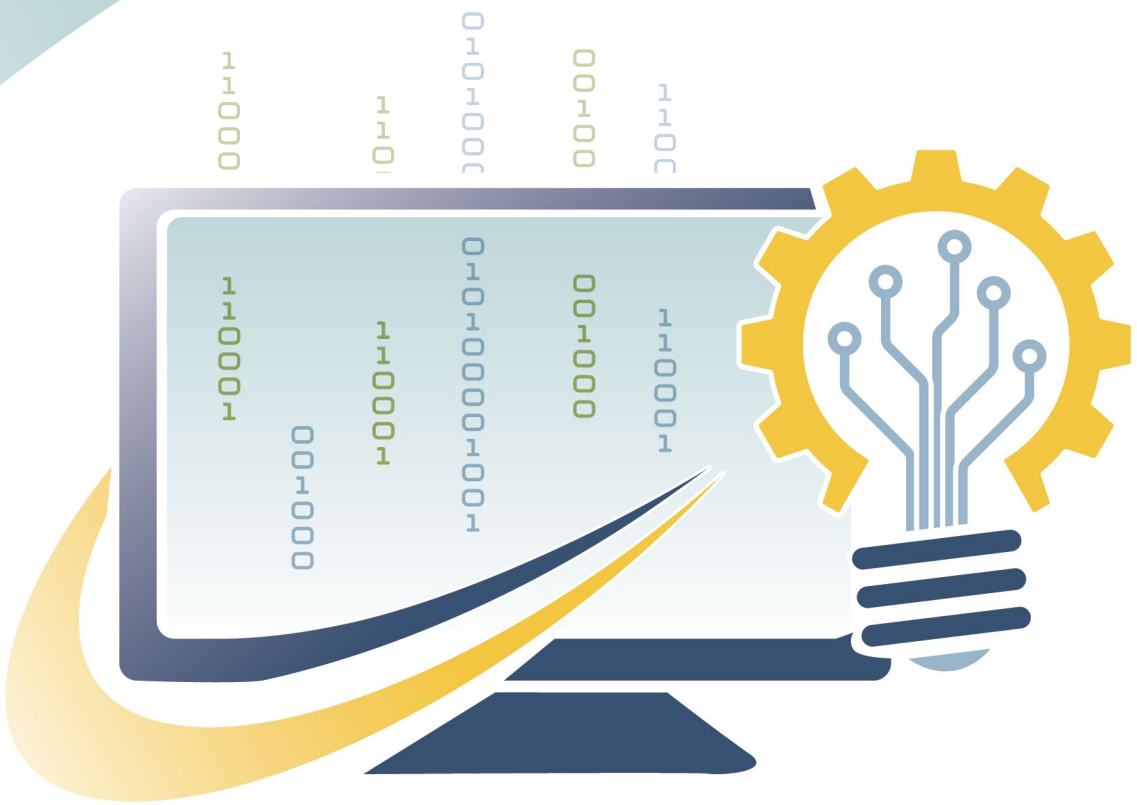


Virtual Capacity Building Workshop for Local Governments in Southeast Florida

Advancing Vulnerability Assessments Among Under-Resourced Communities in Southeast Florida: **A Multi-jurisdictional Approach**

August 8, 2023, 9 am

Broward County Work Authorization #93
Hazen Project No. 40718-004

Agenda

1 - State Requirements

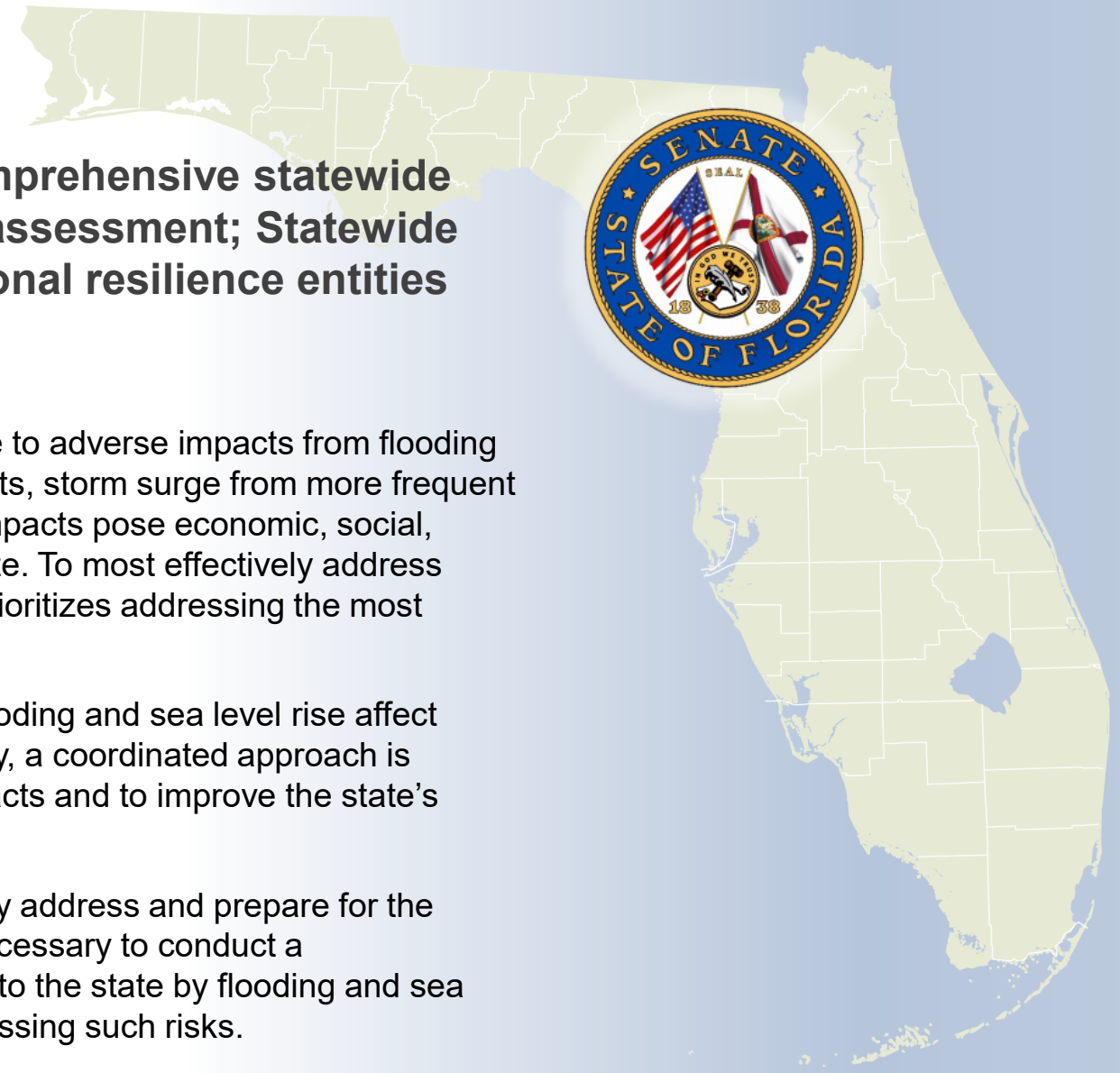
2 - Available Regional Resources and Data Sets and their Use

3 – Best Practices

4 - Lessons Learned/ Key Takeaways

1 - State Requirements

Florida Statute 380.093, F.S.



F.S. 380.093 - Resilient Florida Grant Program; comprehensive statewide flood vulnerability and sea level rise data set and assessment; Statewide Flooding and Sea Level Rise Resilience Plan; regional resilience entities

(1) LEGISLATIVE INTENT

a. The Legislature recognizes that the state is particularly vulnerable to adverse impacts from flooding resulting from increases in frequency and duration of rainfall events, storm surge from more frequent and severe weather systems, and sea level rise. Such adverse impacts pose economic, social, environmental, and public health and safety challenges to the state. To most effectively address these challenges, funding should be allocated in a manner that prioritizes addressing the most significant risks.

b. The Legislature further recognizes that the adverse impacts of flooding and sea level rise affect coastal and inland communities all across the state. Consequently, a coordinated approach is necessary to maximize the benefit of efforts to address such impacts and to improve the state's resilience to flooding and sea level rise.

c. The Legislature further recognizes that to effectively and efficiently address and prepare for the adverse impacts of flooding and sea level rise in the state, it is necessary to conduct a comprehensive statewide assessment of the specific risks posed to the state by flooding and sea level rise and develop a statewide coordinated approach to addressing such risks.

Florida Statute 380.093, F.S.

(3) RESILIENT FLORIDA GRANT PROGRAM

(a) The Resilient Florida Grant Program is established within the department.

(b) Subject to appropriation, the department may provide **grants** to a county or municipality to fund:

1. The costs of **community resilience planning** and necessary data collection for such planning, including comprehensive plan amendments and necessary corresponding analyses that address the requirements of s. 163.3178(2)(f).

2. **Vulnerability assessments** that identify or address risks of inland or coastal flooding and sea level rise.

3. The development of projects, plans, and policies that allow communities to **prepare for threats** from flooding and sea level rise.

4. **Preconstruction activities** for projects to be submitted for inclusion in the Statewide Flooding and Sea Level Rise Resilience Plan that are located in a municipality that has a population of 10,000 or fewer or a county that has a population of 50,000 or fewer, according to the most recent April 1 population estimates posted on the Office of Economic and Demographic Research's website.

(c) A vulnerability assessment conducted pursuant to paragraph (b) must encompass the entire county or municipality; include **all critical assets** owned or maintained by the grant applicant; and use the most recent publicly available Digital Elevation Model and generally accepted analysis and modeling techniques. An assessment may encompass a smaller geographic area or include only a portion of the critical assets owned or maintained by the grant applicant with appropriate rationale and upon approval by the department. Locally collected elevation data may also be included as part of the assessment as long as it is submitted to the department pursuant to this paragraph.

Florida Statute 380.093, F.S.

As defined in s. 380.093, F.S., the water surface depths (i.e., flood scenarios) used to evaluate assets should include the following data:

- **Tidal flooding,** if applicable, including future high tide flooding, which must use thresholds published and provided by the Department. The analysis should also geographically display the number of tidal flood days expected for each scenario and planning horizon (as applicable/practicable).
- **Current and future storm surge flooding,** if applicable, using publicly available NOAA or FEMA storm surge data. The initial storm surge event used must equal or exceed the current **100-year flood event.** Higher frequency storm events may be analyzed to understand the exposure of all critical assets.
- **Rainfall-induced flooding** using spatiotemporal analysis or existing hydrologic and hydraulic modeling results. Future boundary conditions should be modified to consider sea-level rise and high tide conditions (as applicable/practicable).
- **Compound flooding** or the combination of tidal, storm surge, and rainfall-induced flooding (as applicable/practicable).

Florida Statute 380.093, F.S.

As defined in s. 380.093, F.S., the following scenarios and standards should be used for the exposure analysis:

- All analyses performed in **North American Vertical Datum of 1988 (NAVD88).**
- If applicable, at least two local sea-level rise scenarios, including the **2017 NOAA Intermediate-Low and Intermediate-High** sea-level rise projections.
- At least two planning horizons that include planning horizons for the years **2040 and 2070.**
- If applicable, local sea level data that has been interpolated between the two closest NOAA tide gauges. Local sea level data may be taken from one such gauge if the gauge has higher mean sea level. Data taken from an alternate gauge may be used with appropriate rationale and Department approval if it is publicly available or submitted to the Department.
- Encompassing entire municipality/county and including all critical assets owned or maintained by the municipality/county.
- The exposure analysis should use the most recent publicly available DEM which meets the defined minimum standard of 3-meter cell size. The minimum standard modeling technique for the exposure analysis is the “Modified Bathtub Model,” which identifies all 12 Standardized Vulnerability Assessment: Scope of Work Guidance May 2022 areas under a target elevation as potentially flooded with a hydrologic connectivity filter applied to remove isolated inundated areas not connected to a major waterway. A more detailed explanation of the Modified Bathtub approach is outlined in the 2017 NOAA publication Detailed Method for Mapping Sea Level Rise Inundation (NOAA, 2017).

The intent of the Resilient Florida Grant Program is to develop consistent vulnerability assessments (VAs)

These VAs will comprise the Statewide VA and be the basis for the Statewide Resilience Plan

Encompass entire city or county, with all critical assets

Use most recent publicly available DEM and generally accepted analysis and modeling

Address Peril of Flood Compliance (if applicable)

Assess flooding using, at least, Intermediate Low and Intermediate High scenarios from NOAA 2017 for at least 2040 and 2070

Tidal flooding, including future high tide flooding

Current and future storm surge flooding

Rainfall induced flooding to the extent practicable

Compound flooding

Asset categories to be assessed by all VAs include

Critical Community and Emergency Facilities

Critical Infrastructure

Transportation Assets and Evacuation Routes

Natural, Cultural, and Historical Resources

The Statute further allows for future funding for projects that were identified in vulnerability assessments.

(5) STATEWIDE FLOODING AND SEA LEVEL RISE RESILIENCE PLAN.—

d)1. By September 1, 2021, and each September 1 thereafter, the following entities may submit to the department a list of proposed projects that address risks of flooding or sea level rise identified in vulnerability assessments that meet the requirements of subsection (3):a. Counties. b. Municipalities. c. Special districts

(f) To be eligible for inclusion in the plan, a project must have been submitted pursuant to paragraph (d) or must have been identified in the comprehensive statewide flood vulnerability and sea level rise assessment, as applicable.

The State will follow a three-year rolling plan of projects from the VAs

1

Year 1

Preliminary Plan uses already completed local VAs that comply with the requirements in s. 380.093(3), FS

2

Year 2

will update the Year 1 plan

3

Year 3

and following years - will use projects identified in the Statewide VA

The statute includes funding for resilience entities to coordinate intergovernmental solutions (like this project)

- Technical Assistance
- Coordinate multi-jurisdictional VAs
- Develop project proposals for insertion into the Resilience Plan

Further, the statute designates the College of Marine Science at University of South Florida as the Hub

- Lead institution to engage other academic and research institutions, private partners, and financial sponsors
- To coordinate efforts to support applied research and innovation to address the flooding and sea level rise challenges of the state

USF
UNIVERSITY OF SOUTH FLORIDA
COLLEGE OF MARINE SCIENCE

2 – Available Regional Resources and Data Sets and their Use

First, start with Collection of Existing Data Sources

- **Sea Level Rise (CLR) projections** - Unified Sea Level Rise Projections - Southeast Florida Regional Climate Compact (southeastfloridaclimatecompact.org)
- **DEM for Finished Floor Elevations** - Flood Information | Florida Division of Emergency Management (withforerunner.com)
- **ADCIRC for Storm Surge** - Storm Surge | ADCIRC Prediction System™
- **Statewide Model Management System (SMMS)** - Statewide Model Management System (SMMS) (sfwmd.gov)
- **Water and Climate Resilience Metrics on SFWMD site** - Water and Climate Resilience Metrics | South Florida Water Management District (sfwmd.gov)
- **Future Rainfall**
  2022_SFWMD_TM_Adoption_of_Future_Extreme_Rainfall_Change_Facotrs_for_Resiliency_Planning_in_South_Florida_rev2.0.pdf
- Updating the Statewide Extreme Rainfall Projections (fiu.edu)

Rainfall Intensification Tool

Source and Development

How to Use

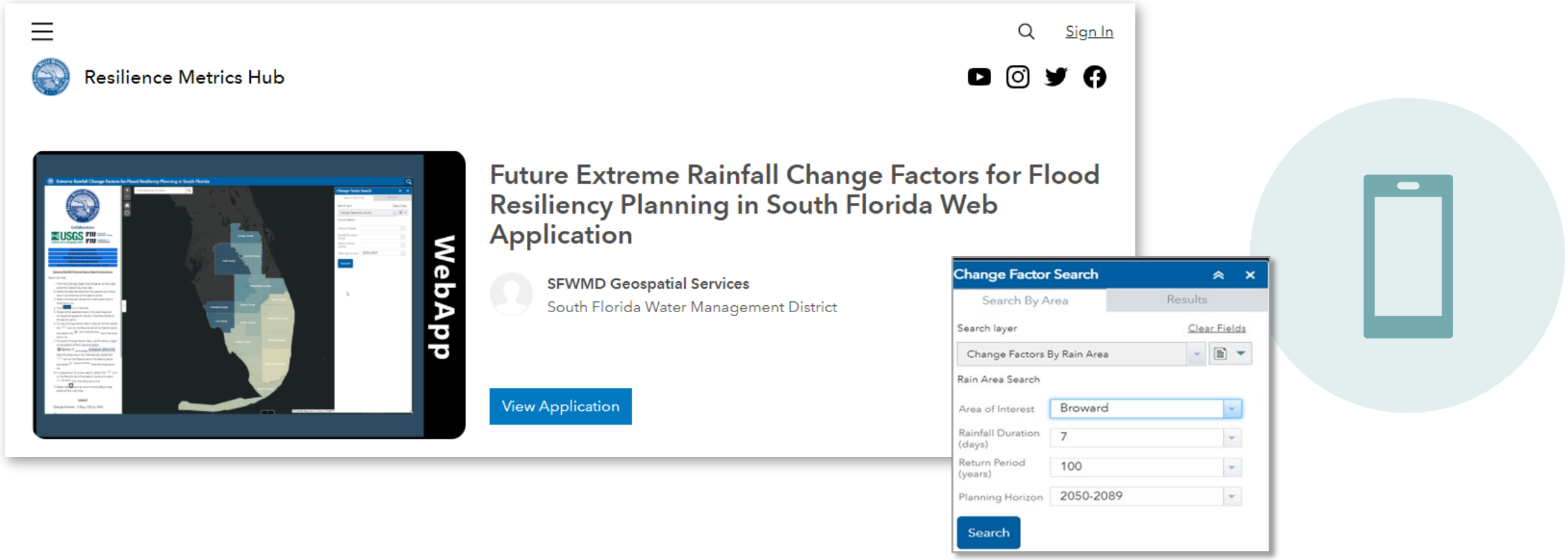
Rainfall Intensification Tool - Source and Development

