIENCE PARTNERSHIP
Southeast Palm Beach County



This map represents the study area for the Coastal Resilience Partnership of Southeast Palm Beach County Climate Change Vulnerabilty Assessment



About The Coastal Resilience Partnership

Officially formed in 2019, the Coastal Resilience Partnership (CRP) of Southeast Palm Beach County consists of seven municipalities and the County working together to complete a joint Climate Change Vulnerability Assessment (CCVA) covering the geographic area shown on Page 2. The CRP fosters collaboration and cooperation in climate adaptation research and planning among jurisdictions sharing similar physical, geographic, and social characteristics in the southeast portion of Palm Beach County. All jurisdictions are vulnerable to climate change; however, levels of vulnerability to future conditions vary across jurisdictions and over time. Notably, all jurisdictions rely on each other for critical services, such as emergency shelter. For these reasons, the ultimate goal of the CRP of Southeast Palm Beach County and the joint effort in this CCVA is to install, inform, and implement long-term resilience and adaptation strategies into all participating local governments.

Coastal Resilience Partnership Logo Explanation

The eight smaller leaves represent the local governments in the Coastal Resilience Partnership.

The three bigger leaves represent the communities' similar physical, geographic, and social characteristics.

The mangrove is a nod to the importance of nature and the region's unique natural resources and how they enhance the local economy.

Water is a tremendous resource to our region but is also a threat.
Sea level rise is the most apparent sign of climate change in the region.

What is a Climate Change Vulnerability Assessment?

A vulnerability assessment provides a foundational understanding of the risks a certain community, place, or asset faces as it relates to specific threats. For this particular CCVA, 12 climate threats were identified. To determine vulnerability, sophisticated modeling, and data analysis were utilized to assess the specific properties, locations, and components within the community that may be at risk of experiencing any of the climate threats identified as part of this study. Once each facility or asset is intersected with the location of extreme events, the vulnerability of all public infrastructure, private property, and social and natural assets may be defined.

It is also crucial to note the importance of vulnerable populations and socioeconomics superimposed on these threats. Socioeconomics were considered throughout this assessment, and the outcome of various vulnerable populations is a critical aspect of this study. Furthermore, sea level rise is a multiplier for many of the threats that the CRP is interested in. Sea level rise is not considered as a threat itself, but as a stressor that exacerbates several of the threats assessed in the CCVA. Threats that are heavily influenced by sea level rise include storm surge, tidal flooding, groundwater inundation, saltwater intrusion, rainfall-induced flooding, and shoreline recession.

Climate Change Impacts 101

Climate is referred to as the usual weather conditions expected for a particular location. Climate change is the change in those usual weather conditions, such as how much rain a location will receive or the average temperature. Increased greenhouse gas emissions by humans is causing changes in our climate on a global scale.

With warmer temperatures, climate threats such as those explored in this study begin to increase in intensity, frequency, or size.

Tidal flooding can cause temporary interruptions in day-to-day activities through flooding of streets with saltwater and backwatering of storm sewer systems that prevent drainage.

Stronger winds may destroy infrastructure and other physical assets.

Extreme heat is a pressing public health risk and may impact frontline communities disproportionately.

More frequent flooding through rainfall, storms, and tides may also exacerbate other threats that involve flooding and will negatively impact infrastructure, stormwater maintenance, and land use.

Sea level rise and high winds may exacerbate shoreline erosion and starve beaches of sediment.

Key Terminology

Below are some key terms that you will see throughout this report

Adaptive Capacity - The ability of an asset to adjust or cope in response to hazards

Assets - The core systems of each jurisdiction: the specific property classes, services, economic strengths, people/socioeconomics, and infrastructure located throughout these communities

Census Tract Scale - A geographic area utilized by the US Census Bureau for data collection and assessment

Climate Threats - Major hazard events or chronic disruptions that negatively impact community assets

Exposure Mapping - Spatially analyzing where assets are in harm's way

Frontline Communities - Communities that will feel the impacts of climate change first and hardest

Sensitivity - The range or magnitude of how much an asset may be hurt by a threat

Social Equity - The ability for all members of the community to equally prosper through collective planning and action

Potential Impacts - How assets are affected by threats due to their sensitivity

Risk - Both threat and asset characteristics used to indicate levels of probability of a particular climate event and its associated consequence

Vulnerability - The output of an analysis and its evaluation of the intersection of various asset characteristics used to indicate levels of sensitivity, potential impact, and adaptive capacity

The Assessment Process

As part of the assessment, the team utilized the recently released *Unified Sea Level Rise Projections in Southeast Florida 2019 Update* executed by the Southeast Florida Regional Climate Change Compact's Sea Level Rise Ad Hoc Work Group, specifically using the 2040 and 2070 projections. For the purpose of this assessment, the 2040 and 2070 projections and findings can also be interpreted as "+5" Sea Level Rise" (SLR) as the low-end projection for 2040 (IPCC Median), "+13" SLR" as the high-end projection for 2040 (NOAA High) and low-end projection for 2070 (IPCC Median), and "+33'' SLR" as the moderately high-end projection for 2070 (NOAA Intermediate High). Three main types of analysis were undertaken: narrative analysis, spatial analysis, and hybrid analysis. Narrative analysis consists primarily of literature review and review of relevant reports to the risk assessment. Narrative analyses were performed for drought, groundwater inundation, pest and disease, saltwater intrusion, and wildfire risks. Spatial analysis consists of reviewing spatial and/or numerical datasets relevant to the risk assessment and utilizes robust modeling to identify the intersections among various components of vulnerability and risk. Spatial analyses were performed on high winds, rainfall-induced flooding, storm surge, and tidal flooding threats. A hybrid analysis consists of both literature review and review of spatial and/or numerical datasets relevant to the risk assessment. Hybrid analyses were performed on harmful algal blooms (HABs), extreme heat, and shoreline recession.

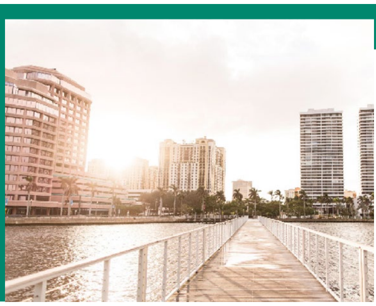
For the spatial analysis assessments, the vulnerability and risk assessment components were applied at the asset scale. For example, commercial property and tidal flooding were assessed at the parcel or property level. A data-driven technique with rulesets developed by the project team was based on factors consistent with the framework concepts. Classifications of vulnerability and risk were assigned using data attributes and spatial analysis. Most asset-threat pairs were assessed through vulnerability and risk (rainfall-induced flooding, tidal flooding, storm surge); however, a few threats were assessed only for vulnerability (high winds, extreme heat, shoreline recession). Due to data limitations, some threats were not spatially analyzed on an asset scale. Harmful algal blooms, drought, wildfire, pest and disease, groundwater flooding, and saltwater intrusion were all primarily narrative-based threat assessments.

Overview of Climate Threats

This section summarizes the threats that were analyzed for the CCVA. For the purposes of this study, threats are defined as major hazard events or chronic disruptions that negatively impact community assets. The interconnections among threats, as well as socioeconomic factors affecting each asset-threat pair, are stressed throughout the study.

Drought

A period of persistent dry weather that occurs long enough to cause environmental and public health challenges. Climate stressors that worsen droughts include increased global temperatures, increased evapotranspiration, and changing rainfall patterns. Non-climate stressors such as increases in freshwater consumption can also worsen the impact of droughts on a population.



Extreme Heat

Extreme heat is a pressing public health risk, particularly for socio economically disadvantaged and elderly communities living in developed areas with low tree canopy cover. In many heavily developed areas, man-made structures such as buildings and roadways trap heat and contribute to what is known as the Heat Island Effect. Extreme heat is a serious threat in South Florida, where it can worsen air quality, exacerbate public health issues, negatively impact crop production, and increase stress on the local economy.

Harmful Algal Blooms

Harmful algal blooms are a complex ecological process that is accelerated by several factors related to climate change. Increased urbanization has accelerated and intensified nutrient loads to water bodies throughout Florida. Southeast Palm Beach County is no exception. This nutrient loading, paired with warmer waters related to climate change and other complex factors, can cause specific species of algae to grow out of control and produce toxins that can harm people, fish, shellfish, marine mammals, and birds. Non-climate stressors that can worsen harmful algal blooms include both human-induced and natural hydrologic alterations, as well as additional pollutants in runoff.

High Winds

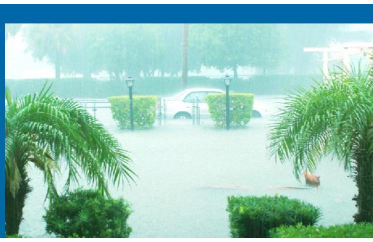
Here in South Florida, high winds from tropical systems or hurricanes are prevalent threats that can lead to numerous issues including power outages, disruptions to roadways and transportation, and damage to infrastructure, including critical infrastructure in particular. Hurricanes can be catastrophic events significantly impacting communities. Due to climate change, the strongest hurricanes (Category 3-5) are expected to increase in frequency. Non-climate stressors that magnify the threat of high winds include changes to building conditions, such as wind load criteria, and less resilient landscaping.

Groundwater Inundation

This type of flooding occurs when there is a rise in groundwater, which is generally associated with a rise in sea level. In addition to sea level rise, other climate stressors include changes in precipitation patterns that result in an increase in the amount of water present at any given time. Non-climate stressors that worsen groundwater inundation include both the land subsidence, or the settling of land, and the potential need to fix or repair large-scale stormwater management systems.

Pest & Disease Outbreaks

A pest outbreak is when a destructive insect or other animal population dramatically increases and heightens the potential threat of illnesses. Pest outbreaks also affect crops and the ability to produce healthy and sellable food commodities. Whereas pest outbreaks are a rapid increase in an insect's population, disease outbreaks are sudden increases in a particular illness that is carried or spread. Climate stressors that exacerbate this problem include extreme heat and changes in rainfall patterns. Additionally, non-climate stressors include rapid population growth, urbanization, and densification.

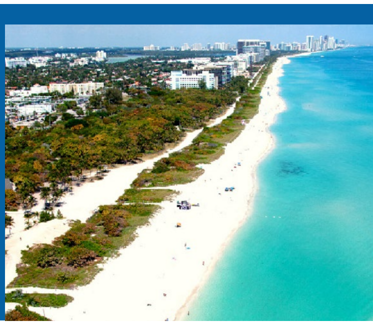


Rainfall-Induced Flooding

Changes in rainfall patterns can cause flooding on normally dry land, which can be exacerbated by sea level rise. Non-climate stressors that further increase challenges related to rainfall-induced flooding include aging infrastructure, floodplain alterations, increases in impervious structures, and maintenance issues concerning stormwater infrastructure.

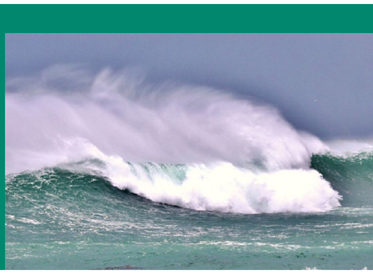
Saltwater Intrusion

As sea level rises, the fresh water-saltwater interface (or boundary) moves further inland and closer to the water supply wells, leading to water-quality deterioration. Saltwater intrusion is a serious threat, and the associated non-climate stressors include changes to large-scale stormwater management systems and changes in the amount of water taken from the aquifer.



Shoreline Recession

This threat occurs when waves and currents remove sand from the beach system by carrying it permanently offshore. This movement and removal of sand leads to a narrower beach and lower elevation, ultimately leaving coastal properties and infrastructure vulnerable to future storms. Sea level rise will exacerbate shoreline recession. Similar to other threats, with eroded beaches and a lack of shoreline, there will be an influx of problems, including further impacts to infrastructure, changes to design and development in high-risk coastal areas, and changes to Level of Service (LOS) requirements.



Storm Surge

As sea level rises, there will be an excess of water coming onto land. Coastal flooding caused by an abnormal rise in the tide from a storm or hurricane will push water further inland and increase the water level well above the natural tide. A climate stressor that further fuels problematic storm surge is the presence of more frequent and stronger storms. Non-climate stressors that exacerbate the hazards associated include increased development in high-risk coastal areas and aging infrastructure.

Tidal Flooding

Tidal flooding is defined by exceptionally high-tidal events that result in the temporary inundation of low-lying areas. This occurs when an increase in water levels causes water to overtop seawalls and flow onto coastal lands. Sea level rise will increase the frequency and intensity of tidal flooding. Non-climate stressors that exacerbate tidal flooding hazards include aging infrastructure and drainage systems that were designed for previous conditions.

Wildfire

Although much of the region is urbanized, wildfires can still impact Southeast Palm Beach County. This threat is examined through the potential for wildfire in the wildland urban interface and its impact on communities, including homes and the critical services people rely on. Wildfires have the ability to significantly damage critical and delicate ecosystems as well as urbanized communities. With wildfires present, air quality greatly diminishes, and infrastructure becomes vulnerable. Climate-related stressors that worsen wildfire conditions include: temperature increase, which can increase drought, precipitation variability, and lightning frequency.

Overview of Assets

Assets relate to the core systems of each jurisdiction – the specific property classes, services, economic strengths, and infrastructure located throughout these communities.

Critical Facilities

These are lifeline facilities that are pivotal to communities because they provide crucial services that ensure the smooth function of everyday life. To consider the range of assets within this theme, the following asset categories will be used: Public Safety, Food, Water, Shelter, Health and Medical, Energy and Communications, and Government Facilities (including all schools).

Water Infrastructure

Water infrastructure facilities are a critical aspect to societies, as individuals rely heavily upon the distribution of clean and safe water, the proper management of drainage systems, and the continual protection of water quality. Within water infrastructure, the asset categories are Wastewater Treatment Facilities and Collection Systems, Water Treatment Facilities and Distribution Systems, Stormwater Treatment, Conveyance, Treatment Systems, and Septic Tanks. Green infrastructure also falls within this asset category, and for the purposes of this study, some green infrastructure (swales, bioswales, retention/detention ponds, etc.) are included within the category of stormwater.

Economic Factors

A prospering society depends on businesses staying open and continuing to contribute to the overall economy. Economic factors are important for the assessment to consider, especially as they relate to the potential for business disruption. This asset theme will consider the two main economic factors through the following asset categories: Annual Sales Volumes and Jobs. The assessment will provide insights into how the vulnerability of properties and business locations translates to potential disruptions to sales and jobs.

Natural Resources

Natural resource assets are critical to the region in how they support recreation and tourism and provide ecosystem services. These assets are also critical in how they mitigate threats, such as flooding and extreme heat. The following asset categories will be considered within this theme: Beaches, Coastal Areas, Natural Areas, and Parks (including water resources).

People & Socioeconomics

This asset theme can be defined as socially vulnerable populations that may be disproportionately vulnerable to climate threats. The Centers for Disease Control and Prevention, (CDC), classifies social vulnerability through a number of factors, including but not limited to socioeconomic status, housing and transportation, and household composition. These communities may be affected by external stressors that impact human health and productivity, such as pandemics and extreme weather. This theme includes the following asset categories: Social Vulnerability, Food SNAP Retailers, and Public Housing.

Property

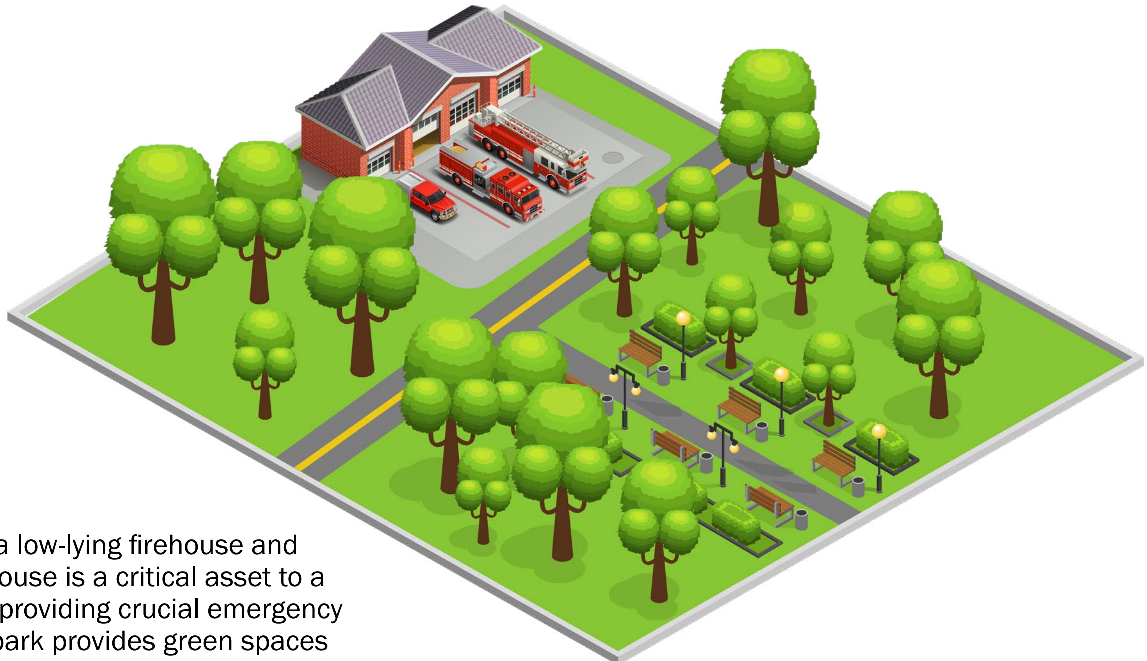
For this asset theme, commercial, cultural, and residential properties are analyzed to determine the likelihood of climate threats influencing or burdening properties. This can be amplified when socially vulnerable communities intersect with physically vulnerable properties. The following asset categories that fall within this theme are Commercial (including industrial), Cultural, and Residential.

Transportation & Mobility

The ability to move and be mobile as a community is pivotal to the continued flow of everyday life. Particularly in Florida, roadways and other major transportation facilities are inherently vulnerable to climate threats such as flooding because of their relatively low elevation. Asset categories within this theme are Roads (major and minor) and Railways, Bridges, and Transportation Facilities.

Vulnerability Explained

Vulnerability not only looks at exposure, but also how sensitive an asset is to a threat. It is also important to understand how easily an asset can change or adapt.



Here we have a low-lying firehouse and park. The firehouse is a critical asset to a community by providing crucial emergency services. The park provides green spaces and opportunities for recreation.

Even if both have the same exposure, a low-lying firehouse is more vulnerable than a park. A few inches of water can significantly disrupt a firehouse, while a park flooding a few inches will likely not cause damage or significant long-term disruptions.

Assessing Asset-Threat Pairs

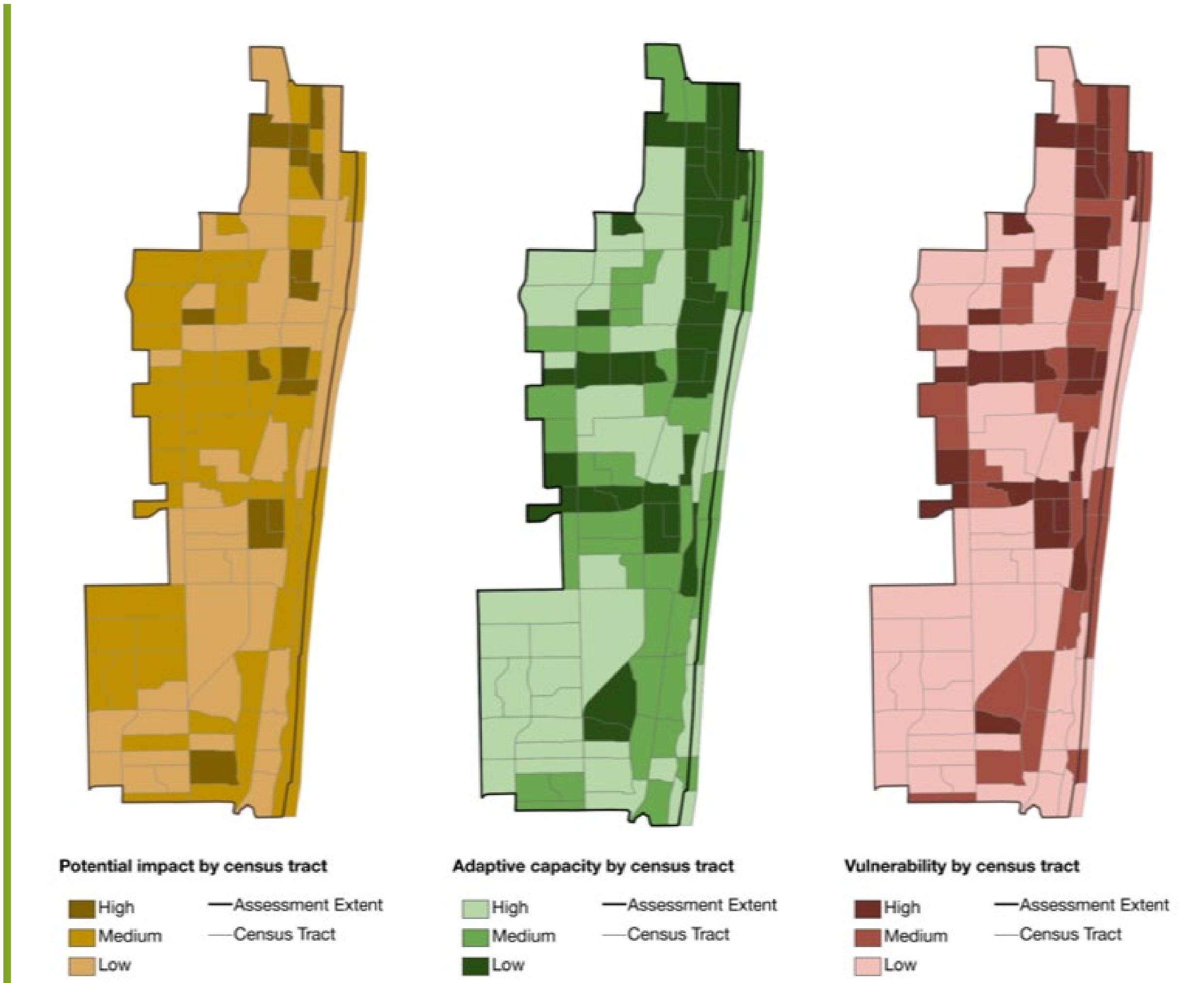
The project team applied a vulnerability and risk assessment framework to the threats and assets that were identified. These are referred to as asset-threat pairs and each was evaluated separately, even though some threats may also be interrelated (e.g., rainfall-induced flooding and tidal flooding). These asset-threat pairs are important for the assessment to inform asset-specific insights regarding the impacts from climate threats. (For example impacts to a commercial corridor are inherently different from the impacts to a residential neighborhood.)

In turn, these insights allow the CRP to develop adaptation strategies that are tailored to address the specific types and locations of vulnerabilities across the jurisdictions. For most asset-threat pairs, the vulnerability and risk assessment components will be applied at the asset scale. Below is an example of how the project team assessed an asset-threat pair.

Extreme Heat

Extreme heat was assessed on the census tract scale. Below are maps of the two inputs – potential impact and adaptive capacity – and the resulting vulnerability output map. Areas with low adaptive capacity have less tree canopy and higher socioeconomic vulnerability. Areas with high potential impact have a high number of sensitive populations, such as those older than 65 or under 18, and a high percentage of developed land. The most vulnerable areas (darker red) in the right-most map represent the intersection of those two factors. Interestingly, every CRP jurisdiction includes one or more census tracts with at least medium vulnerability to extreme heat. For the entire study area, the census tracts with medium or high vulnerability include the following sensitive populations:

- 33,900 households with members 65 years of age or older
- 18,400 households with members under 18 years of age
- 85,715 households below the poverty line, or about 48% of the regional households.



Summary of Regional Vulnerability and Risk

The following is an overview of some of the key regional findings from the assessment.

- Residential properties are vulnerable to all types of flooding: rainfall-induced, tidal, and storm surge. The vulnerability is driven by many factors, including but not limited to coastal proximity, density of development/imperviousness, whether it was built before base flood elevation (BFE) requirements were in place, and impacts to floodplains/native hydrology.
- Critical facilities are often vulnerable to multiple threats (e.g., high winds and flooding).
- Road access is the most widespread vulnerability associated with future tidal flooding.
- Socioeconomic disparities within the region indicate people in certain areas will be disproportionately impacted by climate threats (especially by extreme heat, high winds, and rainfall-induced flooding).
- Sea level rise and climate change will exacerbate existing threats and present new challenges to the region.
- Most climate threats are interconnected.

Findings from the assessment also suggest three main types of vulnerabilities for the CRP to consider in the development and prioritization of adaptation strategies.

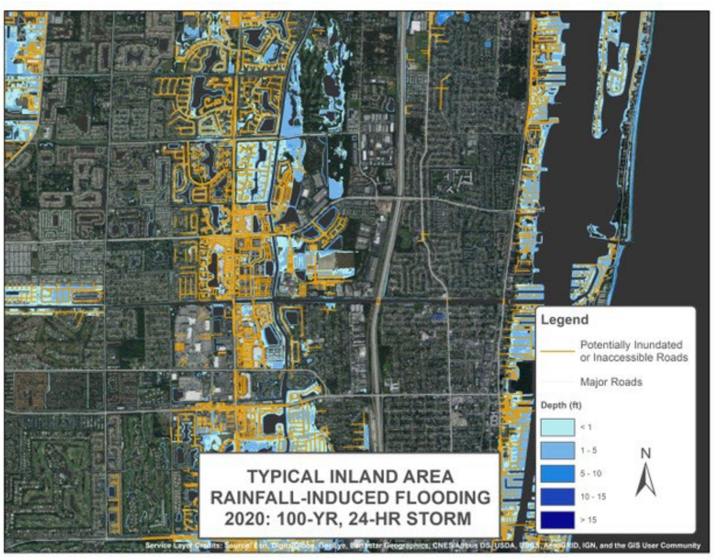
- Near-term vulnerabilities: These threats include rainfall-induced flooding, extreme heat, and tidal flooding.
- Mid to long-term vulnerabilities associated with future conditions and change: Future tidal flooding, groundwater inundation, shoreline recession, drought, and harmful algal blooms.
- High-impact event vulnerabilities: Rainfall-induced flooding, storm surge, high winds.

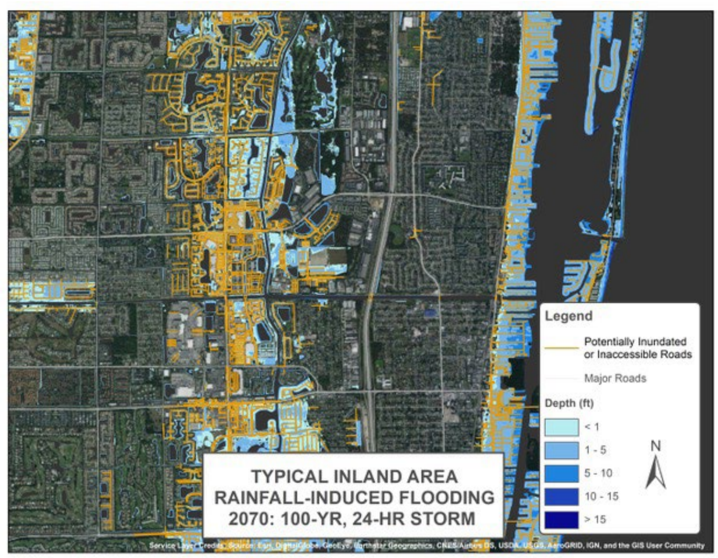
Tidal Flooding

The study revealed a substantial number of waterfront properties across the CRP region are exposed and vulnerable to tidal flooding under existing and all sea level rise (SLR) conditions. This includes neighborhoods as far as two miles from the coast, because increased water levels are pushed up the canal systems that connect these neighborhoods to the Lake Worth Lagoon and Intracoastal Waterway. None of the flooding depicted in the tidal conditions under SLR seems to be a hazard in and of itself. However, if rain-induced or storm surge events were to take place during King Tide events in future sea level rise conditions, then the effects of flooding would be significantly exacerbated.

Rainfall-Induced Flooding

The threat of rainfall-induced flooding presents the greatest exposure and highest levels of vulnerability and risk of all flooding threats assessed in this regional study. Both inland and coastal areas are vulnerable to rainfall-induced flooding. One key insight from this threat assessment is the extent to which assets are vulnerable to the 500-year flood event. While the 500-year event has a lower relative likelihood or risk probability compared to the 100-year or 25-year event, it is one to which the CRP is especially vulnerable. The 500-year inundation mapping and assessment result shows that, of the nearly 73,000 properties in the region that are exposed to the potential for rainfall-induced flooding, only about 36% are found within the current regulatory floodplain extent - the other 64% being outside the current regulatory extent (based on the 2017 FEMA study).

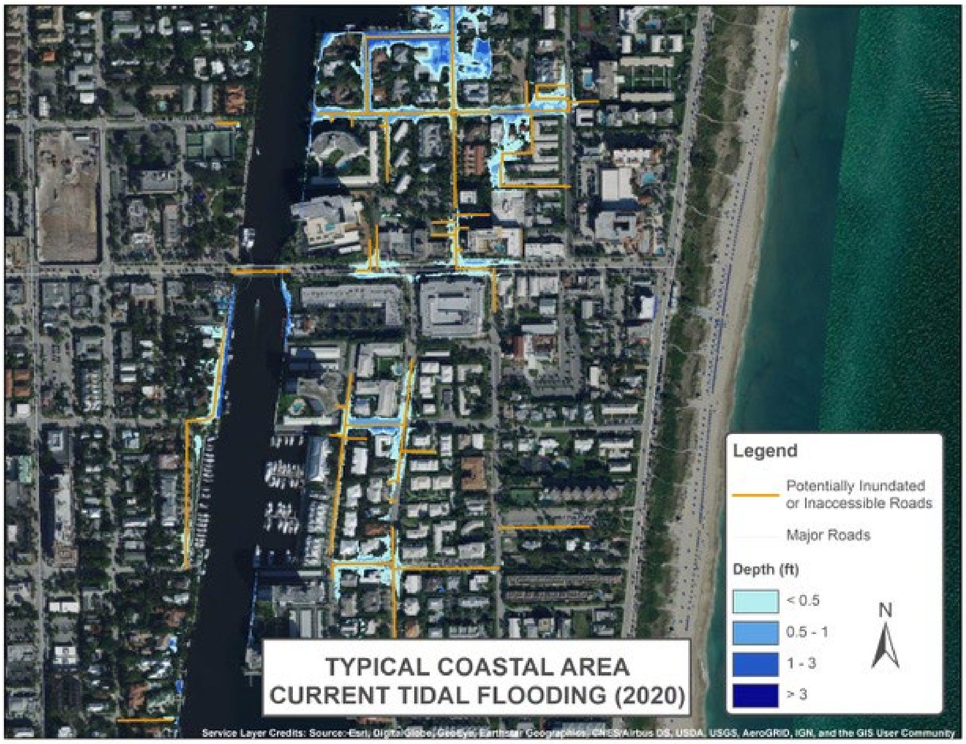


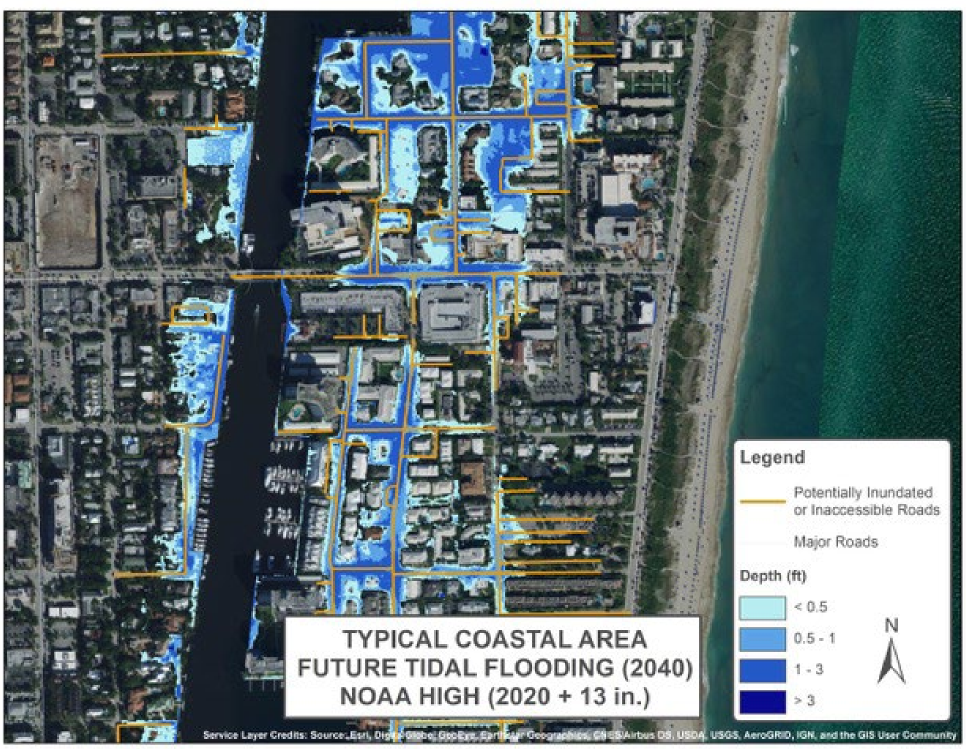


Comparisons of the existing (2020) rainfall-induced flooding and the future (2070) rainfall-induced flooding were assessed for the 100-year, 24-hr storm. The increase in flood extents appears to remain approximately the same, but the depth of inundation increases with the future storm.

TIDAL FLOODING EXAMPLE

Tidal flooding is of top importance and special interest to coastal communities that are already frequently experiencing the impacts associated with this type of flooding. For the purposes of this assessment, tidal flooding may also be referred to as tidal inundation. The comparison of the existing (2020) tidal flooding and the future (2040) NOAA High tidal flooding (+13" SLR from 2020) were assessed and represented in the maps below. The increase in flood extents and depths are seen here. Greater lengths of roadway are affected as well. It is important to understand access concerns with tidal flooding, as many of the barrier island communities have limited-access roadways off the barrier island. Flooding in neighboring communities may significantly impact access requiring regional coordination.



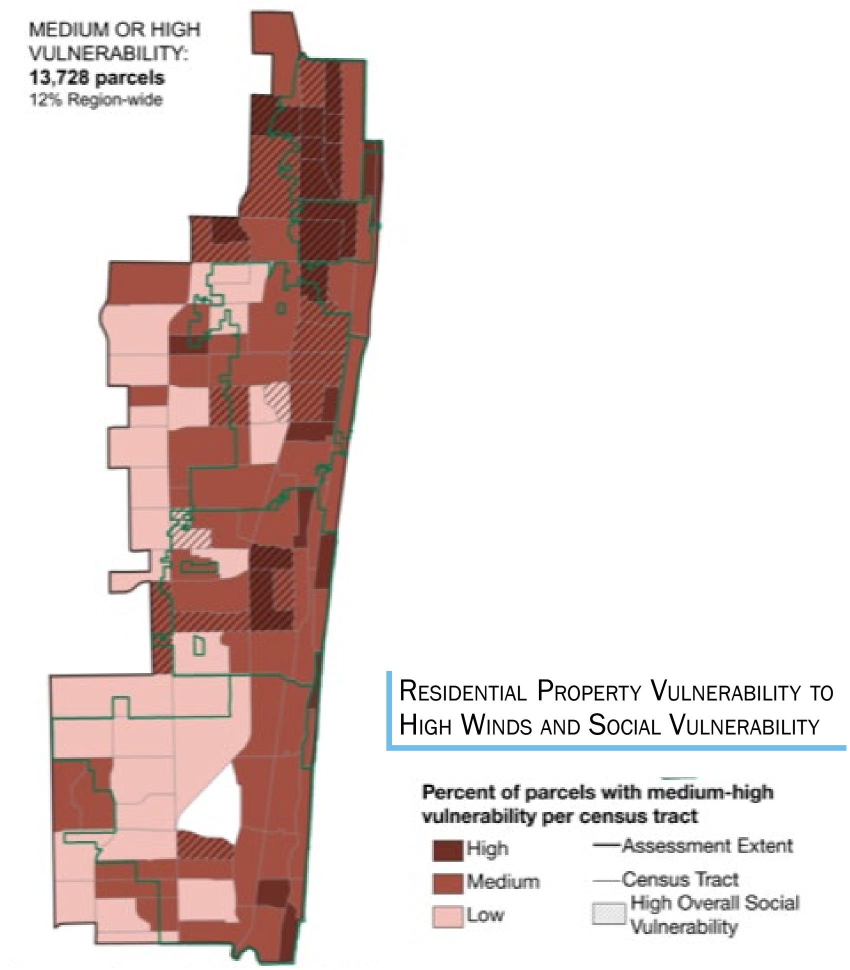


High Winds

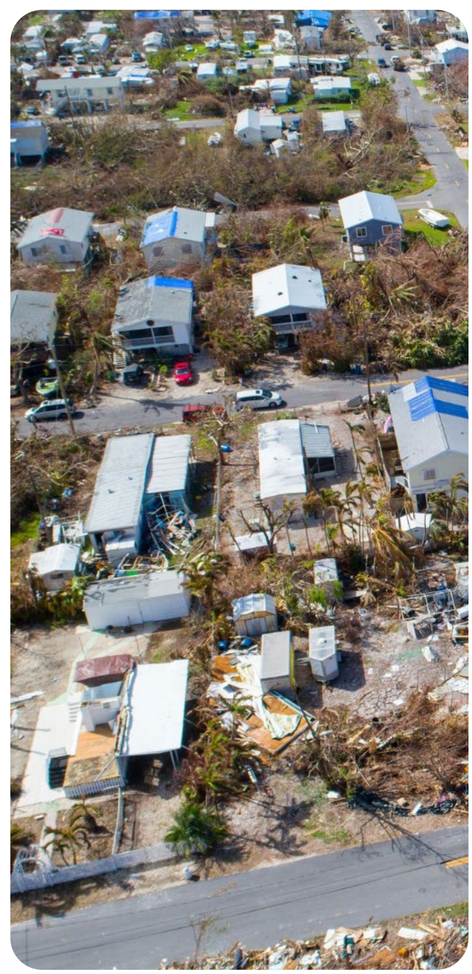
Sustained high winds are typically associated with tropical storms in Southeast Florida and can substantially damage or destroy infrastructure and assets. As our climate changes, the strongest and most damaging tropical systems (Category 3-5 hurricanes) are anticipated to occur more often. For this study, a property-level screening assessment was developed in order to estimate vulnerability. This property-level screening assessment shows properties that may be more vulnerable to high winds based on use type and relevant wind-related building design regulations at the time the primary structure was built. For this assessment, multi-residential and multi-business properties were considered to have a greater potential impact to the threat of high winds. The following property types are considered to be highly sensitive to high winds:

- Multi-residences (due to a great number of people potentially affected)
- Mobile homes
- Assisted housing
- Critical use (fire/police, safety response, electric utility, communications)
- Multi-commercial (multiple retail business locations)

- Health & Medical and Energy & Comms have the highest percentages of vulnerability (largely due to the year of construction).
- About 12% of the residential properties in the region have medium or high vulnerability to high winds. About 9% of all residential properties in the region were constructed before the first building code in 1974.
- About 37% of residential properties in the region were constructed since 1995. The percentage of residential property vulnerability also varies across jurisdictions (from about 5% to 58%).
- Vulnerability to the threat of high winds has a high co-occurrence with socially vulnerable populations. Of the 22 most vulnerable residential areas, 18 are also among the most socially vulnerable.



Residential Property Vulnerability to High Winds and Social Vulnerability



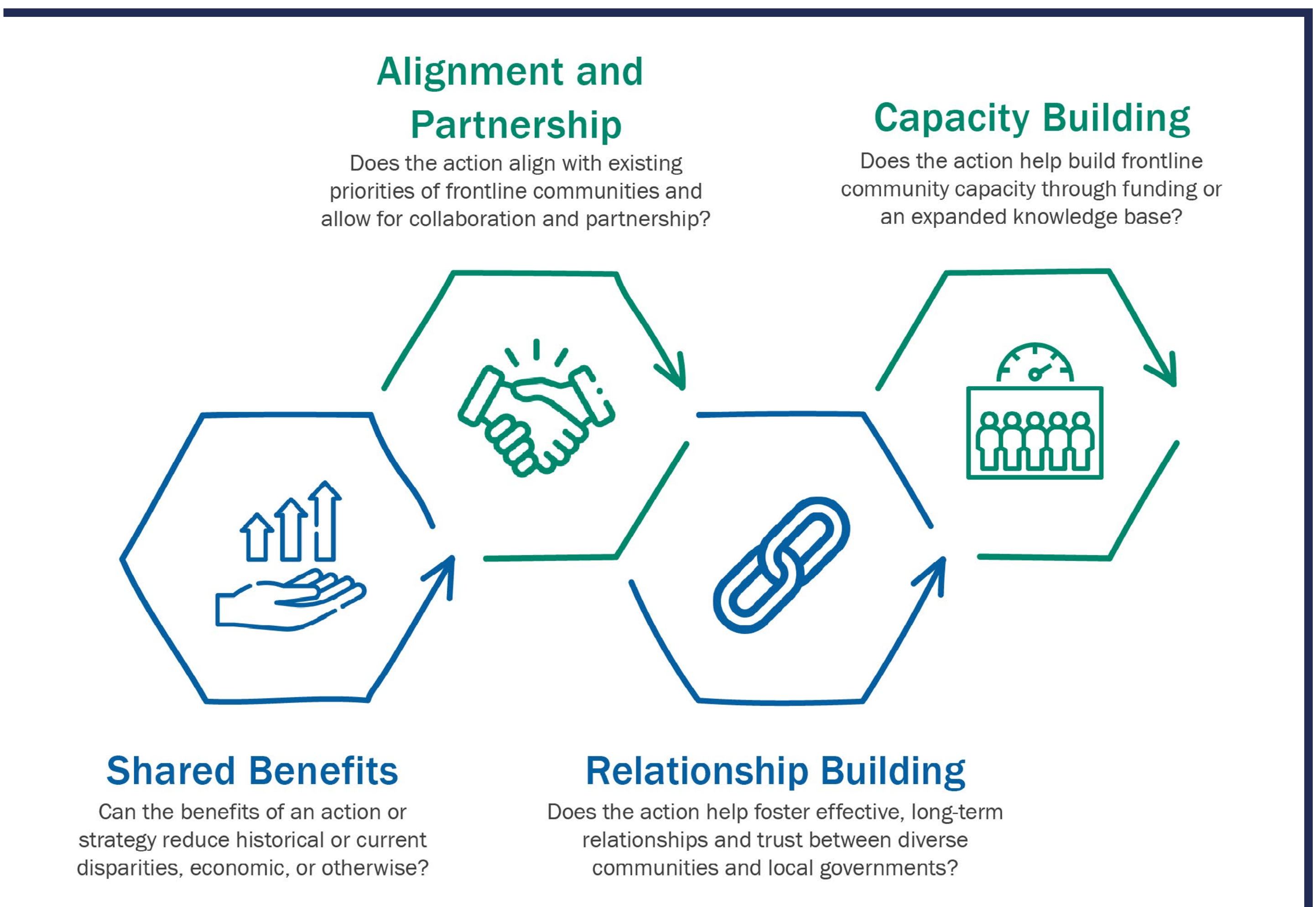
Social Vulnerability and Social Equity

The assessment recognizes that socially vulnerable populations are disproportionately impacted by climate threats. Therefore, social vulnerability and equity are foundational to the methodology and insights of the assessment and were weighted as crucial factors in the development of adaptation strategies. The complexities that arise in relation to social vulnerability and equity also call for a multifaceted approach when building resilience and adaptation.

Within the context of adaptation planning and implementation, equity has two main dimensions: 1) Procedural Equity and 2) Substantive Equitable Outcomes. Procedural equity is about ensuring that overburdened and underrepresented communities have a meaningful voice in the early stages of planning and formulation of adaptation strategies, as well as during implementation and monitoring of those strategies. This means that long-term community engagement objectives should go beyond awareness and education to include building trusting relationships and providing true opportunities to shape decision-making. Equitable involvement of the community is not enough by itself. Adaptation strategies should be designed to achieve substantive equitable outcomes by prioritizing investments in communities experiencing disproportionate impacts, addressing the root causes of disparities, and building social cohesion.

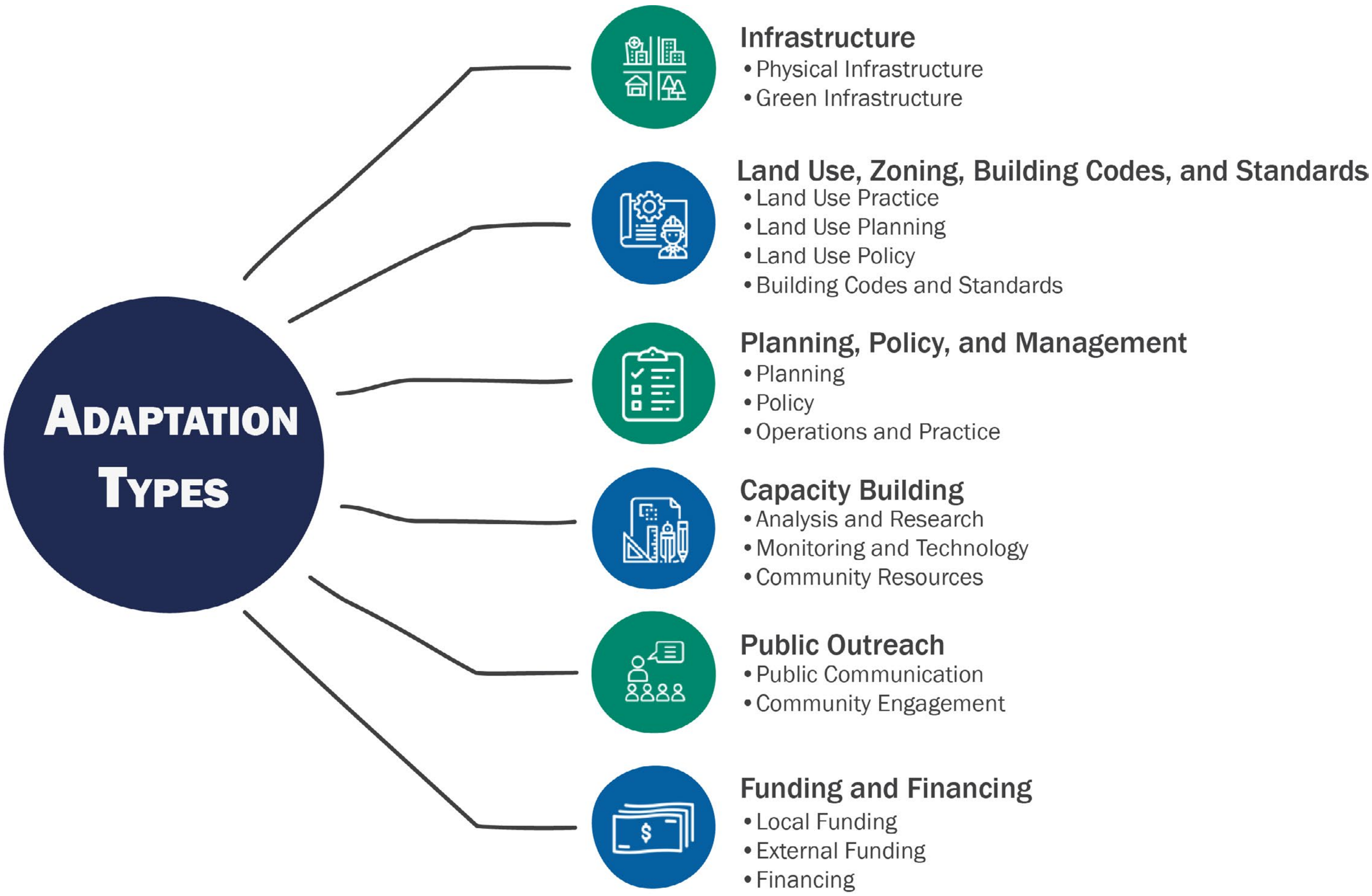
Major Features of Equitable Adaptation Strategies

When considering equitable adaptation strategies, the assessment team utilized the framework developed in the *City of Portland and Multnomah County Climate Action Through Equity Report*. The graphic below highlights some of the features in that framework that were taken into account when identifying and selecting adaptation strategies. Additional considerations include designing strategies that promote economic opportunity and workforce development, devising accountability metrics that ensure vulnerable communities are not disproportionately harmed by an action, and ensuring benefits of a strategy are broadly accessible.



Adaptation Types

To effectively address the climate threats studied in this CCVA, it will be important for the region and local governments to develop and implement a diverse set of adaptation and mitigation strategies. Through a climate change lens, adaptation entails changing or creating a new way of functioning to suit changing environmental conditions. Mitigation may be defined as actions that reduce the severity of an event and minimize the potential impacts. While adaptation strategies are emphasized, mitigation options were also taken into account. Below you will find the six major adaptation categories that the CRP has considered.



Adaptation Types Explained

Infrastructure

Engineering standards and current paradigms of design need to address policy that affects the design, construction, maintenance, operations, and entire life cycle of infrastructure with climate change in mind. Within this category exists both gray infrastructure, such as seawalls and stormwater drainage systems, and green infrastructure, such as living shorelines and bioswales. Incorporating a combination of these types of infrastructure will greatly increase resilience and reduce the impacts of climate change.

Land Use, Zoning, Building Codes, and Standards

Building codes and standards regulate how a building should be built, and in the future, climate change must be a key consideration for these codes. Adaptation strategies discussed here examine land use and zoning, building codes, and standards associated with land use. These actions generally include modifying or implementing new land use management policies, integrating climate into land use planning, and actions that modifying policies related to how land will be used and where development can occur. One such land use authority local governments can utilize is Adaptation Action Areas (AAA).

Planning, Policy, and Management

Adaptation strategies in this category generally examine the future needs of the community, and those that are not specific to land use. Many of these policies correspond to how a local government plans and operates. These actions integrate climate into existing planning processes, such as those focused on creating new regulations or revising existing regulations (other than those related to land use), as well as actions that change operations, management, and programs that include the impacts of climate change.

Capacity Building

Capacity building is defined here as actions, investments, and other activities that grow an entity's capability to identify, assess, and implement actions for adaptation and building resilience. These capacity strategies can come in a variety of forms but generally fall into the following areas: external partnerships, analysis and research, monitoring and technology, community resources, and City/Town staff capacity.

Public Outreach

An overarching approach to public outreach aims to gain public support for the suggested adaptation strategies, and also build public understanding of the intricacies among flooding, property concerns, adaptation implementation, and more. Navigating the public's current perceptions, reframing the conversation on resilience and adaptation, and building approachability to these topics are essential facets to effectively engaging members of the public.

Funding and Financing

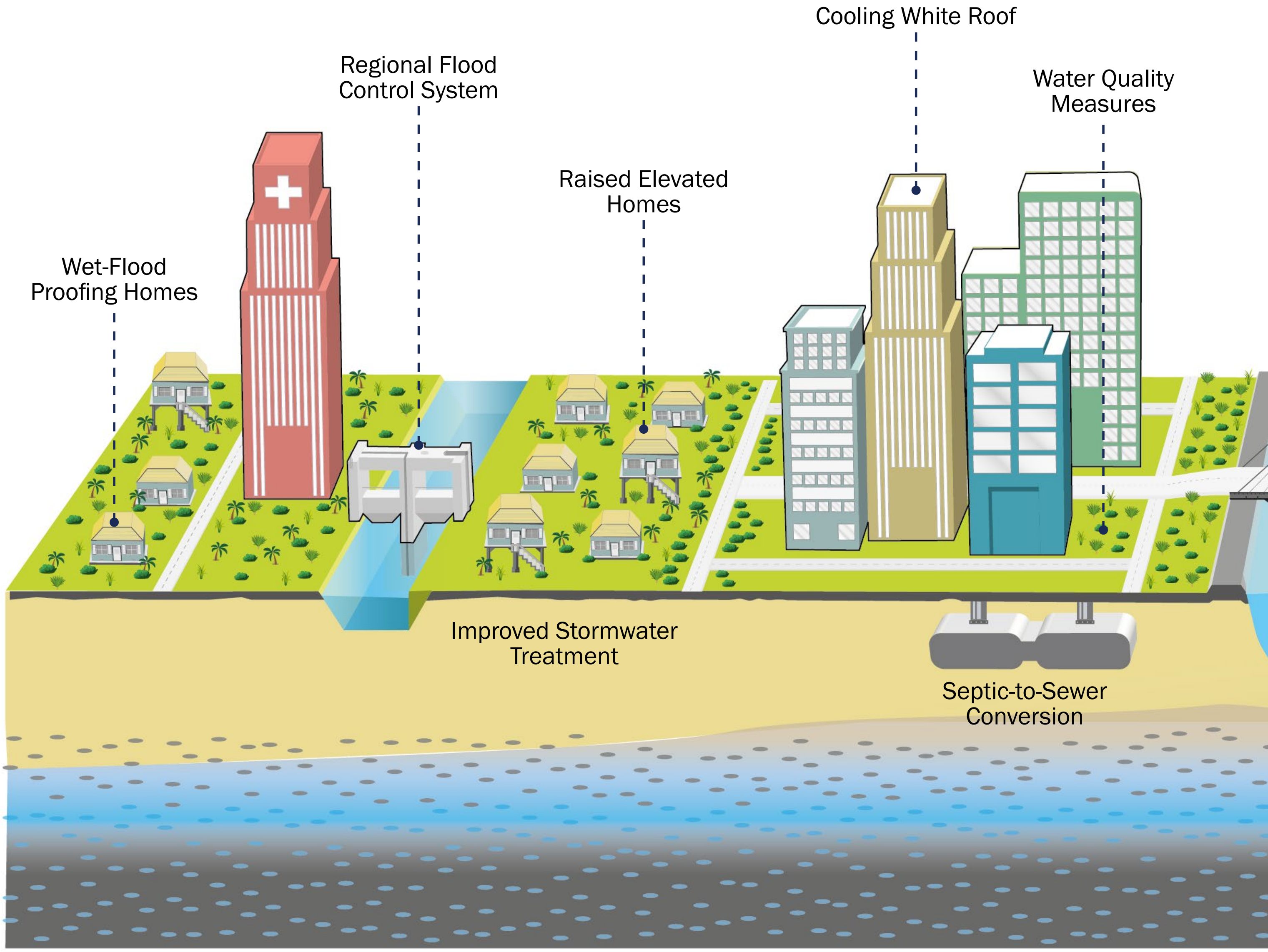
The cost of adapting to and mitigating the effects of climate change will be significant, especially for coastal communities. Nearly every facet of government operation will need to respond and adjust. Local governments in Southeast Palm Beach County have generally limited revenue options – property, sales, and other taxes, charges and fees; and funding from the federal and state governments. Funding and financing climate adaptation and mitigation will require innovation and persistence.

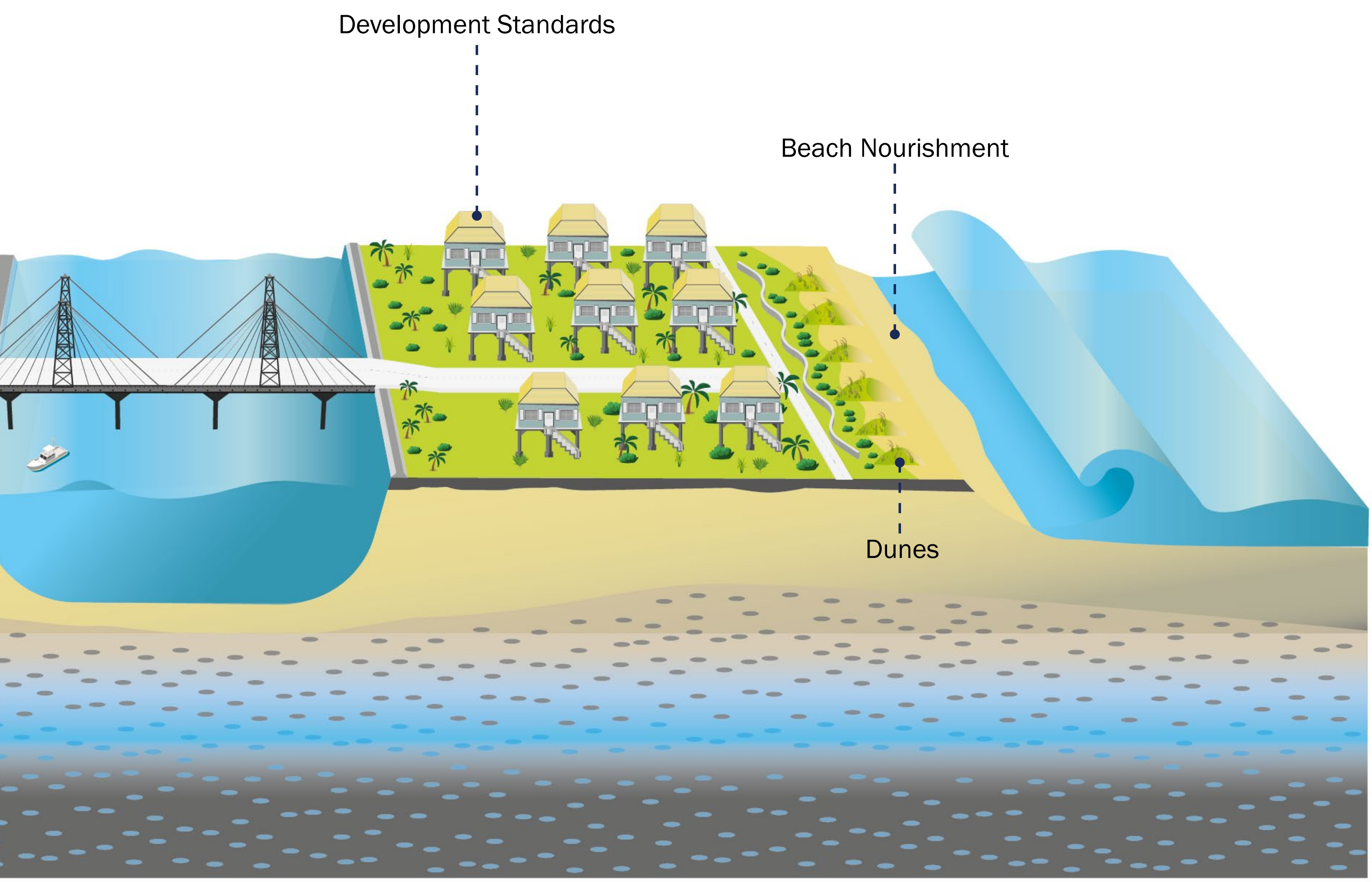
Climate Adaptation Strategies

The cost of adapting to and mitigating the effects of climate change will be significant, especially for coastal communities. Each climate threat will create its own set of disruptions and challenge each community differently. However, nearly every facet of government operation can contribute to resilient solutions for all types of communities through investments made today. While costly, investments in resilience have demonstrated a high return in value.

The Southeast Florida Climate Change Compact Business Case for Resilience found that for every $1 invested in community-wide adaptation, there will be a $2 return in benefits, indicating a 2:1 benefit-cost ratio. Understanding and leveraging the benefits that come with climate adaptation and mitigation will require innovation and persistence, and can encourage local governments to search for funding mechanisms, as well as federal and state grant opportunities. Planning for future climate conditions through regional coordination alongisde investments in resilience will foster prosperous communities that are able to withstand the impacts of these changing conditions.

Below are a variety of adaptation examples, including community-wide and building-level, that can be implemented across the region to address climate challenges such as those explored in this study.




Development Standards
Beach Nourishment
Dunes

Portfolio of Regional Adaptation Strategies

	DESCRIPTION	APPLICABLE THREAT(S)
Infrastructure	Based on the results of this study, evaluate key infrastructure vulnerabilities, and work regionally with regulators to minimize gaps in services: utilities (water, wastewater, and stormwater), schools, critical care, emergency buildings, etc. Special attention should be paid to the locations of vulnerable populations based on the findings of this study.	All
	Build partnerships and opportunities for increasing green infrastructure projects and/or voluntary incentives. Participate in the statewide development of stormwater rules that award Environmental Resource Permit (ERP) credit for use of Low Impact Development measures.	Harmful Algal Blooms (HABs), All Flood Threats, Drought, Extreme Heat, Pest & Disease
	Work as the CRP to facilitate more living shoreline projects in vulnerable locations. Special attention should be paid to the results of this study and how these projects can be used to mitigate climate impacts for socioeconomically challenged areas. Projects that leverage healthy mangroves should also be strategically considered.	Shoreline Recession, High Winds, HABs, Storm Surge
	Deploy mobile food markets connecting residents to food distribution centers and grocery stores in order to address food deserts and other food equity issues. These markets could be strategically deployed based on need – as well as after flooding and adverse weather conditions.	Pest & Disease, Extreme Heat, All Flood Threats
	Collaborate as the CRP to encourage the development of non-motorized transportation facilities (e.g., trails, separated bike paths) that are cross-jurisdictional when possible, to enable impacted populations to access public service/health needs. Shade and safe access to drinking water should be considered as a part of this strategy.	Extreme Heat, Pest & Disease

Portfolio of Regional Adaptation Strategies Cont'd

	DESCRIPTION	APPLICABLE THREAT(S)
Land Use, Zoning, Building Codes, and Standards	In appropriate areas, develop a regional plan to restore wetlands and shoreline to provide more resilient habitats, improve water quality, and slow storm surge. This initiative would be particularly effective near the coastline and waterbodies with impacted water quality and should be linked to other co-benefits when possible (public education, recreation, biodiversity protection, etc.).	Shoreline Recession, HABs, Storm Surge, Pest & Disease
	Using the results of this study, collaborate to identify incentives to divert future development from vulnerable areas, such as transfer of development rights and density bonuses. These provisions for incentives would reduce the introduction of new investments in high-hazard zones and help ensure the long-term economic resiliency and competitiveness of the area.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding
	Advocate for the consideration of resilience in regional transportation plan updates. Consider sea level rise and future hydrology as factors for funding new transportation projects.	All

	DESCRIPTION	APPLICABLE THREAT(S)
Planning, Policy, and Management	Collaborate and advocate for the regional creation of a green infrastructure/low impact development (GI/LID) manual to provide a toolbox of green infrastructure practices and site design options for municipal staff and consulting engineers and architects. The design manual should include pollutant removal efficiencies, design constraints, and appropriate settings and materials for Southeast Palm Beach County. Link this strategy to other engagements with Florida Department of Environmental Protection (FDEP) and South Florida Water Management District (SFWMD) to award ERP credit for LID usage in Palm Beach County.	HABs, All Flood Threats, Pest & Disease, Extreme Heat, Drought, Shoreline Recession
	Explore the concept of Adaptation Urbanism – integrating compact development, sustainable transport, blue and green infrastructure, and equity – and work with regional partners to identify opportunities to apply it to street-level resilience projects in the CRP area.	All
	Collaborate across the CRP to create a program inspired by the Building Efficiency 305 Program in Miami geared towards increasing water and energy efficiency in large buildings. Click here for more information.	Drought, Extreme Heat
	Collaborate as the CRP and with other local agencies to encourage the creation of watershed datasets, models, and floodplain maps. Develop regional maps that reflect build-out and future hydrology that can be updated every 5 years. The work can build upon Palm Beach County's efforts to delineate watersheds for the Community Rating System Program, as well as the watershed approach taken by the Lake Worth Lagoon Initiative.	All Flood Threats, HABs, Drought, Groundwater Inundation

Portfolio of Regional Adaptation Strategies Cont'd

	DESCRIPTION	APPLICABLE THREAT(S)
Capacity Building	Collaborate as the CRP to compile resources to encourage sustainable landscaping practices, pervious surfaces, and downspout disconnection for homeowners and businesses. Tie the initiative to existing resources that encourage Florida-Friendly Landscaping™ and those that reduce fertilizer usage. Cater the specific measures to Southeast Palm Beach County so that the resources are easier for the public to use (plant menus, instructions, local resources, etc.). Tap into the resources provided by the Institute of Food and Agricultural Sciences (IFAS) Extension at the University of Florida and the local Palm Beach County Cooperative Extension.	HABs, All Flood Threats, Pest & Disease, Extreme Heat, Drought, Shoreline Recession
	Study and plan to reduce nutrient loads to receiving waterbodies through planning, modeling, enhanced best management practices, land development regulation updates and other strategies. Water quality requires a watershed approach to be successful, so this is a critical regional strategy. Regional water quality partnerships will also increase opportunities for funding. Coordinate activities strategically with Municipal Separate Storm Sewer System (MS4) permitting and Total Maximum Daily Load (TMDL) reporting/activities.	All Flood Threats, HABs, Drought, Groundwater Inundation, Pest & Disease
	Engage Lake Worth Drainage District (LWDD) and SFWMD regarding the impacts of current and future flood events on the secondary and primary canal systems in Southeast Palm Beach County. Also consider potential of algal blooms and how they would affect structure operations. Work with both parties to develop models and eventually a decision support system that can adapt to further mitigate future flood events. Partnering will also increase the likelihood of funding for some grant opportunities. Establish liaisons and a plan for engagement and/or use existing programs (e.g., Palm Beach County Water Resources Task Force).	Groundwater Inundation, Saltwater Intrusion, Rainfall-Induced Flooding, Drought
	Collaborate on development of neighborhood-based resilience hubs to facilitate communication, distribute resources, and provide services to residents before, during, and after climate disruptions. Use the USDN Guide to Developing Resilience Hubs as a starting point for local and regional knowledge exchange. Seek funding opportunities for a regional network of hubs across the CRP.	All
	Work as the CRP to share information on the use of Adaptation Action Areas throughout the region and the State of Florida.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding
	Engage SFWMD on an ongoing basis regarding the need for rainfall curves, groundwater models, watershed models, and various datasets that can be used to design resilient infrastructure in Southeast Palm Beach County. Establish liaisons and a plan for engagement and/or use existing programs (e.g., Palm Beach County Water Resources Task Force).	Groundwater Inundation, Saltwater Intrusion, Rainfall-Induced Flooding, Drought, HABs
	Start a regional program to encourage more natural management of littoral zones for residential communities, commercial/mixed use, and golf courses. Consolidate and distribute educational resources regarding appropriate fertilizer usage.	HABs, Extreme Heat, Pest & Disease

Portfolio of Regional Adaptation Strategies Cont'd

	DESCRIPTION	APPLICABLE THREAT(S)
Public Outreach	Host regional public meetings about climate threats and solutions that are easily accessible to vulnerable populations. Meetings should be: (a) physically accessible (near public transport); (b) safe for all members; (c) located in places that the community values as gathering spaces (e.g., community centers and cultural centers); (d) led in, or translated into, the primary language(s) of the community; and (e) Scheduled at various times to accommodate different schedules.	All
	Engage artists, activists, youth, and elders in public climate change education. Since Palm Beach County has strong cultural resources, this strategy should leverage existing programs and networks.	All
	Further the discussions related to the results of this study, and continue regionally important conversations regarding climate change, sustainability, and resilience.	All
	Collect data through citizen science initiatives/programs. For example, map urban heat islands with citizen input to inform development of policies to mitigate their effects.	All

	DESCRIPTION	APPLICABLE THREAT(S)
Funding and Financing	Identify grant opportunities to fund adaptation strategies. Share information on these resources via the CRP and other established Palm Beach County governmental groups. Partner strategically and proactively on projects. Review this strategy as part of every CRP meeting and update annually for new funding sources.	Shoreline Recession, HABs, All Flood Threats, Drought
	Continue leadership as a region through collaborative partnerships with strategic partners (e.g., the Palm Beach County League of Cities, Chambers of Commerce, etc.) with a focus on strategic funding for the region to build resilience throughout Southeast Palm Beach County.	All
	Collaborate as the CRP to identify and share resources and tools to assist individuals with financing home or business adaptation efforts.	All
	Engage in the implementation of the new landmark 'Always Ready' resilience law, and ensure the CRP has taken the necessary steps to be at the front of the line when planning and infrastructure funds become available.	All

Consultant Team

NOTES

NOTES

Notes

CONCLUSION

The work of the Coastal Resilience Partnership is a model of how neighboring local governments can come together to address regional climate challenges. Understanding the problem, identifying the impacts, and developing a menu of strategies is only the first step. Preparing our communities for a changing climate will require a sustained effort and collaboration across all levels of government. The Coastal Resilience Partnership is committed to continuing its efforts in creating a more resilient and climate-ready Southeast Palm Beach County.

Table of Contents

List of Appendices

List of Figures

Section 1. Threats and Assets

Section 2. Assessment of Vulnerability and Risk

Section 3. Adaptation Strategies and Priorities for Resilience

No figures are located in Section 3.

Appendices

List of Tables

Section 1. Threats and Assets

Section 2. Assessment of Vulnerability and Risk

Section 3. Adaptation Strategies and Priorities for Resilience

Project Team and Timeline

This report encompasses the second phase of planning for the Coastal Resilience Partnership of Southeast Palm Beach County. **This phase kicked off on April 14, 2020 and was completed in June of 2021**. This is the Final Project Report.

Project Team

Coastal Resilience Partnership: Working Group Members

CITY OF BOCA RATON: ***Lindsey Roland Nieratka, Sustainability Manager***

CITY OF BOYNTON BEACH: ***Rebecca Harvey, Sustainability Coordinator***

CITY OF DELRAY BEACH: ***Kent Edwards, Sustainability Officer***

TOWN OF HIGHLAND BEACH: ***Ingrid Allen, Town Planner***

CITY OF LAKE WORTH BEACH: ***Felipe Lofaso, Assistant Director of Public Works***

TOWN OF LANTANA: ***Nicole Dritz, Development Services Director***

TOWN OF OCEAN RIDGE: ***Tracey Stevens, Town Manager***

PALM BEACH COUNTY: ***Katelyn Cucinotta, Office of Resilience Analyst***

The Working Group gratefully acknowledges the staff and elected officials who provided expertise and assistance towards the preparation of this Climate Change Vulnerability Assessment. We also wish to acknowledge the support of the Florida Department of Environmental Protection for their financial support via the 2019 Resilience Planning Grant program.

External Experts

The Working Group would like to thank the panel of external experts that provided lessons learned, guidance, and countless hours of their time in the development of this plan:

SAMANTHA DANCHUCK: ***Broward County***
CAROLINA MARAN: ***South Florida Water Management District***
PENELOPE REDFORD: ***City of West Palm Beach***
TOMMY STROWD: ***Lake Worth Drainage District***

Consultant Team

COLLECTIVE WATER RESOURCES, LLC (PRIME CONTRACTOR)
Elizabeth Perez, Stephanie Nevadunsky, Desiree Heinl, Stephanie Dunham, Anna Leitschuh, Maria Loinaz, Joel Jordan, Brianna Fearon

APPLIED TECHNOLOGY & MANAGEMENT, INC.
Steve Peene, Melany Larenas, Nicolas Pisarello, Michael Jenkins

BRIZAGA, INC.
Alec Bogdanoff, Michael Antinelli, Lea Mayer

CHEN MOORE & ASSOCIATES, INC.
Brent Whitfield

ERIN L. DEADY, PA
Erin Deady

NEMAC+FERNLEAF
Matthew Hutchins, Aashka Patel, James Fox, Jeff Hicks, Josh Wilson, Dalton Nickerson, Kim Rhodes

The authors also wish to thank to the photographers on Unsplash and the team members that generously donated their photography for inclusion in this report. Readers are encouraged to visit https://unsplash.com/.

Glossary

Glossary terms will appear in bold blue text the first time each term appears in each section of this report and in select convenient locations to aid readers.

Adaptive Capacity: The ability the asset has to cope with a potential impact with minimal disruption or cost.

Adaptation: "Adjusting actual or expected future climate"[29]

Air Pollution: The presence of toxic chemicals or compounds in the air that are usually not present or not present at unhealthy quantities, and which lower the quality of the air and pose health risks as well as possible changes to the quality of life.[1]

Annual Sales Volume:The quantity or number of products sold or services provided by a company in a year.[2]

Asset: The people, resources, infrastructure, and services that people and communities rely on, value, and expect their leaders to manage and protect.[26]

Base Flood Elevations (BFEs): "The elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year,"[3] as defined by the National Flood Insurance Program.

Coastal Resilience Partnership (CRP): The Coastal Resilience Partnership of Palm Beach County is the collaborative partnership of eight local governments: Boca Raton, Boynton Beach, Delray Beach, Highland Beach, Lake Worth Beach, Lantana, Ocean Ridge, and Palm Beach County and adjacent areas of unincorporated Palm Beach County.

Critical Facilities: "Buildings and facilities that are essential for the delivery of vital services or protection of a community." Typical critical facilities include hospitals, fire stations, police stations, data centers, wastewater treatment plants, and similar facilities. [4]

Capacity Building: Strategies that build a community's ability to design strategies and implement actions to build resilience.

Digital Elevation Model (DEM): A three-dimensional digital representation of terrain comprised of evenly spaced elevation values.

Drought: A period of unusually persistent dry weather that occurs long enough to cause serious problems such as crop damage and/or water supply shortages.[5] See https://www.drought.gov/drought/ for more information.

Extreme Heat: A series of days where the weather is hotter and/or more humid than average for an area and time of year.[6]

Exposure: "The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards." [25]

Federal Emergency Management Agency (FEMA): "1) An agency within the U.S. Department of Homeland Security charged with responding to Presidentially-declared disasters. 2) The Federal agency under which the National Flood Insurance Policy (NFIP) is administered. In March 2003, FEMA became part of the newly created U.S. Department of Homeland Security."[3] FEMA aims to help people "before, during and after disasters"[3] as well as regulate floodplain management. For more information, please visit https://www.fema.gov/.

Flood Insurance Study (FIS): "A compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. When a flood study is completed for the NFIP, the information and maps are assembled into an FIS. The FIS report contains detailed flood elevation data in flood profiles and data tables."[3] For more information, please visit https://www.fema.gov/.

Government-Owned Property: Property owned by federal, state, or local government. Properties may include libraries, parks, government agency buildings, roads, and other similar properties.

Grey Infrastructure: Traditional stormwater structures, including curbs, gutters, drains, pipes and other systems, that collect and convey water away from impervious surfaces and ultimately discharge the untreated stormwater to local waterbodies.[7]

Green Infrastructure: "Refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of low impact development (LID)."[8] Green infrastructure also includes leaving natural systems intact since healthy ecosystems provide significant benefits in addressing climate change.

Green Street: "A stormwater management approach that incorporates vegetation, soil and engineered systems (e.g., permeable pavements) to slow, filter, and cleanse stormwater runoff from streets and sidewalks."[9]

Groundwater Inundation: Localized flooding from a rise in groundwater table levels due to a rise in sea level. Due to the porous limestone bedrock of Southeast Florida, groundwater inundation is a significant concern with rising sea levels.[10]

Harmful Algal Blooms (HABs): When specific colonies of algae grow out of control and produce toxins that can harm people, fish, shellfish, marine mammals, and birds.[11]

Hazardous Materials: Substances in quantities or forms that may pose a reasonable risk to health, property, or the environment. Hazardous materials may include toxic chemicals, fuels, nuclear waste products, and biological agents.[12]

High Winds: Sustained, strong winds. Tropical systems are the biggest threat for sustained high winds in Southeast Florida.

Human Migration: Any movement by human beings from one location to another, historically over long distances or in large groups in response to push factors (reasons to leave an area) or pull factors (reasons to go to an area). Data sources for this information include US Census Bureau, State of Florida, and various regional Chambers of Commerce.

Infrastructure Hardening: "Refers to physically changing the infrastructure to make it less susceptible to damage from extreme wind, flooding, or flying debris."[24] Also called "Hardening" or "Storm hardening."

Invasive Species: An invasive species is an organism that causes ecological or economic harm in a new environment where it is not native. For more information see https://www.srs.fs.usda.gov/factsheet/pdf/invasives_lr.pdf

Low Impact Development: "An approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. A key element of LID is to mimic a site's pre-development hydrology as closely as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to crate functional and appealing site drainage that treat stormwater as a resource rather than a waste product" [8]

Mean Sea Level (MSL): The arithmetic mean of hourly heights observed over 19 years at a local tide station.[28]

Mean Higher High Water (MHHW): "The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch."[28]

Mitigation: Reducing the causes of climate change in order to avoid significant human interference with the climate system. [29]

Pest and Disease Outbreaks: A pest outbreak refers to a sudden increase in the population of an insect species.[13] Disease outbreak refers to a sudden increase of disease cases beyond normal expectancy. The number of cases may vary according to the type of disease and the exposure to the agent.[14]

Public Housing: Housing for low-income residents, usually provided using Federal aid from the U.S. Department of Housing and Urban Development (HUD).[15]

Public Services: Services provided by a government to all members of the community, such as education, public transportation, and public safety.[16]

Rainfall-Induced Flooding: Flooding due to the accumulation of rainwater on normally dry land. This can occur in various ways including when a river/lake/pond overflows its banks or when urban drainage systems fail or are overwhelmed by the water trying to enter the system. Rainfall-induced flooding can happen when it rains for an extended time period, when it rains heavily in a short amount of time, or both. Rainfall-induced flooding is often characterized by how likely that level, or extent, of flooding is to reoccur or be exceeded.[17]

Red Tide: A Harmful Algal Bloom (HAB) caused by *Karenia brevis,* a type of algae that produces potent neurotoxins. Blooms discolor the water and cause widespread mortality of fish, turtles, birds, and marine mammals. The toxins can be suspended in the air, causing human respiratory illness, or accumulated in shellfish, causing Neurotoxic Shellfish Poisoning in humans.[18]

Risk: The probability (likelihood) and the consequence, or negative outcome, of a hazard occurring.

Saltwater Intrusion: Migration of seawater into freshwater aquifers that are hydraulically connected to the sea.[19] The migration can be caused by too much freshwater being extracted from the aquifer, which then pulls the seawater into the aquifer as well.