- Compliant with FS, 380.093, F.S. compound flooding or the combination of tidal storm surge, and rainfall-induced flooding should be incorporated into the VA

- Atlas 14 published by NOAA was utilized for extreme rainfall information
  - **Does not include upward trend in rainfall intensity via climate change**

- USGS change factors used to derive projected future precipitation depth-duration-frequency (DDF) curves at 174 NOAA Atlas14 stations in Florida
  - **Historical NOAA Atlas 14 DDF curves multiplied by the change factor determine projected future extreme precipitation events**

Rainfall Intensification Tool - How to Use



[Future Extreme Rainfall Change Factors for Flood Resiliency Planning in South Florida Web Application | Resilience Metrics Hub (arcgis.com)]

Microsoft Edge recommended to use the tool

Sea Level Rise

- Planning Horizons for 2040 and 2070 utilized to have a statutorily compliant VA

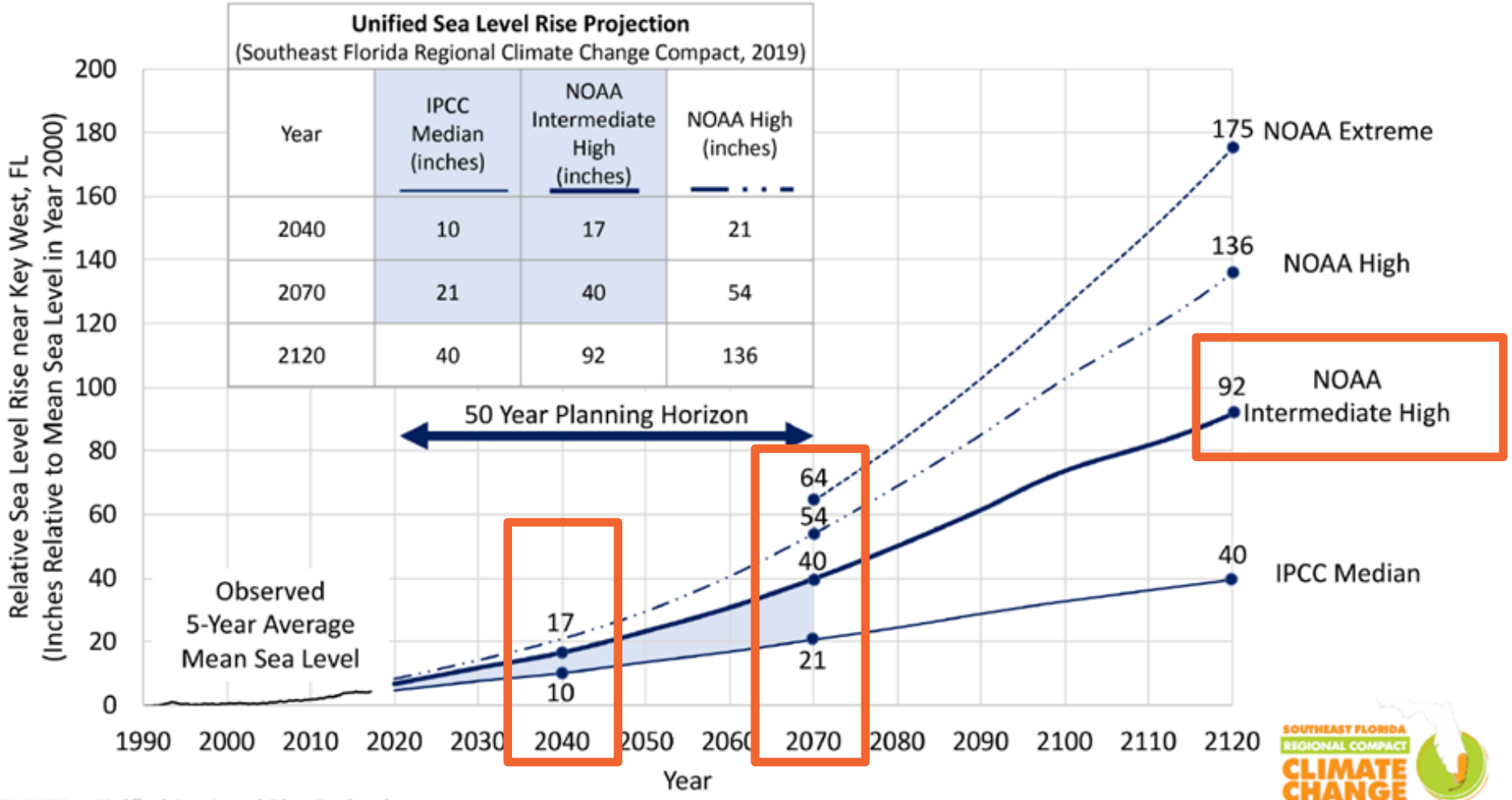


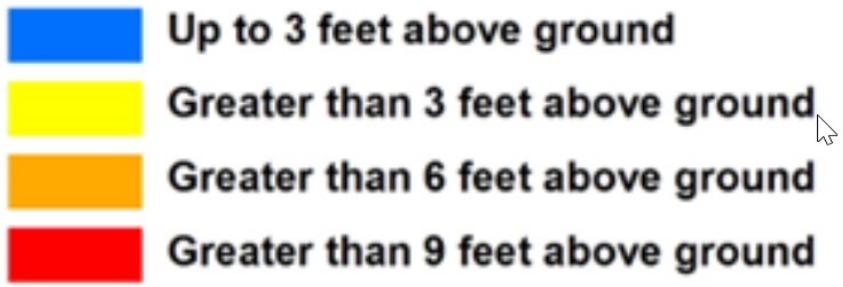
FIGURE 1: Unified Sea Level Rise Projection

SLOSH Models for South Florida (Surge)

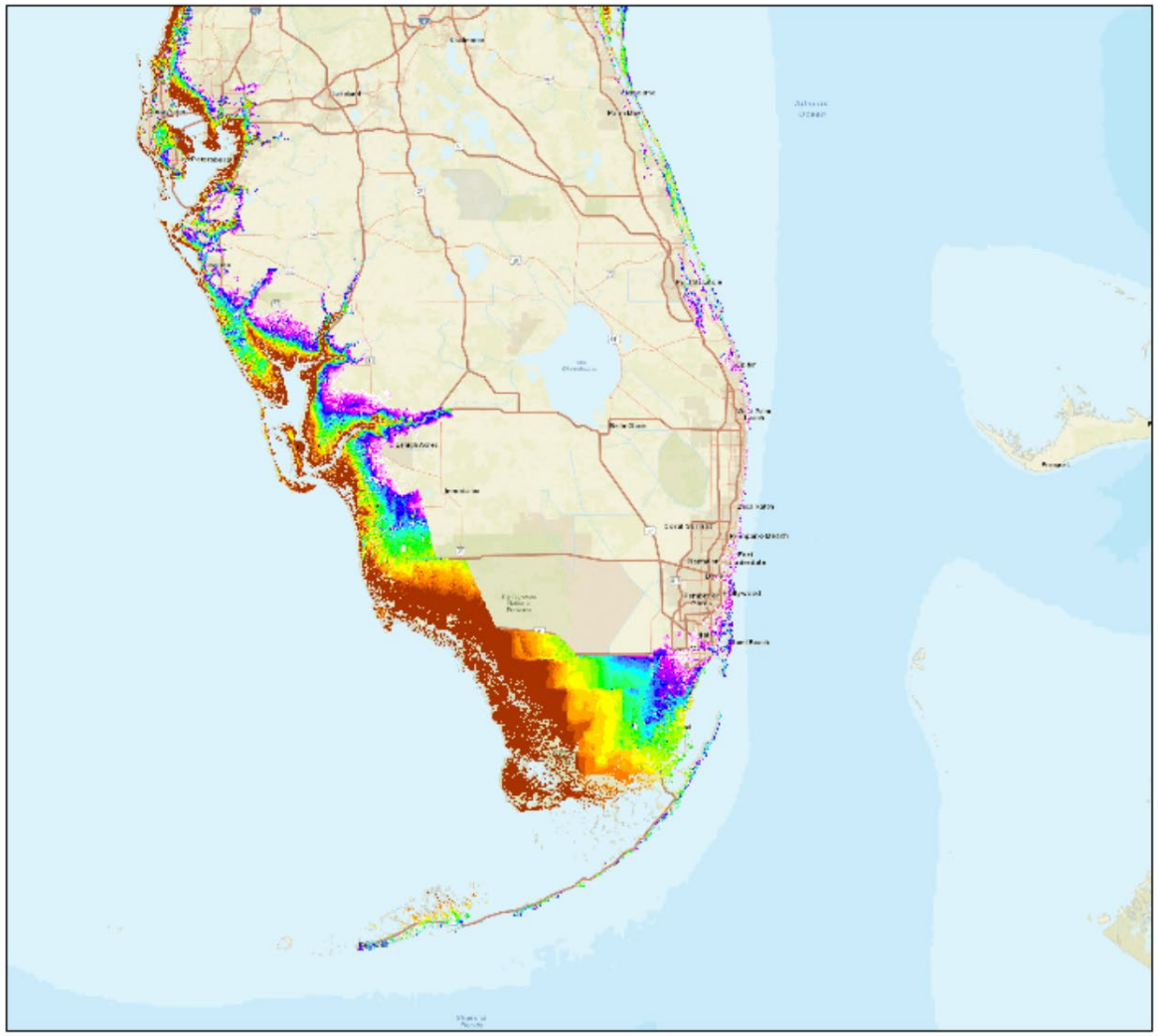
- Description : Sea, Lake, and Overland Surges from Hurricanes (SLOSH) (noaa.gov)
- Site to download results: https://www.nhc.noaa.gov/nationalsurge/?text

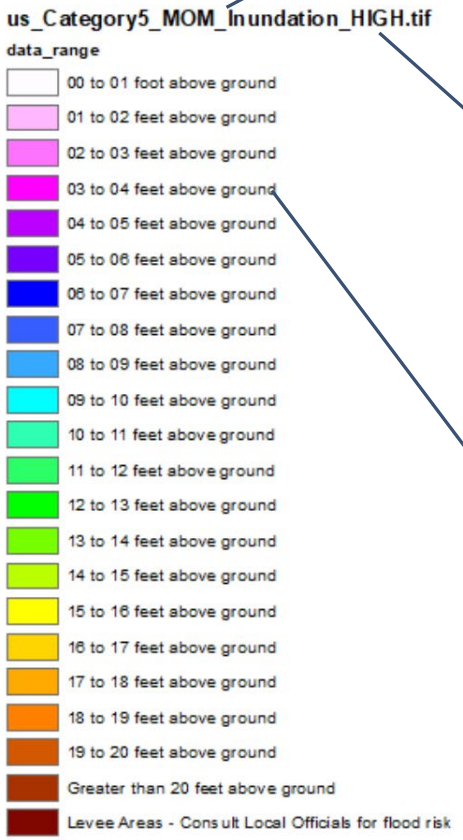
Composite Approach

- Predicts surge by running SLOSH several thousand times with hypothetical hurricanes under different storm conditions. SLOSH results are provided in flooding depth. Processing is required to convert depth to elevations in NAVD using available DEM.
- Generates the Maximum Envelopes of Water (MEOWs) and the Maximum of MEOWs (MOMs)
  - Regarded by NHC as the best approach for determining storm surge vulnerability for an area since it takes into account forecast uncertainty.
  - The MEOWs and MOMs play an integral role in emergency management as they form the basis for the development of the nation's evacuation zones.



SLOSH Models for South Florida (Surge)





Maximum of Maximum

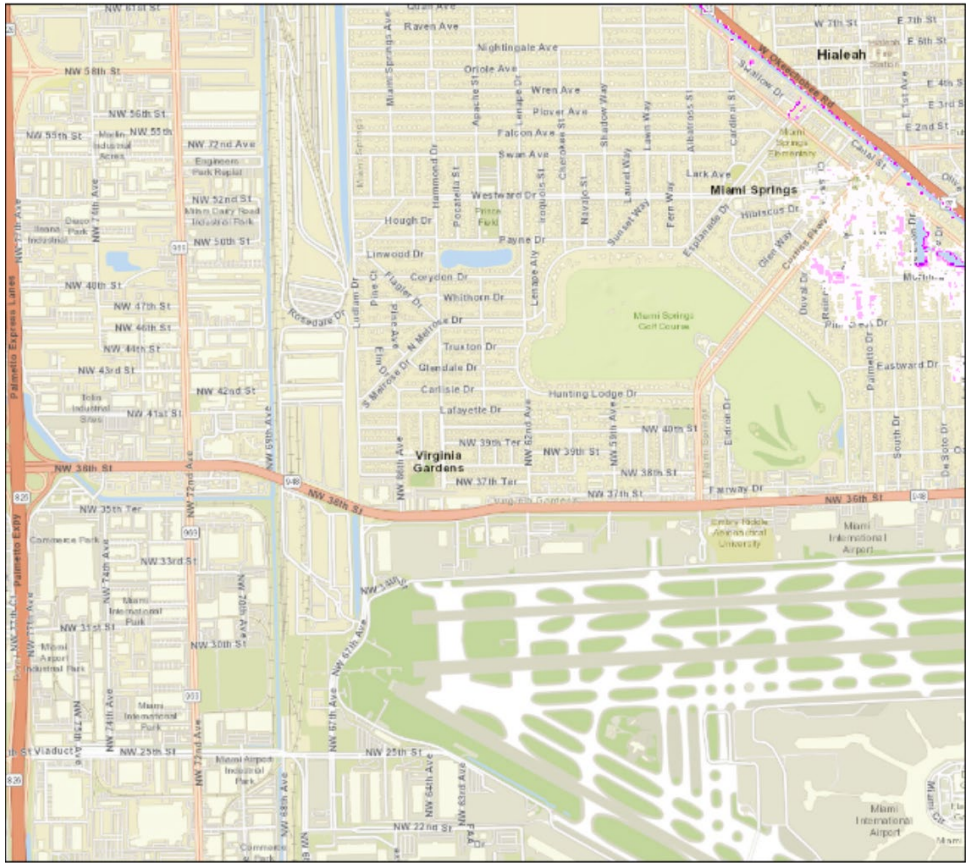
High Tide

Water Depth

03 to 04 feet above ground

Does not include SLR

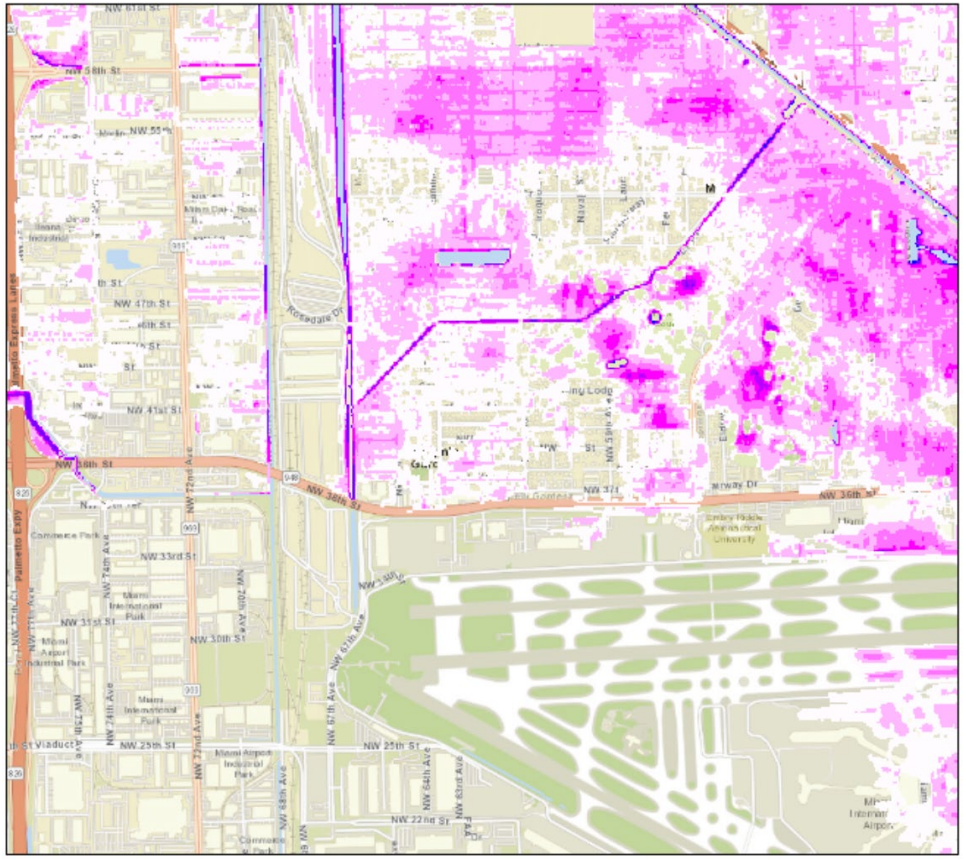
SLOSH Models for South Florida (Surge)



Category 3

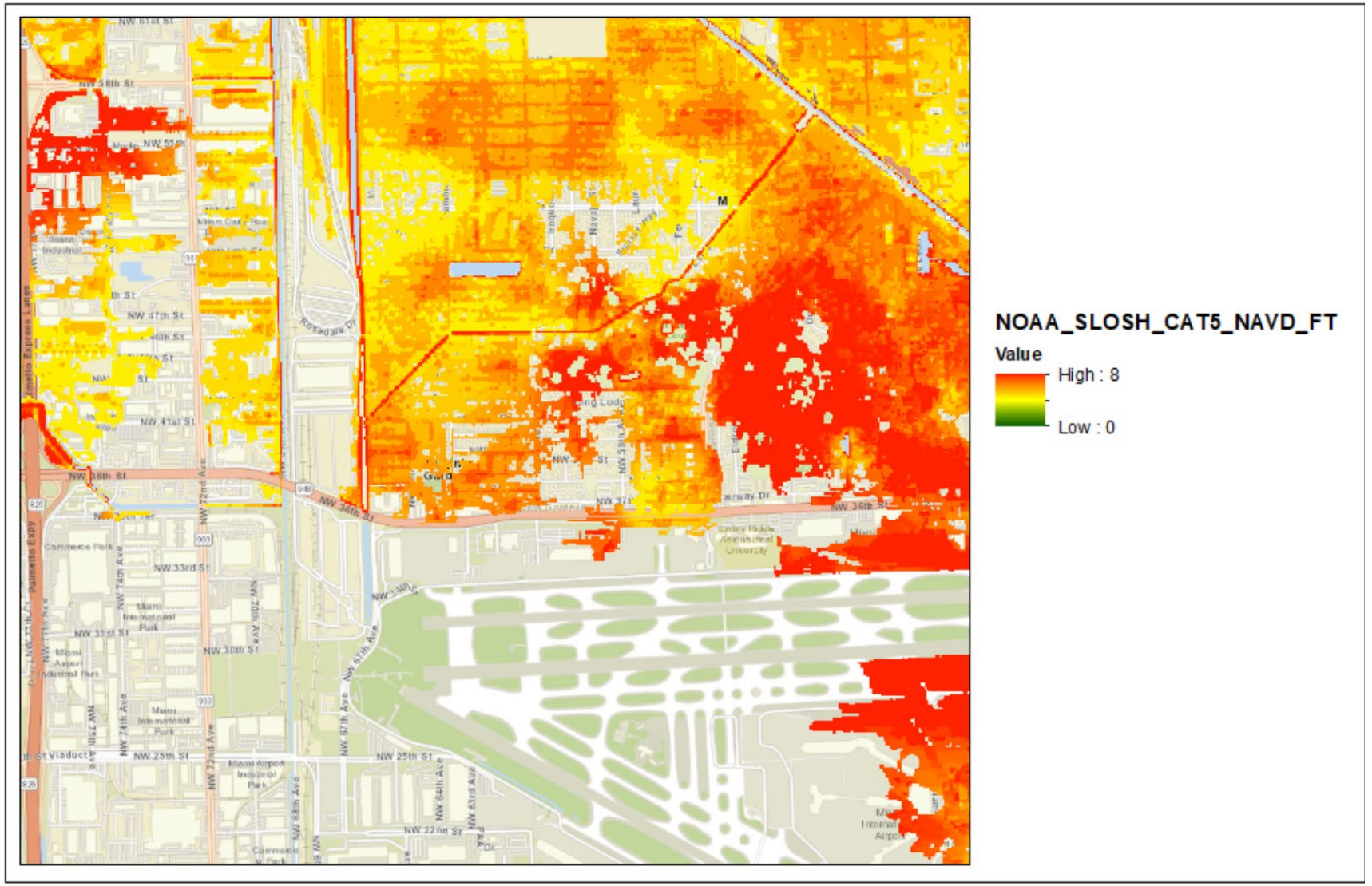
00 to 01 foot above ground
01 to 02 feet above ground
02 to 03 feet above ground
03 to 04 feet above ground
04 to 05 feet above ground
05 to 06 feet above ground

SLOSH results for higher category storms provide insights on potential hydraulic connectivity at higher elevations



Category 5

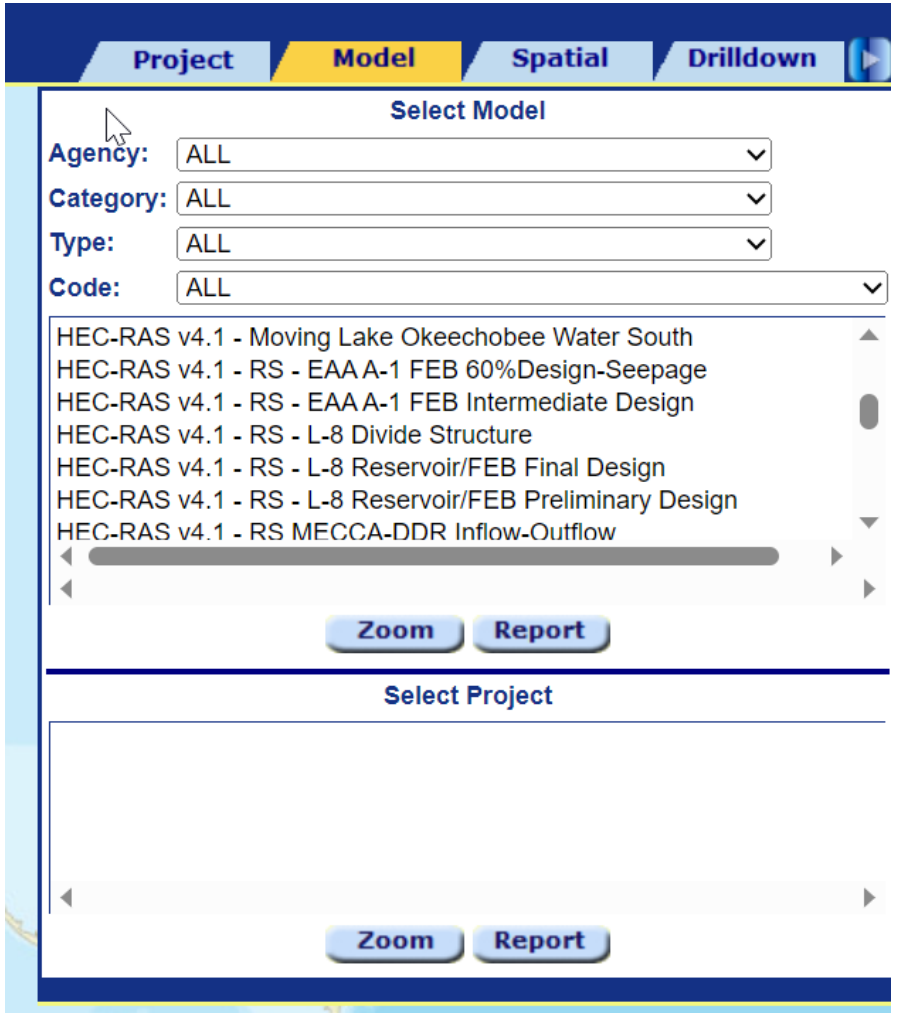
SLOSH Models for South Florida (Surge)



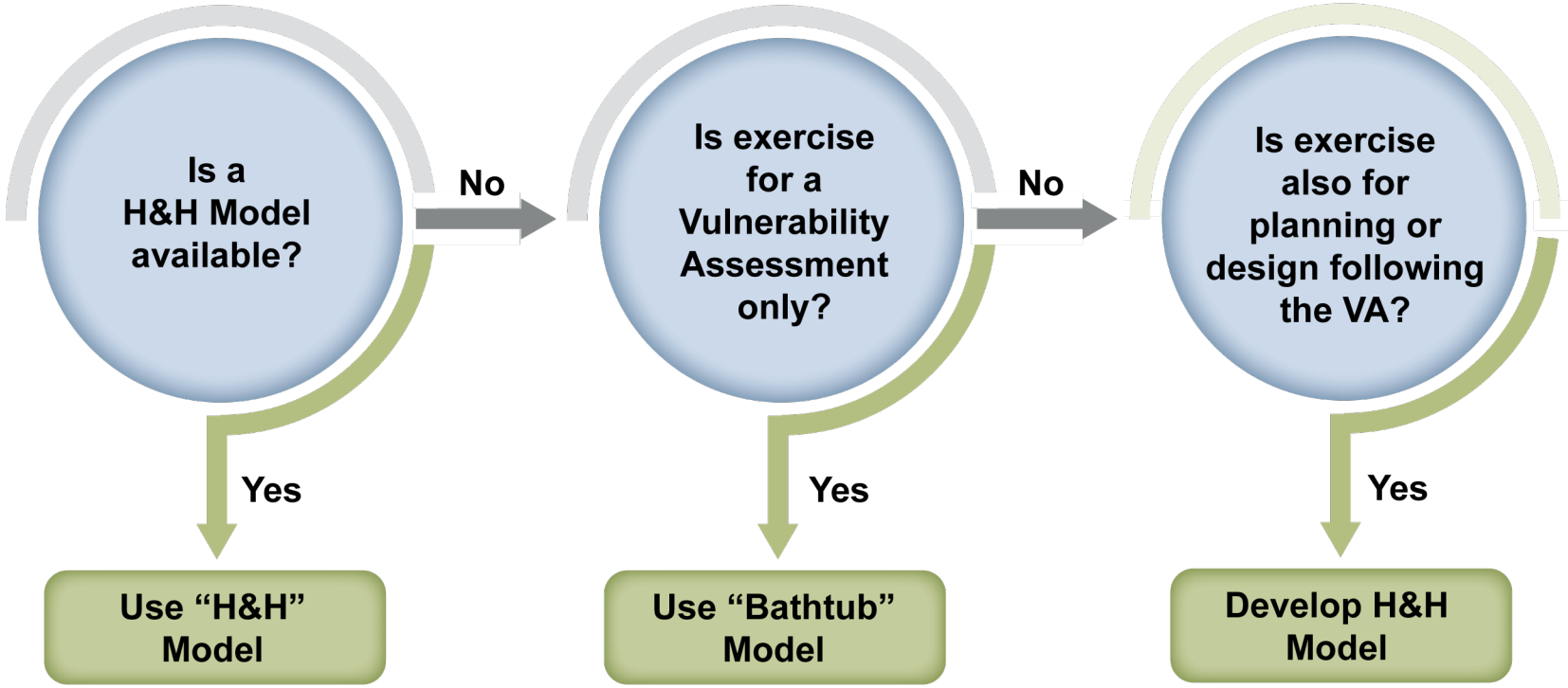
SLOSH results should be converted to NAVD to be compared against FFE and CFE. The use of the original DEM is preferred.
Average values will need to be used because of rounding applied to the Water Depth data set.

Second, determine what models are available for assessing flood depth

- **Broward County** – MIKE SHE/MIKE HYDRO is available and should be used
- **Palm Beach County, Miami-Dade County, Monroe County** – search the available model database - [Statewide Model Management System (SMMS) (sfwmd.gov)]

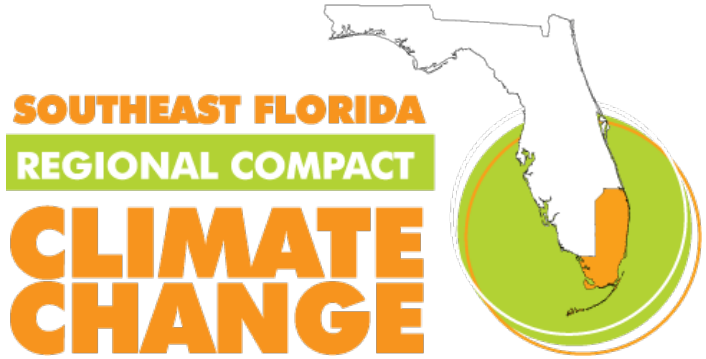


What approach is required? What does municipality wish to accomplish?



All four counties in the Compact are addressing flooding impacts of climate change and creating tools/resources for the further assessment of vulnerabilities

- Check for previous studies before initiating any study
- Lists are not comprehensive; only representative
- Continuous sharing of data will benefit all entities
- Examples of studies/tools/resources are provided in slides that follow



Additional Resources

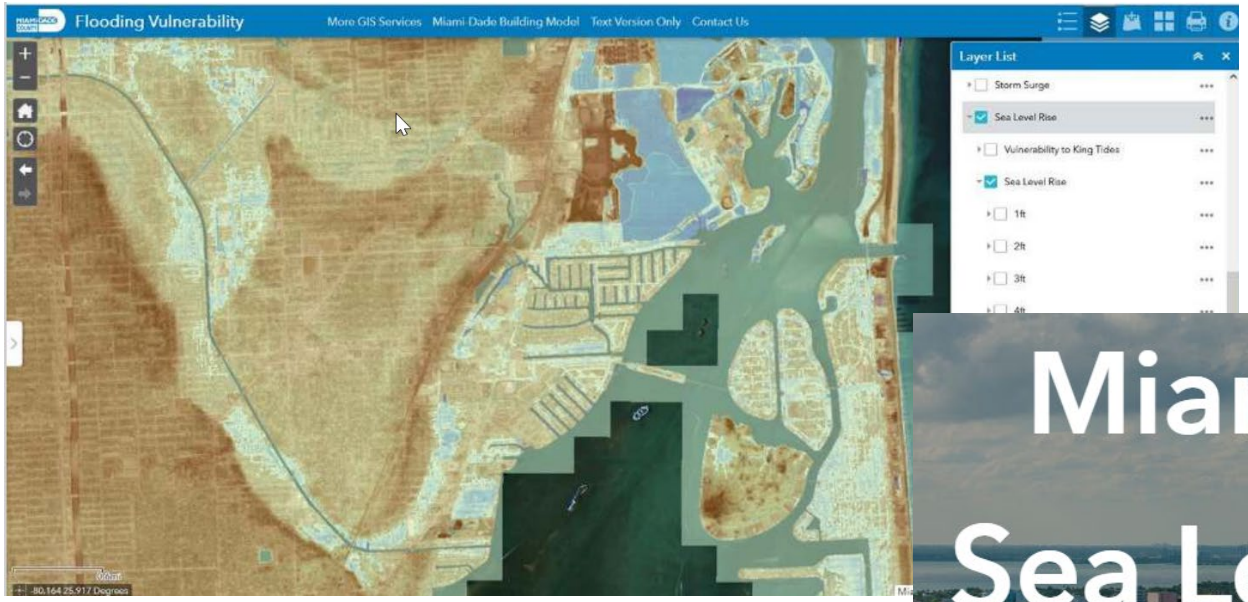
Monroe County Resources

- **Sustainability website** - Sustainability | Monroe County, FL - Official Website (monroecounty-fl.gov)
- **Regional Resilience Project** - Monroe-County-Regional-Resilience-Project-All-06-29-2020 (monroecounty-fl.gov)
- **Vulnerability Assessment** - Sea Level Rise Vulnerability Assessment | Monroe County (arcgis.com)
- **Sustainability Action Plan** - 5-Year-Projects-Plan (monroecounty-fl.gov)
- **Keys Roads Project** - monroecounty-fl.gov/DocumentCenter/View/31905/MCRVS-Final-Report
- **Florida Keys Risk Management Assessment** - Army-Corp-Feb-2021-Briefing---for-Plan-formal-support (monroecounty-fl.gov)

MONROE COUNTY
FLORIDA

Miami-Dade County Resources

- **Resilience Office** - Office of Resilience (miamidade.gov)
- **Miami-Dade Vulnerability Viewer** - Flooding Vulnerability (miamidade.gov)
- **Sea Level Rise Strategy** - Miami-Dade County Sea Level Rise Strategy (arcgis.com)



Broward County Resources

- **Resilient Environment Department** - Resilience Home (broward.org)
- **Future Conditions 100 Year Flood** - Planning Future Conditions 100 Year Flood Elevation (broward.org)
- **Future Conditions Groundwater Map** - Resilience Resilience Investment Planning (broward.org)
- **Seawall Ordinance** - Planning Seawalls and Flood Barriers (broward.org)
- **Priority Planning Areas** - Priority Planning Areas for Sea Level Rise (broward.org)
- **Resilience Dashboard** - Resilience Dashboard 1/10/23 (arcgis.com)
- **Vulnerability Assessment** – Ongoing - Complete 2024