Sea Level Rise: Relative rise of the mean sea level over time. While the local tides vary daily, seasonally, and from year to year, the average of all measurements over a specified time period is called Mean Sea Level.[17]

Sensitivity: The level at which an exposed asset is negatively affected (also called Potential Impact).

Shoreline Recession: Occurs when waves and currents, usually from a storm, remove sand from the beach system by carrying it offshore. The sand removal causes the beach to become narrower and lower in elevation leaving coastal properties and infrastructure vulnerable to future storms.[18]

Stillwater Flood Elevations (SWELs): The base water surface elevation of coastal waters, not including waves.

Special Flood Hazard Area (SFHA): "An area having special flood, mudflow or flood-related erosion hazards and shown on a Flood Hazard Boundary Map (FHBM) or a Flood Insurance Rate Map (FIRM) Zone A, AO, A1-A30, AE, A99, AH, AR, AR/A, AR/AE, AR/AH, AR/AO, AR/A1-A30, V1-V30, VE or V. The SFHA is the area where the National Flood Insurance Program's (NFIP) floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. For the purpose of determining Community Rating System (CRS) premium discounts, all AR and A99 zones are treated as non-SFHAs."[3]

Storm Surge: Coastal flooding caused by an abnormal rise in tide from a storm (e.g., hurricane) over and above the usual, astronomical tide. The wind and air pressure from a storm push the water towards the shore which causes an increase in water level above the natural tide. The height of the storm surge depends on the intensity of the storm, how fast the storm is moving, the size of the storm, the direction it's coming from, and the shape of the shoreline.[16]

Social Vulnerability Index: Databases to help emergency response planners and public health officials identify and map communities that will most likely need support before, during, and after a hazardous event. The databases are based on Social Vulnerability – the factors, including poverty, lack of access to transportation, and crowded housing, that may weaken a community's ability to prevent human suffering and financial loss in a disaster.[20]

Stressor: A condition, event, or trend that can exacerbate threats. Stressors can be either climate or non-climate related. For more information see https://toolkit.climate.gov/content/glossary

Supplemental Nutrition Assistance Program (SNAP) Retailers: Stores (usually grocery stores and large supermarkets) who participate in SNAP, a national program in which participating retailers receive benefits in exchange for providing low-income families and individuals with affordable food.[21]

Sustainable Infrastructure: Systems of energy generation/distribution, water/wastewater control, stormwater management and flood control, airports, roads, bridges, dams, parks and recreational amenities, transit and transportation, or information/communication networks that are resilient and equitable.[27]

Tidal Flooding: Indicates above normal high-tide events, unrelated to a storm, where water levels flow over the tops of sea walls and onto streets or force water into stormwater outfalls. The flooding may disrupt traffic and damage infrastructure. The height of the daily tides can vary seasonally and from year to year due to the position of the earth, sun and moon, ocean currents, wind currents, and changes in ocean circulation (such as El Niño/La Niña).[17] As sea levels rise, so too will the tides, increasing the frequency of tidal flooding.

Threat: This study includes twelve (12) climate threats. Threats are major hazard events or chronic disruptions that negatively impact community assets.

Total Maximum Daily Load (TMDL): "A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant."[22]

Undergrounding: "Placing utility lines underground and lowering susceptibility to wind damage and lightening that is typically experienced with overhead lines."[24]

Utilities: Services, commodities, and their corresponding facilities/infrastructure that provide a service to the community. For the purpose of this assessment, utilities include any infrastructure related to electrical, potable water, sewer, and stormwater systems such as wastewater treatment plants or potable water pipes.

Vulnerability: The susceptibility of exposed assets based on the two core concepts: (1) potential impact – the degree to which an asset is affected due to its sensitivity; and (2) adaptive capacity – the ability the asset has to cope with a potential impact with minimal disruption or cost.

Water Pollution: Harmful substances contaminating a body of water, degrading water quality, and often making the water toxic to humans or the environment.[23] Harmful substances may include chemicals, microorganisms, sewage, animal waste, and garbage.

Wildfire: Unplanned fire that burns in a natural area. Wildfires can cause damage to important natural ecosystems as well as surrounding communities. For more information see https://www.southernforests.org/fire

Glossary References

1. "What Is Air Pollution?" *Environmental Pollution Centers*, Environmental Pollution Centers, 2017, www.environmentalpollutioncenters.org/air/.

2. "SALES VOLUME." *Definition in the Cambridge English Dictionary*, Cambridge University Press, www.dictionary.cambridge.org/us/dictionary/english/sales-volume.

3. "Glossary." Glossary | FEMA.gov, www.fema.gov/about/glossary.

4. *Critical Facilities Located in Tornado-Prone Regions: Recommendations for Facility Owners*. FEMA: Tornado Recovery Advisory, https://www.fema.gov/sites/default/files/2020-07/critical-facilities-tornado-regions_facility-owners_recovery-advisory.pdf

5. "What Is Meant by the Term Drought?" *National Weather Service*, NOAA's National Weather Service, 14 Sept. 2015, www.weather.gov/bmx/kidscorner_drought.

6. Environmental Protection Agency and Center for Disease Control and Prevention. "Climate Change and Extreme Heat: What you can do to Prepare." 2016. PDF file. https://www.epa.gov/sites/production/files/2016-10/documents/extreme-heat-guidebook.pdf.

7. US EPA. "Why You Should Consider Green Stormwater Infrastructure for Your Community." US EPA, 19 July 2019, www.epa.gov/G3/why-you-should-consider-green-stormwater-infrastructure-your-community.

8. Clar, Michael. "Low Impact Development (LID) Technology and Green Infrastructure (GI) | ASCE." American Society of Civil Engineers, 24 Sept. 2014, https://www.asce.org/all/news/20140924-low-impact-development-(lid)-technology-and-green-infrastructure-(gi)/#:%7E:text=intends%20the%20term%20%22green%20infrastructure,is%20generated%20(Figure%202)

9. US EPA. "Learn About Green Streets." US EPA, Accessed 30 April 2020, https://www.epa.gov/G3/learn-about-green-streets#main-content.

10. Rotzoll, K., Fletcher, C. Assessment of groundwater inundation as a consequence of sea-level rise. *Nature Clim Change* 3, 477–481 (2013). https://doi.org/10.1038/nclimate1725

11. "What Is a Harmful Algal Bloom?" *National Oceanic and Atmospheric Administration*, U.S. Department of Commerce, 27 Apr. 2016, www.noaa.gov/what-is-harmful-algal-bloom.

12. "What is HAZMAT?" *National Ocean Service*, U.S. Department of Commerce, https://oceanservice.noaa.gov/facts/hazmat.html.

13. "Pest Outbreak, Insecticidal Resistance in Agricultural Pests." *International Journal of Scientific & Engineering Research*, vol. 8, no. 3, Mar. 2017, https://www.ijser.org/researchpaper/Pest-outbreak-insecticidal-resistance-in-agricultural-pests.pdf.

14. "Disease Outbreaks." *World Health Organization*, World Health Organization, www.who.int/environmental_health_emergencies/disease_outbreaks/en/.

15. "Public Housing." *HUD.gov*, U.S. Department of Housing and Urban Development, www.hud.gov/program_offices/public_indian_housing/programs/ph.

16. "Public Services." *ScienceDaily*, ScienceDaily, www.sciencedaily.com/terms/public_services.htm.

17. City of Charleston. "All Hazards Vulnerability and Risk Assessment." 2020. PDF file. (not publicly available as of June 2020)

18. Hall, Danielle. "What Exactly Is a Red Tide?" *Smithsonian Ocean*, Smithsonian National Museum of Natural History, Aug. 2018, www.ocean.si.edu/ocean-life/plants-algae/what-exactly-red-tide.

19. "Salt Water Intrusion." *ScienceDirect*, Science Direct, www.sciencedirect.com/topics/engineering/salt-water-intrusion.

20. "CDC's Social Vulnerability Index (SVI)." *U.S. Department of Health & Human Services*, Agency for Toxic Substances & Disease Registry, 2018, www.svi.cdc.gov/factsheet.html.

21. "SNAP Retailers Database." *Center on Budget and Policy Priorities*, www.cbpp.org/snap-retailers-database.

22. Environmental Protection Agency. (2018, September). *Overview of Total Maximum Daily Loads (TMDLs). Impaired Waters and TMDLs.* Accessed 5 May 2021. Available at: https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls

23. Denchak, Melissa. *Water Pollution: Everything You Need to Know*. NRDC, 14 May 2018, www.nrdc.org/stories/water-pollution-everything-you-need-know#whatis.

24. "Hardening and Resiliency U.S. Energy Industry Response to Recent Hurricane Seasons." *U.S. Department of Energy.* (2010, August). https://www.oe.netl.doe.gov//docs/HR-Report-final-081710.pdf

25. "Explore Hazards." *U.S. Climate Resilience Toolkit.* 19 May 2021 https://toolkit.climate.gov/steps-to-resilience/explore-hazards

26. "Risk Management and Critical Infrastructure Protection: Assessing, Integrating, and Managing Threats, Vulnerabilities, and Consequences." *Congressional Research Service*. 4 February 2005. https://fas.org/sgp/crs/homesec/RL32561.pdf

27. *Institute for Sustainable Infrastructure Brochure.* https://sustainableinfrastructure.org/wp-content/uploads/2021/03/Final-ISI-B-Orange.pdf

28. "Tidal Datums." *National Oceanic and Atmospheric Administration*, Tides and Currents, https://tidesandcurrents.noaa.gov/datum_options.html

29. "Responding to Climate Change." *NASA,* Global Climate Change Vital Signs of the Planet, https://climate.nasa.gov/solutions/adaptation-mitigation/.

1. Threats and Assets

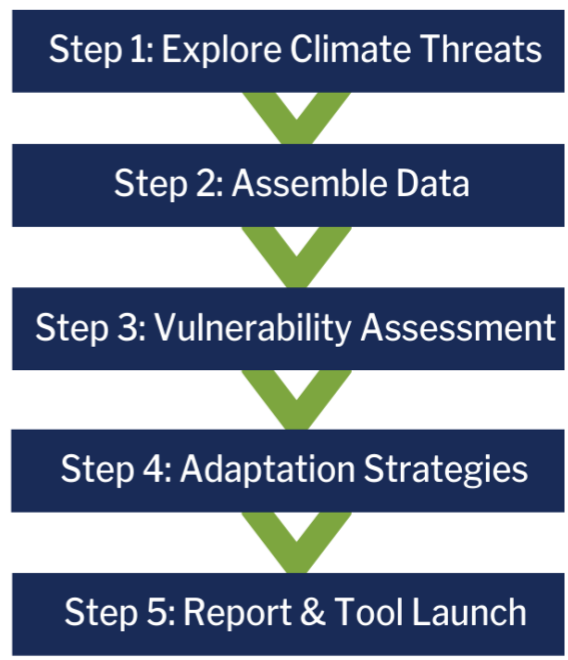
1.1 Project Introduction

This report documents and summarizes the results of the Southeast Palm Beach County **Coastal Resilience Partnership's** (CRP) Multi-Jurisdictional Climate Change Vulnerability Assessment (CCVA). This project represents the second substantial resilience planning phase for eight communities: Boca Raton, Boynton Beach, Delray Beach, Highland Beach, Lake Worth Beach, Lantana, Ocean Ridge, and adjacent areas of unincorporated Palm Beach County. The study area, which was aligned to optimize the use of best-available socioeconomic and climate data, is shown on the following page as Figure 1-2.

Project steps are summarized in Figure 1-1. Datasets, project library, outreach tools, and an analysis tool (AccelAdapt) were also developed as electronic deliverables. This collaboration benefits all member communities by providing consistent CCVA methodology, coordinated outreach strategies, integrated data outputs and **adaptation** recommendations, and reduced costs for each jurisdiction.

The first phase of study is documented in the Technical Memorandum issued by consulting engineering firm Carollo in 2019 (Deslauriers, 2019). Phase 1 was supported by Florida Department of Environmental Protection (FDEP) Grant Agreement No. R1817. Steps 1 and 2 of the CCVA were supported by FDEP Grant Agreement No. R1906. The project schedule and team are further detailed in the beginning of this report (*see Project Team and Timeline*).

Figure 1-1. Steps of the CCVA.



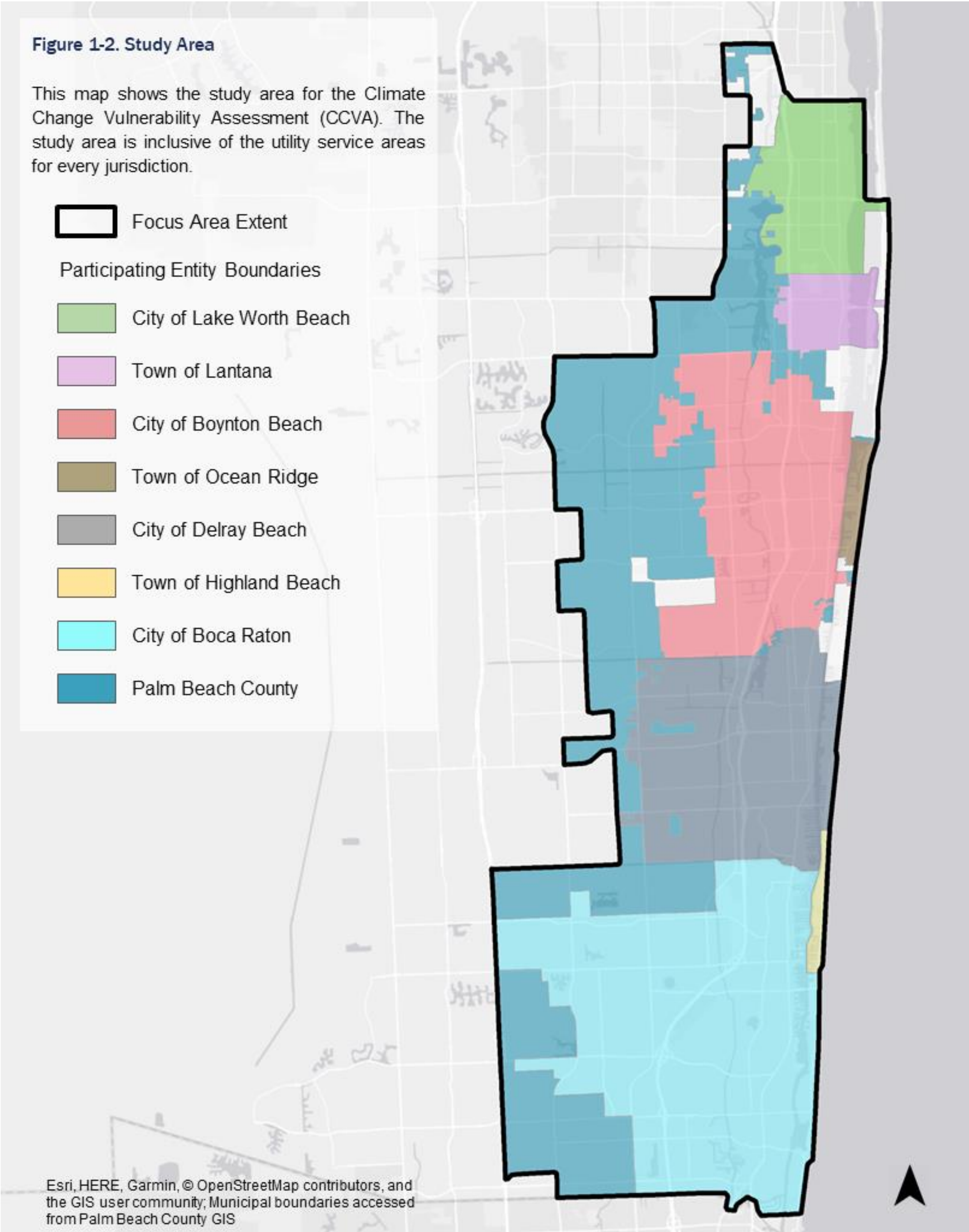


Figure 1-2. Study Area

This map shows the study area for the Climate Change Vulnerability Assessment (CCVA). The study area is inclusive of the utility service areas for every jurisdiction.

The remainder of Section 1 summarizes the threats and assets that were analyzed for the CCVA. For the purposes of this study, **threats** are defined as major hazard events or chronic disruptions that negatively impact community assets. **Assets** relate to the core systems of each jurisdiction – the specific property classes, services, economic strengths, and infrastructure located throughout these communities. **Stressors** will also be discussed in this section and are defined as a condition, event, or trend that can exacerbate threats, which can be either climate- or non-climate-related**.** Ultimately, the analysis looks at how specific assets may be exposed to climate change threats, and the impact that **exposure** may have on the operation or use of such an asset.

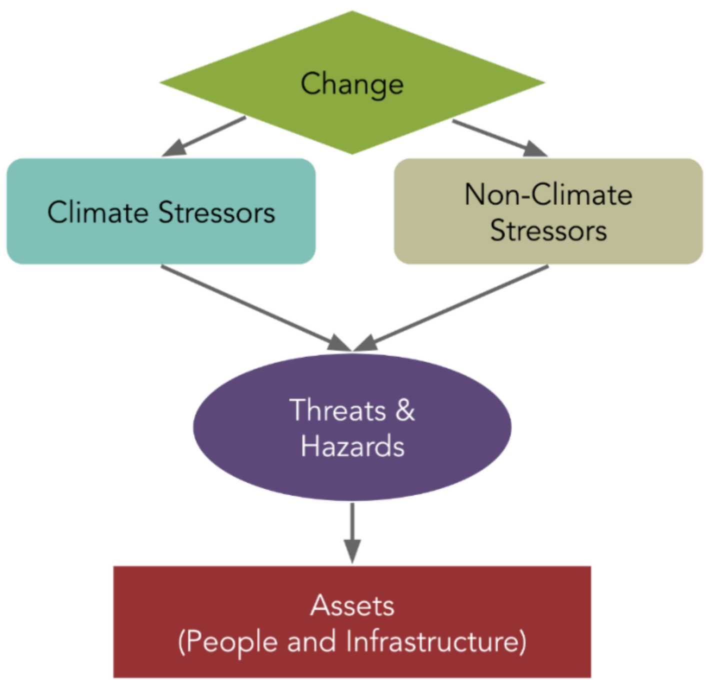
1.2 Climate Stressors

For communities facing the impacts of climate change, challenges include reducing the impact and making informed decisions related to changing conditions. To allow the communities participating in the CRP to make informed decisions about climate threats, the impacts of those threats must be evaluated and measured in a structured and systematic way. To begin evaluating and measuring impacts in a structured way, the project team asked four primary questions:

1. What are the primary threats and drivers of changing conditions related to climate change for communities in the CRP?
2. How do climate and non-climate **stressors** influence threats for communities in the CRP?
3. How do threats impact community assets?
4. Are communities resilient to these threats (based on past events and possible future events)?

This conceptual model framework (Figure 1-3) illustrates the relationships between climate and non-climate stressors, threats and hazards, and assets that may be affected. The change in this case would be related to climate change. The arrows in the model are drawn to reflect the causal influences between these different components. This type of model can also be used to reveal strategies or actions (not shown) that have the potential to reduce **vulnerability** and build resilience.

Figure 1-3. Conceptual model framework.



As shown in the conceptual model, climate threats and hazards are the result of the interaction between climate and non-climate stressors. Changing climate and non-climate stressors have the potential to cause changes in the frequency or severity of the threats that could impact communities in the future. For example, the amount of precipitation (or lack thereof) in and of itself is not a hazard. However, extreme precipitation is a climate stressor if enough precipitation falls in a given time, or in combination with a substantial amount of impervious surface (a non-climate stressor) that can lead to the threat of flooding. In this example, future increases in either climate or non-climate stressors could result in increased frequency or severity of the flooding hazard. In the opposite case, decreases in precipitation over a prolonged period of time can create **drought** conditions.

1.2.1 Heavy Precipitation Events

Changes in the frequency and intensity of heavy precipitation events is an important climate stressor for the CRP due to the impact on **rainfall-induced flooding**. This underscores the need to move beyond an examination of average precipitation to a more detailed look at heavy precipitation events and drought (Section 1.2.2) and how these compare to one another.

The annual precipitation for the Florida Lower East Coast climate division (which contains the CRP area) has increased on average 0.78 inches/decade since 1970 (Figure 1-4). While the overall precipitation levels are gradually increasing and interannual variability (changes year to year) appear to be decreasing, the variability on season scales – especially the timing and severity of precipitation – is increasing. For instance, summers may range between exceptionally wet or exceptionally dry. The extremes are becoming more common and more extreme.

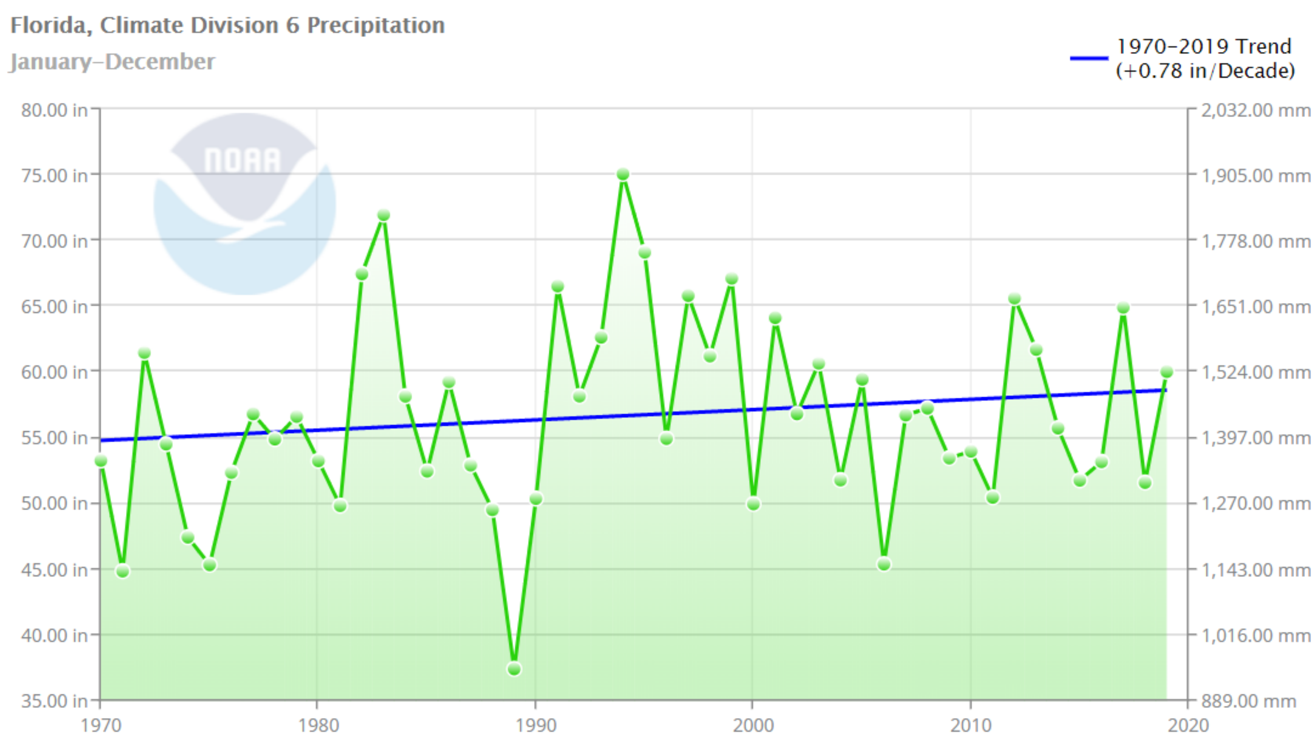


Figure 1-4. Average precipitation for the Southeast Palm Beach County (CRP) area from 1970 to 2019 (Data source: NOAA NCEI Climate at a Glance, U.S. Time Series).

The heaviest precipitation events occur when the atmosphere is near or completely saturated. As warmer air can result in an increase in atmospheric water vapor, extreme precipitation is consequently also expected to increase (Easterling et al. 2017). According to the Fourth National Climate Assessment (NCA4), an increasing trend in the frequency and intensity of heavy precipitation events is already being observed in the Southeast and across the United States (Figure 1-5). Observed through several metrics, including looking at the 5-year 2-day storm, the more intense rain events are occurring more frequently and in a shorter amount of time. From 1958 to 2016 the Southeastern region of the United States experienced a 27 percent increase in rainfall during the heaviest one percent of events. In this same period, the number of 2-day events that are probabilistically equivalent to occurring once every 5 years have increased by 49 percent (Easterling et al. 2017).

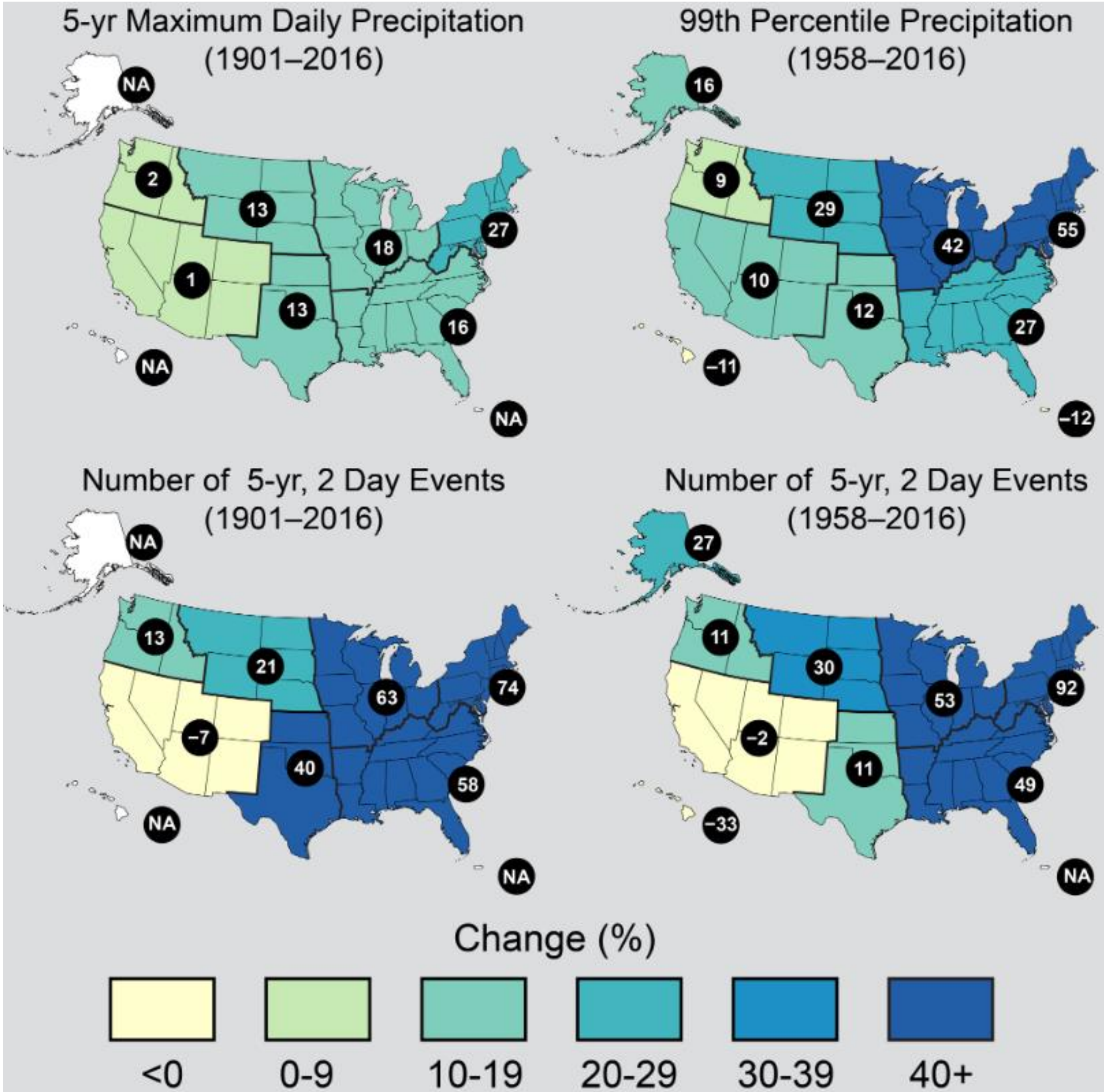


Figure 1-5. Observed regional changes in extreme precipitation (Figure source: Easterling et al. 2017 / CICS-NC / NOAA NCEI).

This trend is expected to continue at the national and regional scale. Figure 1-6, from the NCA4 Climate Science Special Report (Easterling et al. 2017), shows the projected changes in the amount of precipitation that falls in a 24-hour, 20-year event for two emission scenarios. It is important to note that these trends are not as clear for Southeast Florida and there is uncertainty in the projections about whether these increases will continue for the study area.

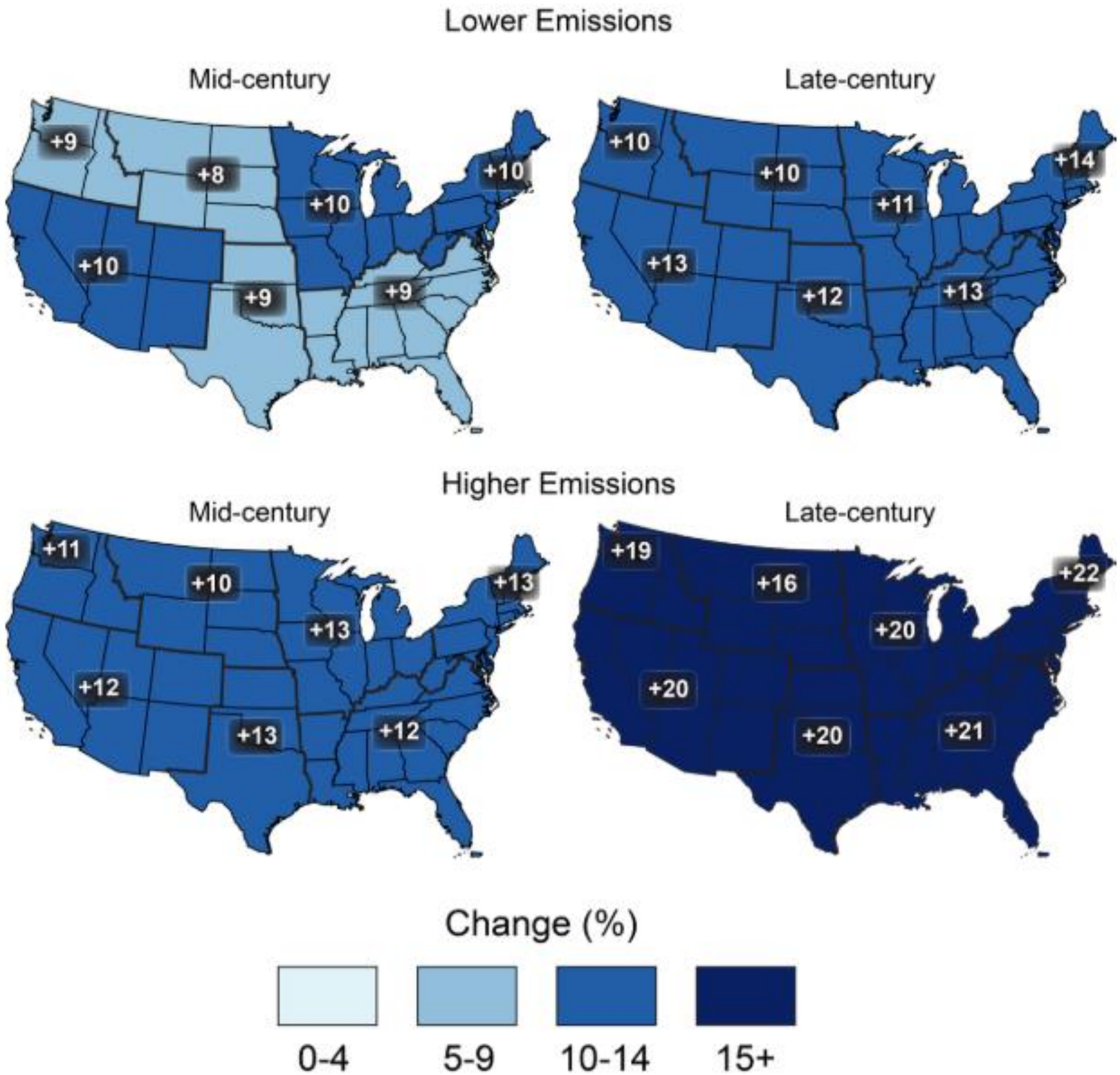


Figure 1-6. Projected regional changes in extreme precipitation by percentage (Figure source: Easterling et al. 2017 / CICS-NC / NOAA NCEI).

Figure 1-6 shows projected changes in the 20-year return period amount for daily precipitation for mid- (left maps) and late-21st century (right maps). Results are shown for a lower scenario (top maps; RCP4.5) and for a higher scenario (bottom maps, RCP8.5). These results are calculated from the LOCA downscaled data. Localized Constructed Analogs or LOCA are statistically downscaled climate projections.

1.2.2 Drought

The Palmer Hydrological Drought Index, a metric to understand **drought** severity, for the Florida Lower East Coast climate division indicates there have been several recent droughts (signified by the orange bars in Figure 1-7 below) that have been several years in duration.

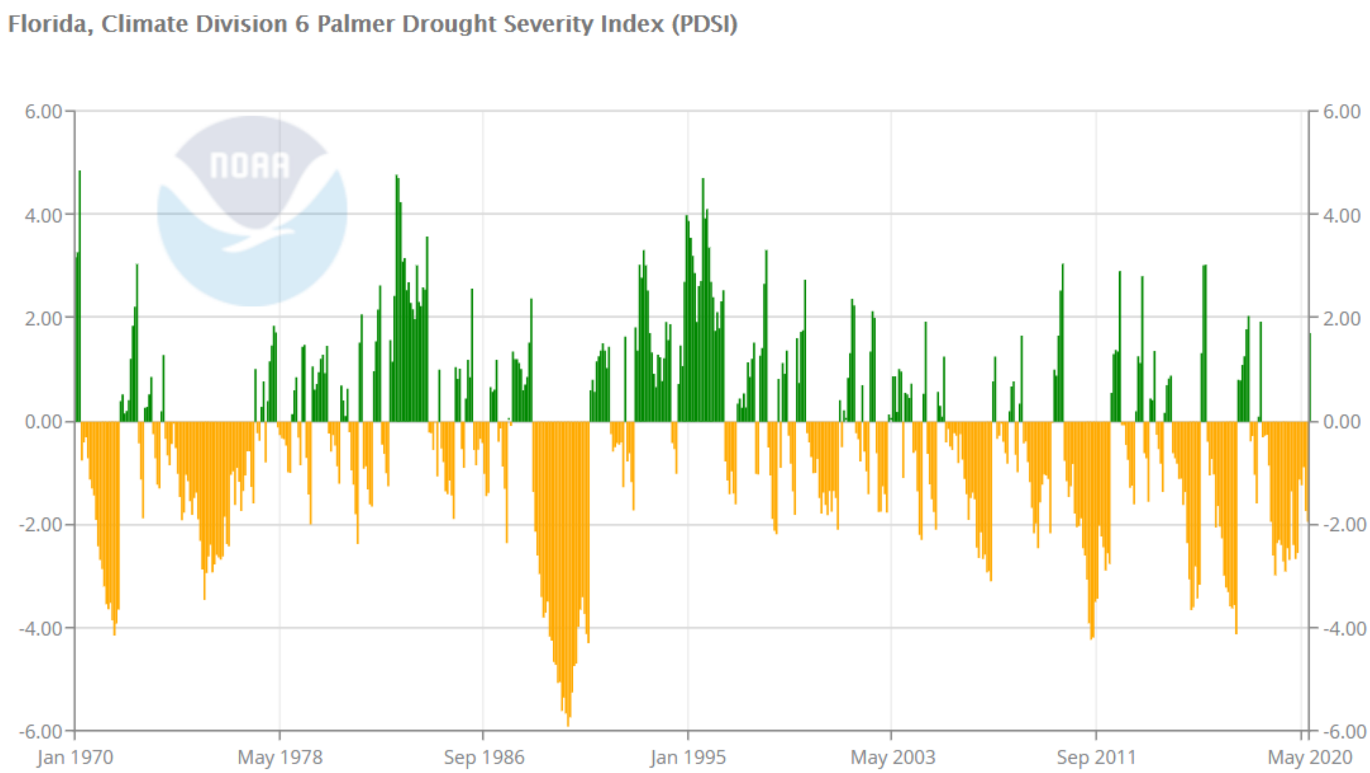


Figure 1-7. Historic drought occurrence for CRP area from 1970 to 2020 (Data source: NOAA NCEI Climate at a Glance, U.S. Time Series).

Palm Beach County's water supply is derived from a combination of surface water and groundwater sources, both of which are affected by drought conditions. For example, surface water availability will be more limited as the area experiences more frequent droughts, increasing the need for wells drilled into the shallow aquifer and construction of additional desalination plants. The heavy reliance on groundwater as a water supply is also a significant issue for the study area as **saltwater intrusion** continues. Table 1-1 describes the surface water and groundwater withdrawals for Palm Beach County for 2012 and 2015.

Table 1-1. Water withdrawals for Palm Beach County
All values in million gallons per day (Data sources: Marella, R.L., 2015 and Marella, R.L., 2020).

Groundwater				Surface Water			
Fresh		Saline		Fresh		Saline	
2012	2015	2012	2015	2012	2015	2012	2015
247.78	227.99	0	27.23	434.44	592.34	0	493.39

In addition to variability in precipitation, soil moisture may be decreasing due to higher summer temperatures. This means the CRP will need to plan for decreasing water availability while managing population growth and land use change.

Increasing drought increases the threat of **wildfire**. The peak wildfire season in Florida is typically January through mid-June, burning over 100,000 acres of land annually (Florida Department of Agriculture 2010). Wildfire can impact homes located in the Wildland Urban Interface with most of the reported fires to the west of the CRP. Figure 1-8 shows the perimeters of large wildfires from 2000 to 2019 (MTBS and USFS). Additionally, smoke from wildfires impacts air quality, which in turn impacts human health. Very few homes in the CRP are in the Wildland Urban Interface, so one of the primary impacts during periods of drought may be from wildfire smoke.

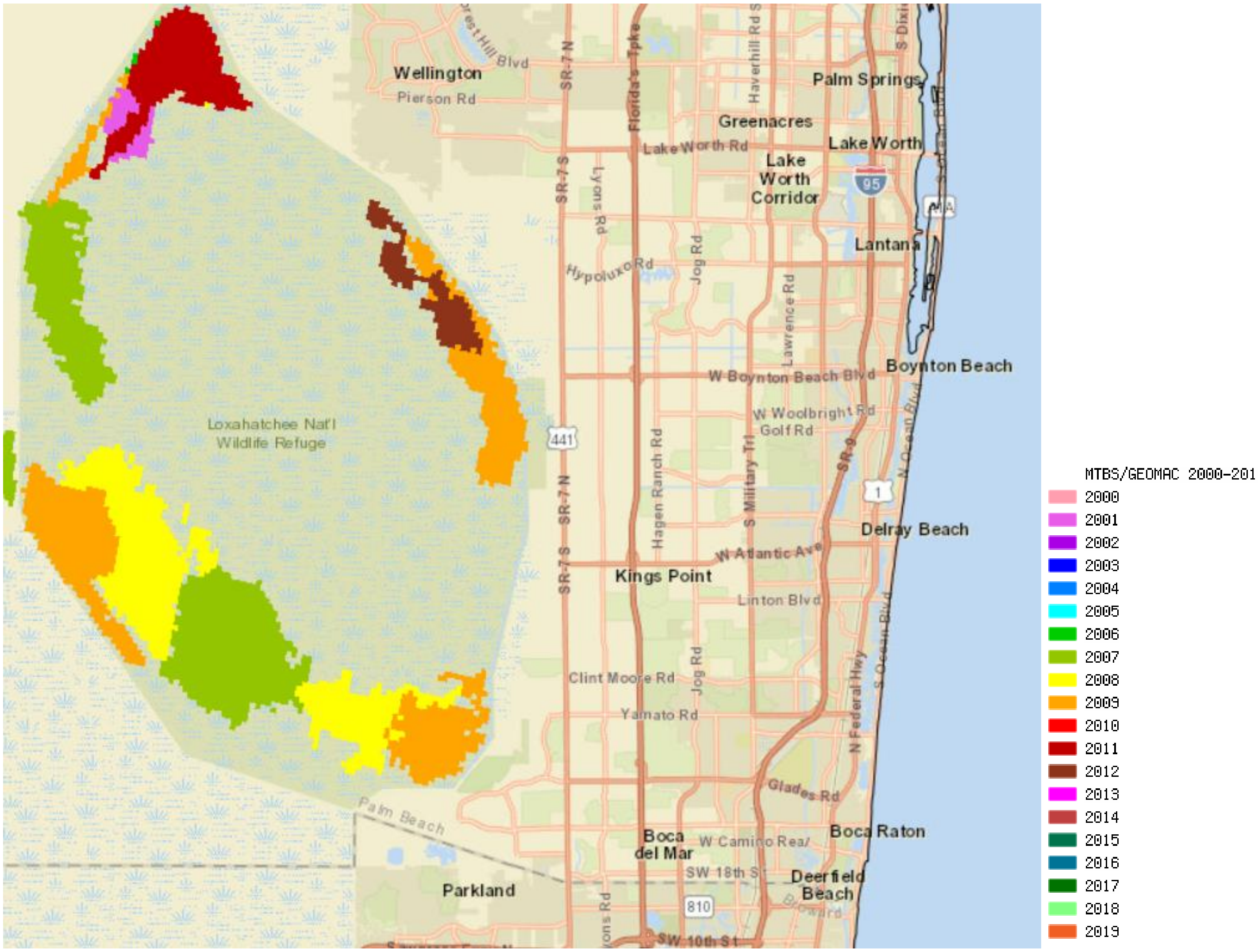


Figure 1-8. Historic wildfire occurrence near the CRP study area from 2000 to 2019 (Data source: U.S. Forest Service, Fire Perimeters and Hotspots 2000-2019).

1.2.3 Tropical Systems

Historically, hurricanes have been a principal climate stressor for Florida, bringing flooding from **storm surge** and damage from **high winds**. Examining historic data from the HURDAT2 data set (Landsea, 2013), the tropical cyclone risk becomes clear. Figure 1-9 shows the tracks of tropical systems where the center of the system comes within 100 statute miles of the CRP study area between the years 1851 and 2019. The region is crisscrossed by the tracks of tropical systems.

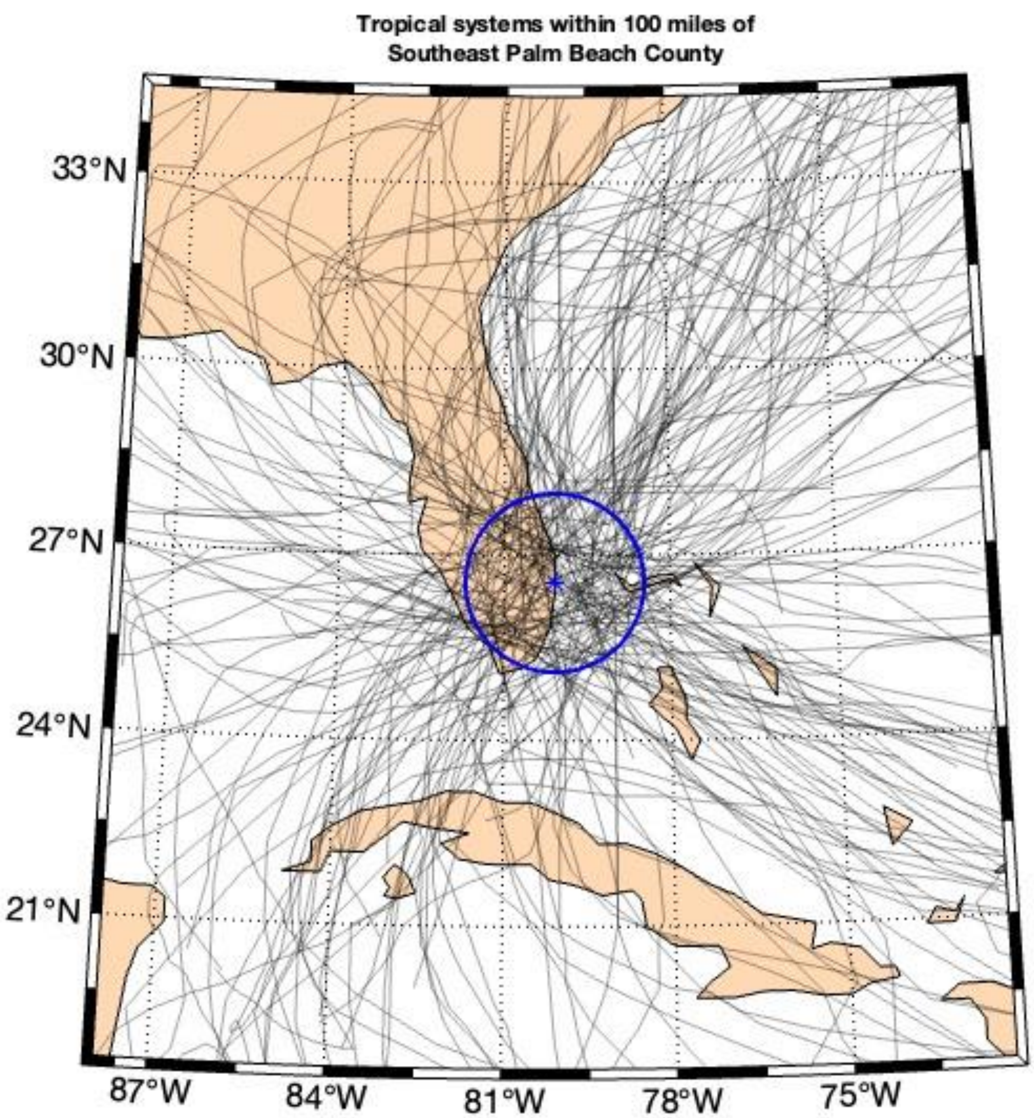


Figure 1-9. Historic hurricane tracks where the center of the storm came within 100 miles of the CRP study area from 1851 to 2019 (Data Source: NOAA 2016).

Most 5-year periods see at least three hurricanes making landfall in Florida (NOAA NCEI, 2017). The past few decades have been relatively quiet compared to historic storms that passed within 100 miles of Southeast Palm Beach County (see Figure 1-10). The very active 2017 hurricane season may have marked a return to normal incidence.

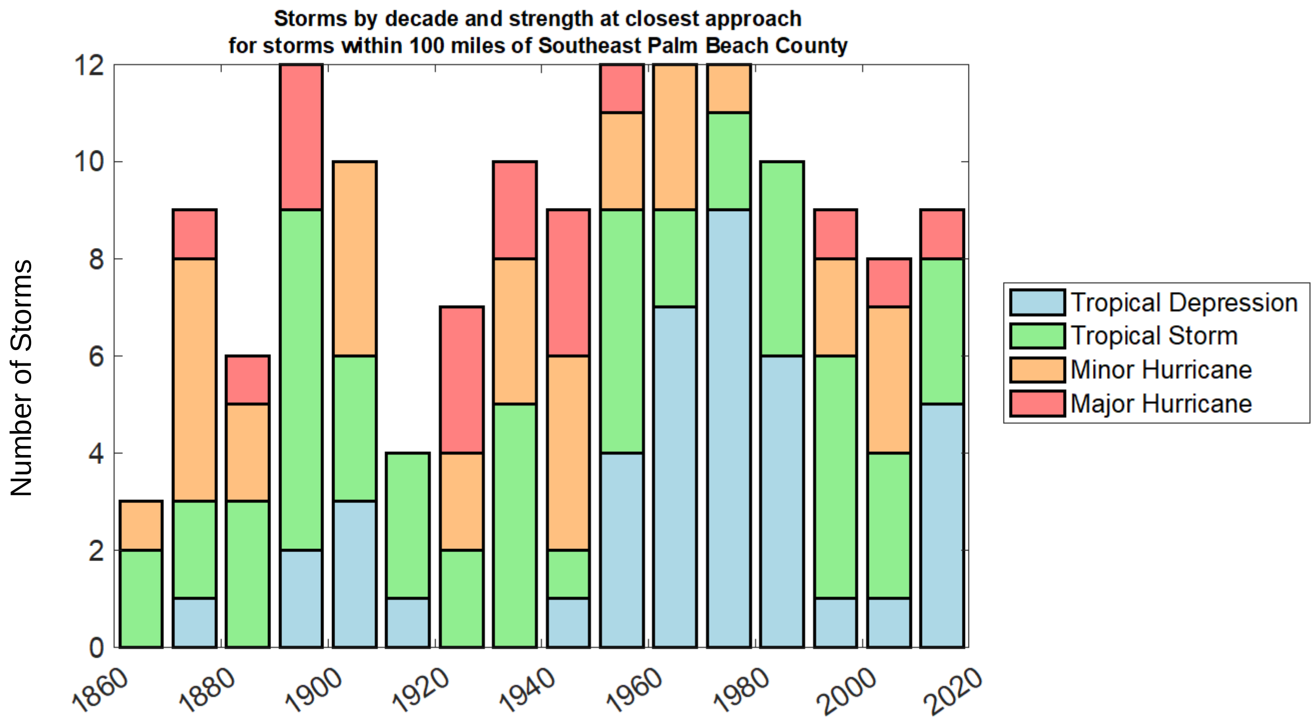


Figure 1-10. Bar chart of tropical systems by decade for storms where the center came within 100 miles of the CRP study area. The strength is provided based on strength at the point of closest approach (Data Source: NOAA 2016).

With a warming climate, scientists have high confidence that tropical systems in the Atlantic are likely to have higher rainfall rates than present-day hurricanes. Multiple studies agree that the mean intensity of these storms (wind strength) is likely to be higher in the future as well, with the frequency of the most intense storms (Saffir-Simpson Category 3 or greater) in the Atlantic expected to increase in the future. Overall, these storms are relatively rare based on historic data (see Figure 1-11). While not necessarily intuitive, changes to the frequency of intense storms are now an area of active research as scientists consider the competing effects of increasing mean intensity of all tropical storms with a general decrease in overall tropical storm frequency (Kossin et al. 2017). This means that while the average storm may be stronger, the region may not see more storms, and may possibly see even fewer tropical storms.

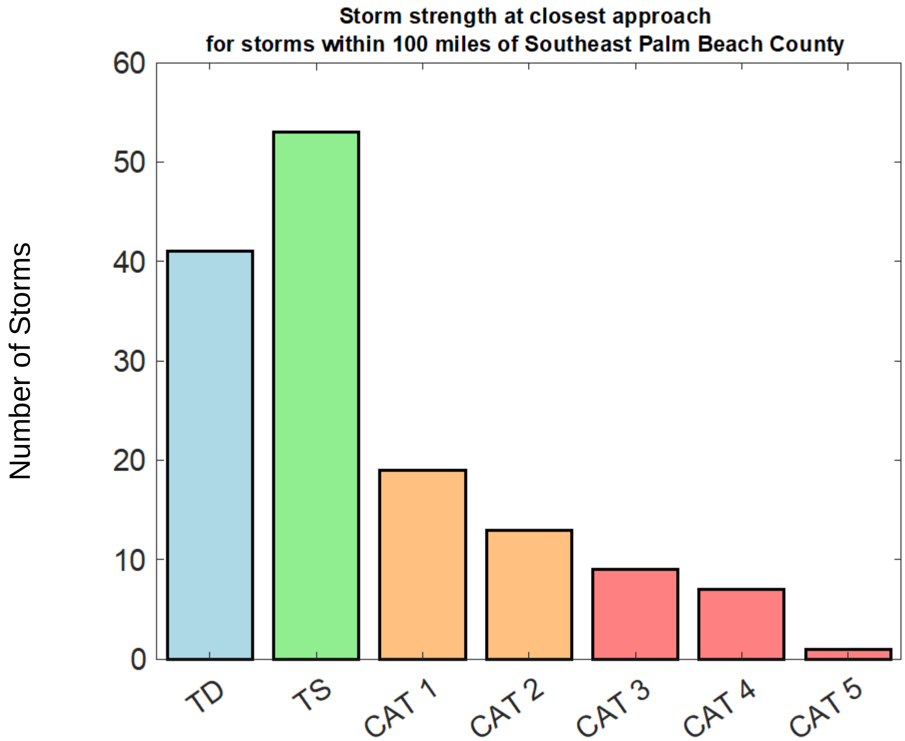


Figure 1-11. Bar graph of number of tropical systems (categorized by hurricane category) within 100 miles of Southeast Palm Beach County in the past 100 years (Data Source: NOAA 2016).

To understand the types of major hurricanes considered as the most severe, it is helpful to look at recent storms for reference. Major hurricanes (Category 3 or greater) that came within 100 miles of Southeast Palm Beach County since 1970 include Andrew, Jeanne, and Matthew (based on the strength at point of closest approach). One way to understand the energy or strength of tropical systems is through Accumulated Cyclone Energy (ACE), which, as defined by NOAA, has been above normal in the past few decades (see Figure 1-12, NOAA 2016). The ACE is the measure of seasonal activity for storms of at least tropical intensity in the form of a wind energy index (NOAA 2016). This will be one measure to observe over the coming decades and will provide insight into the strength of storms that may develop in the Atlantic Basin.

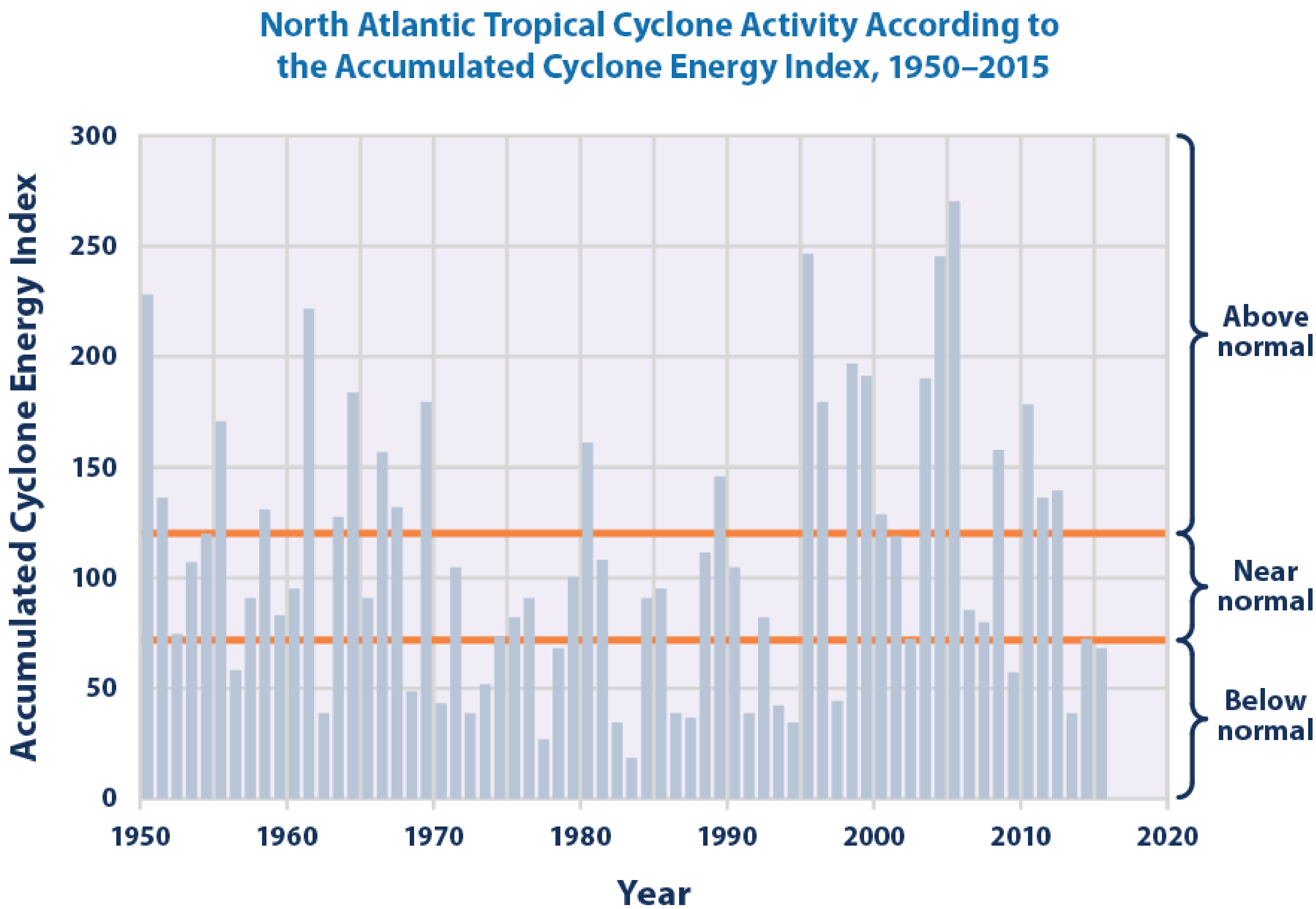


Figure 1-12. North Atlantic tropical cyclone activity from 1950 to 2015 based on Accumulated Cyclone Energy (ACE) Index (Data Source: NOAA 2016).

The threat of storm surge associated with tropical systems significantly drives the coastal flood risk of the region. The direction of the approach of tropical systems will change the associated storm surge risk. Figure 1-13 provides the number of all tropical systems on record by directional approach where those from the east and southeast will likely have the worst associated storm surge.

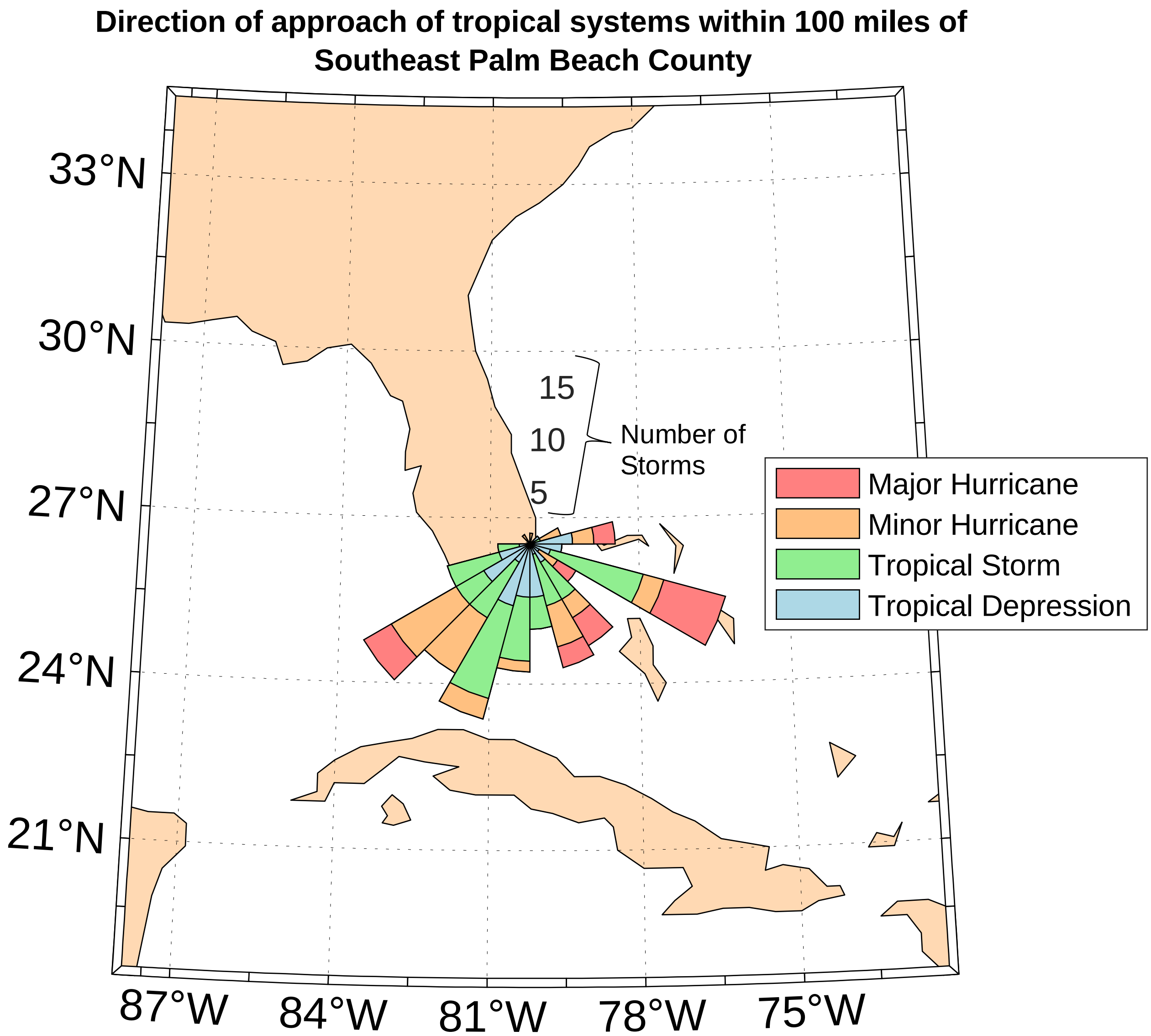


Figure 1-13. Historic direction of approach of tropical systems (Data Source: NOAA 2016).

CRP

1.2.4 Sea Level Rise

Sea level rise has been measured by tidal gauges all over the world, including one within Palm Beach County at the Lake Worth Pier. Based on historic data, sea levels are rising in this area at 3.74 mm/year, which is approximately 1.5 inches/decade (see Figure 1-14). The graphic is relative to 1992, which is the centroid of the tidal epoch, an 18.6-year period over which sea level data is analyzed. However, sea level rise is anticipated to accelerate due to continued global warming (Southeast Florida Regional Climate Compact, 2020).

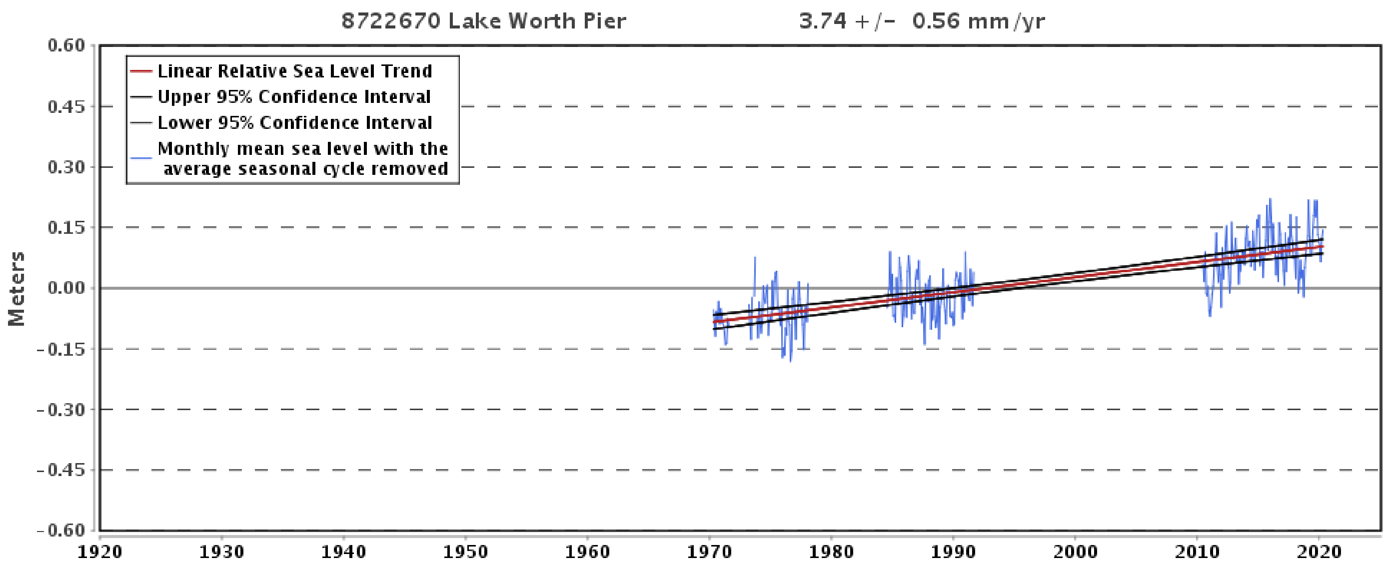


Figure 1-14. Historic sea level rise from Lake Worth Pier. As is visible from the Lake Worth Pier tidal station, the mean sea level has risen about half a foot since 1970 (Data source: NOAA Tides and Currents, Lake Worth Pier).

Due to astronomical, meteorological, and other factors, there is interannual variation in sea level. The monthly **mean sea level** at Lake Worth Pier is about eight inches higher in October than it is in July (see Figure 1-15), primarily due to the warmer waters at the end of summer. This peak period of sea level occurs within hurricane season, which can exacerbate the impact of storm surge.

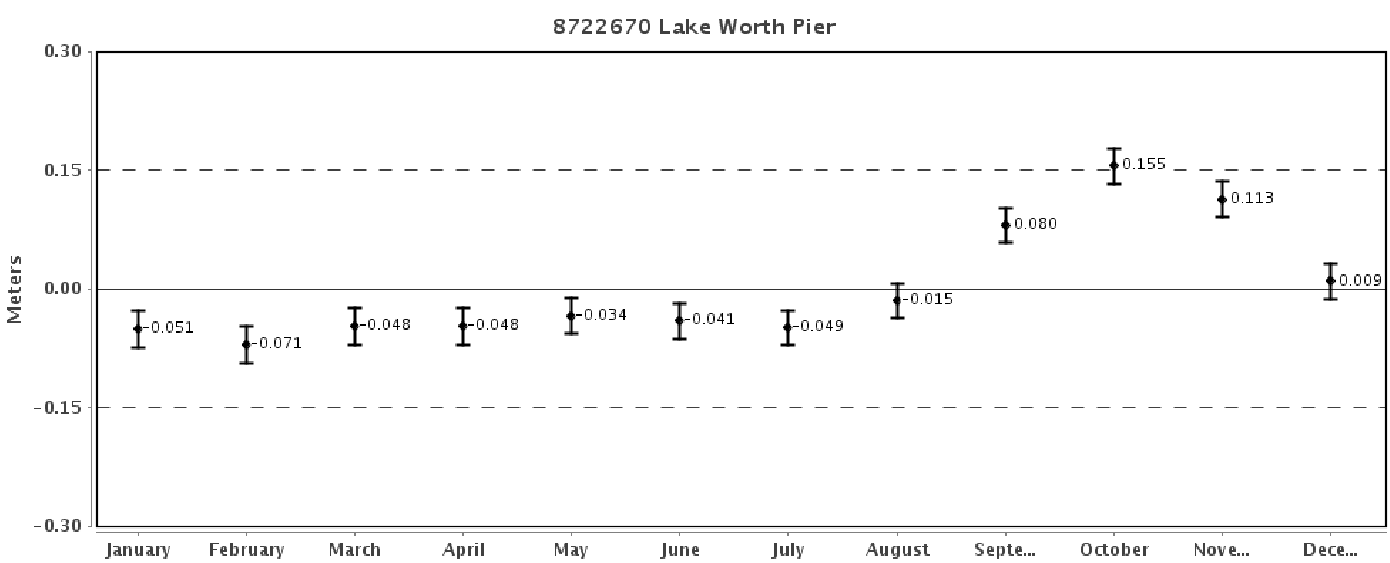


Figure 1-15. Average season cycle of sea level at Lake Worth Pier tidal station (Data source: NOAA Tides and Currents, Lake Worth Pier).

Sea levels are expected to continue to rise. The regional unified sea level rise projections produced by the Southeast Florida Regional Climate Change Compact are further discussed in Section 1.6.

The short-term impacts of sea level rise include increased risk of high-tide flooding and storm surge. The figure below illustrates the projected impact of sea level rise on the frequency of high-tide flooding at the Virginia Key tide gauge (NOAA Gauge No. 8723214), for different scenarios (Sweet et al. 2018). The Virginia Key tide gauge is utilized as a representative gauge for Southeast Florida due to the length of the record and is frequently used in scientific analysis. Figure 1-16 shows, under different sea level rise scenarios, that the region will see a significant increase in the number of days with **tidal flooding**, and the near exponential increase in the number of days of high-tide flooding annually over the coming decades. Sea level rise will also exacerbate **shoreline recession**, groundwater flooding, and **saltwater intrusion.**

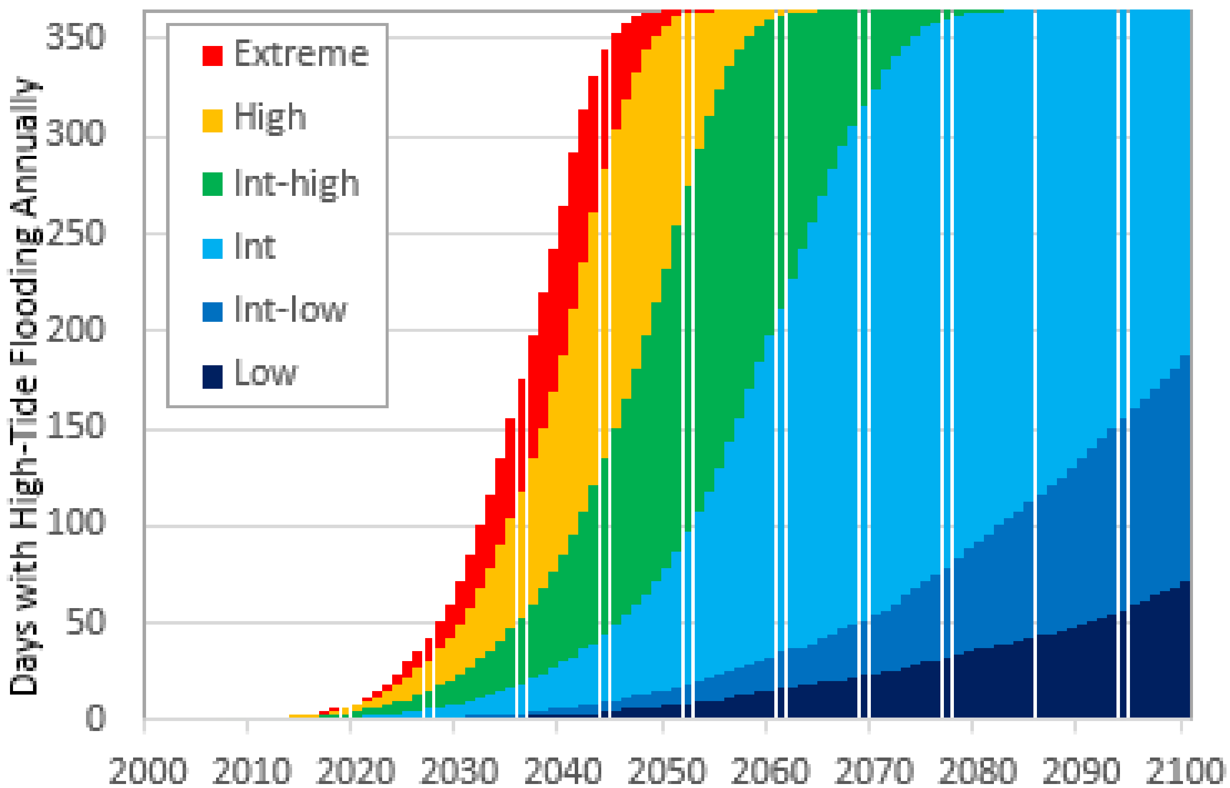


Figure 1-16. Projected days of future high-tide flooding at Virginia Key Tide Gauge (Data source: Sweet et al. 2018; Figure source: Collini et al. 2018).

1.2.5 Temperature Variability

The average temperature for the region (specifically the Florida Lower East Coast Climate Division) has been increasing an average of 0.5°F per decade over the last 50 years. However, as visible in Figure 1-17, the increase is variable rather than a steady, year-to-year progression.

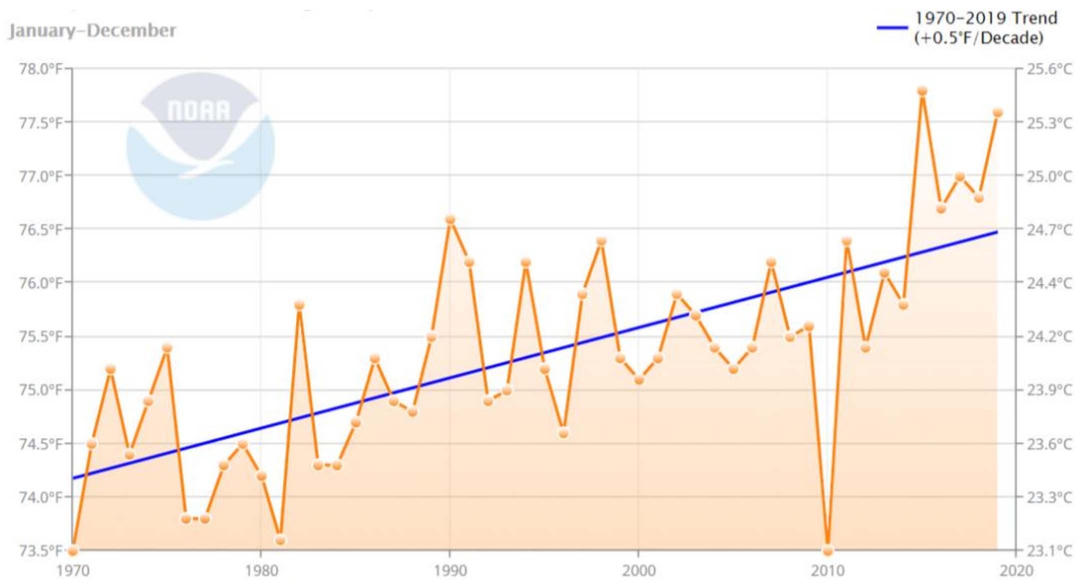


Figure 1-17. Average temperature for the Florida Lower East Coast Climate Division, which includes the CRP study area, from 1970 to 2020 (Data source: NOAA NCEI Climate at a Glance, U.S. Time Series).

The number of very warm nights is increasing (see Figure 1-18). From the mid-1950s to the mid-1980s, the number of very warm nights during each 5-year period was comparatively low. There has been a noticeable change over the past 20 years, with the nights not cooling down to below 75°F for over 30 days during the summer. Because of this, many air conditioning systems run continuously during many parts of the summer.

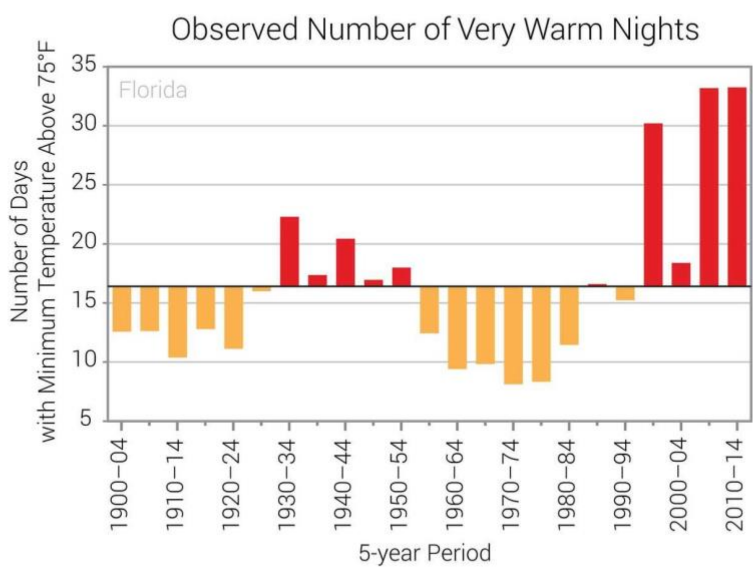


Figure 1-18. Average number of very warm nights across the State of Florida with minimum temperature above 75°F degrees (Figure source: NOAA NCEI, State Climate Summaries 2017, Florida).

Examining future projections of mean daily minimum temperature for Palm Beach County, the lower-emissions (RCP4.5) and higher-emissions (RCP8.5) climate scenarios indicate that a warming trend will continue (See Figure 1-19). The region should expect to see more hotter days, more warmer nights, and higher average temperatures. Warmer summer nights will impact not only vulnerable populations, who may not be able to afford to cool their homes, but also put an increased demand on power providers.

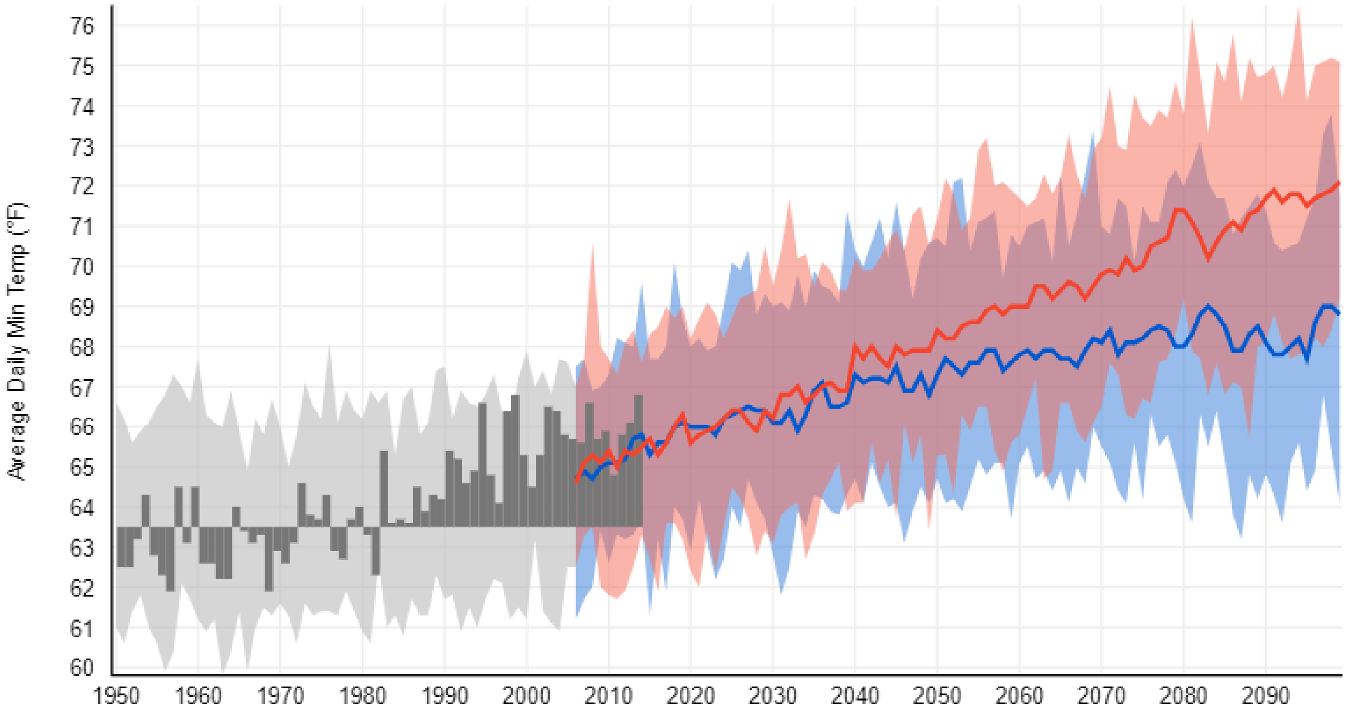


Figure 1-19. Average daily minimum temperature for Palm Beach County. The blue color indicates the mean and spread of lower-emission scenarios, and the red likewise for the high-emissions scenario (Figure source: U.S. Climate Resilience Toolkit Climate Explorer 2020).

CRP

Another measure of temperature impact is **cooling degree days**, defined as the number of degrees by which the average daily temperature is higher than 65°F multiplied by the number of days this threshold is exceeded (See Figure 1-20). This measure is thus a proxy that can show trends in expected energy demand for cooling. In Palm Beach County, the number of cooling degree days relative to the 1961–1990 average is projected to increase by 25 percent in nearly 10 years and by 50 percent in nearly 40 years.

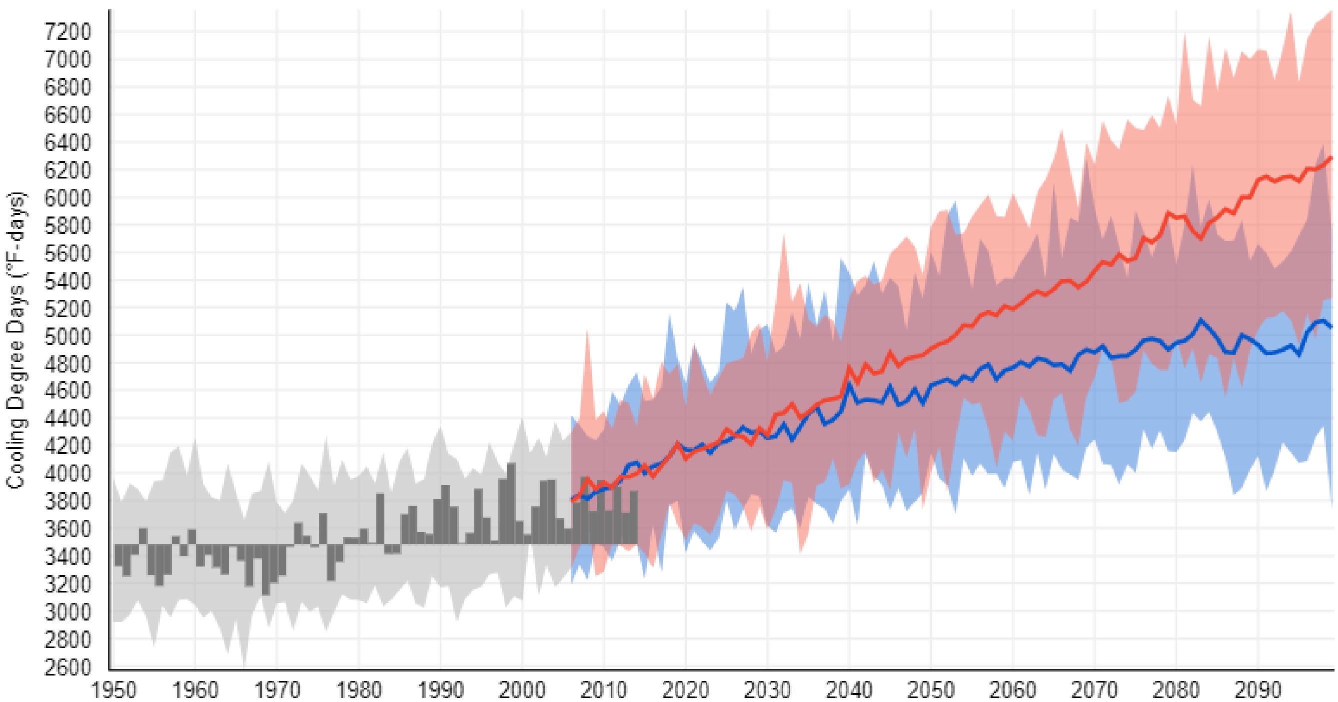


Figure 1-20. Cooling degree days for Palm Beach County. The blue color indicates the mean and spread of lower-emission scenarios, and the red likewise for the high-emissions scenario (Figure source: U.S. Climate Resilience Toolkit Climate Explorer 2020).

1.3 Threats

As a Climate Change Vulnerability Assessment, this study focused on twelve (12) climate-related **threats** that were determined through stakeholder engagements. During both the kickoff meeting (April 14, 2020) and Workshop 1 (May 14, 2020), those 12 climate-related threats were determined. These threats are shown below as Figure 1-21. Other threats were discussed, however the Working Group determined that the selected threats likely pose the most significant risk to Southeastern Palm Beach County as of 2020. These threats will be the focus of this section and the remainder of this report.

Most of the selected threats have complex and interconnected relationships, and all of them are undergoing intense scientific study. Just within Southeastern Palm Beach County, many of the threats interact and are exacerbated by both climate and non-climate stressors. Climate stressors are specifically related to climate change, where non-climate stressors would be related to other factors, such as population growth, migration, or land use changes. These are further described in Table 1-2. The importance of various threats may also change over time and by geographic area. The CRP used best-available data to analyze these complexities within the scope of the project with full acknowledgement of these complexities.

It is also key to note the importance of socioeconomics superimposed on these threats. Socioeconomics will be considered throughout this report, and the response of various vulnerable populations is a critical aspect of this study. Populations vulnerable to each type of threat will be carefully considered, particularly as part of Steps 3 and 4.

Threats were separated into major categories for the study based on type (see Figure 1-21) and include meteorological (light blue), health and environmental (yellow), heat-related (red), and water-related (blue).

Furthermore, although discussed widely throughout many climate change studies, sea level rise is a multiplier for many of the threats that the CRP is interested in – but sea level rise alone will be considered a stressor in the CCVA. Threats heavily influenced by sea level rise include **rainfall-induced flooding**, **shoreline recession**, **tidal flooding**, **storm surge**, **groundwater inundation**, and **saltwater intrusion**. The method of analysis for each threat is discussed in Section 2 of this report.

Top Threat Identification

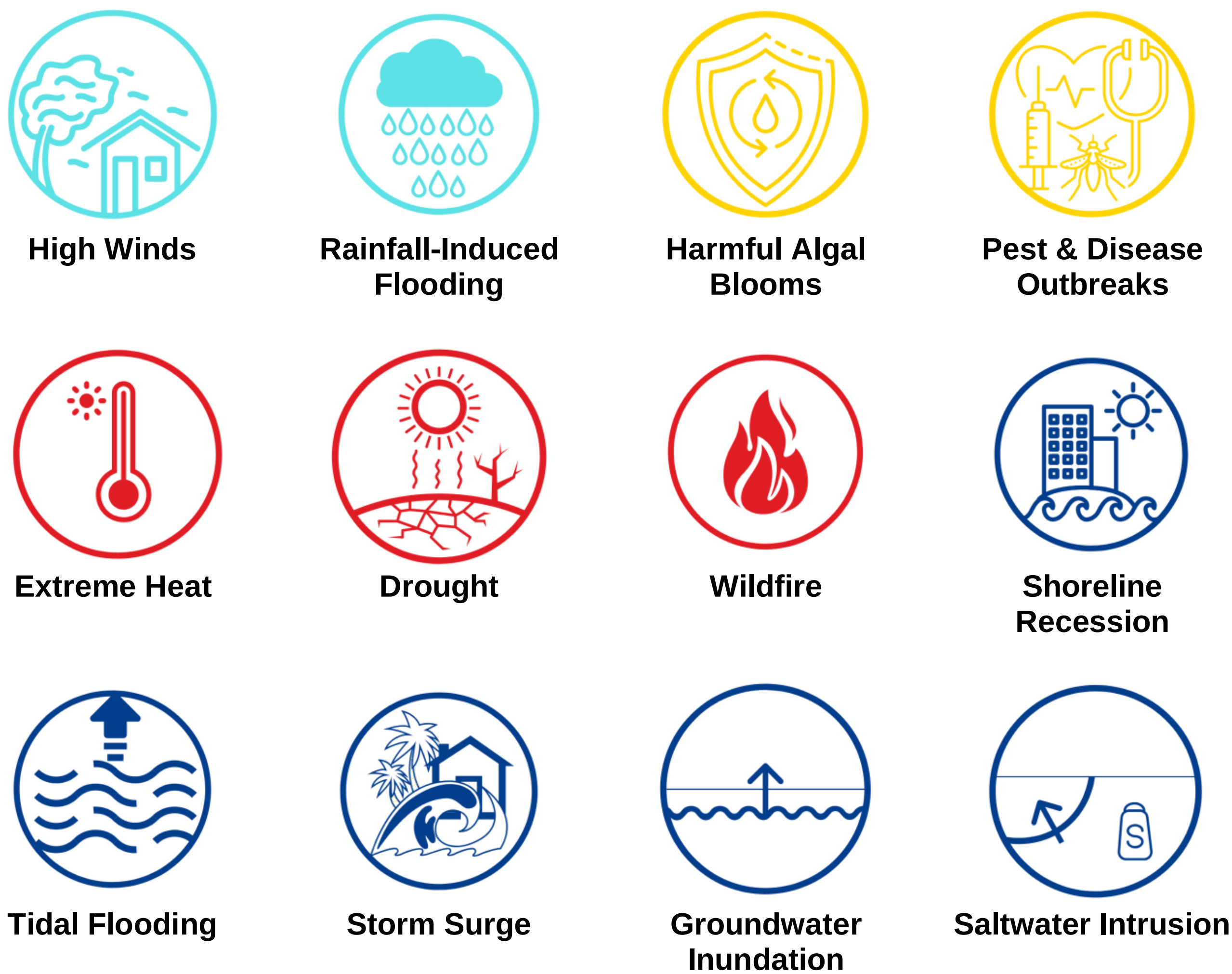


Figure 1-21. Icons for each of the selected twelve climate threats, colored thematically by meteorological (light blue), health and environmental (yellow), heat-related (red), and water-related (blue) threats.

Table 1-2. Threats and related climate and non-climate stressors.

Threat	Climate Stressors	Non-Climate Stressors
High Winds	Tropical systems	Building conditions, urbanization, landscaping choices (e.g., non-native large trees)
Rainfall-Induced Flooding	Sea level rise, heavy precipitation, and precipitation variability	Impervious surfaces, land use change, aging infrastructure
Harmful Algal Blooms (HABs)	Oceanic and atmospheric temperatures	Nutrient loading (point and nonpoint), impervious surfaces, land use changes and other hydrologic alterations)
Pest & Disease Outbreaks	Temperature variability, precipitation variability	Urbanization, population growth
Extreme Heat	Increased temperatures	Impervious surfaces, land use change
Drought	Precipitation variability, increased temperatures, increased evapotranspiration	Hydrologic alterations, population growth, water demand (consumption of fresh water)
Wildfire	Temperature variability, precipitation variability	Development, land use change
Tidal Flooding	Sea level rise, heavy precipitation	Aging infrastructure, impervious surfaces, land use changes
Storm Surge	Sea level rise, tropical systems	Aging infrastructure, impervious surfaces (density of development in coastal areas), land use changes
Shoreline Recession	Sea level rise, tropical systems	Aging infrastructure, impervious surfaces (density of development in coastal areas), land use changes
Groundwater Inundation	Sea level rise, changing precipitation patterns	Geology, land settling, stormwater management systems
Saltwater Intrusion	Sea level rise, changing precipitation patterns	Geology, land settling, stormwater management systems, population growth, water demand

1.3.1 High Winds

Sustained **high winds** are typically associated with tropical systems in Southeast Florida, and thus most common during hurricane season (June 1 through November 30). Sustained high winds can destroy infrastructure and other physical **assets**. As the climate warms, it is anticipated that the most intense hurricanes (Categories 3-5) will become more frequent while the overall frequency of hurricanes may not change. This means that the likelihood of a strong hurricane with high sustained winds hitting South Florida will increase. Hurricane Dorian, which barely missed Palm Beach County in 2019, had sustained winds in excess of 185 mph, making it one of the strongest hurricanes in the Atlantic Basin at landfall on record (Avila et al. 2020). A detailed review of historic tropical systems is provided earlier in Section 1.

1.3.2 Rainfall-Induced Flooding

Rainfall-induced flooding refers to flooding that is the result of spatial or temporal shifts in rainfall patterns. As climate change occurs, hydrologic shifts are likely causing increases to both the frequency and intensity of rainfall-induced flooding throughout South Florida. This threat is closely linked to and may exacerbate other climate threats that involve flooding. Rainfall-induced flooding is also exacerbated by several significant non-climate stressors such as changes to historical hydrology via land use alteration, aging infrastructure, and the many challenges related to maintenance of stormwater infrastructure (Viessman et al. 2009). Sea level rise is worsening rainfall-induced flooding in parts of Southeastern Palm Beach County where coastal stormwater sewer networks cannot discharge as designed (Southeast Florida Regional Climate Compact 2015).

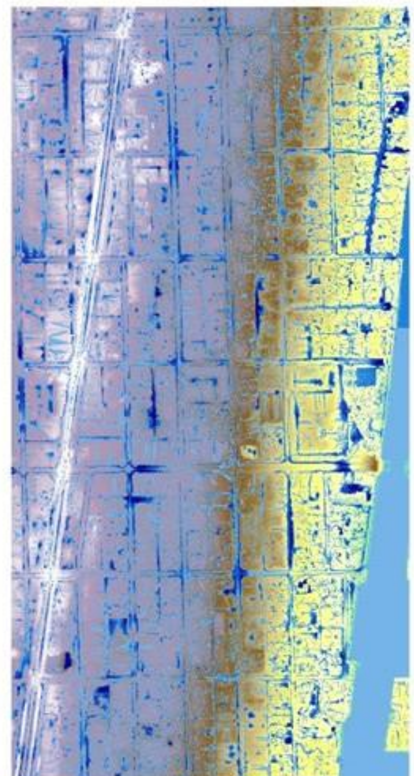


Figure 1-22. Inundation results for the 100-year storm event (1% annual chance) in the study area.

The project team used a combination of results from stormwater models (for watersheds that have models) and an inundation mapping tool as the primary datasets to examine this threat. Figure 1-22 shows an example of preliminary inundation mapping results. Stormwater experts also compared this data to problem area reports and repetitive loss data from each jurisdiction. This secondary check was an important step in vetting the data layers that were used during Step 3 of the project. This methodology is defined in Section 2 of the report including a discussion of stormwater studies and models as compared to inundation maps produced by the project team.

1.3.3 Harmful Algal Blooms (HABs)

Although algae are a natural occurrence in South Florida waters, **Harmful Algal Blooms (HABs)** occur when particular species of algae grow out of control, negatively impacting humans, fish, shellfish, marine mammals, and birds. HABs have occurred in recent years and have not only affected these natural systems, but they also have significant impacts on local economies. HABs are expected to start increasing in frequency and intensity (EPA 2013). These increased blooms are related to increases in oceanic temperatures and changes to historical hydrologic patterns (e.g., changes in rainfall patterns). Non-climate stressors are also a significant factor in the production of HABs because they are linked to increased loads of nutrients entering waterways via stormwater runoff. Nutrients are linked to both non-point and point source pollution throughout the study area.

This is a complex threat both scientifically and in terms of data involved, and is a threat that has rarely, if ever, been included in vulnerability analyses. However, HABs and water quality certainly warrant further study given the grave nature of this threat to the micro-region and to Florida in general.

1.3.4 Pest and Disease Outbreaks

Pest and disease outbreaks include the threat of illnesses from water or vector-borne diseases, such as those carried or spread by mosquitoes. This threat may also include issues related to **invasive species**.

Climate stressors for pests and disease include temperature variability and changes in spatial and temporal variability of rainfall (more standing water). Non-climate stressors include urbanization and population growth.

Special considerations for general disease outbreak include

- How pest and disease outbreaks could present dual emergencies and impact public health response measures. For example, a disease outbreak could impact emergency evacuation and sheltering procedures during storms.
- The disproportionate impact a disease outbreak (and any hindered response measures) could have on socially vulnerable populations.
- Contextual information from assessment could also serve as baseline information and may be useful for outbreak response. For example, the location of critical services (e.g., **SNAP** retailers and food supply, medical facilities), economic factors including businesses by type, associated sales volumes, and jobs, and mobility and response drive time.
- How the threat of flooding is related to the spread of waterborne diseases.

Threat data on pest and disease outbreaks is limited for higher spatial resolutions (sub-county level detail). This assessment incorporates socioeconomic metrics for vulnerable populations, including data from the CDC's **Social Vulnerability Index (SVI).** Information on pests and the presence of invasive species in the study area was used to consider the types of impacts and inform the vulnerabilities that are present.

1.3.5 Extreme Heat

Extreme heat events are periods of excessively hot and/or humid weather that can last multiple days. Extreme heat is a pressing public health risk, particularly for low-income and elderly communities living in developed areas with limited options for relief from heat (USGCRP 2018, Burgess and Foster 2019).

The primary climate stressor for extreme heat is increasing temperature, including increased number of hot days (the daily maximum temperature) and increasing night-time temperatures (resulting in less relief from heat). Non-climate stressors include population growth and urban expansion, and the associated concentration of areas with impervious surfaces that can contribute to urban heat islands (NOAA NCEI 2017, EPA 2008b, US CRT 2017b).

The data used to assess extreme heat will be based on socioeconomic metrics in order to identify the populations most sensitive to extreme heat events. This includes families living below the poverty line and households with members 65 years of age and older. To assess the potential for urban heat islands, landcover information will be analyzed to identify areas with the highest levels of developed land cover. Tree canopy data from recent studies was integrated from jurisdictions across the region in order to understand the potential mitigating effect that tree canopy coverage may have during heat events. Tree canopy coverage information from the National Landcover Database (NLCD 2016) was used to fill in where local studies were not available.

1.3.6 Drought

Drought is prolonged dry period that can impact availability of water supply, agriculture, and other aspects of life. It is a significant threat since it relates to the basic human requirement for safe and adequate drinking water. Drought also creates significant impacts on natural systems, socioeconomics, and agriculture. This is a complex threat as it relates to several climate stressors and other threats (primarily, but not limited to, **groundwater inundation** and **saltwater intrusion**). These complexities are well documented in the Southeast Florida Climate Compact's RCAP Implementation Guide *Integrating Climate Change & Water Supply Planning in Southeast Florida* (Southeast Florida Regional Climate Compact, 2014). Climate stressors that exacerbate drought primarily include increases in spatial and temporal variability in rainfall, increased global temperatures, and increased evapotranspiration. Changes in human populations – such as increased consumption of freshwater and **human migration** – also affect drought (Viessman et al. 2009).

Drought is considered a climate threat for this project, although the project team acknowledges that drought is also considered a climate stressor. When drought is considered a climate stressor, related threats may include water shortage, agricultural damage, and wildfire.

1.3.7 Wildfire

Wildfire is a natural uncontrolled fire that burns in wildland vegetation and can provide natural benefits to ecosystems. Wildfire can become a threat when it negatively impacts communities and the assets of value. This assessment examined the threat of wildfire in the Wildland Urban Interface (WUI). The WUI includes areas where homes and assets are within or adjacent to vegetation and fuels for wildfire. The assessment of vulnerability and risk to wildfire may help prioritize areas for active fuel management, especially in areas where fire response may be more challenging. The risk of wildfire is also greatest in years of drought (Radeloff et al. 2005, Radeloff et al. 2018, Stewart et al. 2007). An image of a prescribed burn that later prevented wildfire is shown in Figure 1-23.

Figure 1-23. Observation of a prescribed burn that later prevented wildfire in the Loxahatchee River National Wildlife Area within Palm Beach County (Photo Credit: U.S. Fish and Wildlife Service https://www.fws.gov/fire/news/fl/newsitem2.shtml).

Climate stressors for wildfire include temperature variability and drought. Lightning is also known as a source of wildfire ignitions in more remote areas such as the Loxahatchee National Wildlife Refuge (USFWS). Non-climate stressors include growth, hydrologic alterations, and homes in the WUI (Radeloff et al. 2005, Stewart et al. 2007).

Data from the SILVIS Lab and the University of Wisconsin (Radeloff et al. 2018) was used to understand the WUI in this study area. This includes where homes are in proximity to wildland vegetation and are in areas identified as being part of either the WUI interface or intermix (Radeloff et al. 2018).

1.3.8 Tidal Flooding

Tidal flooding, also referred to as "King Tide," "nuisance flooding" or "sunny day" flooding, occurs during non-storm periods and is due to high astronomical tides that occur periodically throughout the year. King Tides generally refer to the highest tidal flooding events of the year and is a colloquial term. Astronomical tides are caused by the gravitational pull of the sun and the moon and have their greatest effects on seawater level during new and full moons – when the sun, the moon, and the Earth are in alignment. Tidal flooding can occur due to direct inundation of upland areas as well as through storm drain systems that cannot outfall (due to higher tidal elevations) and overflow into interior low-lying areas. This type of flooding can cause temporary interruptions in day-to-day activities through flooding of streets with saltwater and backing up of storm sewer systems that prevents drainage during even small rainfall events. When these high-tide events coincide with even small coastal storms or wind events, the flooding levels can be further exacerbated.

As sea levels rise, the time periods when tidal flooding occurs will increase in frequency and duration. This will also be exacerbated by land subsidence and losses of natural barriers. Data has shown that tidal flooding has risen over the past few decades (Sweet et al. 2018).

The primary sources of base data for this threat are measured and predicted tide records in the study area. This includes primary and secondary NOAA and USGS stations along the coast as well as water levels measured downstream of structures that block tidal propagation into interior areas.

1.3.9 Storm Surge

Storm surge is the abnormal rise in sea level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore (US CRT 2017a). The amplitude of the storm surge at any given location depends on the orientation of the coastline with the storm track; the intensity, size, and speed of the storm; and the local bathymetry (NOAA 2021).

Storm tide is the total observed seawater level during a storm, resulting from the combination of storm surge and the astronomical tide. As a result, the highest storm tides are often observed during storms that coincide with a new or full moon, and during a high tide (NOAA 2021).

The risk under a storm surge event is also exacerbated by local wave conditions, which can amplify the overall risk levels through wave set-up (additional rise in the mean water level due to the energy transfer from the waves) and wave height/breaking, which can cause additional structure damage.

When considering future conditions, sea level rise would be added to the above conditions in order to get a final projected water level/impact area during a storm. It is important to note that sea level rise can have the effect of increasing each of the different components beyond just the long-term sea level rise – e.g., waves are bigger in deeper water, storm surge can propagate in farther and higher when water levels are deeper. All of these aspects should be understood when preparing for storm surge in the face of rising seas.

An assessment of storm surge ties with other identified threats in that storm surge is directly tied to rainfall-induced flooding through potential backflow during storm conditions. It is also directly tied to **shoreline recession** as higher storm surge, and the associated waves, are some of the key driving mechanisms.

The data used to assess storm surge (and the related components discussed above) are projections of peak water level and waves, which vary across the CRP study area. Those peak water levels/waves are associated with specific return periods/risk levels. **The Federal Emergency Management Agency (FEMA)** projects the 100-year storm (or 1 percent annual chance) condition for storm surge impacts, though different risk levels and return periods can be developed if the base models or raw data are available for use. For this project, the data utilized comes from modeling and other analyses developed as part of the South Florida **Flood Insurance Studies** (completed in 2017).

The sea level rise projections were determined utilizing the base 100-year flood elevations (or **Base Flood Elevation**, **BFE**), and added to the base 100-year flood conditions outlined above to define the revised BFE under the sea level rise condition. The overall BFE coverage will be extended to reflect the revised elevations utilizing the selected **Digital Elevation Model** (**DEM**) of the area.

1.3.10 Shoreline Recession

Coastal erosion, which results in **shoreline recession**, is the process by which wave action, wind, sea level rise, and other factors wear down and transport soil and/or sand away from or along the coast. This is compounded in the study area by the disruption of sediment transport by coastal development, jetties, inlets, and hardened shorelines. In addition to longer term erosion processes, beaches in the region are prone to storm events that can worsen erosion impacts and lead to more serious shoreline recession. Figure 1-24 shows shoreline recession in a Palm Beach County community.

Figure 1-24. Shoreline recession in a Palm Beach County community. Photo by Melany Larenas, ATM.

Sea level rise and climate threats are anticipated to exacerbate erosion in the future, especially as storms increase in intensity and frequency (Kossen, J.P. et al., 2020). Beaches in the study area are regularly maintained to mitigate the impacts of erosion and provide a level of storm protection for adjacent coastal areas. However, a changing climate will make these mitigation measures less effective over time if the maintenance procedures remain the same.

1.3.11 Groundwater Inundation

Groundwater inundation is primarily connected to climate change through sea level rise. South Florida sits upon porous limestone, which allows the freshwater aquifer to fluctuate with sea levels more readily. As sea levels rise, this will eventually push groundwater up above ground level, flooding dry land. With continual flooding, not only will critical infrastructure and vulnerable assets be adversely affected with erosion, but natural ecosystems may also degrade due to their inability to thrive in persistent inundation.

Groundwater inundation is further exacerbated by seasonal fluctuations in sea levels, as well as with the presence of previously unprecedented King Tides. According to the Southeast Florida Regional Climate Change Compact's Sea Level Rise Ad Hoc Work Group, when King Tides are present, resulting flood water can impair stormwater drainage infrastructure and negatively impact natural systems. Moreover, the Climate Compact states that sea level rise may additionally contribute to "reduced drainage capacity thus causing less rainfall to be infiltrated and stored in the soil." However, if proper improvements are implemented in water management infrastructures, such as reinvigorating "stormwater storage, increasing pumping capacity to remove water from developed areas, and increase discharge from coastal structures," the burden of groundwater inundation would be greatly mitigated (Miami Dade Government, 2016).

1.3.12 Saltwater Intrusion

Like groundwater inundation, **saltwater intrusion** is primarily connected to climate change through sea level rise. The freshwater aquifer in South Florida floats atop the saltwater below as a lens. Experts in the U.S. Geological Survey conducted a study focusing on saltwater intrusion as it pertains to the Biscayne aquifer, which lies below southern Palm Beach County. The report found that saltwater intrusion occurs in three different processes: water moving inland from the sea or "lateral saltwater intrusion," water moving upward from the lower part of the aquifer, or water moving downward by a downstream reach of a tidal canal (Dausman et al. 2005).

Ultimately, the limestone allows the groundwater to fluctuate more readily compared to less porous bedrock because as sea levels rise, so does the groundwater table. The permeable nature of Florida's limestone, in the face of increasing water levels, causes the freshwater to push toward the surface leaving less storage capacity for freshwater as saltwater takes its place. Additionally, as sea levels rise, more interaction and mixing between the freshwater lens and saltwater of the oceans is expected. Water quality and quantity become a primary concern as potable water becomes increasingly scarce and more difficult to maintain as a result of saltwater intrusion.

1.4 Community Assets

For this vulnerability assessment, **community assets** are defined as the people, resources, infrastructure, and services that people and communities rely on, value, and expect their leaders to manage and protect. The purpose of the vulnerability assessment is to provide community leaders and staff with a resource to continuously assess and better manage their assets in response to the impacts of key threats. Therefore, defining and representing these community assets is an important aspect of the assessment.

Seven themes of community assets are identified as part of the CCVA. They are described below and provided in a summary table (Table 1-3) at the end of this section.

1.4.1 Critical Facilities

Critical facilities include fire and police stations, medical facilities, food supply and distribution facilities, schools, and energy and communication facilities. To consider the range of assets within this theme, the following asset categories are used:

- Energy and Communications
- Food Infrastructure
- Health and Medical
- Public Safety and Government Facilities (includes public and private schools)
- Transportation Facilities

These asset categories are also consistent with FEMA's Community Lifelines (FEMA 2019a) that "enable the continuous operation of critical government and business functions and [are] essential to human health and safety or economic security." These categories are also consistent with Presidential Policy Directive 21 (PPD21) and Department of Homeland Security classifications of critical infrastructure (Office of the Press Secretary 2013).

The asset categories within this theme are represented primarily by parcel datasets in addition to building and property use information. Assessments within this theme consider property and building-level characteristics and the services they provide to the community. Criticality and use of facilities are also considered in order for the assessment to support prioritization of vulnerable facilities and areas.

1.4.2 Water Infrastructure

Water infrastructure is universal and critical. In a coastal area with a complex socio-political environment, such as Southeastern Palm Beach County, water infrastructure is particularly complicated, critical, and sophisticated. All eight jurisdictions within the study area have various forms of water infrastructure in place. Many communities also leverage interconnections so that water and wastewater services can be provided across jurisdictional boundaries during both routine and emergency operations. Water infrastructure in the study area generally includes:

- Wastewater Treatment Facilities and Collection Systems

- Water Treatment Facilities and Distribution Systems
- Stormwater Treatment, Conveyance, and Treatment Systems
- Septic Tanks

Figure 1-25. A stormwater inlet in Delray Beach. Photo by Anna Leitschuh, Collective Water Resources.

Green infrastructure is an important part of a community's water infrastructure. For the purposes of this study, most green infrastructure (swales, bioswales, retention/detention ponds, etc.) are included within the category of stormwater. Some types of green infrastructure, such as trees, are included within the Natural Resources theme (discussed in Section 1.4.4 below).

1.4.3 Economic Factors

Economic factors are important for the assessment to consider, especially as they relate to the potential for business disruption. This asset theme considers the three main economic factors through the following asset categories:

- **Annual Sales Volume**
- Jobs and employees
- Improved value or assessed value of a home

Figure 1-26. The Lake Worth Street Painting Festival is a major annual event in Palm Beach County. Photo by Debby Hudson on Unsplash https://unsplash.com/.

Assets in these three categories are represented primarily through information on business locations, estimates on sales and jobs, and Palm Beach County's tax-assessed value of assets exposed and vulnerable to specific hazards. The assessment provides insights into how the vulnerability of properties and business locations translates to potential disruptions to sales and jobs. In addition to the assessment of these two asset categories, other information is used in the study that could provide insights to the potential for economic impacts, including the number and types of commercial and industrial businesses that are vulnerable, the total property improvement values potentially affected, and the level at which key commercial corridors are vulnerable (see Property, Section 1.4.6 below).

1.4.4 Natural Resources

Natural resource assets are critical to the region in how they support recreation and tourism and provide ecosystem services. These assets are also critical in how they mitigate threats, such as flooding and **extreme heat**. The following asset categories will be considered within this theme:

- Beaches and Coastal Areas
- Natural Areas and Parks (including water resources)

These asset categories are represented primarily through property information and a natural areas database (including protected conservation lands). Assessments consider how recreation facilities and infrastructure have the potential to be directly impacted by threats. Criticality of natural areas in terms of the ecosystem services they provide is also considered.

Figure 1-27. A streetscape in Boynton Beach demonstrating many of the asset types. Photo by Liz Perez, Collective Water Resources.

1.4.5 People and Socioeconomics

Social vulnerability is a key consideration for all threat assessments. Socially vulnerable populations are disproportionately affected by climate threats. This asset theme will consider overall social vulnerability for all threats using the CDC's **Social Vulnerability Index (SVI)**. The SVI defines social vulnerability through four themes, including socioeconomic status, minority status and language, household composition and disability, and housing and transportation (CDC/ATSDR 2018). In addition to these themes, more specific socioeconomic information will be evaluated, such as **public housing** and food **SNAP retailers**. This theme includes the following asset categories:

- Social Vulnerability (and associated SVI themes)
- Food SNAP Retailers
- Assisted and Public Housing

These asset categories are considered using census tract information (and census block group information when available), in addition to property parcel and building information.

1.4.6 Property

Property assets include private properties of businesses and homes as well as cultural and religious properties. Asset categories within this theme include

- Commercial (including Industrial)
- Parks & Cultural
- Residential

These asset categories are represented in the assessment primarily through property parcel and building information. Criticality and property use information were used to understand different levels of impact (e.g., single vs. multi-residence units). Cultural property assessments also consider important religious or cultural landmarks, where the information was available. Assessments of these asset categories evaluate potential for direct impacts from threats and were used to identify vulnerable neighborhood areas, commercial corridors, and where those physical vulnerabilities coincide with **social vulnerability.**

1.4.7 Roads & Mobility

The Roads & Mobility theme focuses on the infrastructure and facilities that support mobility throughout the CRP study area. Asset categories within this theme include

- Roads (major and minor)
- Bridges (as part of road network)

These asset categories are represented primarily through road infrastructure and connectivity. With transportation facilities as part of **critical facilities**, together these categories are consistent with the FEMA Community Lifeline of "Transportation" (FEMA 2019a).

Figure 1-28. Major roadway in Boca Raton (time elapsed). Photo by Alexander Raissis on Unsplash https://unsplash.com/.

Assessments also focus on mobility through road connectivity and road network assessments that consider (1) roads that could be directly impacted (e.g., inundated by flooding); (2) roads that may not be directly impacted but could become inaccessible by emergency response; and (3) properties that could become isolated and inaccessible during threat events.

The following table (Table 1-3) provides a summary of all themes and asset categories that are used as the basis of the vulnerability assessment and for the summary of vulnerability and risk metrics.

Table 1-3. Overview of asset themes, categories and descriptions.

Asset Theme	Asset Category	Description or Details
Critical Facilities	Energy and Communications	Electrical utilities, substations, radio/cell tower properties
	Food Infrastructure	Food distribution centers, SNAP retailers, food pantries
	Health and Medical	Hospitals, extended care facilities, medical clinics
	Public Safety, Government, and Schools	Police stations, fire stations, government buildings, schools
	Transportation Facilities	Railway, transportation, and fleet facilities
Water Infrastructure	Wastewater, drinking water, and storm water	Wastewater treatment facilities and collection systems; water treatment facilities and distribution systems; stormwater treatment, conveyance, and treatment systems; septic tanks
Economic Factors	Annual Sales Volume	Annual sales for businesses
	Improvement Value (Assessed)	Assessed value of structures
	Jobs/Employees	Number of employees for business locations
Natural Resources	Natural Areas (including Beaches & Coastal Areas)	Greenways, beaches or natural coastal property, waterbodies, water resources
People & Socioeconomic	Population/Social Vulnerability	Social vulnerability (and associated SVI themes), food SNAP retailers, assisted and public housing
Property	Parks & Cultural Property	Religious or cultural property, landmarks, historical properties
	Commercial & Industrial Property	Retail, offices, industrial or manufacturing
	Residential Property	Any multi or single residence, group homes, public housing, apartments, and condos
Roads & Mobility	Major and Minor Roads	All roads and connectivity of road systems, including critical road access and properties potentially inaccessible

1.5 Asset-Threat Pair Combinations

The project team took the **threats** and **assets** identified during Steps 1 and 2 and applied a vulnerability and risk assessment framework to every combination of relevant threats and assets that were identified. These are referred to as asset-threat pairs and each was evaluated separately, even though some threats may also be interrelated (e.g., rainfall-induced flooding and tidal flooding). These asset-threat pair combinations are important in order for the assessment to inform asset-specific insights regarding the impacts from climate threats (e.g., impacts to a commercial corridor are inherently different from the impacts to a residential neighborhood). These insights then allow the CRP to develop adaptation strategies that are tailored to address the specific vulnerabilities across the jurisdictions.

For most asset-threat pairs, the vulnerability and risk assessment components were applied at the asset scale. For example, commercial property and tidal flooding is assessed at the parcel level. Summary information and materials were then generated for each of the asset-threat pair combinations identified.

The table on the following page (Table 1-4) provides a summary of the asset categories, the units of analysis for each, and the threats that were assessed. Based on the current information, there are 62 identified asset-threat pairs (when considering inaccessible roads and parcels separately). This does not include asset-threat pairings for future conditions (see Section 2), which were examined for rainfall-induced flooding, tidal flooding, and storm surge. This created an additional 72 asset-threat pairs. These were assessed using various methods, but included spatial, non-spatial, and narrative assessment types (which were fully detailed in the Step 3: Assessment of Vulnerability and Risk).

Table 1-4. Asset-Threat Pair combination details.

Assets	Unit	Threats											
		Drought	Wildfire	Groundwater Inundation	Saltwater Intrusion	High Winds	Pest & Disease Outbreaks	Rainfall-Induced Flooding	Tidal Flooding	Storm Surge	HABs	Extreme Heat	Shoreline Recession
Critical Facilities													
Energy and Communications	parcels					S		S	S	S			
Food Infrastructure	parcels					S		S	S	S			
Health and Medical	parcels					S	N	S	S	S			
Public Safety, Government and Schools	parcels					S		S	S	S			
Transportation Facilities	parcels					S		S	S	S			
Water Infrastructure													
Water Infrastructure	parcels, structures	N		N	N			S	S	S	H		
Economic Factors													
Annual Sales Volume	parcels					S		S	S	S			
Jobs/Employees	parcels					S		S	S	S			
Natural Resources													
Natural Areas (including Beaches & Coastal Areas)	parcels	N		N	N			S	S	S	S		H
People													
Residents/Social Vulnerability	census tracts		N				N		see note*			S	
Property													
Commercial & Industrial Property	parcels					S		S	S	S			
Parks & Cultural Property	parcels					S		S	S	S			
Residential Property	parcels					S		S	S	S			
Roads & Mobility													
Roads Systems (Major and Minor	roads, parcels							S	S	S			

*Note: S=Spatial Assessment, H = Hybrid Assessment, N = Narrative Assessment; blank cells were not assessed; areas of high social vulnerability will be considered for every relevant asset-threat pair assessment. For example, residential property/storm surge. Asset-threat parings were prioritized by impact, available data, and CRP stakeholder input.

CRP

1.6 Sea Level Rise Projections

Scenario selection was an important initial task of this Climate Change Vulnerability Assessment. This project takes advantage of the recently released South Florida Regional Climate Change Compact's 2019 **Sea Level Rise** Curves (Figure 1-29, Southeast Florida Regional Climate Compact 2020). The project team used projections for 2040 and 2070 for the analyses. This is consistent with the timelines provided by the Compact. However, it is highly likely that some specifics will apply to certain asset-threat pairs. These variations in methodology are discussed in Section 2.

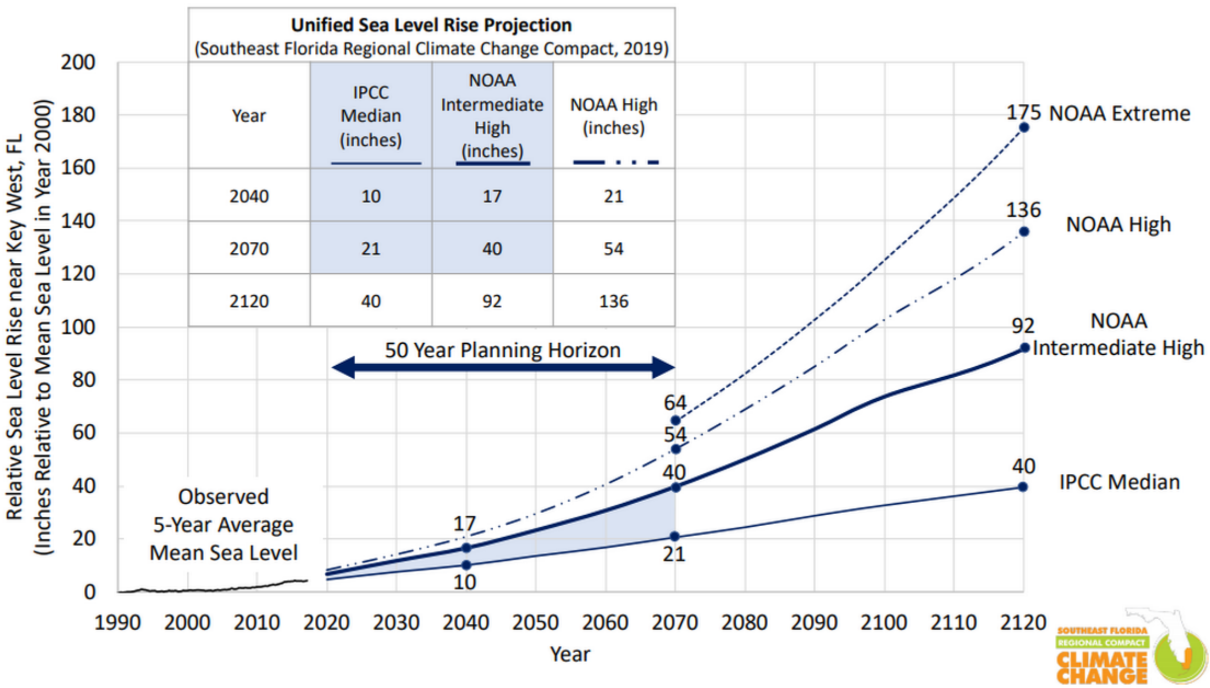


Figure 1-29. Unified Sea Level Rise Curves (2019) of the Southeast Florida Regional Climate Change Compact.

The Unified Sea Level Rise Projections provide guidance on which curves to use for different types of assets. The following text is taken from Page 14 of the recently released guidance for the three different curves used in the guidance (note that the NOAA Extreme curve is not used). Specifically, the Work Group that authored the report concludes that, "[t]he Work Group recommends the use of the NOAA High curve, the NOAA Intermediate High curve, and the median of the IPCC AR5 RCP 8.5 scenario (IPCC, 2013) as the basis for a Southeast Florida sea level rise projection for the 2040, 2070 and 2120 planning horizons."

From the 2019 Update of the Unified Sea Level Rise Projection Southeast Florida (the text is copied verbatim):

Application of the IPCC Median Curve
The IPCC Median or lower blue shaded portion of the projection can be applied to most infrastructure projects before 2070 or projects whose failure would result in limited consequences to others. An example low risk projects may be a small culvert in an isolated area. The designer of a type of infrastructure that is easily replaced, has a short lifespan, is adaptable, and has limited interdependencies with other infrastructure or services must weigh the potential benefit of designing for higher sea level rise with the additional costs. Should the designer opt for specifying the lower curve, she/he must consider the consequences of under-designing for the potential likely sea level condition. Such consequences may include premature infrastructure failure.

Application of the NOAA Intermediate High Curve
Projects in need of a greater factor of safety related to potential inundation should consider designing for the NOAA Intermediate High Curve. Examples of such projects may include evacuation routes planned for reconstruction, communications and energy infrastructure, and critical government and financial facilities or infrastructure that may stay in place beyond a design life of 50 years.

Application of the NOAA High Curve
Due to the community's fundamental reliance on major infrastructure, existing and proposed critical infrastructure should be evaluated using the NOAA High curve. Critical projects include those projects which are not easily replaceable or removable, have a long design life (more than 50 years), and are interdependent with other infrastructure or services. If failure of the critical infrastructure would have catastrophic impacts, it is considered to be high risk. Due to the community's critical reliance on major infrastructure, existing and proposed high risk infrastructure should be evaluated using the NOAA High curve. Examples of high risk critical infrastructure include nuclear power plants, wastewater treatment facilities, levees or impoundments, bridges along major evacuation routes, airports, seaports, railroads, and major highways.

Another way to think about the assets and sea level rise projection selection is through a risk tolerance and **adaptive capacity** framework, illustratively shown in Figure 1-30. Assets with low risk tolerance (e.g., **critical facilities**) and low adaptive capacity (e.g., infrastructure with less potential to cope with impacts) should be examined through more severe sea level rise projections. Assets with high risk tolerance (e.g., an open park) or high adaptive capacity can be examined utilizing a less severe projection (the IPCC Median Curve).

Figure 1-30. Risk tolerance and adaptive capacity framework.

IPCC Median Curve	NOAA Intermediate High	NOAA High
HIGH	← Risk Tolerance → ← Adaptive Capacity →	LOW

1.6.1 Projection Selection

Using the Climate Compact curves and specific time horizons (2040 and 2070), estimates of sea level rise can be made from the available projections. The relative sea level rise rates for the three recommended curves by the Climate Compact are provided from the year 2000 (Table 1-5).

Table 1-5. Relative sea level rise from 2000 for the selected curves of the Southeast Florida Regional Climate Change Compact.

Relative Sea Level Rise (Inches above 2000 MSL)

	2000	2020	2040	2070
IPCC Median	0	5	10	21
NOAA Int. High	0	7	17	40
NOAA High	0	8	21	54

Since the Unified Sea Level Rise projections are based on **Mean Sea Level (MSL)** in 2000, it is necessary to make an adjustment to current time as we are utilizing 2020 as the baseline for sea level. The relative sea level rise from 2020 is calculated by subtracting the projected sea level rise for 2020 from the projected values in 2040 and 2070 for each curve (Table 1-6).

Table 1-6. Relative sea level rise from 2020 for the selected curves of the Southeast Florida Regional Climate Change Compact. Highlighted and bolded values are used for this study.

Relative Sea Level Rise (Inches above 2020 MSL)

	2040	2070
IPCC Median	**5**	16
NOAA Int. High	10	**33**
NOAA High	**13**	46

Based on the Compact guidance, the CCVA consultant team utilized four specific thresholds as the lower and higher ends of sea level rise projections for 2040 and 2070, and the current value. The NOAA High projection for 2040 and the IPCC Median projection for 2070 are similar enough to each other that the consultant team is comfortable using the NOAA High projection as both the high end 2040 and the low end 2070 threshold.

The four selected thresholds are

- Current sea level (2020)
- 5 inches above current sea level (IPCC Median 2040)
- 13 inches above current sea level (NOAA High 2040, serves as low-end of 2070 projection)
- 33 inches above current sea level (NOAA Intermediate High 2070)

These 5-, 13-, and 33-inch sea level increases are utilized throughout the assessment.

In this case, the NOAA High Curve in 2070 is not utilized for the CCVA vulnerability assessment. **However**, any critical infrastructure that is being built or modified should examine the NOAA High Curve as part of the design standards for such infrastructure and will be considered as part of the adaptation strategies for this project.

The impacts of **tidal flooding** on a location occur far before **Mean Sea Level (MSL)** or even **Mean Higher High Water (MHHW)** reach the elevation of that location. There is currently not a widely accepted and used threshold for frequent tidal flooding. As such, the consultant team uses an Adaptation Action Elevation (AAE) as a standard threshold for frequent tidal flooding. The AAE is defined as the 98th percentile of the local observed higher high-water elevations recorded over the previous five years. Therefore, the AAE is projected to increase at the same rate as mean sea level. The AAE is an estimate of the elevation that the highest tides will reach in a given year, causing tidal flooding at locations lying at or below the AAE whenever sea level exceeds the AAE. More colloquially, the threshold can be considered a King Tide threshold and removes the most extreme events generally associated with meteorological events, such as coastal storms, beyond events that would solely be qualified as tidal flooding. Locations with an elevation below the AAE and hydrologically connected to the tidal water body may experience significant tidal flooding when tides exceed this elevation. The AAE is provided in NAVD88 so it can be directly compared to the elevations of parcels, structures, and infrastructure.

To ensure consistency in the methodology, 1992 was utilized as the centroid of the tidal epoch. The calculated AAE for Virginia Key for the year 1992 is 1.2 feet NAVD88. There is a data gap at the Lake Worth Pier tidal gauge during that period necessitating the use of Virginia Key to approximate the Lake Worth Pier AAE. MHHW is 0.4 feet higher at Lake Worth Pier than Virginia Key based on their respective tidal datums, so a 0.4-foot adjustment (increase) is made to the 1992 Virginia Key AAE. Lastly, there is 0.5 feet of sea level rise between 1992 and 2020, with 0.4 feet (5 inches, based on the IPCC Median curve, which is the most conservative estimate in the projections) from 2000 to 2020, and an additional 0.1 foot (about 1 inch) of rise from 1992 to 2000. This provides an estimated 2.1-foot AAE for the Southeast Palm Beach County region. This is consistent (within 0.1 feet) with the calculated AAE for 2020 based on the Lake Worth Pier tidal gauge (see Figure 1-31), which is 2.2 feet. The higher of the two is utilized for this study, which provides an AAE of 2.2 feet NAVD88.

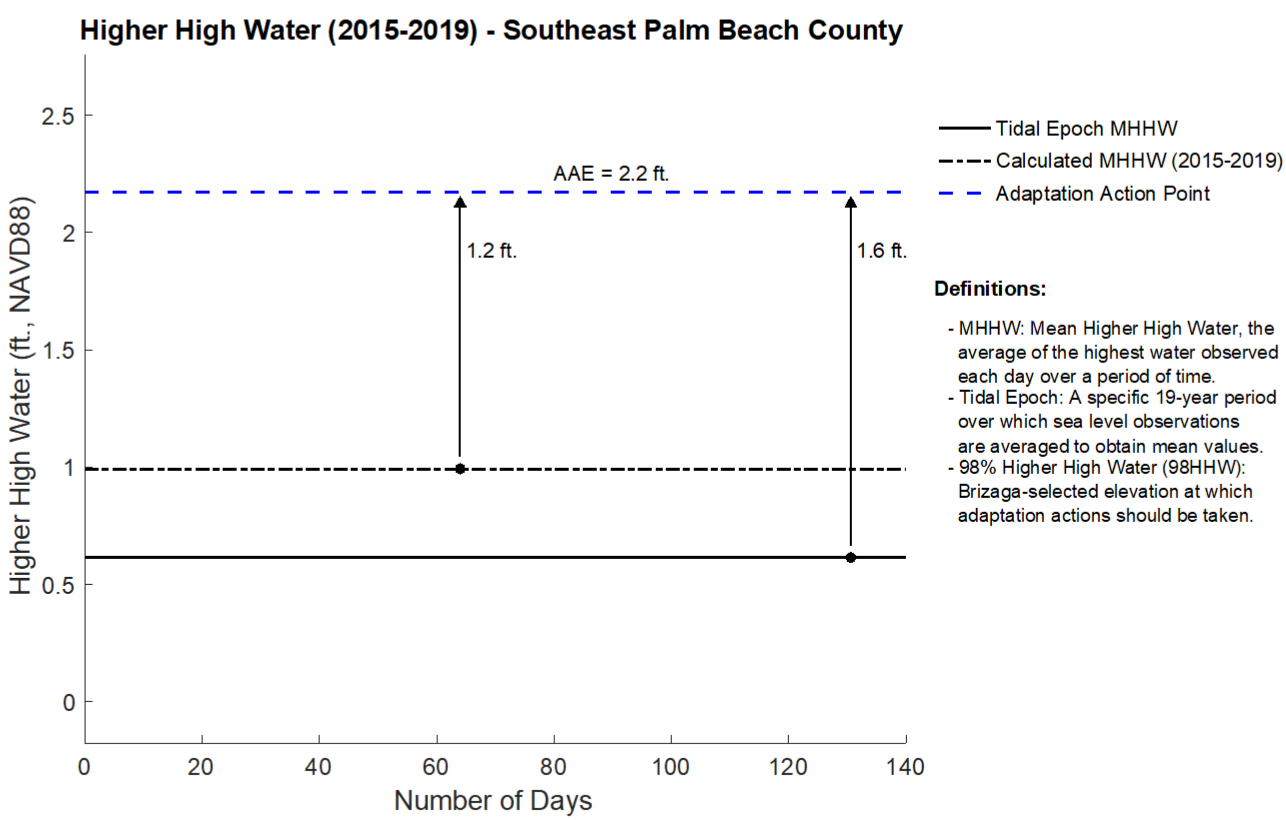


Figure 1-31. Histogram of Higher High Water, with the calculated Adaptation Action Elevation for the year 2020.

To examine tidal flooding, three different metrics are used: the AAE (tidal flooding threshold), MHHW (this can be considered permanent inundation), and MSL. The elevations are provided in NAVD88 in Table 1-7. For MSL and MHHW, the value in the year 2020 is estimated using appropriate sea level rise between 1992 (centroid of tidal epoch) and 2020, as explained previously by adding the 0.5 foot in rise from 1992 to 2020. MHHW and MSL for 2020 are calculated using a similar methodology as described to obtain the AAE.

Table 1-7. Tidal flooding thresholds based on the selected thresholds and future sea level rise projections.

Tidal Flooding Thresholds (feet, NAVD88), Lake Worth Pier, FL

Tidal Flooding Threshold	Current	Current + 5”	Current + 13”	Current + 33”
98% Higher High Water (AAE)	2.2’	2.6’	3.3’	5.0’
Mean Higher High Water	1.1’	1.5’	2.2’	3.9’
Mean Sea Level	-0.4’	-0.0’	0.7’	2.4’

2. Assessment of Vulnerability and Risk

This section summarizes the methodology of the **vulnerability** and **risk** assessment and provides a summary of results of the analysis with key findings for each **threat** throughout the study area**.**

2.1 Process and Methodology

2.1.1 Assessment Process

The project team applied a vulnerability and risk assessment framework to the combination of **threats** and **assets** identified. These are referred to as asset-threat pairs and each was evaluated separately; however, the assessment also highlights how many threats are interrelated (e.g., rainfall-induced flooding and storm surge). Each asset-threat pair includes a distinct set of criteria or "rules" for how levels of vulnerability and risk were determined. Summaries and findings were generated for every asset-threat pair.

Three main types of analysis were undertaken: narrative analysis, spatial analysis, and hybrid analysis. Narrative analysis consists primarily of literature review and review of relevant reports to the risk assessment. Narrative analyses were performed for **drought**, **groundwater inundation**, **pest and disease outbreaks**, **saltwater intrusion**, and **wildfire** threats. Spatial analysis consists of reviewing spatial and/or numerical datasets relevant to the risk assessment. Spatial analyses were performed for **high winds**, **rainfall-induced flooding, storm surge**, **tidal flooding**, and **extreme heat**. A hybrid analysis consists of both literature review and review of spatial and/or numerical datasets relevant to the risk assessment. Hybrid analyses were performed for **harmful algal blooms (HABs)**, and **shoreline recession**.

This assessment uses a risk analysis framework based on NOAA's U.S. Climate Resilience Toolkit and its Steps to Resilience. In particular, this assessment uses Steps 1-2 to "Explore climate threats" and "Assess vulnerability and risk" along with the key concepts within those steps. It is important to keep in mind that the purpose of any assessment is to help inform resilience and climate **adaptation** strategies. The diagram on the following page (Figure 2-1) shows each step of the CCVA and how the assessment of vulnerability and risk follows the identification of threats and data gathering and then serves as a foundation to inform strategies in Step 4.

For the spatial analysis assessments, the vulnerability and risk assessment components were applied at the asset scale. For example, commercial property and tidal flooding were assessed at the parcel or property level. Classifications of vulnerability and risk were assigned using data attributes and spatial analysis. Most asset-threat pairs were assessed through vulnerability and risk (rainfall-induced flooding, tidal flooding, storm surge); however, a few threats were assessed only for vulnerability (high winds, extreme heat, shoreline recession). Harmful algal blooms (HABs), drought, wildfire, pest and disease, and groundwater/saltwater intrusion were all non-spatially explicit or narrative-based threat assessments. The following sections describe the vulnerability and risk assessment components and key concepts in more detail.

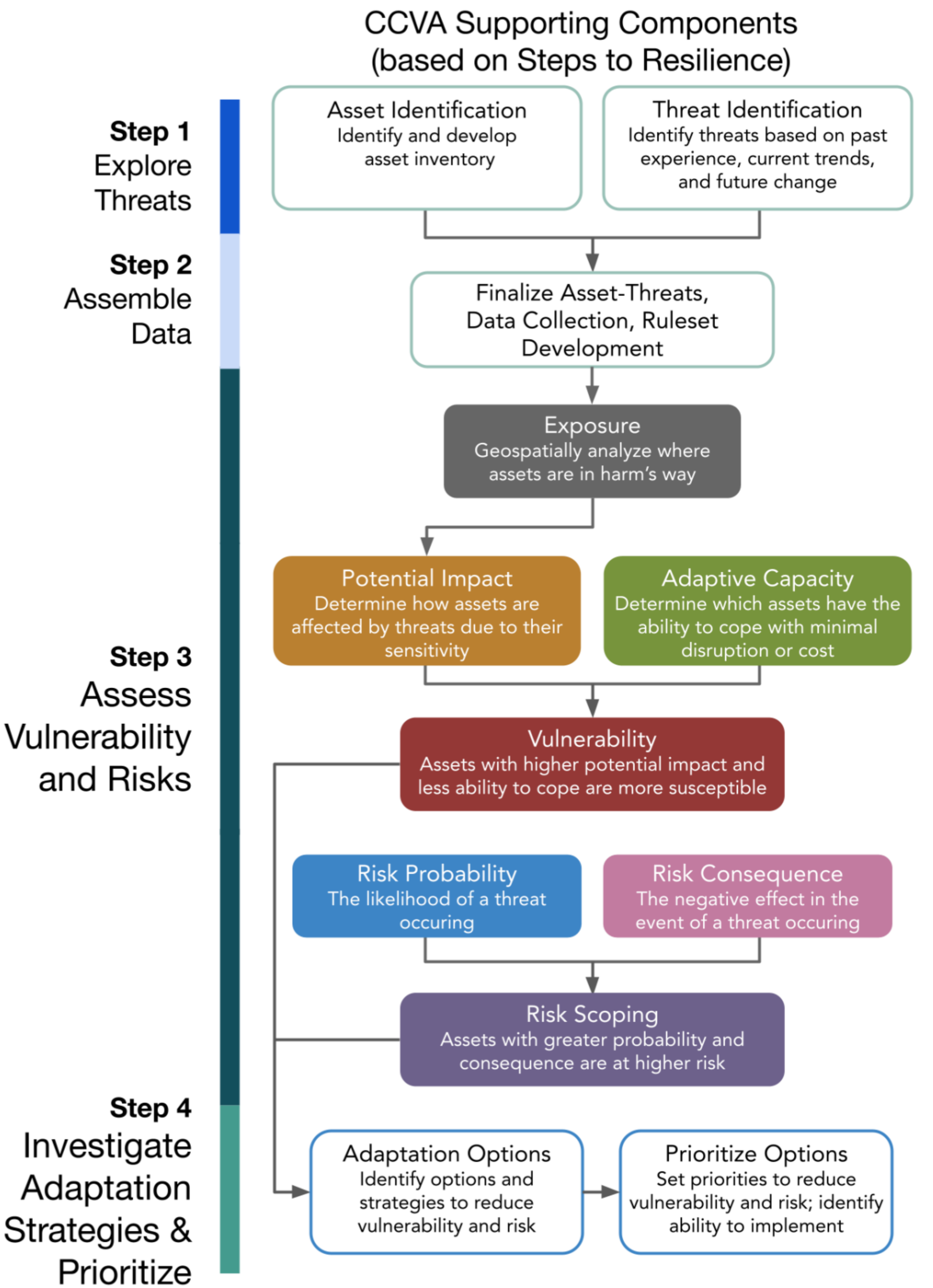


Figure 2-1. CCVA Assessment steps and components of assessing vulnerability and risk.

2.1.2 Components of Vulnerability and Risk

Key concepts and components were evaluated and explored throughout the assessment process (and are described in more detail in the following sections):

- **Exposure**: The presence of assets in harm's way.
- **Vulnerability**: The susceptibility of exposed assets based on the two core concepts: (1) potential impact – the degree to which an asset is affected due to its **sensitivity**; and (2) **adaptive capacity** – the potential of the asset to cope with an impact with minimal disruption or cost.
- **Risk**: The probability (likelihood) and the consequence, or negative outcome, of a hazard occurring.

As described in Section 1, the **threats** to which **assets** are exposed are influenced by both climate and non-climate stressors. For purposes of this assessment, these threats are represented using threat information and models. The impact these threats may have on community assets is evaluated through an assessment of vulnerability and risk.

The vulnerability and risk assessment framework used multi-criteria decision analysis as well as spatial analysis in a data-driven pipeline (Malczewski and Rinner 2015). 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 (EPA 2014).

The assessment was conducted in four stages:

1. Asset and threat identification, data collection and normalization (CCVA steps 1-2)
2. Spatial relation analysis of individual assets to each threat layer to define exposure
3. Application of asset-scale vulnerability and risk rulesets
4. Aggregation of vulnerable and at-risk assets to census tracts

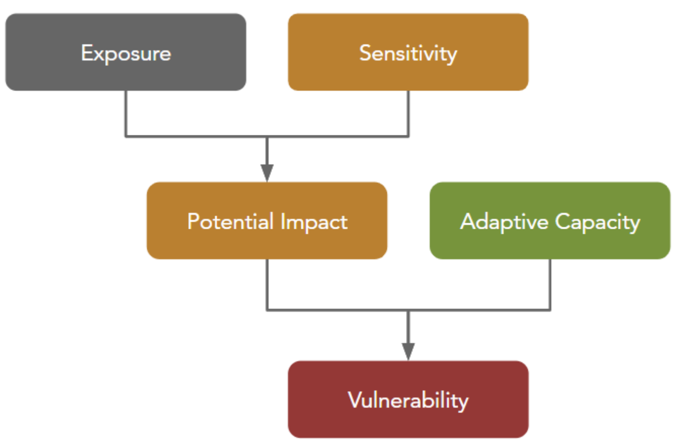
Exposure

The U.S. Climate Resilience Toolkit defines **exposure** as "the presence of people, assets, and ecosystems in places where they could be adversely affected by hazards." For purposes of this assessment, exposure specifically means that a community asset (e.g., a structure, parcel, or roadway) is spatially coincident with a specific hazard (e.g., flooding). For example, a warehouse located within the 500-year floodplain is "exposed" to flooding.

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. Based on this framework, the most vulnerable assets are those with high potential impact and low adaptive capacity. Figure 2-2 shows the components of vulnerability.

Figure 2-2. Components of vulnerability.



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.

Factors used to determine levels of potential impact were based on the asset's characteristics or on the level of impact due to service loss if the asset were to be affected (Glick et al. 2011). For example, a property with a building structure in a flood hazard area has a higher potential impact than does a property that does not have a building in a flood hazard area.

The following table (Table 2-1) shows the assets identified as highly sensitive with greater potential impact for the purposes of this assessment. These potential impact classifications were used for all spatial asset-scale assessments (rainfall-induced flooding, tidal flooding, storm surge, and high winds).

Table 2-1. Assets identified as having high potential impact.

Asset Category	High Potential Impact Assets
Energy & Communications	Electric facilities, critical communication assets, and critical fuel facilities (as determined by the jurisdiction's **critical facilities** list)
Food Infrastructure	**SNAP** food locations and food banks/pantries
Health & Medical	Hospitals, life support centers, and long-term care facilities
Public Safety & Gov-owned	Schools, law enforcement facilities, fire departments, and emergency management centers
Commercial & Industrial	Multi-business commercial and industrial, and industrial hazmat properties
Parks & Cultural	Cultural properties and park facilities
Residential	Multi-residential, group homes, retirement, assisted housing, mobile home properties
Transportation	Transit, airports, critical rail properties, fleet properties
People & Socioeconomics	Median household income, household poverty, and indices such as the CDC's Social Vulnerability Index (SVI)

Adaptive Capacity

Adaptive capacity considers how an asset is able to 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 include both physical and social elements, conditions, and designs in place that help an asset absorb an impact. Assets exposed to flooding and high winds were evaluated for indicators of adaptive capacity and classified accordingly. For both flooding and high winds threats, the year of construction provides an indication of or proxy for the adaptive capacity of properties and facilities based on the developments standards and requirements that were in place at the time of construction. Table 2-2 shows the measures of adaptive capacity for flood and high wind threats.

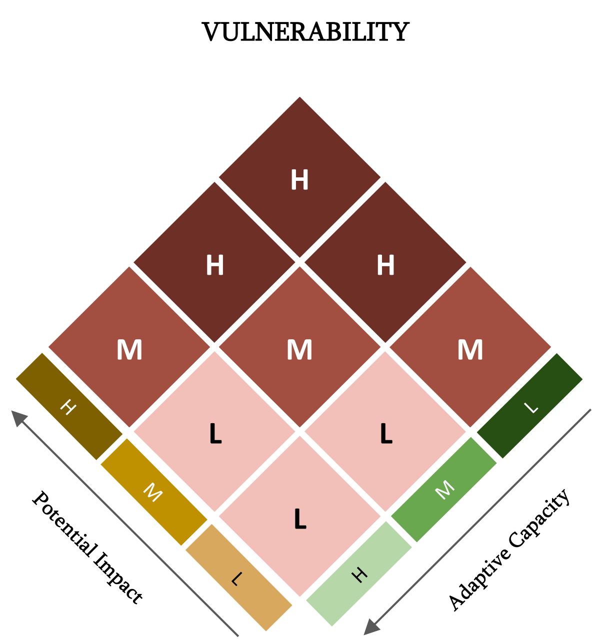
For example, a commercial building that has flood-proofed its foundation and raised its ground floor above flood levels has more adaptive capacity than a commercial building that has not done so. As another example, a park with facilities designed to withstand flood waters without damaging its infrastructure has adaptive capacity.

Levels of potential impact and adaptive capacity are then combined to inform vulnerability (Figure 2-3). 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. For example, a multi-business structure in the inundation extent has a "high" level of potential impact and, if the building was constructed pre-FIRM or before floodplain development requirements were in place, it is classified as having "low" adaptive capacity. Together, they result in a "high" vulnerability classification.

Table 2-2. Measures of adaptive capacity.

Spatially Assessed Threat	Primary Measure of Adaptive Capacity
Flood Threats (Rainfall-Induced Flooding, Tidal Flooding, Storm Surge)	Floodplain development requirements and standards, with base flood elevation (BFE) requirements and floodproofing being primary measures.
High Winds	Wind load and pressure design requirements for buildings
Extreme Heat	Amount of tree canopy coverage and socioeconomic status

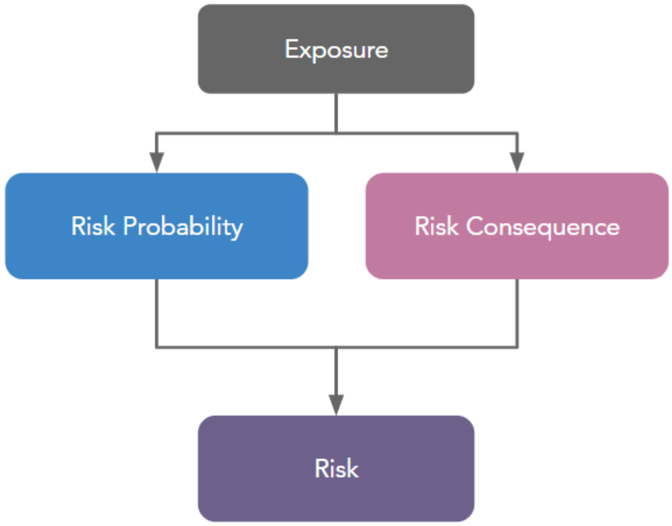
Figure 2-3. Combination of potential impact and adaptive capacity.



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. High-risk assets are those with high-risk probability and high-risk consequence. Risk scoping was only performed for the flood threats in the assessment. Components of Risk Scoping are shown in Figure 2-4.

Figure 2-4. Components of risk scoping.



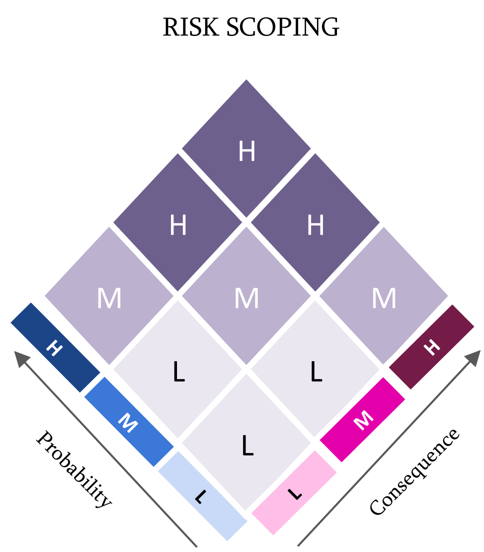
Risk Probability

Probabilities were determined for each threat using annualized likelihoods of threat occurrence or relative levels based on known risk factors. For example, for 2020 rainfall-induced flooding, the 25-year, 100-year, and 500-year inundation extents were used to evaluate different probabilities. The highest risk probability for a parcel or building (if exposed) is then considered. However, for future Rainfall-Induced Flooding, Tidal Flooding and Storm Surge threat levels of risk probability were non-differentiated due to separate extents being generated for each current and future condition.

Risk Consequence

Risk consequence refers to negative outcomes or critical thresholds that indicate varying levels of significance if a threat were to occur. For this assessment, estimated potential flood depths were used as indicators of risk consequence for all flood threats. Depth information from the inundation maps for each threat were used and maximum potential depths were calculated within a 2-meter proximity (buffer) to building footprints on properties. Maximum parcel flood depths were also calculated. The maximum depth in proximity to a structure was used for risk consequence classification if the structure was exposed, and the max parcel flood depth was used if the parcel was not exposed. Parcels with structures exposed were classified as having medium- to high-risk consequence, whereas parcels with no structure exposed was considered to have low-risk consequence. While depth-damage curve functions were not applied to this assessment, general depth-damage curves established for the region and by **FEMA** were considered in determining important inflection points (FEMA 2010, US Army Corps of Engineers 1992). Other hazard mitigation considerations were also used in establishing thresholds for the Limit of Moderate Wave Action (LiMWA) zone separate from stillwater zones (FEMA 2021, FEMA 2019c). Different depths were used depending on the flooding threat and the level of data available. The following threat sections provide more detail on the levels of depth used for the classification of risk consequence levels.

Figure 2-5. Combination of risk probability and consequence.



Levels of risk probability and risk consequence are then combined to inform risk scoping (Figure 2-5). For example, a property with a building in the 25-year inundation extent with a potential flood depth of more than 3 feet would have a high-risk classification, while a property in the 500-year inundation extent without an exposed building would have a low-risk classification. It is important to note that this step is referred to as risk scoping, as no loss estimates are quantified.

Combined Vulnerability and Risk

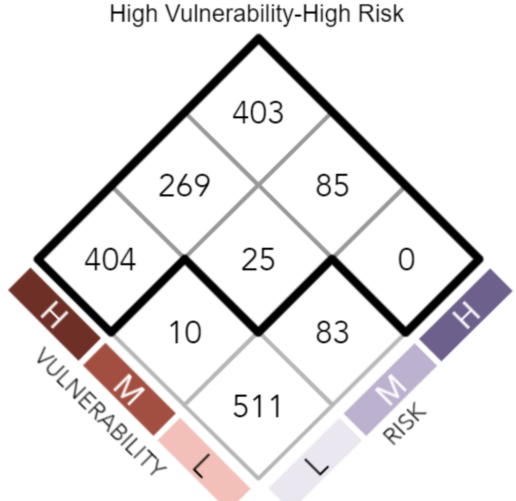
Vulnerability considers how an asset might be impacted and its ability to cope if a given threat event were to occur; risk considers the probability of the threat occurring and the general consequence of the threat. Combining these concepts allows decision makers to evaluate which assets are most susceptible and most likely to be impacted, and to consider options according to different levels of risk thresholds. The matrix shown in Figure 2-6 features the combination of vulnerability and risk for Commercial Property and Rainfall-Induced Flooding. 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.

Spatial Aggregation of Combined Vulnerability and Risk

To focus on the most vulnerable and at risk assets, the assets with either medium or high combined vulnerability and risk are mapped at an aggregate scale, which in this case are census block groups. In the matrix at the right, these are the cells within the bold outline.

Due to varying sizes of census tracts in the region, the *percent of assets with medium-high combined vulnerability and risk* map is used to provide a relative perspective of vulnerability within different areas in the city. Figure 2-7 shows an example map aggregating combined vulnerability and risk for census tracts.

Figure 2-6. Example Matrix Showing Combination of Vulnerability and Risk



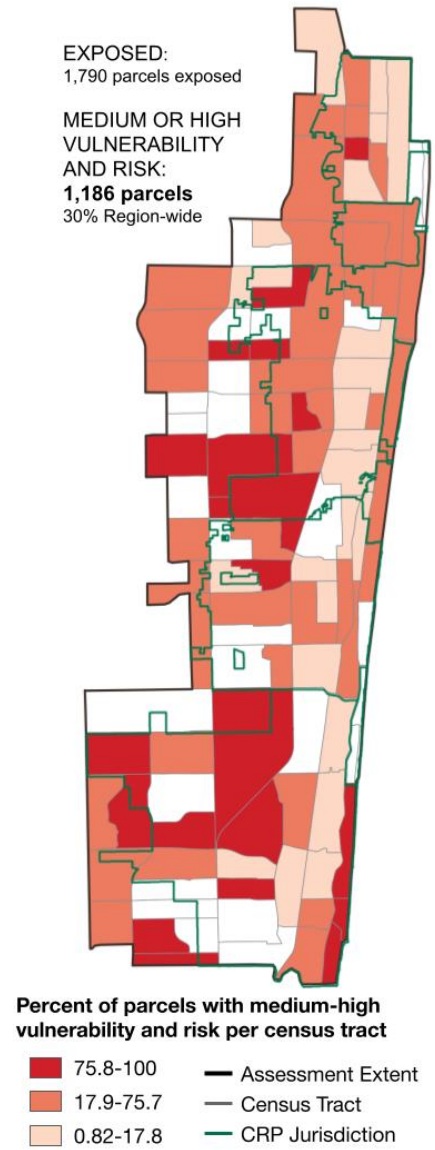


Figure 2-7. Example map showing aggregation of combined vulnerability and risk for census tracts.

People and Social Vulnerability

The assessment recognizes that socially vulnerable populations are disproportionately impacted by climate threats. Therefore, social vulnerability is foundational to the methodology and insights of the assessment. This also means that elements of social vulnerability call for a multifaceted approach to building resilience and adaptation centered on social vulnerability, from the identification of community assets and definition of vulnerability to community engagement and the development of strategies. Having a social vulnerability focus in the assessment can provide a useful foundation to help inform socially equitable considerations by identifying disproportionate impacts on socially vulnerable populations and by better understanding the underlying stressors that make people socially vulnerable and that are exacerbated by climate events. This assessment integrates social vulnerability using a data and metric-based approach. However, a data-driven process is only one part of a socially equitable foundation for building resilience that also has its limits in what it can inform. Many existing social equity frameworks and community practices highlight that many organizations and communities are leading “embedded equity” approaches to resilience planning. Within the context of a data-driven assessment, social vulnerability may be considered through multiple lenses and in a variety of ways throughout the assessment that are described below.

1. Socially Vulnerable Populations and Co-occurrence with Physical Vulnerability

Several socioeconomic metrics and sources of census tract-level information are used in the assessment, including the CDC’s overall **social vulnerability index (SVI)** and its four themes of socioeconomic status, household composition and disability, minority status and language, and housing and transportation. In addition, socioeconomic metrics from the American Community Survey (U.S. Census Bureau 2019) are used to examine individual metrics, such as households living below the poverty line or median household income. Socioeconomic metrics and the SVI are both used to understand and identify disproportionate impact on socially vulnerable populations and the level of co-occurrence of socially vulnerable populations and physical vulnerabilities, such as from the asset-based assessments (e.g., the co-occurrence of high food infrastructure vulnerability with high **SNAP** participation or high residential property vulnerability with high overall social vulnerability). In addition, socioeconomic metrics are integrated into the rulesets of the vulnerability assessment framework, such as with sensitive populations and extreme heat.

2. Consideration of Critical Community Assets

Several sources of information on key community resources were used in the asset-level assessments. These include

- Assisted housing that includes **public housing**, homeless shelters, and other low-income or subsidized housing locations (Shimberg Center for Housing Studies 2020)
- Medical congregate facilities that include nursing homes
- Supplemental building-level information, such as the availability of residential cooling
- Food infrastructure and food SNAP retailers: all food SNAP retailers considered in the assessment along with food pantries

3. Loss and Disruption of Community Services

Certain asset-threat pair assessments lend themselves to thinking about potential loss of or disruption of important community services. While these services are not evaluated directly, many of the asset categories in the assessment, especially **critical facility** assets, include assets that support services. Here are a few examples of asset categories and the services they provide:

- Schools (part of Public Safety and Gov-Owned asset category) provide a critical service of education in the community, but they also often serve as shelter locations in case of emergency or evacuation. Loss or disruptions to schools can have a profound impact on neighborhood and communities.
- Government-owned properties (part of the Public Safety and Gov-Owned asset category), some of which support critical government and safety functions, such as EOC, public safety, and essential local government operations.

- Road access (from both major and minor roads) provides a critical service of transportation and access to essential needs such as food and shelter and emergency response services.
- Community centers, parks, and faith-based locations (part of Parks & Cultural Property) include community resources that people rely on for access to health and information resources, social cohesion, and sense of place within the community.
- Food infrastructure locations provide essential services to the community. These include grocery stores, food SNAP retailers, and food pantries.
- Assisted and public housing are other resources providing essential need for housing and shelter within the community.
- Health and medical facilities also provide essential services to the community. These include long-term care facilities, hospitals, and other clinics (such as dialysis centers).