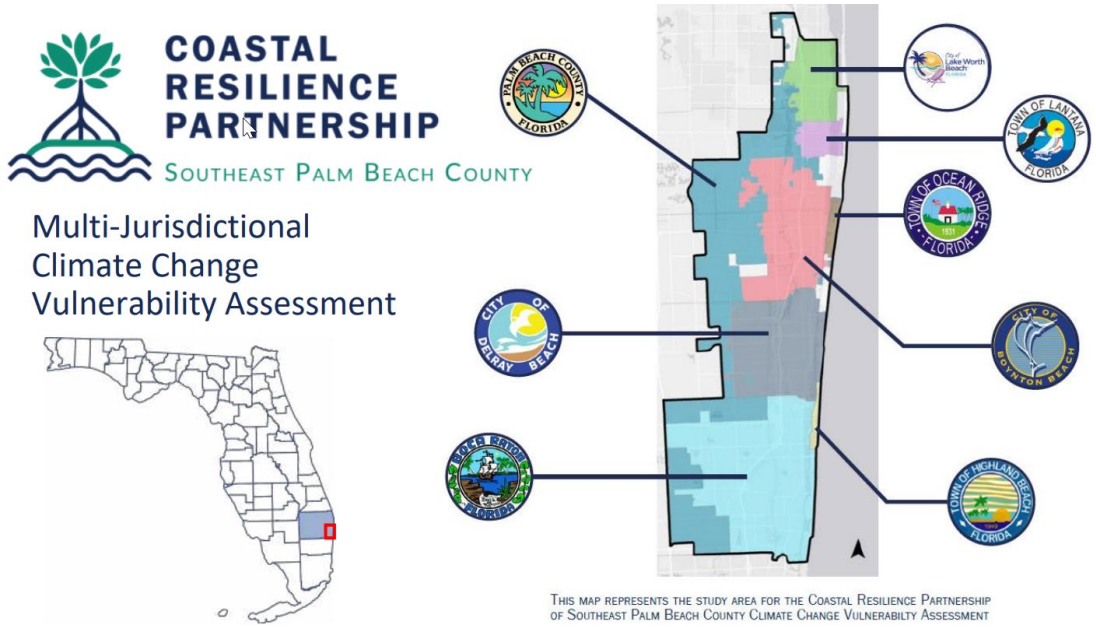
Resilience Plan Resilient Broward

Palm Beach County Resources

- **Office of Coastal Resilience** - Office of Resilience Coastal Resilience Partnership (pbcgov.org)
- **Resilience Office** - Office of Resilience Home (pbcgov.org)
- **Mapping tools** - Office of Resilience Mapping Tools (pbcgov.org)
- **Property Assessed Clean Energy program** - Office of Resilience PACE (pbcgov.org)
- **Vulnerability Assessment** - completed in 2022

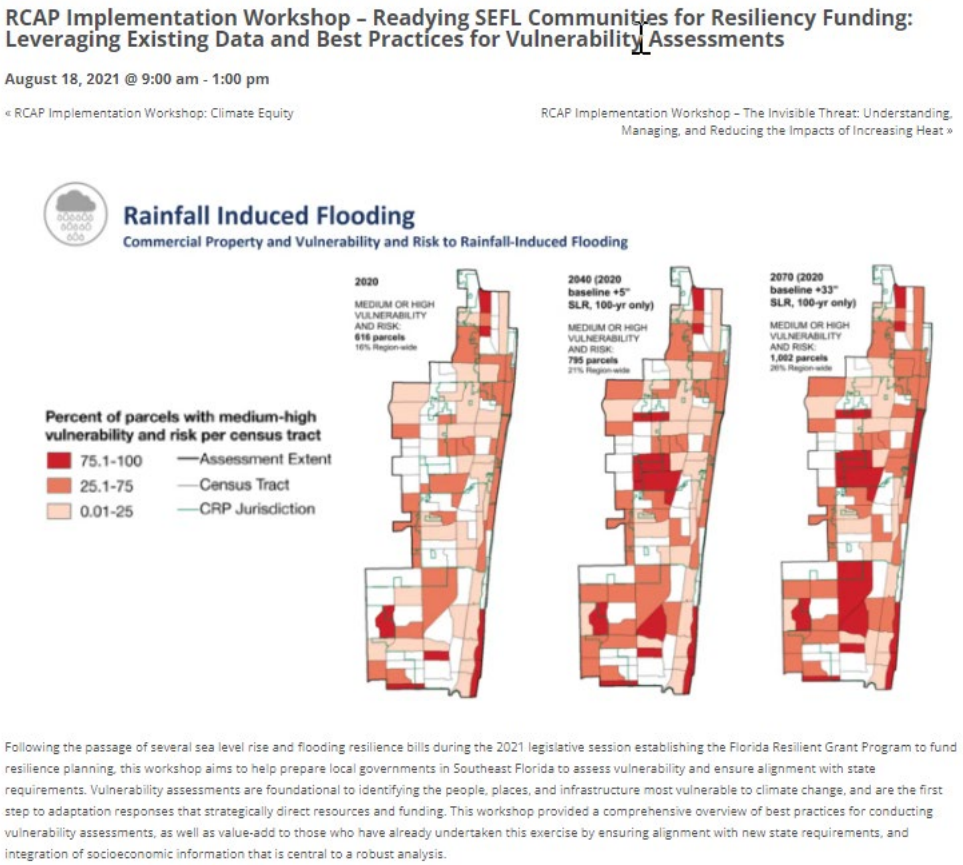
FINAL - Climate Change Vulnerability

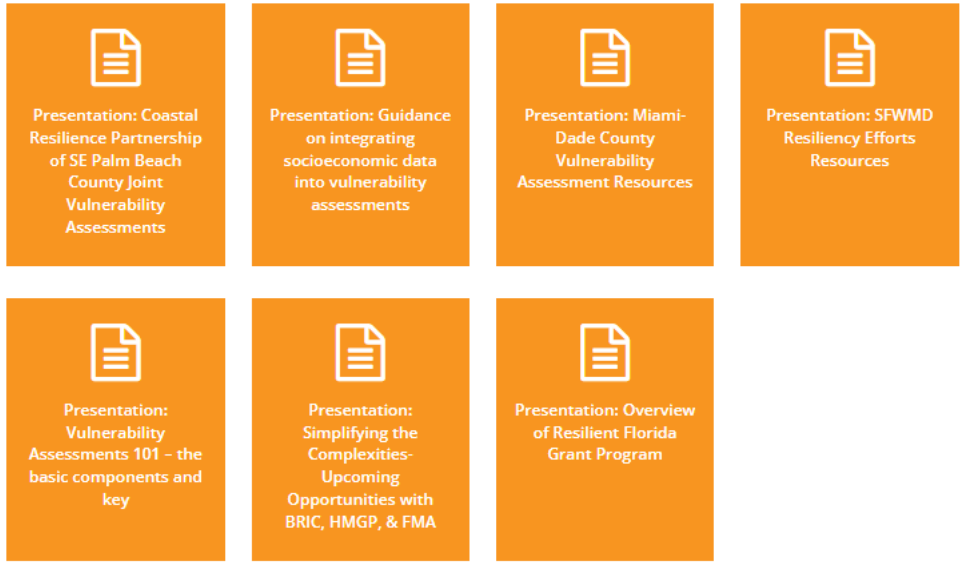
Assessment Report - ADA.pdf (pbcgov.org)



Additional information is available under the Southeast Florida Regional Compact Climate Change site

- [RCAP Implementation Workshop - Readying SEFL Communities for Resiliency Funding: Leveraging Existing Data and Best Practices for Vulnerability Assessments - Southeast Florida Regional Climate Compact (southeastfloridaclimatecompact.org)]





Questions/Discussion

10 Minute Break

3 – Best Practices

Example Study - Three communities in SE Florida were selected to participate in this grant funded study

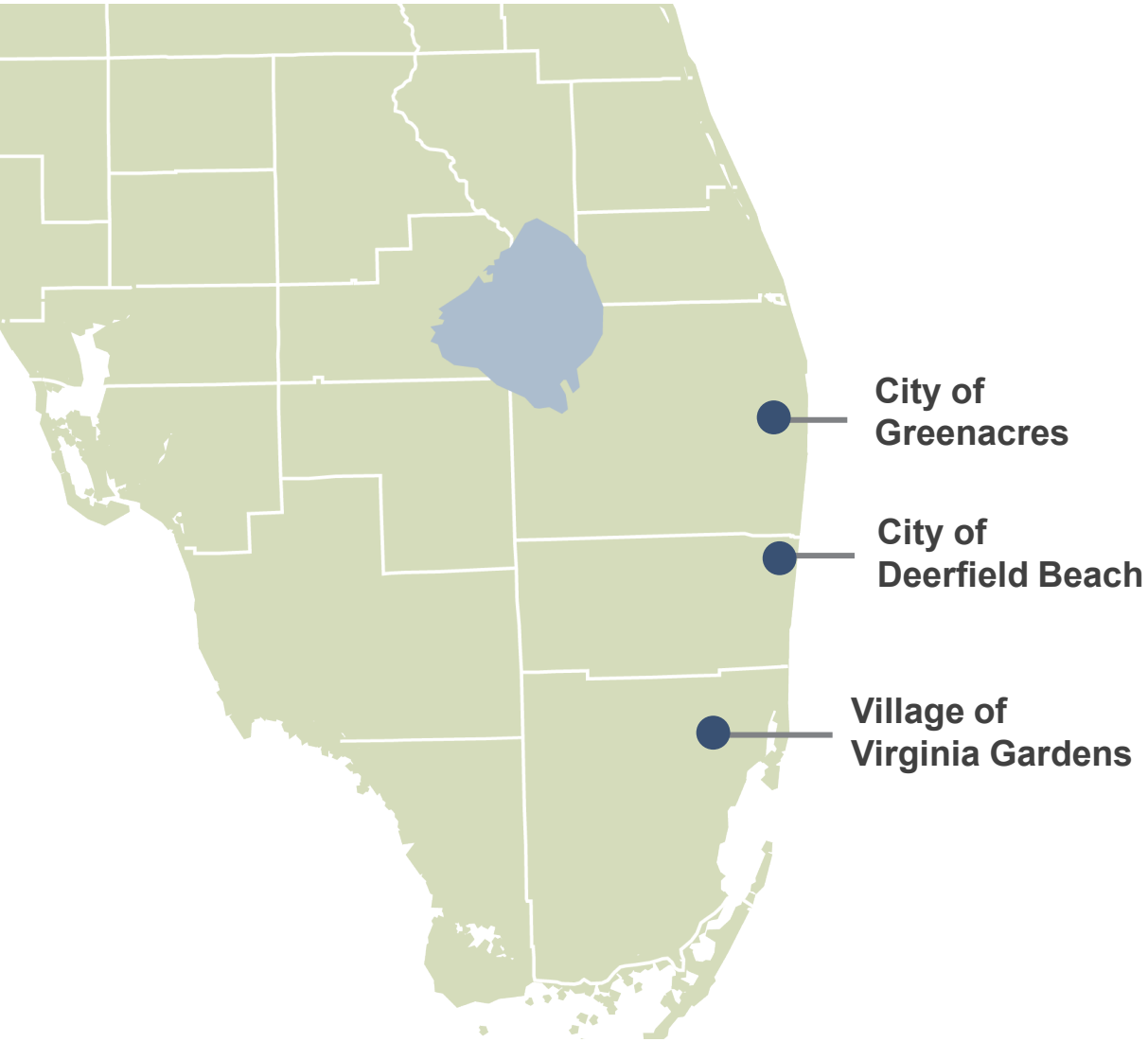
- Compact analyzed various criteria to identify need for assistance
- Qualifying and interested communities applied to participate
- Three communities were selected

City of Greenacres
(Palm Beach County)

City of Deerfield Beach
(Broward County)

Village of Virginia Gardens
(Miami-Dade County)

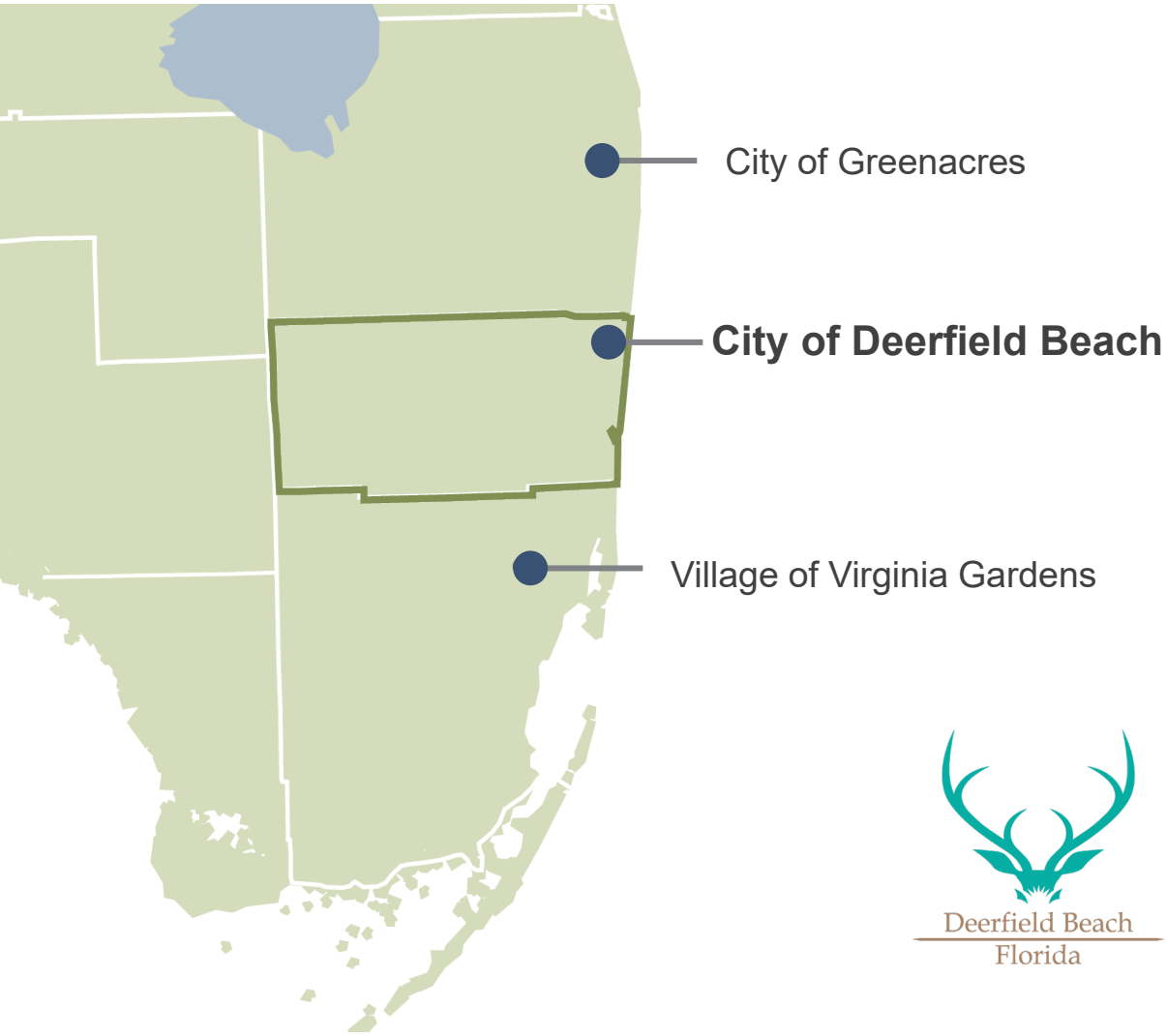
The three communities selected provide a cross section of characteristics and approaches to Vulnerability Assessment (VA)



- Three of four Compact Counties are represented
- Varying sizes, from very small to medium/large
- Both coastal and inland areas are represented
- Access to robust recent hydrologic and hydraulic (H&H) modeling tools to limited access to such resources

This allows us to evaluate the use of multiple analytical techniques

One of these communities is within Broward County, an entity which recently developed a detailed hydrologic and hydraulic model (H&H)