2.1.3 High-Level Summary of Vulnerability and Risk

The following are high-level findings that are described in more detail in the following summary materials and sections of assessment results by threat:

- Residential properties are vulnerable to all types of flooding, which is driven by many factors including but not limited to coastal proximity, density of development/imperviousness, pre-FIRM building construction, and impacts to floodplains/native hydrology.
- Critical facilities are often vulnerable to multiple threats (e.g., high winds and flooding).
- Road access is the most widespread vulnerability associated with future tidal flooding.
- All jurisdictions are vulnerable to climate change, however, levels of vulnerability to future conditions vary across jurisdictions and over time.
- Socioeconomic disparities within the region indicate people in certain areas will be disproportionately impacted by climate threats (especially by extreme heat, high winds, and inland/rainfall-induced flooding).
- **Sea level rise** and climate change will exacerbate existing threats and present new challenges to the region.
- Most climate threats are highly interconnected.

Findings from the assessment also suggest three main types of vulnerabilities for the **CRP** to consider in the iterative development of strategies and in prioritization:

- Near-term vulnerabilities: These threats include rainfall-induced flooding, extreme heat, and tidal flooding (current)
- Mid to long-term vulnerabilities associated with future conditions and change: Future tidal flooding, groundwater inundation, shoreline recession, drought, harmful algal blooms (HABs)
- High-impact event vulnerabilities: Rainfall-induced flooding, storm surge, high winds

The summary table (Table 2-3) on the next page shows the number of assets with medium or high vulnerability or combined vulnerability and risk for the spatially assessed threats. The first column ("Asset Total") shows the number of assets in the region with the levels of vulnerability and risk under a separate column for each threat assessed. Percentages reflect the percent of assets in the CCVA study area that have medium to high vulnerability and risk.

More information on each assessment summarized in Table 2-3 is provided in the following pages with information about how each threat was defined and assessed as well as a series of key findings about how people and assets are vulnerable and at risk.

Table 2-3. Summary of spatially assessed vulnerability and risk for the CCVA Study Area.

Asset Category	Total Assets	High Winds	Rainfall-Induced Flooding			Storm Surge (100-year)				Tidal Flooding			
			2020 (100-year only)	2040 (2020 +5" SLR, 100-year only)	2070 (2020 +33" SLR, 100-year only)	2020	2040 (2020 +5" SLR)	2040 (2020 +13" SLR)	2070 (2020 +33" SLR)	2020	2040 (2020 +5" SLR)	2040 (2020 +13" SLR)	2070 (2020 +33" SLR)
Critical Facilities													
Energy & Communications	243	89 (37%)	34 (14%)	59 (24%)	66 (27%)	8 (3%)	12 (5%)	15 (6%)	20 (8%)	1 (0.4%)	1 (0.4%)	2 (1%)	3 (1%)
Food Infrastructure	219	78 (36%)	42 (19%)	57 (26%)	66 (30%)	7 (3%)	12 (5%)	13 (6%)	21 (10%)	1 (0.5%)	1 (0.5%)	2 (1%)	4 (2%)
Health & Medical	207	127 (61%)	34 (16%)	55 (27%)	61 (29%)	5 (2%)	7 (3%)	9 (4%)	17 (8%)	0	0	1 (0.48%)	2 (1%)
Public Safety, Gov & Schools	1,466	432 (29%)	146 (10%)	172 (12%)	187 (13%)	115 (8%)	121 (8%)	136 (9%)	159 (11%)	3 (0.2%)	5 (0.34%)	8 (0.55%)	19 (1%)
Transportation Facilities	64	16 (25%)	1 (2%)	2 (3%)	2 (3%)	3 (5%)	3 (5%)	5 (8%)	7 (11%)	0	0	0	0
Property													
Commercial & Industrial Properties	3,792	1,059 (28%)	616 (16%)	795 (21%)	997 (26%)	176 (5%)	199 (5%)	244 (6%)	373 (10%)	13 (0.3%)	22 (1%)	33 (1%)	87 (2%)
Residential	113,571	12,312 (11%)	20,207 (18%)	30,666 (27%)	33,872 (30%)	8,458 (7%)	9,347 (8%)	10,587 (9%)	12,796 (11%)	341 (0.3%)	499 (0.44%)	1,014 (1%)	3,805 (3%)
Parks & Cultural	938	930 (99%)	81 (9%)	131 (14%)	150 (16%)	117 (12%)	120 (13%)	128 (14%)	144 (15%)	3 (0.32%)	5 (1%)	10 (1%)	24 (3%)
Natural													
Natural Areas	478	116 (24%)	40 (8%)	47 (10%)	53 (11%)	72 (15%)	74 (15%)	77 (16%)	80 (17%)	2 (0.4%)	2 (0.4%)	2 (0.4%)	8 (2%)

Asset Category	Total Assets	High Winds	Rainfall-Induced Flooding			Storm Surge (100-year)				Tidal Flooding			
			2020 (100-year only)	2040 (2020 +5" SLR, 100-year only)	2070 (2020 +33" SLR, 100-year only)	2020	2040 (2020 +5" SLR)	2040 (2020 +13" SLR)	2070 (2020 +33" SLR)	2020	2040 (2020 +5" SLR)	2040 (2020 +13" SLR)	2070 (2020 +33" SLR)
Roads & Mobility													
Major Roads Inaccessible (Lane Miles)	1,072	N/A	584 (45%)	594 (55%)	641 (60%)	110 (8%)	116 (11%)	124 (12%)	144 (15%)	24 (2%)	28 (3%)	39 (4%)	81 (8%)
Minor Roads Inaccessible (Lane Miles)	5,191	N/A	2,700 (43%)	2,734 (53%)	2,871 (55%)	457 (9%)	483 (9%)	514 (10%)	604 (12%)	51 (1%)	75 (1%)	127 (2%)	309 (6%)
Inaccessible Property	122,540	N/A	66,341 (54%)	67,294 (50%)	69,374 (57%)	10,186 (8%)	11,109 (9%)	11,905 (10%)	14,134 (11%)	1,583 (1.3%)	1,976 (1.6%)	3,155 (2.6%)	6,330 (5.2%)
Economic Factors													
Improvement Value (assessed)	$47.1B	$29.3B (62%)	$23.2B (49%)	$28.1 (60%)	$30.9B (66%)	$17.7B (38%)	$18B (38%)	$19B (40%)	$20.6B (44%)	$2.2B (5%)	$2.9B (6%)	$4.5%B (9%)	$10B (21%)
Sales Volume	$20.7B	$8.4B (40%)	$7.3B (35%)	$10B (48%)	$10.8B (52%)	$870M (4%)	$950M (5%)	$1.2B (6%)	$1.3B (6%)	$99M (0.48%)	$180M (1%)	$210M (1%)	$560M (3%)
Jobs	93,861	43,353 (46%)	31,879 (34%)	45,904 (49%)	52,411 (56%)	6,160 (7%)	6,525 (7%)	7,856 (8%)	8,451 (9%)	598 (0.64%)	1,279 (1%)	1,558 (2%)	2,951 (3%)
Additional Social Vulnerability Metrics													
SNAP Retailers	206	73 (35%)	50 (24%)	51 (25%)	60 (29%)	7 (3%)	11 (5%)	12 (6%)	20 (10%)	1 (<1%)	1 (<1%)	2 (1%)	4 (2%)
Assisted Housing	69	69 (100%)	7 (10%)	12 (17%)	11 (16%)	0	0	0	0	0	0	0	0
Census tracts with co-occurrence of residential property and social vulnerability	49 high overall SVI	26 (53%)	16 (33%)	18 (37%)	19 (39%)	1 (2%)	1 (2%)	1 (2%)	2 (4%)	2 (4%)	2 (4%)	2 (4%)	2 (4%)

One of the primary goals of the assessment was to perform and present the methods and findings with transparency, which is key for the assessment to be successfully used and integrated for resilience planning. Key findings and summaries for each threat assessment are presented in the sections below, which include the following information:

- Background and methodology
- Assessment criteria and rulesets (for spatial assessments)
- Key findings on vulnerability and risk

2.2 Algal Blooms

2.2.1 Vulnerability and Risk Assessment Process

Background

The assessment of **Harmful Algal Blooms (HABs)** was accomplished via spatial and narrative analysis; therefore, it is classified as a hybrid analysis for the purposes of this study. Historic occurrences of HABs were reviewed in and around the project area and existing impairments were explored.

Record/Map of HAB Events

HAB data was retrieved from various sources:

- FDEP Algal Bloom Sampling Activities and Analytical Results 2017-2019 for Palm Beach County (FDEP 2020d)
- Internet search of public news records for instances of HABs in which local and national news reported on issues in the South Florida area (EWG, 2020)
- NOAA Tides and Currents HAB forecast archived data for East Florida (NOAA 2020b)

The FDEP Algal Bloom Sampling Activities (FDEP 2020d) were noted spatially for samples reading positive for Microcystin Toxin above the detection limit (Figure 2-8). If multiple samples for the same location had positive reading for the same year, there was only one point marked in that location for that year.

Locations in the NOAA Tides and Currents Harmful Algal Bloom Forecast Archive data for East Florida between 2002 and 2018 (NOAA 2020b) were marked spatially for dates in which **red tide** warnings in and near Palm Beach County occurred (Figure 2-8). A point was marked for each year in each location in and around Palm Beach County. One bloom stretched between the end of 2017 and the beginning of 2018 in length and so received two points in the same location.

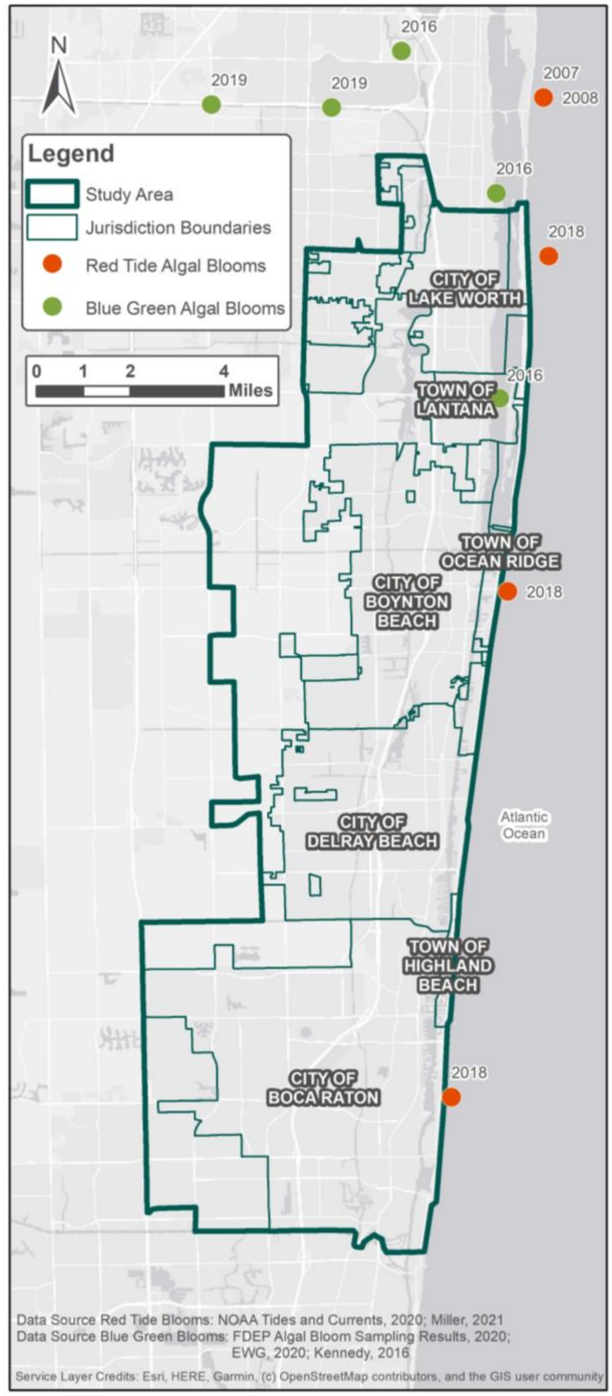


Figure 2-8. Map of Algal Blooms within and surrounding the Study Area from 2002-2020.

In instances where a news article appeared to be reporting on the same bloom described in the NOAA archives, only one point was marked in that location for that year. Many blooms occurred in Southwest and Central Florida that are not included in the immediate assessment. **It is critical to note that due to data limitations the earliest HAB recorded in the dataset is from 2002, but that is not the beginning of occurrences of HABs in the CCVA study area.**

Impaired Waterbodies

The project team retrieved the impaired waterbody data from FDEP ArcGIS data available online (FDEP 2020c). Data used included FDEP's Comprehensive Verified List, updated June 3, 2020, of the waterbody identification numbers (WBIDs) and the corresponding nutrient and fecal coliform impairments (Figure 2-9). The verified list used for assessment is the list of Florida's waterbodies that fail to attain designated uses and/or meet the minimum criteria for surface waters established in the Surface Water Quality Standards (62-302, F.A.C.) and the Impaired Waters Rule (IWR, 62-303, F.A.C.). See FDEP's Comprehensive Verified List (FDEP 2020c) for further information.

At a basic level, since excess nutrients are a primary driver of HABs, the status of waterbodies within the study is very relevant to assessing the potential for this threat to occur both now and into the future.

It is also important to mention that as of the issuance of this report, FDEP is actively developing **Total Maximum Daily Loads (TMDLs)** for both Lake Ida and Lake Osborne. According to the EPA (EPA, 2018), "A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant." In Florida, this portion of the Clean Water Act is implemented through the Florida Watershed Restoration Act. It calls for the State to assess waterbodies and identify those not meeting water quality standards found in 62-302 F.A.C. These impaired waterbodies are prioritized and TMDLs are developed to identify the maximum pollutant loads from both point and nonpoint sources and the associated load reductions required to bring the waterbody into compliance for that pollutant. The TMDLs for Lake Ida and Lake Osborne will impact partner jurisdictions and are further indication of likely impairment due to nutrients in the study area.

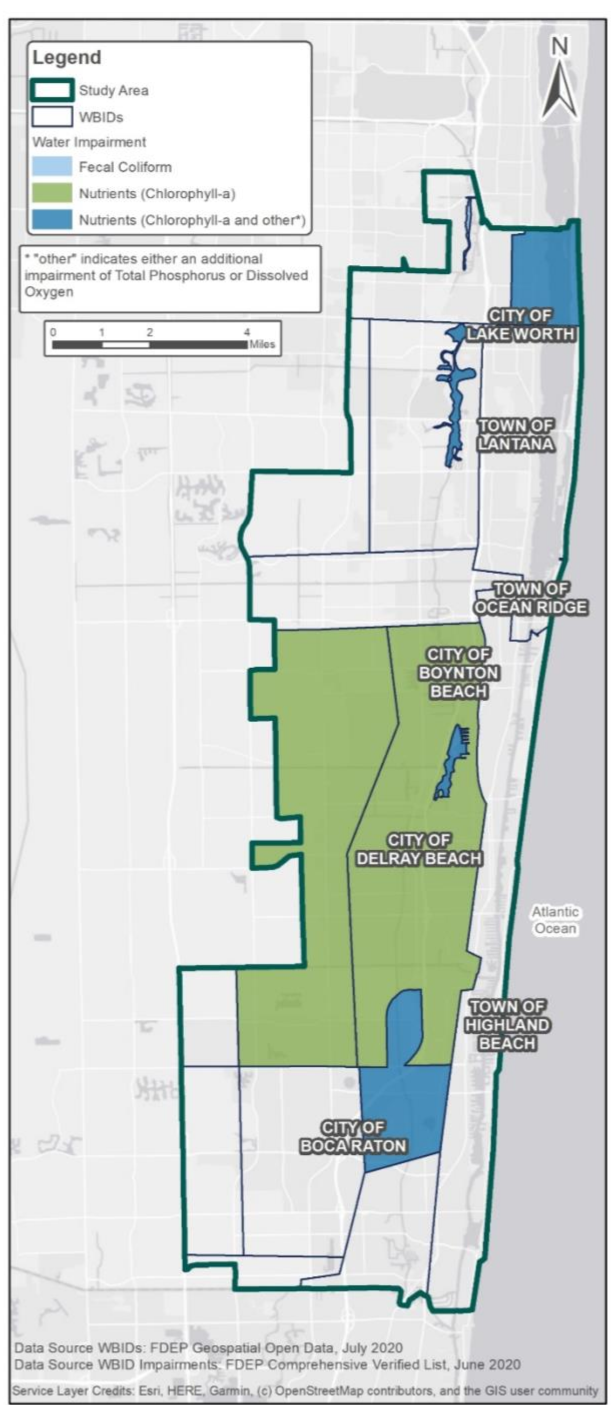


Figure 2-9. Map of relevant impaired WBIDs in the Study Area.

Septic Systems

Interviews with the partner jurisdictions also indicated that a significant presence of septic systems was a potential issue in this study area. As septic systems age and/or as **groundwater inundation** occurs, increased nutrient loads may originate from these septic systems. The spatial display of parcels and a breakdown of septic systems throughout the study area can be seen below in Figure 2-10.

Figure 2-10. Summary of septic systems in the Study Area.

Location	Area (acres)*	Septic Area (acres)	Percent Septic
City of Boca Raton	19207.7	15.7***	0.082%
City of Boynton Beach	10595.8	45.7**	0.43%
City of Delray Beach	10456.5	96.4**	0.92%
City of Lake Worth	4360.8	5.3**	0.12%
Town of Highland Beach	417.1	NA	NA
Town of Lantana	1870.2	1.8**	0.09%
Town of Ocean Ridge	617.8	277.6**	44.93%
Unincorporated	24530.4	3332.9**	13.59%
Jurisdictions not included in CCVA study			
City of Atlantis	910.6	2.8	0.30%
Town of Briny Breezes	44.8	NA	NA
Village of Golf	521.4	NA	NA
Town of Gulf Stream	544.8	177.1	32.50%
Town of Hypoluxo	511.9	9.0	1.76%
Town of Lake Clarke Shores	662.4	292.0	44.08%
Town of Manalapan	664.5	50.5	7.60%
Town of Palm Beach	917.5	NA	NA
Town of South Palm Beach	74.8	NA	NA
Village of Palm Springs	1325.1	253.1	19.10%
Totals	**78234.1**	**4559.9**	**5.83%**

*from County-provided City Boundaries
**from County MS4 data (PBC NPDES, 2020)
***from Jurisdiction

NA - No septic in this part of the project area

CRP

Fertilizer Ordinances

Available fertilizer codes and ordinances for each jurisdiction were also reviewed. Many of the jurisdictions reference fertilizer regulation in compliance with Rule 5E-1.003(2), F.A.C. This rule outlines requirements of fertilizers applied to turf, including application rate and frequency maximums. Fertilizer codes and ordinances vary across jurisdictions and are summarized in Table 2-4 below.

Table 2-4. Summary of fertilizer ordinances in the Study Area.

Jurisdiction	Regulation of Fertilizer City Ordinance	Guidance to use "Florida-Friendly" landscape principles in Code/Ordinance[1]	Referred to use Rule 5E-1.003(2), F.A.C
Boca Raton	Ord No. 5469	Yes	Yes
Boynton Beach	Ord. No. 19-19	Yes	Yes
Delray Beach	Ord. No. 07-17 Ord. No. 06-12	Yes	No
Highland Beach	Ord. No 14-005 O	No	No
Lake Worth Beach	Ord. No. 2013-51	Yes	Yes
Lantana	Ord. No. O-23-2012	Yes	Yes
Ocean Ridge	Ord. No. 602	Yes	No
County	Ord. No. 2020-039	Yes	Yes

[1] "Florida-Friendly landscape principles" is reference to the document *Florida-Friendly Best Management Practices for Protection of Water Resources by the Green Industries, 2008* in which best management practices for fertilization are outlined, including but not limited to timing and season for application.

2.2.2 Key Findings

Observations and Issues

As stated previously, **HABs** will likely occur as oceanic temperatures increase and changes to hydrology take place throughout the study area. The analysis indicated that impairments and HABs are occurring in the study area and that these issues spatially interact. As more development occurs, increasing nutrient loads are also likely unless more strategic and scientific action is taken to address water quality in Palm Beach County. As of the issuance of this study, there is no definitive hydrologic modeling for Southeastern Palm Beach County. This hydrologic modeling is an important foundational tool to develop water quality models. There is also no detailed pollutant loading model for the watersheds included in this study. Therefore, it is not possible to determine the sources of nutrients in this study area and then strategically reduce those loads.

Addressing HABs will require a regional watershed approach, which is particularly challenging in Palm Beach County due to the relatively large number of jurisdictions that would need to participate in this exercise. Palm Beach County is also just beginning to experience the regulatory activity involved in **Total Maximum Daily Load (TMDL)** development when compared to other regions throughout Florida. TMDLs have energized other local governments in Florida to develop cooperative and scientific watershed approaches because of the economy of scale that can be achieved and perhaps most importantly because TMDLs can be very expensive for local governments to address.

One such example of an outstanding watershed approach is the recent Lake Worth Lagoon Management Plan, which was coordinated and drafted by Palm Beach County Environmental Resources Management. The plan notes that goals and actions of the plan should improve water quality, enhance habitat, better prepare the watershed for climate change, and foster public awareness, among other goals. Since the Lagoon and watershed cross multiple jurisdictions, it will require cross-jurisdictional work to accomplish these goals. The plan can be viewed at https://discover.pbcgov.org/erm/Publications/DRAFT-2021LWLManagementPlan.pdf.

Given the severe impacts to other communities throughout Florida, it is critical that the CRP continue working on understanding the origins of nutrients in watersheds throughout the study area and then strategically address water quality through effective adaptation strategies. It is also important to note that this effort will likely take longer than other parts of Florida because of the complex nature of the hydrology in the South County watersheds and the relatively low level of monitoring data.

Recommendations for Future Analysis

Several analyses would improve the CRP's understanding of the likelihood of HABs in Southern Palm Beach County:

- Calibrated and verified baseline hydrologic and hydraulic models should be developed for the watersheds that overlap with the study area. These models would also be helpful in addressing the flood threats discussed throughout this report and provide helpful information to all participating jurisdictions. Ideally, partners at the Lake Worth Drainage District and South Florida Water Management District would participate.
- A network of water quality data should be strategically developed on a watershed basis so that the water quality of waterbodies can be proactively discerned (before regulatory action is taken).
- Continuous pollutant loading models should be developed for watersheds that overlap with the study area with a focus on cross-jurisdictional watersheds.
- The CRP should consider more sophisticated water quality modeling efforts once these baselines are established (e.g., hydrodynamic and water quality models for the Lake Worth Lagoon). These models would be important to aid in addressing potential regulation and would also provide a clear scientific basis for decision making for the future. Many similar waterbodies have been modeled throughout

Florida in this manner (Tampa and Biscayne Bay, for example). Without these models, it will be difficult to understand the potential for HABs with a changing climate.

2.3 Drought

2.3.1 Assessment Process

Background

The assessment of **drought** was accomplished via narrative analysis. Historic occurrences of drought as well as water-supply planning documentation were reviewed for the project area.

Participating jurisdictions in the CCVA study area predominately rely on groundwater to provide water supply. Documentation reviewed for historic drought information includes:

- The Drought of 1998-2002: Impacts on Florida's Hydrology and Landscape by Richard Jay Verdi, Stewart A. Tomlinson, and Richard L. Marella produced by USGS and the U.S. Department of the Interior (2006)
- Drought.gov, the U.S. Drought Monitor created in 2000 to map and categorize areas of drought throughout the country. (National Drought Mitigation Center & USDA Federal Drought Assistance, n.d.)

The most recent prolonged droughts in Florida occurred between 2006 and 2008 (National Drought Mitigation Center & USDA Federal Drought Assistance, n.d.) and 1998 through 2002 (Verdi et al., 2006). During these periods of drought, rainfall was well below normal levels throughout the State, causing low streamflow and low groundwater levels. Water use varies throughout the year based on irrigation and population need, and when drier conditions occur, the demand for freshwater increases, putting stress on the groundwater aquifer system. Water conservation as well as water reuse can offset some of the demand on the aquifer systems during times of drought. In the year 2000, due to the drought conditions, water-shortage mandates were issued in three of the water management districts to help reduce water consumption (Verdi et al., 2006).

In addition to water supply being at risk during periods of drought, the area becomes more susceptible to sink holes, **wildfires**, and **saltwater intrusion**. Sink holes appear when the groundwater table no longer supports the roof of a limestone cavity and the cavity collapses. Wildfires (discussed in detail in Section 2.12) increase in likelihood and intensity during periods of drought. In 1998, during one of Florida's most severe droughts, almost 5,000 fires occurred throughout the State and burned over 500,000 acres of land (Verdi et al., 2006). Although the CCVA study area is not particularly prone to fires, crop damage and smoke from fires in other areas of the State can have a trickle-down effect throughout the study area. Saltwater intrusion (discussed further in Section 2.5) can also worsen when the pressure and volume of freshwater in the groundwater aquifers is insufficient to hold the salt water out during times of drought.

Water Supply Plans

The South Florida Water Management District (SFWMD) developed the 2000 Lower East Coast Water Supply Plan (LEC) in 2000. This document outlines the goals for the SFWMD to "identify sufficient water supply sources and projects to meet existing and future reasonable-beneficial uses during 1-in-10-year drought conditions while sustaining water resources and related natural systems." The LEC requires local governments to write a 10-year water supply plan to be updated every five years.

Documentation reviewed for water supply plan analysis includes

- SFWMD Lower East Coast Water Supply Plan Update 2018
  - The "2018 LEC Plan Update concludes there is sufficient water to meet the needs of the LEC Planning Area during a 1-in-10-year drought condition through 2040 while sustaining water resources and related natural systems"
  - Water conservation and alternative source developments include monitoring the Floridan Aquifer, promoting reuse projects, and developing more water storage options

  - The LEC is working to reduce withdrawals and dependency on the Surficial Aquifer system, lower per capita water use, increase conservation and reclaimed water reuse efforts, and increase storage of water during the rainy season.
- Lake Worth Drainage District 2019 Water Control Plan
  - Lake Worth Drainage District (LWDD) controls water levels in the South Florida canal and basin system to maintain optimum levels for the underlying groundwater table and to recharge the area wellfields. Nearby canals and conservation areas are used to keep optimum water levels in the canal system during dry periods, but drought conditions can stress the system and canals can drop below the optimum elevation.
- City of Boca Raton 10-Year Water Supply Facilities Work Plan (January 2020)
  - The City of Boca Raton has an aggressive water reuse program, a wellfield protection program, and an advanced program for water conservation/raw water demand reductions.
  - The conservation efforts include a water conservation rate structure, public education, low-volume plumbing requirements, irrigation limitations, Florida Friendly Landscaping principles, leak detection programs, rain sensors, and counting "Unaccounted for Water" on monthly basis to see if there are leaks or potable water misuse.
- City of Boynton Beach 10-Year Water Supply Facilities Work Plan Update Report 2020
  - Regionally, increased withdrawals from the Surficial Aquifer system are limited. Boynton Beach has an existing consumptive use permit that cannot increase in allocation. The City is working to expand its reclaimed water program to stay within their permitted allocation.
  - The City has implemented various protection and conservation approaches including protecting and maintaining groundwater recharge areas and enacting water conservation ordinances, such as the Florida Friendly Landscape Ordinance. The City also just passed a new irrigation restriction ordinance.
  - Boynton Beach is not located within the Lake Okeechobee Service Area and does not plan to seek water allocation from Lake Okeechobee or other connected surface waters in the future.
- City of Delray Beach Water Supply and Treatment Feasibility Study 2019
  - The City of Delray has a current water use permit for Surficial Aquifer wells but will need to find alternative water source for increased demands of the future. Increased Surficial Aquifer allocation would only happen if alternative sources were created as well.
  - One option for the City is to apply for allocation from the C-51 Canal – Regional Reservoir for surface water recharge for the 1-in-10-year drought conditions. The reservoir is operated by SFWMD.
  - The City of Delray Beach Water Supply and Treatment Feasibility Study 2019 mentions the most likely alternative water supply will be the Floridan Aquifer. Additional wells would be constructed as well as a reverse osmosis (RO) plant.
  - The City is also working to offset aquifer demands with reclaimed water.
- City of Lake Worth Beach 2020 10-Year Water Supply Facilities Work Plan
  - The City of Lake Worth's current water sources are the Surficial and Floridan aquifers
  - The City has implemented various practices to store, conserve, and protect their water supply including additional stormwater detention measures for higher aquifer recharge for the Surficial Aquifer, saltwater intrusion monitored with monitoring wells, and starting an RO plant (further reducing demands on the Surficial Aquifer).
  - The City's water conservation program to lower per capita use includes irrigation ordinance, landscape regulations, public education, ultra-low volume plumbing fixture ordinance, water conservation rate structure, leak detection program, rain sensor device ordinance, and automatic meter infrastructure.
  - Re-use is not currently available to Lake Worth Beach, but the City participates in a regional group sending wastewater to be treated at the East Central Regional Water Reclamation Facility where reclaimed water is then used in another location.
- Town of Highland Beach 10-Year Water Supply Work Plan (Updated 2020)
  - The Town has a Consumptive Use Permit and three production wells. A reverse osmosis plant converts the lower-quality brackish water to high quality drinking water.
  - The Town has ground and elevated storage facilities.

- The Town's water distribution system is interconnected with Boca Raton and Delray Beach and has a bulk water agreement with the two cities.
- The Town encourages water conservation through Palm Beach County programs and Florida friendly landscaping and has adopted amendments to the standard plumbing code which requires the use of low-flow fixtures for new construction or remodeling.
- Re-use is not currently available for the Town for use of reclaimed wastewater for irrigation purposes.

2.3.2 Key Findings

As populations increase and freshwater resources become scarcer, each jurisdiction is facing similar water supply issues, especially when the additional threat of drought appears. The LEC mandated a program where each jurisdiction is required to provide a 10-year Water Supply Plan. These plans use the key elements described in the LEC to plan for sufficient water supply for a 1-in-10-year drought. The most discussed regional issue was the fact that fresh surface water and groundwater supplies are limited. Various solutions were addressed through the water supply plans, including

- Adding additional storage systems and aquifer recharge areas for capturing water during the wet season
- Additional use of reclaimed water to be further implemented where applicable
- Increased wellfield management to protect the quality of water in the aquifers
- Adding aquifer storage and recovery (ASR) wells into the water systems
- Further enforcing conservation efforts and ordinances such as water conservation programs to lower per capita use
- Supplementing Surficial Aquifer withdrawals with Floridan Aquifer withdrawals that must be treated by reverse osmosis plants

Recommendations for Future Analysis

Like other water threats included in this study, regional modeling efforts are needed to evaluate current and future drought potential. Calibrated and verified baseline hydrologic models should be developed for the southern portion of Palm Beach County. To analyze drought, it would be necessary to develop groundwater and/or integrated models. Ideally, partners at the Lake Worth Drainage District and South Florida Water Management District would participate in the modeling process.

2.4 Extreme Heat

2.4.1 Vulnerability Assessment Process

Background and Methodology

A screening-level extreme heat vulnerability assessment was performed by examining land cover, sensitive populations, tree canopy cover, and socioeconomic stress. Figure 2-11 shows the developed land cover (left) and the tree canopy (right) that provide two foundational inputs to the assessment of extreme heat.

All of the CCVA study area was considered as being exposed to the potential for extreme heat. A ruleset-based approach was then developed for considering aspects of potential impact (focused on sensitive populations and developed land cover) and **adaptive capacity**, which considers tree canopy coverage and socioeconomic vulnerability (based on the CDC's socioeconomic status theme, one component of their overall social vulnerability index). Criteria used for the assessment of vulnerability based on these factors are shown in Table 2-5.

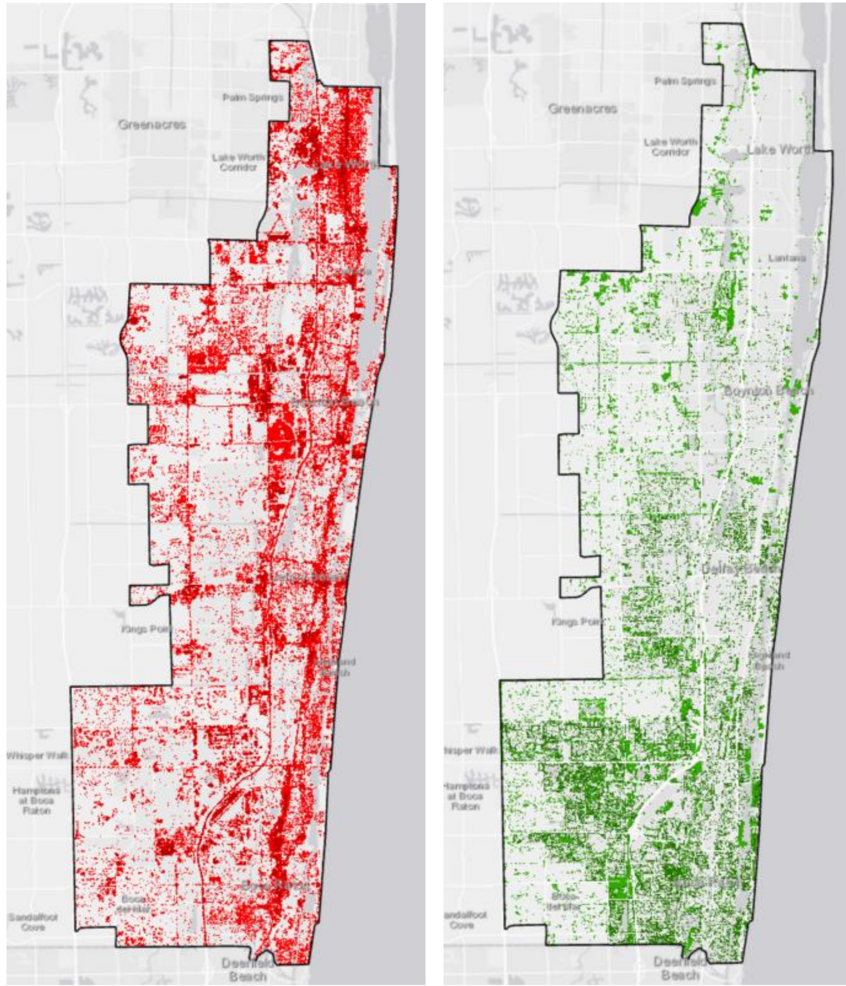


Figure 2-11. Developed land cover (left) and tree canopy coverage (right) for the Study Area.

Table 2-5. Components of vulnerability assessment for Extreme Heat

Level	Vulnerability Component	
	Potential Impact	Adaptive Capacity
High	High percentage of households with sensitive populations (members 65+ or under 18 years of age) and high percentage of developed land cover	High amount of tree canopy coverage and low socioeconomic vulnerability
Med	Moderate levels of both sensitive populations and developed land cover; lower percentage of sensitive populations OR lower percentage of developed land cover	Lower amount of tree canopy coverage OR lower socioeconomic vulnerability, but not both
Low	Moderate to lower percentage of sensitive populations AND moderate to low percentage of developed land cover	Lower amount of tree canopy coverage AND lower median household income

Potential Impact

Developed land cover contributes to the urban heat island effect. For this assessment, the landcover classes of high and medium development intensity from the National Land Cover Database (NLCD 2016) were used in the analysis to identify areas with areas with higher developed land cover (see Figure 2-11). This was then combined with socioeconomic information on sensitive populations, including households with members 65 years of age or older and households with members under 18. Census tracts with both relatively high developed land cover and high percentage of sensitive populations were determined to have a high potential impact.

Adaptive Capacity

Tree canopy data from the U.S. Forest Service (USFS) Geospatial Technology and Applications Center (GTAC) was integrated as a consistent tree canopy coverage dataset for the CCVA study area. This data was used to understand the adaptive capacity, or potential mitigating effects, that tree canopy coverage may have during heat events. Using the USFS tree canopy product, the focus was on the percent area of canopy coverage of 40% or greater (at the 30-meter resolution). Tree canopy coverage from the USFS dataset is shown in Figure 2-11. This tree canopy data was used in conjunction with the National Land Cover Dataset (NLCD), which was used to separately examine the amount and intensity of development within census tracts.

The CDC's social vulnerability index theme of socioeconomic status vulnerability was used as an additional measure of adaptive capacity to extreme heat.

2.4.2 Key Findings

Vulnerability to extreme heat was assessed based on the combination of potential impact and adaptive capacity on the census tract scale.

Figure 2-12 shows the two inputs (potential impact and adaptive capacity) followed by the resulting vulnerability map. The potential impact map (on the left) is based on percent developed land cover and sensitivity of residents. The dark tan areas in that map have a relatively high percent area with medium to high intensity developed land cover and a high percentage of senstive populations. The center map shows levels of adaptive capacity, which is based on percent tree canopy coverage and relative socioeconomic stress. Census tracts with low adaptive capacity are symbolized by dark green and represent census tracts with relatively low tree canopy coverage, which include census tracts below the 25th percentile in the study area, and that have relatively high socioeconomic vulnerability (census tracts above the top 75th percentile based on the CDC SVI socioeconomic theme).

Census tracts shown in darker red in the map in Figure 2-12 (on the far right) are 1) highly developed areas with higher percentages of sensitive residents (older than 65 or under 18), 2) have relatively low tree canopy coverage and high socioeconomic stress. Every CRP jurisdiction includes a census tract with at least medium vulnerability to extreme heat. For the entire study area, the census tracts with medium or high vulnerability include the following sensitive populations, which are a key factor in potential impact:

- 33,900 households with members 65 years of age or older
- 18,400 households with members under 18 years of age

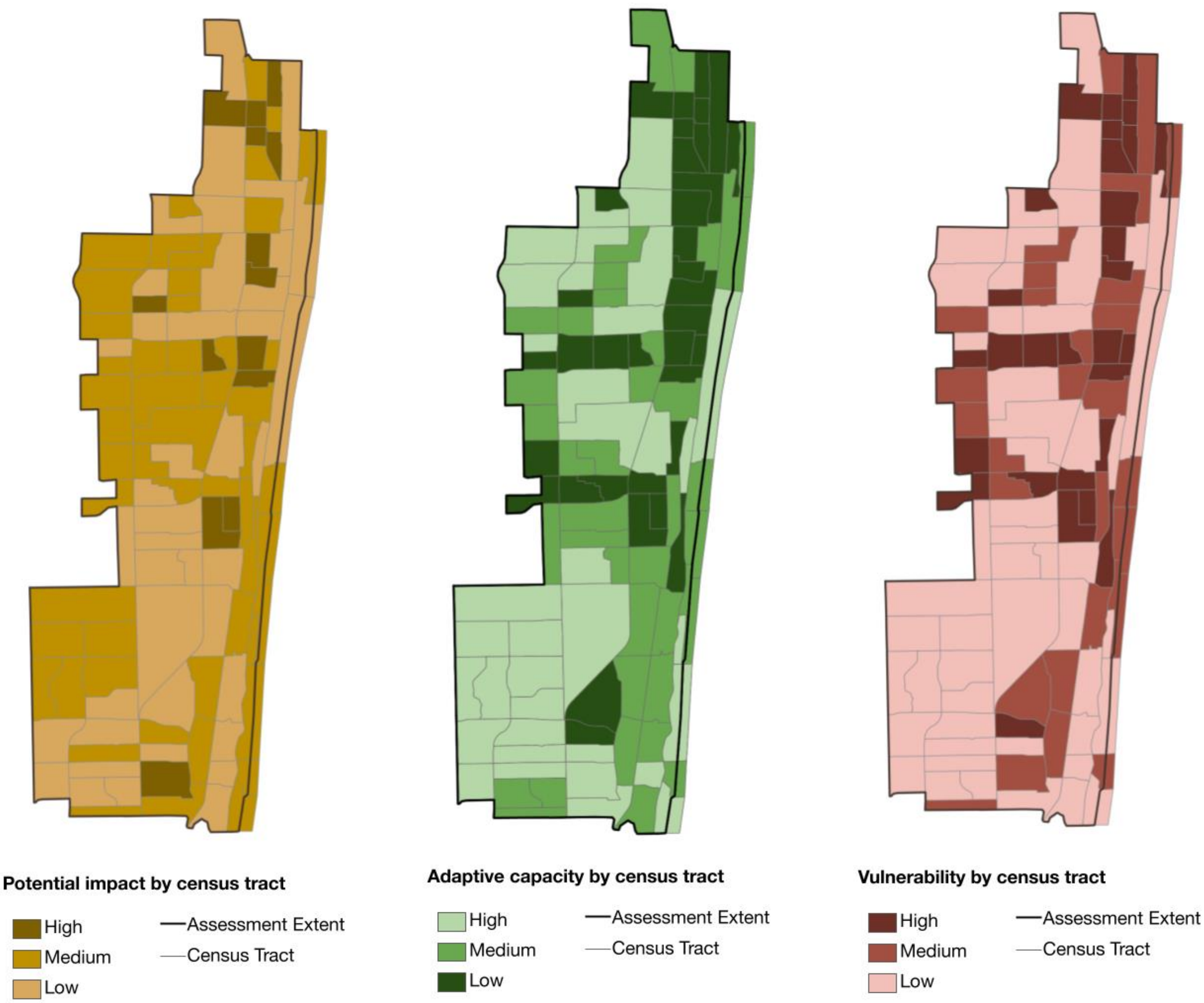


Figure 2-12. Potential impact (left), adaptive capacity (center), and vulnerability (right). Vulnerability is the result of both potential impact and adaptive capacity.

2.5 Groundwater Inundation and Saltwater Intrusion

2.5.1 Vulnerability and Risk Assessment Process

Background

As noted, **saltwater intrusion** and **groundwater inundation** are primarily connected to climate change through **sea level rise**. As the climate warms, causing ice melt and thermal expansion of the oceans, sea levels will rise. The freshwater aquifer in South Florida floats atop the saltwater below as a lens. The porous limestone allows the water to oscillate with sea levels. This will allow groundwater to breach the surface in low-lying areas, permanently inundating land. This is in addition to tidal flooding concerns. Long before permanent inundation however, other significant issues will occur related to groundwater such as reduced capacity for stormwater storage and failure of septic tanks.

Saltwater intrusion is caused by both climate and non-climate-related stressors. Climate-related stressors are drought (Section 2.3), changes in precipitation patterns and sea level rise. Sea level rise is also the primary stressor for groundwater inundation. While heavy rainfall can temporarily enhance groundwater levels, the sustained groundwater rise expected as part of sea level rise is a greater long-term threat. The combined threat of groundwater inundation and heavy rainfall-induced flooding will likely be the greatest concern for large-scale sustained flooding for the region.

Given the interconnected nature and narrative approach of groundwater inundation and saltwater intrusion, the two threats are addressed together in this section. The assessment of groundwater inundation was accomplished by a primarily narrative analysis to understand some key vulnerable areas within Southeast Palm Beach County.

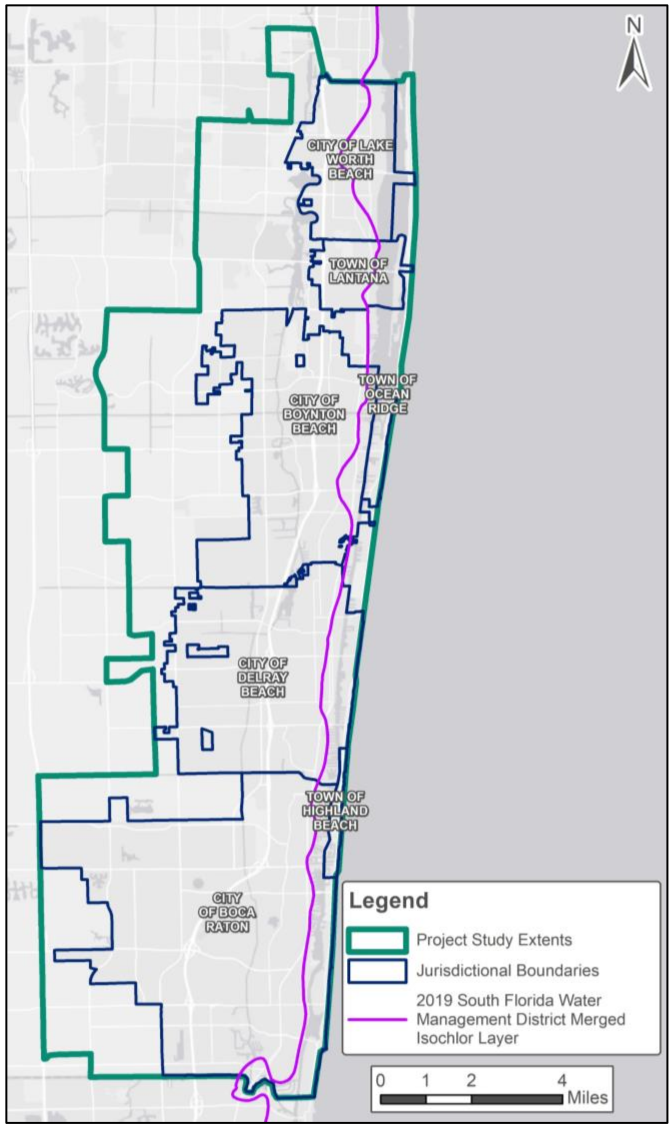


Figure 2-13. South Florida Water Management District's 2019 Isochlor (Data Source: SFWMD, 2020).

The South Florida Water Management District has developed and provides a "merged isochlor" layer, which is an estimate of the location of the 250 mg/L chloride concentration or farthest inland extent of saline surface water (see Figure 2-13). An isoline is a line of a constant variable, and this case it is the chloride concentration, which is a proxy for salinity. The team explored the 2009, 2014, and 2019 merged isochlor data. There was no describable pattern relating the location of the isochlor to sea level rise. The complex relationship between the isochlor location, sea level rise, flood control system, climatological conditions, and water usage also make any observed pattern likely speculative. The team also examined the depth of groundwater in low-lying areas to estimate the minimum depth to groundwater. The results were to inform this narrative analysis and not robust enough to develop quantitative results. Furthermore, the consultant team examined drinking water well locations with respect to the merged isochlor data. However, given the sensitive nature of those assets and the detailed modeling associated with potable water allocation, the consultant team provided a narrative analysis of such results.

General Discussion

A comprehensive groundwater model that includes sea level rise is not available for the region. Therefore, a relatively straightforward and defensible approach to quantitatively evaluate groundwater and saltwater intrusion is not present. The scope of this project does not include groundwater modeling to complete the vulnerability assessment. Broward County has developed a Future Conditions Groundwater Elevation Map, which provides expected groundwater levels 50 years out. This is an important tool the community has developed and uses for planning, development, and regulatory purposes. The preparation of a similar model and subsequent analyses is recommended for Palm Beach County and discussed further in Section 3 of this report.

A primary concern associated with rising groundwater is decreased stormwater infiltration and therefore partial or complete failure of various stormwater systems. As rising sea levels cause groundwater levels to rise, the soils closer to the surface will be saturated and will have reduced storage capacity. This means that our methods of managing stormwater will need to be rethought and modified. Many of our stormwater systems were designed based on historical groundwater conditions and assumptions. This also means that designs for green infrastructure must take future conditions into account as the hydrology of our natural systems may also shift. Rising groundwater levels may also impact erosion rates, especially in low-lying coastal areas. This is an area that requires further study.

Furthermore, coastal drinking water wells may become brackish due to saltwater intrusion. This is already occurring in coastal areas across South Florida. Some CRP jurisdictions noted, as a part of this study, that they are considering or actively moving wells to prevent saltwater intrusion.

As sea level rises, septic tanks, which are prevalent in several communities in the CRP, will fail. This is a significant issue across South Florida and can impact water quality and lead to harmful algal blooms. As noted throughout this report, most of the threats addressed in this CCVA are interconnected, requiring thoughtful approaches to solving many of these challenges.

2.5.2 Key Findings

Saltwater intrusion and groundwater inundation will be significant and underestimated threats. Groundwater inundation is often overlooked but will likely be the primary cause of significant widespread flooding across the region over time in combination with heavy rainfall.

- There are several low-lying areas east of Federal Highway at risk of flooding related to rising groundwater levels. Although it may appear that these areas do not experience significant groundwater-related issues, there are several low-lying areas on the mainland east of Federal Highway that likely have high groundwater levels. The capacity of the soils in these areas to infiltrate stormwater is limited. As sea levels rise, capacity will become even more limited. A major finding across all of the flood threats included in the study is that the interconnection of the flood threats and that sea level rise is likely to exacerbate flooding (in terms of both depth and geography) up to and occasionally west of Federal Highway.

- Near tidally influenced water bodies, it is challenging to discriminate between tidal flooding and groundwater inundation, especially when the groundwater is brackish or saline. There are many portions of the western barrier islands along the Intracoastal Waterway where tidal and groundwater flooding cause frequent flooding.

- Once groundwater is no longer underground, it is not considered groundwater; however, groundwater inundation implies that the groundwater has breached the surface. This is a complex and almost paradoxical issue, not only from a science perspective, but also a regulatory and legal perspective.

- Potable drinking water will be impacted by sea level rise.

- There is no doubt that the freshwater aquifer will be challenged as sea levels rise and saltwater intrudes on the fresher water we need. Saltwater intrusion will be exacerbated by sea level rise, but there are also several other complex contributing factors to potable water availability in the region. There is a need to understand how long the region will be able to utilize the aquifer as the primary drinking water source without desalinization. Eventually, there will be a point at which the water will no longer be fresh enough for human consumption. While estimates show that this will happen decades in the future, planning for such an occurrence will take decades and a regional and informative groundwater model would take several years to create. This should be a continued regional conversation.

- The proper upgrades and maintenance to the Central and Southern Florida (C&SF) Flood Control System will be essential to the overall long-term viability of the region.

- The region's freshwater aquifer, groundwater recharge, and surface flooding are maintained by one of the most complex flood control systems in the world. The C&SF is old and getting older. A significant number of the salinity or flood control structures along the eastern coast of the South Florida Water Management District were within six inches of inoperability (SFWMD, 2009). This means that the flood control structures cannot be opened during high tides without the risk of saltwater backflowing through the canals ultimately impacting the freshwater supply. The system is currently in need of a detailed study to allow for the Federal government to authorize additional expenditures to improve the system.

- There are a significant number of septic tanks in low-lying coastal portions of Southeast Palm Beach County that are at risk of failure due to rising groundwater.

- Septic tanks will fail as sea levels continue to rise, pushing groundwater closer to the levels of septic tanks. It will be an enormously expensive multi-jurisdictional undertaking to convert the region from septic systems to municipal sewer systems. Given that several of the larger municipalities provide **utility** service to smaller municipalities involved in this study, this assessment provides the perfect starting point for a sustained regional conversation. Converting septic tanks is not only essential from a waste management perspective, but also essential to protect regional water quality and the economy, given the importance of the region's natural assets as an economic driver.

2.6 High Winds

2.6.1 Vulnerability Assessment Process

Background and Methodology

Sustained **high winds** are typically associated with tropical storms in Southeast Florida, with the Atlantic hurricane season extending from June 1 through November 30. Sustained high winds can destroy infrastructure and assets.

As the climate warms, it is anticipated that while overall frequency of hurricanes may not change, the storms that do form will be stronger, resulting in more frequent category 3-5 hurricanes. This means that the likelihood of a strong hurricane with high sustained winds hitting South Florida will increase. Dorian, which just missed Palm Beach County in 2019, had sustained winds in excess of 186 mph, making it one of the strongest hurricanes in the Atlantic Basin at landfall on record and the strongest hurricane to hit the northwestern Bahamas in modern records (Avila et al. 2020).

For this study, a screening-level assessment was developed for all properties in the study area in order to estimate vulnerability to high winds. This assessment shows properties that may be more vulnerable to high winds based on use type and relevant wind-related building design regulations at the time the primary structure on a property was built. It is important to note that this assessment should not replace site-specific assessments of wind vulnerability and is not intended to be used for insurance purposes (FEMA 2019b).

Building Design Requirements and Standards

The year of construction for structures is particularly important for estimating vulnerability to high winds in Palm Beach County, in particular the wind-load and wind-pressure design requirements in place at the time of construction (D. Wise, personal communication, September 2020). Table 2-6 shows how particular years were used for determining levels of **adaptive capacity** in the vulnerability assessment.

- Buildings constructed before 1974 in Palm Beach County were built before the inception of Florida's first building code (Florida Housing 2017). Therefore, properties with buildings constructed before this year are considered to have low adaptive capacity (more vulnerability) based on the lack of general structural design requirements.
- Between 1974 and 1995 general structural design requirements were in place through the Florida Building Code and through adoptions of design standards from the American Society of Civil Engineers (ASCE) (Mehta 2010). No jurisdiction-specific amendments within the County are documented to have been made during this time (D. Wise, personal communication, September 2020). These standards included minimum wind-load design criteria. Properties with buildings constructed during this period are considered to have medium/moderate adaptive capacity for the purposes of this assessment.
- In 1995, the County adopted ASCE 7-95. This adoption included significant changes in the wind-load criteria for building construction, with the most significant change being the wind-speed reference that changed from fastest-mile to the 3-second gust (Mehta 2010). Additional changes to wind design criteria at this time include:
    - A topographic factor to consider wind speed-up over certain terrains.
    - Wind-load parameters to account for torsional effects.
    - A separate procedure for determining wind-loads on main wind-force resisting systems (MWFRS) of buildings with roof heights less than 60 feet.
    - Internal pressure coefficients in hurricane-prone regions to reflect debris impact.
    - Pressure coefficients for Components and Cladding (C&C) for multiple roof types.
    - The Gust Effect Factor (GEF) for structures in a unified equation form.
- Since 1995 additional changes in wind-borne debris region maps and building design requirements have taken place. Changes in wind-load design criteria also continue to be made across newer ASCE codes and standards, such as in how pressure coefficients are applied (Florida Dept of Business and

Professional Regulation). However, for the purposes of this screening-level assessment, this ASCE 7-95 (after 1995) is the most significant in terms of considering property-level adaptive capacity (Mehta 2010).

Wind-borne debris regions

ASCE wind-borne debris regions and related risk categories were considered within the region. While different risk categories apply to different types of assets (e.g., residential vs. medical facilities) all of the study area is within the same debris region and mean recurrence interval (MRI) zones. Therefore, all of the study area was considered exposed to the threat of high winds.

Parcel and Structural Data

Property parcel and building-level year-built information from the Palm Beach County Tax Appraiser's Office and CAMA database was used for parcel boundaries and year-built information.

Table 2-6. Summary of assessment components for High Winds.

<table>
<tr><th colspan="2">Assessment Component</th><th>Consideration</th><th colspan="2">Level and Description</th></tr>
<tr><td rowspan="6">Vulnerability</td><td rowspan="3">Potential Impact</td><td rowspan="3">Sensitivity of asset and whether the asset structure is within inundation extent</td><td>High</td><td>Highly sensitive asset with structure</td></tr>
<tr><td>Med</td><td>N/A (Only high and low potential impact were assessed)</td></tr>
<tr><td>Low</td><td>Asset is not a highly sensitive property/facility</td></tr>
<tr><td rowspan="3">Adaptive Capacity</td><td rowspan="3">Wind load and wind pressure design requirements in place at the time of construction</td><td>High</td><td>Constructed after 1995: significant changes (increased standards) in the wind-load criteria for building construction</td></tr>
<tr><td>Med</td><td>Constructed 1974 to 1995: general structural design requirements in place through the Florida Building Code and adoption of design standards</td></tr>
<tr><td>Low</td><td>Constructed before 1974: constructed prior to the Florida Building Code</td></tr>
</table>

2.6.2 Key Findings

The following are high-level regional findings from the assessment of high winds. Table 2-7 shows the total number and percentage of assets for the three types of **critical facilities** that have the highest levels of vulnerability in the region along with residential and commercial properties vulnerable to high winds for the study area.

Table 2-7. Asset categories with high levels of vulnerability.

36% Food Infrastructure	37% Energy & Communications
99% Parks & Cultural	61% Health & Medical

Health & Medical and Parks & Cultural properties have the highest percentages of vulnerability to high winds (61% and 99%, respectively). This is largely due to the year of construction and low adaptive capacity identified for these critical facilities. Figure 2-14 shows the Health & Medical facilities vulnerability map.

Energy & Communication and Food Infrastructure also have high levels of vulnerability to high winds with more than a third (37% and 36%, respectively). Like other critical facilities, low adaptive capacity is a driver of vulnerability for these assets. Figure 2-15 shows the Energy & Communications assets vulnerable to high winds.

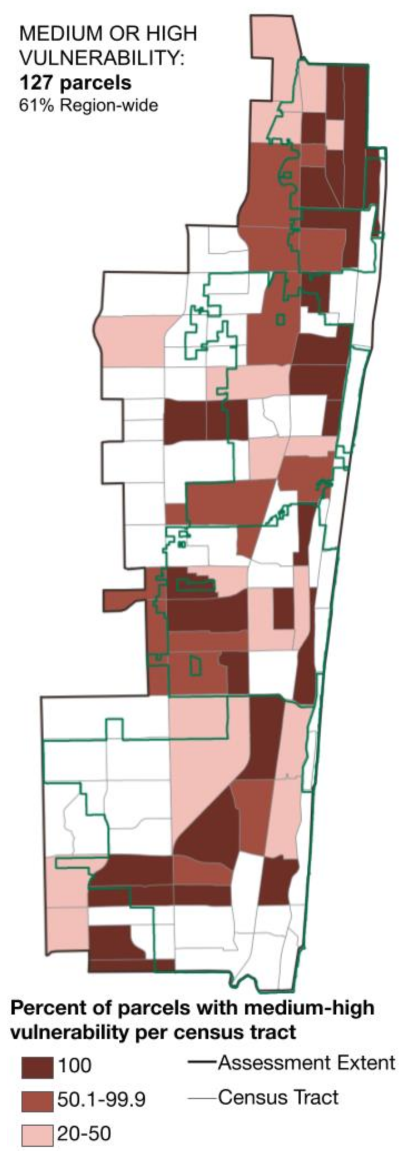


Figure 2-14. Health & Medical and High Winds.

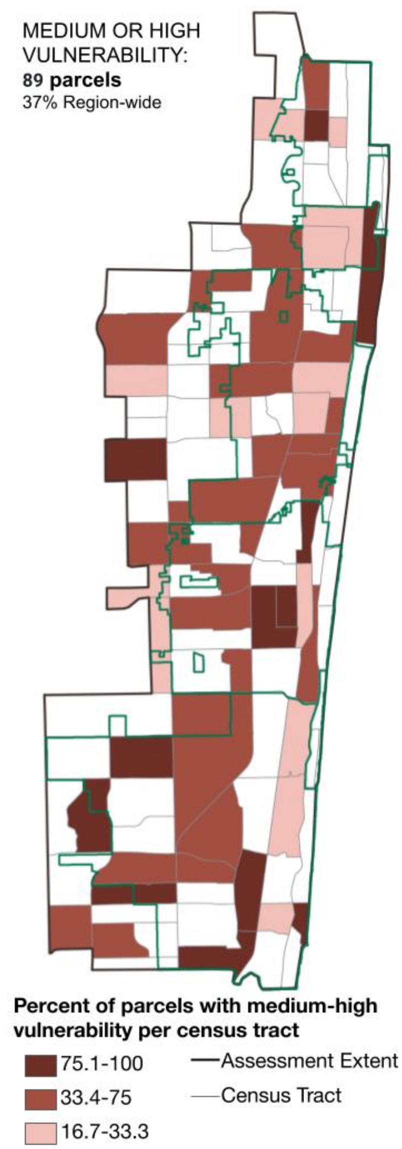


Figure 2-15. Energy & Communications and High Winds.

About 11% of the residential properties in the region have medium or high vulnerability to high winds. Within the study area about 9% of all residential properties were constructed before the first Florida building code adoption in 1974. About 37% of residential properties in the study area were constructed after 1995. The percentage of residential property vulnerability also varies across jurisdictions (from about 5% to 58%).

Residential property vulnerability also has a high co-occurrence with socially vulnerable populations. For example, 18 of the 22 residential census tracts most vulnerable to high winds are also among the most socially vulnerable. Figure 2-16 shows the areas of the region with the highest residential property vulnerability to high winds (dark red) and the areas with the highest social vulnerability (hatching).

Figure 2-17 shows the distribution of the 12,312 residential properties vulnerable to high winds in the study area. For example, the figure shows that almost 22% of all the vulnerable residential properties in the study area are located in Lake Worth Beach.

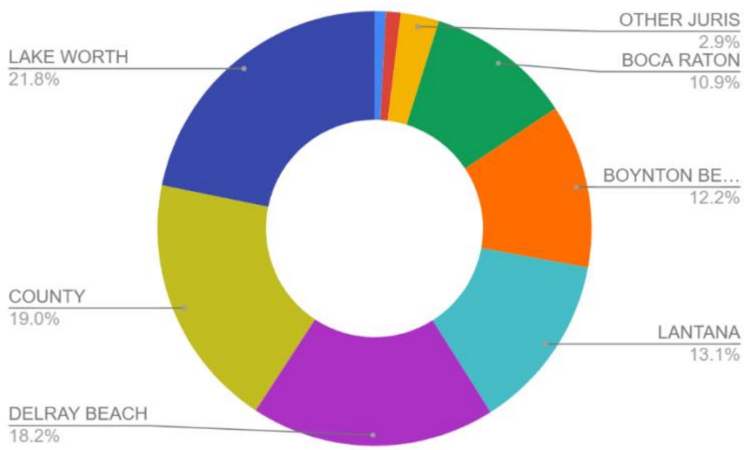


Figure 2-17. Distribution of vulnerable Residential Properties in the CCVA Study Area.

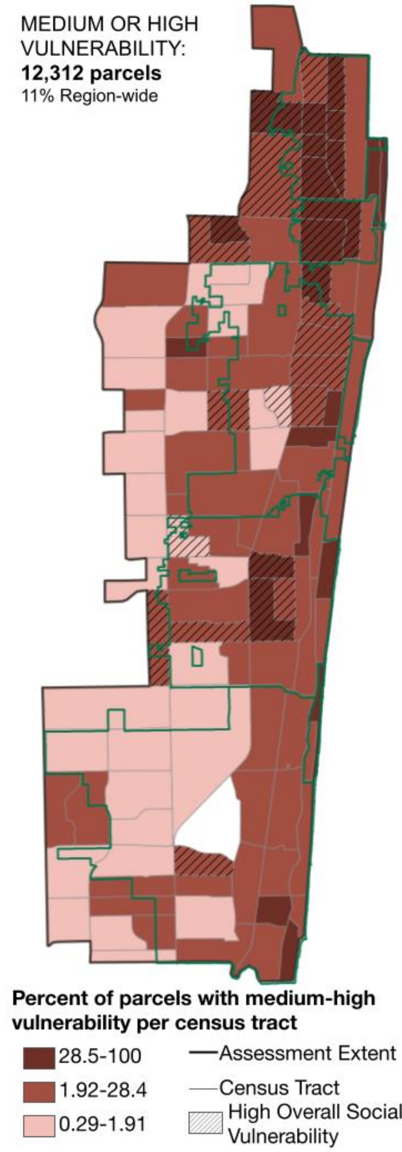


Figure 2-16. Residential Property and High Winds.

2.7 Pest & Disease Outbreaks

2.7.1 Vulnerability and Risk Assessment Process

For the purpose of this project, the **Pest and Disease** threat is considered to include outbreaks of diseases transmitted 1) directly from humans to humans (e.g., influenza, tuberculosis, COVID-19), 2) indirectly through vectors like mosquitoes and ticks, and 3) indirectly through food (e.g., shellfish) and water. This threat also includes pests such as rodents and **invasive species** like iguanas and Burmese pythons.

Climate influences infectious disease transmission directly by affecting the biological processes of pathogens and vectors as well as indirectly by affecting their habitats (Patz et al., 2003). This is true for pests as well. Some of the effects of a changing climate that are expected to increase pest and disease outbreaks include the following:

- In general, warmer temperatures and more humid conditions are likely to provide more favorable conditions for vectors that are already present in a place. In addition, warmer temperatures are expected to result in northward expansion of the geographic range of many vectors.
- Incidents of waterborne diseases are known to be associated with heavy precipitation events. For example, a study estimated that 68% of waterborne outbreaks in the U.S. over a period of 50 years were preceded by extreme precipitation events (Liang et al. 2017, and references therein). More intense precipitation in a warming world has the potential to exacerbate the threat from waterborne diseases.
- The CDC estimates that roughly three quarters of new infectious diseases have emerged from wildlife, i.e., the infection or disease is passed from a vertebrate animal to humans first and then transmitted between humans (e.g., Ebola, Nipah, HIV/AIDS). Drastic changes in land use combined with climate changes have caused habitat destruction and significant loss in biodiversity, increasing human-wildlife interactions and the chances of novel infectious diseases.

The assessment of pest and disease outbreaks was accomplished by narrative analysis. The team first reviewed the literature about patterns in historically observed disease outbreaks, climate and non-climate contributing factors, and differential vulnerability of people to these threats. Based on this review, the team then highlighted baseline contextual information that could be useful for local disease outbreak response.

2.7.2 Key Findings

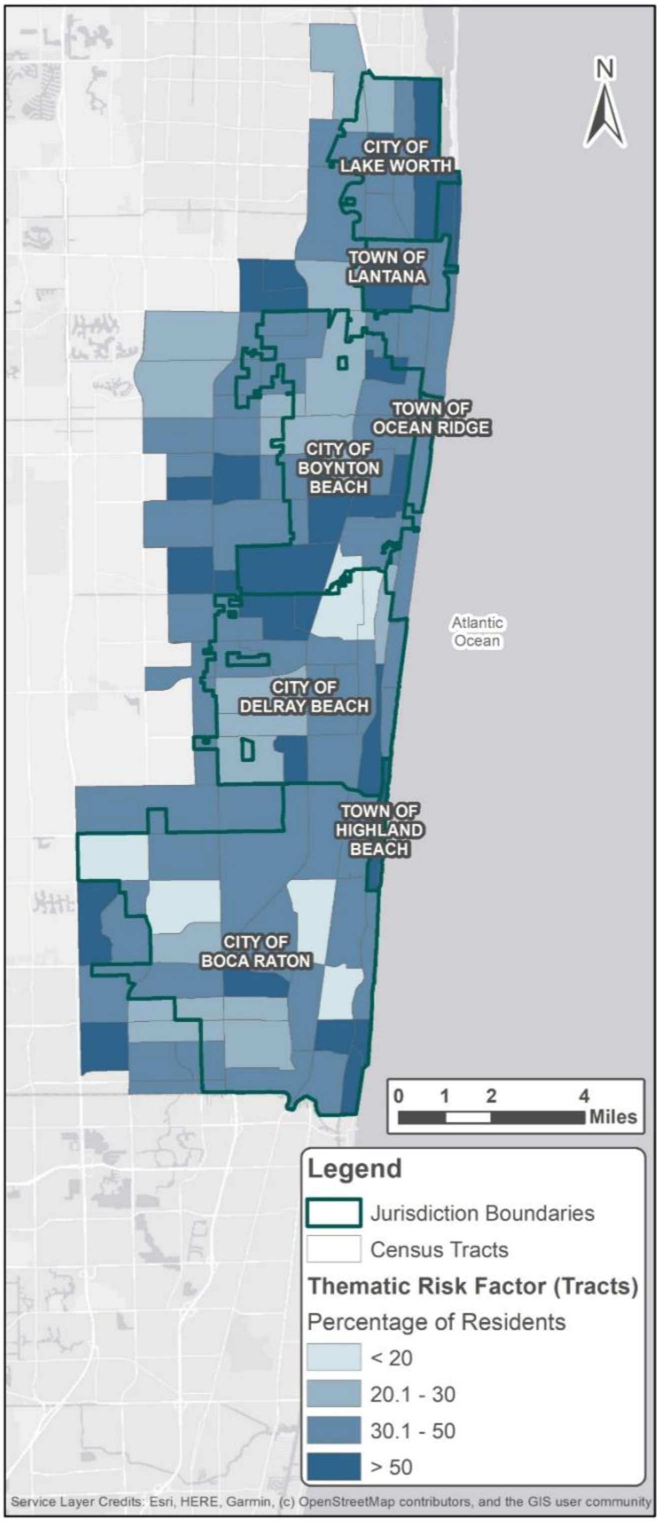


Figure 2-18. US Census Community resilience estimates.

Observed Infectious Diseases

Historical records of infectious disease cases and outbreaks for Palm Beach County are available from two sources:

- According to the ArboNET database maintained by the CDC, between 2015-2019, 114 cases of vector-borne diseases such as dengue, Zika and chikungunya were reported in Palm Beach County. The incidences vary significantly from year to year. Note that the CDC expects these numbers to be underestimated since the data is collected passively i.e., a case is registered in the database only when a clinician reports a confirmed diagnosis to the State public health officials.
- Information on county-level food and waterborne disease outbreaks is available from the Florida Department of Health. According to this database, between 1997 to 2020, there were 2,610 cases and 264 incidents of food and waterborne diseases in Palm Beach County. Multiple cases are often associated with individual incidents (e.g., a school may have many cases from a contaminated cafeteria food incident.)

Indicators of Social Vulnerability

Like the CDC's Social Vulnerability Index, the new Community Resilience Estimates (CRE) from the U.S. Census Bureau highlights the differential vulnerability of individuals and households to cope and recover from infectious disease outbreaks. While the CRE is configured by the Census Bureau specifically for COVID-19, it can be useful to identify at risk populations for response planning for future outbreaks. COVID-19 was a hard lesson that less-resourced members of the community are most at-risk due to unexpected shocks and long-term stressors. As we plan to address the impacts of climate change, it is important to consider how to ensure that all members of our community are prepared, and that our actions do not disadvantage particular members of the population.

The CRE map in Figure 2-18 shows the percentage of residents by census tract that have three or more "risk factors" that are known to reduce the capacity of individuals or households to cope with disease outbreaks. The eight risk factors include income-to-poverty ratio, single- or zero-caregiver household, household crowding, communication barriers, employment, disability status, and health insurance coverage (US Census Bureau 2020). These factors can be used to indicate areas that may be disproportionately impacted or have a more difficult time recovering from pest and disease outbreaks. In Palm Beach County around 38% of residents have three or more risk factors and around 48% have one to two risk factors. The darker colors on the map indicate those tracts with a larger percentage (more than 50%) of residents with three or more risk factors.

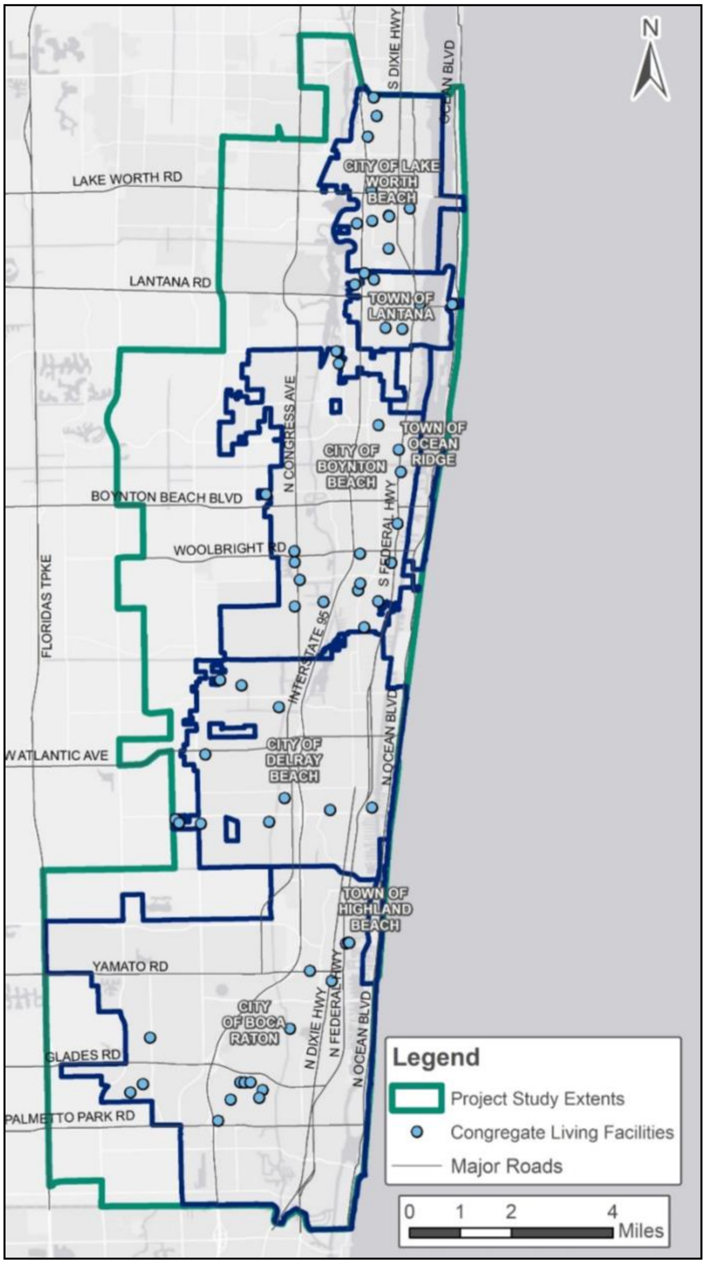


Figure 2-19. Locations of congregate living facilities in the CCVA Study Area.

As the COVID-19 pandemic has highlighted, residents of congregate living facilities such as nursing homes, assisted living facilities and correctional facilities are particularly vulnerable to infectious diseases that are transmitted directly from humans to humans. Figure 2-19 shows the location of congregate living facilities in the study area (Shimberg Center for Housing Studies 2020).

Pests and Invasive Species

Unique climate and non-climate aspects of Florida contribute to the more than 500 nonnative invasive plant and animal species in the State (FWC 2021). Florida's warm and wet climate has been attributed to being particularly hospitable to exotic plants and animals, but the State is also home to the largest reptile trade in the world, making it especially susceptible to pests and invasive species (TNC 2018). There are at least 139 nonnative fish and wildlife species identified in the State and more nonnative reptiles and amphibians than anywhere else in the world. The types of invasive animal species include the following examples (FWC 2021):

- Invertebrates (such as flatworms, mollusks, and insects)
- Freshwater and marine fish
- Amphibians and reptiles (frogs, toads, snakes, lizards and iguanas)
- Birds
- Mammals (rodents, bats)

The consequences of pests and nonnative invasive species in Florida are estimated to cost more than $500 million each year. Invasive species are also the second-leading cause of native species endangerment after habitat loss (USFWS 2019). Just recently the State banned the importation, breeding and possession of 16 high-risk invasive reptiles as a measure to mitigate the presence and spread of nonnative species (FWC 2021).

The South Florida Water Management District is also tracking more than 200 invasive plant and animal species in the region, including exotic plants within the primary water control system throughout the region. The SFWMD employs a range of control methods, including prescribed burns, biological control, herbicide, and mechanical removal (SFWMD 2021).

2.8 Rainfall-Induced Flooding

2.8.1 Vulnerability and Risk Assessment Process

Background and Methodology

The assessment of **rainfall-induced flooding** was accomplished via spatial analyses. Various standard storm intervals and depths were assessed for the project area using a rapid inundation modeling and mapping. Regional-scale Interconnected Channel and Pond Routing (ICPR) modeling (version 4.07.01) was used to determine likely areas of flooding from the varying rainfall distributions throughout the project area.

Rainfall Distributions

Design storm rainfall distributions were determined using the SFWMD Environmental Resource Permit Applicant's Handbook Volume II. Rainfall depths were determined from NOAA Atlas 14 Precipitation-Frequency Atlas of the United States Volume 9 Version 2, using the Precipitation Frequency Data Server.

Boundary conditions were based on the 2020 high-tide elevation for existing conditions. For future conditions, sea level rise estimates were added to the existing conditions high-tide value to estimate future water depths. Table 2-8 highlights the storm events and boundary conditions that were used for the ICPR modeling.

Table 2-8. Summary of scenarios for Rainfall-Induced Flooding.

Conditions	Storm Interval	Rainfall Depth over Storm Interval (inches)
Existing	10-year, 24-hour storm	9.06
Existing	25-year, 24-hour storm	11.6
Existing	100-year, 24-hour storm	16.1
Existing	500-year, 24-hour storm	22.3
Future – 2040 (2020 baseline + 5" Sea Level Rise)	100-year, 24-hour storm	16.1
Future – 2070 (2020 baseline + 33" Sea Level Rise)	100-year, 24-hour storm	16.1

The team developed peak rainfall flood stages for the project area (divided into 66 sub-basins) in ICPR using the rainfall distributions, depths, and boundary conditions described in Table 2-8, above. Flood Insurance Rating Map (FIRM) data for the project area was determined to be insufficient at the time of analysis.

Floodplains were mapped using the ArcHydro tool in ArcGIS (Floodplain Delineation by Node for the generated ICPR data) at a 2.5-foot grid size using the peak elevations generated in the ICPR analysis.

Post-processing consisted of removing the eastern edges of each floodplain raster to correct for inland boundary conditions that did not apply to the eastern border. The surge depth raster generated for 2020 was merged to the floodplain raster for each storm interval to create the project-wide depth estimation. Waterbodies and canals were removed from the analysis as to not identify false bathymetric depths in those areas.

Components of Vulnerability and Risk

The assessment was then used to provide information on systems and assets within the project area that are vulnerable to rainfall-induced flooding. The assessment of vulnerability and risk to assets focused on identifying assets that have greater potential impact, such as critical assets (e.g., major medical facilities) or where more people could be affected (e.g., apartment buildings). The assessment also considered how adaptive buildings are based on the year they were built and the **Base Flood Elevation (BFE)** requirement in place at the time they were built, the most frequent potential flood recurrence interval, and potential flood depth. The table below (Table 2-9) provides a brief description of each assessment component.

Table 2-9. Summary of assessment components for Rainfall-Induced Flooding.