- MIKE SHE – MIKE HYDRO model
- High level of detail and granularity

Deerfield Beach Florida

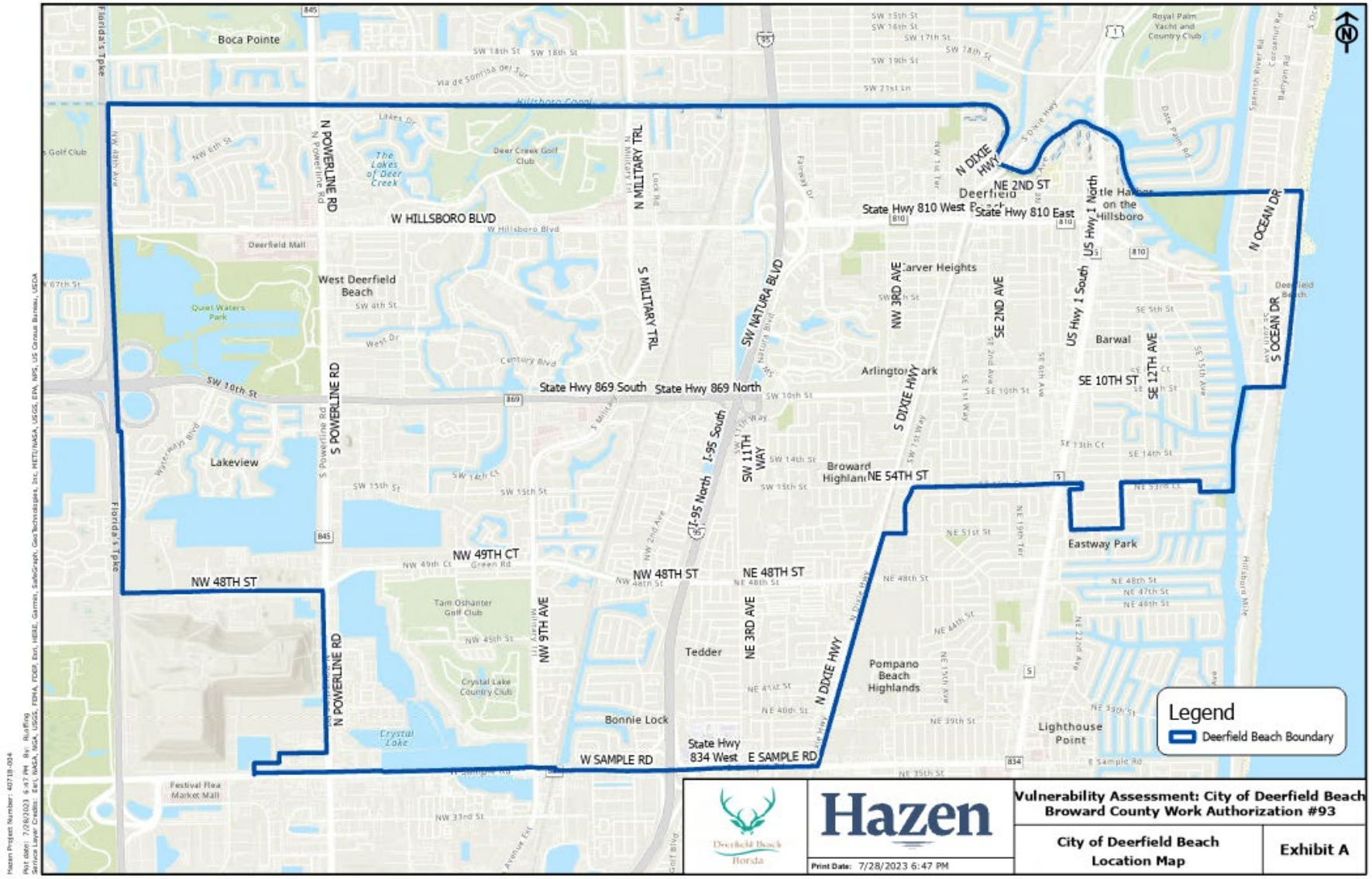
BROWARD COUNTY FLORIDA

RESILIENT BROWARD Community Resilience Strategies

3 – Best Practices

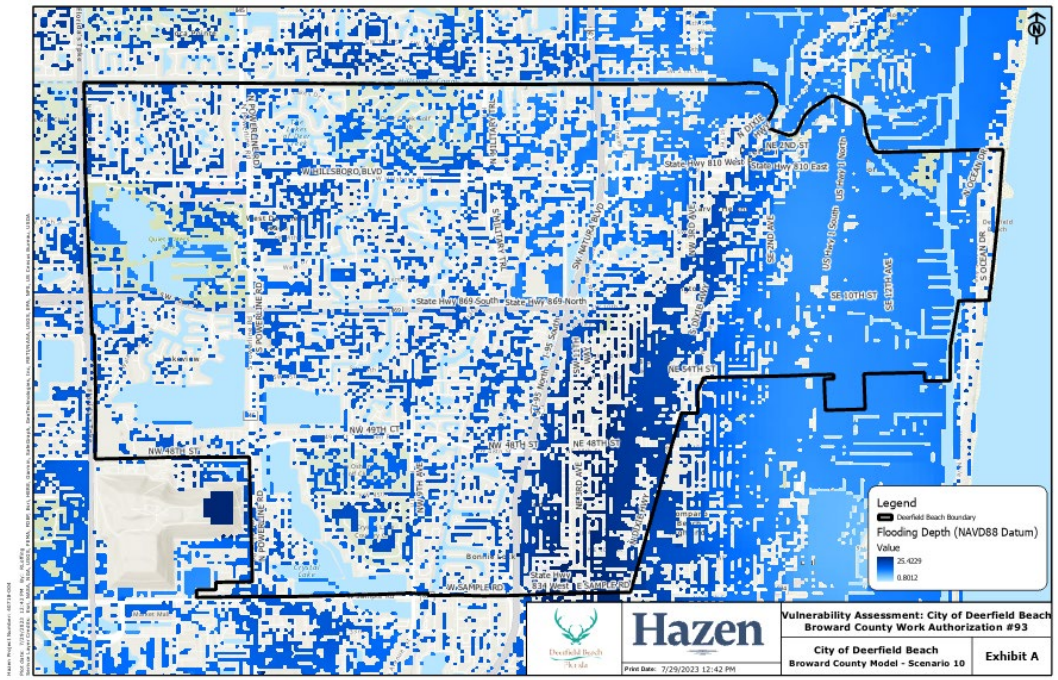
Example of a VA Performed with an H&H Model

The City of Deerfield Beach is the example of employing a hydrologic and hydraulic (H&H) model

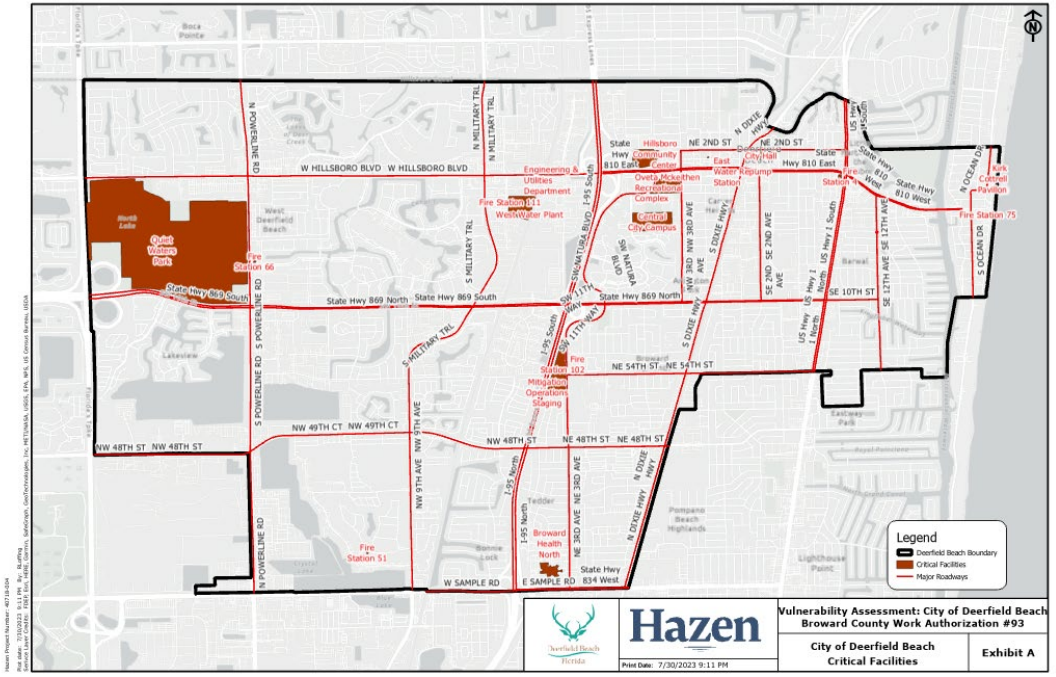


The VA for Deerfield Beach merged the City's critical assets into the Broward H&H Model

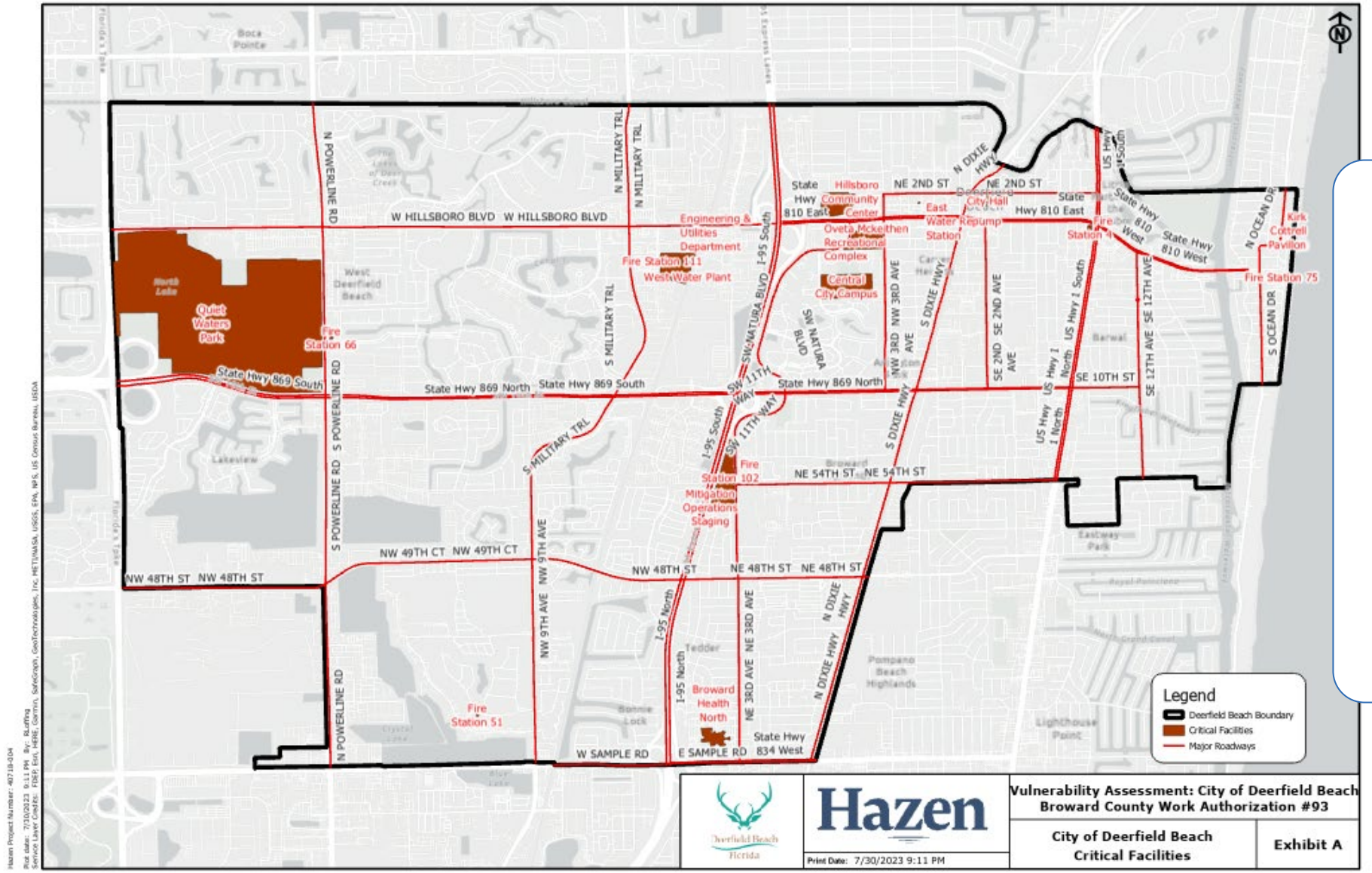
Broward H&H Model



Deerfield Beach Critical Assets



Critical assets were identified within the City limits



20

critical facilities

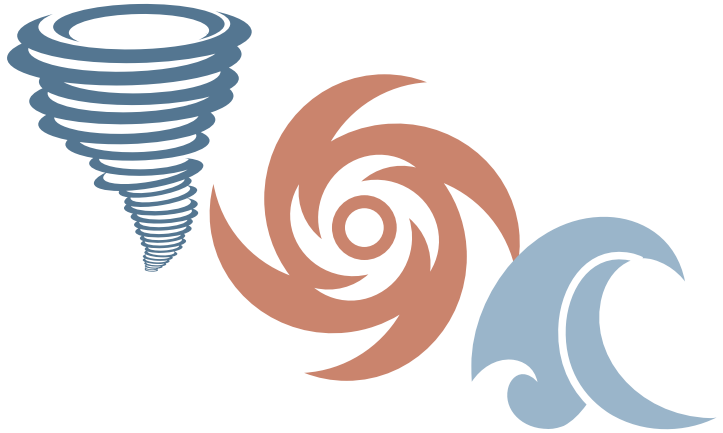
and

33

major roadways

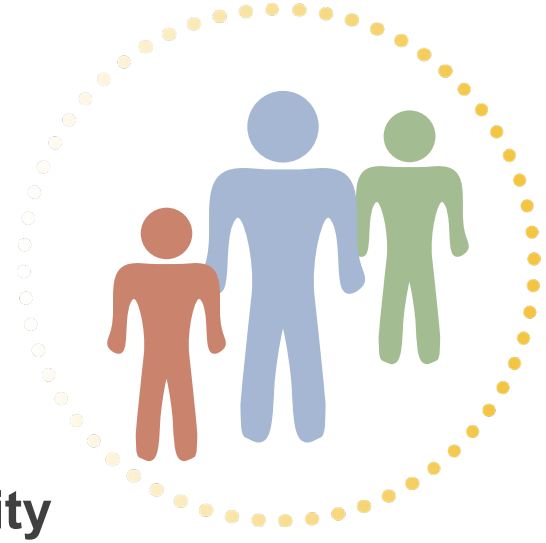
were included in the VA

The VA addresses both Exposure and Sensitivity



Exposure

Presence of
assets in harm



Sensitivity

The degree to which
asset is affected by a threat

Goal

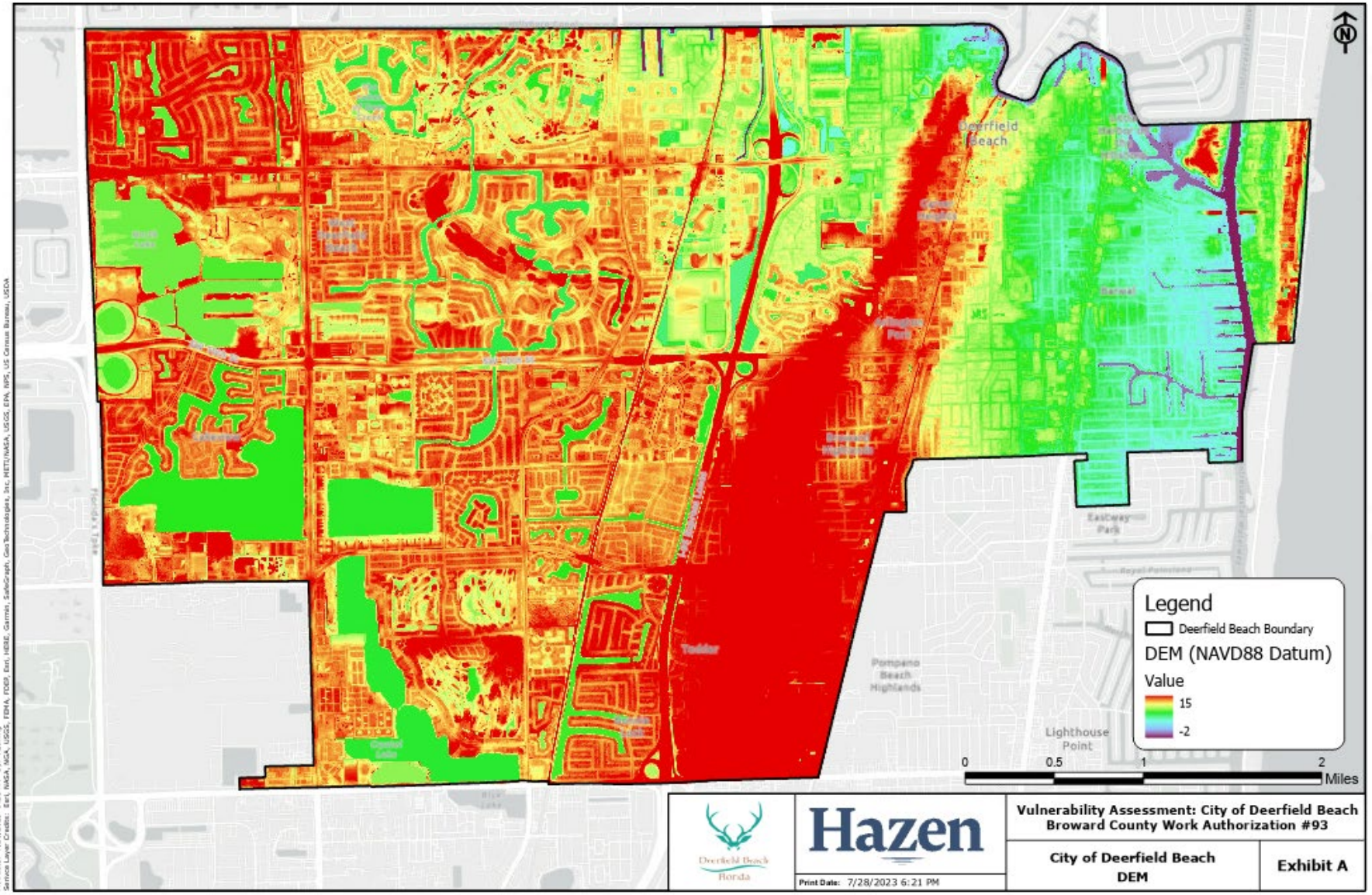
Understand the susceptibility of societal assets due to physical and social factors combined with understanding the probability and negative outcome of threats

Data collection is foundational to the VA

- Critical and regionally significant assets
- Best available DEM (digital elevation model)
- Sea Level Rise (F.S. required time horizons and projection curves)
- Design Storm data (F.S. required events, intensification factors)
- Existing hydrologic modeling efforts

ArcGIS

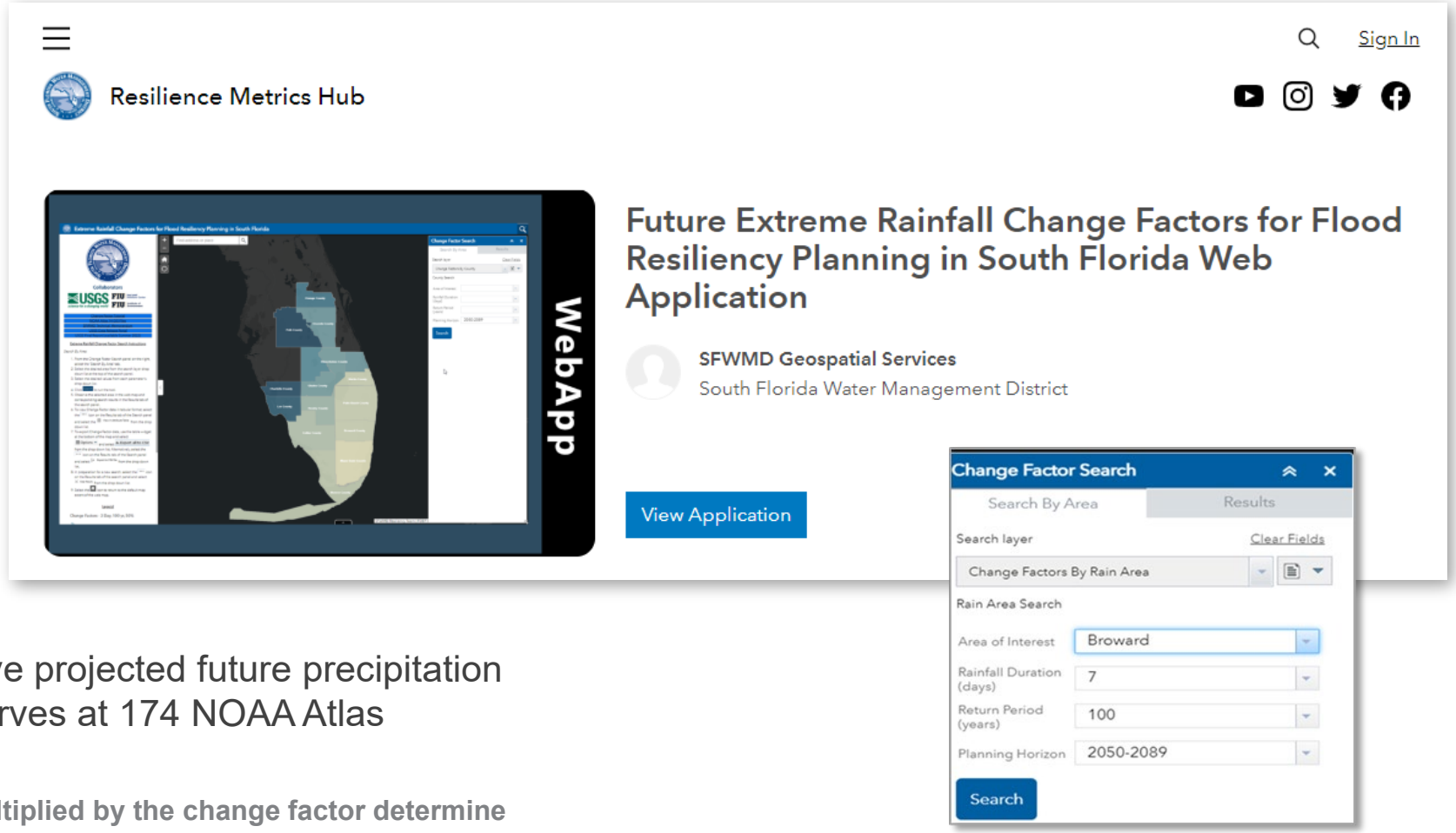
DEM – Developed by USGS/SFWMD in 2018 with a 2-foot resolution



- Provides a topographic ground surface from which depths can be measured
- Publicly available from NOAA at [NOAA: Data Access Viewer]

Rainfall induced Flooding Change – Factor Methodology

- Compliant with FS, 380.093, F.S. compound flooding or the combination of tidal storm surge, and rainfall-induced flooding should be incorporated into the VA
- Atlas 14 published by NOAA was utilized for extreme rainfall information
  - **Does not include upward trend in rainfall intensity via climate change**



- USGS change factors used to derive projected future precipitation depth-duration-frequency (DDF) curves at 174 NOAA Atlas 14 stations in Florida
  - **Historical NOAA Atlas 14 DDF curves multiplied by the change factor determine projected future extreme precipitation events**

Sea Level Rise

Planning Horizons for 2040 and 2070 were utilized to have a statutorily compliant VA

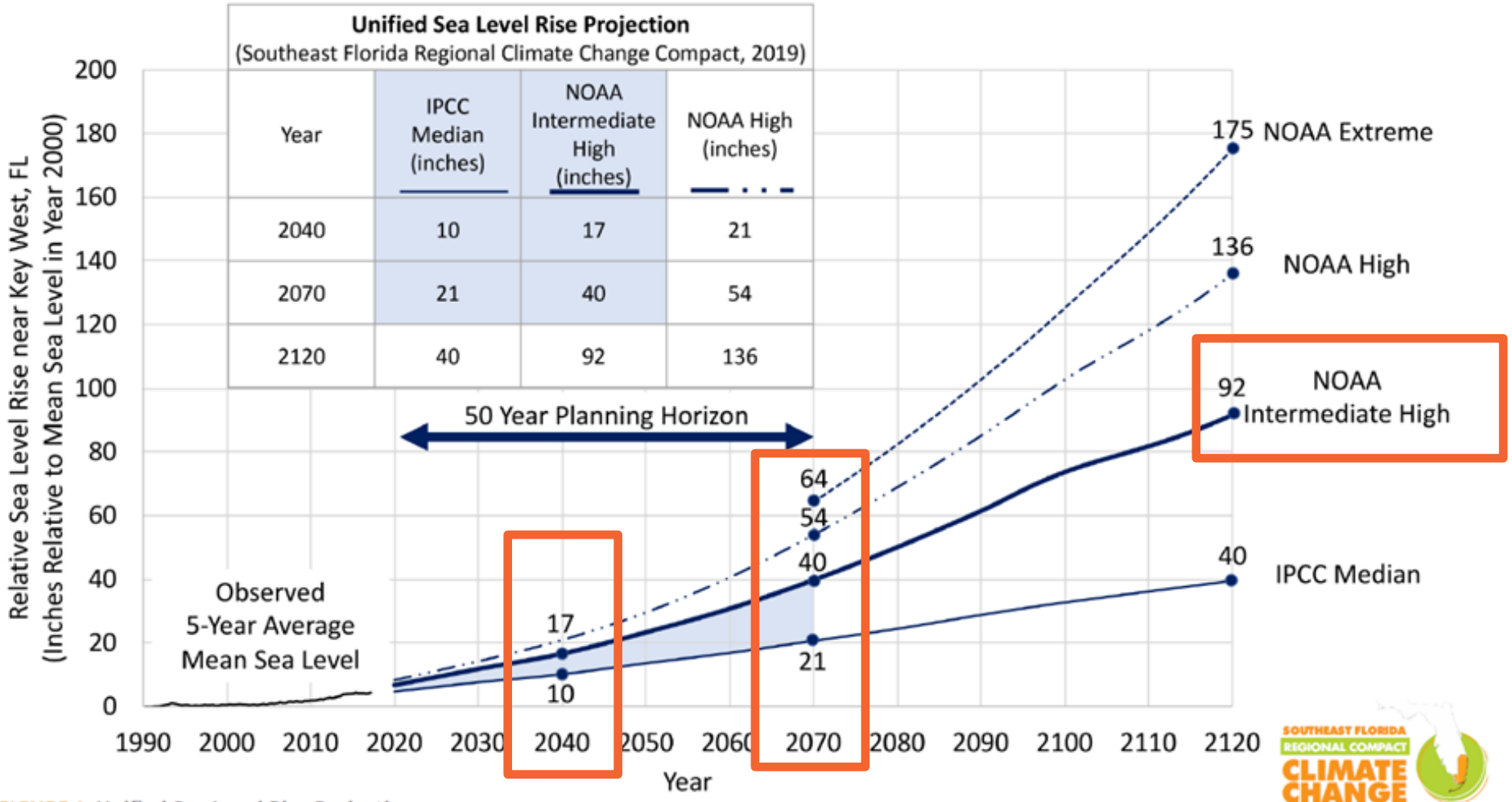


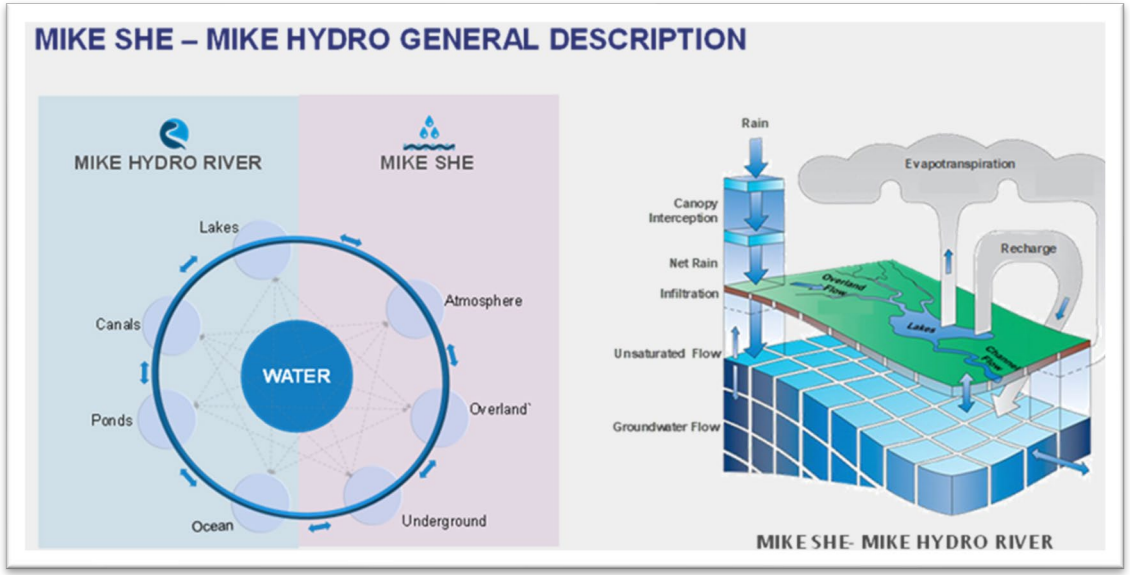
FIGURE 1: Unified Sea Level Rise Projection

Modeling Methodology

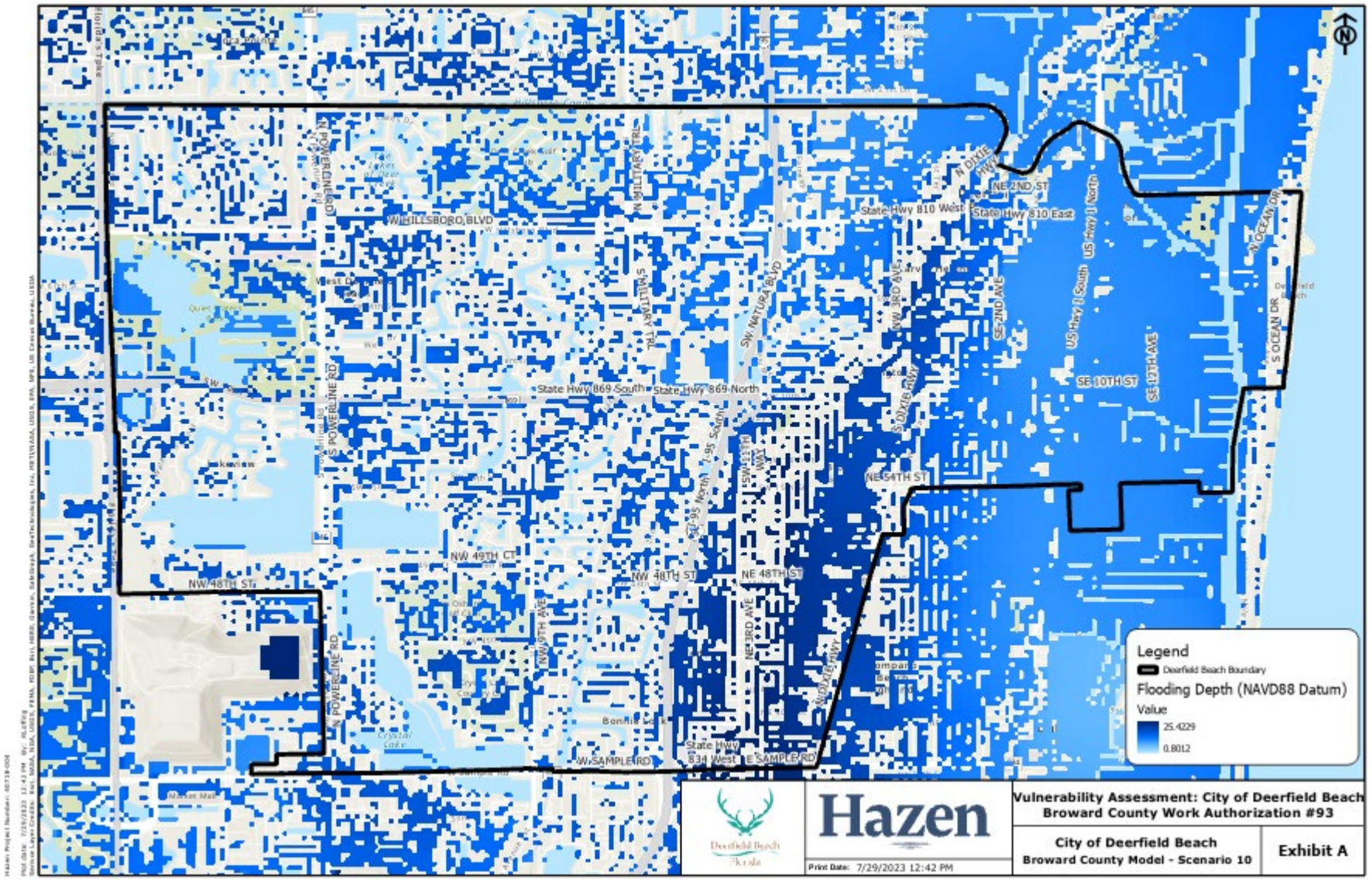
- Broward County MIKE SHE-MIKE HYDRO Model
- Developed to support the Broward County Risk Assessment and Resilience Plan

History of the Broward County Model (2002-2023)

CADA* (2002)
NADA* (2005)
SADA* (2005)
→ Consolidated Broward County Model (2006)
→ FEMA Model (2014)
→ 100-YR Flood Map (2020)
→ SFWMD FPLOS (2022)
→ Broward County Resilience Plan (2023)