Assessment Component		Consideration	Level and Description	
Exposure		Asset is in harm's way (within potential inundation extent)	2020 baseline condition: Any rainfall-induced flood extent (25-, 100-, or 500-year) Future conditions: 100-year rainfall-induced flood extent	
Vulnerability	Potential Impact	Sensitivity of asset and whether the asset structure is within inundation extent	High	Highly sensitive asset with structure within inundation extent
			Med	Non-highly sensitive asset with structure within inundation extent
			Low	Structure outside inundation extent
	Adaptive Capacity	Floodplain development BFE requirements and year of building or facility construction	High	Constructed after 2017: first floor elevation required to be at least 1 foot above BFE, or constructed outside inundation extent
			Med	Constructed 1982 to 2017: first floor elevation required to be at BFE
			Low	Constructed before 1982: Pre-FIRM, no floodplain development requirements
Risk	Probability	Likelihood of flooding and recurrence interval. Most frequent return interval, if multiple	High	Property within 25-year flood recurrence interval
			Med	Property within 100-year flood recurrence interval
			Low	Property within 500-year flood recurrence interval
	Consequence	Potential depth of flooding	High	Structure exposed to potential flood depth of 3 feet or more
			Med	Structure exposed to potential flood depth between 1 foot and up to 3 feet
			Low	Structure exposed to potential flood depth of less than 1 foot

2.8.2 2020 Baseline Conditions

The threat of rainfall-induced flooding presents the greatest exposure and highest levels of vulnerability and risk of all flooding threats assessed in this study. The table to the right (Table 2-10) shows the four asset categories with the highest levels of vulnerability and risk.

Table 2-10. Asset categories with highest vulnerability and risk.

43% Residential	34% Energy & Communications
36% Food Infrastructure	39% Health & Medical

Both inland and coastal areas within the region and jurisdictions are vulnerable to rainfall-induced flooding. Low-lying areas without drainage systems and areas near ponds and other waterbodies are especially vulnerable to rainfall-induced flooding. These areas stand out in the site-wide floodplain mapping for all storms, existing and future.

Interestingly, as the most widespread flooding threat in this assessment, the levels and specific types of vulnerabilities still vary throughout areas and jurisdictions within the study area. As one example, the levels of residential vulnerability and risk range from about 11% to 86% across the eight CRP jurisdictions. Of the nearly 50,000 residential properties in the study area that are highly vulnerable, almost a third (31%) are found in the unincorporated areas of Palm Beach County. Importantly, some of the smaller jurisdictions in the study area have the highest percentages of vulnerable assets, which highlights that an event does not need to have a widespread regional impact to still have a large impact on certain communities (see CRP jurisdictional summaries in Appendices 1-8 for more details).

A key insight from this threat assessment is the extent to which assets are vulnerable to the 500-year flood event. While the 500-year event has a lower relative likelihood or risk probability compared to the 100- or 25-year event, it is one in which the CRP study area is especially vulnerable. The 500-year inundation mapping and assessment result shows that of the nearly 73,000 properties in the study area exposed to the potential for rainfall-induced flooding, only about 36% are found within the current 100-year regulatory floodplain extent (1% annual chance flood), based on the effective 2017 FEMA **Flood Insurance Study** (**FIS**) for Palm Beach County.

As described earlier, the assessment also examined different characteristics of assets within the study area to understand what makes them vulnerable and at risk to rainfall-induced flooding. For example, a high proportion of properties in the study area were found to have low adaptive capacity.

Properties with low adaptive capacity include those with buildings in a potential inundation extent that were either constructed before the first floodplain development ordinances were in place in Palm Beach County (pre-FIRM) or that are outside the 100-year regulatory floodplain extent (e.g., within the 500-year extent) and have limited ability to cope with flooding. Figure 2-20 shows for residential properties, almost 63% fall within this category (in dark green). About 37% of residential properties were constructed post-FIRM that have either moderate (medium green) or high adaptive capacity (light green) and were constructed since adaptive measures such as additional freeboard requirements were in place or are properties with

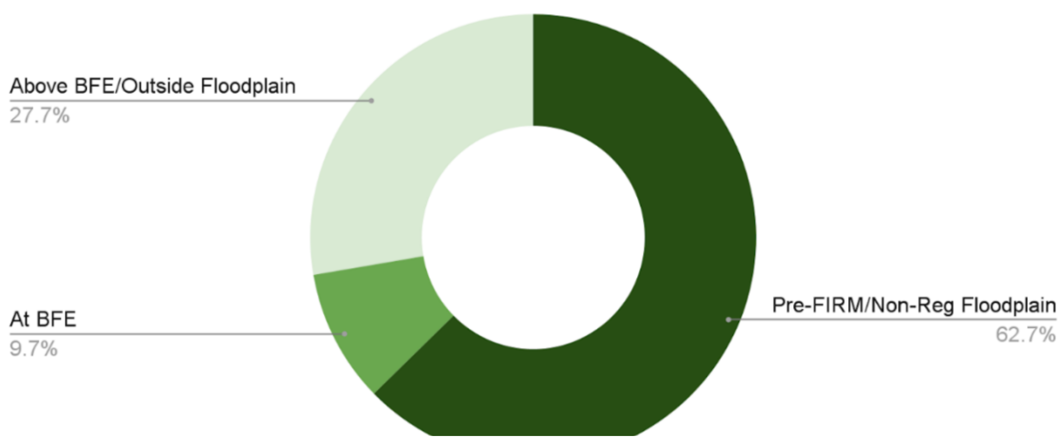


Figure 2-20. Levels of adaptive capacity for the 67,371 Residential Properties Exposed to Rainfall-Induced Flooding.

buildings located outside the floodplain.

Critical Facilities

Energy & Communications and Health & Medical assets have the highest percentage of highly vulnerable and at-risk properties (34% and 39% respectively). These vulnerable assets are throughout the region with many census tracts containing between 80% to 100% of assets that are highly vulnerable and at risk. Vulnerability and risk of Energy & Communications is shown in Figure 2-21 and for Health & Medical facilities throughout the region in Figure 2-22.

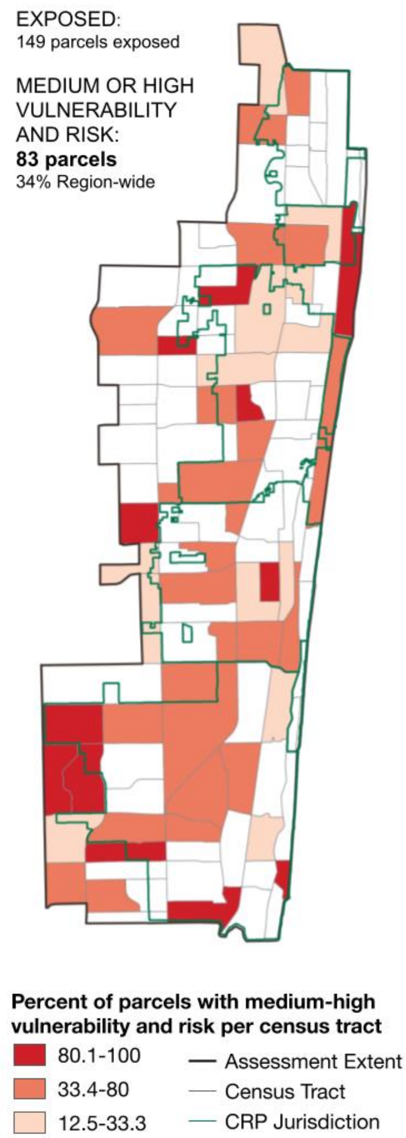


Figure 2-21. Energy & Communications and Rainfall-Induced Flooding.

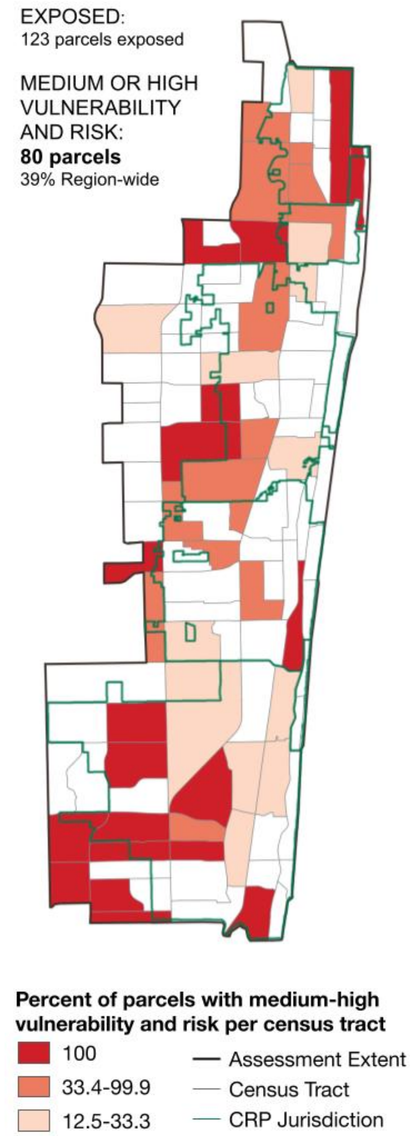


Figure 2-22. Health & Medical Facilities and Rainfall-Induced Flooding.

More than a third of all grocery stores, food SNAP retailers, and food pantries are vulnerable across the region (Figure 2-23). About half of the census tracts with the highest SNAP participation (areas with at least 12% participation) have a high percentage of food infrastructure assets vulnerable and at risk.

Public safety and government-owned assets are vulnerable (Figure 2-24). These include schools and facilities that support government functions. This vulnerability could result in cascading impacts and the loss of critical services throughout the region if affected by flooding.

Property

Residential property has the highest level of vulnerability and risk of all property types with 43% of all residential properties in the study area having medium-high combined vulnerability and risk associated with a 500-year storm event, and 18% for 100-year only. As mentioned previously, about 44% of the residential properties exposed to rainfall-induced flooding have low adaptive capacity. In addition, about 49% are within the 25-year or 100-year extent and about 40% have the potential for at least 1 foot of flood depth.

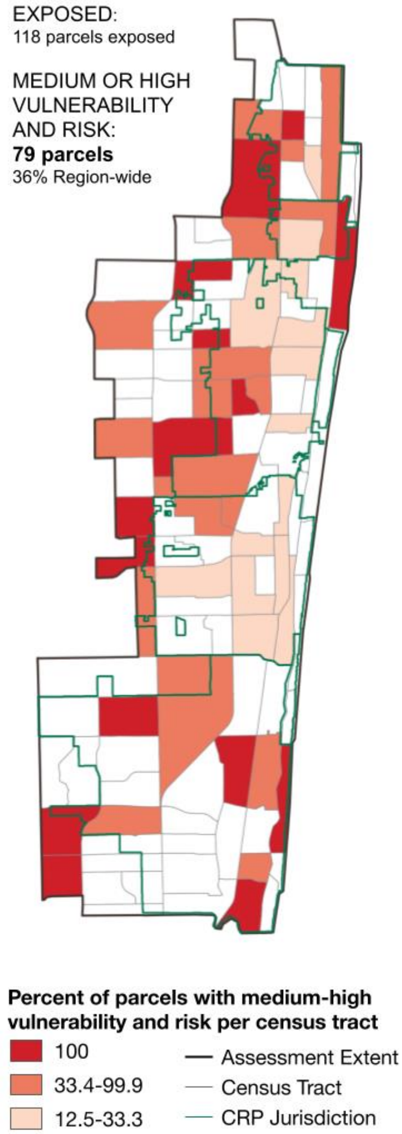


Figure 2-23. Food Infrastructure and Rainfall-Induced Flooding.

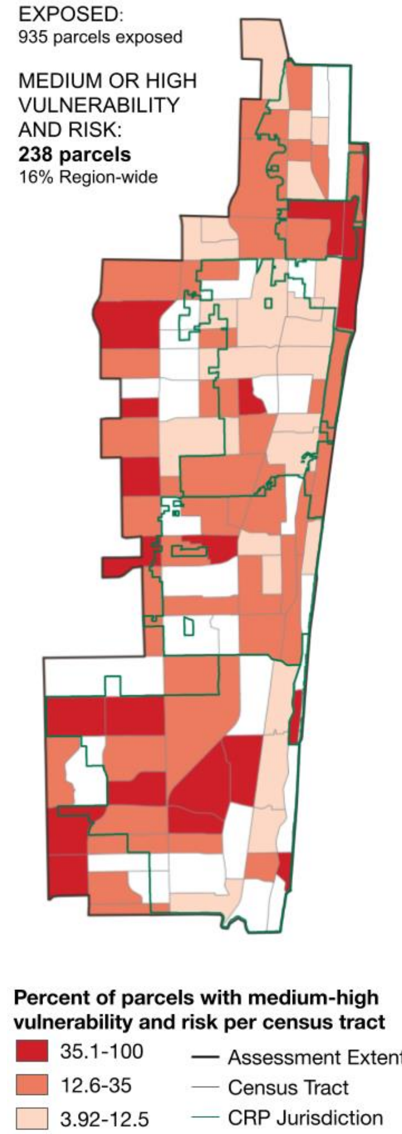


Figure 2-24. Public Safety & Gov-Owned and Rainfall-Induced Flooding.

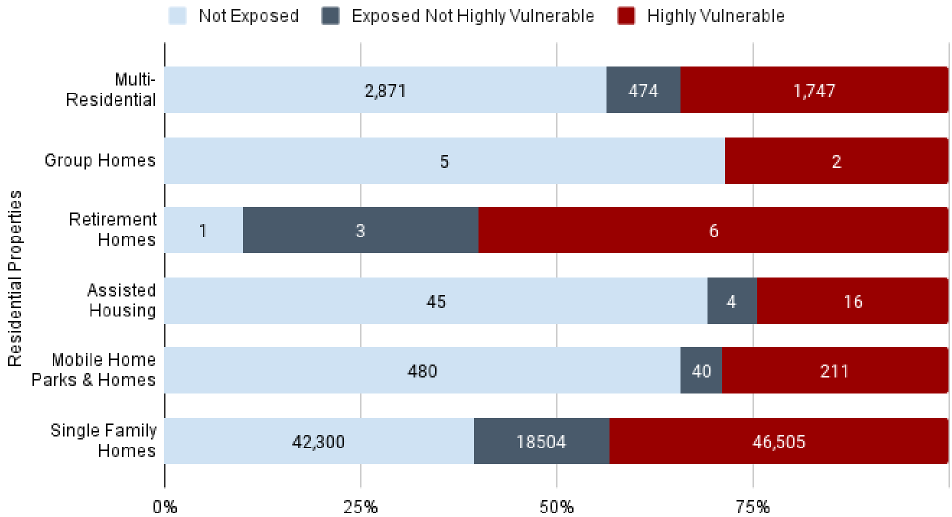


Figure 2-25. All Residential Properties and the number highly vulnerable, exposed but not highly vulnerable and not exposed.

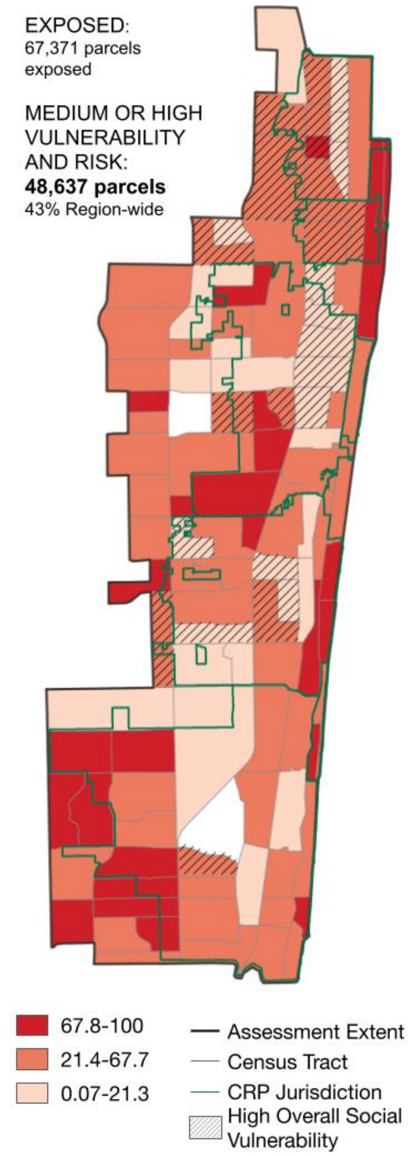


Figure 2-26. Residential Property and Rainfall-Induced Flooding.

Looking at specific residential property types, 16 of the 65 (25%) of the assisted and public housing properties in the region are highly vulnerable and at risk (medium-high vulnerability and risk). Many of these properties are not only locations where residents may experience disproportionate impacts from flooding, but they are also multi-residential units where a greater number of people may be impacted. Figure 2-25 shows for each type of residential property, the total number of properties that are highly vulnerable to rainfall-induced flooding (red), properties exposed but not highly vulnerable (gray), and the number not exposed (light blue). The number exposed and highly vulnerable include properties that are within any potential inundation extent (including 500-year).

Areas with high levels of residential physical vulnerability also co-occur with many of the most socially vulnerable areas of the region, based on the CDC's Social Vulnerability Index (see Figure 2-26). About half of the census tracts in the study area with the relatively highest social vulnerability have at least 21% residential property vulnerability. It is also important to keep in mind these are also properties and not the number of residential units within the properties.

Commercial corridors across the region are vulnerable, with about 31% of all commercial and industrial properties being highly vulnerable and at risk. Figure 2-27 shows the levels of vulnerability to rainfall-induced flooding for commercial and industrial property. Highly vulnerable areas include key corridors in the study area, such as along Congress Ave and Federal Hwy/Dixie Hwy (HWY 1). Another notable observation is that each CRP jurisdiction has at least one census tract with medium or high vulnerability, suggesting that this vulnerability is widespread in the region. These properties include businesses that support economic activity and jobs in the region, with more than a third of the region's business sales volume and jobs associated with these vulnerable properties.

Almost half (49%) of the tax assessed improvement value throughout the study area is associated with 100-year flood risk. This includes the total improvement tax value that is associated with properties in the 100-year flood extent with medium or high vulnerability and risk.

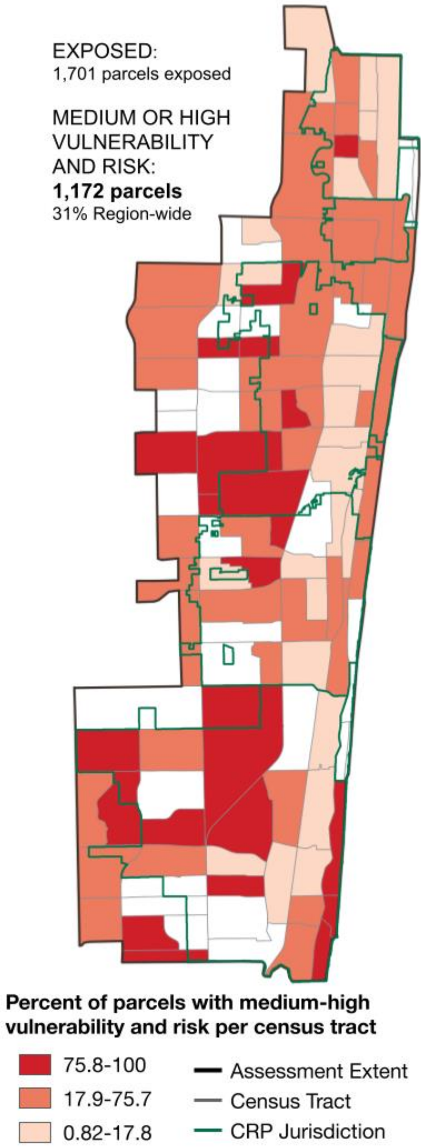


Figure 2-27. Commercial & Industrial Property and Rainfall-Induced Flooding.

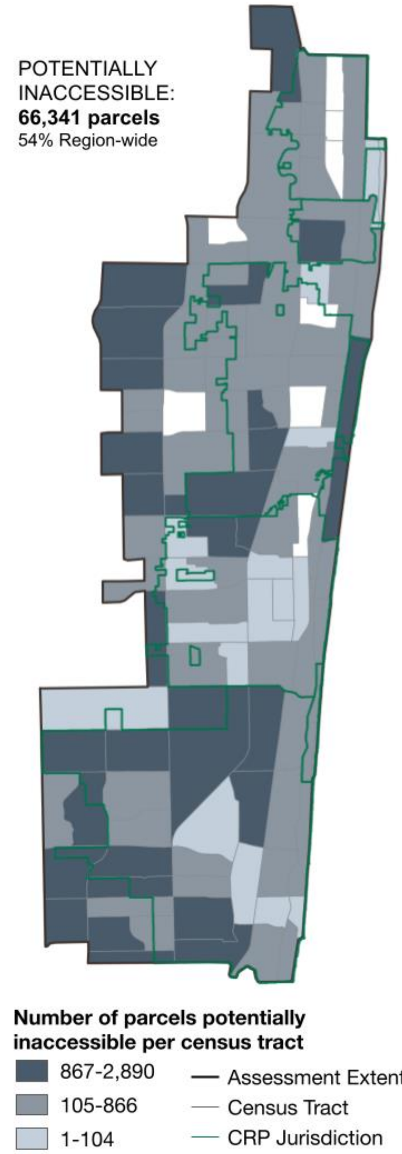


Figure 2-28. Properties Potentially Inaccessible to Rainfall-Induced Flooding (100-year).

Roads & Mobility

About 50% of roads (both major and minor) and properties in the study area have the potential for inaccessibility in the 100-year rainfall-induced flooding scenario.

With over 66,000 properties (about 54%) identified as having the potential for inaccessibility based on the 100-year inundation extent, this is one of the most widespread vulnerabilities for the study area. Figure 2-28 shows the number of properties (of any property type) potentially inaccessible per census tract for the study area. The dark gray areas have the highest number of properties potentially inaccessible. Accessibility is determined as being potentially inaccessible from any fire station location due to a potential flood depth of at least 1 foot. Most potentially inaccessible properties are residential (and include recently constructed developments with limited ingress/egress).

2.8.3 Future Change

Two future conditions for rainfall-induced flooding were assessed, including the 2040 (2020 baseline + 5” of sea level rise (SLR)) and the 2070 (2020 baseline + 33” SLR) levels (more details on the selection of scenario projections can found in section 2.5).

The assessment shows that the greatest percent increases in vulnerability to rainfall-induced flooding, as a result of future sea level rise, are to certain critical facilities (Energy & Communications, Health & Medical, and Food Infrastructure), Residential, and Commercial property, each with more than 10% potential increase in vulnerability between the 2020 baseline and 2070 (2020 + 33” SLR) future condition. Figure 2-29 shows the levels of vulnerability and risk for the baseline condition (100-year only) for rainfall-induced flooding and the two future conditions that were assessed (also 100-year only).

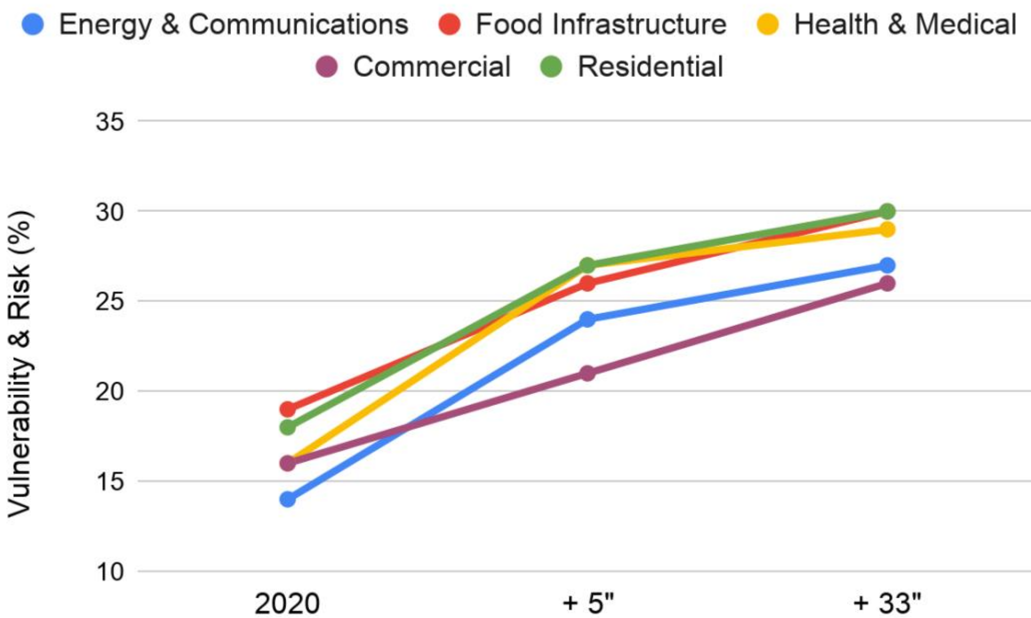


Figure 2-29. Asset categories and vulnerability and risk to Rainfall-Induced Flooding (100-year) for 2020 and future scenario projections.

The following provides a detail for a selection of asset-threat vulnerability and risk assessments for 2020 and the future projection of 2040 with 5” increased sea level rise. Both display results for 100-year only assessment results.

Residential Property

For residential property, the 2020 100-year only assessment shows that about 18% (19,939) have medium to high vulnerability and risk. By 2040, this total is projected to increase by over 10,000 to about 27% by 2040 (2020 baseline +5” SLR) and to about 29% by 2070 (2020 baseline +33” SLR), or to more than 30,000 residential properties in the study area. Figure 2-30 shows a comparison of 100-year only assessment results showing the percent of residential properties highly vulnerable and at risk for the study area.

While many of the most vulnerable areas in terms of greatest proportion of properties are along the coast, these are not generally the areas that are vulnerable to the greatest amount of increase in vulnerability (in terms of percent assets vulnerable and at risk, see Figure 2-30). Most of the census tract areas with the greatest percent increase in vulnerability are inland areas. Overall, for 2020 conditions a total of 36 census tracts in the study area have more than 25% of residential properties highly vulnerable and at risk. With the 2040 +5” projection this number increases to 50 census tracts.

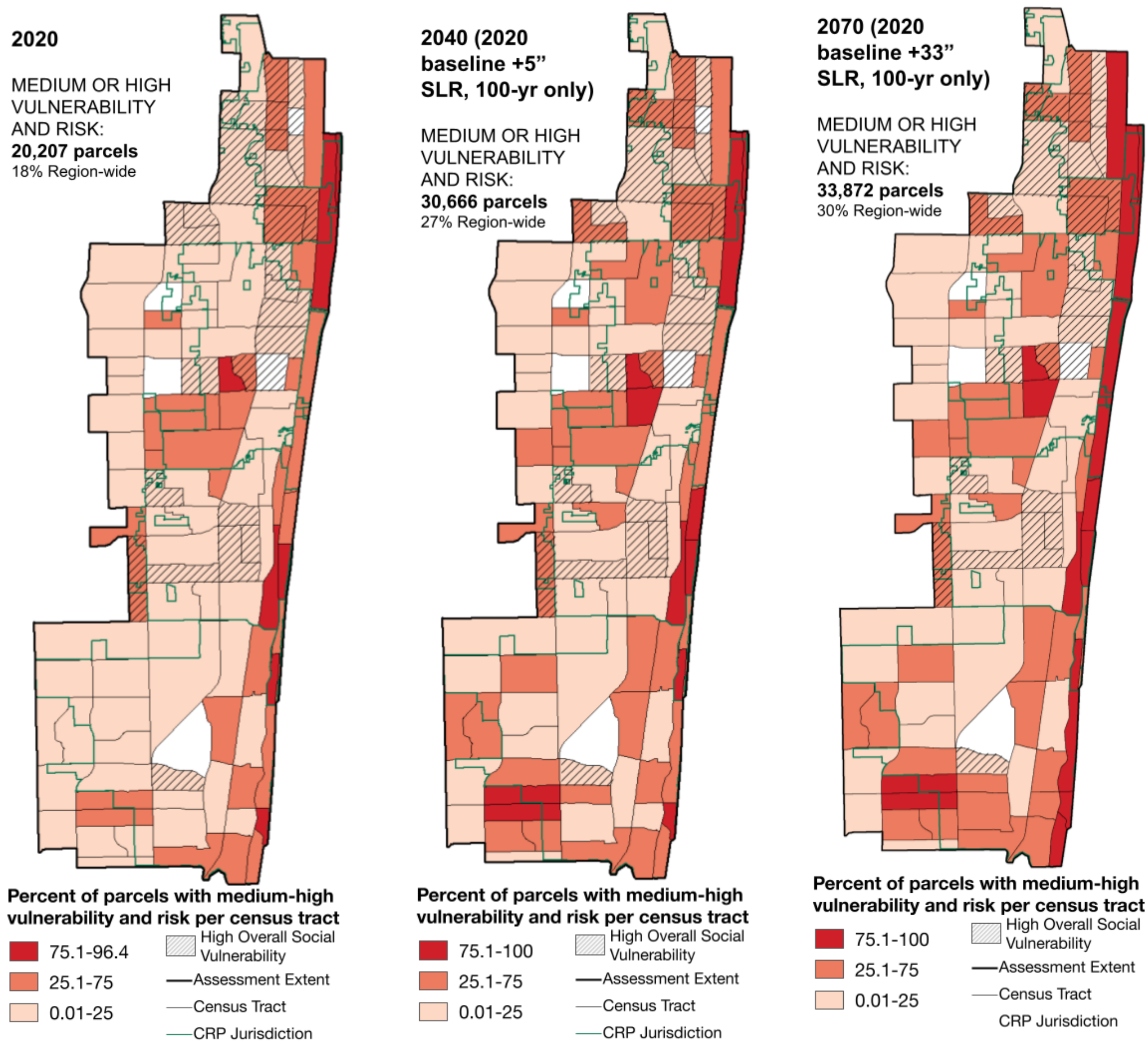


Figure 2-30. Residential Property and vulnerability and risk to Rainfall-Induced Flooding (100-year) for 2020 and scenario projections for 2040 (2020 baseline +5" SLR) and 2070 (2020 baseline +33" SLR).

Commercial Property

For commercial property, the 2020 100-year only assessment shows that about 16% (616) are highly vulnerable. By 2040, this total is projected to increase to about 21% (or to nearly 800 properties in the study area). Figure 2-31 shows a comparison of 100-year only assessment results showing the percent of commercial properties highly vulnerable and at risk for the study area.

Commercial corridors are most vulnerable areas in terms of greatest proportion of properties and most of these same areas are vulnerable to future change (in terms of percent assets vulnerable and at risk, see Figure 2-31). Most of the census tract areas with the greatest percent increase in vulnerability are inland commercial corridors. Overall, for 2020 conditions a total of 32 census tracts in the study area have more than 25% commercial properties highly vulnerable and at risk. This number of census tracts increases to 44 by 2040 (2020 +5" SLR) and 52 by 2070 (2020 + 33" SLR).

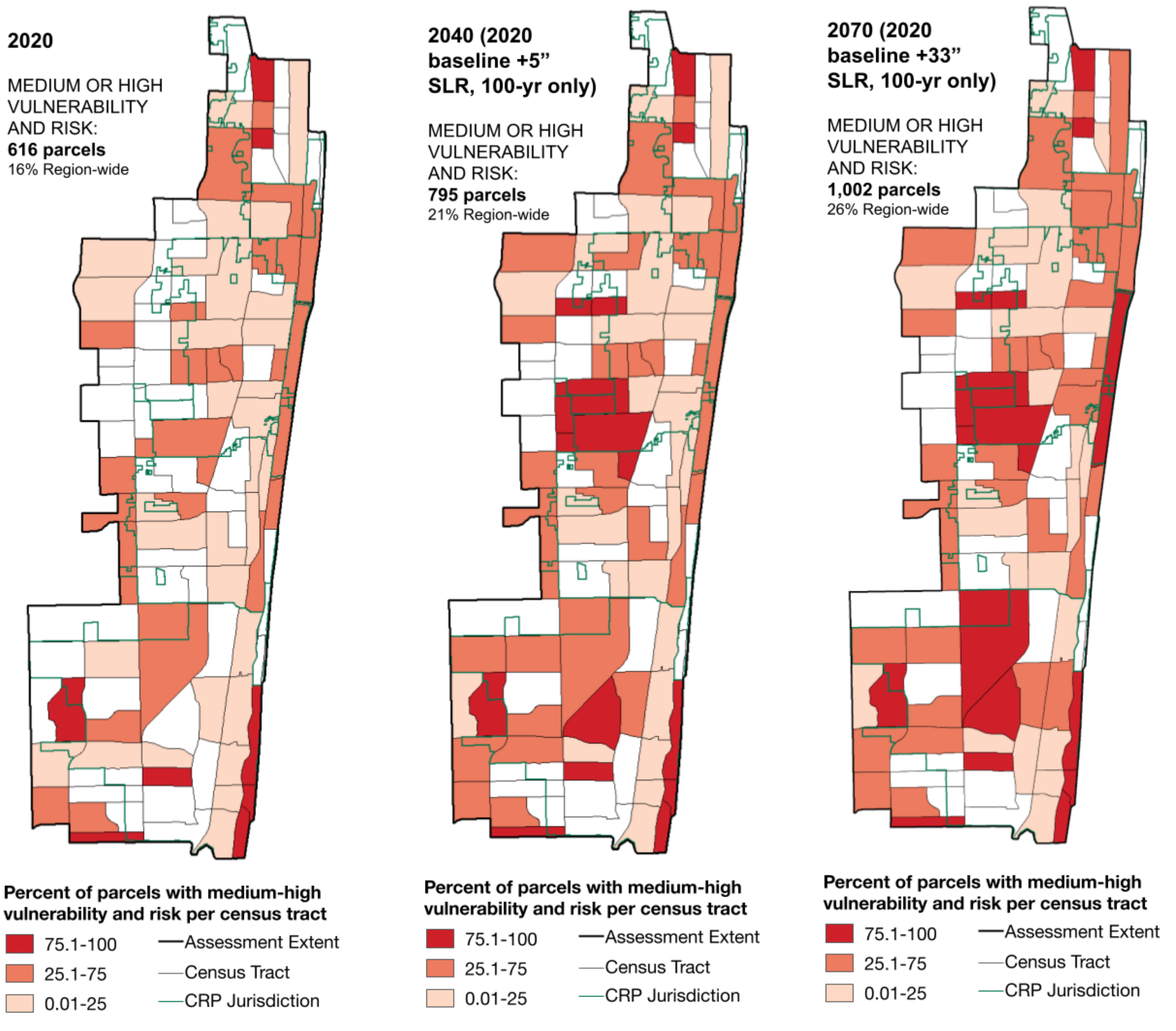


Figure 2-31. Commercial Property and vulnerability and risk to Rainfall-Induced Flooding (100-year) for 2020 and scenario projections for 2040 (2020 baseline +5" SLR) and 2070 (2020 baseline +33" SLR).

2.9 Shoreline Recession

2.9.1 Vulnerability and Risk Assessment Process

Background and Methodology

The assessment of **shoreline recession** was accomplished via spatial analyses. The shoreline recession index described in Table 2-11 was developed as a tool to spatially assess the existing capacity of the shoreline to provide protection to coastal assets. The analysis of the shoreline's current protection capacity was then used to project how the levels of protection will likely change in response to sea level rise, using the three project-defined sea level rise scenarios (see Section 1.5 for more detail on the selection of scenario projections).

The shoreline recession index was developed based on four parameters: beach width, the presence of dunes, the presence of coastal structures (seawalls or revetments), and the critical erosion zone designation from the FDEP. Google Earth Satellite imagery from January 2019 was used to determine the beach width and presence or absence of dunes and coastal structures along the Atlantic coastline of the project area. Measured values and the critical erosion zone designation were compiled and used to develop the shoreline recession index.

Shoreline Data

The following data was utilized in the Shoreline Recession analysis:

- Google Earth Satellite imagery from January 2019
- Coastal Critical Erosion Areas shapefile, Florida Department of Environmental Protection Geospatial Open Data website. Data contained in the shapefile corresponds to the coverages published in the 2017 Critically Eroded Beaches in Florida report (FDEP, 2017a). Florida Department of Environmental Protection, Division of Water Resource Management.
- Slope data collected by the USGS between the location of the Mean High Water and seaward-most dune toe elevations was used to determine the average beach slope within the project area (Overbeck, 2015).
- Coastal Range Monument Locations shapefile, Department of Environmental Protection Geospatial Open Data website (FDEP, 2017b).

General Description of Methodology

To develop the index, the beach length along the project area was divided into segments for analysis based on FDEP Coastal Range Monuments, which are typically 1000 feet apart. In areas with anomalously sited structures, the segments were further subdivided to capture the beach width variability at these locations. Google Earth Satellite imagery from January 2019 was used to determine the beach width and presence or absence of dunes and coastal structures for each segment. The average beach width was visually estimated from the rack line (approximate mean high-water line) to the landward edge of dune vegetation (if present), or constructed boundary (such as a seawall, building, or road). Dunes were identified based on the presence of dune vegetation and confirmed by review of topographic data. Coastal structures were visually identified from the satellite imagery, and segments were designated as having complete coverage, partial coverage, or no structures present.

The range of values for the four parameters was used to generate a combined shoreline recession score, which is the basis of the index. A point system was used to assign values to each of the four index parameters. Beach width was estimated to be between 5 and 290 feet. A beach width score of 1 point was given for every 15 feet of beach width to evenly divide the width and cover the existing range of values in a meaningful way. The presence of a dune adds 2 points to the overall score. Complete coverage of stabilizing structures adds 2 points and partial coverage of stabilizing structures adds 1 point to the combined score. Segments that are designated as critically eroded by the FDEP will add 1 point to the total score. The resulting total range of the combined scores were then evenly divided into the five shoreline recession index score categories, with an index score of 1 having the greatest vulnerability to shoreline recession and 5 having the least (Table 2-11).

Table 2-11. Shoreline Recession Index key.

Index Score Values	Description
1	Severe – The shoreline provides little to no protection to coastal assets. High risk of potential immediate damage from storms, background erosion and future sea level rise.
2	Poor – The shoreline provides little protection to coastal assets. High risk of potential damage from storms, background erosion and future sea level rise.
3	Fair – The shoreline provides a moderate level protection to coastal assets. Moderate risk of potential damage from storms and potential long-term damage from background erosion. Sea level rise poses a longer-term threat.
4	Good – The shoreline provides a high level of protection to coastal assets. Risk of potential damage from storms is relatively low. Background erosion is likely actively managed or not an issue in these areas. Potential sea level rise should be examined to determine if additional protection measures should be implemented in the future to maintain the current level of protection.
5	Excellent – The shoreline provides significant protection to coastal assets. Risk of potential damage from storms is the lowest in these areas. Background erosion is likely actively managed or not an issue in these areas. Potential sea level rise should be examined to determine if additional protection measures should be implemented in the future to maintain the current level of protection.

Slope data collected by the USGS between the location of the Mean High Water and seaward-most dune toe elevations was used to determine that the average beach slope within the project area is 0.96 (Overbeck, 2015). The average beach width was adjusted for the three project-identified sea level rise scenarios (2020 + 5" SLR, 2020 + 13" SLR, and 2020 + 33" SLR) by using the beach slope to determine how far the shoreline is likely to recede under each scenario. The revised beach widths were used to develop new shoreline recession index scores along the shoreline for each scenario.

2.9.2 Key Findings

Under 2020 baseline conditions, the healthiest shorelines with recession index scores in the Good to Excellent range are found in areas having benefitted from long-term beach management programs that include beach nourishment and, where appropriate, inlet management. Areas that currently fall under the Poor to Severe category are associated with a range of issues including anomalously seaward constructed assets and impacts from inlets. These areas tend to not have an active or long-standing beach nourishment program.

Shoreline recession associated with sea level rise further reduces the level of protection provided along the coast. Maps of shorelines in the study area as scored by the Shoreline Recession Index are shown in Figures 2-32 and 2-33. With the 2020 baseline condition map, the maps allow decision makers to visually assess where shoreline vulnerabilities currently exist and how future sea level rise will likely impact their coastline. Additionally, the index descriptions are designed to aid in future decision making by indicating the level of protection each shoreline provides coastal assets as well as the likely impact from coastal storms, background erosion, and sea level rise.

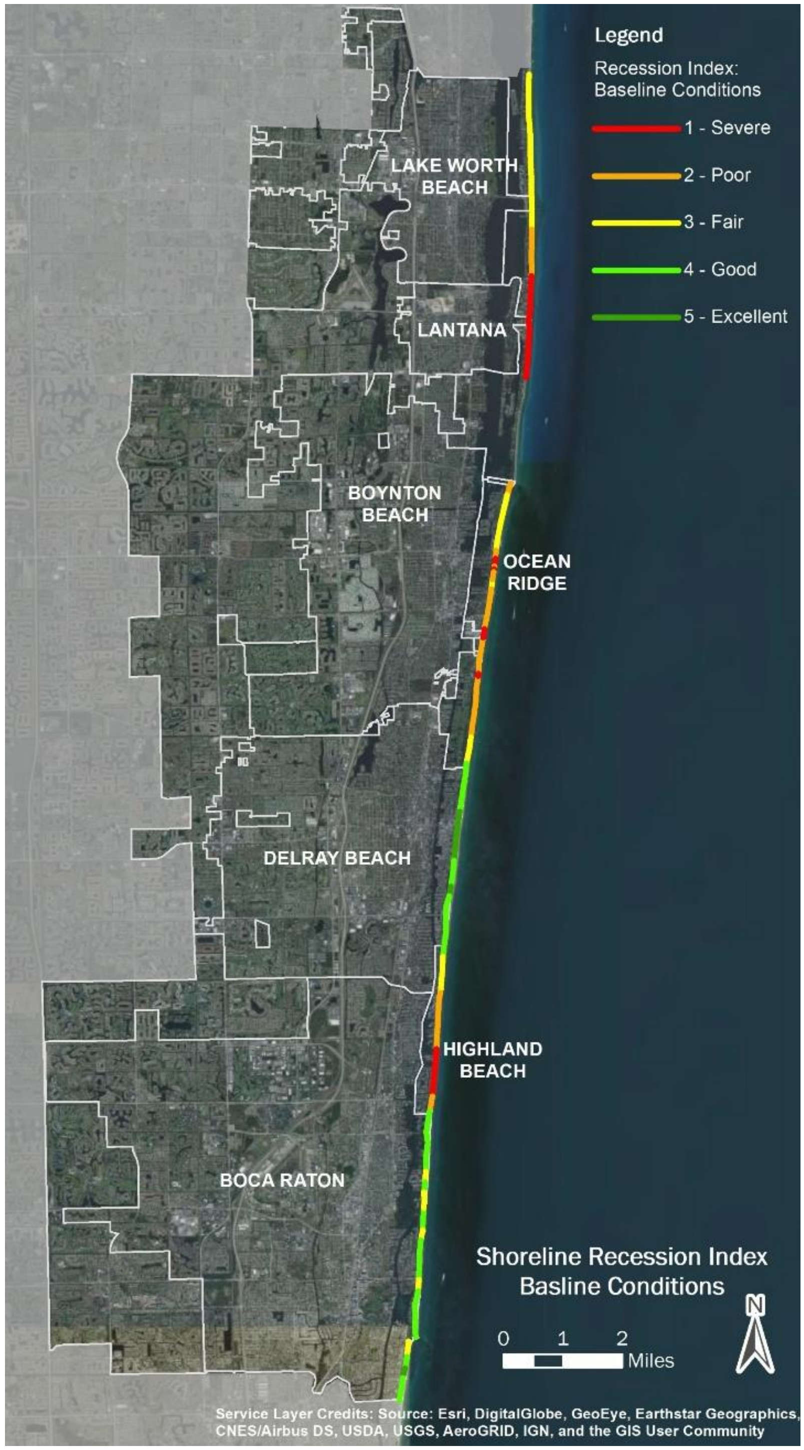


Figure 2-32. Shoreline Recession Index map for the 2020 Baseline Condition.

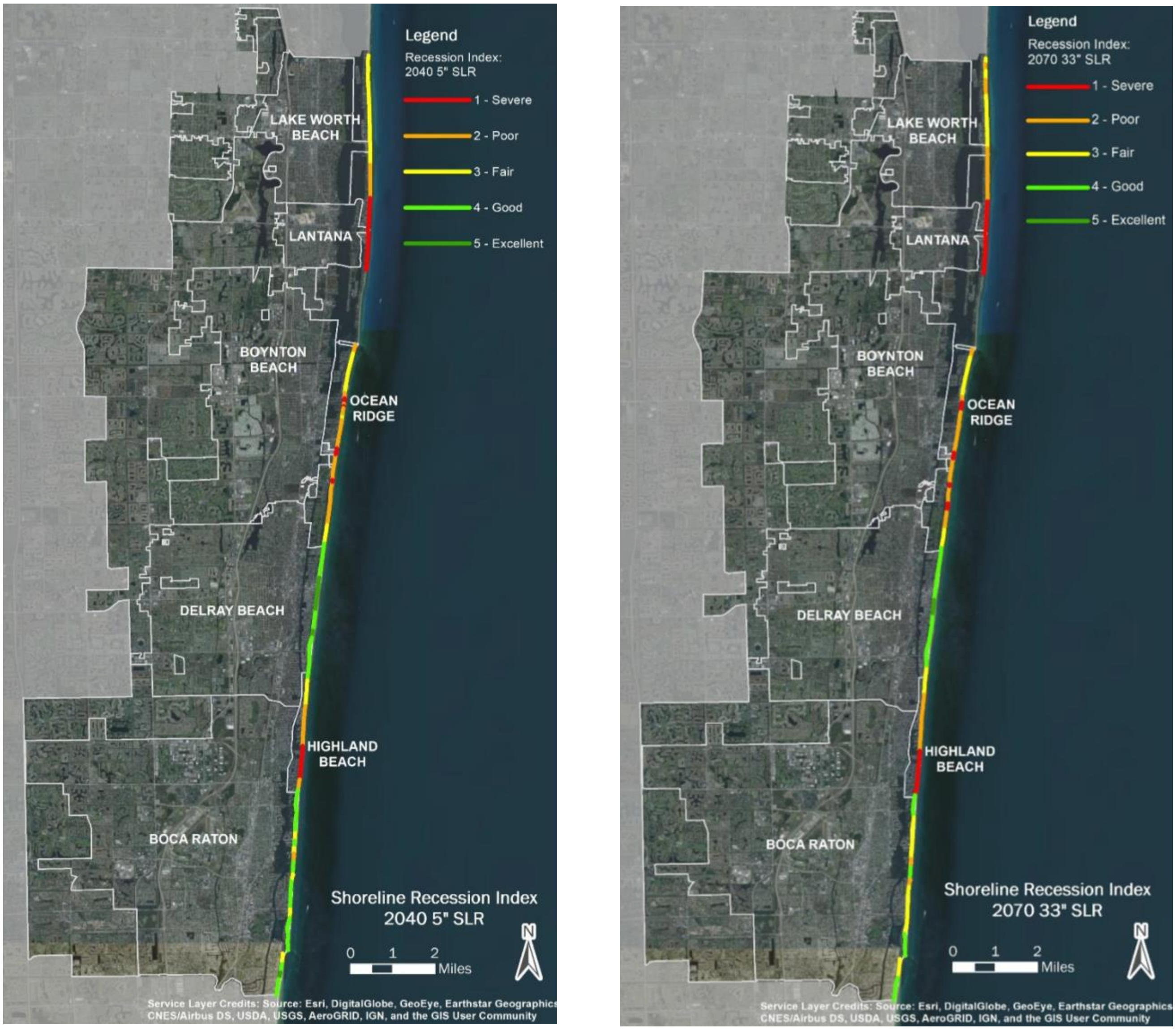


Figure 2-33. Shoreline Recession Index map for 2040 (2020 baseline + 5" SLR) (left) and 2070 (2020 baseline + 33" SLR) (right).

2.10 Storm Surge

2.10.1 Vulnerability and Risk Assessment Process

Background and Methodology

The assessment of future coastal flood risks from increased storm surge elevations was accomplished via spatial analyses. Extents of **stillwater flood elevations (SWELs)** under various Sea Level Rise scenarios were assessed for the project area.

Special Flood Hazard Areas and Sea Level Rise

A Special Flood Hazard Area (SFHA) is an area identified by the United States **Federal Emergency Management Agency (FEMA)** that is vulnerable to flooding during a 100-year storm event. Existing SFHAs were determined using the effective 2017 FEMA Flood Insurance Study (FIS) for Palm Beach County. FEMA designates BFEs for each SFHA by analyzing existing rainfall-induced flooding, storm surge, and wave impacts.

Selected sea level rise projections were evaluated for storm surge, including 2040 (2020 baseline +5" SLR), 2040 (2020 baseline +13" SLR), and 2070 (2020 baseline +33" SLR)

Flood Depths

Flood depths were mapped by modifying the current **digital elevation model (DEM)**, a 3D computer graphics representation of elevation data to represent terrain. The selected sea level rise values were computed into the DEM and subsequently analyzed against the SWEL to determine the new extents of flooding. SFHA zones were overlaid onto the modified SWEL extents in order to determine updated flood depths.

Post-processing consisted of removing isolated areas of flooding to ensure the analyses only accounted for the expansion of existing SWEL extents due to surge flooding in sea level rise scenarios. Waterbodies and canals were removed from the storm surge analysis as to not identify false bathymetry/depths in those areas.

Components of Vulnerability and Risk

Like the assessment of rainfall-induced flooding, the assessment of storm surge also considered how adaptive buildings are based on the year they were built and the BFE requirement in place at the time they were built, and potential flood depth. There were no differential flood recurrence intervals or varying levels of risk probability for this assessment (100-year only). Table 2-12 provides a brief description of each assessment component.

Table 2-12. Summary of assessment components for storm surge.

Assessment Component		Consideration	Level and Description	
Exposure		Asset is in harm's way (within potential inundation extent)	2020 baseline condition and future conditions: 100-year storm surge inundation extent	
Vulnerability	Potential Impact	Sensitivity of asset and whether the asset structure is within inundation extent	High	Highly sensitive asset with structure within inundation extent
			Med	Non-highly sensitive asset with structure within inundation extent
			Low	Structure outside inundation extent
	Adaptive Capacity	Floodplain development BFE requirements and year of building or facility construction	High	Constructed after 2017: first floor elevation required to be at least 1 foot above BFE, or constructed outside inundation extent
			Med	Constructed 1982 to 2017: first floor elevation required to be at BFE
			Low	Constructed before 1982: Pre-FIRM, no floodplain development requirements
Risk	Probability	N/A		
	Consequence	Maximum potential depth of flooding (within 2 meters of structure, if applicable)	High	Structure exposed to potential flood depth of 3 feet or more
			Med	Structure exposed to potential flood depth between 0.5 feet and up to 3 feet
			Low	Structure exposed to potential flood depth of less than 0.5 foot

2.10.2 2020 Baseline Conditions

The new extents of the flood zones under SLR conditions expose the vulnerability of communities and developments adjacent to the Intracoastal Waterway (IWW). Neighborhoods near canal systems that drain into the IWW are also at significant risk of surge flooding despite being up to 2 miles inland from the open coast due to the increased water levels being pushed up the drainage systems. The natural ridgeline along the coast provides some protection from the increased effects on shoreline coastal flood zones, but water is still able to flow in through the major inlets in both the northern and southern portions of the project area and inundate areas east of Federal Highway US-1.

At current 2020 (100-year) storm surge inundation levels, percentages of vulnerability and risk are relatively low for the study area compared to rainfall-induced flooding. However, part of this is due to storm surge risk being concentrated along the coastal and intracoastal areas of the study area. Assets with the highest levels of vulnerability and risk to storm surge include Parks & Cultural, Residential, and Roads & Mobility (including potentially inaccessible major roads, minor roads, and property). Table 2-13 shows the asset categories with the highest vulnerability and risk. The percent assets with medium to high vulnerability and risk to storm surge varies widely between jurisdictions. For example, percentages of vulnerable residential properties within jurisdictions range from 1% to 98%. Like rainfall-induced flooding, some of the smaller jurisdictions also have the highest percentages of vulnerable assets.

Table 2-13. Asset categories with highest vulnerability and risk.

7% Residential	9% Minor Roads
12% Parks & Cultural	8% Public Safety & Gov-Owned

Looking at the components of vulnerability and risk, both adaptive capacity and risk consequence stand out as important drivers of vulnerability and risk to storm surge. Figure 2-34 shows levels of adaptive capacity for residential properties exposed to storm surge. Interestingly, residential properties in storm surge areas have more adaptive capacity compared to properties exposed to rainfall-induced flooding, but still almost 32% of residential properties are identified as having low adaptive capacity.

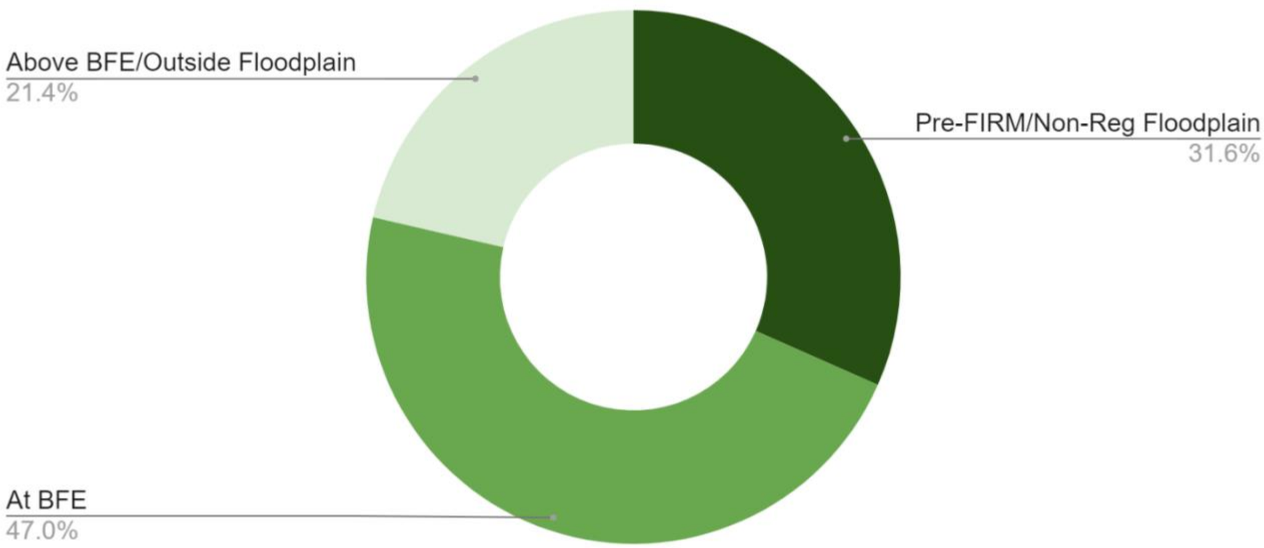


Figure 2-34. Levels of adaptive capacity for the 9,906 Residential Properties exposed to Storm Surge.

Risk consequence associated with potential flood depths is also important to consider for the study area. The assessment highlights that more than half the of the residential properties in 100-year storm surge zones have the potential for more than 3 feet of flood inundation depth (see Figure 2-35).

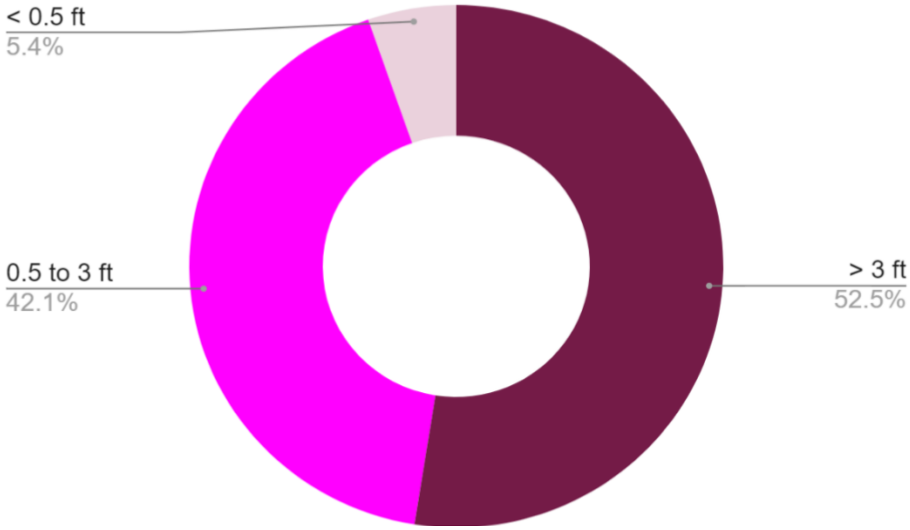


Figure 2-35. Levels of risk consequence for Residential Properties exposed to Storm Surge.

Critical Facilities

About 8% of Public Safety and Government owned properties are vulnerable to storm surge in the region, including four law enforcement properties, four schools, and 16 other government-owned properties. Figure 2-36 shows the map of the study area and the 6 census tracts where more than 54% of the Public Safety & Government-owned properties have medium or high vulnerability and risk.

Property

Parks & Cultural have the highest levels of vulnerability and risk among the property types with 12%. Figure 2-37 shows 7 census tracts in the study area where 100% of the Parks & Cultural properties have medium or high vulnerability and risk.

Over 8,000 (7%) of the residential properties in the CCVA study area have medium to high vulnerability. Areas with the highest residential vulnerability do not generally coincide with areas with the highest social vulnerability.

Two of the census tract areas with the highest shoreline recession vulnerability for 2020 (see Section 2.9) also have among the highest residential vulnerability and risk to storm surge (Figure 2-20 shows the 2020 residential vulnerability and risk map). This includes on the coastal areas on northern end of the study area near Lantana and along Highland Beach. Two additional areas, including most of the Delray Beach coastal area and the southern end of Boca

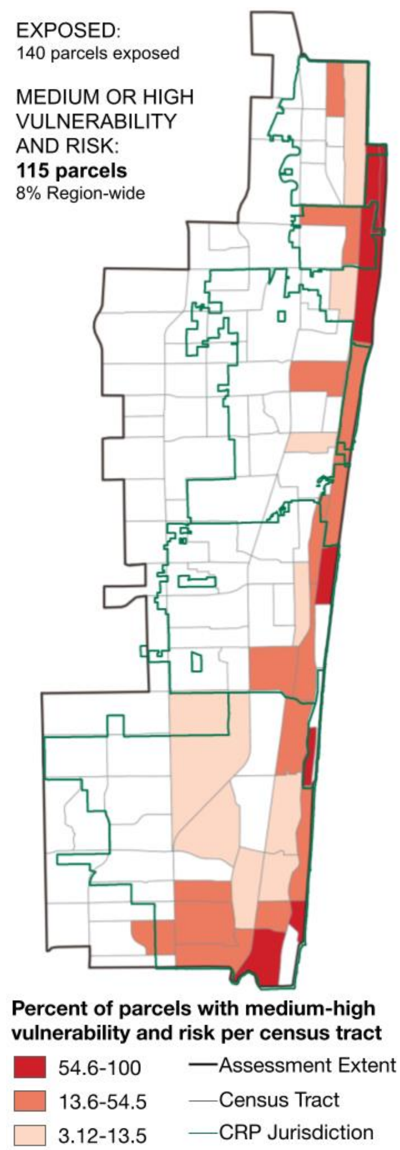


Figure 2-36. Public Safety & Government-owned and Storm Surge 2020.

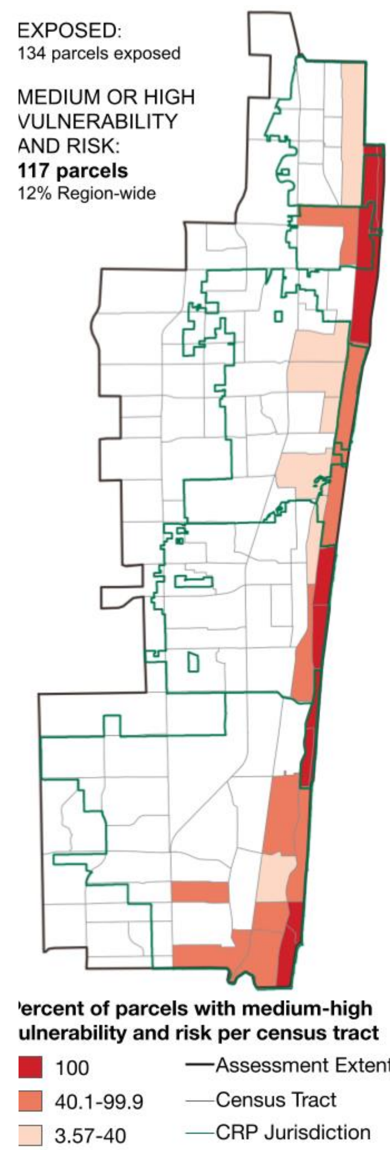


Figure 2-37. Parks & Cultural and Storm Surge 2020.

Raton, also have relatively high residential vulnerability and risk to storm surge but have lower shoreline recession vulnerability, based on 2020 baseline conditions (see Shoreline Recession for more information).

Also, 38% of the study area's tax-assessed improvement value is associated with property vulnerable to storm surge. This percentage compared to the total number of properties is proportionally higher compared to other flooding threats. This could indicate that higher improvement values are associated with the coastal properties that are at risk. This could also be related to the type of properties, such as more condominium or large multi-residence properties.

Roads & Mobility

About 8% major and 9% minor roads are vulnerable to potentially inaccessibility due to storm surge (100-year) in the study area. These include roads that could become inaccessible due to at least 0.5 feet of storm surge inundation. Figure 2-38 shows properties by census tract that are potentially inaccessible to 2020 storm surge.

Over 10,000 (8%) of the properties in the study area are vulnerable to becoming inaccessible. Accessibility is determined by whether or not there is a potential flood depth of 0.5 feet or greater relative to the location of fire stations. Vulnerability related to Roads & Mobility are not necessarily in the areas with the with the highest social vulnerability, however, sensitive populations with limited mobility or access to modes of transportation will be especially vulnerable to storm surge inundation.

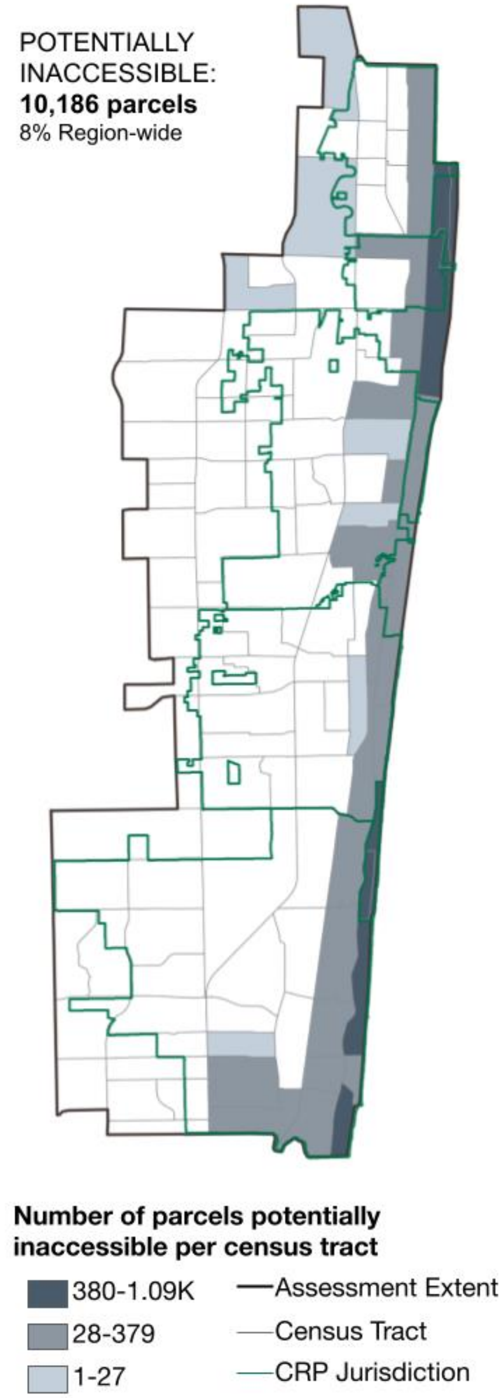


Figure 2-38. All properties potentially inaccessible to Storm Surge 2020.

2.10.3 Future Change

With future sea level rise, the assessment highlights that the percent of assets highly vulnerable and at risk to storm surge is likely to increase. Figure 2-39 shows the potential of increasing vulnerability and risk to storm surge over time for multiple assets.

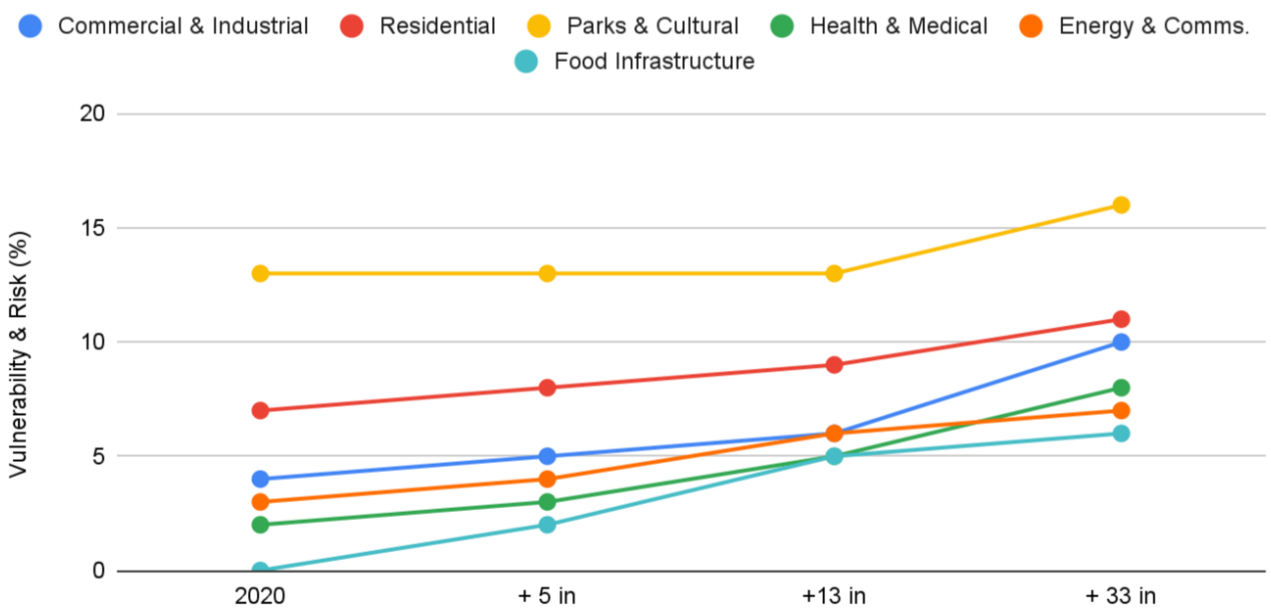


Figure 2-39. Asset categories and vulnerability and risk to Storm Surge 2020 (100-year) for 2020 and future scenario projections.

The number of commercial and industrial properties with medium to high vulnerability and risk to storm surge more than double over the next 50 years from a total of 176 (5%) properties to 373 (10%) properties.

Vulnerability and risk to critical facilities also increases steadily over time, especially for health & medical, energy & communications, and food infrastructure.

Vulnerability related to road inaccessibility increases steadily starting from 8% for major roads and 9% for minor roads in 2020 and increasing over the next 50 years to 15% and 12% respectively. Under 2020 conditions, over 10,000 properties are potentially inaccessible, and this number increases over the next 50 years to over 14,000 properties, which underscores the importance of emergency response and evacuation in the region, especially for vulnerable populations with limited mobility or access to transportation.

Residential property vulnerability and risk increases from about 7% in 2020 to 11% by 2070 (2020 baseline + 33" SLR). Figure 2-40 shows the increase in residential property vulnerability and risk over time with 8 census tracts having at least 75% vulnerability and risk in 2020, 10 by 2040 (2020 baseline + 5" SLR), and 14 by 2070 (2020 baseline + 33" SLR). A few further inland areas also change from having no medium to high vulnerability and risk to having up to 25% vulnerability and risk.

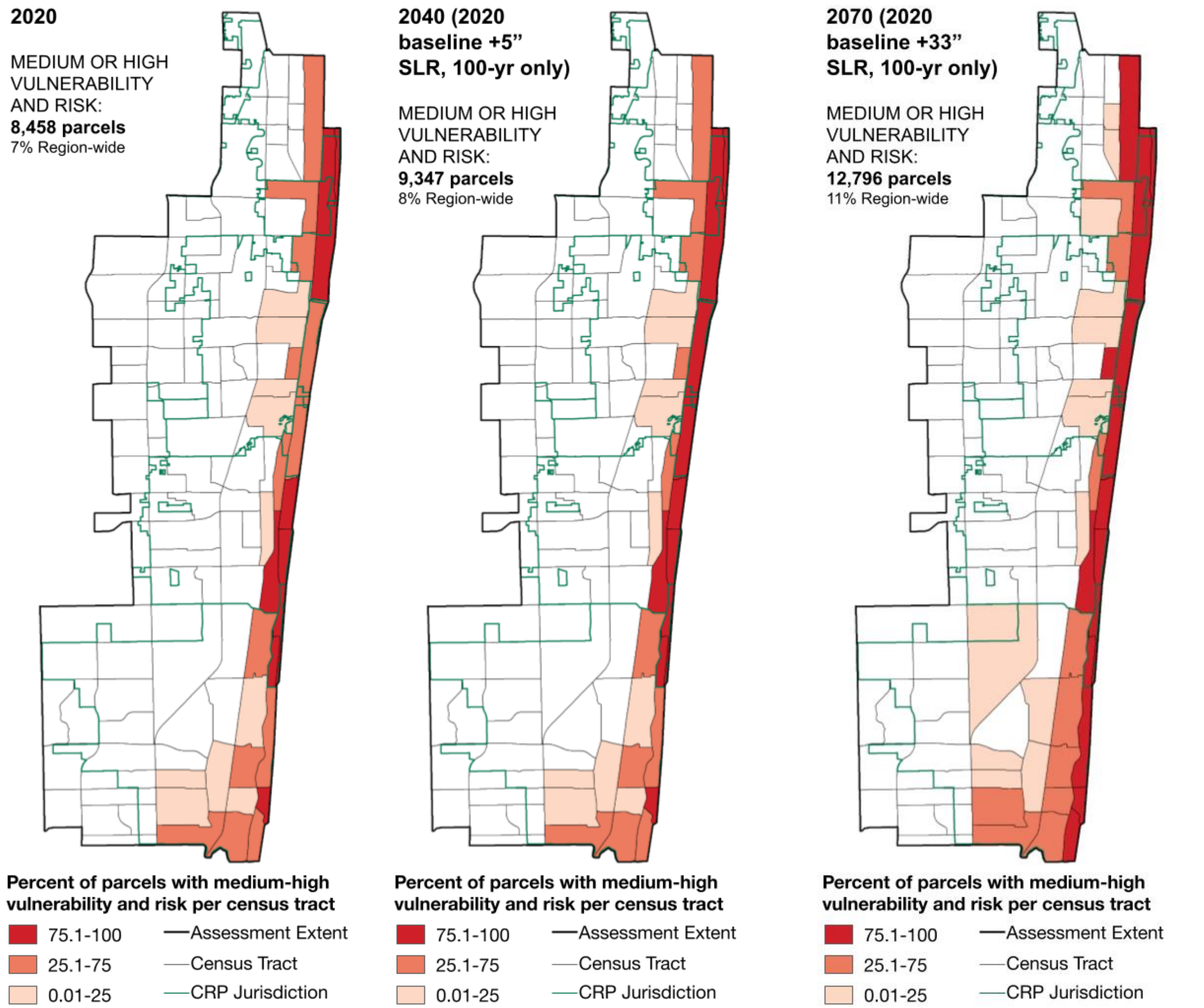


Figure 2-40. Residential Property and vulnerability and risk to Storm Surge (100-year) for 2020 and scenario projections for 2040 (2020 baseline +5" SLR) and 2070 (2020 baseline +33" SLR).

2.11 Tidal Flooding

2.11.1 Vulnerability and Risk Assessment Process

Background and Methodology

The assessment of future **tidal flooding** was accomplished via spatial analyses. Extents of water level increases under various sea level rise scenarios were assessed for the project area. ArcGIS Pro version 2.6 was used to determine areas of vulnerability from increased flooding throughout the project area.

2020 and Projected Tidal Flood Thresholds

There is currently no widely accepted threshold for frequent tidal flooding in Florida. Therefore, the CCVA consultant team adopted a threshold referred to here as the Adaptation Action Elevation (AAE) as a standard to estimate tidal flooding under the sea level rise scenarios discussed in detail as part of Section 1.6 of this report. The AAE is defined as the 2% chance of exceedance in observed higher high-water elevations throughout a 5-year period. This threshold can be considered King Tide events, which are designed around empirical observations instead of considering extreme meteorological events. Table 2-14 shows the tidal flooding thresholds for Lake Worth Pier, FL. The development of Table 2-14 is described in full detail in Section 1.6 of this report.

Table 2-14. Tidal Flooding thresholds based on the selected thresholds and future sea level rise projections.

Note: Table 2-14 is identical to Table 1-7 and is provided in this section for the convenience of the reader.

Tidal Flooding Thresholds (feet, NAVD88), Lake Worth Pier, FL

Tidal Flooding Threshold	Current	Current + 5”	Current + 13”	Current + 33”
98% Higher High Water (AAE)	2.2’	2.6’	3.3’	5.0’
Mean Higher High Water	1.1’	1.5’	2.2’	3.9’
Mean Sea Level	-0.4’	-0.0’	0.7’	2.4’

Projected Sea Level Rise

Selected sea level rise projections were evaluated for storm surge, including 2040 (2020 baseline +5” SLR), 2040 (2020 baseline +13” SLR), and 2070 (2020 baseline +33” SLR).

Lake Worth Drainage Structures

The Lake Worth Drainage District (LWDD) monitors and provides flood control for approximately 500 miles of canals and 1,000 miles of associated rights-of-way and manages the water resources for much of Southeastern Palm Beach County. The LWDD hydrological network consists of 20 major water control structures as well as numerous minor structures.

The CCVA consultant team considered the schematics of the LWDD network and used the locations of structures labeled “Major Drainage Control” as well as canals labeled as “Affected by Tidal Currents” for baseline assumptions in the analysis of SLR effects on King Tide flooding.

Flood Depths

The CCVA project boundary extents (study area) were used to consider tidal flooding. Additionally, The LWDD structures discussed above were considered in defining the limits of tidal effects on waterways. Flood depths were mapped by modifying the current digital elevation model (DEM), a 3D computer graphics representation of elevation data to represent terrain. The DEM was delineated by the King Tide thresholds in Table 2-14 above and areas that fell below the selected values were identified as “flooded”. Furthermore, only the “flooded” areas that were in direct connection to waterbodies or canals were selected for the analysis while all other isolated areas below the threshold were removed. By eliminating the unconnected areas, the analyses only accounted for flooding caused by increased water levels along canals and waterways due to King Tide events.

A coverage layer was made of the final areas identified as “flooded” and given a value of the respective King Tide Flooding level. That coverage layer was subtracted by the DEM to produce flood depth values for the areas affected. Post-processing consisted of waterbodies and canals being removed from the tidal flooding analysis so that the results would not identify false bathymetry/depths in those areas.

Components of Vulnerability and Risk

Like other flooding assessments, the assessment of tidal flooding also considers adaptive capacity of buildings based on the year they were built and the BFE requirement in place at the time they were built, and potential flood depth. Like storm surge, there are no differential flood recurrence intervals or varying levels of risk probability for this assessment. Table 2-15 provides a brief description of each assessment component.

Table 2-15. Summary of assessment components for Tidal Flooding.

Assessment Component		Consideration	Level and Description	
Exposure		Asset is in harm's way (within potential inundation extent)	2020 baseline condition and future conditions	
Vulnerability	Potential Impact	Sensitivity of asset and whether the asset structure is within inundation extent	High	Highly sensitive asset with structure within inundation extent
			Med	Non-highly sensitive asset with structure within inundation extent
			Low	Structure outside inundation extent
	Adaptive Capacity	Floodplain development BFE requirements and year of building or facility construction	High	Constructed after 2017: first floor elevation required to be at least 1 foot above BFE, or constructed outside inundation extent
			Med	Constructed 1982 to 2017: first floor elevation required to be at BFE
			Low	Constructed before 1982: Pre-FIRM, no floodplain development requirements
Risk	Probability	N/A		
	Consequence	Maximum potential depth of flooding (within 2-meters of structure, if applicable)	High	Structure exposed to flood depth greater than 1.1 feet (above MHHW water level)
			Med	Structure exposed to potential flood depth between 0.5 and 1.1 feet
			Low	Structure exposed to potential flood depth of less than 0.5 feet

2.11.2 2020 Baseline Conditions

The coverages of the tidal flooding areas under SLR conditions denoted a risk for areas far removed from the coast to experience slight flooding along existing waterways. This includes neighborhoods near canal systems that drain into the Intracoastal Waterway despite being 2 miles inland from open coast due to the increased water levels being pushed up the drainage systems. Table 2-16 shows the assets with the highest levels of vulnerability and risk to tidal flooding. While the overall levels of vulnerability and risk are not as high for tidal flooding compared to the other flood threats, it is important to keep in mind the impact from the frequency of tidal flooding, especially with future change, and the thresholds that will lead to more persistent flooding over time. It is also important to point out that if rain-induced or storm surge events were to take place during a King Tide event in a SLR scenario then the effects of flooding would be significantly exacerbated.

Table 2-16. Asset categories with highest vulnerability and risk.

<1% Residential	2% Major Roads
1% Inaccessible Property	1% Minor Roads

Like properties exposed to storm surge, properties exposed to tidal flooding are also constructed more recently compared to those exposed to rainfall-induced flooding. Different from rainfall-induced and storm surge flooding, the tidal flooding assessment shows that only about

6% of residential properties exposed to tidal flooding have low adaptive capacity to current tidal flooding levels and 84% have high adaptive capacity (light green in Figure 2-41). However, most of those with high adaptive capacity include properties that are exposed to tidal flooding but where buildings are not within the 2020 tidal flooding extent. This aspect of structures being in close proximity to areas of tidal flooding (but not within them) has implications for future change that are discussed later. This is also evidenced by the high property exposure to tidal flooding. For example, while about 340 (<1%) residential properties have medium or high vulnerability and risk to tidal flooding in the study area, about 2,600 (2%) are exposed.