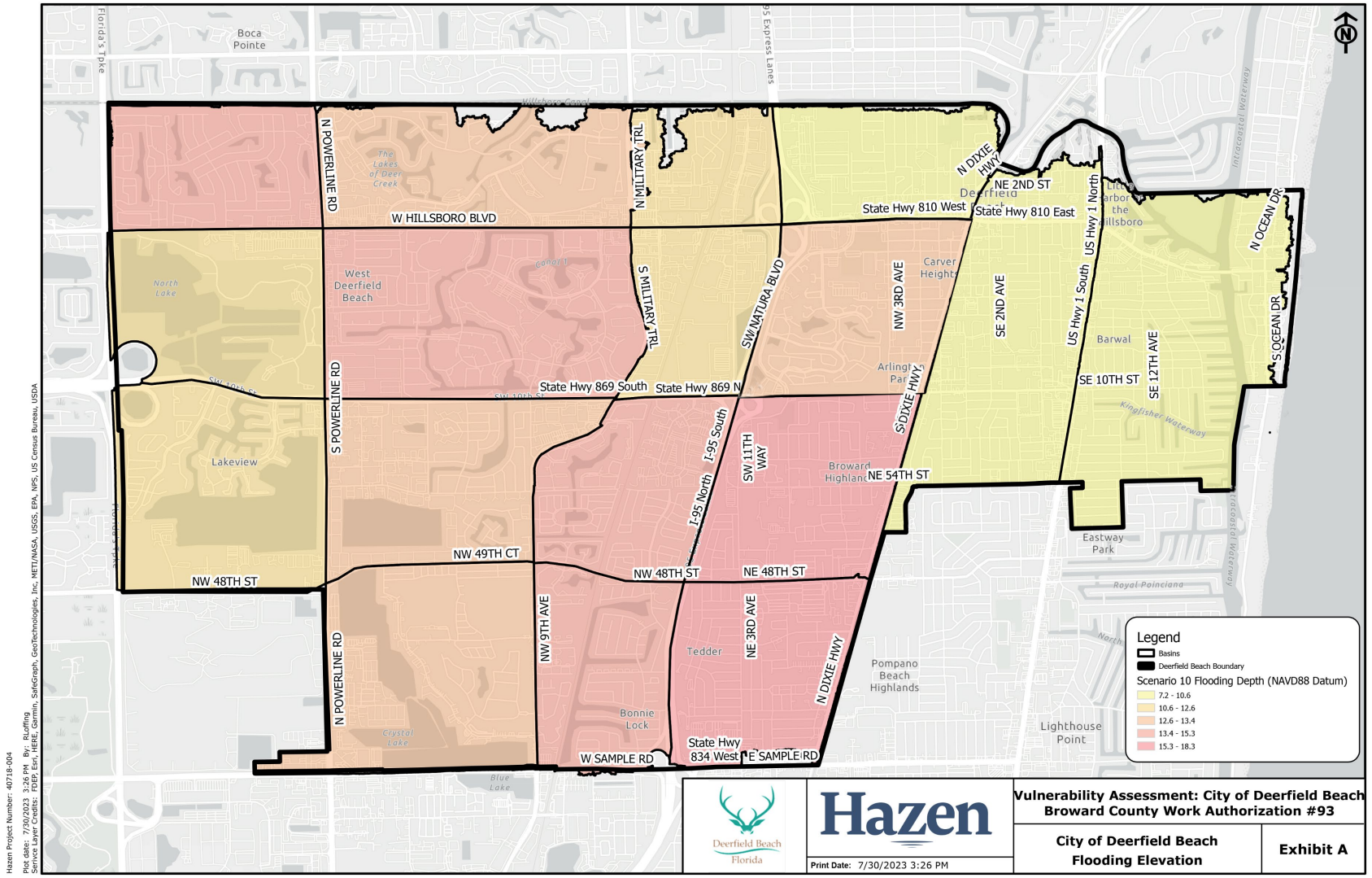
Broward County MIKE SHE / MIKE HYDRO – Scenario 10 Results



- Provides a topographic ground surface from which depths can be measured
- Available upon request from Broward County Resilient Environment Department

Simplified approach results compared well to the Broward Model

Modeling Subbasins with Flooding Elevation – Scenario 10

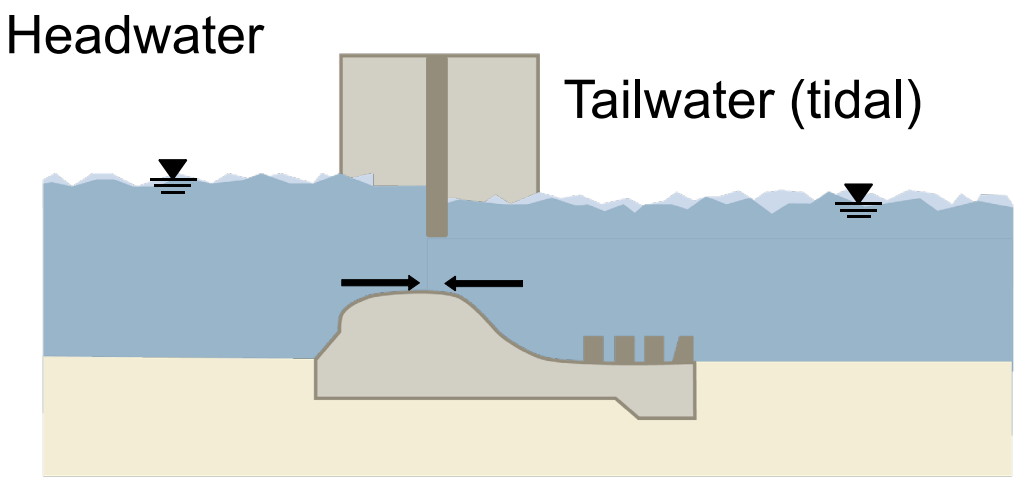


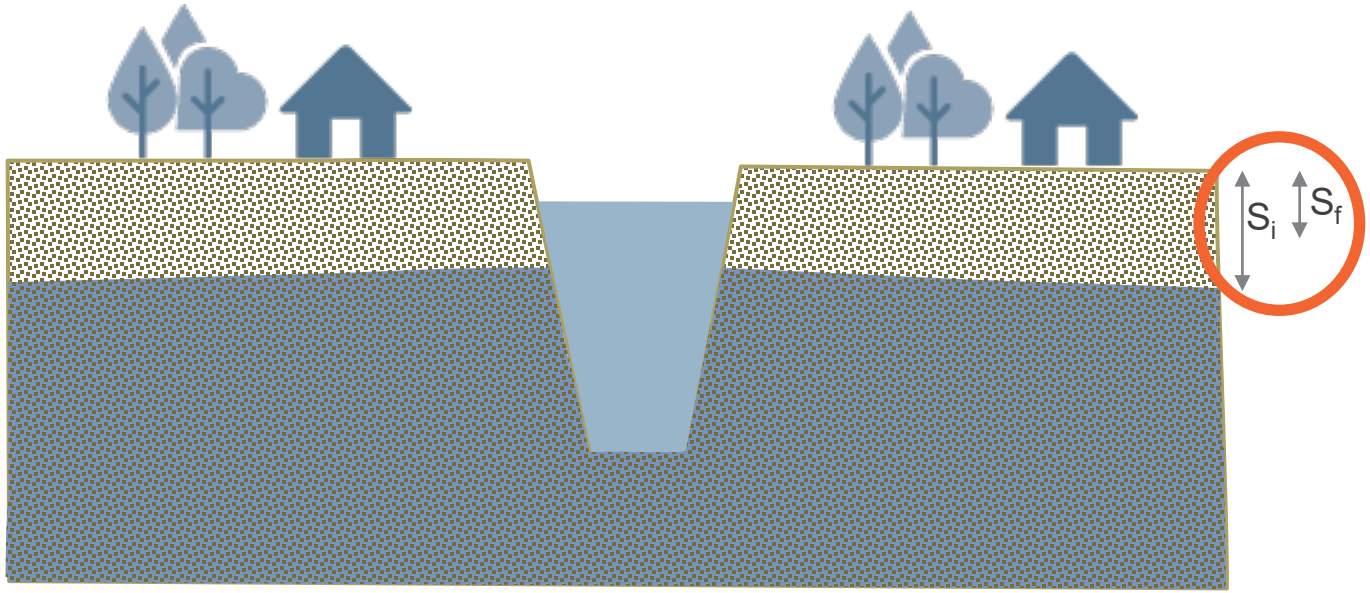
- Subbasins divided based on topographic features
- Hydrologic analyses performed at subbasin level

Typical Stormwater Management System

Assumption: There is no connection towards the canal system through an outfall due to assumed high levels in the canal

Gated Coastal Structure, effect on water levels

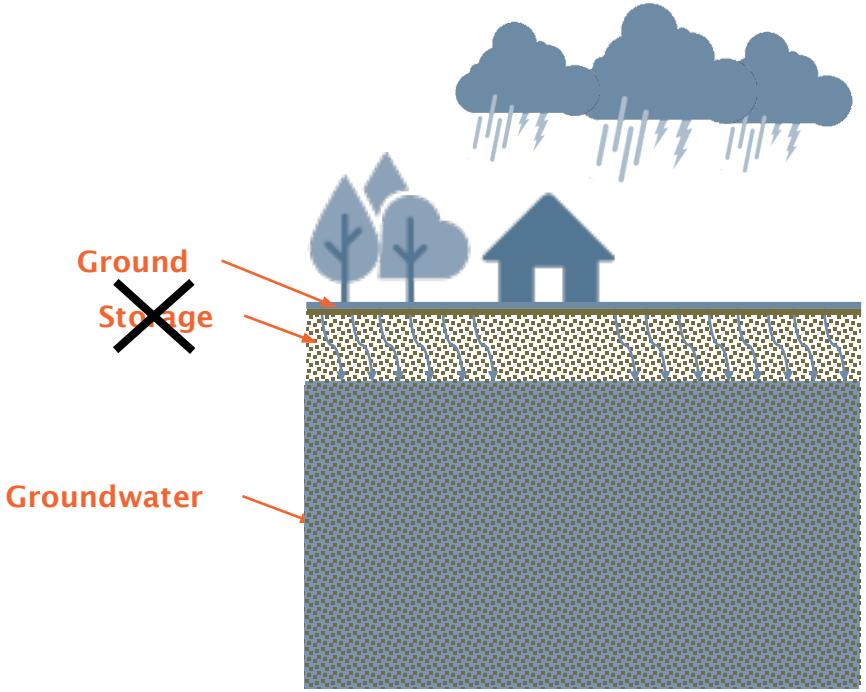




The storage capacity will be reduced as the headwater elevation increases to limit saltwater intrusion as the sea level rises over time.

Soil Storage and SLR

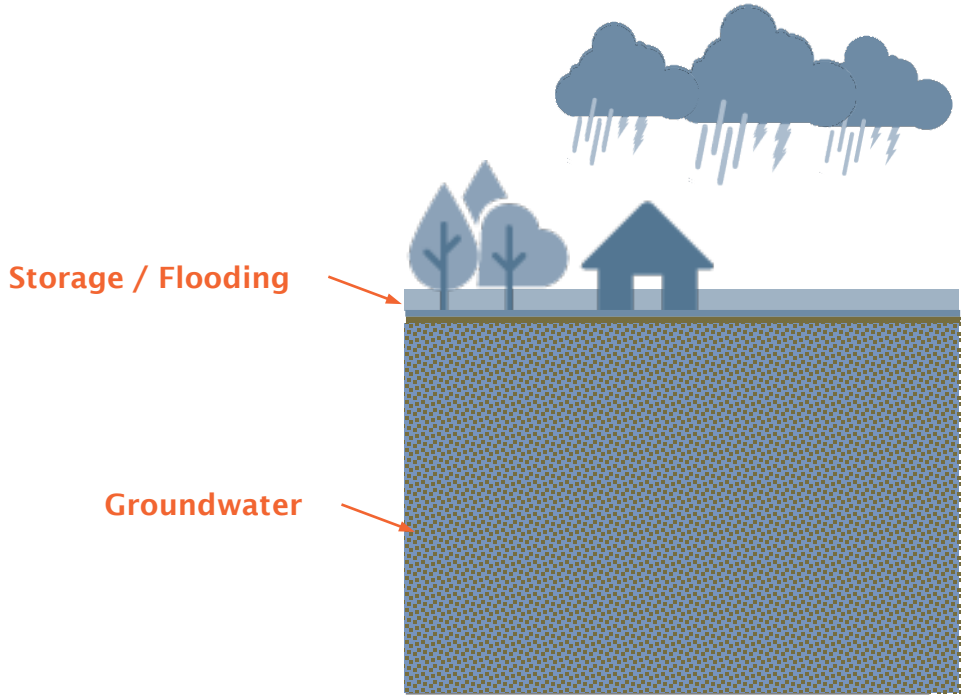
Storage matters



Hazen

Soil Storage and SLR

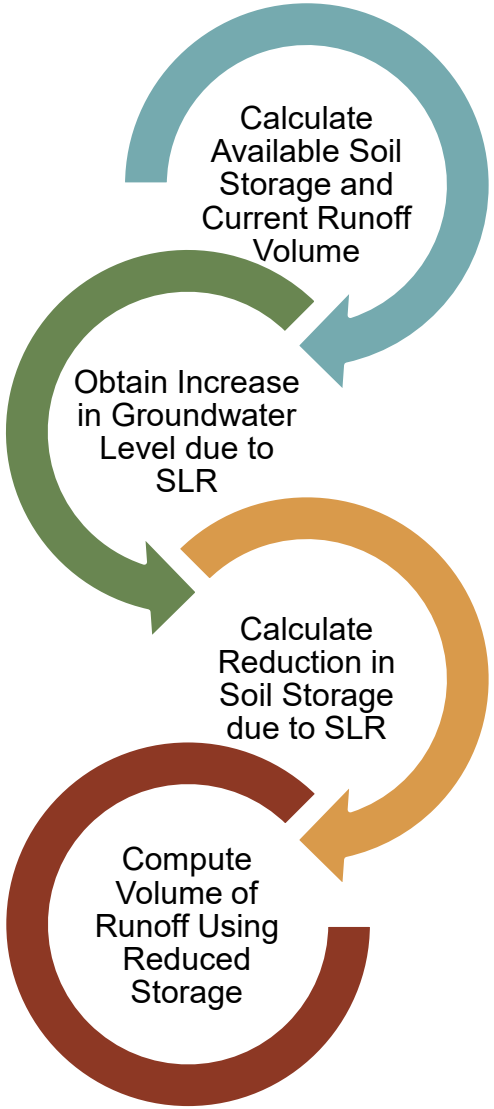
Storage matters



Groundwater Level at the beginning of the storm defines how much storage is available

Simplified Approach

Including SLR in simplified Approach



SCS (NRCS) methodology could be applied. The SCS defines the available Storage based in a "Curve Number – CN"

$$S = \frac{1000}{CN} - 10$$

$$Pe = \frac{(P - Ia)^2}{P - Ia + S}$$

1 : 1 ratio assumed downstream of Tidal Structures. Consult local GW models to obtain a ratio for areas upstream of the structures.

$$\Delta GW = f(SLR)$$

Use soil data or WMD recommendations to account for high GW

$$\Delta S = f(\Delta GW)$$

$$S_{adj} = S - \Delta S$$

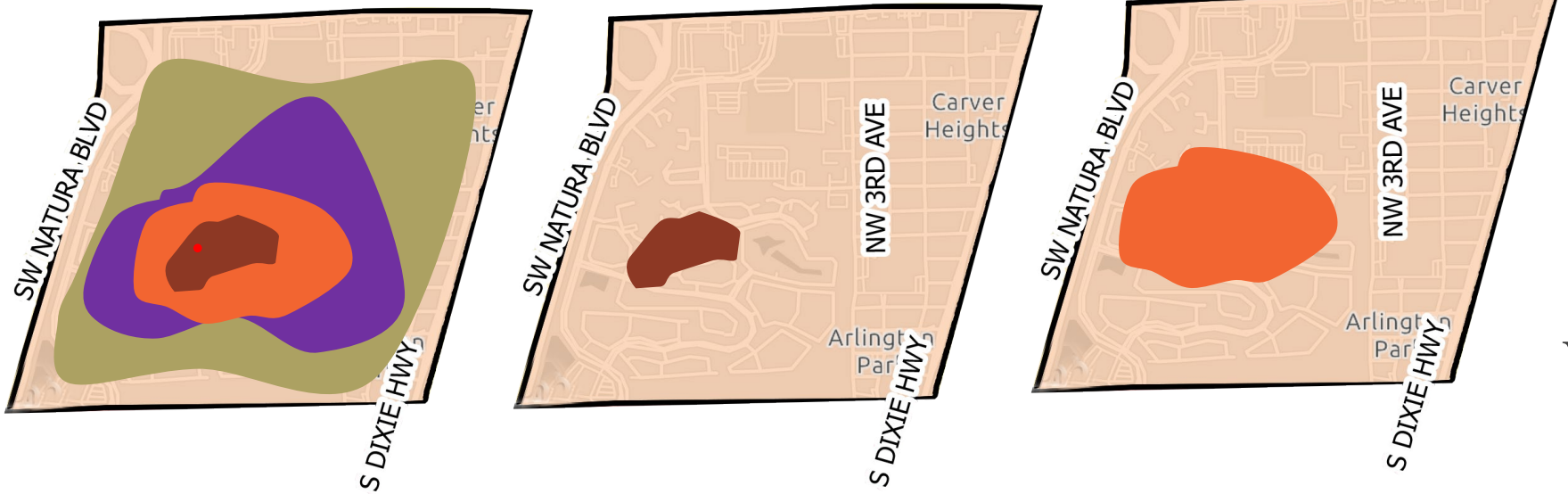
Adjust S based on last step and back-calculate Adjusted CN, compute Runoff Volume with adjusted CN.