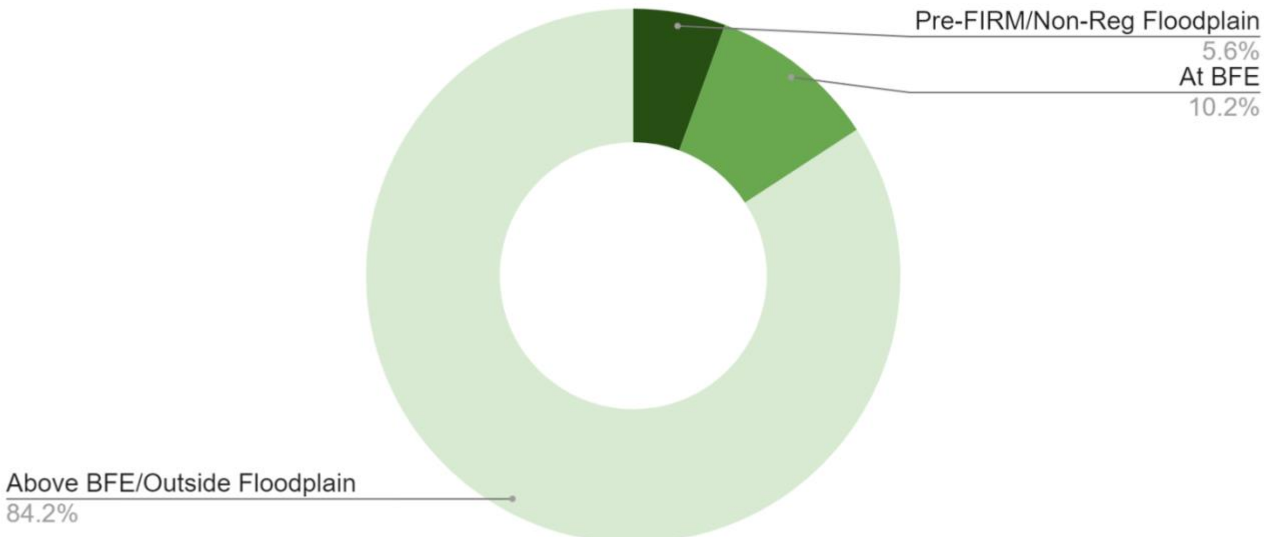


Figure 2-41. Levels of adaptive capacity for the 2,624 Residential Properties exposed to Tidal Flooding based on structure elevation relative to the Base Flood Elevation.

Two of the primary asset categories vulnerable to tidal flooding are residential properties and roads (both major and minor) with potential loss of access to these roads and the properties associated with them.

Property

Residential properties are vulnerable along sections of the Intracoastal Waterway throughout the study area. Interestingly, residential exposure is nearly ten times higher than vulnerability and risk. While less than 1% of residential properties in the study areas have medium or high vulnerability and risk, about 2% properties are exposed to tidal flooding. Vulnerability and risk to 2020 tidal flooding also ranges between 0% and 8% across the CRP jurisdictions.

Roads & Mobility

Throughout the study area, about 2% of major roads and 1% of minor roads are potentially inaccessible to 2020 tidal flooding conditions (based on the number of lane miles potentially affected). Associated with these roads are just over 1,500 (1%) properties that are vulnerable to potential inaccessibility. However, vulnerability to road inaccessibility ranges from 0% to 4% across the CRP jurisdictions. Road accessibility is determined by examining if a route from any fire station location to the roads adjacent to a property exists. Roads are considered impassable due to tidal flooding if they have 0.5 feet or more of flood depth.

2.11.3 Future Change

A key insight from this threat assessment is the increasing vulnerability of multiple asset categories over time. Even where tidal flooding may not be a current issue vulnerability will increase over time for nearly every asset type and for most jurisdictions in the study area. Figure 2-42 shows the potential for increasing vulnerability and risk for multiple assets over time.

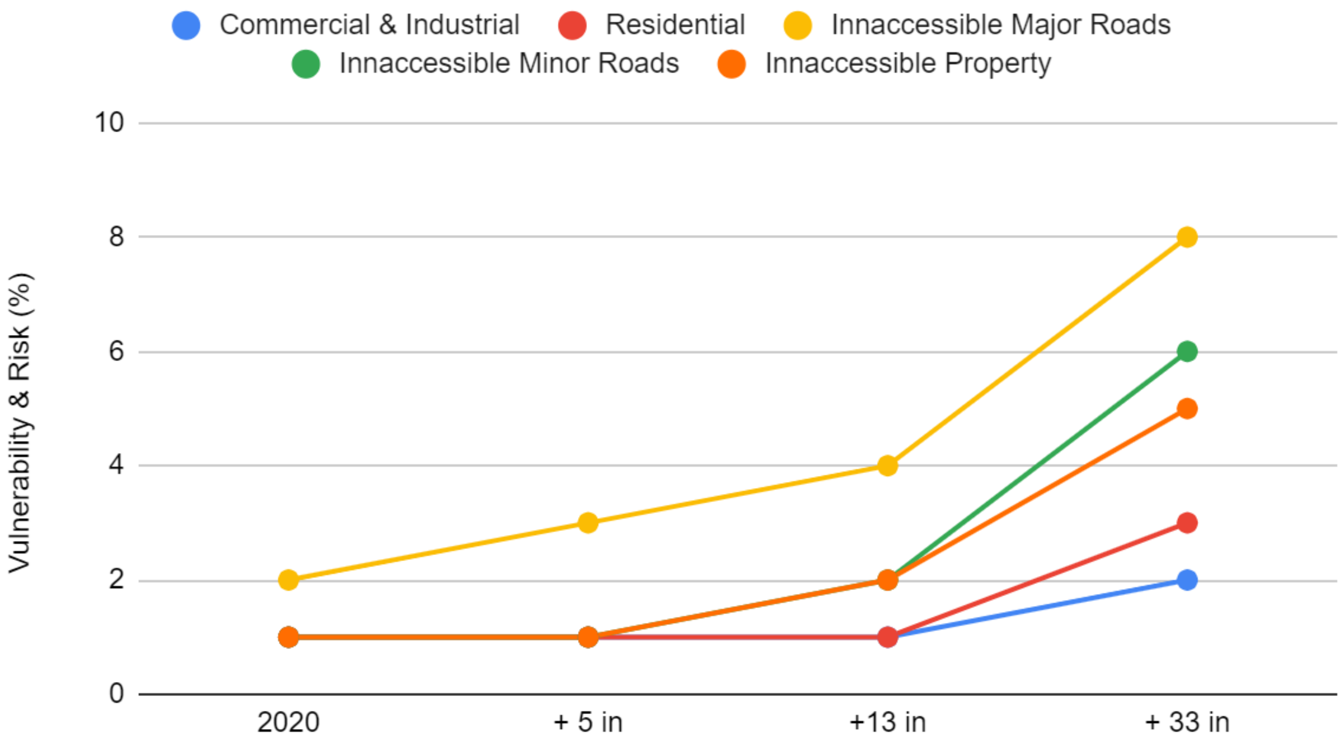


Figure 2-42. Asset categories and vulnerability and risk to Tidal Flooding 2020 for 2020 and future scenario projections.

Vulnerability and risk to residential properties increases more than ten times between 2020 and 2070 (2020 baseline + 33" SLR). As Figure 2-43 shows, vulnerability and risk to residential property increases by more than 15% in most of the census tracts along the coastal and tidal areas between 2020 and 2070. While this still may not be a high overall percentage of properties in the study area, it does represent high proportion of properties within the coastal areas and within some coastal neighborhoods and communities.

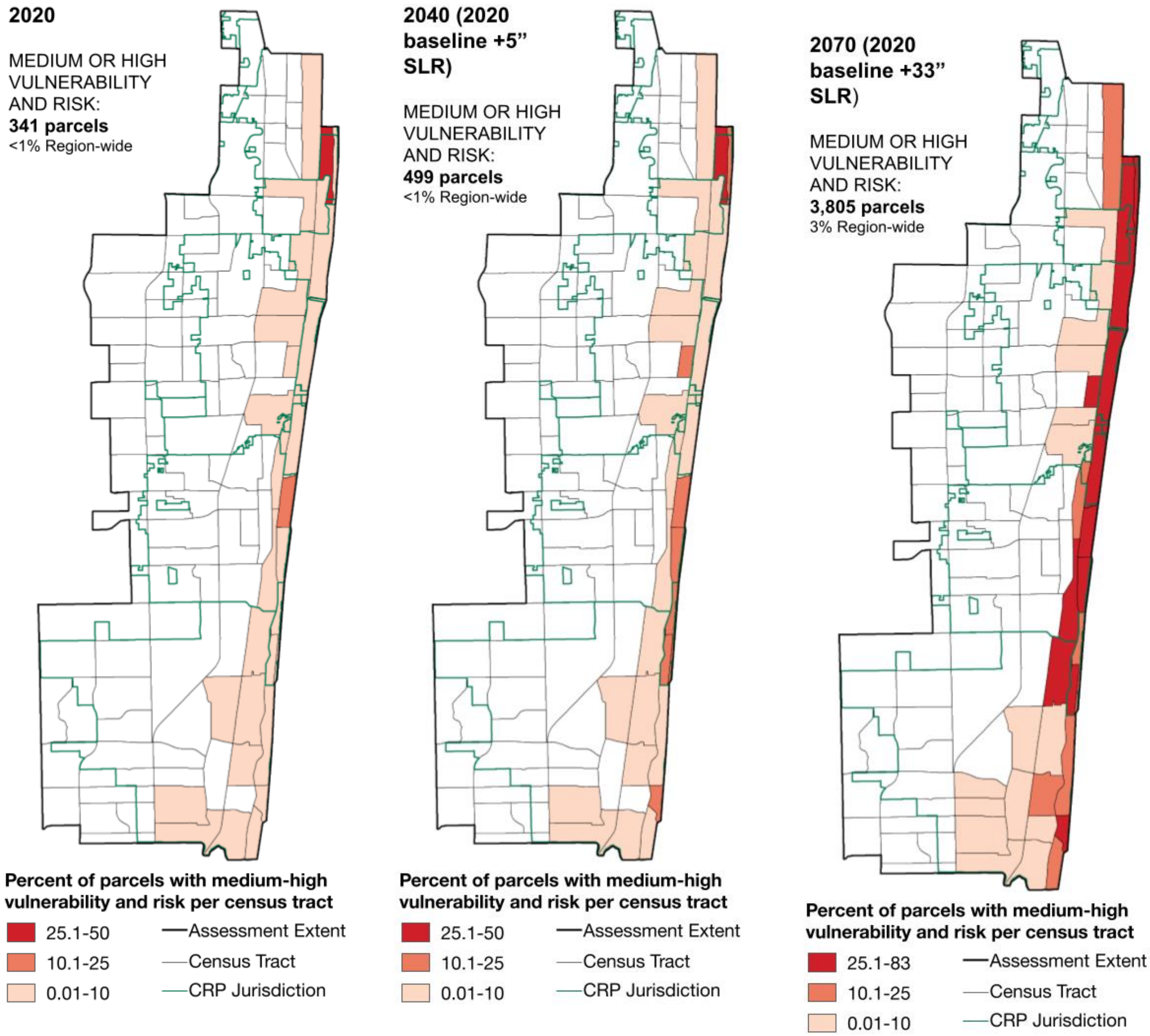


Figure 2-43. Residential Property and vulnerability and risk to Tidal Flooding for 2020 and scenario projections for 2040 (2020 baseline +5" SLR) and 2070 (2020 baseline +33" SLR).

Road connectivity related vulnerabilities (for both major and minor roads) have the greatest potential increase with future change and tidal flooding. For example, major roads potentially inaccessible increase from about 2% in 2020 to about 8% over the next 50 years. Figure 2-44 shows the number of all properties that are potentially inaccessible to major or minor roads. Overall, about five times more properties are expected to be vulnerable to potential inaccessibility due to tidal flooding by 2070 (2020 baseline + 33" SLR).

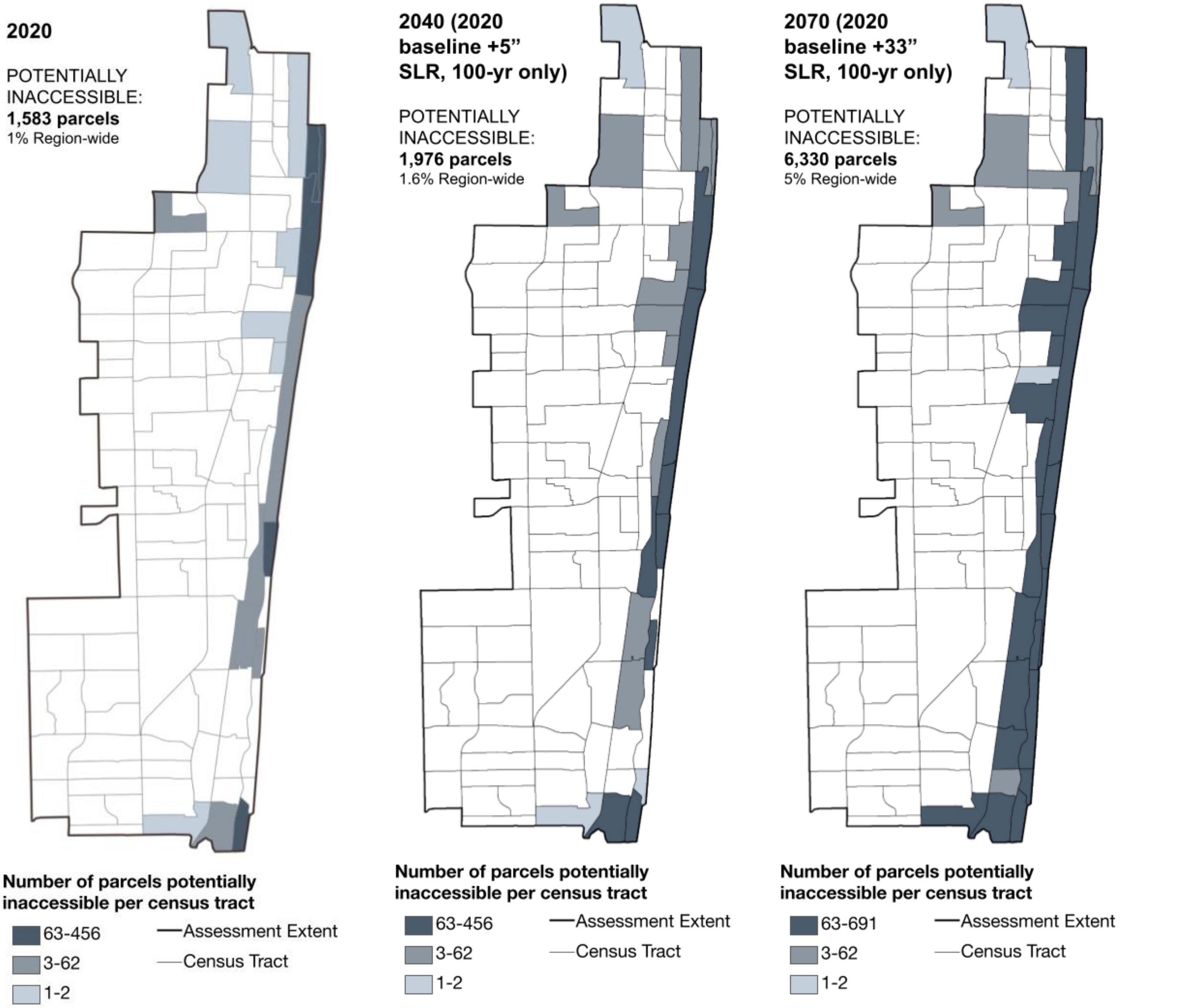


Figure 2-44. All properties potentially inaccessible due to tidal flooding for 2020 and scenario projections for 2040 (2020 baseline +5" SLR) and 2070 (2020 baseline +33" SLR).

2.12 Wildfire

2.12.1 Vulnerability and Risk Assessment Process

Background and Methodology

The assessment of wildfire was accomplished by narrative analysis. This assessment examined the threat of wildfire in the Wildland Urban Interface (WUI). The WUI includes areas where homes and assets are within or adjacent to vegetation and fuels for wildfire. The assessment of vulnerability and risk to wildfire may help prioritize areas for active fuel management, especially in areas where fire response may be more challenging. The risk of wildfire is also greatest in years of drought (Radeloff et al. 2005, Stewart et al. 2007).

Wildfire is a natural disturbance that provides benefits to ecosystems and natural systems but can become a threat when it negatively impacts communities and the assets we value.

Climate stressors for wildfire include temperature variability and drought. Lightning is also known as a source of wildfire ignitions in more remote areas such as the Loxahatchee National Wildlife Refuge (USFWS). Non-climate stressors include growth, hydrologic alterations, and homes in the WUI (Radeloff et al. 2005, Stewart et al. 2007).

Data from the University of Wisconsin-Madison's Spatial Analysis for Conservation and Sustainability SILVIS Lab (2020) was used to understand risk of wildfire in the WUI. This included the WUI mapping products (for intermix and interface). These maps illustrate where the WUI is located and provide an understanding of the areas where homes and developments intermingle with or are in close proximity wildland vegetation and fuels for wildfire (Radeloff et al. 2018). These maps provide spatially delineated areas at the local level that identify WUI areas, or areas exposed to WUI wildfire for the purposes of this assessment.

The peak wildfire season in Florida is typically January through mid-June, burning over 100,000 acres of land annually. Within Palm Beach County over the past 20 years there have been 10 wildfires over 10,000 acres in size. Lightning is one of the main causes of large wildfires on managed lands (Florida Dept. of Agriculture 2010). While wildfire can impact homes located in the WUI, the smoke generated from wildfires can impact air quality, which in turn impacts human health.

2.12.2 Key Findings

Wildfire has an important role on the natural landscape in Southeast Florida and Palm Beach County and South Florida as a region has among the most acres burned in the Southeast. However, the direct wildfire risk to people and assets in the CCVA study area is relatively low due to limited WUI areas (compared to some neighboring communities, as illustrated in Figure 2-45).

Wildfire response capacity is also something that seems to be adequate throughout the study area, with all of the study area being within a 5-min drive time from the nearest fire station. However, ingress/egress could be an issue for housing developments in any wildfire event. Even if response time to communities is sufficient, wildfire apparatus availability and wildfire response training still may be a concern.

Since the study area includes relative low levels of WUI, wildfire is a minimal threat. Palm Beach County also manages all lands owned by the County that may be subject to wildfire. **However, wildfire smoke should be considered, especially for sensitive populations.** Of general concern is PM2.5, which is the main pollutant generated in wildfire smoke, and which can travel across the region. Over the past 20 years, the Air Quality Index (AQI, based on U.S. EPA standards) has been "orange," or unhealthy for sensitive groups or general population, on 9 days (EPA 2020b). Socially vulnerable populations and those sensitive to poor air quality are the most potentially impacted. Figure 2-46 shows the number of U.S. EPA AQI unhealthy air days in Palm Beach County (bars) with the number of wildfires (red line) and acres burned (black line) in the South Florida region from 2000 through 2017.

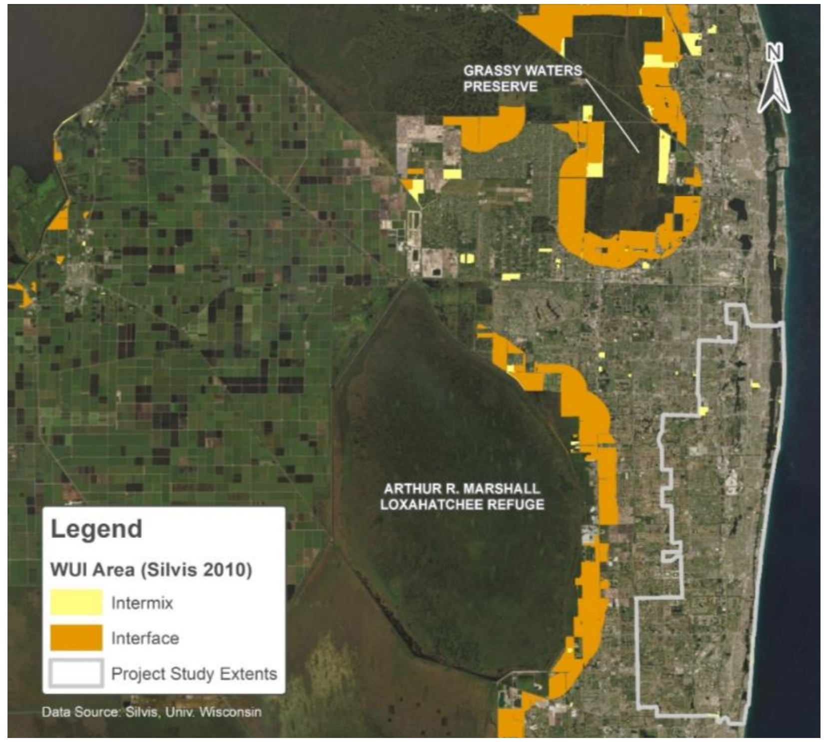


Figure 2-45. Wildlife Urban Interface (WUI) areas.

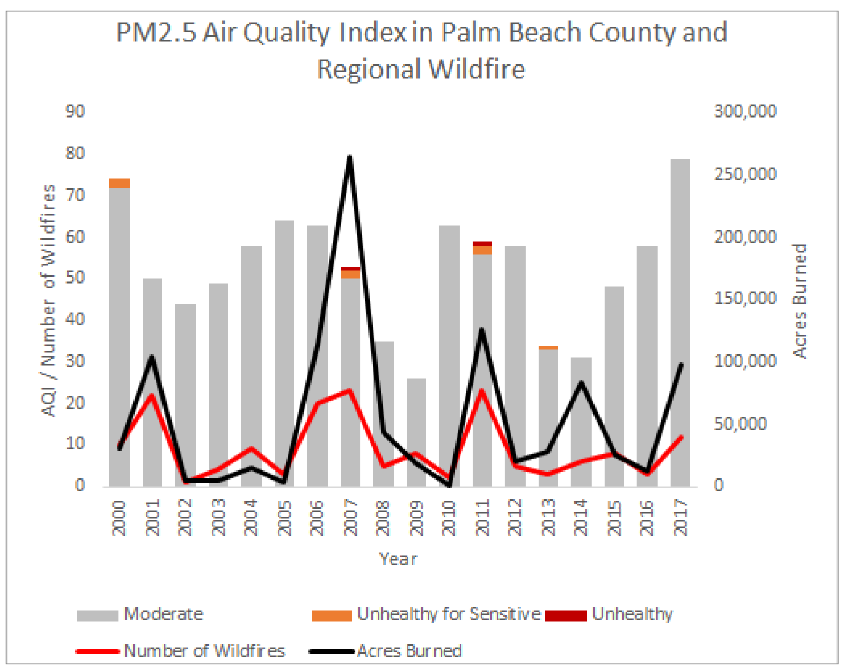


Figure 2-46. Air Quality Index in Palm Beach County and wildfire in Palm Beach County.

3. Adaptation Strategies and Priorities for Resilience

3.1 Transforming Analyses into Strategy

This section folds together the results of the four previous steps of the project to explore types of **adaptation** strategies and then recommends portfolios of adaptation strategies. Strategies will be explored by six (6) major types and then organized into portfolios for the region. Adaptation strategies for each jurisdiction are summarized in the Appendices to this report. The final section of this report summarizes recommended future steps for using the results of this study and implementing the adaptation strategies highlighted in this plan.

3.2 Overview of Adaptation Strategies

3.2.1 Types of Adaptation Strategies

To employ a complete toolbox for adaptation, strategies are broken into 6 distinct types for the purposes of this study:

- Infrastructure
- Land Use, Zoning, Building Codes, and Standards
- Planning, Policy, and Management (non-land use related)
- **Capacity Building**
- Public Outreach
- Funding and Finance

To effectively address climate change, it will be important for the region and local governments to develop and implement a diverse portfolio across all 6 strategy types. It is also important to note that while **adaptation** strategies are emphasized, some **mitigation** strategies are also included in this report. The participating **CRP** jurisdictions vary somewhat in terms of needs and preferences, so mitigation strategies were not excluded from the menu of strategies explored throughout Step 4 of the project.

Beyond the scientific impacts of climate change, the CRP also prioritized examining who will be impacted and how they might be impacted. Frontline communities will feel the effects of climate change first and hardest, meaning not all people will feel the effects equally. Hence their needs were prioritized throughout the planning process and particularly during the creation of the adaptation strategies featured in this report.

Several communities throughout the southeastern United States have used similar resilience planning frameworks and/or have assessed similar **threats** in their communities. Strategies published by these other communities were examined for their relevance to the CRP jurisdictions and were used to inform some of the strategies that were developed for this region. The use of this relevant information from other jurisdictions emphasizes the value of information sharing between communities as part of resilience planning. Appreciable time was saved by examining adaptation strategies developed by other communities. The communities that informed some of the strategies included in this report are:

- City of Asheville, NC: Planning for Climate Resilience, 2018
- City of Charleston, SC: All Hazards Vulnerability and Risk Assessment, 2020

- City of Tallahassee: Community Resilience Plan, 2019
- City of West Palm Beach: Climate Resilience and Vulnerability Assessment, 2021
- Triangle Regional Resilience Partnership: Regional Resilience Assessment, 2018

Over 50% of the strategies featured in this section were developed specifically for Southeastern Palm Beach County and/or each jurisdiction. The methodology for the development of all the CRP strategies is provided in Section 3.2.3.

3.1.1.1 Infrastructure

The first type of adaptation strategy that the CRP explored is infrastructure.

Summary of Adaptation Strategy Type #1: Infrastructure

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Adaptation strategies that involve the construction or retrofit of a physical project.	• Living Shorelines • Seawall Improvements • Stormwater Treatment and Storage • **Infrastructure Hardening** and **Undergrounding** • Safe and Sustainable Paths for Pedestrians and Bicycles • Trees and Urban Canopy • Facilities for Electric Vehicles • Wetlands	• **Grey Infrastructure** • **Green Infrastructure** • **Sustainable Infrastructure**	• Engineering • Public Works • **Utilities** • Development Services

Adaptation strategies in the infrastructure category are those that usually involve construction or retrofit of a physical project. Infrastructure is the first type of strategy that the CRP explored. Step 4 of the CCVA focused on improvements to these assets and new classes of assets that can be used to both mitigate and adapt to a changing climate. One prominent goal of climate adaptation strategies is to "reduce the **vulnerability** or increase the resiliency of built infrastructure to a changing climate" (Stewart et al., 2014).

For the purposes of climate adaptation, **sustainable infrastructure** should be rolled into all categories of infrastructure whenever possible – versus being isolated within specific classes of infrastructure or as a category of infrastructure itself. **Green infrastructure** refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate, or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of **low impact development (LID)** (EPA 2020a). Green infrastructure also includes leaving natural systems intact since healthy ecosystems provide significant benefits in addressing climate change, in addition to many other community benefits. In other words, in the realm of successful future infrastructure, it is also important to strategically keep healthy ecosystems intact and restore ecosystems that were previously impacted. Table 3-1 (below) breaks infrastructure into major categories and then describes the climate threats that could be potentially addressed through different types of adaptation.

Table 3-1. Major Categories of Infrastructure that Can be Adapted to Build Resilience

Major Category of Infrastructure	Sample Adaptation Strategies	Relevant Climate Threats Identified in the CCVA
Major and Minor Roads	Raising Roads with Harmonization, Alternative Pavements, Complete Streets, Green Streets, Alternative Pavements	Algal Blooms, Extreme Heat, Groundwater Inundation, Rainfall-Induced Flooding, Storm Surge, Tidal Flooding
Transportation Facilities	Green Infrastructure, Low Impact Development (LID), Sustainable Infrastructure	Algal Blooms, Extreme Heat, Rainfall-Induced Flooding
Public Safety and Schools	Green Infrastructure, LID, Trees, Parks, Greenspaces, Sustainable Infrastructure	Algal Blooms, Extreme Heat, Rainfall-Induced Flooding
Energy and Communications	Hardening and Undergrounding	High Winds, Storm Surge, Tidal Flooding
Stormwater	LID, Pump Stations, Trees, Treatment Wetlands	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge, Extreme Heat
Wastewater	Wastewater Treatment Plant Improvements, Septic to Sewer, Lift Station Retrofits (to build resilience)	Groundwater Inundation, All Flood Threats
Potable Water Supply	Desalination Plants, Surface Water Reservoirs, Alternative Water Supply	Drought, Saltwater Intrusion
Coastal Protection	Living Shorelines, Seawalls, Dune Restoration, Sand Restoration, Inlet Sand Transfer, Mangroves	Shoreline Recession, Storm Surge, Tidal Flooding

It is critical to note the importance of engineering standards and how current paradigms of design do not normally address climate change. Because many engineering design standards are based on historical conditions, it will be important for the members of the CRP to address policy that affects the design, construction, maintenance, operations, and entire life cycle of infrastructure. Infrastructure is also closely tied to the other 5 types of adaptation strategies that are discussed throughout the remainder of this report.

It is also of critical importance that the CRP advocate for permitting credit (as appropriate) for the use of sustainable infrastructure and the inclusion of considerations for climate change as part of the design process with regulators at the State and Federal Level. The CRP (and local governments in general) will need regulatory and funding assistance from the Federal and State levels to develop and implement new engineering standards, as the resources to develop these standards do not currently exist at the local level.

A few key themes emerged from the CCVA for future infrastructure in Palm Beach County:

- While some similarities do exist, the CRP jurisdictions have different infrastructure challenges and preferences. Throughout all jurisdictions, maintaining the character and quality of life of the community was the most important goal but the path to reach that goal will likely be different for each jurisdiction.
- Generally, there is a preference to continue implementing more sustainable infrastructure in Palm Beach County. Both the CRP participants and public noted that they believe living shorelines, stormwater low-impact development initiatives, and urban tree canopy are good examples of future elements of green infrastructure throughout the study area, among many other forms of sustainable infrastructure.
- Swales and right-of-way concerns are a significant issue in many of the CRP jurisdictions. The issues related to swales are complex and generally involve misperceptions about maintenance and ownership. Some, but not all, of the CRP jurisdictions noted that they would continue to encourage swales as a form of stormwater treatment and storage due to these issues.
- CRP jurisdictions differed in their beliefs about stormwater pump stations. Some of the communities are using pump stations currently to alleviate various forms of flooding while other jurisdictions noted that they would use pump stations in the future once other strategies were less effective.
- Where septic systems still exist in the study area, jurisdictions generally noted that they were all in favor of converting these areas to sanitary sewer.

3.2.1.2 Land Use, Zoning, Building Code, and Standards

The second type of adaptation strategy that the CRP explored are land use, building code, and standards.

Summary of Adaptation Strategy Type #2: Land Use, Zoning, Building Code, and Standards

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Strategies that modify or implement new land use practice, land use planning, land use policies, and building codes.	• Modifying or implementing new land use management practices on city-managed land • Integrating climate into land use plans, planning processes, and zoning (e.g., Comprehensive Plan) • Improving building codes, standards, and engineering considerations for building physical infrastructure	• Land Use Practice • Land Use Policy & Zoning • Building Codes & Standards	• Planning and Development • Economic Development • Building Division

As our climate changes, so too will the **vulnerabilities** and **risks** to specific parcels. It is essential to consider multi-hazards associated with climate change as part of current and future land use policy across all types of land use. As the community needs grow, the implicit consideration of climate change will reduce risk and mitigate hazards. Through climate-smart planning, communities can reduce the impact of the many threats associated with climate change.

One such way to consider future conditions is through zoning ordinances and building codes. Zoning ordinances describe how land can be used and what limitations may be put on a property to consider public health and safety. Building codes and standards regulate how a building should be built, and in the future, climate change must be a key consideration for these codes. It is also important to consider historical land use policies and how they relate to socioeconomically disadvantaged communities, and how future land use decisions will impact those communities and frontline communities that will feel the effects of climate change first and hardest.

This second type of strategy generally examines the future needs of the community, and those that are specific to land use. These include modifying or implementing new land use management policies, actions that integrate climate into land use planning, and actions that modify policies related to how land will be used and where development can occur.

One such land use authority local governments can utilize is Adaptation Action Areas (AAAs). The details of AAAs were discussed throughout the project. As shown throughout this and similar studies, some areas are more vulnerable to climate threats, and therefore the application of policies may need to vary based on geography to be more effective. AAAs address the need for geographic specificity.

Throughout the assessment, a few key themes emerged for land use, zoning, building codes, and standards:

- The larger local governments tend to have more complex land use challenges than some of the smaller communities. Specifically, some of the smaller municipalities do not have as many land use types as their larger counterparts. This means that there is not a one-size-fits-all solution to many of the land use challenges associated with climate change, and the solutions will need to be applied in a municipal-specific way. However, there is benefit in working across jurisdictions when it comes to research and connecting around ideas.
- Another challenge with changing environmental conditions is preserving history and the character of many of the CRP communities. There is a need to be thoughtful and diligent when enacting new land use policies around climate change to ensure that broad changes do not unintentionally change desired characteristics. This includes considering frontline and historically disadvantaged communities.
- Lastly, there are some extremely vulnerable areas where property-level adaptation may not be possible or the right approach. As such, the region needs to start considering managed orderly relocation and modify the land use to natural open space. Palm Beach County also needs to manage this complexity with the likelihood of climate migration from southern counties.

3.2.1.3 Planning, Policy, and Management (Non-Land Use)

The third type of adaptation strategy that the CRP explored is planning, policy, and management as it relates to all other aspects of local government that do not involve land use.

Summary of Adaptation Strategy Type #3: Planning, Policy & Management

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Strategies that integrate climate into existing or new planning processes, new or existing policies, and the management of operations or programs.	• Integration of CCVA findings into existing plans (e.g., Emergency Management Plan) • Identify opportunities and ways to mainstream use of the CCVA to add a “resilience lens” in current processes (e.g., Capital Improvement Plans) • Modifying ordinances with increased standards or new requirements	• Planning • Policy • Operations & Practice	• Planning • Public Safety • Emergency Management

As part of policy approaches, non-land use planning, policy, and management are separated out as a separate category to highlight the importance of strategies that do not pertain to how land is utilized. Many of these policies correspond to how a local government plans and operates. As such, the results of this multi-hazard vulnerability assessment should be utilized in nearly all planning conversations, and across all master planning processes.

For example: how might tidal flooding impact the operations of trash pickup in low-lying coastal neighborhoods during King Tides? Will vehicles that travel through saltwater have higher maintenance costs and a shorter lifetime?

Adaptation strategies discussed here generally examine the future needs of the community, and those that are not specific to land use. These are actions that integrate climate into existing planning processes or other planning actions not related to land use, actions focused on creating new or revising existing regulations other than those related to land use, and actions that change operations, management, and programs to include the impact of climate change.

Climate change will impact all facets of life in Southeast Palm Beach County. As such, it should be a consideration in all planning done across all levels of government, departments, and organizations. This assessment is a tool, and the results of this multi-hazard vulnerability assessment should be utilized in all planning conversations.

In the outreach events hosted during the project, residents favored actions that had obvious results and made immediate tangible differences. This does not mean to solely focus on small projects, but rather utilize these projects and policies to build good will with the public, making future policy changes and adaptation easier. These can be small, incremental changes and provide relatively achievable goals.

The operations of local governments will be impacted by climate change. Through the assessment of critical assets, it is clear that climate change will create long-term challenges that need to be considered now. As new equipment is purchased, infrastructure is replaced, and plans are made, climate change should be a major consideration. This will not only ensure the long-term viability of the community, but also make sure that community dollars are spent responsibly – such as infrastructure having the expected lifetime.

Throughout the assessment, a few key themes emerged for planning, policy, and management:

- Data and models to inform future risk and vulnerability for water threats emerged as a theme of the study several times. Most of these models are cost prohibitive for one jurisdiction to create and would only be nominally effective since water does not observe political boundaries. Many of these datasets and models take years to develop so ideally development should begin as soon as possible:
    - A regional groundwater and/or integrated surface-groundwater model was discussed many times during CRP meetings. Since water supply is a significant need for all communities and all the CRP participants use groundwater as primary water supply, understanding and planning for **saltwater intrusion** is key to the future of Palm Beach County. A groundwater model has many uses and could also inform decisions and adaptation strategies as **groundwater inundation** becomes more common in Palm Beach County.
    - CRP members discussed water quality and ecological protection of the Lake Worth Lagoon and other regional water resources throughout the study. Members agreed that continued monitoring and planning is important for water quality. It is notable that **Harmful Algal Blooms (HABs)** was selected as a key threat for the region, but no regional water quality models currently exist within the study area. Identifying where nutrients are originating and then examining the transport of those nutrients will be key to addressing HABs in the future.
- Many established planning and coordination platforms exist throughout Palm Beach County for local governments, but it will be key for the CRP members to work with these organizations to provide the results of this study and then begin discussions on how to roll climate change into their planning processes.

3.2.1.4 Capacity Building

The fourth type of adaptation strategy that the CRP explored is capacity building.

Summary of Adaptation Strategy Type #4: Capacity Building

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Strategies that build a community's ability to design strategies and implement actions to build resilience.	• Collaborate as a CRP on the development of initiatives such as Resilience Hubs • Engage Lake Worth Drainage District (LWDD) and SFWMD • Share information on the use of Adaptation Action Areas with the region and the State of Florida	• External Partnerships • Analysis & Research • Monitoring & Technology • Community Resources • Staff Capacity	All Departments

Climate adaptation and resilience planning is an iterative process. Therefore, one of the most important investments that a local government can make is in building internal as well as community capacity to identify, assess, and implement actions for adaptation and building resilience. Capacity building strategies can come in a variety of forms but generally fall into the following major subcategories.

External Partnerships

External partnership strategies can include other local, State, Federal, academic, private, or non-profit entities. Partnerships are critical for addressing issues that may be shared across the operational or geographic areas of multiple entities. They also provide ways of aligning resources and capacities to more effectively or efficiently address issues and work towards common goals.

Analysis and Research

New information and ideas are always becoming available in the areas of climate adaptation and resilience. Tracking this information is not efficient or possible for a single local government. Within capacity building, strategies for analysis and research focus on ways of gathering data, analyzing data and information, or using new models as new information becomes available, or developing maps and reports for internal or external purposes. These strategies may also focus on research and development of ways to use or integrate information into planning processes or other activities.

Monitoring and Technology

Monitoring involves taking repeated observations or measurements. These strategies could involve monitoring to obtain better or missing information. Monitoring can also be focused on actions that have been implemented to better understand environmental or community impacts, potential unintended consequences, or to understand the effectiveness that implemented actions have had in building resilience. Technology investments can also build capacity by increasing the availability or efficiency of information that is available to guide or inform resilience actions. It is important to note that this type of capacity building can also appear as part of the other types of strategies discussed in this report, like infrastructure, planning, or public outreach.

Community Resources

Local governments can play an important role in enhancing the capacity of under-resourced groups in the community to not just withstand climate impacts, but thrive in the face of climate impacts. This requires long-term proactive planning and protection of people and community assets. Therefore, important types of strategies to consider are related to providing resources directly to residents and both formal and informal community-based organizations. Community resources can come in many forms, such as funding, monetary or material resources, and other services. These resources may be provided directly to residents or community groups.

Staff Capacity Building

Having people with the resources they need to develop and carry out the work of building resilience is critical to making progress within local government. Staff **capacity building** refers to investments such as staff training, time, and funding support. Dedicated staff time is often one of the most precious resources within a local government but is necessary for people to do quality work in building resilience. As a relatively new field and area of work, resilience planning and action implementation requires an investment in staff to build the institutional knowledge and resources that are needed for taking action. Also, as an area addressing changing conditions and using new approaches, time and opportunities for learning new information can also be important. Therefore, one of the most critical investments local governments can make is in building capacity within their organization and staff to carry out ongoing work.

Throughout the assessment, a few key themes emerged for capacity building:

- The CRP has been and will continue to be a key part of capacity building in Southeastern Palm Beach County with regards to climate change and similar issues. Now that the CCVA is completed, the CRP can use the results of this study to inform both future actions of the group and to inform similar stakeholder groups across the County.
- The CRP agreed that continued coordination with South Florida Water Management District, Florida Department of Environmental Protection, Army Corps of Engineers, and Lake Worth Drainage District will be key to climate adaptation in this region. Since many climate threats within the study area are closely interconnected with these agencies, the jurisdictions and the CRP will need to continue significant coordination efforts.

3.2.1.5 Public Outreach

The fifth type of adaptation strategy that the CRP explored is public outreach.

Summary of Adaptation Strategy Type #5: Public Outreach

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Adaptation strategies that involve engaging the public for information and feedback.	• Public workshops around climate change • **Commission/Council member community meetings** • **Community Surveys** • **Educational flyers, such as flood risk flyers** • **Social media content around climate change, flooding, and the environment** • **Focused discussions of shared responsibility to tackle certain threats, such as rainfall-induced flooding**	• Public Communications • **Public Engagement**	All CCVA Threats

A changing climate induces a complex set of governance challenges that require building effective partnerships between members of the public and the local government. Community engagement strategies within an adaptation portfolio can have a variety of objectives towards this long-term overarching goal. To begin with, building an understanding of the intricacies in the impacts of and solutions to climate threats is crucial. Navigating current perceptions, connecting the conversation on resilience and adaptation with strongly held values, and building approachability to these topics are essential facets to effectively engaging members of the public.

Building on education and awareness efforts, creating strong public support for adaptation actions also requires involving community members in planning and decision making early and often. In addition, shifting the conversation from issues-based to solutions-based, highlighting the co-benefits to be found for all involved, plays a crucial role in gaining traction and support for investments in adaptation. For example, emphasizing the benefits, such as making the business case for resilience investments and communicating possible avoided losses and recreational opportunities, all foster a collective understanding that what is adapted today may engender a climate-resilient community tomorrow.

For ensuring equitable outcomes, it is critical that community engagement efforts are targeted to reach and then include historically under-represented and overburdened communities. Engagement with and procedural inclusion of these communities can also create opportunities for not only education and awareness but also for building trusting relationships. This theme of the project was so critical that it is discussed separately as part of Section 3.2.2.

Throughout the assessment, a few key themes emerged for public outreach:

- Adaptation strategies related to public outreach and engagement include reframing how we communicate climate vulnerability and adaptation, engaging frontline communities and effectively using their input, as well as refining and deeply rooting the topic of resilience at the start of every project so that all may understand interconnected systems.
- The CRP agreed that continued coordination with South Florida Water Management District, Florida Department of Environmental Protection, Army Corps of Engineers, Florida Department of Transportation, and Lake Worth Drainage District will be key to climate adaptation in this region. Since many climate threats within the study area are closely interconnected with these agencies, the jurisdictions and the CRP will need to continue significant coordination efforts.

3.2.1.6 Funding and Finance

The sixth and final type of adaptation strategy that the CRP explored is funding and finance.

Summary of Adaptation Strategy Type #6: Funding and Finance

	Definition	Major Examples for Palm Beach County	Major Subcategories	Most Relevant Local Government Departments
	Strategies to generate local revenue, securing funding from State and Federal programs, and financing mechanisms such as bonds.	• 'Always Ready' Legislation • **319 Grants** • **FEMA Grants** • **Stormwater Utility Income**	• Grants • Bonds • **Taxes** • **Fees**	• Elected Officials • Finance Department • Legislative Assistants • **Grants Coordinator**

The final category that was explored by the CRP includes all matters related to funding and finance. This includes strategies to generate local revenue and secure funding from State and Federal programs and financing mechanisms such as bonds. Due to the nature of this strategy, it is interconnected to all other types of strategies discussed throughout this report.

The cost of adapting to and mitigating the effects of climate change will be significant, especially for coastal communities. Each climate threat will create its own challenges and challenge each community differently. Nearly every facet of government operation will need to change, and it could be a costly endeavor. Local governments in Southeast Palm Beach County have generally limited revenue options – property, sales, and other taxes, charges and fees, and funding from the Federal and State governments. Funding and financing climate adaptation and mitigation will require innovation and persistence.

For example, the gravest threat to the economy of the region is flooding and rising sea levels. Properties prone to flooding are worth less, which will reduce property tax revenue, and local government's ability to spend money to adapt. However, if local governments invest in adaptation, thereby protecting property and preserving values, the opposite can be true – the revenue base will be protected and may even increase. This will provide greater sources of revenue to fund adaptation in the future. This simple approach explains why proactive investment in mitigating climate change is a financial imperative.

The recently completed Business Case for Resilience in Southeast Florida found that investment in both property-level and community-wide adaptation is cost beneficial in Palm Beach County (Urban Land Institute, 2020). Furthermore, local governments often bond large improvements and bond rating agencies are watching the work of local governments. Governments that invest in adaptation are seeing improved bond ratings – Miami and Miami Beach are good examples.

Throughout the assessment, a few key themes emerged for funding and finance:

- Jurisdictions varied in their approach to funding and finance, although there was general agreement that partnering is advantageous in securing grants and sharing knowledge regarding funding sources.
- Continuing to create strategies that are multi-benefit enhances the probability of funding for all the CRP members.
- A diverse funding strategy will be necessary for each jurisdiction. For example, some of the barrier island jurisdictions need to focus more on capacity building for personal adaptation for residential properties versus focusing on adaptation of the assets owned by the municipality.

Table 3-2 summarizes major funding sources as they were available at the conclusion of the study in May of 2021.

Table 3-2. Funding Options Available for Resilience Projects (as of May 2021).

Entity	Name of Grant/Funding Source	General Description	Relevant Type(s) of Adaptation Strategies	Website for More Information
Department of Transportation	Transportation Alternatives Program (TAP)	"The Transportation Alternatives Program (TAP) provides funding for projects defined as transportation alternatives, including on- and off-road pedestrian and bicycle facilities, infrastructure projects for improving non-driver access to public transportation and enhanced mobility, community improvement activities, and environmental mitigation; recreational trail program projects; and safe routes to school projects."	Complete Streets, Green Streets	https://www.transportation.ohio.gov/wps/portal/gov/odot/programs/local-funding-opportunities/resources/transportation-alternatives-program
Federal Emergency Management Agency	Building Resilient Infrastructure and Communities (BRIC)	"Building Resilient Infrastructure and Communities (BRIC) will support states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. BRIC is a new FEMA pre-disaster hazard mitigation program that replaces the existing Pre-Disaster Mitigation (PDM) program… The BRIC program guiding principles are supporting communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; enabling large projects; maintaining flexibility; and providing consistency."	Raising Roads with Harmonization, Hardening and Undergrounding Energy and Communications Assets	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities
	Hazard Mitigation Grant Program (HMGP)	"FEMA's Hazard Mitigation Grant Program provides funding to State, local, tribal and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses in their communities. This grant funding is available after a presidentially declared disaster."	Raising Roads with Harmonization, Hardening and Undergrounding, Energy and Communications Assets	https://www.fema.gov/grants/mitigation/hazard-mitigation
	Flood Mitigation Assistance (FMA) Grant	"The Flood Mitigation Assistance Program is a competitive grant program that provides funding to states, local communities, federally recognized tribes and territories. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program."	Stormwater Projects	https://www.fema.gov/grants/mitigation/floods

Entity	Grant Name	General Description	Relevant Type(s) of Adaptation Strategies	Website for More Information
Housing and Urban Development	Community Development Block Grant (CDBG) Programs	"Community development activities build stronger and more resilient communities. To support community development, activities are identified through an ongoing process. Activities may address needs such as infrastructure, economic development projects, public facilities installation, community centers, housing rehabilitation, public services, clearance/acquisition, microenterprise assistance, code enforcement, homeowner assistance, etc. Federal support encourages systematic and sustained action by State and local governments."	Complete Streets, Green Streets	https://www.hud.gov/program_offices/comm_planning/communitydevelopment
National Fish and Wildlife Foundation	Multiple	Multiple grant programs listed as part of conservation programs	Multiple	https://www.nfwf.org/apply-grant https://www.nfwf.org/programs
Environmental Protection Agency	Green Infrastructure Funding Opportunities	Many grant programs including Sewer Overflow and Stormwater Reuse Municipal Grants Program and EPA Water Finance Clearinghouse, a database of financial assistance sources available to fund a variety of watershed protection projects.	LID, Pump Stations, Trees, Treatment Wetlands, Wastewater Treatment Plant Improvements, Septic to Sewer, Lift Station Retrofits (to build resilience), Green Infrastructure	https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities
	Environmental Justice Grants	Multiple grant opportunities listed.	Multiple	https://www.epa.gov/environmentaljustice/environmental-justice-grants-funding-and-technical-assistance
Florida Department of Environmental Protection	Florida DEP 319 TMDL Fund	Nonpoint Source Funds: "The program administers both the Federal Clean Water Act Section 319(h) Grants (also known as "319 Grants") and the State Water-quality Assistance Grants (also known as "SWAG"). The goal of these grants is to reduce nonpoint source pollution from land use activities. Total funding amounts available each year in these two grant programs depends on Federal and State appropriations but is usually around $8 - $9 million."	LID, Green Infrastructure	https://floridadep.gov/wra/319-tmdl-fund

Entity	Grant Name	General Description	Relevant Type(s) of Adaptation Strategies	Website For More Information
Florida Department of Environmental Protection	Florida Resilient Coastlines Program (FRCP) Resilience Grants	"The Florida Resilient Coastlines Program (FRCP) provides financial assistance aimed at preparing coastal communities for current and future effects of rising sea levels, including coastal flooding, erosion and ecosystem changes. Resilience Planning Grants (RPG) and Resilience Implementation Grants (RIGs) are available to Florida communities that are required to have a coastal management element in their comprehensive plan....": Resilience Planning Grants (RPG) and Resilience Implementation Grants (RIG)	Living Shorelines, Seawalls, Dune Restoration, Sand Restoration, Inlet Sand Transfer, Mangroves	https://floridadep.gov/rcp/florida-resilient-coastlines-program/content/frcp-resilience-grants
	Coastal Partnership Initiative Grants	Florida Coastal Management Program Grant Opportunities and Documents: Coastal Partnership Initiative Grant Program and State Agency and Water Management District Grant Program	Living Shorelines, Seawalls, Dune Restoration, Sand Restoration, Inlet Sand Transfer, Mangroves	https://floridadep.gov/rcp/fcmp/content/grants
	Water Protection Grants	Provides wastewater grants "for projects that reduce excess nutrient pollution within a basin management action plan (BMAP), alternative restoration plan adopted by final order, or rural area of opportunity." Provides innovative technology grants "for projects that evaluate and implement innovative technologies and short-term solutions to combat algal blooms and nutrient enrichment; restore and preserve Florida waterbodies; and implement certain water quality treatment technologies;"	Septic Tank Upgrades, Conversion of Septic Systems to Centralized Sewer, Solutions to Combat Algal Blooms and Nutrient Enrichment, Wastewater treatment plant improvements, Lift Station Retrofits (to build resilience), Treatment Wetlands, Green Infrastructure, Low Impact Development (LID)	https://protectingfloridatogether.gov/state-action/grants-submissions,

Entity	Grant Name	General Description	Relevant Type(s) of Adaptation Strategies	Website For More Information
Other Florida Grant Opportunities	Department of State Cultural and Historical Resources	Many grants listed	Multiple	https://dosgrants.com/Program
	Always Ready Bill	"… Senate Bill 1954 requires the development of the Comprehensive Statewide Flood Vulnerability and Sea Level Rise Data Set, led by the Chief Science Officer. Additionally, it facilitates the development of statewide sea level rise projections and other data necessary to determine the risks to inland and coastal communities. The data set is to be completed by July 1, 2022, and the Comprehensive Statewide Flood Vulnerability and Sea Level Rise Assessment is to be completed by July 1, 2023. The Statewide Flooding and Sea Level Rise Resilience Plan is to be submitted by Dec. 1, 2023. This bill authorizes local governments to develop Regional Resilience Coalitions to allow communities to join in resilience planning efforts and share technical assistance. It also creates the Florida Flood Hub for Applied Research and Innovation at the University of South Florida to coordinate efforts between the academic and research institutions of Florida."	Raising Roads with Harmonization, Green Infrastructure, Trees, Parks, Greenspaces, Low impact development, Pump Stations, Treatment Wetlands, Living Shorelines, Seawalls, Dune Restoration, Sand Restoration, Inlet Sand Transfer, Mangroves	https://www.flgov.com/2021/05/12/governor-ron-desantis-signs-bill-to-further-strengthen-floridas-resiliency-efforts/
	Lake Worth Lagoon Initiative Legislative Funding Request Program	"Palm Beach County (PBC) will solicit project proposals to provide collaborative support for a stronger Lake Worth Lagoon Initiative (LWLI) legislative funding request, and to assist local municipalities and special taxing districts in improving the lagoon through projects such as habitat restoration, storm water retrofits and septic-to-sewer conversions."	Living Shorelines, Mangroves, Septic to Sewer, LID, Pump Stations, Trees, Treatment Wetlands	https://discover.pbcgov.org/erm/LWLagoon/Funding-Request.aspx
Federal Assistance	Biden Administration Infrastructure Bill (Pending)	Plan for improving Nation's infrastructure and shifting to greener energy	Pending information	Not available
Adaptation Clearing House Website		Many grants listed	Multiple	https://www.adaptationclearinghouse.org/search/?type_a=t&type%5B%5D=&i_a=&s_a=&jf_a=&ri_a=&rc_a=t&rc%5B%5D=245&sid_a=&sid%5B%5D=&keyword_a=f&q=

3.2.2 Development of Equitable Strategies

Throughout the study, social equity was an important consideration for both the region and individual jurisdictions. Therefore, it was weighted as an important factor in the development of adaptation strategy portfolio. This section provides a conceptual framing and practical guidance for integrating equity in adaptation efforts.

Within the context of adaptation planning and implementation, equity has two primary dimensions:

1) Procedural Equity
2) Substantive Equitable Outcomes (Georgetown Climate Center, 2020)

Procedural equity is about ensuring that overburdened and underrepresented communities have a meaningful voice in the early stages of planning and formulation of adaptation strategies – and then during implementation and monitoring of those strategies. This means that long-term community engagement objectives go beyond awareness and education to include building trusting relationships and providing true opportunities to shape decision making. Substantive equitable outcomes are achieved through equitable distribution of adaptation benefits to reduce disproportionate climate impacts, actions that address the drivers of disparities, and investments in building social cohesion. This also includes addressing pervasive community **stressors** (e.g., affordable housing and food deserts) (Georgetown Climate Center, 2020).

Translating this conceptual understanding of multiple dimensions of equity into an equitable portfolio can be done by recognizing that while some adaptation strategies may address social inequities directly (e.g., building climate-safe affordable housing), there are also opportunities to advance social equity goals within *all* adaptation strategies. To that end, a helpful set of guiding questions are provided in the framework developed for the Multnomah County and Portland's "Climate Action Through Equity" report (Table 3-3). The framework illuminates the variety of ways in which social equity can be enhanced through adaptation strategies. This framework can be utilized for a thoughtful and deliberate approach to centering equity when designing adaptation strategies at a high-level, as well as during implementation of specific actions.

Table 3-3. Considerations for Equitable Adaptation Strategies (Source: City of Portland, Oregon and Multnomah County, 2016)

Disproportionate Impacts [of the action]	Does the action generate burdens to communities of color (CoC), low-income populations (LiP) and disadvantaged communities?
Shared Benefits	Can the benefits of action reduce historical or current disparities?
Accessibility	Are the benefits of the action broadly accessible to households and businesses throughout the community – particularly, CoC, LiP and emerging small businesses?
Engagement	Does the action engage and empower in a meaningful, authentic, and culturally appropriate manner?
Capacity Building	Does the action help build community capacity through funding, and expanded knowledge base or other resources?

Alignment & Partnership	Does the action align with and support existing CoC, LiP priorities, creating an opportunity to leverage resources and build collaborative partnerships?
Relationship Building	Does the action help foster the building of effective, long-term relationships and trust between diverse communities and local government?
Economic Opportunity & Staff Diversity	Does the proposed action support CoC and LiP through workforce development, contracting opportunities or increased diversity of city and county staff?
Accountability	Does the action have accountability mechanisms to ensure CoC, LiP or other vulnerable communities will equitably benefit and not be disproportionately harmed?

3.2.3 Regional Prioritization Process and Results

At the conclusion of Step 4 of the project, the CRP and consultant team developed the portfolio of strategies for the region (Table 3-4).

The regional portfolio of adaptation strategies was developed via the following steps:

1. The consultant team inventoried strategies from previous projects and staff interviews conducted throughout the project. A literature review was also conducted and the results of the jurisdictional (Community Captain) meetings were added to the list. This step resulted in a list of over 500 strategies across all strategy types and asset classes. Strategies were classified according to whether they were appropriate for regional and/or jurisdictional use.
2. Subject matter experts from the consultant team scrubbed the strategy list for regulatory and/or feasibility concerns. Duplicative strategies or measures that were deemed infeasible were removed. Strategy removal usually related to the unique hydrology of South Florida and/or relevant regulations (usually Environmental Resource Permitting requirements). This step took considerable time considering the number of strategies and the cross-section of expertise required (engineering, legal, planning, regulatory, etc.). As mentioned previously, social equity was also considered throughout the process. Strategies were specifically included that address social equity.
3. Filter 1 was applied to the strategies as follows:
    a. Threat weights were developed for the region so that co-benefits could be examined between strategies. This involved digesting the results of the spatial analyses and developing weights for the other non-spatial threats based on best available data and a basic algorithm. For the flood threats, both current and future conditions were considered. A weight was also applied based on the consequence of the threat to the region multiplied by the frequency of the threat.
    b. For the regional analysis, threat weights were calculated based on averages across the jurisdictions.
    c. All strategies were scored based on this first filter.
4. Filter 2 was applied to the strategies as follows:
    a. A final filter was applied so that some critical benefits could be examined, including social equity, permit-ability/feasibility, ease of funding, sustainability, and likelihood of public support.
    b. All projects were re-scored using this second filter. The filters were combined to create the list of scores for all strategies.
5. Final scores were tallied and reported out of a spreadsheet as both a raw score and by typology.
6. The consultant team scrubbed the list, and the portfolio presented the results to the CRP representatives. During this step, some strategies were combined, and all the strategies were further refined based on subject matter expertise, local issues, and the results of the study (for example, discussions at project meetings regarding specific strategy features).
7. A meeting was scheduled with the CRP to finalize regional strategies in a collaborative manner.
8. The list of final strategies was compiled.

Table 3-4. Portfolio of Regional Adaptation and Mitigation Strategies for the Coastal Resilience Partnership of Palm Beach County (CRP)

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Infrastructure	Based on the results of this study, evaluate key infrastructure vulnerabilities, and work regionally with regulators to minimize gaps in services: utilities (water, wastewater, and stormwater), schools, critical care, emergency buildings, etc. Special attention should be paid to the locations of vulnerable populations based on the findings of this study.	All
	Build partnerships and opportunities for increasing green infrastructure projects and/or voluntary incentives. Participate in the statewide development of stormwater rules that award Environmental Resource Permit (ERP) credit for use of Low Impact Development measures.	Harmful Algal Blooms (HABs), All Flood Threats, Drought, Extreme Heat, Pest & Disease
	Work as the CRP to facilitate more living shoreline projects in vulnerable locations. Special attention should be paid to the results of this study and how these projects can be used to mitigate climate impacts for socioeconomically challenged areas. Projects that leverage healthy mangroves should also be strategically considered.	Shoreline Recession, High Winds, HABs, Storm Surge
	Deploy mobile food markets connecting residents to food distribution centers and grocery stores in order to address food deserts and other food equity issues. These markets could be strategically deployed based on need, as well as after flooding and adverse weather conditions.	Pest & Disease, Extreme Heat, All Flood Threats
	Collaborate as the CRP to encourage the development of non-motorized transportation facilities (e.g., trails, separated bike paths), that are cross-jurisdictional when possible, to enable impacted populations to access public service/health needs. Shade and safe access to drinking water should be considered as a part of this strategy.	Extreme Heat, Pest & Disease

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Land Use, Zoning, Building Codes and Standards	In appropriate areas, develop a regional plan to restore wetlands and shoreline to provide more resilient habitats, improve water quality, and slow storm surge. This initiative would be particularly effective near the coastline and waterbodies with impacted water quality and should be linked to other co-benefits when possible (public education, recreation, biodiversity protection, etc.).	Shoreline Recession, HABs, Storm Surge, Pest & Disease
	Using the results of this study, collaborate to identify incentives to divert future development from vulnerable areas, such as transfer of development rights and density bonuses. These provisions for incentives would reduce the introduction of new investments in high-hazard zones and help ensure the long-term economic resiliency and competitiveness of the area.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding
	Advocate for the consideration of resilience in regional transportation plan updates and for making consideration of sea level rise and future hydrology a factor for funding new transportation projects.	All

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Planning, Policy, and Management	Collaborate and advocate for the regional creation of a green infrastructure/low impact development (GI/LID) manual to provide a toolbox of green infrastructure practices and site design options for municipal staff and consulting engineers and architects. The design manual should include pollutant removal efficiencies, design constraints, and appropriate settings and materials for Southeastern Palm Beach County. Link this strategy to other engagements with Florida Department of Environmental Protection (FDEP) and South Florida Water Management District (SFWMD) to award ERP credit for LID usage in Palm Beach County.	HABs, All Flood Threats, Pest & Disease, Extreme Heat, Drought; Shoreline Recession
	Explore the concept of Adaptation Urbanism – integrating compact development, sustainable transport, blue and green infrastructure, and equity – and work with regional partners to identify opportunities to apply it to street-level resilience projects in the CRP area.	All
	Collaborate across the CRP to create a program inspired by the Building Efficiency 305 Program in Miami geared towards increasing water and energy efficiency in large buildings. See https://www.miamidade.gov/global/economy/resilience/building-efficiency-305.page for more information.	Drought, Extreme Heat
	Collaborate as the CRP and with other local agencies to encourage the creation of watershed datasets, models, and floodplain maps. Develop regional maps that reflect build-out and future hydrology that can be updated every 5 years. The work can build upon Palm Beach County's efforts to delineate watersheds for the Community Rating System (CRS) Program, as well as the watershed approach taken by the Lake Worth Lagoon Initiative.	All Flood Threats, HABs, Drought, Groundwater Inundation

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Capacity Building	Collaborate as the CRP to compile resources to encourage sustainable landscaping practices, pervious surfaces, and downspout disconnection for homeowners and businesses. Tie the initiative to existing resources that encourage Florida-Friendly Landscaping™ and those that reduce fertilizer usage. Cater the specific measures to Southeast Palm Beach County so that the resources are easier for the public to use (plant menus, instructions, local resources, etc.). Tap into the resources provided by the Institute of Food and Agricultural Sciences (IFAS) Extension at the University of Florida and the local Palm Beach County Cooperative Extension.	HABs, All Flood Threats, Pest & Disease, Extreme Heat, Drought, Shoreline Recession
	Study and plan to reduce nutrient loads to receiving waterbodies through planning, modeling, enhanced best management practices, land development regulation updates and other strategies. Water quality requires a watershed approach to be successful, so this is a critical regional strategy. Regional water quality partnerships will also increase opportunities for funding. Coordinate activities strategically with Municipal Separate Storm Sewer System (MS4) permitting and Total Maximum Daily Load (TMDL) reporting/activities.	All Flood Threats, HABs, Drought, Groundwater Inundation, Pest & Disease
	Engage Lake Worth Drainage District (LWDD) and SFWMD regarding the impacts of current and future flood events on the secondary and primary canal systems in Southeastern Palm Beach County. Also consider potential of algal blooms and how they would affect structure operations. Work with both parties to develop models and eventually a decision support system that can adapt to further mitigate future flood events. Partnering will also increase the likelihood of funding for some grant opportunities. Establish liaisons and a plan for engagement and/or use existing programs (e.g., Palm Beach County Water Resources Task Force).	Groundwater Inundation, Saltwater Intrusion, Rainfall-Induced Flooding, Drought

CAPACITY BUILDING (CONTINUED)	Collaborate on development of neighborhood-based resilience hubs to facilitate communication, distribute resources, and provide services to residents before, during, and after climate disruptions. Use the Urban Sustainability Directors Network (USDN) Guide to Developing Resilience Hubs as a starting point for local and regional knowledge exchange; seek funding opportunities for a regional network of hubs across the CRP.	All
	Work as the CRP to share information on the use of Adaptation Action Areas throughout the region and the State of Florida.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding
	Engage SFWMD on an ongoing basis regarding the need for rainfall curves, groundwater models, watershed models, and various datasets that can be used to design resilient infrastructure in Southeast Palm Beach County. Establish liaisons and a plan for engagement and/or use existing programs (e.g., Palm Beach County Water Resources Task Force).	Groundwater Inundation, Saltwater Intrusion, Rainfall-Induced Flooding, Drought, HABs
	Start a regional program to encourage more natural management of littoral zones for residential communities, commercial/mixed use, and golf courses. Consolidate and distribute educational resources regarding appropriate fertilizer usage.	HABs, Extreme Heat, Pest & Disease

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Public Outreach	Host regional public meetings about climate threats and solutions that are easily accessible to vulnerable populations. Meetings should be (a) Physically accessible (near public transport); (b) Safe for all members; (c) Located in places that the community values as gathering spaces (e.g., community centers and cultural centers); (d) Led in, or translated into, the primary language(s) of the community; and (e) Scheduled at various times to accommodate different schedules.	All
	Engage artists, activists, youth, and elders in public climate change education. Since Palm Beach County has strong cultural resources, this strategy should leverage existing programs and networks.	All
	Further the discussions related to the results of this study and continue regionally important conversations regarding climate change, sustainability, and resilience.	All
	Collect data through citizen science initiatives/programs. For example, map urban heat islands with citizen input to inform development of policies to mitigate their effects.	All

STRATEGY TYPE	DESCRIPTION	APPLICABLE THREAT(S)
Funding and Finance	Identify grant opportunities to fund adaptation strategies. Share information on these resources via the CRP and other established Palm Beach County governmental groups. Partner strategically and proactively on projects. Review this strategy as part of every CRP meeting and update annually for new funding sources.	Shoreline Recession, HABs, All Flood Threats, Drought
	Continue leadership as a region through collaborative partnerships with strategic partners (e.g., the Palm Beach County League of Cities, Chambers of Commerce, etc.) with a focus on strategic funding for the region to build resilience throughout Southeastern Palm Beach County.	All
	Collaborate as the CRP to identify and share resources and tools to assist individuals with financing home or business adaptation efforts.	All
	Engage in the implementation of the new landmark 'Always Ready' resilience law and ensure the CRP has taken the necessary steps to be at the front of the line when planning and infrastructure funds become available.	All

3.2.4 Jurisdictional Prioritization Process and Results

At the conclusion of Step 4 of the project, the CRP and consultant team developed a portfolio of adaptation strategies for each jurisdiction. The steps were like those used to develop regional strategies except the results of jurisdictional meetings were more heavily integrated.

Each jurisdictional portfolio of adaptation strategies was developed via the following steps:

1. The consultant team inventoried strategies from previous projects and staff interviews conducted throughout the project. A literature review was also conducted and the results of the jurisdictional (Community Captain) meetings were added to the list. This step resulted in a list of over 500 strategies across the typology and asset classes. Strategies were classified according to whether they were appropriate for regional and/or jurisdictional use.
2. Subject matter experts from the consultant team scrubbed the strategy list for regulatory and/or feasibility concerns. Duplicative strategies or measures that were deemed infeasible were removed. Strategy removal usually related to the unique hydrology of South Florida and/or relevant regulations (usually Environmental Resource Permitting requirements). This step took considerable time considering the number of strategies and the cross-section of expertise that was required (engineering, legal, planning, regulatory, etc.). This step also included equity experts on the team adding specific strategies.
3. Filter 1 was applied to the strategies as follows:
    a. Threat weights were developed for the region so that co-benefits could be examined between strategies. This involved digesting the results of the spatial analyses (those featured in AccelAdapt) and developing weights for the other non-spatial threats based on best available data and a basic algorithm. For the flood threats, both current and future conditions were considered. A weight was also applied based on the consequence of the threat multiplied by the frequency of the threat.
    b. For the jurisdictional analyses, threat weights were calculated based on specifics of each jurisdiction.
    c. All strategies were scored based on this first filter.
4. Filter 2 was applied to the strategies as follows:
    a. A final filter was applied so that some critical benefits could be examined, including equity, permit-ability/feasibility, ease of funding, sustainability, and likelihood of public support.
    b. All projects were re-scored using this second filter. The filters were combined to create the list of scores for all strategies.
5. Final scores were tallied and reported out of a spreadsheet as both a raw score and by typology.
6. The consultant team scrubbed the list and the portfolio for each jurisdiction was assembled. Some strategies were combined, and all of the strategies were further refined based on subject matter expertise, local issues, and the results of the study (for example, discussions at project meetings regarding specific strategy features). For the jurisdictional analyses, the Community Captain meetings were carefully considered as part of the portfolio assembly so that the specifics of each jurisdiction could be captured.
7. The consultant team met with key staff from each jurisdiction to refine strategies and discuss any remaining needs of the specific jurisdiction. CRP members also compared strategies and assisted one another in refining final details of key strategies.
8. A list of final strategies was compiled for each jurisdiction.

The portfolio of recommended adaptation strategies for each partner jurisdiction is provided in Appendices 1-8 of this report.

3.3 Next Steps

This study will provide the participant jurisdictions with opportunities for enhanced collaboration, more funding opportunities, and a deeper level of knowledge regarding risk and vulnerability to numerous climate threats. The CRP created a list of adaptation strategies (Table 3-4) that will provide a cohesive path forward for many years to come that are based on mutual goals, sound science, and significant areas of need for the region. It will also be important to leverage the momentum of this study and continue the regional CRP dialogue with the regulatory agencies that participated in the creation of this study (Florida Department of Environmental Protection, South Florida Water Management District, and Lake Worth Drainage District, among others).

For the participating jurisdictions, all 8 communities now also have an improved understanding of their climate risk and vulnerability. Future steps for the individual jurisdictions may include

- Creating venues to educate stakeholders regarding the results of the study. This will likely include other local governments that did not participate in this study, inter-governmental groups, and various agencies, among many others. Many of these interactions will focus on capacity building so that the actions can be magnified. The CRP can consider if a formal plan is required to accomplish this outreach need.
- Expanding the public's exposure to the results of the study through interactive and community-led experiences. Many of these engagement processes will focus on vulnerable populations and frontline communities that were identified during this study.
- Rolling these measures into other plans created by each local government and developing detailed metrics to measure success. Some of these plans may include updates to Sustainability Plans, Comprehensive Plans, Stormwater Master Plans, and annual Capital Improvement Planning processes.
- Continuing discussions regarding policy decisions that arose out of this study. For example, considering if Adaptation Action Areas are a strategy that is appealing to each individual jurisdiction.
- Each jurisdiction will need to examine and create a timetable for implementation of the strategies developed as part of this study. The results of the study can be used to prioritize areas and refine the strategies further based on the individual preferences of each jurisdiction.
- Funding to implement adaptation strategies is and will continue to be a significant need for the CRP and the individual member communities. As of the conclusion of this study, new funding sources are becoming available, and it will be critical for the CRP to align the findings of this study with the requirements of these funding sources. This study will provide a foundation for each jurisdiction to qualify for existing and new funding sources, and to prioritize areas for adaptation.
- The CRP and each individual jurisdiction should continue staff interactions regarding the findings of this study and to further disseminate project data for future staff usage.
- This study improved the knowledge base for several key climate threats in Southeast Palm Beach County (rainfall-induced flooding, storm surge, tidal flooding, shoreline recession, and high winds) and illuminated the need to accelerate modeling efforts related to groundwater inundation, saltwater intrusion, and water quality, among others.

Literature Cited

Abtew, W. (2011). South Florida Water Management District. *Briefing on the 2010-2011 Drought in South Florida* (Presentation to the Technical Oversight Committee).

AECOM (2014-2019). *South Florida Flood Insurance Study, Version 2.0*, Multiple Sections.

Bureau, U. S. C. (2020). *American Community Survey Data*. The United States Census Bureau. https://www.census.gov/programs-surveys/acs/data.html.

Avila, L. A., S. R. Stewart, R. Berg, and A. B. Hagen (2020). *National Hurricane Center Tropical Cyclone Report on Hurricane Dorian*. Available at: https://www.nhc.noaa.gov/data/tcr/AL052019_Dorian.pdf

Burgess, Katharine, and Elizabeth Foster (2019). *Scorched: Extreme Heat and Real Estate.* Washington, DC: Urban Land Institute. Available at: https://2os2f877tnl1dvtmc3wy0aq1-wpengine.netdna-ssl.com/wp-content/uploads/ULI-Documents/Scorched_Final-PDF.pdf

Carollo Engineers (2019). *Technical Memorandum: Southeast Palm Beach County Coastal Resiliency Partnership (for DEP Agreement No. R1817 Task 1 Deliverables).* Florida Department of Environmental Protection.

CDM Smith. (2020, August). *10-Year Water Supply Facilities Work Plan Update Report*. City of Boynton Beach.

City of Boca Raton (1997). *Boca Raton Inlet Management Study Implementation Plan.*

City of Boca Raton Planning and Zoning Division and Utility Services Department. (2020, January). *City of Boca Raton 10-Year Water Supply Facilities Work Plan*. City of Boca Raton.

City of Charleston, South Carolina. (2020, November). *All Hazards Vulnerability and Risk Assessment.* Available at: https://www.charleston-sc.gov/DocumentCenter/View/27994/All-Hazards-Vulnerability-Assessment-Full-Report

City of Lake Worth. (1996). *Lake Worth Inlet Management Study Implementation Plan.*

Centers for Disease Control and Prevention (CDC)/ Agency for Toxic Substances and Disease Registry (ATSDR)/ Geospatial Research, Analysis, and Services Program. (2018) CDC/ATSDR Social Vulnerability Index 2018 Database, Florida. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html. Accessed on June 10, 2020.

Centers for Disease Control and Prevention (CDC). (2015). *Planning for an Emergency: Strategies for Identifying and Engaging At-Risk Groups. A guidance document for Emergency Managers: First edition*. Atlanta (GA).

Centers for Disease Control and Prevention (CDC). ArboNET. https://wwwn.cdc.gov/arbonet/maps/ADB_Diseases_Map/index.html. Accessed November 2020.

City of Asheville, North Carolina. (2018, April). *Planning for Climate Resilience Final Assessment Report.*

City of Portland, Oregon, and Multnomah County. (2016). *Climate Action Through Equity: The integration of equity in the Portland/ Multnomah County 2015 Climate Action Plan*. City of Portland, Oregon and Multnomah County. Available at: https://www.portland.gov/sites/default/files/2019-07/cap-equity-case-study-web29jul.pdf

City of Tallahassee, Florida. (2019, July). *Tallahassee Community Resilience Plan.* Available at: https://www.talgov.com/uploads/public/documents/publicsafety/resplansm.pdf

City of West Palm Beach, Florida. (2021, February). City of West Palm Beach Climate Resilience Plan (Draft).

Collective Water Resources, LLC. (2020). *Potential Impacts of the ACOE's 2020 Planned Deviation to the Water Control Plan for Lake Okeechobee and Everglades Agricultural Area (LORS 2008).* City of West Palm Beach.

Collini, R., W. Sweet, C. Weaver, C. Roche, C. Fulford, N. Garfield, M. Hanisko, K. Hintzen, A. Luscher, D. Marcy, G. Scott, S. Spiegler, H. Stiller, T. Sudol (2018). Sea Level Rise Two Pager Resource. Available at: http://masgc.org/northern-gulf-of-mexico-sentinel-site-co/two-pager

Dausman, A., and Langevin, C.D. (2005). *Movement of the Saltwater Interface in the Surficial Aquifer System in Response to Hydrologic Stresses and Water-Management Practices, Broward County, Florida:* U.S. Geological Survey Scientific Investigations Report 2004-5256, 73 p. 11. https://pubs.usgs.gov/sir/2004/5256/pdf/sir20045256.pdf

Department of Homeland Security (DHS) (2003). *Homeland Security Presidential Directive 7: Critical Infrastructure Identification, Prioritization, and Protection*. Cybersecurity & Infrastructure Security Agency. Available at: https://www.cisa.gov/homeland-security-presidential-directive-7

Deslauriers, Sarah. (2019). Technical Memorandum: Southeast Palm Beach County Coastal Resiliency Partnership. City of Boynton Beach, Florida.

Easterling, D. R., J. R. Arnold, T. Knutson, K. E. Kunkel, A. N. LeGrande, L. R. Leung, R. S. Vose, D. E. Waliser, and M. F. Wehner. (2017). *Precipitation Change in the United States. Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, Eds., U.S. Global Change Research Program, Washington, DC, USA, 207–230. doi:10.7930/J0H993CC.

Emanuel, K. (2020). *Evidence that Hurricanes are Getting Stronger.* Proceedings of the National Academy of Sciences of the United States of America, 117 (24) 13194-13195.

Environmental Protection Agency (EPA). (2008a, December)*. Managing Wet Weather with Green Infrastructure - Municipal Handbook - Green Streets*. Available at: https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_green_streets_0.pdf

Environmental Protection Agency (EPA). (2008b). *Reducing urban heat islands: Compendium of strategies. Draft*. Available at: https://www.epa.gov/heat-islands/heat-island-compendium

Environmental Protection Agency (EPA). (2013, May). *Impacts of Climate Change on the Occurrence of Harmful Algal Blooms*. Available at: https://www.epa.gov/sites/production/files/documents/climatehabs.pdf

Environmental Protection Agency (EPA). (2014). Office of Water, Climate Ready Estuaries. *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans.* Available at: https://www.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf

Environmental Protection Agency (EPA). (2018, September). *Overview of Total Maximum Daily Loads (TMDLs). Impaired Waters and TMDLs.* Accessed 5 May 2021. Available at: https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls.

Environmental Protection Agency (EPA). (2020a, November). *What is Green Infrastructure?* Accessed 30 March, 2021. Available at: https://www.epa.gov/green-infrastructure/what-green-infrastructure

Environmental Protection Agency (EPA). (2020b). *Air Data: Air Quality Data Collected at Outdoor Monitors Across the US.* Accessed 13 September, 2020. Available at: https://www.epa.gov/outdoor-air-quality-data

Environmental Working Group (EWG). (2020b, August). *News Reports of Algae Blooms, 2010 to Present*. Available at https://www.ewg.org/interactive-maps/algal_blooms/map/

Federal Emergency Management Agency (FEMA). (2010, December). *Home Builder's Guide to Coastal Construction. FEMA P-499.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema499_2010_edition.pdf

Federal Emergency Management Agency (FEMA). (2017a). *Flood Insurance Study.* Palm Beach County, Florida.

Federal Emergency Management Agency (FEMA). (2017b). Flood Insurance Rate Map (FIRM)12099C, October 2017.

Federal Emergency Management Agency (FEMA). (2019a). *Community Lifelines Implementation Toolkit.* Available at: https://www.fema.gov/sites/default/files/2020-05/CommunityLifelinesToolkit2.0v2.pdf

Federal Emergency Management Agency (FEMA). (2019b). Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities (FEMA P-2062 / September 2019). Available at: https://www.fema.gov/sites/default/files/2020-07/guidelines-wind-vulnerability.pdf

Federal Emergency Management Agency (FEMA). (2019c). *User's Guide to Technical Bulletins: NFIP Technical Bulletin 0*. Available at: https://www.fema.gov/sites/default/files/2020-07/fema_using-technical-bulletins_guide.pdf

Federal Emergency Management Agency (FEMA). (2020, 19 December). *Community Lifelines Toolkit 2.0*. Available at: https://www.fema.gov/media-library/assets/documents/177222

Federal Emergency Management Agency (FEMA). (2021). *FEMA Fact Sheet: Using the Limit of Moderate Wave Action to Build Resilient Coastal Communities.* Available at: https://www.fema.gov/sites/default/files/documents/fema_using-limit-oderate-wave-action_fact-sheet_5-24-2021.pdf

Florida Department of Agriculture and Consumer Services, Division of Forestry. (2010). *Wildfire Risk Reduction In Florida: Home, Neighborhood, And Community Best Practices*. Available at: https://www.fdacs.gov/ezs3download/download/25647/516527/Media/Files/Florida-Forest-Service-Files/Wildfire_Risk_Reduction_in_FL.pdf.

Florida Department of Business and Professional Regulation. (2020). Building Codes and Standards. Accessed September, 2020. Available at: http://www.floridabuilding.org/fbc/codes_standards_intro/1_%20overview_codes_standards.htm

Florida Department of Environmental Protection (FDEP). (2017a). *Critically Eroded Beaches in Florida.* Florida

Department of Environmental Protect, Division of Water Resource Management.

Florida Department of Environmental Protection (FDEP). (2017b). *Coastal Range Monument Locations.* Available at: https://geodata.floridagio.gov/datasets/FDEP::coastal-range-monument-locations/about

Florida Department of Environmental Protection (FDEP). (2008). *Florida Friendly Best Management Practices for Protection of Water Resources by the Green Industries.* Florida. A Florida–Friendly Landscape Publication.

Florida Department of Environmental Protection (FDEP). (2020a, June 8). *Living Shorelines: Natural Protection of Florida's Coasts.* https://floridadep.gov/rcp/rcp/content/living-shorelines

Florida Department of Environmental Protection (FDEP). (2020b). *Strategic Beach Management Plan for the Southeast Atlantic Region*.

Florida Department of Environmental Protection (FDEP). (2020c, June 3). *Comprehensive Verified List.* Available at https://floridadep.gov/dear/watershed-assessment-section/documents/comprehensive-verified-list

Florida Department of Environmental Protection (FDEP). (2020d, July 21). *Algal Bloom Sampling Results.* Available at https://floridadep.gov/dear/algal-bloom/content/algal-bloom-sampling-results

Florida Department of Environmental Protection Geospatial Open Data (FDEP). (2020e, January). *Verified List Waterbody Ids (WBIDs)*. Available at https://geodata.dep.state.fl.us/datasets/89be6289aaca45dfb197ccd485f833cd_5

Florida Department of Environmental Protection Open Data Portal (FDEP). (2020f, July 22). *Waterbody IDs (WBIDs).* Available at https://geodata.dep.state.fl.us/datasets/d3bb23dc9507422a86c95eb5efc964c9_0/explore?location=27.987700%2C-83.466600%2C6.86

Florida Department of Health. (2020). *Food and Waterborne Disease Outbreak Database.* Accessed November 2020. Available at: http://www.floridahealth.gov/diseases-and-conditions/food-and-waterborne-disease/food-waterborne-outbreak-data-search.html .

Florida Fish and Wildlife Conservation Commission (FWC). (2021, February 25). *FWC approves rule changes to help protect Florida from 16 high-risk invasive reptiles.* Available at: https://myfwc.com/news/all-news/invasive-comm-221/

Florida Housing Finance Corporation (Florida Housing). (2017). *Overview of the Florida Building Code.* Available at: https://www.floridahousing.org/docs/default-source/aboutflorida/august2017/august2017/tab4.pdf

Florida Power and Light. (2019, March 1). *News Releases: FPL delivers best-ever service reliability in 2018, plans to harden all main power lines within six years*. Available at: http://newsroom.fpl.com/news-releases?item=126077#:~:text=By%20the%20end%20of%202022,will%20be%20steel%20or%20concrete.&text=Hardening%20means%20that%20FPL%20is,withstand%20major%20hurricane%2Dforce%20winds

Georgetown Climate Center. (2020). *Equitable Adaptation Legal and Policy Toolkit*. Available at: https://www.georgetownclimate.org/adaptation/toolkits/equitable-adaptation-toolkit/authors-and-acknowledgements.html

Glick, P., B. A. Stein, and N.A. Edelson, editors. (2011). *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. National Wildlife Federation. Available at:

https://www.nwf.org/~/media/pdfs/global-warming/climate-smart-conservation/nwfscanningtheconservationhorizonfinal92311.ashx

Interagency Security Committee. (2015). *Presidential Policy Directive 21 Implementation*. Available at: https://www.cisa.gov/sites/default/files/publications/ISC-PPD-21-Implementation-White-Paper-2015-508.pdf

Intergovernmental Panel on Climate Change (IPCC). (2013). *The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley. Available at: https://www.ipcc.ch/report/ar5/wg1/ .

Intergovernmental Panel on Climate Change (IPCC). (2019). *Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.* H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. Weyer. Available at: https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/ .

Kennedy, M. (2016, July 2). *Thick, Putrid Algae Bloom Overwhelms Miles Of Florida Coastline.* WLRN. https://www.wlrn.org/2016-07-02/thick-putrid-algae-bloom-overwhelms-miles-of-florida-coastline

Kimley Horn. (2019, May). *Water Supply and Treatment Feasibility Study*. City of Delray Beach.

Kossin, J.P., T. Hall, T. Knutson, K.E. Kunkel, R.J. Trapp, D.E. Waliser, and M.F. Wehner. (2017). *Extreme storms. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 257-276, doi: 10.7930/J07S7KXX.

Kossin, J., Knapp, K., Olander, T., and Velden, C. (2020). *Global Increase in Major Tropical Cyclone Exceedance Probability Over the Past Four Decades.* Proceedings of the National Academy of Sciences of the United States of America, 117 (22) 11975-11980.

Landsea, C. W. and J. L. Franklin. (2013). *Atlantic Hurricane Database Uncertainty and Presentation of a New Database Format*. Mon. Wea. Rev., 141, 3576-3592.

Lake Worth Drainage District. (2019, October). *Lake Worth Drainage District 2019 Water Control Plan*. LWDD.

Liang, S., Kintziger, K., Reaves, P., & Ryan, S. J. (2017). Climate Change Impacts on Human Health. *Florida's Climate: Changes, Variations, & Impacts.* Retrieved from http://purl.flvc.org/fsu/fd/FSU_libsubv1_scholarship_submission_1515442924_f244ee60

Malczewski, Jacek, and Claus Rinner. (2015). *Multicriteria Decision Analysis in Geographic Information Science*. Springer-Verlag.

Marella, R.L. (2015). *Water withdrawals in Florida, 2012*. U.S. Geological Survey Open-File Report 2015–1156, 10 p., http://dx.doi.org/10.3133/ofr20151156.

Marella, R.L. (2020). *Water withdrawals, uses, and trends in Florida, 2015*. U.S. Geological Survey Scientific Investigations Report 2019–5147, 52 p., https://doi.org/10.3133/sir20195147

Mehta, Kishor C. (2010). *Wind Load History: ANSI A58.1-1972 to ASCE 7-05*. 2010 Structures Congress. Available at: https://ascelibrary.org/doi/pdf/10.1061/41130%28369%29193

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe. (2014). *Climate Change Impacts in the United States: The Third National Climate Assessment*. Washington, D.C.: U.S. Global Change Research Program. Available at: https://nca2014.globalchange.gov

Miami Dade Government. (2016). *Report on Flooding and Saltwater Intrusion, Final Report for Resolution 4-48-15 in support of the Sea Level Rise Task Force Final recommendations*. Miami-Dade County. https://www.miamidade.gov/green/library/sea-level-rise-flooding-saltwater-intrusion.pdf

Miller, K. (2021, January 11). *Is red tide outbreak in southwest Florida a threat to Palm Beach County?* Palm Beach Post. https://eu.palmbeachpost.com/story/weather/2021/01/11/red-tide-no-threat-palm-beach-county-beaches-now/6620253002/

Mock Roos Consulting Engineers. (2020). *City of Lake Worth Beach 2020 10-Year Water Supply Facilities Work Plan*. City of Lake Worth Beach.

Monitoring Trends in Burn Severity (MTBS) and the US Forest Service (USFS). *Historical Large Wildfire Perimeters*. Accessed from the US Forest Service's Forest Change Assessment Viewer, April 6, 2020. Available at: https://forwarn.forestthreats.org/fcav/

National Drought Mitigation Center & USDA Federal Drought Assistance. (n.d.). *Florida | Drought.gov*. Drought.Gov U.S. Drought Portal. Retrieved November 5, 2020, from https://www.drought.gov/drought/states/florida#:%7E:text=from%202000%20%2D%202020,affected%2039.08%25%20of%20Florida%20land

National Landcover Dataset (NLCD). (2016). Multi-Resolution Land Characteristics Consortium. Available at: https://www.mrlc.gov/

NOAA National Centers for Environmental Information (NOAA NCEI). (n.d). *Climate at a Glance, U.S. Time Series*. Accessed June 25, 2020. Available at: https://www.ncdc.noaa.gov/cag/divisional/time-series

NOAA National Centers for Environmental Information (NOAA NCEI). (2017). *State Climate Summaries*. Available at: https://statesummaries.ncics.org/chapter/fl/

National Oceanic and Atmospheric Administration (NOAA). (2016). *The Atlantic Hurricane Database Re-analysis Project*. Available at: https://www.aoml.noaa.gov/hrd/hurdat/comparison_table.html

NOAA Center for Operational Oceanographic Products and Services (NOAA). (n.d.) Sea level trends

NOAA's National Weather Service (NOAA). (2010, April 21). *NOAA Atlas 14 Point Precipitation Frequency Estimates: FL*. Available at https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=fl

NOAA Tides and Current (NOAA). (2020a). *Lake Worth Pier, Atlantic Ocean, FL - Station ID: 8722670*. Accessed June 25, 2020. Available at: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml? id=87 22670

NOAA Tides and Currents (NOAA). (2020b). *Gulf of Mexico Harmful Algal Bloom Forecast: Forecast Archive, East Florida*. Accessed August 18, 2020. Available at: https://www.tidesandcurrents.noaa.gov/hab/gomx.html

NOAA National Ocean Service (NOAA). (2021, February 26). *What is storm surge?* Available at: https://oceanservice.noaa.gov/facts/stormsurge-stormtide.html

Office of the Press Secretary, The White House. (2013). Presidential Policy Directive -- Critical Infrastructure Security and Resilience. Available at: https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil

Overbeck, J.R., and Doran, K.S. (2015). *Data Release, Beach slopes of Florida: Miami to Jupiter.* U.S. Geological Survey data release*.* Available at: http://dx.doi.org/10.5066/F72805P1 .

Palm Beach County, Environmental Resources Management. (n.d). *Beaches.* Accessed 3 March, 2021. Available at: https://discover.pbcgov.org/erm/pages/beaches.aspx

Palm Beach County, Florida Water Utilities Department. (2020, March). *Palm Beach County 10-Year Water Supply Facilities Work Plan*. Palm Beach County, FL.

Palm Beach County MS4 NPDES (PBC NPDES). *Cycle 4, Year 2 (2017-2018) Pollutant Loading Coverages*. Accessed August 17, 2020. Available at http://www.pbco-npdes.org/reports_2018_C4Y2/PollutantLoadingCoverages/list.asp

Patz, J. A., Githeko, A. K., McCarty, J. P., Hussein, S., Confalonieri, U., & de Wet, N. (2003). *Chapter 6: Climate change and infectious diseases. In Climate Change and Human Health - Risks and Responses. Essay.* WHO, Geneva.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I.; Fried, J.S.; Holcomb, S.S.; McKeefry, J.F. (2005). *The wildland-urban interface in the United States*. Ecological Applications 15(3): 799-805.

Radeloff, V. C., D. P. Helmers, H. A. Kramer, M. H. Mockrin, P. M. Alexandre, A. Bar-Massada, V. Butsic, T. J. Hawbaker, S. Martinuzzi, A. D. Syphard, and S. I. Stewart. (2018). *Rapid growth of the U.S. Wildland Urban Interface raises wildfire risk.* Proceedings of the National Academy of Sciences, 115(13): 3314-3319.

Roshani, Atena & Mirfenderesk, & Rajapakse, & Gallage, Chaminda. (2013). *Groundwater Table response to Sea Level Rise and its Impact on Pavement Structure.*

Shimberg Center for Housing Studies. (2020). Florida Housing Data Clearinghouse. Available at: http://flhousingdata.shimberg.ufl.edu/

South Florida Water Management District (SFWMD). (2002). *The 2000-2001 Drought in South Florida.*

South Florida Water Management (SFWMD). (2009, November 12). *Climate Change and Water Management in South Florida.* Available at: https://www.sfwmd.gov/sites/default/files/documents/climate_change_and_water_management_in_sflorida_12nov2009.pdf

South Florida Water Management District (SFWMD). (2016). *Environmental Resource Permit Applicant's Handbook Volume II.*

South Florida Water Management District (SFWMD). (2018). *2018 Lower East Coast Water Supply Plan Update*. Available at: https://www.sfwmd.gov/sites/default/files/documents/2018_lec_plan_planning_doc.pdf .

South Florida Water Management District (SFWMD). (2020, March 31). *Merged Isochlor, 2019*. South Florida Water Management District Open Data. Available at: https://geo-sfwmd.hub.arcgis.com/datasets/merged-isochlor-2019 .

South Florida Water Management District (SFWMD). (2021, April 15). *Vegetation and Exotic Control*. Available at: https://www.sfwmd.gov/our-work/vegetation

Southeast Florida Regional Climate Compact. (2014, September 9). *RCAP Implementation Guidance Series: Integrating Climate Change & Water Supply Planning in Southeast Florida.* Available at: https://southeastfloridaclimatecompact.org//wp-content/uploads/2014/09/rcap-igd-water-supply-final-9-9.pdf

Southeast Florida Regional Climate Compact. (2015). *RCAP Implementation Guidance Series: Regional Impacts of Climate Change and Issues for Stormwater Management.* Available at: https://southeastfloridaclimatecompact.org/wp-content/uploads/2015/11/Stormwater-Guide.pdf

Southeast Florida Regional Climate Compact. (2020). *Unified Sea Level Rise Projection Southeast Florida: 2019 Update.* Available at: https://southeastfloridaclimatecompact.org/wp-content/uploads/2020/04/Sea-Level-Rise-Projection-Guidance-Report_FINAL_02212020.pdf.

Stewart, M. Deng, X. (2014). *Climate Impact Risks and Climate Adaptation Engineering for Built Infrastructure.* ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, Vol. 1, Issue 1 (March 2015). Available at: https://ascelibrary.org/doi/10.1061/AJRUA6.0000809#:~:text=Climate%20adaptation%20measures%20aim%20to,and%20changes%20to%20inspection%20and

Stewart, S., Volker C. Radeloff, Roger B. Hammer, Todd J. Hawbaker. (2007). *Defining the Wildland–Urban Interface*. Journal of Forestry, Volume 105, Issue 4, June 2007, Pages 201–207. Available at: https://academic.oup.com/jof/article/105/4/201/4734816

Sweet, W.V., G. Dusek, J. Obeysekera, and J. Marra. (2018). *Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold*. NOAA Technical Report NOS CO-OPS 086, 44 pp. Available at: https://tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf

The Nature Conservancy (TNC). (2018, September 11). *Stopping the Spread of Invasive Species The threat posed by invasive species is second only to habitat destruction through development.* Available at: https://www.nature.org/en-us/about-us/where-we-work/united-states/florida/stories-in-florida/combating-invasive-species-in-florida/

Town of Highland Beach, Florida. (2020, July 31). *Town of Highland Beach 10 Year Water Supply Work Plan.*

Triangle Regional Resilience Partnership (October, 2018). *Triangle Regional Resilience Partnership Resilience Assessment Technical Report.* Available at: https://www.tjcog.org/sites/default/files/uploads/trrp_report_technicalreport_102418.pdf

Urban Land Institute. (2020). *The Business Case for Resilience in Southeast Florida: Regional Economic Benefits of Climate Adaptation.* Available at: https://knowledge.uli.org/-/media/files/research-reports/2020/the-business-case-for-resilience-in-southeast-florida221reduced.pdf?rev=705c255e215b481e9a5ebfba1a45959a&hash=1598861F717B7875869FDC6E9CA33F64

U.S. Army Corps of Engineers (USACE), Institute for Water Studies. (1992). Catalog of Residential Depth-damage Functions Used by the Army Corps of Engineers in Flood Damage Estimation. IWR Report 92-R-3. May, 1992. Available at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a255462.pdf

U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Estimates. Available at: https://www.census.gov/programs-surveys/acs/data/summary-file.2018.html

U.S. Census Bureau. (2020). *Community Resilience Estimates: Quick Guide*. Available at: https://www2.census.gov/data/experimental-data-products/community-resilience-estimates/2020/technical-document.pdf

U.S. Climate Resilience Toolkit (USCRT). (2016, November 16). *Changing Ecosystems and Infectious Diseases*. U.S. Federal Government. Available at: https://toolkit.climate.gov/topics/human-health/altered-risk-infectious-diseases

U.S. Climate Resilience Toolkit. (2017a). *Coasts, Storm Surge*. Available at: https://toolkit.climate.gov/topics/coastal/storm-surge

U.S. Climate Resilience Toolkit. (2017b). *Extreme Heat—NIHHIS*. U.S. Federal Government. Available at: https://toolkit.climate.gov/topics/human-health/extreme-heat

U.S. Climate Resilience Toolkit Climate Explorer. (2020). *The Climate Explorer*. Available at: https://crt-climate-explorer.nemac.org

U.S. Environmental Protection Agency. (2008). *Reducing urban heat islands: Compendium of strategies. Draft*. Available at: https://www.epa.gov/heat-islands/heat-island-compendium

U.S. Fish and Wildlife Service (USFWS). (2004). *South Florida Prescribed Burn Helps Stop Wildfire from Spreading.* Loxahatchee National Wildlife Refuge. Available at: https://www.fws.gov/fire/news/fl/newsitem2.shtml

U.S. Fish and Wildlife Service (USFWS). (2017). *Arthur R. Marshall Loxahatchee National Wildlife Refuge, Florida: Fire Management*. Available at: https://www.fws.gov/refuge/arm_loxahatchee/what_we_do/resource_management/fire_management.html

U.S. Fish and Wildlife Service (USFWS). (2019, May 3). *South Florida Ecological Services Field Office: Invasive Species*. Available at: https://www.fws.gov/verobeach/InvasiveSpecies.html

U.S. Forest Service (USFS). (2016). *2016 Tree Canopy Cover*. Multi-Resolution Land Characteristics Consortium. Available at: https://www.mrlc.gov/data

U.S. Global Change Research Program (USGCRP). (2018). *Impacts, Risks, and Adaptation in the* United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018. Available at: https://nca2018.globalchange.gov/

University of Wisconsin-Madison/ SILVIS Lab. (2020, September 15). Wildland-Urban Interface (WUI) Change 1990-2010. Available at: http://silvis.forest.wisc.edu/data/wui-change/

Verdi, R. J., Tomlinson, S. A., & Marella, R. L. (2006). *The Drought of 1998-2002: Impacts on Florida's Hydrology and Landscape*. U.S. Geological Survey Circular 1295. https://pubs.usgs.gov/circ/2006/1295/pdf/circ1295.pdf

Viessman, W., Hammer, M., Perez, E., Chadik, P. (2009). *Water Supply & Pollution Control.* 8th Edition. Pearson Prentice-Hall.

CRP
Coastal Resilience Partnership

Climate Change Vulnerability Assessment City of Boca Raton

Boca Raton's participation and support of the CRP reflects the City leadership's continued commitment to community sustainability and environmental stewardship. Staff recognize that the results of the CCVA will help identify additional opportunities to improve climate resilience through infrastructure, local rules and policy, public outreach and education, and capacity building throughout the region.

Key Study Findings for Boca Raton

- Highest levels for vulnerability to high winds are associated with the following asset categories: Parks & Cultural properties (100%), Health and Medical (57%), Energy and Communications (44%), and Food Infrastructure (43%).
- Residential properties have lower vulnerability compared to the study area as whole due to more recent residential building construction in the area.
- The highest levels of citywide vulnerability and risk are associated with rainfall-induced flooding when compared to other flood threats.
- An especially high number of commercial properties (81%) in the census tract encompassing the industrial district located in the north-central area of the City have medium or high vulnerability and risk to rainfall-induced flooding (just North of the Boca Raton Airport and along the Clint Moore Road and Yamato Road corridors).
- Vulnerability and risk to 2020 conditions (100-year storm event only) for critical facilities ranges from 14-30% across critical facility asset types. With future change these ranges increase to 19%-57% by 2070 (2020 baseline + 33" SLR) with the largest percent increases associated with Energy and Communications, Food Infrastructure, and Health and Medical facilities.
- With 2020 conditions, about a third of the SNAP retailers are highly vulnerable to rainfall-induced flooding. By 2040 (2020 baseline + 5" SLR) about half of these food infrastructure facilities could be vulnerable to rainfall-induced flooding.
- Nearly 20% of residential properties in the City are highly vulnerable to 100-year rainfall-induced flooding.
- 8 of the 28 census tracts within the City have more than 67% of residential properties with medium to high vulnerability and risk. Most of these census tracts are in the western part of the city.
- About 80% of residential properties have medium to high vulnerability and risk to rainfall-induced flooding in an area in the southwestern corner of the City (between W. Camino Real and W. 18th Street and along S. Military Trail). A relatively high proportion of these households are below the poverty line (as well as relatively low median household income).

- While the citywide number of properties vulnerable to storm surge is less than those vulnerable to rainfall-induced flooding, within three census tracts in the eastern part of the City over 65% of the residential properties are highly vulnerable to storm surge inundation. Storm surge vulnerability extends further west than in other communities because of the El Rio Canal and the number of important assets which are located near the canal. Regional studies conducted by South Florida Water Management District and Lake Worth Drainage District to prepare for climate change are significant to the future of the City. The area surrounding Lake Boca Raton has high vulnerability to shoreline recession and storm surge for both 2020 and future conditions. Future work should focus on the protection of shoreline and mitigation of future surge events.
- Many of the areas vulnerable and at risk to storm surge could potentially see flood depths of more than three feet; therefore, evacuation planning is critical for these areas.
- Vulnerability and risk to tidal flooding (2020) conditions is relatively low when compared to the remainder of the region. By 2070, vulnerability of commercial and residential properties to tidal flooding is expected to increase 7-10 fold.
- Under 2020 tidal flooding conditions, road inaccessibility is mostly limited to the coastal census tract south of Lake Boca Raton. However, by 2070 a high proportion of roads and properties (over 90%) along the Intracoastal Waterway and the coast could be potentially inaccessible.
- The area surrounding and to the south of the Boca Raton airport is identified as the most vulnerable to extreme heat due to relatively high development densities and low tree canopy coverage.

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the City owns and the second list describes assets located within the City that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

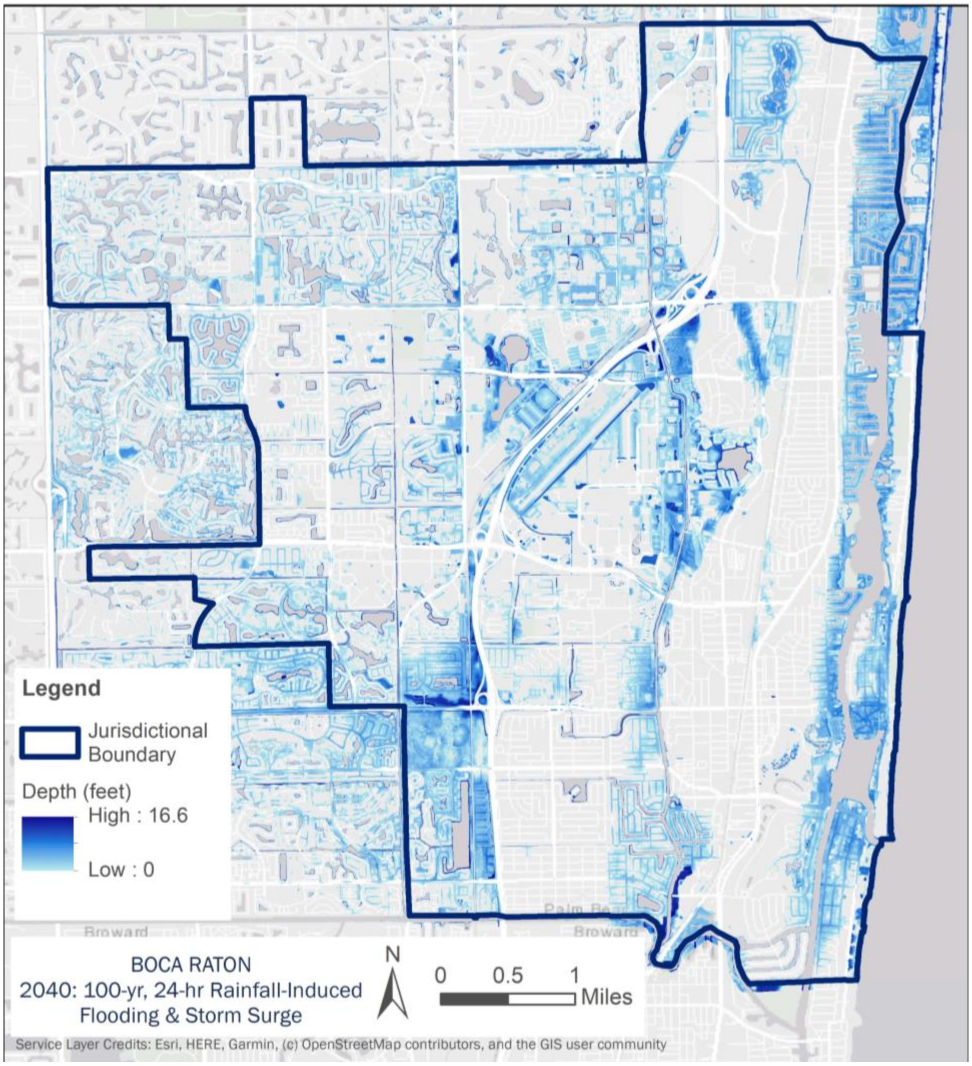


Figure A1-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Boca Raton, Florida (2040).

Top 5 City-Owned Asset Categories of Concern

- City-owned fire stations near the Intracoastal Waterway and canals as listed below:
  - City of Boca Raton Fire Rescue Station 3 (100 S Ocean Boulevard) is vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds due to its location near the coast.
  - City of Boca Raton Fire Rescue Station 6 (1901 Clint Moore Road) is vulnerable to rainfall-induced flooding and high winds, but it is not located on the Intracoastal Waterway or canals.
  - City of Boca Raton Fire Rescue Station 5 (2333 Glades Road) is vulnerable to rainfall-induced flooding and high winds and is located near the Gulf Stream Canal.
- Boca Raton Housing Authority – Dixie Manor (1350 N Dixie Highway) is vulnerable to rainfall-induced flooding and high winds, but it is not located on the Intracoastal Waterway or canals.

Top 5 Non-City-Owned Asset Categories of Concern

- Private educational facilities near the coast and/or canals as follows:
  - St Paul Lutheran Church and School (701 W Palmetto Park Road) is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds and is located on the Gulf Stream Canal.
  - Grace Community Church and Preschool (600 W Camino Real) is vulnerable to storm surge, rainfall-induced flooding, high winds, and tidal flooding and is located on the Gulf Stream Canal.
- Higher education facilities, including buildings and various outparcels as follows:
  - Florida Atlantic University (777 Glades Road) is vulnerable to rainfall-induced flooding, storm surge, high winds, and tidal flooding.
  - Florida Atlantic University (1880 Florida Atlantic Boulevard) is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
- FPL Substation North of SW 20th Street, South of SW 19th Street, East of Gonzalo Rd, and West of SW 8th Avenue. This substation is vulnerable to rainfall-induced flooding, storm surge, and high winds. It is located near the Gulf Stream Canal.
- Suntrust Bank (880 E Palmetto Park Road) is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds. It is located near the coast.
- Palm Beach County Schools:
  - Verde Community Elementary (6590 Verde Trail) is vulnerable to rainfall-induced flooding and high winds. It is located near the Gulf Stream Canal.
  - Calusa Elementary School (2051 Clint Moore Road) is vulnerable to rainfall-induced flooding and high winds. It is not located near a canal or the Intracoastal Waterway.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the City of Boca Raton are highlighted in a portfolio format that follows.

Boca Raton: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-BR-1	Maintain and restore existing coastal habitats, such as mangroves and maritime hammock, and develop incentives and strategies to expand the spatial extent of these systems on developed properties for the benefit of attenuation of storm surge waves and to prevent shoreline recession.	Shoreline Recession, Storm Surge, Harmful Algal Blooms (HABs)
	INF-BR-2	Expand renewable energy in the community by increasing solar installations on City property, creating solar ready requirements for commercial and residential property, and increasing incentives for solar energy systems that also address equity and energy burden related to cooling costs.	Extreme Heat
	INF-BR-3	Along canals and other upland water bodies potentially impacted by surge and/or rainfall-induced flooding, provide/enhance vegetated buffers and/or restore wetlands to provide more resilient habitats to improve water quality and reduce velocities of flood waters. This effort should be linked to the City's/region's development of any Low Impact Development (LID) Manuals.	HABs, Storm Surge, Rainfall-induced Flooding, Tidal Flooding, Shoreline Recession
	INF-BR-4	Evaluate and design strategic seawall projects to address vulnerable areas based on the findings of this study and staff recommendations. Design seawalls to withstand conditions for future tidal and storm surge to the greatest extent possible.	Tidal Flooding, Storm Surge, Shoreline Recession
	INF-BR-5	Evaluate and design strategic stormwater projects to address vulnerable areas based on the findings of this study and staff recommendations. Whenever possible, link Capital Improvement Projects (CIPs) to water quality and Federal Emergency Management Agency (FEMA) requirements for funding to increase likelihood of grants.	Rainfall-induced Flooding, HABs

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE (CONTINUED)	INF-BR-6	Assess existing shorelines in the City and identify needs and opportunity for seawall improvements and the implementation of natural shorelines or living seawalls to protect public infrastructure and mitigate erosion. Once assessed, begin strategic restoration projects and use nature-based solutions whenever possible.	Shoreline Recession, Storm Surge, HABs, Tidal Flooding
	INF-BR-7	Maintain and improve existing coastal dunes through exotic species removal and habitat restoration.	Shoreline Recession, Storm Surge, Tidal Flooding
LAND USE BUILDING CODES AND STANDARDS	LU-BR-1	Review and consider revising requirements for commercial projects that require high percentages of native plants to achieve aesthetic and irrigation-related water reduction goals.	Saltwater Intrusion, HABs
	LU-BR-2	Improve resilience to heat and flooding in new development by creating code requirements that increase green space and pervious area.	Extreme Heat, Rainfall-induced Flooding, HABs
	LU-BR-3	Create safe and shaded walking and biking connectivity to schools, employment centers, and transportation hubs.	Extreme Heat
	LU-BR-4	Consider developing green building standards for multi-family and commercial developments focused on enhanced sustainable practices. Focus on reducing energy usage and enhancing the overall livability of communities in Boca Raton.	Extreme Heat, Rainfall-Induced Flooding
	LU-BR-5	Expand renewable energy purchasing options by encouraging investment in community solar and energy programs. Program including developing a consortium of Homeowners Associations (HOAs) to pilot and test solar and energy co-ops in various communities. Eventual programming to include citywide rollout.	Extreme Heat

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT	PP-BR-1	Create a green infrastructure design manual to provide a toolbox of green infrastructure practices and site design options for municipal staff and consulting engineers and architects. The design manual should include pollutant removal efficiencies, design constraints, and appropriate settings and materials. The manual can serve as a reference for ordinances and regulations and be similar in nature to Florida Department of Environmental Protection's (FDEP) guidance (https://floridadep.gov/rcp/coral/documents/low-impact-development-green-infrastructure-pollution-reduction-guidance-water) but would be modified for usage in Boca Raton. Consider incorporating the Boca LID Manual into the City's codes and regulation by reference.	HABs, Rainfall-Induced Flooding
	PP-BR-2	Develop and implement policies and design standards that recognize the transportation system's most vulnerable users and incorporate sustainable design elements that address those vulnerabilities (shade trees, LID principles, pervious pavement, low energy usage, measures to make electronic vehicle (EV) and public transportation usage easier, etc.).	Extreme Heat, Rainfall-Induced flooding, HABs
	PP-BR-3	Design public infrastructure and critical facilities with longevities of greater than 50 years to accommodate expected sea level rise based on the 2070 (National Oceanic and Atmospheric Administration (NOAA) high) projections according to the recommended projection from the Southeast Florida Regional Climate Compact Unified Projection for critical infrastructure.	Storm Surge, Tidal Flooding, Shoreline Recession
	PP-BR-4	Identify through vulnerability assessments and capital planning efforts vulnerable infrastructure and rehabilitate those that are at high risk of failure. Use capital planning processes to upgrade and rehabilitate vulnerable infrastructure identified by this assessment.	High Winds, Storm Surge, Tidal Flooding, Rainfall-Induced Flooding

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)	PP-BR-5	Assess the feasibility of implementing solar energy and battery storage in critical facilities for emergency management and disaster recovery and add solar/battery projects to the Capital Improvement Plan.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
	PP-BR-6	Create a program inspired by the Building Efficiency 305 Program in Miami geared towards increasing water and energy efficiency in large buildings.	Saltwater Intrusion, Extreme Heat
	PP-BR-7	Identify and expand incentives for sustainable businesses to locate within the area, such as those that research and add capacity to strategic workforce initiatives like the development of green jobs.	All Threats
	PP-BR-8	Create a strategic Stormwater Study that includes a potential Community Rating System (CRS) rating increase for the City. Study should focus on enhanced water quality measures that the City can use towards future Total Maximum Daily Load (TMDL) credits and other CIPs that are grant-worthy for the City (such as FEMA funding and 319 grants).	HABs, Rainfall-induced Flooding
	PP-BR-9	Continue exploring integration of Adaptation Action Areas (AAAs) into City planning processes based on the findings of this study.	Storm Surge, Tidal Flooding
CAPACITY BUILDING	CB-BR-1	Build partnerships and opportunities for increasing sustainable infrastructure projects and/or voluntary incentives.	All Threats
	CB-BR-2	Provide/require training for municipal and private engineers on the menu of effective green stormwater practices. Discuss challenges due to climate, groundwater, and proximity to canals and waterbodies.	HABs, Saltwater Intrusion, Rainfall-induced Flooding
	CB-BR-3	Facilitate home weatherization and energy efficiency programs for low- and medium-income households. Consider the use of State and Federal funding programs.	Extreme Heat, High Winds
	CB-BR-4	Help golf courses manage water use, plant littoral zones around their waterways so they do not have to complete chemical treatment	HABs

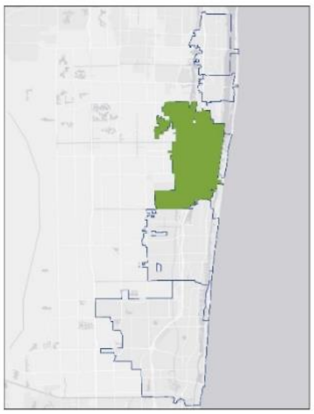
STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
CAPACITY BUILDING (CONTINUED)	CB-BR-5	Revise landscape codes to maintain and expand urban tree canopy.	Extreme Heat
PUBLIC OUTREACH	PO-BR-1	Continue engagement with businesses and neighborhoods on issues of resilience and sustainability. Modify existing programs as needed to align with the findings of this study.	All Threats
	PO-BR-2	Work with community groups to fund and commission a credible third-party study assessing the risk and extent of climate gentrification, and possible solutions.	All Threats
	PO-BR-3	Create a volunteer flood watch system where local residents report observations to the City. A hotline and App can be employed to collect and manage this information.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	PO-BR-4	Use heat maps to show "hot spots" for reported flooding (locations of calls over time).	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	PO-BR-5	Recruit a network of climate liaisons in vulnerable communities and neighborhoods to connect with residents and better understand how climate threats affect vulnerable populations and to disseminate information to their community. Liaisons should be advocates and communicators that live in Boca Raton and that are tied to each community.	All Threats
FUNDING AND FINANCE	FF-BR-1	Seek new legislation and appropriate streams of revenue to support projects.	All Threats
	FF-BR-2	Develop incentives for construction of affordable housing designed for natural cooling to minimize the need for air conditioning and resultant energy use.	Extreme Heat
	FF-BR-3	Change City planning processes to include a "funding first" approach where economics, finance, and climate change are considered first and then throughout the planning processes.	All Threats
	FF-BR-4	Find ongoing funds to replant established canopy after wind events	High Winds, Extreme Heat

CRP

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
FUNDING AND FINANCE (CONTINUED)	FF-BR-5	Begin preparing key findings of this study to compete for funding with the landmark 'Always Ready' resilience law. Share lessons learned and resources as a part of the CRP.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding
	FF-BR-6	Collaborate with the Coastal Resilience Partnership (CRP) to locate resources regarding a diverse suite of financing and tools to assist individuals with personal home or business adaptation.	All Threats
	FF-BR-7	Consider re-evaluating the City's Stormwater Utility rate structure. Set a schedule for routine revisions to the City's rate structure based on the findings of the study.	Rainfall-Induced Flooding, HABs
	FF-BR-8	Develop stormwater projects with multi-benefits (particularly geared to water quality) to align with State and Federal funding sources. Primary funding sources include but are not limited to FEMA and 319 Grants.	Rainfall-Induced Flooding, HABs

Coastal Resilience Partnership

Climate Change Vulnerability Assessment City of Boynton Beach



Boynton Beach is a vibrant City with a focused and holistic approach to building resilience. Staff are dedicated to both traditional engineering techniques but also emerging processes and practices to help the City adapt to conditions in future years. Trees, green infrastructure, environmental stewardship, and strategic policy were common topics at the Boynton Beach meetings that were held throughout the study. Staff leadership also made social equity a key issue for the study.

Key Study Findings for Boynton Beach

- The most vulnerable areas within the City of Boynton Beach consist of areas with aging infrastructure and where critical facilities are located near waterbodies (both near the Intracoastal Waterway and inland). Some of these vulnerable areas are west of Interstate-95 and Congress Avenue, which may be a surprising finding that demonstrates the importance of understanding inland flooding. Specifically, some of these areas of concern also include Lake Boynton Estates and Industrial Way.
- Areas within Boynton Beach are particularly vulnerable to flooding due to relatively low topography. For example, some of these areas are near North Lake Drive, where roadways are less than 2 feet (NAVD 88). This elevation is generally lower than King Tide elevations.
- Schools, particularly those located near waterbodies, were found to be particularly vulnerable to rainfall-induced flooding. These results suggest that facility hardening and adaptation be considered as part of any refurbishment or upgrades to educational facilities in the coming years.
- The highest levels (percentages) of vulnerability and risk are associated with rainfall-induced flooding. The following property types and critical facilities categories have the highest percentages of vulnerability and risk to rainfall-induced flooding (2020, 100-year storm event only): residential (25%), food infrastructure (21%), and commercial and industrial (16%). In addition to these, about 43% of the City's assessed improved (building) values are associated with properties vulnerable to the 100-year storm event flood extent. Vulnerability of the City's Roads & Mobility is another key issue with 55% of major roads potentially inaccessible with a 100-year event, along with 45% of the minor roads and 47% of the properties associated with potentially inaccessible roads.
- While the overall number of properties vulnerable to storm surge is less compared to rainfall-induced flooding, high vulnerability of residential (including large multi-residential) and commercial properties to storm surge is concentrated in several areas near the Intracoastal Waterway. Vulnerability to tidal flooding is primarily limited to low-lying residential property (including large multi-residential) and roads. While this

vulnerability is relatively low based on 2020 conditions, vulnerability in the future could increase to almost 10 times current levels when compared with the 2070 (2020 baseline + 33" SLR) condition.

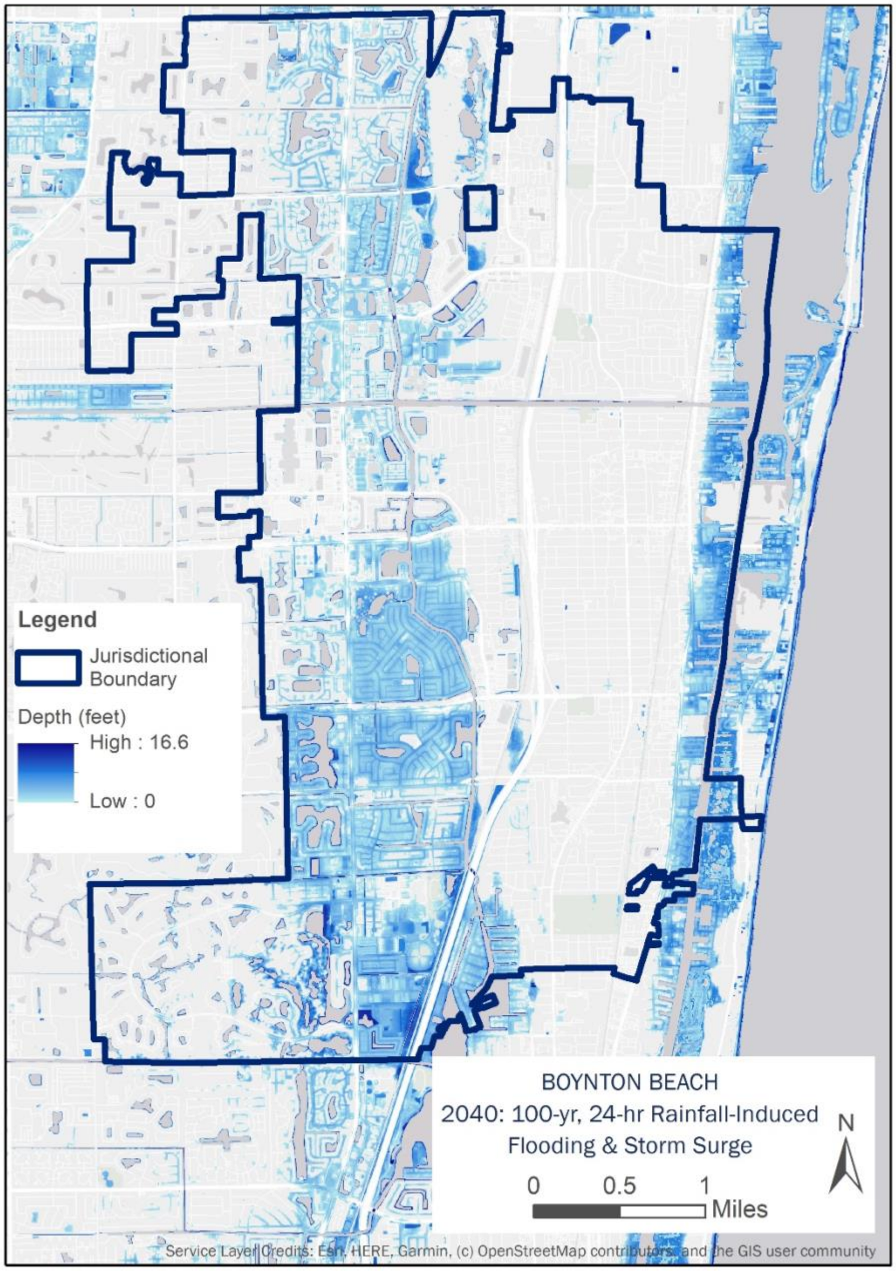


Figure A2-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Boynton Beach, Florida (2040).

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed on the following page. The first list focuses on assets that the City owns, and the second list contains assets located within the City that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

Top 5 City-Owned Asset Categories of Concern

- Boynton Harbor Marina (320 N Federal Hwy, Boynton Beach, FL 33435) is a coastal government facility that is expected to be damaged in a significant storm event and has relatively lower replacement costs. It is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
- Boynton Beach Fire Station 3 (3501 N Congress Ave, Boynton Beach, FL 33436) is vulnerable to rainfall-induced flooding and wind.
- Boynton Beach Fire Station 4 (1919 S Federal Hwy, Boynton Beach, FL 33435) is vulnerable to storm surge, rainfall-induced flooding, and high winds and is located near the Intracoastal Waterway.
- Boynton Beach Fire Station 2 (2615 Woolbright Rd, Boynton Beach, FL 33426) is vulnerable to rainfall-induced flooding and high winds but is not located near a canal or the Intracoastal Waterway.
- Hester Community Center (1901 N Seacrest Blvd, Boynton Beach, FL 33435) is vulnerable to rainfall-induced flooding and high winds. It is located less than 1 mile from the Intracoastal Waterway and from Boynton Canal.

Top 5 Non-City-Owned Asset Categories of Concern

- Palm Beach County Schools and transportation lots:
    - Congress Middle School (101 S Congress Ave, Boynton Beach, FL 33426) is vulnerable to rainfall-induced flooding and high winds.
    - Palm Beach District Schools Transportation Department – South Facility (1302 SW 30th Ave, Boynton Beach, FL 33426) is vulnerable to rainfall-induced flooding and high winds.
- Commercial properties, especially along Congress Avenue (properties subject to high winds and located near waterbodies that have not been re-developed in the past 10 years) are vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
    - Wells Fargo Bank (1600 S Federal Hwy, Boynton Beach, FL 33435) is located near the Intracoastal Waterway.
    - Catalina Shopping Center (1775 N Congress Ave, Catalina Centre N Dr, Boynton Beach, FL 33426) is located on the Boynton Canal.
- Fuel and gas stations near the Intracoastal Waterway are vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
    - Texaco Gas Station (5002 N Ocean Blvd, Boynton Beach, FL 33435)
    - Marathon Gas Station (2403 S Federal Hwy, Boynton Beach, FL 33435)
- Private Educational Facilities near the Intracoastal Waterway and/or canals are vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds when near the coast, and vulnerable to rainfall-induced flooding and high winds when near canals or inland.
    - St Mark Catholic School (730 NE 6th Ave, Boynton Beach, FL 33435) is located near the coast.
    - Trinity Christian Academy (7259 S Military Trail, Lake Worth, FL 33463) is located near a canal.
    - Bright Horizons Preschool (1490 Gateway Blvd, Boynton Beach, FL 33426) is near a canal.
- Greentree Villas, (4674 Greentree Place, Boynton Beach, FL 33436) a multi-residential 55 and older complex, is vulnerable to rainfall-induced flooding and high winds.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the City of Boynton Beach are highlighted in a portfolio format that follows.

Boynton Beach: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-BB-1	Use the shoreline recession index developed for this project to identify vulnerable coastline areas that would benefit from coastal measures such as seawalls and living shorelines. Projects should focus on building capacity with homeowners to support living shoreline reinforcement for vulnerable locations whenever possible.	Shoreline recession, Harmful Algal Blooms (HABs), Storm Surge
	INF-BB-2	Expand and connect networks of bicycle and pedestrian facilities by funding and implementing recommendations in the City's Greenways, Blueways & Trails Plan and Complete Streets Mobility Plan. Cross-reference projects against the threats and results of the Climate Change Vulnerability Assessment (CCVA) to ensure projects are sufficiently and strategically designed.	Extreme Heat, HABs
	INF-BB-3	Study and plan to reduce nutrient loads to receiving waterbodies through capital projects, enhanced best management practices, land development regulation updates, and other strategies. Link activities to Municipal Separate Storm Sewer System (MS4) Permit reporting and requirements whenever possible.	HABs, Rainfall-Induced Flooding
	INF-BB-4	Fund and implement solar telemetry systems for post-storm power backup at utilities lift stations, wells, pumps, and water tanks.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding
	INF-BB-5	Expand reclaimed water distribution system to reuse wastewater effluent for irrigation of golf courses, cemeteries, sports fields, and other big water-users.	Drought, Saltwater Intrusion
	INF-BB-6	Encourage and support septic-to-sewer conversion throughout the Utilities Service Area, particularly in areas with high groundwater table.	HABs

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE, ZONING, BUILDING CODES AND STANDARDS	LU-BB-1	Conduct an assessment of unused or underutilized properties (e.g., parking garages) and develop an approach for utilizing such properties that enhances overall resilience goals (e.g., stormwater treatment, urban parks, emergency shelters).	All Threats
	LU-BB-2	Reduce use of conventional lawns and establish more urban trees and native vegetation, incorporate preferred landscaping materials into land development regulations and guidance documents.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat
	LU-BB-3	Where opportunities for improvement exist, modify local land use policies and codes to support compact development patterns, creating more walkable and affordable communities.	All Threats
	LU-BB-4	Modify local land use policies and codes to incentivize green infrastructure/low impact development (GI/LID) practices such as minimizing pervious areas (e.g., setting parking area maximums), pervious pavement/pavers, etc. in private development. Draw on Florida Department of Environmental Protection (FDEP) guide and regional toolkit as referenced in the Coastal Resilience Partnership's (CRP) Regional Strategies.	All Threats
	LU-BB-5	Modify local land use policies and codes to provide vegetative buffer for land development on canals or other water bodies.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat
	LU-BB-6	Designate adaptation action areas as a priority-setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the City.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT	PP-BB-1	Identify and expand incentives for sustainable businesses to locate within the area, such as those that research and add capacity to strategic workforce initiatives like the development of green jobs.	All Threats
	PP-BB-2	Facilitate a transition to transportation electrification by expanding the citywide network of electric vehicle (EV) charging stations, implementing the City's Sustainable Development Standards which require a minimum amount of EV parking spaces, and require new commercial properties to have EV-ready electrical infrastructure.	Extreme Heat
	PP-BB-4	Assess the feasibility of implementing solar energy and battery storage in critical facilities for emergency management and disaster recovery and add solar/battery projects to the Capital Improvement Plan (CIP).	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
	PP-BB-5	Work with emergency management staff to integrate community resilience initiatives into emergency management operations, and vice versa – such as during the development and implementation of citywide and departmental hurricane plans.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
CAPACITY BUILDING	CB-BB-1	Expand on the success of the City's Energy Edge Rebate Program to further increase access to energy efficiency and reduce household utility cost burdens. Utilize available grants strategically, particularly those that will provide resources to fund energy-efficient technologies for low-income residents.	Extreme Heat
	CB-BB-2	Connect with members of highly vulnerable populations to build trust and inform emergency management planning. Work with programs like the Community Emergency Response Team and AmeriCorps, as well as other local groups including faith-based organizations, to serve as ambassadors.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds

CAPACITY BUILDING (CONTINUED)	CB-BB-3	Initiate a process of developing one or more neighborhood-based Resilience Hubs to facilitate communication, distribute resources, and provide services to residents before, during, and after climate disruptions. Use the Guide to Developing Resilience Hubs as a starting point for local and regional knowledge exchange; work with CRP to seek collaborative funding opportunities.	All Threats
	CB-BB-4	Integrate climate equity and resilience considerations into the City's forthcoming Racial and Social Equity Comprehensive Community Needs Assessment, particularly in terms of the impacts of extreme heat on public health.	All Threats
	CB-BB-5	Work with community groups to fund and commission a credible third-party study assessing the risk and extent of climate gentrification, and possible solutions.	All Threats
PUBLIC OUTREACH	PO-BB-1	Ensure frontline communities are a priority and engaged in an approachable way by offering information in other languages and outreach opportunities at community events on climate change.	All Threats
	PO-BB-2	Utilize visual arts, signage, installations, and participatory events to creatively communicate to residents and visitors the localized impacts of climate change and avenues for community action.	All Threats
	PO-BB-3	Hold events where residents can interact with local experts to develop an emergency preparedness kit to take home.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
	PO-BB-4	Engage artists, activists, youth, and elders in public climate change education.	All Threats

FUNDING AND FINANCE	**FF-BB-1**	**Review existing/create protocols to address funding needs and to facilitate response in the event of a price spike in vehicle fuel, natural gas, or electricity, so that other budgetary items are not strained.**	**All Threats**
FUNDING AND FINANCE	**FF-BB-2**	**Promote funding strategies in under-resourced communities to establish an equitable distribution of infrastructure investments across the City. Review the results of the CCVA/social vulnerability as part of the CIP planning process.**	**All Threats**
FUNDING AND FINANCE	**FF-BB-3**	**Find ongoing funds to replant established canopy after wind events.**	**High Winds, HABs, Shoreline Recession**
FUNDING AND FINANCE	**FF-BB-4**	**Change City planning processes to include a "funding first" approach where economics, finance, and climate change are considered first and then throughout the planning processes.**	**All Threats**
FUNDING AND FINANCE	**FF-BB-5**	**Begin preparing key findings of this study to compete for funding with the landmark 'Always Ready' resilience law. Share lessons learned and resources as a part of the CRP.**	**Rainfall-Induced Flooding, Storm Surge, Tidal Flooding**
FUNDING AND FINANCE	**FF-BB-6**	**Design stormwater capital improvement projects to mitigate nuisance flooding in low-lying areas. Develop projects that have multiple co-benefits (including water quality) to align with State and Federal funding sources. Funding sources can be strategically targeted according to the results of this study and the grants matrix provided by the CCVA.**	**Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Groundwater Inundation**
FUNDING AND FINANCE	**FF-BB-7**	**Collaborate with the CRP to locate resources regarding a diverse suite of financing and tools to assist individuals with personal home or business adaptation.**	**All Threats**

CRP

Coastal Resilience Partnership

Climate Change Vulnerability Assessment Delray Beach

As a coastal city with historic character, Delray Beach is committed to adapting to climate change with a sustainable and phased approach. Staff value working with the public early and often to build equitable strategies for effective resilience. The City has been proactive with sustainability and conservation planning. At Delray Beach meetings that were hosted for the project, staff emphasized maintaining open space and increasing tree canopy while also utilizing traditional engineering practices and preserving historic character.

Key Study Findings for Delray Beach

- Levels of vulnerability and risk are proportionally very similar to the overall region.
- Highest levels (percentages) of current vulnerability are associated with high winds. Many critical facilities and approximately a third of the commercial properties are highly vulnerable. These vulnerable areas include many of the historic properties that are iconic to Delray Beach.
- For residential properties, the total vulnerability is currently similar for rainfall-induced flooding and storm surge. However, the number of commercial properties that are vulnerable to rainfall-induced flooding is double that of storm surge.
- Road inaccessibility will likely be a major impact in many areas of the City during larger storm events.
- Increasing tidal flooding risk for residential properties is likely to increase and become more problematic. In the coming decades, with deeper tidal flood depths, high tide events are likely to go beyond being “disruptive” to causing property damage, particularly for older construction at or below the Base Flood Elevation.

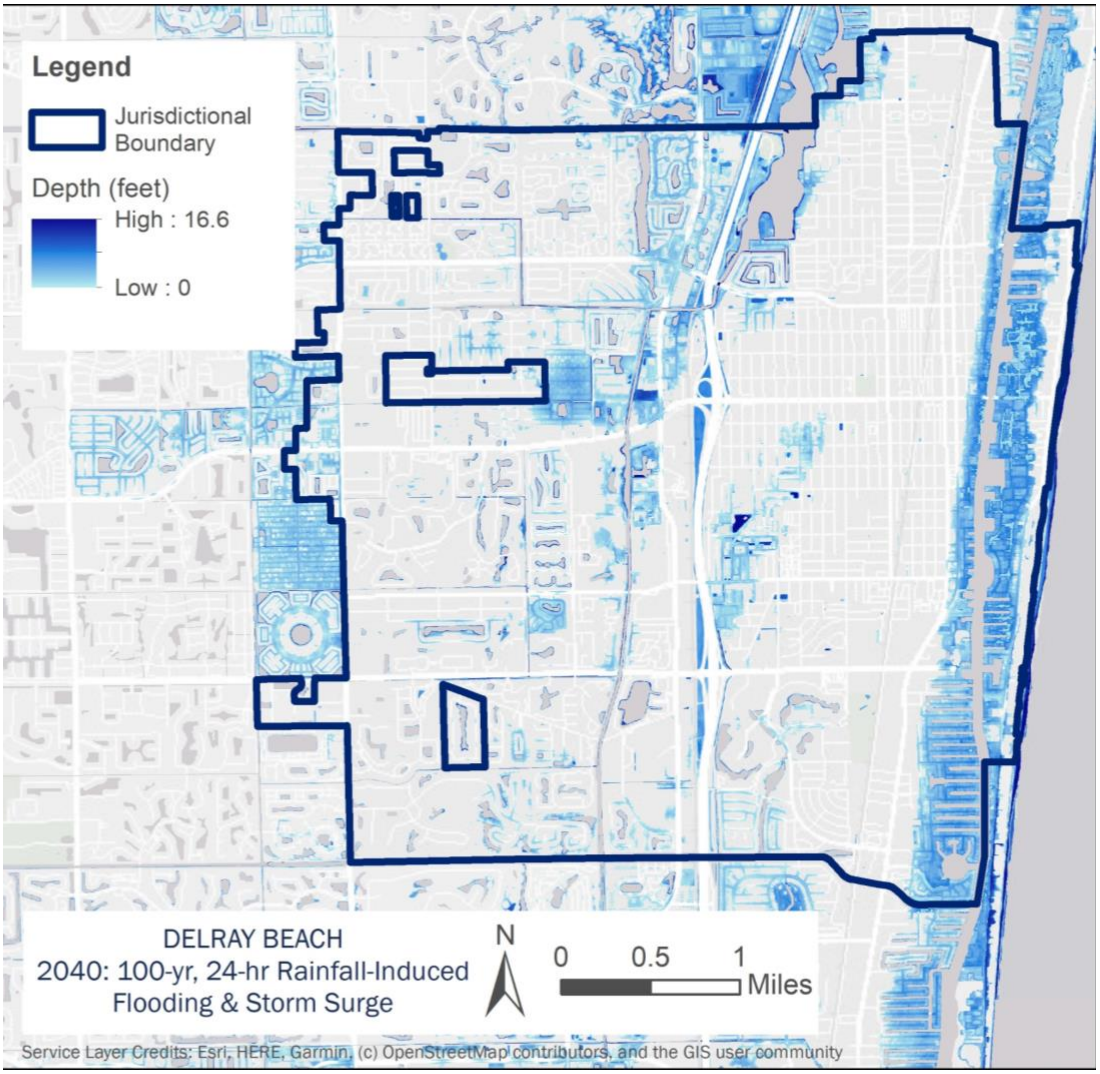


Figure A3-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Delray Beach, Florida (2040).

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the City owns, and the second list are assets located within the City that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

Top 5 City-Owned Asset Categories of Concern

- Coastal and non-coastal parks are vulnerable to rainfall-induced flooding, and a coastal park also is vulnerable to storm surge, and/or tidal flooding. Veterans Park (802 NE 1st St, Delray Beach, FL 33483), La Hacienda Gardens Recreational Area (833 Lake Ave N, Delray Beach, FL 33483), and Catherine Strong Park (1500 SW 6th St, Delray Beach, FL 33444) are the most vulnerable.
- Delray Beach Swim and Tennis Club (2350 Jaeger Dr, Delray Beach, FL 33444), Delray Beach Golf Club (2200 Highland Ave unit a, Delray Beach, FL 33445) are vulnerable to rainfall-induced flooding.
- Delray Beach Fire Station No. 2 (35 Andrews Ave, Delray Beach, FL 33483) is vulnerable mostly to storm surge and rainfall-induced flooding. It is located near the coast.
- Coastal Parking areas at 134 S Ocean Blvd, and 148 S Ocean Blvd are vulnerable to storm surge, tidal flooding, and rainfall-induced flooding.

- City of Delray Beach Police Department (300 W Atlantic Avenue) is vulnerable primarily to high winds and rainfall-induced flooding.

Top 5 Non-City-Owned Asset Categories of Concern

- Because of their coastal locations, several banks near the coast are vulnerable to rainfall-induced flooding, tidal flooding, and storm surge.
  - Bank of America (1001 E Atlantic Ave, Delray Beach, FL 33483)
  - Bank of America (551 SE 5th Ave, Delray Beach, FL 33483)
- Two Palm Beach County Schools are vulnerable to rainfall-induced flooding. Both are categorized as historic.
  - Atlantic Community High School (2455 W Atlantic Ave, Delray Beach, FL 33445) is located near the Gulf Stream Canal.
  - Delray Full Service Center (301 SW 14th Ave, Delray Beach, FL 33444)
- Unity of Delray Beach (101 NW 22nd St, Delray Beach, FL 33444), a private school near Lake Eden, is vulnerable to rainfall-induced flooding.
- St Vincent Ferrer School (810 George Bush Blvd, Delray Beach, FL 33483), a private school near the intracoastal, is vulnerable to storm surge and rainfall-induced flooding.
- Chevron (445 SE 6th Ave, Delray Beach, FL 33483) near the coast is vulnerable to storm surge and rainfall-induced flooding.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the City of Delray Beach are highlighted in a portfolio format that follows.

Delray Beach: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-DB-1	Identify and expand electronic vehicle (EV) charging infrastructure, including supporting a regional framework for locating public EV charging stations and expanding EV opportunities at multifamily buildings, workplaces, and commercial and retail centers.	Extreme Heat
	INF-DB-2	Make public fleet less dependent on fossil fuel (coming in from outside region).	Extreme Heat
	INF-DB-3	Implement more living shoreline projects in vulnerable locations.	Shoreline Recession, Harmful Algal Blooms (HABs), Storm Surge
	INF-DB-4	Set new design standards for sea wall heights for private landowners with a future deadline for compliance.	Storm Surge, Tidal Flooding
	INF-DB-5	Make water and wastewater treatment plants and related infrastructure Cat 5 Ready.	High Winds, Storm Surge
	INF-DB-6	Provide 72-hour emergency power generation for all government infrastructure from storm, surge and/or tidal events. Make generators and/or solar with battery backup available as well as storage and points of relocation.	High Winds, Storm Surge, Tidal Flooding, Rainfall-Induced Flooding
	INF-DB-7	Make sure there is shade, safe biking, and safe walking connections in socially vulnerable areas.	Extreme Heat
LAND USE, ZONING, BUILDING CODES AND STANDARDS	LU-DB-1	Incorporate green infrastructure techniques, where possible into land development regulations and permits: Low Impact Development (LID) Manual Implementation, Bioretention, Rain Gardens, Trees and Tree Boxes, Canal Restorations Using Sustainable Techniques, Permeable Pavements, Suspended Pavement, Biosorption Activated Media, Green Roofs, Downspout Disconnects, Cisterns, Stormwater Reuse, Native Vegetation, Urban Forestry, Combined Ecological Art in Public Places Projects.	Rainfall-Induced Flooding, HABs, Drought

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE, ZONING, BUILDING CODES AND STANDARDS (CONTINUED)	LU-DB-2	Conduct an assessment of unused or underutilized properties (e.g., parking garages) and develop an approach for utilizing such properties that enhances overall resilience goals (e.g., Stormwater flow and storage, Green space or urban parks, Emergency shelters).	All Threats
	LU-DB-3	Incorporate green infrastructure in complete streets or other capital improvements through revisions to the land development regulations.	Rainfall-Induced Flooding, HABs, Drought, Storm Surge, Tidal Flooding
PLANNING, POLICY, AND MANAGEMENT	PP-DB-1	Develop local Greenhouse Gas (GHG) emissions reduction targets through climate action plans aligned with regional priorities.	Extreme Heat
	PP-DB-2	Integrate social vulnerability data into all local government processes. Identify locally relevant social vulnerability data and planning tools that already exist, including (a) Florida Institute of Health Innovation reports (b) Center for Disease Control reports (c) Census data (d) U.S. Global Change Research Program Climate and Health Assessment (e) County and municipal data for incorporation into Comprehensive Plan policies or to develop criteria that equitably prioritize adaptation projects.	All Threats
	PP-DB-3	When ranking capital projects, base return on investment (ROI) calculations on criteria beyond property value; include Social Vulnerability Index or other social factors in those processes.	All Threats
	PP-DB-4	Create and invest in strategic pre-disaster plans for post-disaster recovery.	Storm Surge, Tidal Flooding, HABs, Rainfall-Induced Flooding, Pest & Disease Outbreak, High Winds, Extreme Heat

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)	PP-DB-5	Streamline permitting of renewable energy technologies. Create incentives, make rules clear and readily available, expedite the permitting process, and make inspections convenient for property owners. Determine if, and develop if needed, additional or revised land development regulations to promote solar within the community.	Extreme Heat
	PP-DB-6	Develop and implement policies and design standards that recognize the transportation system's most vulnerable users and incorporate sustainable elements.	Extreme Heat
CAPACITY BUILDING	CB-DB-1	Prioritize planting efforts in low-income areas and communities of color where the existing tree canopy is disproportionately sparse.	Extreme Heat
	CB-DB-2	Develop a toolkit for personal adaptation targeted to sensitive populations.	All Threats
	CB-DB-3	Identify climate ambassadors (members of the community) that can work with neighborhoods to identify priority projects.	All Threats
	CB-DB-4	Provide resources for homeowners and businesses to plant trees on private property that have significant carbon sequestration and stormwater retention values.	Rainfall-Induced Flooding, Extreme Heat, HABs
PUBLIC OUTREACH	PO-DB-1	Partner with local artists and community groups to fund community green space around water infrastructure components such as stormwater pumps. For example, partner with a school district to make "stormwater schoolyard" with green infrastructure (San Francisco).	Rainfall-Induced Flooding, HABs, Drought, Storm Surge, Tidal Flooding
	PO-DB-2	Host public meetings about climate threats that are easily accessible to vulnerable populations: (a) Physically accessible (near public transport) (b) Safe to all members (c) Located in places communities' value as gathering spaces (e.g., community centers and	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH (CONTINUED)		cultural centers) (d) Led in, or translated into, the primary language(s) of the community (e) Scheduled at various times to accommodate different schedules.	
	PO-DB-3	Utilize visual arts, signage, installations, and participatory events to creatively communicate to residents and visitors the localized impacts of climate change and avenues for community action.	All Threats
	PO-DB-4	Hire a liaison in vulnerable communities to connect with residents' day-to-day lives and better understand how climate threats affect vulnerable populations and to disseminate information to their community.	All Threats
	PO-DB-5	Create a demonstration street or area in city to showcase green streets transportation planning policies. Include LID elements that provide strong aesthetic and treatment benefits.	Rainfall-Induced Flooding, HABs, Drought, Storm Surge, Tidal Flooding
FUNDING AND FINANCE	FF-DB-1	Review existing/create protocols to address funding needs and to facilitate response in the event of a price spike in vehicle fuel, natural gas, or electricity, so that other budgetary items are not strained.	All Threats
	FF-DB-2	Promote funding strategies in under-resourced communities to establish an equitable distribution of infrastructure investments across the City. Review the results of the CCVA/social vulnerability as part of the CIP planning process.	All Threats
	FF-DB-3	Find ongoing funds to replant established canopy after wind events.	High Winds, HABs, Shoreline Recession
	FF-DB-4	Change City planning processes to include a "funding first" approach where economics, finance, and climate change are considered first and then throughout the planning processes.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
FUNDING AND FINANCE (CONTINUED)	**FF-DB-5**	**Begin preparing key findings of this study to compete for funding through the landmark 'Always Ready' resilience law. Share lessons learned and resources as a part of the CRP.**	**Rainfall-Induced Flooding, Storm Surge, Tidal Flooding**
	FF-DB-6	**Design stormwater capital improvement projects to mitigate nuisance flooding in low-lying areas. Develop projects that have multiple co-benefits (including water quality) to align with State and Federal funding sources. Funding sources can be strategically targeted according to the results of this study and the grants matrix provided by the CCVA.**	**Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Groundwater Inundation**
	FF-DB-7	**Collaborate with the CRP to locate resources regarding a diverse suite of financing and tools to assist individuals with personal home or business adaptation.**	**All Threats**

Coastal Resilience Partnership

Climate Change Vulnerability Assessment Highland Beach

Highland Beach is an engaged, predominately residential coastal community with a keen understanding of how building the Town's resiliency to climate hazards is interconnected with those of its neighbors. Adaptation strategies related to the Town's beaches, Intracoastal shoreline, government assets, and primary access along Highway A1A must consider the regional inter-relationships, financial phasing, and balancing the built and natural environments.

Key Study Findings for Highland Beach

- As expected, the Town has fewer critical facility assets compared to other jurisdictions in the region.
- Even with few overall assets, proportionally, Highland Beach has high vulnerability to storm surge, especially for residential property and with regards to the accessibility of roads (during storm events).
- Residential properties and roads have some vulnerability to current tidal flooding, but this could increase significantly in future years, with the majority of these assets highly vulnerable to the 2070 (2020 baseline + 33 inches of sea level rise) projection levels (highest proportion of vulnerability to future tidal flooding in the region).
- Residential vulnerability to high winds is about twice that of the region as whole. This is due to having many multi-residential and retirement properties, in addition to the age of the buildings (year of construction).
- The Town of Highland Beach also includes one of the highest shoreline recession vulnerability areas in the region.

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the Town owns, and the second list contains assets located within the Town that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

Top Town-Owned Asset Categories of Concern

- The Town of Highland Beach Municipal Complex (3614 S Ocean Blvd, Highland Beach, FL 33487) is vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds.

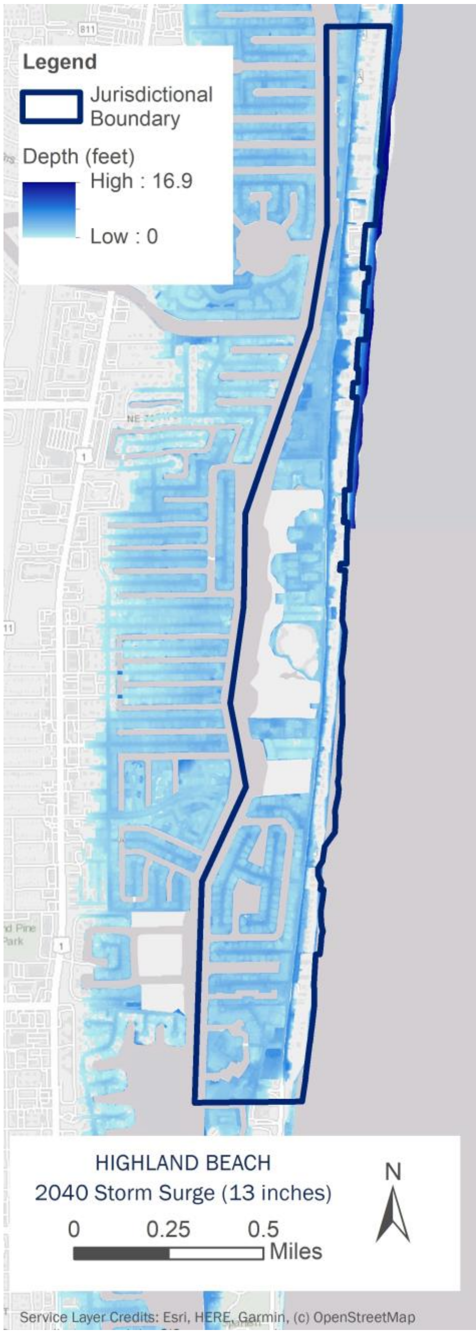


Figure A4-1: Predicted storm surge in Highland Beach, Florida (2040).

Top Non-Town-Owned Asset Categories of Concern

- Government-owned vacant coastal lands (PCN 24-43-46-33-00-003-0100 and PCN 24-43-47-04-00-002-0030) are vulnerable to rainfall-induced flooding, tidal flooding, and high winds.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the Town of Highland Beach are highlighted in a portfolio format that follows.

Highland Beach: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-HB-1	Raise two lift stations over the next two years to build resilience. Identify elevations based on the results of this study and the recent FEMA study for Palm Beach County.	Tidal Flooding, Rainfall-Induced Flooding, Storm Surge
	INF-HB-2	Install in-line check valves in strategic locations to reduce tidal flooding at strategic locations throughout the Town.	Tidal Flooding, Storm Surge
	INF-HB-3	Line sanitary sewer system over the next three years to build resilience and reduce inflow and infiltration.	HABs, Pest & Disease
	INF-HB-4	Through involvement with the Coastal Resilience Partnership (CRP) and other regional organizations, work to build stronger relationships with FDOT regarding stormwater issues within the Town on and adjacent to SR-A1A (Ocean Boulevard). Including but not limited to: • Maintaining and preventing damage to roadside swales on SR-A1A. These activities should focus on restoring and maintaining storage and treatment capacity in these swales. • Preventing compaction of the swales by allowing traffic to park and/or drive over swales. • Future stormwater retrofits to the roadway that will likely be needed due to sea level rise, storm surge, and tidal flooding.	Rainfall-Induced Flooding, Harmful Algal Blooms (HABs)

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE (CONTINUED)	INF-HB-5	Review the results of this study and re-evaluate critical infrastructure and potential service vulnerabilities. Work with other stakeholders to minimize gaps in services: utilities, critical care, emergency buildings, Town Hall access, etc.	All Threats
LAND USE BUILDING CODES AND STANDARDS	LU-HB-1	Preserve open space in flood-prone areas to maintain pervious surface and reduce offsite discharges to the greatest degree possible, particularly on Town property and roadway.	Rainfall-Induced Flooding, Tidal Flooding, HABs
	LU-HB-2	Evaluate existing land development regulations and development standards to encourage for installation and use of energy-efficient and small-scale distributed renewable and modular waste-to-energy systems that are grid independent.	Extreme Heat
	LU-HB-3	Consider using the Adaptation Action Areas developed as a recommendation for this study. Evaluate based on the recommendations of this study specific to the Town.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
PLANNING, POLICY, AND MANAGEMENT	PP-HB-1	Conduct an annual review of sea level rise and climate change strategy before the capital budgeting process initiates to ensure coordination on project funding and implementation schedules.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge, Extreme Heat
	PP-HB-2	Based on the results of this study, consider modifying roadway design specifications to specifically provide a higher level of service for evacuation routes and priority roadways.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)	PP-HB-3	Create and invest in strategic pre-disaster plans for post-disaster recovery. Focus on maintenance of Town facilities and amenities to provide resources for post-disaster recovery to residents.	All Threats
CAPACITY BUILDING	CB-HB-1	Develop financing and tools to assist individuals with personal/home adaptation and mitigation. Use the Personal Adaptation Menu to education homeowners and residents regarding personal adaptation. Emphasize personal adaptation strategies specific to barrier island communities and the unique attributes of the Town.	All Threats
	CB-HB-2	Using the results of this study, encourage and empower homeowners to create shoreline protection measures on their properties. 1. Leverage the personal adaptation guide produced for this study and other resources to educate homeowners about shoreline protection measures appropriate for use in the Town. 2. Encourage homeowners to maintain natural measures to stabilize and protect their properties such as using Florida-Friendly vegetation, maintaining and raising seawalls, and protecting healthy mangrove forests.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge, Extreme Heat, HABs, Pest & Disease
	CB-HB-3	As a member of the CRP, continue to compile and encourage sustainable landscaping practices. Tie the initiatives to current Town ordinances and existing resources appropriate for use within the Town.	HABs, Pest & Disease
	CB-HB-4	Educate homeowners on right-of-way issues and interconnection with adaptation to climate change. Examples include • Keeping stormwater flow paths open so that stormwater can reach	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
CAPACITY BUILDING (CONTINUED)		storage and treatment facilities with a proper outfall. • Keeping certain vegetation types out of the right-of-way that can damage utilities and prevent proper maintenance.	
	CB-HB-5	Using the results of this study, encourage residents to report any climate-related issues or questions via the existing "Tell the Town" website and/or hotline.	All Threats
PUBLIC OUTREACH	PO-HB-1	Promote Town amenities like the library and Town Hall as hubs for climate education. Make spaces available to Town residents for climate conversations, guest speakers, art exhibitions, etc.	All Threats
	PO-HB-2	Partner with local artists and community groups to collaborate on climate education components as part of infrastructure projects at the Town Hall and strategic locations throughout the Town. Use educational signage and community events to promote the art exhibitions and unique features of each project.	All Threats
	PO-HB-3	Using the results of this study, evaluate access to critical services for vulnerable portions of the Town population, particularly post disaster and during extreme heat.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
FUNDING AND FINANCE	FF-HB-1	Change Town planning processes to include a “funding first” approach where economics, finance, and climate change are considered first and then throughout the planning processes.	All Threats
	FF-HB-2	Begin preparing key findings of this study to compete for funding with the landmark ‘Always Ready’ resilience law. Share lessons learned and resources as a part of the CRP.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	FF-HB-3	Collaborate with the CRP to locate resources regarding a diverse suite of financing and tools to assist individuals with personal home adaptation.	All Threats
	FF-HB-4	Find ongoing funds to replant established canopy after wind events	High Winds

CRP
Coastal Resilience Partnership

Climate Change Vulnerability Assessment Lake Worth Beach

Lake Worth Beach is a spirited City with a focus on creating a sustainable community and resilient foundation. Staff leadership look towards preserving existing natural systems and promoting diverse menus of adaptable and green infrastructure for enhanced resilience in the years to come. Common practice of the City includes taking a holistic and equitable approach to understanding all the threats of climate change and then leaning in with all sectors of the community to bring these plans to fruition.

Key Study Findings for Lake Worth Beach

- High levels (percentages) of vulnerability are associated with high winds throughout the City due to the relative old age of structures.
- A large percentage of properties (75%) are vulnerable to potential inaccessibility during current conditions (2020) rainfall-induced flooding.
- Primary tidal flooding vulnerability related primarily to residential property (including large multi-residential) and roads. While this vulnerability is currently relatively low, with future change vulnerability could increase, especially at the 2070 (2020 baseline +33-inches sea level rise) projection level.
- Lake Worth Beach is unique in the region in its social vulnerability characteristics. Therefore, it is important to recognize many of the City's residents face disproportionate impacts from climate threats. Within the region, the City has among the highest percentages of households living below the poverty line, the highest food SNAP participation, and the highest levels of overall social vulnerability.

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the City owns, and the second list contains assets located within the City that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

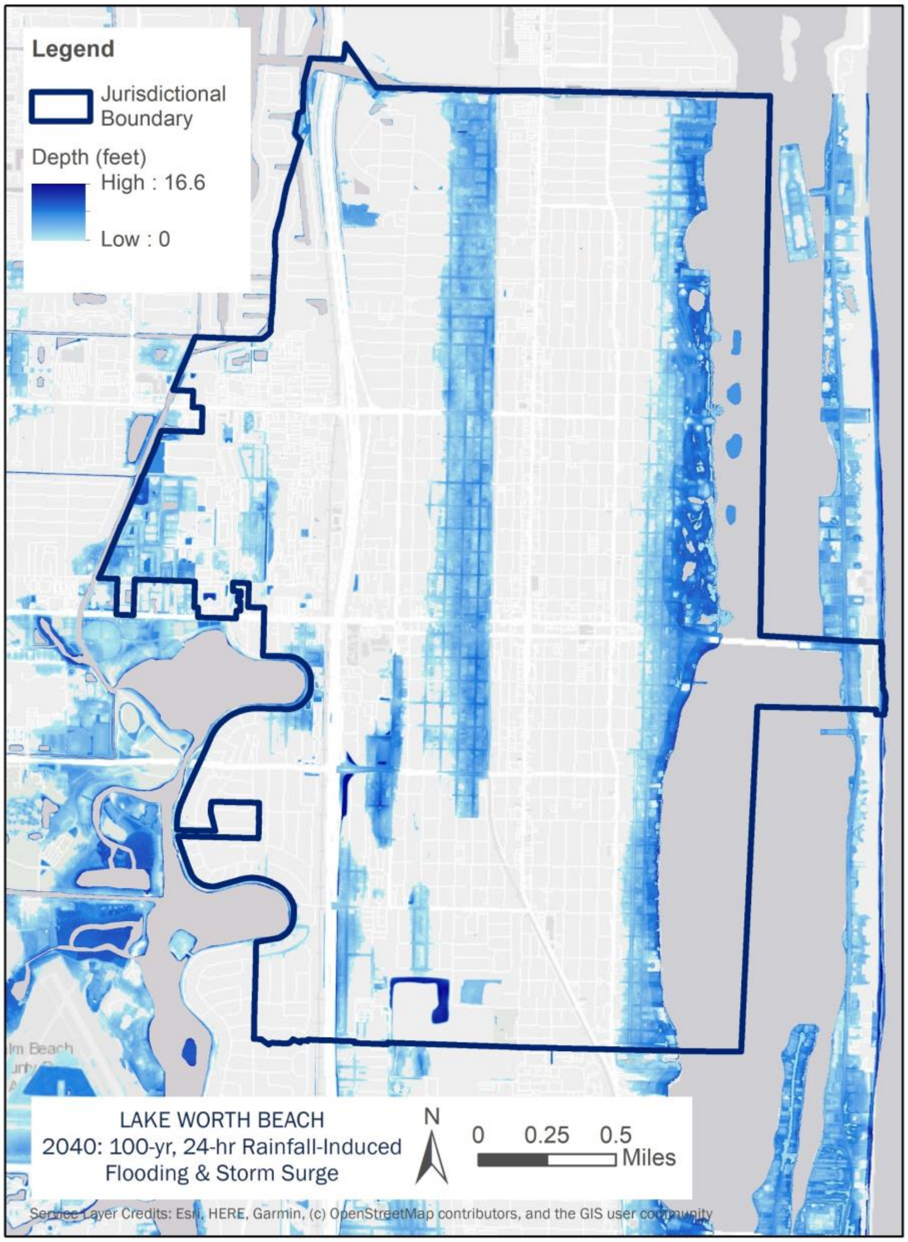


Figure A5-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Lake Worth Beach, Florida (2040).

Top 5 City-Owned Asset Categories of Concern

- Beach Recreational and Parking Facility at 10 S Ocean Blvd is vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds.
- Lake Worth Community Redevelopment Building (1121 Lucerne Ave, Lake Worth, FL 33460) is vulnerable to rainfall-induced flooding and high winds.
- Electric Utility (1109 1st Ave S, Lake Worth, FL 33460) is vulnerable to rainfall-induced flooding and high winds.
- City-owned Palm Beach County Fire Rescue Station 93 (1229 N Detroit St, Lake Worth, FL 33461) is vulnerable to rainfall-induced flooding and high winds.
- Parking lot on Sunrise Ct. near Harold Grimes Memorial Park is vulnerable to rainfall-induced flooding.

Top 5 Non-City-Owned Asset Categories of Concern

- John Prince Park (2700 6th Ave S, Lake Worth, FL 33461) near Lake Osborne is vulnerable to rainfall-induced flooding and high winds.
- Private schools near Lake Osborne are vulnerable to rainfall-induced flooding and high winds.
  - Global Learning Preschool (544 Sunrise Ct, Lake Worth, FL 33460)
  - Montessori Learning Center (1845 Lake Worth Rd, Lake Worth, FL 33461)
- Commercial buildings near water bodies are vulnerable to rainfall-induced flooding and high winds.
  - Shopping plaza on Congress (6074 S Congress Ave, Lake Worth, FL 33462)
  - Office building near a canal (2328 10th Ave N, Lake Worth, FL 33461)
- Three Palm Beach County Schools are vulnerable to rainfall-induced flooding and high winds.
  - Palm Beach State College – Lake Worth Campus
  - Lake Worth Community High School (109 Montrose St, Lake Worth, FL 33460)
  - Barton Elementary School (1700 Barton Rd, Lake Worth, FL 33460)
- Lantana Airport (2633 Lantana Rd, Lake Worth, FL 33462) is vulnerable to rainfall-induced flooding and high winds.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the City of Lake Worth Beach are highlighted in a portfolio format that follows.

Lake Worth Beach: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-LW-1	Work towards implementing more living shoreline projects in vulnerable locations, include natural elements wherever possible to preserve the character of the City's coastline and neighborhoods. Examine potential projects against the results of the Climate Change Vulnerability Assessment (CCVA) analyses for shoreline recession, tidal flooding, and storm surge to optimize and prioritize project locations.	Shoreline recession, Harmful Algal Blooms (HABs), Storm Surge, Tidal Flooding, Extreme Heat
	INF-LW-2	Make sure there is shade, safe biking, and walking connections in socially vulnerable areas. Consider using alternative materials for paving that produce less heat in these areas and provide access to safe drinking water stations along pathways. Cross-reference projects against the threats and results of the CCVA to ensure projects are sufficiently and strategically designed.	HABs, Extreme Heat, Pest & Disease
	INF-LW-3	Using the results of the study, re-evaluate critical infrastructure vulnerabilities and work with regulators and other local governments to minimize gaps in services: utilities, schools, critical care, emergency buildings, etc.	All Threats
	INF-LW-4	Expand renewable energy purchasing options by encouraging investment in community solar and energy co-ops. Continue building resilience with regards to electric utility.	Extreme Heat, High Winds

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
 LAND USE BUILDING CODES AND STANDARDS	LU-LW-1	Conduct an assessment of unused or underutilized properties (e.g., parking garages) and develop an approach for utilizing such properties that enhances overall resilience goals (e.g., stormwater treatment/storage, urban parks with green space, multi-use emergency shelters).	HABs, Extreme Heat, Pest & Disease, Rainfall-Induced Flooding, Tidal Flooding
	LU-LW-2	Designate adaptation action areas as a priority-setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the City.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	LU-LW-3	Increase greenspace by requiring larger setbacks in building code.	HABs, Extreme Heat, Pest & Disease, Rainfall-Induced Flooding
	LU-LW-4	Incentivize private property owners to implement green infrastructure projects by creating options within the land development regulations.	HABs, Extreme Heat, Rainfall-Induced Flooding
 PLANNING, POLICY, AND MANAGEMENT	PP-LW-1	Explore the concept of Adaptation Urbanism – integrating compact development, sustainable transport, blue and green infrastructure, and equity – and work with regional partners to identify opportunities to apply it to street-level resilience projects in the City.	All Threats
	PP-LW-2	Conduct an annual review of sea level rise projections before the capital budgeting process initiates to ensure the most recent climate science is used to design Capital Improvement Plans (CIPs). Consider updating and re-visiting projects from the City's Stormwater Master Plan for sea level rise and climate science and revise for co-benefits, equity, and resilience.	Tidal Flooding, Rainfall-Induced Flooding

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)	PP-LW-3	Using the results of this study, provide information about where vulnerable populations are located (and the threats they are most vulnerable to) to appropriate City departments so that the information can be used as part of emergency planning process.	All Threats
	PP-LW-4	Consider working with regional partners to develop a suite of resources so that nonprofits, developers, and homebuyers can rehabilitate and reuse vacant properties. Redevelopment should focus on resilient measures that enhance equity throughout the City.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease
	PP-LW-5	Minimize the impact to natural areas from future development by controlling the alteration of existing wetlands, natural shorelines, and impacts to floodplains.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease, Tidal Flooding, Storm Surge, High Winds
CAPACITY BUILDING	CB-LW-1	Collaborate with the Coastal Resilience Partnership (CRP) to compile resources to encourage sustainable landscaping practices, pervious surfaces, and downspout disconnection for homeowners and businesses. Tie the initiative to existing resources that encourage Florida-Friendly Landscaping™ and those that reduce fertilizer usage. Cater the specific measures to Southeast Palm Beach County so that the resources are easier for the public to use (plant menus, instructions, local resources, etc.). Tap into the resources provided by the Institute of Food and Agricultural Sciences (IFAS) Extension at the University of Florida and the local Palm Beach County Cooperative Extension.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease, Tidal Flooding, Storm Surge, High Winds

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
CAPACITY BUILDING (CONTINUED)	CB-LW-2	As part of the CRP and as the City, engage Lake Worth Drainage District (LWDD) and South Florida Water Management District (SFWMD) regarding the impacts of current and future flood events on the secondary and primary canal systems in the City. Also consider potential of algal blooms and how they would affect structure operations. Work with both parties to develop models and eventually a decision support system that can adapt to further mitigate future flood events. Partnering will also increase the likelihood of funding for some grant opportunities.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease, Tidal Flooding, Storm Surge, Groundwater Inundation, Saltwater Intrusion
	CB-LW-3	Help homeowners and business owners invest in renewables by adopting a Property Assessed Clean Energy (PACE) program.	Extreme Heat
	CB-LW-4	Connect with members from highly vulnerable populations to build trust and inform emergency management planning. Work with programs like the Community Emergency Response Team and AmeriCorps, as well as other local groups including faith-based organizations, to serve as ambassadors.	All Threats
	CB-LW-5	Partner with intermediary organizations that have deep community ties with socially vulnerable populations to co-create engagement and outreach strategies.	All Threats
	PO-LW-1	Promote collective ownership by creating community spaces where meetings and movement-building activities can occur.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH	PO-LW-2	Collect, measure, and analyze the impacts of extreme weather and coastal flood events, including information from the community through photographic, anecdotal, and scientific data.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease, Tidal Flooding, Storm Surge
	PO-LW-3	Partner with community groups to proactively reach out to vulnerable people before and during extreme weather.	HABs, Extreme Heat, Rainfall-Induced Flooding, Pest & Disease, Tidal Flooding, Storm Surge
	PO-LW-4	Leverage the talents of the City's many local artists and community groups to fund community ecological art installations focused on climate change and adaptation. For example, create a program to work with local artists to create ecological art intended to provide engagement throughout the City's many parks and greenspaces. Consider including climate change as a special focus of the City's future Street Painting Festivals.	All Threats
FUNDING AND FINANCE	FF-LW-1	Identify grant opportunities to fund adaptation strategies. Partner strategically and proactively on projects. Review this strategy and update annually for new funding sources. Reference the grant matrix provided in the CCVA report against potential projects.	All Threats
	FF-LW-2	Review existing/create protocols to address funding needs and to facilitate response in the event of a price spike in vehicle fuel, natural gas, or electricity, so that other budgetary items are not strained.	Extreme Heat
	FF-LW-3	Revisit stormwater utility rate structure. Consider adding elements for equity and the use of newer datasets in the development of the City's rate structure.	Rainfall-Induced Flooding, Tidal Flooding, HABs

CRP

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
FUNDING AND FINANCE (CONTINUED)	FF-LW-4	Align relevant City plans for co-benefits and equity to more readily qualify for Federal and State funding sources. Create a prioritized list of resilience projects and complete required calculations in advance (for example, Federal Emergency Management Agency (FEMA) cost-benefit analyses).	All Threats
	FF-LW-5	Develop incentives for construction of affordable housing designed for natural cooling to minimize the need for air conditioning and resultant energy use	Extreme Heat
	FF-LW-6	Engage in the implementation of the new landmark 'Always Ready' resilience law and ensure the CRP has taken the necessary steps to be at the front of the line when planning and infrastructure funds become available.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	FF-LW-7	Collaborate with the CRP to identify and share resources and tools to assist individuals with financing home or business adaptation efforts.	All Threats
	FF-BB-4	Change City planning processes to include a "funding first" approach where economics, finance, and climate change are considered first and then throughout the planning processes.	All Threats

CRP

Coastal Resilience Partnership

Climate Change Vulnerability Assessment Lantana

Lantana is a waterfront enclave in Southeast Palm Beach County, nestled along the Intracoastal Waterway, which is a significant asset to the community. The Intracoastal Waterway also increases vulnerability to flooding, including future tides and storm surge. The community is currently celebrating its centennial and looking to the future to ensure the community is vibrant for the decades to come.

Key Study Findings for Lantana

- Rainfall-induced flooding is a major threat to roads, potentially making a large percentage of properties inaccessible.
- High numbers of residential and commercial properties are affected by current and future inundation related to rainfall-induced flooding and storm surge.
- Out of ten health and medical facilities in the Town, nine of them are highly vulnerable to high winds.
- Currently, around 1% of residential properties are affected by tidal flooding. Under future scenarios, this percentage jumps to around 9%.

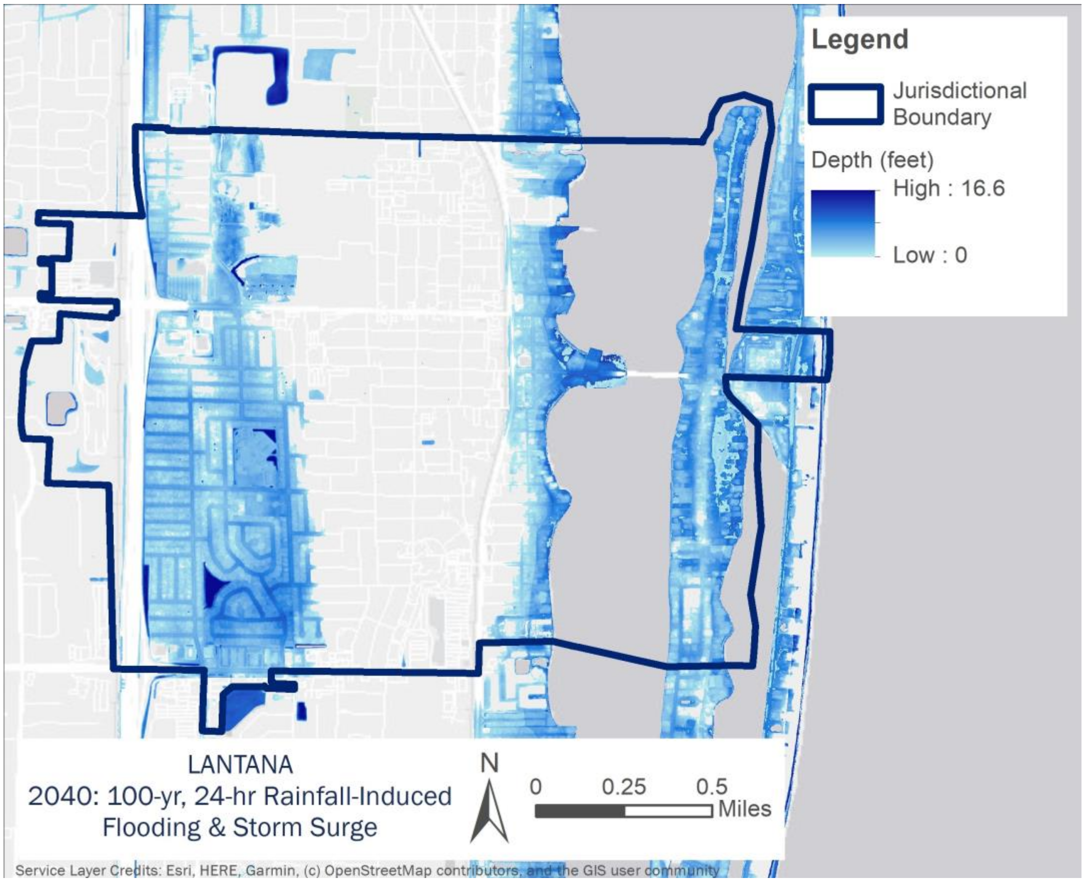


Figure A6-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Lantana, Florida (2040).

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the Town owns, and the second list contains assets located within the Town that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

Top 5 Town-Owned Asset Categories of Concern

- Lantana municipal beach parking lot and recreational area is located on the coast at 100 N Ocean Blvd and is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
- Coastal parks such as the Town of Lantana Recreation Center (418 S Dixie Hwy, Lantana, FL 33462) are vulnerable to storm surge, rainfall-induced flooding, and high winds. Also, McKinley Park is vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds.
- Parks and Recreation Bicentennial Building is located near the coast (318 S Federal Hwy, Lantana, FL 33462) and is vulnerable to storm surge, rainfall-induced flooding, and high winds.
- Town of Lantana Town Hall (500 Greynolds Cir, Lantana, FL 33462) is vulnerable to rainfall-induced flooding and high winds. It is located near the Intracoastal Waterway.
- Lantana Public Library is located near the Intracoastal Waterway (205 W Ocean Ave, Lantana, FL 33462) and is vulnerable to rainfall-induced flooding, high winds, and storm surge.

Top 5 Non-Town-Owned Asset Categories of Concern

- Department of Health building (1250 Southwinds Dr, Lantana, FL 33462) is vulnerable to rainfall-induced flooding and high winds.
- Several coastal gas stations are vulnerable to storm surge, rainfall-induced flooding, and high winds.
  - Sunoco (106 S Dixie Hwy, Lantana, FL 33462)
  - 7-Eleven (112 E Lantana Rd, Lantana, FL 33462)
  - Rocket Fuel (408 E Lantana Rd, Lantana, FL 33462)
- Three Palm Beach County Schools (public and charter) are vulnerable to rainfall-induced flooding and high winds.
  - Lantana Community Middle School (1225 W Drew St, Lantana, FL 33462) is between Lake Osborne and the Intracoastal Waterway.
  - Lantana Elementary is close to the Intracoastal Waterway (710 W Ocean Ave, Lantana, FL 33462)
  - Palm Beach Maritime Academy (1518 W Lantana Rd, Lantana, FL 33462 and 600 E Coast Ave, Lantana, FL 33462) is between Lake Osborne and the Intracoastal Waterway.
- USPS near the coast (201 W Ocean Ave, Lantana, FL 33462) is vulnerable to storm surge, rainfall-induced flooding, and high winds.
- Wells Fargo Bank on Lantana Road (1500 W Lantana Rd, Lantana, FL 33462) is vulnerable to rainfall-induced flooding and high winds. It is located between lake Osborne and the Intracoastal Waterway.

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the Town of Lantana are highlighted in a portfolio format that follows.

Lantana: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-LA-1	Use the shoreline recession index developed for this project to identify vulnerable coastline areas that would benefit from coastal measures such as seawalls and living shorelines. Projects should focus on building capacity with homeowners to support living shoreline reinforcement for vulnerable locations whenever possible.	Shoreline recession, Harmful Algal Blooms (HABs), Storm Surge, Tidal Flooding
	INF-LA-2	Review the results of this study and re-evaluate critical infrastructure and potential service vulnerabilities. Work with other stakeholders to minimize gaps in services: utilities, critical care, emergency buildings, Town Hall access, etc.	All Threats
	INF-LA-3	Optimize stormwater projects to align with co-benefits to maximize probability of funding from State and Federal sources (co-benefits include an emphasis on water quality in addition to flood mitigation and resilience). Use the results of the Climate Change Vulnerability Assessment (CCVA) and recent data from storm events to prioritize stormwater projects throughout the Town.	HABs, Rainfall-Induced Flooding, Storm Surge, Extreme Heat

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE BUILDING CODES AND STANDARDS	LU-LA-1	Consider creating additional flexible metrics for new development that emphasize resilience through open and green space.	Extreme Heat, HABs, Rainfall-Induced Flooding, Storm Surge, Tidal Flooding.
	LU-LA-2	Through involvement with the Coastal Resilience Partnership (CRP) and other regional organizations, work to build a dialogue with community and business organizations regarding • Maintaining and preventing damage to roadside swales in residential communities and within commercial properties. These activities should focus on restoring and maintaining storage and treatment capacity within these swales. • Preventing compaction of swales by allowing traffic to park and/or drive over swales. • Removing and preventing the growth of vegetation that obstructs the flow of stormwater through and into swale systems.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat
	LU-LA-3	Consider transportation projects that include multi-model and pedestrian elements that build resilience. Cross-reference projects against the threats and results of the CCVA to ensure projects are sufficiently and strategically designed.	Extreme Heat, HABs, Rainfall-Induced Flooding, Storm Surge, Tidal Flooding

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE BUILDING CODES AND STANDARDS (CONTINUED)	LU-LA-4	Encourage the use of more urban trees and native vegetation, incorporate preferred landscaping materials into land development regulations and guidance documents.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Drought
	LU-LA-5	Designate adaptation action areas as a priority-setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the region.	Rainfall-Induced Flooding, Storm Surge
PLANNING, POLICY, AND MANAGEMENT	PP-LA-1	Prioritize and retrofit impacted residential neighborhoods for optimal stormwater management. Work with partners at the County, Florida Department of Transportation (FDOT), and Lake Worth Drainage District (LWDD) to improve operational protocol and structure operations for larger storm events and prolonged wet conditions (including the overall wet season).	Rainfall-Induced Flooding, Storm Surge
	PP-LA-2	Work with emergency management staff to integrate community resilience initiatives into emergency management operations, and vice versa – such as during the development and implementation of town-wide and departmental hurricane plans.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
	PP-LA-3	Identify and expand incentives for sustainable businesses to locate within the area, such as those that research and add capacity to strategic workforce initiatives like the development of green jobs.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
	PP-LA-4	Study and plan to reduce nutrient loads to receiving waterbodies through capital projects, enhanced best management practices, land development regulation updates, and other strategies. Link activities to Municipal Separate Storm Sewer System (MS4) Permit reporting and requirements whenever possible.	HABs, Rainfall-Induced Flooding
CAPACITY BUILDING	CB-LA-1	Build opportunities and resources to encourage sustainable infrastructure projects and/or voluntary incentives.	All Threats
	CB-LA-2	Collaborate with the CRP to encourage the creations of mobile food markets connecting to food distribution centers and grocery stores to address food deserts and other food equity issues. Use the results of this study to determine needs throughout the Town and plan for post-disaster service throughout Lantana.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, Extreme Heat, Pest & Disease
	CB-LA-3	Examine three diverse methods of public engagement to report climate-related issues (including flooding) for the diverse population of the Town. Consider experimenting with social media, website modifications, hotline modifications, and cell phone apps, among others.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, Extreme Heat, Pest & Disease, High Winds

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH	PO-LA-1	Connect with members from highly vulnerable populations to build trust and inform emergency management planning. Work with community-based organizations, including faith-based organizations.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding, HABs, Extreme Heat, Pest & Disease, High Winds
	PO-LA-2	Initiate a process of developing one or more neighborhood-based Resilience Hubs to facilitate communication, distribute resources, and provide services to residents before, during, and after climate disruptions. Use the Urban Sustainability Directors Network (USDN) Guide to Developing Resilience Hubs as a starting point for local and regional knowledge exchange; work with CRP to seek collaborative funding opportunities.	All Threats
	PO-LA-3	Promote collective ownership by creating community spaces at Town facilities where meetings and movement-building activities can occur. These events can focus on specific community need and various climate issues.	All Threats
	PO-LA-4	On strategic infrastructure projects, consider partnering with local artists and community groups to collaborate on climate education components at strategic locations throughout the Town. Use educational signage and community events to promote the art exhibitions and unique features of each project.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH (CONTINUED)	PO-LA-5	Offer drainage reviews to property owners free of charge to provide recommendation on improvements that reduce offsite discharges and improve water quality.	Rainfall-Induced Flooding, HABs, Tidal Flooding, Extreme Heat
FUNDING AND FINANCE	FF-LA-1	Change Town planning processes to include a "funding first" approach where economics, finance, and climate change are considered first and then throughout the planning processes.	All Threats
	FF-LA-2	Make use of State and Federal funding programs for home weatherization for low- and medium-income households.	Extreme Heat, High Winds
	FF-LA-3	Begin preparing key findings of this study to compete for funding with the landmark 'Always Ready' resilience law. Share lessons learned and resources as a part of the CRP.	Rainfall-Induced Flooding, Tidal Flooding, Storm Surge
	FF-LA-5	Find ongoing funds to replant established canopy after wind events.	High Winds

Coastal Resilience Partnership

Climate Change Vulnerability Assessment Ocean Ridge

Ocean Ridge is a thriving and spirited barrier island community that has tremendous natural beauty and critical residential areas to care for in the coming years. The Town is aware of the challenges it faces with regards to climate change and looks forward to productive and holistic strategies that can be implemented within the CRP and other regional partners.

Key Study Findings for Ocean Ridge

- As expected, the Town has fewer critical facility assets compared to other jurisdictions in the region but does have vulnerable government-owned properties.
- Ocean Ridge has high vulnerability to storm surge, especially for residential property and road accessibility (among the highest percentages in the region for both).
- Residential properties and roads have some vulnerability to current tidal flooding, but these levels could increase, especially for the 2070 (2020 baseline +33-inches sea level rise) projection levels.
- Florida Department of Transportation (FDOT) will be critical in effectively addressing roadway flooding throughout the Town as they maintain significant stormwater assets within the Town.
- Residential vulnerability to high winds is higher than the region as whole. This is due to the general older age of the buildings (years of construction).
- Ocean Ridge is one of the more vulnerable areas in the region due to shoreline recession, thus is at increased risk to severe storms and future sea level rise.

Top asset categories of concern, as identified by the study's planning tools (AccelAdapt and APEX), are listed below. The first list focuses on assets that the Town owns, and the second list contains assets located within the Town that are owned by other parties. Both lists focus on the threats of tidal flooding, storm surge, rainfall-induced flooding, and high winds.

Top Town-Owned Asset Categories of Concern

- Ocean Ridge Town Hall (6450 N Ocean Blvd, Boynton Beach, FL 33435) is vulnerable to storm surge, rainfall-induced flooding, tidal flooding, and high winds.
- Town-owned natural coastal lands (PCNs: 46-43-45-22-11-000-0700, 46-43-45-27-00-003-0091, 46-43-45-34-05-001-0712, 46-43-45-34-05-001-0092) are vulnerable to storm surge, tidal flooding, and rainfall-induced flooding.

Top Non-Town-Owned Asset Categories of Concern

- The beach parking lot at 6620 N Ocean Blvd, Boynton Beach, FL 33435 is vulnerable to storm surge, rainfall-induced flooding, high winds, and tidal flooding.
- State-owned natural coastal lands (PCNs: 46-43-45-27-07-003-0110, 46-43-45-27-07-003-0100, and 46-43-45-27-07-004-0100) are vulnerable to storm surge, tidal flooding, and rainfall-induced flooding.

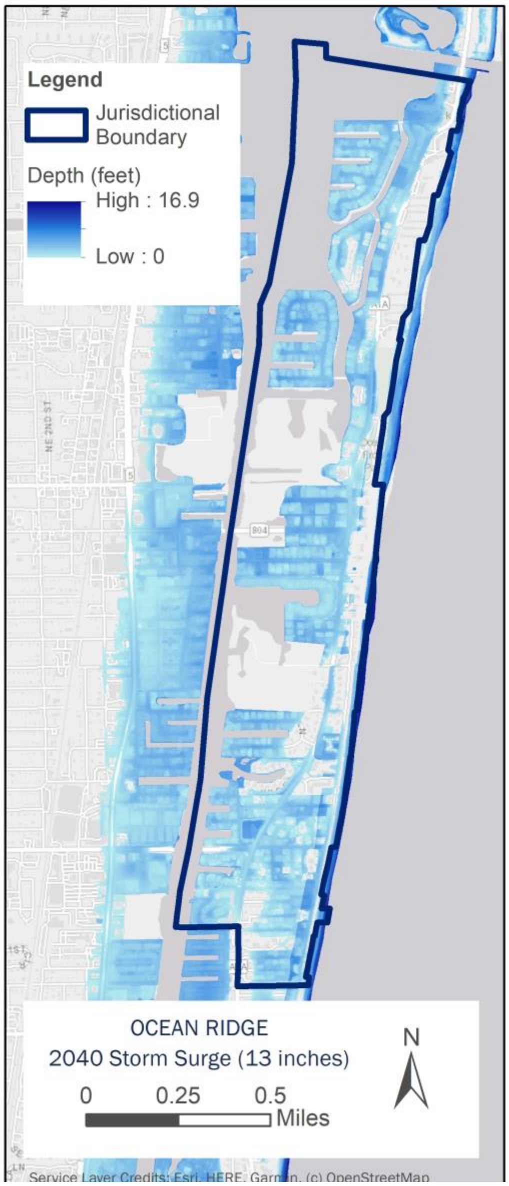


Figure A7-1: Predicted storm surge in Ocean Ridge, Florida (2040).

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for the Town of Ocean Ridge are highlighted in a portfolio format that follows.

Ocean Ridge: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-OR-1	Implement shoreline protection, natural or otherwise, to protect shorelines and mitigate erosion.	Shoreline Recession, Storm Surge, Tidal Flooding
	INF-OR-2	Implement more living shoreline projects in vulnerable locations.	Shoreline Recession, Storm Surge, Tidal Flooding, Harmful Algal Blooms (HABs)
	INF-OR-3	Prioritize nutrient reduction through a multi-pronged plan: septic-to-sewer, multi-benefit stormwater projects, and improved monitoring.	HABs, Rainfall-Induced Flooding
	INF-OR-4	Make sure there is shade, safe biking, and walking connections throughout the Town.	Extreme Heat
	INF-OR-5	Evaluate critical infrastructure vulnerabilities and work with regulators and partners to minimize gaps in services: utilities, schools, critical care, emergency buildings, etc.	All Threats
LAND USE BUILDING CODES AND STANDARDS	LU-OR-1	Preserve open space in flood prone areas to maintain pervious surface and reduce offsite discharges	Rainfall-Induced Flooding, HABs, Saltwater Intrusion
	LU-OR-2	Create flood maps based on future conditions (including maximum imperviousness) that can be incorporated in land development regulations.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding
	LU-OR-3	Conduct an assessment of unused or underutilized properties and develop an approach for utilizing such properties that enhances overall resilience goals (e.g., stormwater treatment, small parks, etc.).	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE BUILDING CODES AND STANDARDS (CONTINUED)	LU-OR-4	Evaluate existing land development regulations and development standards to encourage installation and use of energy-efficient and small-scale distributed renewable and modular waste-to-energy systems that are grid independent.	Extreme Heat
	LU-OR-5	Designate adaptation action areas as a priority-setting tool for vulnerable areas, and as a means to maximize benefits to natural systems while guiding people and commerce to less vulnerable places in the Town.	Storm Surge, Tidal Flooding
PLANNING, POLICY, AND MANAGEMENT	PP-OR-1	Conduct an annual review of sea level rise strategy before the capital budgeting process initiates to ensure coordination on project funding and implementation schedules.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding, Saltwater Intrusion, Shoreline Recession
	PP-OR-2	Undertake a comprehensive, integrated roads and flood mitigation analysis and identify recommendations to modify roadway design specifications to provide a higher level of service for evacuation routes and priority roadways.	Tidal Flooding, Storm Surge, Rainfall-Induced Flooding
	PP-0R-3	Create and invest in strategic pre-disaster plans for post-disaster recovery.	All Threats
	PP-OR-4	Develop regulatory criteria to include ecologic/habitat functional considerations in stormwater planning procedures.	HABs, Rainfall-Induced Flooding, Saltwater Intrusion
	PP-OR-5	Draft a community-level emergency response plan and revisit annually based on latest	All Threats

CRP

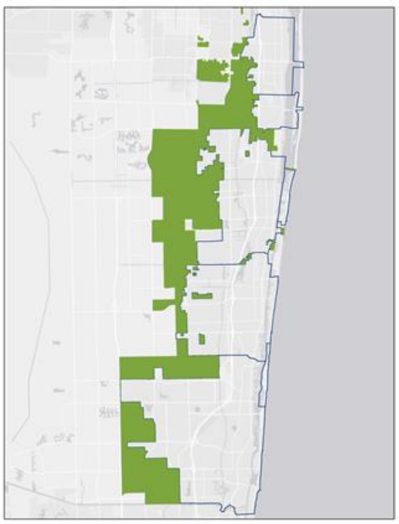
STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)		climate science (for example, new tidal data).	
CAPACITY BUILDING	CB-OR-1	Develop financing and tools to assist individuals with personal/home adaptation.	All Threats
	CB-OR-2	Work with public health departments to identify early warnings of water-related illness due to water quality impairments. Track public health data after water system failures, flooding, and storm surge.	HABs, Storm Surge, Rainfall-Induced Flooding, Tidal Flooding
	CB-OR-3	Use heat maps to show "hot spots" for reported flooding (locations of 311 calls over time).	Storm Surge, Rainfall-Induced Flooding, Tidal Flooding
	CB-OR-4	Create a volunteer flood watch system where local residents report observations to the Town.	Storm Surge, Rainfall-Induced Flooding, Tidal Flooding
PUBLIC OUTREACH	PO-OR-1	Promote collective ownership by creating community spaces where meetings and movement-building activities can occur	All Threats
	PO-OR-2	Partner with local artists and community groups to fund community green space around water infrastructure components such as stormwater pumps. For example, partner with a school district to make "stormwater schoolyard" with green infrastructure (San Francisco).	HABs, Rainfall-Induced Flooding

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH (CONTINUED)	PO-OR-3	Offer drainage reviews to property owners free of charge to provide recommendation on improvements that reduce offsite discharges and improve water quality.	HABs, Rainfall-Induced Flooding
	PO-OR-4	Develop a central web portal that is dedicated to all items related to flooding for public education and outreach.	HABs, Storm Surge, Rainfall-Induced Flooding, Tidal Flooding
	PO-OR-5	Develop app for citizen scientists to take and submit photos of flooding. These photos are helpful to Town staff for multiple purposes. It is particularly helpful when a structure is captured in each photo with date, time so that a depth and elevation can later be determined.	Storm Surge, Rainfall-Induced Flooding, Tidal Flooding
FUNDING AND FINANCE	FF-OR-1	Seek new legislation and appropriate streams of revenue to support projects.	All Threats
	FF-OR-2	Find ongoing funds to replant established canopy after wind events.	High Winds, Extreme Heat
	FF-OR-3	Begin preparing key findings of this study to compete for funding with the landmark 'Always Ready' resilience law. Share lessons learned and resources as a part of the CRP.	Rainfall-Induced Flooding, Storm Surge, Tidal Flooding
	FF-OR-4	Incentivize private property owners to implement green infrastructure and stormwater Best Management Practices (BMPs) through a reduced stormwater fee incentive program.	HABs, Rainfall-Induced Flooding

CRP

Coastal Resilience Partnership

Climate Change Vulnerability Assessment Palm Beach County



Palm Beach County is in a unique position as both a participant in the study and a local government encompassing all the municipalities in the Coastal Resilience Partnership. The County has sizable "unincorporated" areas, mainly towards the western side of the study area. As the third largest and wealthiest County in Florida, the County is a rapidly growing and urbanizing community. While the threats of climate change in the area are significant, the County is relatively elevated compared to its southern neighbors. So, not only does the County need to address its own challenges but it will also have to consider population growth and migration within the region as sea levels rise.

Key Study Findings for Palm Beach County

- As expected, most flood-related vulnerabilities in the unincorporated area are confined to further inland areas where rainfall-induced flooding is the primary issue.
- There are relatively fewer critical facility assets in the unincorporated area of the County within the study area. Residential property, jobs (business employees) and road infrastructure are a few of the primary asset types covered by the study area.
- For rainfall-induced flooding, levels of vulnerability and risk are comparable to levels of the region as a whole (unincorporated areas are also fairly distributed throughout region).
- Vulnerability to high winds is somewhat lower for the County, which is partly due to more recent development (after 1995).
- There are highly sensitive populations vulnerable to extreme heat in several areas, mostly in the Western portion of the study area, including along the S. Military Trail corridor and the Northwest part of the CRP region.

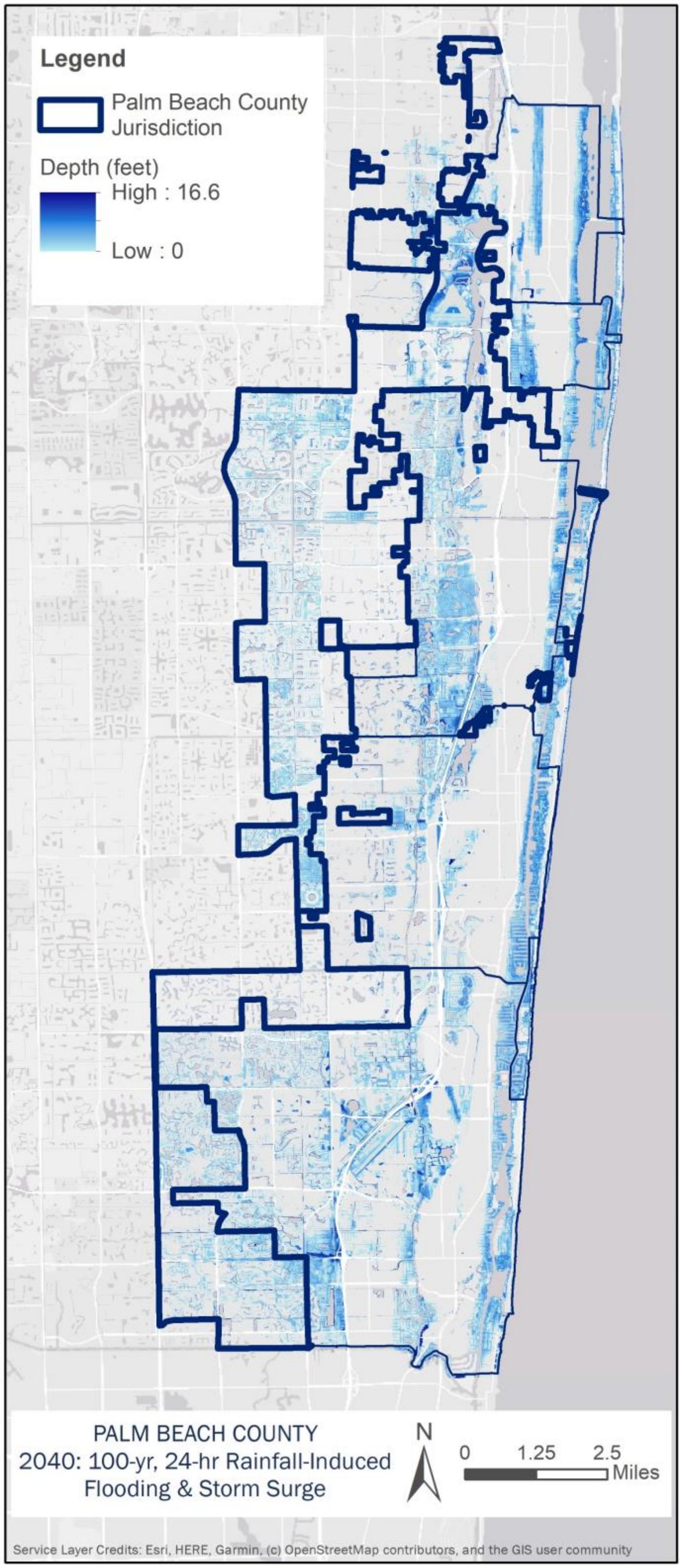


Figure A8-1: Predicted combined 100-year, 24-hour rainfall-induced flooding and storm surge in Palm Beach County, Florida (2040).

Top 5 County-Owned Asset Categories of Concern

- John Prince Park (2700 6th Ave S, Lake Worth, FL 33461) is vulnerable to rainfall-induced flooding and high winds.
- Palm Beach County Fire Rescue Station 55 (6787 Palmetto Cir N, Boca Raton, FL 33433) is located near the Gulf Stream Canal and is vulnerable to rainfall-induced flooding and high winds.
- Ocean Ridge Natural Area (1 Corrine St, Ocean Ridge, FL 33435) is vulnerable to storm surge, tidal flooding, rainfall-induced flooding, and high winds.
- Ocean Ridge Beach Parking is located on the coast and is vulnerable to storm surge, rainfall-induced flooding, high winds, and tidal flooding (6620 N Ocean Blvd, Boynton Beach, FL 33435)
- Palm Tran South County Facility is located near the Gulf Stream Canal (100 N Congress Ave, Delray Beach, FL 33445) and is vulnerable to rainfall-induced flooding and high winds.

Top Non-County-Owned Asset Categories of Concern in Unincorporated Palm Beach County

- Multi-residences near canals are vulnerable to rainfall-induced flooding and high winds.
  - High Point of Delray West, a 55+ Community, (5230 Lakefront Blvd, Delray Beach, FL 33484)
  - Greentree Villas, a 55+ Community, (4674 Greentree Pl, Boynton Beach, FL 33436)
- Private schools near canals are vulnerable to rainfall-induced flooding and high winds.
  - Saint Jude Catholic School (21689 Toledo Rd, Boca Raton, FL 33433) is located near the Gulf Stream Canal.
  - Trinity Christian Academy (7259 S Military Trail, Lake Worth, FL 33463) is located near a canal.
- The two Palm Beach County Schools below are most vulnerable to rainfall-induced flooding and high winds.
  - Christa McAuliffe Middle School (6500 Le Chalet Blvd, Boynton Beach, FL 33472)
  - Crystal Lakes Elementary School (6050 Gateway Blvd, Boynton Beach, FL 33472) is located near a canal.
- Several commercial properties are vulnerable to rainfall-induced flooding and high winds.
  - Plaza near Lake Osborne (6074 S Congress Ave, Lake Worth, FL 33462)
  - The Boardwalk at 18th Street is near the Gulf Stream Canal (6853 SW 18th St, Boca Raton, FL 33433)

Over 500 adaptation strategies were investigated as part of the study. The top recommended strategies for Palm Beach County are highlighted in a portfolio format that follows.

Palm Beach County: Portfolio of Recommended Adaptation & Mitigation Strategies

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
INFRASTRUCTURE	INF-PBC-1	Continue to expand electric vehicle (EV) charging infrastructure, including through support of a regional framework for locating public EV charging stations and expanding EV opportunities at multifamily buildings, workplaces, and commercial and retail centers.	Extreme Heat
	INF-PBC-2	Continue to provide leadership on alternate transportation facilities that are safe and low-impact (i.e., trails, separated bike paths, etc.) to allow impacted populations a safe route to public service/health facilities.	Extreme Heat
	INF-PBC-3	Continue to reduce nutrient loads to receiving waterbodies through capital projects, enhanced best management practices, land development regulation updates and other strategies.	Harmful Algal Blooms (HABs), Rainfall-Induced Flooding
	INF-PBC-4	Continue to create community gardens within vulnerable communities with limited access to transportation. Also create mobile food markets connecting communities to food distribution centers and grocery stores to address food deserts and other food equity issues.	Extreme Heat

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
 **LAND USE, ZONING, BUILDING CODES AND STANDARDS**	**LU-PBC-1**	**Where opportunities for improvement exist, modify local land use policies and codes to continue support for compact development patterns, creating more walkable and affordable communities.**	**All Threats**
	LU-PBC-2	**Collaborate and advocate for the regional creation of a green infrastructure/low impact development (GI/LID) manual to provide a toolbox of green infrastructure practices and site design options for municipal staff and consulting engineers and architects. The design manual should include pollutant removal efficiencies, design constraints, and appropriate settings and materials for Southeastern Palm Beach County. Link this strategy to other engagements with Florida Department of Environmental Protection (FDEP) and South Florida Water Management District (SFWMD) to award Environmental Resource Permit (ERP) credit for LID usage in Palm Beach County.**	**HABs, Rainfall-Induced Flooding, Storm Surge, Tidal Flooding**
	LU-PBC-3	**Continue to incorporate green infrastructure in "complete streets" or other capital improvements through revisions to the land development regulations.**	**Rainfall-Induced Flooding, HABs, Drought, Storm Surge, Tidal Flooding**
	LU-PBC-4	**Continue supporting, prioritizing, and planning living shoreline projects.**	**Shoreline Recession, Storm Surge, Tidal Flooding, HABs**

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
LAND USE, ZONING, BUILDING CODES AND STANDARDS (CONTINUED)	LU-PBC-5	Assess unused or underutilized properties (e.g., parking garages) and develop an approach for utilizing such properties to enhance overall resilience goals (e.g., stormwater treatment/storage, green space or parks, emergency shelters).	All Threats
PLANNING, POLICY, AND MANAGEMENT	PP-PBC-1	Continue to ensure there are safe, shaded biking and walking connections in socially vulnerable areas and rural areas.	Extreme Heat
	PP-PBC-2	Review existing literature, data and studies related to climate change and public health and determine opportunities to enhance local policy to better address these issues particularly for socially vulnerable communities.	All Threats
	PP-PBC-3	Continue to map watersheds and floodplains and document the County's water resources and stormwater systems via an engaged and regional modeling effort. Consider including integrated modeling (both groundwater and surface water similar to Broward County's approach), as well as flood-risk and water quality considerations for both current and future conditions.	HABs, Rainfall-Induced Flooding, Tidal Flooding, Storm Surge, Saltwater Intrusion
	PP-PBC-4	Collaborate as part of the Coastal Resilience Partnership (CRP) to compile resources to encourage sustainable landscaping practices, pervious surfaces, and downspout disconnection for homeowners and businesses. Tie the initiative to existing resources that encourage Florida-Friendly Landscaping™ and those that reduce fertilizer usage. Cater the	HABs, Rainfall-Induced Flooding

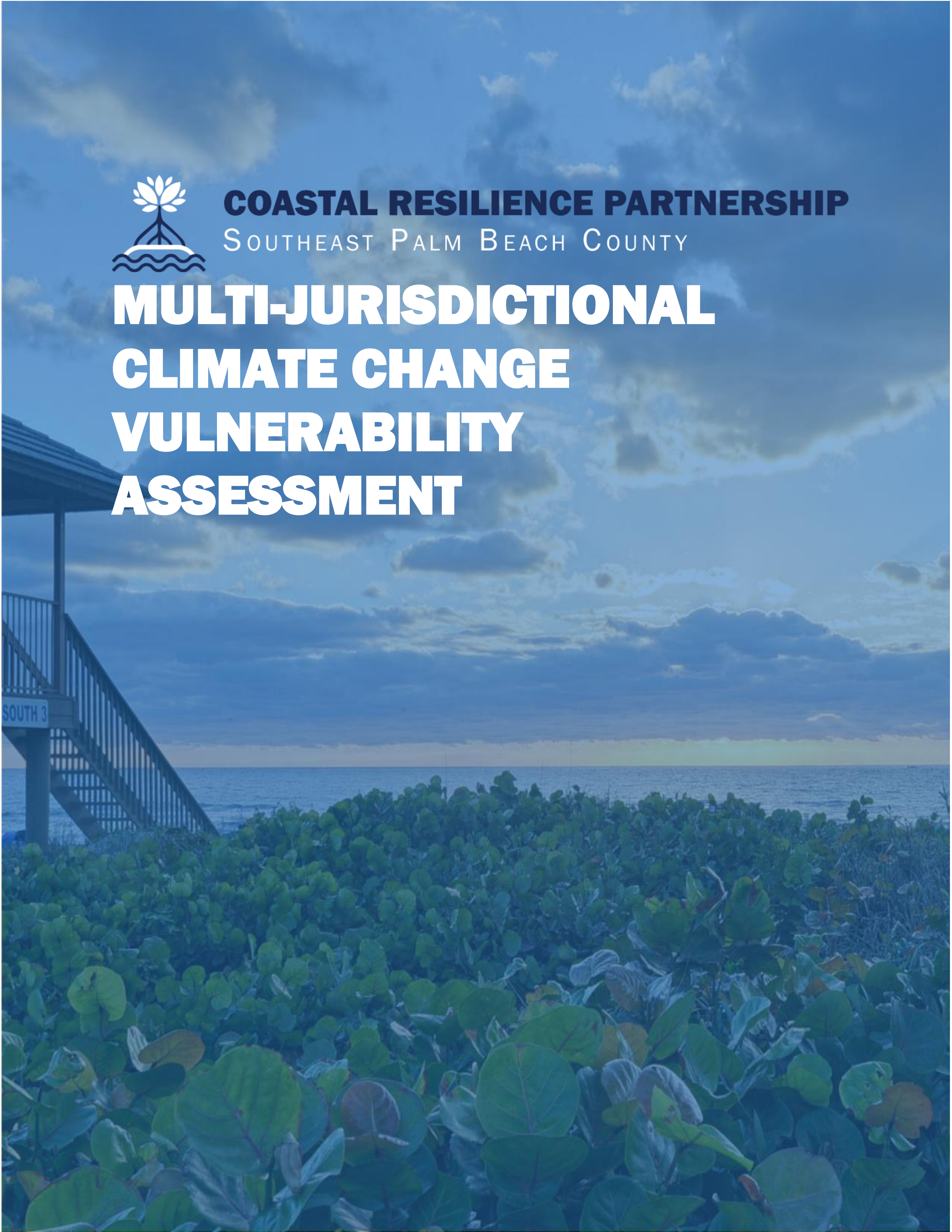
STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PLANNING, POLICY, AND MANAGEMENT (CONTINUED)		specific measures to Southeast Palm Beach County so that the resources are easier for the public to use (plant menus, instructions, local resources, etc.). Tap into the resources provided by the Institute of Food and Agricultural Sciences (IFAS) Extension at the University of Florida and the local Palm Beach County Cooperative Extension.	
	PP-PBC-5	Continue to coordinate with the Florida Department of Health on data collection and monitoring for insect infestation and disease outbreaks.	Pest & Disease Outbreak
CAPACITY BUILDING	CB-PBC-1	Continue to develop economic analyses in partnership with local universities, colleges, and other local government agencies that can be used to quantify the value and impact of resilience investments.	All Threats
	CB-PBC-2	Continue to work with PalmTran and other regional service providers to further identify areas of inequality in availability or use of transportation services and identify additional partnerships and resources to expand services.	Extreme Heat
	CB-PBC-3	Continue to prepare, educate, and train stakeholder groups and other local governments across the County to improve response time to climate-related threats and expand scope as needed to include additional threats.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
CAPACITY BUILDING (CONTINUED)	CB-PBC-4	Continue to offer climate and resilience information in other languages at community events and other outreach opportunities to ensure frontline communities are a priority and are engaged in an approachable way.	All Threats
PUBLIC OUTREACH	PO-PBC-1	Utilize visual arts, signage, installations, and participatory events to creatively communicate to residents and visitors the localized impacts of climate change and avenues for community action.	All Threats
	PO-PBC-2	Develop a toolkit of information for personal adaptation targeted to vulnerable populations.	All Threats
	PO-PBC-3	Connect with the community through the Office of Community Revitalization's "Neighborhood Connectors," who engage with residents regularly. Work with Neighborhood Connectors and other community stakeholders to disseminate information on climate science and gather first-hand feedback on how climate threats are affecting vulnerable populations.	All Threats
	PO-PBC-4	Continue to provide equity and social justice training for local government staff covering topics such as (a) How systemic inequity and racism are threat-multipliers for climate change and (b) How to design and implement equitable climate solutions through collaboration between community groups and City and County leaders.	All Threats

STRATEGY TYPE	ID	DESCRIPTION	APPLICABLE THREAT(S)
PUBLIC OUTREACH (CONTINUED)	**PO-PBC-5**	**Continue to identify and implement strategies to fund wetland restoration. Projects should include major restoration efforts as well as pocket wetlands in urbanized areas.**	**HABs, Rainfall-Induced Flooding, Saltwater Intrusion**
FUNDING AND FINANCE	**FF-PBC-1**	**Revisit the potential of a dedicated funding source (e.g., stormwater utility) for stormwater improvements and/or resilience planning.**	**HABs, Rainfall-Induced Flooding**
	FF-PBC-2	**Continue leadership on legislative matters and regional funding for building resilience.**	**All Threats**
	FF-PBC-3	**Collaborate as the CRP to identify and share resources and tools to assist individuals with financing home or business adaptation efforts.**	**All Threats**
	FF-PBC-4	**Engage in the implementation of the new landmark ‘Always Ready: Flooding & Sea Level Rise Act’ resilience law and ensure the County has taken the necessary steps to be at the front of the line when planning and infrastructure funds become available.**	**All Threats**

COASTAL RESILIENCE PARTNERSHIP
SOUTHEAST PALM BEACH COUNTY

MULTI-JURISDICTIONAL CLIMATE CHANGE VULNERABILITY ASSESSMENT



Coastal Resilience Partnership

Climate Change Vulnerability Assessment Update (2022)

The Coastal Resilience Partnership of Southeast Palm Beach County continues to show commitment to community sustainability and environmental stewardship by updating the 2021 Climate Change Vulnerability Assessment to meet the additional standards for the Resilient Florida Grant Program. This phase of the project expanded the climate scenarios and knowledge of critical infrastructure for all members of the Coastal Resilience Partnership.

Introduction

The Coastal Resilience Partnership of Southeast Palm Beach County (CRP) completed a Climate Change Vulnerability Assessment (CCVA) for the jurisdictions of Boynton Beach, Boca Raton, Delray Beach, Highland Beach, Ocean Ridge, Lantana, Lake Worth Beach, and a portion of unincorporated Palm Beach County in July of 2021. The CRP CCVA 2021 meets many of the requirements of the new Resilient Florida Grant Program (Section 380.093, Florida Statute (F.S.)), but the analysis needed to be expanded to include the National Oceanic and Atmospheric Administration (NOAA) intermediate-low and intermediate-high sea level rise projections for 2040 and 2070 to be fully compliant. The new analysis updated the storm surge and tidal flooding vulnerability assessment for all critical assets per the statute. Both storm surge and tidal flooding were included in the original 2021 CCVA but the climate scenarios differed from Resilient Florida, so the updates were necessary.

Interested parties should consult the original CRP CCVA 2021 report for more information on the original analyses and foundational information on the overall study. That report can be viewed here:

https://discover.pbcgov.org/resilience/PDF/20210903_ADA_CCVA_FinalReport.pdf

This Appendix is an official modification to the original CRP CCVA 2021 report. It is also notable that the terms rainfall-induced flooding (as outlined in the CRP CCVA 2021) and compound flooding (as defined by Resilient Florida) are interchangeable.

Sea Level Rise

The sea level rise estimates were updated using the 2017 NOAA intermediate-low and NOAA intermediate-high projections to 2040 and to 2070 to comply with Section 380.093, F.S. The total rise was calculated using guidance available in the "Unified Sea Level Rise Projection Southeast Florida, 2019 Update" from the Southeast Florida Regional Climate Change Compact. The curves for the Key West gauge were used to maintain consistency with the original CRP CCVA 2021 and to apply the most conservative estimate of rise. This resulted in the estimated future rise relative to 2020 as shown in Table 1 below. **Please note, the values below represented in feet (ft) and inches (in) have been rounded to the nearest tenths place and whole number, respectively.**

Table A9-1: Sea Level Rise relative to 2020 estimated from 2017 NOAA Intermediate-High and Intermediate-Low Curves

Estimate of Future Sea Level Rise relative to 2020				
Current (2020)	2017 NOAA Intermediate-Low Curve		2017 NOAA Intermediate-High Curve	
	2040	2070	2040	2070
0 ft	0.4 ft (4 in)	1.0 ft (11 in)	0.8 ft (10 in)	2.8 ft (33 in)

Tidal Flooding

The sea level rise estimates shown in Table A9-1 were added to 2020 King Tide flood elevation to develop inundation depths and extents. The King Tide flood elevation was established using the Adaptation Action Elevation (AAE) as defined by Brizaga in the July CRP CCVA 2021 Report. Brizaga' s AAE is defined as the 98th percentile daily higher high water. This was established as 2.2 ft North American Vertical Datum (NAVD-88 or NAVD) for the Lake Worth Pier gauge. Table A9-2 below shows the projected future King Tide flood elevations. **Please note, the values below represented in feet (ft) and inches (in) have been rounded to the nearest tenths place and whole number, respectively.**

Table A9-2: King Tide flooding with sea level rise from 2017 NOAA Intermediate-High and Intermediate-Low Curves. Elevations in feet NAVD-88.

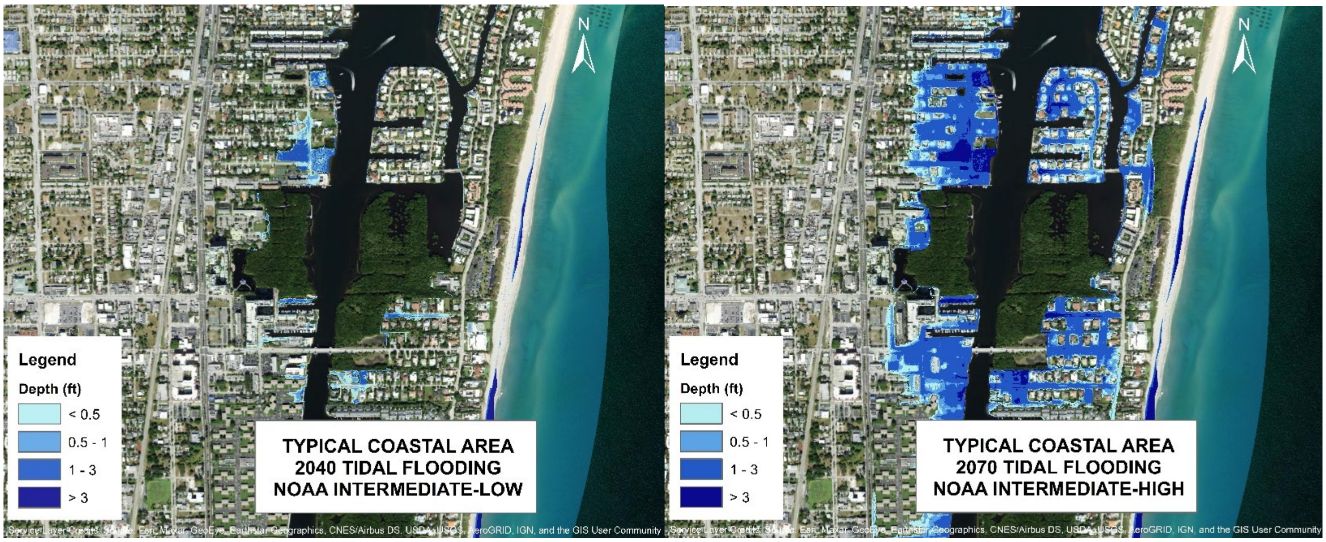
Current King Tide (2020) (ft NAVD)	2017 NOAA Intermediate-Low Curve		2017 NOAA Intermediate-High Curve	
	2040	2070	2040	2070
	Current + 4" (ft NAVD)	Current + 11" (ft NAVD)	Current + 10" (ft NAVD)	Current + 33" (ft NAVD)
2.2	2.6	3.2	3.0	5.0

Inundation depths and extents were created for areas connected directly to tidal waterbodies. Seawalls were not explicitly included unless they were reflected in the LIDAR datasets (which is uncommon in southern Palm Beach County). Engineering judgement was used to determine areas directly connected to tidal waterbodies based on:

- South Florida Water Management District (SFWMD) tidal structures and canals (SFWMD, 2022)

- Lake Worth Drainage District (LWDD) tidal structures and canals (LWDD, 2022)
- Aerial imagery (ESRI et al, 2022)
- 2016 Palm Beach County DEM (Digital Elevation Model) average vertical error (Dewberry, 2018)

Figure A9-1: Example of Tidal Flooding Analyses Completed for the CRP in April 2022



Storm Surge

The estimated sea level rise values shown in Table A9-1 were added to existing storm surge flood elevations to develop inundation depths. Existing storm surge elevations were developed from the Effective 2017 Federal Emergency Management Agency (FEMA) Special Flood Hazard Areas (SFHA) Base Flood Elevations (BFEs) (FEMA, 2017b). It should be noted that the preliminary 2019 FEMA SFHAs BFEs (FEMA, 2019) are up to 4 feet higher within parts of the assessment area but were not used for this analysis since they were still preliminary when this analysis was completed.

To be conservative and maintain consistency with the first phase of the CRP CCVA 2021, the 2017 FEMA BFEs were adjusted for sea level rise. According to the 2017 FEMA Flood Insurance Study (FIS) Report, coastal stillwater elevations developed in 1977 were used as starting elevations for the wave runup analysis to develop the coastal SFHAs. Therefore, for this analysis, the 2017 FEMA BFEs were adjusted to account for sea level rise from 1977. The historic rate of rise at the NOAA Lake Worth Pier gauge is 3.81 millimeters (mm)/year (0.0125 ft/year); this result is a rise of approximately 0.5 feet between 1977 and 2020. Therefore, 0.5 feet was added to the 2017 FEMA BFEs to establish current 2020 flood elevations.

The minimum and maximum storm surge elevations used for the study area are shown in Table A9-3 below. The minimum elevations were used along the most inland portions of the storm surge flooding while the maximum elevation was used along the coast. Elevations vary between the minimum and maximum elevation based on the 2017 FEMA BFEs. **Please note, the values below represented in feet (ft) and inches (in) have been rounded to the nearest tenths place and whole number, respectively.**

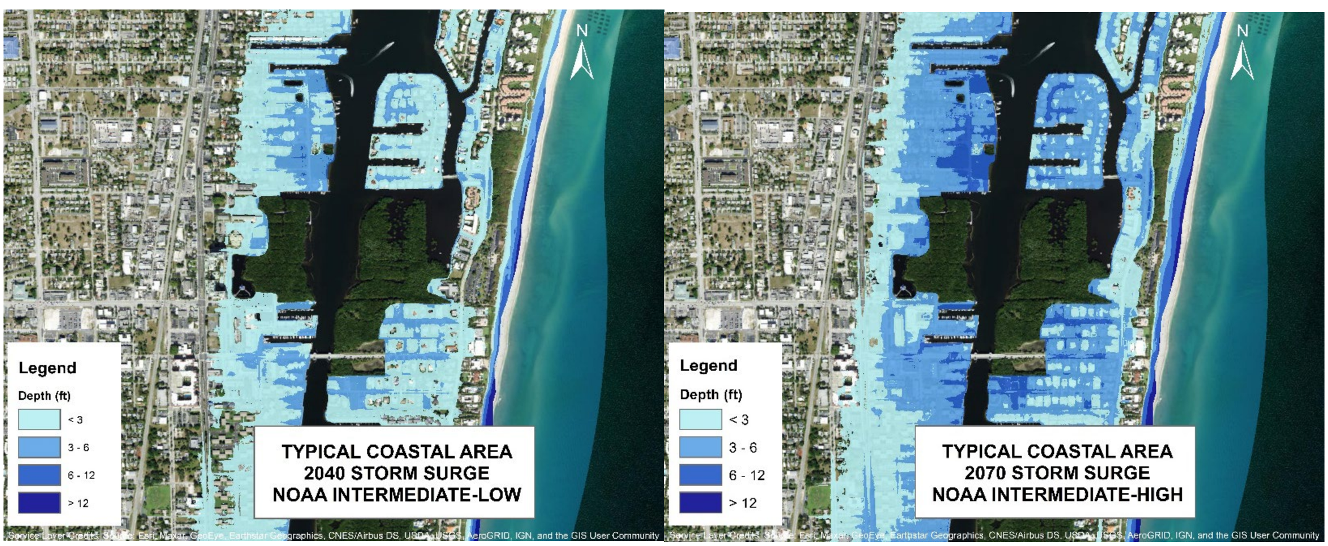
Table A9-3: Storm surge minimum and maximum elevations used within the study area with sea level rise from 2017 NOAA Intermediate-High and Intermediate-Low curves. Elevations in feet NAVD-88.

	Current 2020 BFEs (2017 BFE + 0.5') (ft NAVD)	NOAA INT-LOW		NOAA INT-HIGH	
		2040 Current + 4" (ft NAVD)	2070 Current + 11" (ft NAVD)	2040 Current + 10" (ft NAVD)	2070 Current + 33" (ft NAVD)
Minimum	6.5	6.9	7.5	7.3	9.3
Maximum	13.5	13.9	14.5	14.3	16.3

Inundation depths and extents were created for areas connected directly to tidal waterbodies. Seawalls were not explicitly included unless they were reflected in the LIDAR datasets (which is uncommon in southern Palm Beach County). Engineering judgement was used to determine areas directly connected to tidal waterbodies based on available information including:

- South Florida Water Management District (SFWMD) tidal structures and canals (SFWMD, 2022)
- Lake Worth Drainage District (LWDD) tidal structures and canals (LWDD, 2022)
- Aerial imagery (ESRI et al, 2022)
- 2016 Palm Beach County DEM (Digital Elevation Model) average vertical error (Dewberry, 2018)

Figure A9-2: Example of Storm Surge Analyses Completed for the CRP in April 2022



Updated Asset Vulnerability Analysis

Once the tidal flooding and storm surge elevation information was updated to comply with Section 380.093, F.S., the asset data for the CRP jurisdictions was analyzed against the updated elevations.

The update included 80 permutations (2 time horizons x 2 sea level rise scenarios x 2 flood threats x 10 asset categories). The 10 asset categories were based on the previous asset categories used in the 2021 CCVA. The Resilient Florida Grant Program (Section 380.093, Florida Statute (F.S.)) specified analysis of asset categories for transportation assets and evacuation routes; critical infrastructure; critical community and emergency facilities; and natural, cultural, and historic resources.

The 4 asset categories specified were spread across 9 of the 10 categories* used in the CRP CCVA 2021. The categories included:

- Energy and Communications
- Health and Medical
- Public Safety and Government Owned
- Natural
- Commercial and Industrial
- Parks and Cultural Property
- Residential
- Transportation Facilities
- Roads

*Food Infrastructure was also assessed but did not include assets listed from 380.093 F.S.

Table A9-4 shows how the specific critical asset categories called out in Resilient Florida intersect with each of the CRP CCVA 2021 categories.

Table A9-4: Detailed comparison of CRP CCVA 2021 asset categories compared to 2022 Resilient Florida critical asset categories.

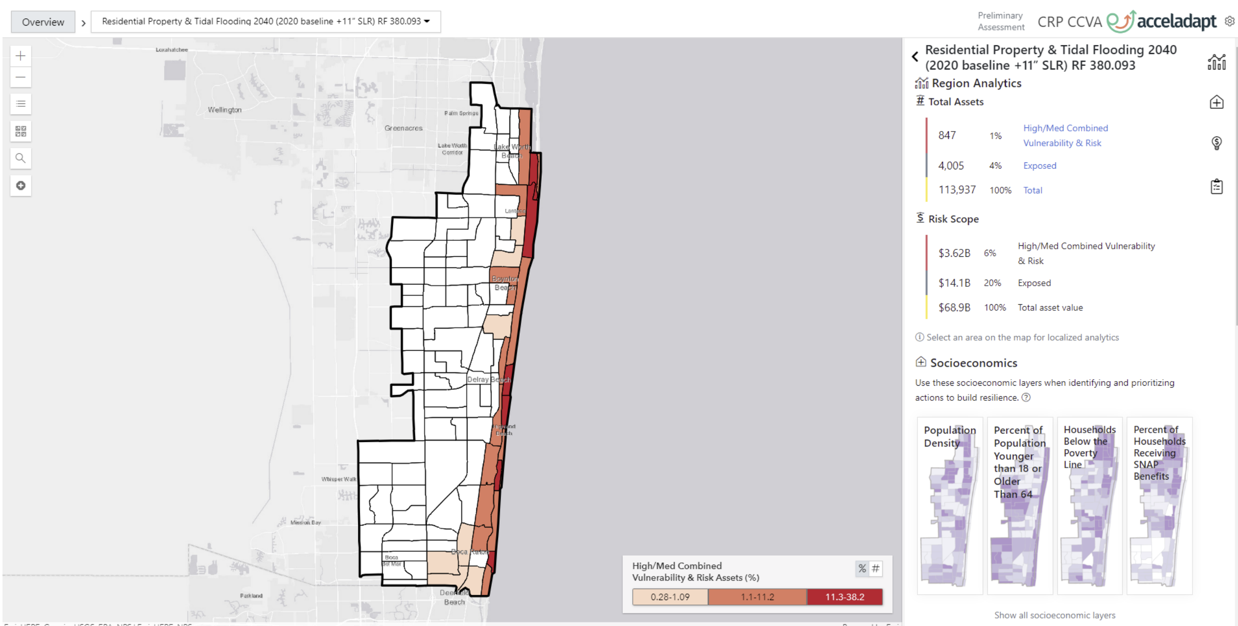
CRP 2021 CCVA Asset Categories	2022 Resilient Florida Critical Assets			
	Transportation Assets and Evacuation Routes	Critical infrastructure	Critical Community and Emergency Facilities	Natural, Cultural, and Historical Resources
Energy and Communications		Electric production and supply facilities, communications facilities		
Food Infrastructure	No Resilient Florida Reference but included in 2021 CCVA			
Health and Medical			Emergency medical service facilities, health care facilities, hospitals	
Natural				Conservation lands, wetlands (if part of managed areas), shorelines, surface waters
Commercial and Industrial		Solid and hazardous waste facilities, disaster debris management sites		
Parks and Cultural Property			Community centers	Parks, historical and cultural assets

CRP 2021 CCVA Asset Categories	2022 Resilient Florida Critical Assets (Continued)			
	Transportation Assets and Evacuation Routes	**Critical infrastructure**	**Critical Community and Emergency Facilities**	**Natural, Cultural, and Historical Resources**
Public Safety and Government Owned		Military installations (federal-owned properties were included in the CRP's analyses, it is possible some military installations were included but local governments do not have military specific data). Wastewater treatment facilities and lift stations, stormwater treatment facilities and pump stations, drinking water facilities, water utility conveyance systems (this analysis is contained in a separate confidential dataset that was provided to each jurisdiction).	Schools, colleges, universities, correctional facilities, disaster recovery centers, emergency operation centers (if part of municipal-owned), fire stations, law enforcement facilities, local government facilities, logistical staging areas (if part of municipal-owned property), risk shelter inventory (if part of municipal-owned), state government facilities (only state-owned properties were included)	
Residential			Affordable public housing	
Transportation Facilities	Airports, bus terminals, ports, marinas, rail facilities, railroad bridges (railroad bridges are not contained in study area)			
Roads	Bridges, major roadways, evacuation routes			

The analysis tool AccelAdapt (Fernleaf, 2022) was updated with the new horizons, updated scenarios, and updated threats (https://sepbc.acceladapt.com/). A screen shot of AccelAdapt is shown below in Figure A9-3. In addition to the AccelAdapt tool, deliverables submitted included:

1) "1_20220819_Task2Memo_Final" in .pdf and .docx formats – Technical memorandum (including a summary of the workshop with attendee feedback and outcomes)
2a) "2a_CCVA Update and AccelAdapt.pptx" - Slide deck of material covered in the workshop in a PowerPoint format
2b) "2b_update_pngs.zip" – All maps from AccelAdapt in PNG format
3a) "3a_CCVA 2022 Update Data Sources.docx" – Sources of GIS data that were developed into ESRI compatible formats
3b) "3b_Data Documentation Update 2022_5.26.2022.docx" – a summary of the data and metadata
4) "4_GISfiles" – GIS shapefiles and other electronic mapping data
5) "5_20220707_SigImpAssets.xlsx" – The list of critical assets and regionally significant assets

Figure A9-3: Image from AccelAdapt - Residential Property & Tidal Flooding 2040 (2020 Baseline + 11" SLR) RF 380.093



Outcomes

The Tidal Flooding and Storm Surge rasters corresponding with the 2017 NOAA Intermediate-High and Intermediate-Low curves did not visually appear significantly different than the CCVA project as finalized in July 2021 - primarily because each scenario was within a few inches. These differences (a few inches) are virtually undetectable upon visual inspection and are very close to the uncertainty created through both the use of the LIDAR data and subsequent inundation modeling. **So, while the data is now fully compliant with Resilient Florida (as of 2022), the update did not appreciably change the results for tidal flooding and storm surge.**

The CRP was consulted on updating analysis datasets in AccelAdapt to use the flood elevations aligning with the 2017 NOAA Intermediate-High and Intermediate-Low curves that satisfy the Resilient

Florida Grant Program (Section 380.093, Florida Statute (F.S.)). The CRP agreed to having datasets updated with corresponding values.

Additionally, as seen previously in Table A9-1, the resulting values for future sea level rise are 4-, 11-, 10- and 33-inches corresponding with NOAA intermediate-low values for 2040 and 2070 and with NOAA intermediate-high values for 2040 and 2070, respectively. For the asset analyses, the 11" SLR scenario appears to provide a reasonable estimate for the NOAA Intermediate-High 2040 scenario as well as the NOAA Intermediate-Low 2070 scenario; therefore, the 11" SLR was used to reflect both. Vulnerability at the census tract level of analysis did not change when using this parameter.

Table A9-5: Example Outcome: Roads and Parcels Storm Surge Analytics from 2022 Update (as portrayed in AccelAdapt Assessment (Fernleaf, 2022))

Roads and Parcels Inaccessible Due to Storm Surge (100-yr, 24-hr storm)			
Assessment Year	**Scenario**	**Number of Assets Exposed (out of 120,220 Assets)**	**Percent of Assets Exposed**
2020	Baseline 2020	10,145	8%
2040	2020 + 4" SLR	11,097	9%
2040/2070	2020 + 11" SLR	11,813	10%
2070	2020 + 33" SLR	15,489	13%

Table A9-6: Example Outcome Roads and Parcels Tidal Flooding Analytics from 2022 Update (as portrayed in AccelAdapt Assessment (Fernleaf, 2022))

Roads and Parcels Inaccessible Due to Tidal Flooding			
Assessment Year	**Scenario**	**Number of Assets Exposed (out of 120,220 Assets)**	**Percent of Assets Exposed**
2020	Baseline 2020	1,011	1%
2040	2020 + 4" SLR	1,488	1%
2040/2070	2020 + 11" SLR	2,385	2%
2070	2020 + 33" SLR	5,923	5%

All analytics for the updated datasets, such as those portrayed in Tables A9-5 and A9-6, can be found within the AccelAdapt program.

References

Coastal Resilience Partnership: Palm Beach County. Multi-Jurisdictional Climate Change Vulnerability Assessment. (2021). Final Project Report. Version 1.1 (July 2021). Available at: https://discover.pbcgov.org/resilience/PDF/20210903_ADA_CCVA_FinalReport.pdf.

Dewberry, 2018. Palm Beach County LiDAR: Report Produced for U.S. Geological Survey.

Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. World Imagery. Accessed 2022.

Federal Emergency Management Agency (FEMA). (2017a). Flood Insurance Study. Palm Beach County, Florida.

Federal Emergency Management Agency (FEMA). (2017b). Flood Insurance Rate Map (FIRM)12099C CV001B, October 2017.

Federal Emergency Management Agency (FEMA). (2019). Preliminary Flood Insurance Study 12099C CV001B, December 2019.

FernLeaf Interactive, LLC. (2022). Accel Adapt- CRP Climate Change Vulnerability Assessment. Available at: https://sepbc.acceladapt.com/#/overview/

Lake Worth Drainage District (LWDD), 2022. The Whole Kit.
Available at: https://lwdd.maps.arcgis.com/home/item.html?id=f4218237d103430aaa0c9120e3a1b809

Resilient Florida Grant Program, Section 380.093, F.S.

Southeast Florida Regional Climate Compact. (2020). Unified Sea Level Rise Projection Southeast Florida: 2019 Update. Available at: https://southeastfloridaclimatecompact.org/wp-content/uploads/2020/04/Sea-Level-Rise- Projection-Guidance-Report_FINAL_02212020.pdf.

SFWMD, 2022. Arc Hydro Enhanced Database (AHED), version updated February 2, 2022. Available at: SFWMD Arc Hydro Database (FGDB Download) | South Florida Water Management District Open Data (arcgis.com)