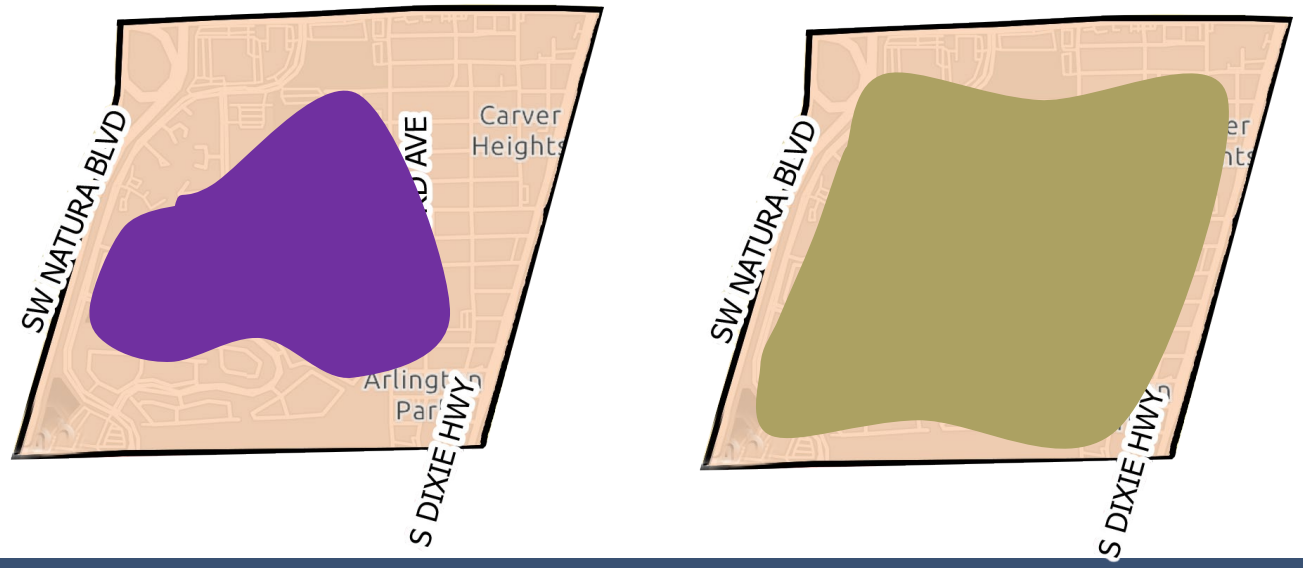
$$CN_{adj} = \frac{1000}{S_{adj} + 10}$$

$$Pe_{adj} = \frac{(P - Ia)^2}{P - Ia + S_{adj}}$$

Simplified Approach

Modeling Subbasins with Flooding Elevation – Scenario 10





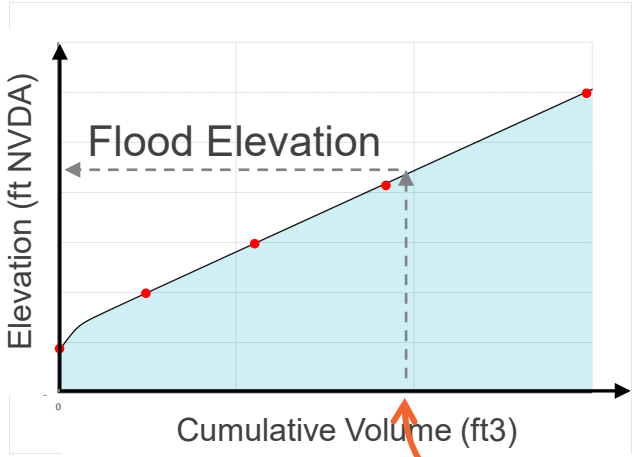
$$Pe = \frac{(P - Ia)^2}{P - Ia + S}$$

x

Area

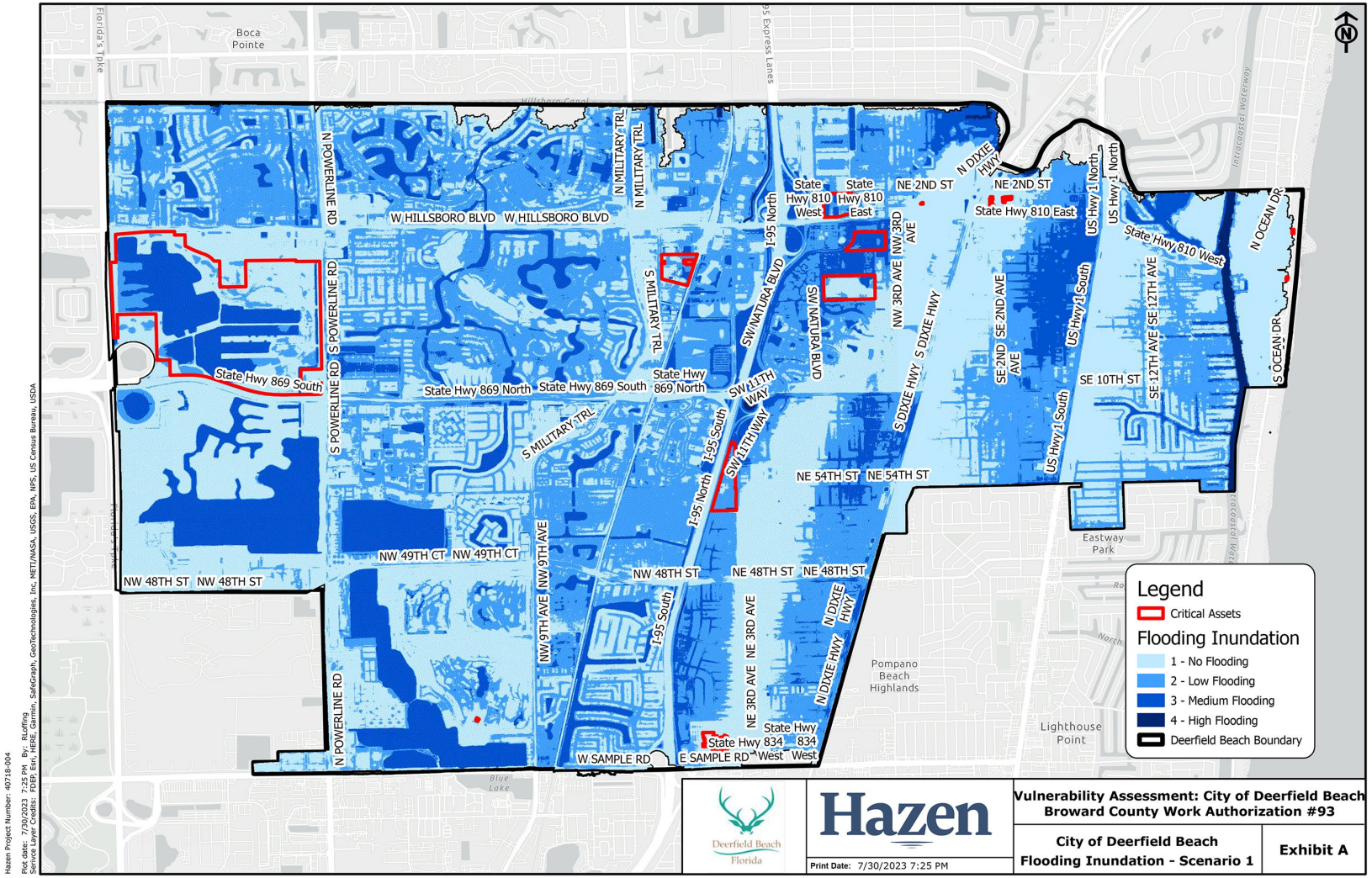
=

Volume of Runoff



Simplified Approach

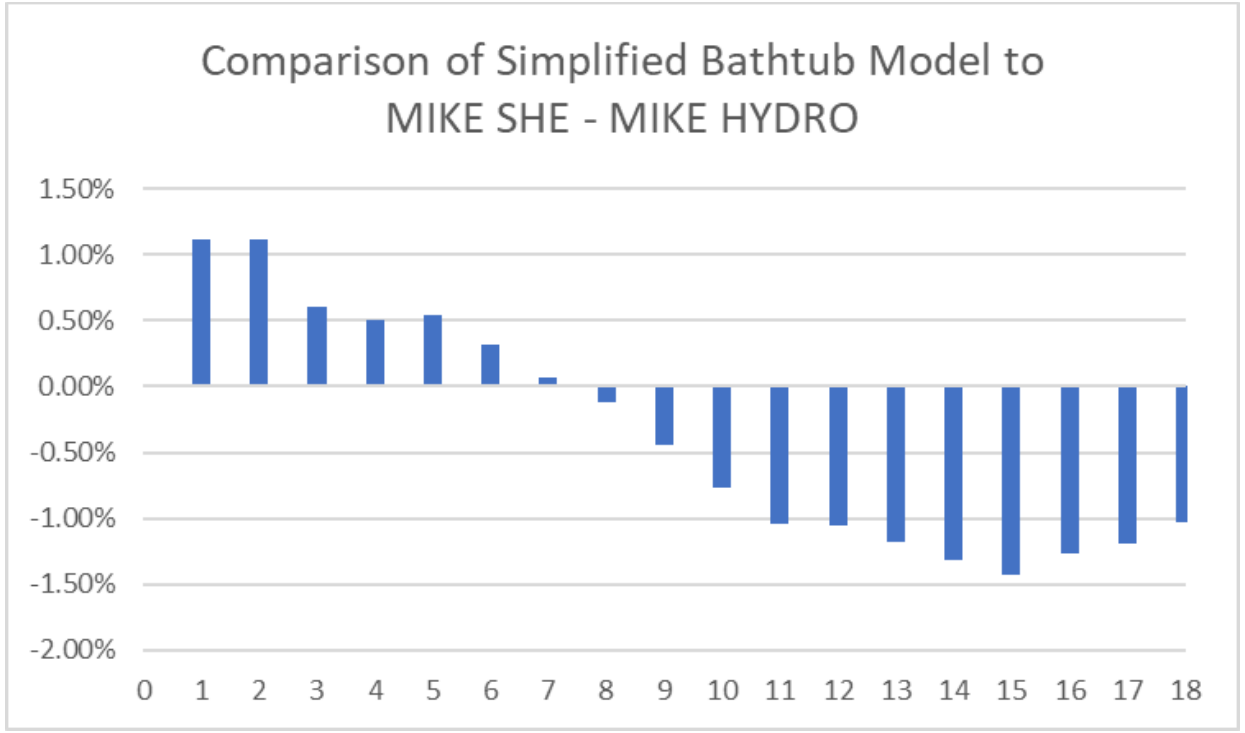
Modeling Subbasins with Flooding Elevation – Scenario 10



Analysis results can be visually shared via a colorized floodplain map

Comparison of Simplified Model to Broward H&H Model

- Less than 1.4% difference between the two models
- MIKE SHE – MIKE HYDRO guided the parameter selection for the simplified model
- MIKE SHE – MIKE HYDRO provides much more granularity to simulate adaptation strategies
- Simplified model is appropriate for conceptual level, vulnerability assessments



Exposure Analysis

Flooding Scenarios

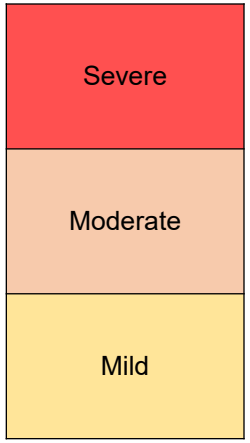
Scenario No.	Rainfall	Sea Level Rise Projection	Planning Horizon	Tidal Condition	Change Factor
1	100-yr	N/A	2021-Current	Normal High Tide	None
2	100-yr	N/A	2021-Current	Storm Surge (Cat 5)	None
3	100-yr	2017 NOAA Intermediate Low	2040	Normal High Tide	None
4	100-yr	2017 NOAA Intermediate High	2040	Normal High Tide	None
5	100-yr	2017 NOAA Intermediate Low	2070	Normal High Tide	None
6	100-yr	2017 NOAA Intermediate High	2070	Normal High Tide	None
7	100-yr	2017 NOAA Intermediate Low	2040	Storm Surge (Cat 5)	None
8	100-yr	2017 NOAA Intermediate High	2040	Storm Surge (Cat 5)	None
9	100-yr	2017 NOAA Intermediate Low	2070	Storm Surge (Cat 5)	None
10	100-yr	2017 NOAA Intermediate High	2070	Storm Surge (Cat 5)	None
11	100-yr	2017 NOAA Intermediate Low	2040	Normal High Tide	50th percentile
12	100-yr	2017 NOAA Intermediate High	2040	Normal High Tide	50th percentile
13	100-yr	2017 NOAA Intermediate Low	2070	Normal High Tide	50th percentile
14	100-yr	2017 NOAA Intermediate High	2070	Normal High Tide	50th percentile
15	100-yr	2017 NOAA Intermediate Low	2040	Storm Surge (Cat 5)	50th percentile
16	100-yr	2017 NOAA Intermediate High	2040	Storm Surge (Cat 5)	50th percentile
17	100-yr	2017 NOAA Intermediate Low	2070	Storm Surge (Cat 5)	50th percentile
18	100-yr	2017 NOAA Intermediate High	2070	Storm Surge (Cat 5)	50th percentile

- Critical Asset Analysis
  - **Flood depth is the depth of water above the finished floor elevation or the critical flood elevation of the asset**
- Roadway Analysis
  - **Roadway flooding was estimated as 6” below the roadway centerline as roadways typically flood on the shoulder of the road (lower elevation)**

Roadway Exposure Level

Exposure Level	Flood Depth (at centerline of roadway)
High	>6”
Medium	>0 and ≤6”
Low	>-6” and ≤0”

Comparison of Exposure Results

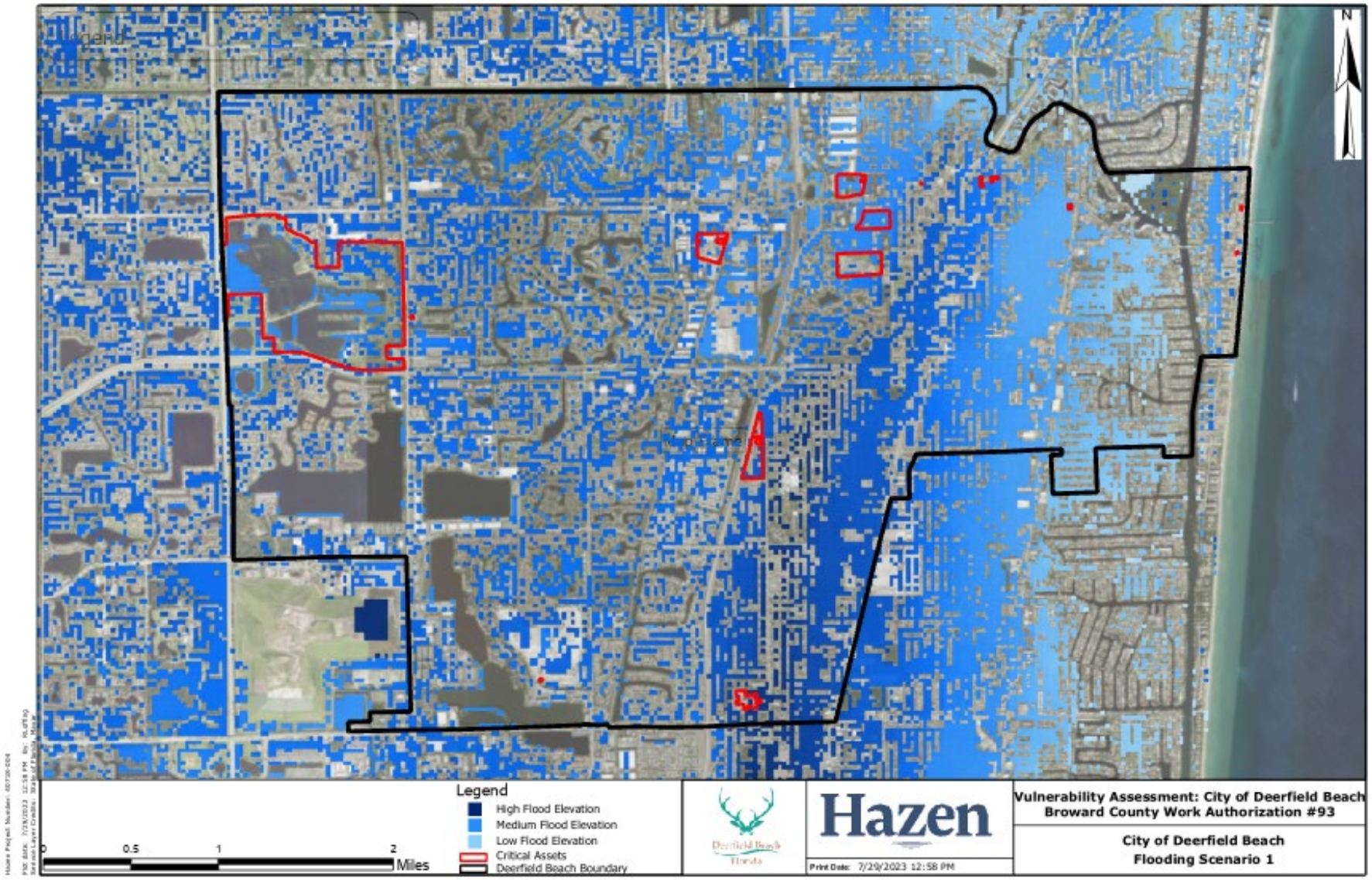


- **Mild, Moderate and Severe Flooding Scenarios**
  - **Scenario 1** - current planning horizon with no SLR and normal high tide
  - **Scenario 10** - 2070 planning horizon with intermediate-high SLR and Category 5 storm surge
  - **Scenario 18** - 2070 planning horizon with intermediate-high SLR and Category 5 storm surge with the addition of the rainfall change factor
- Scenarios were chosen for comparison to highlight the existing, average, and worst-case flooding conditions based on the modeling parameters

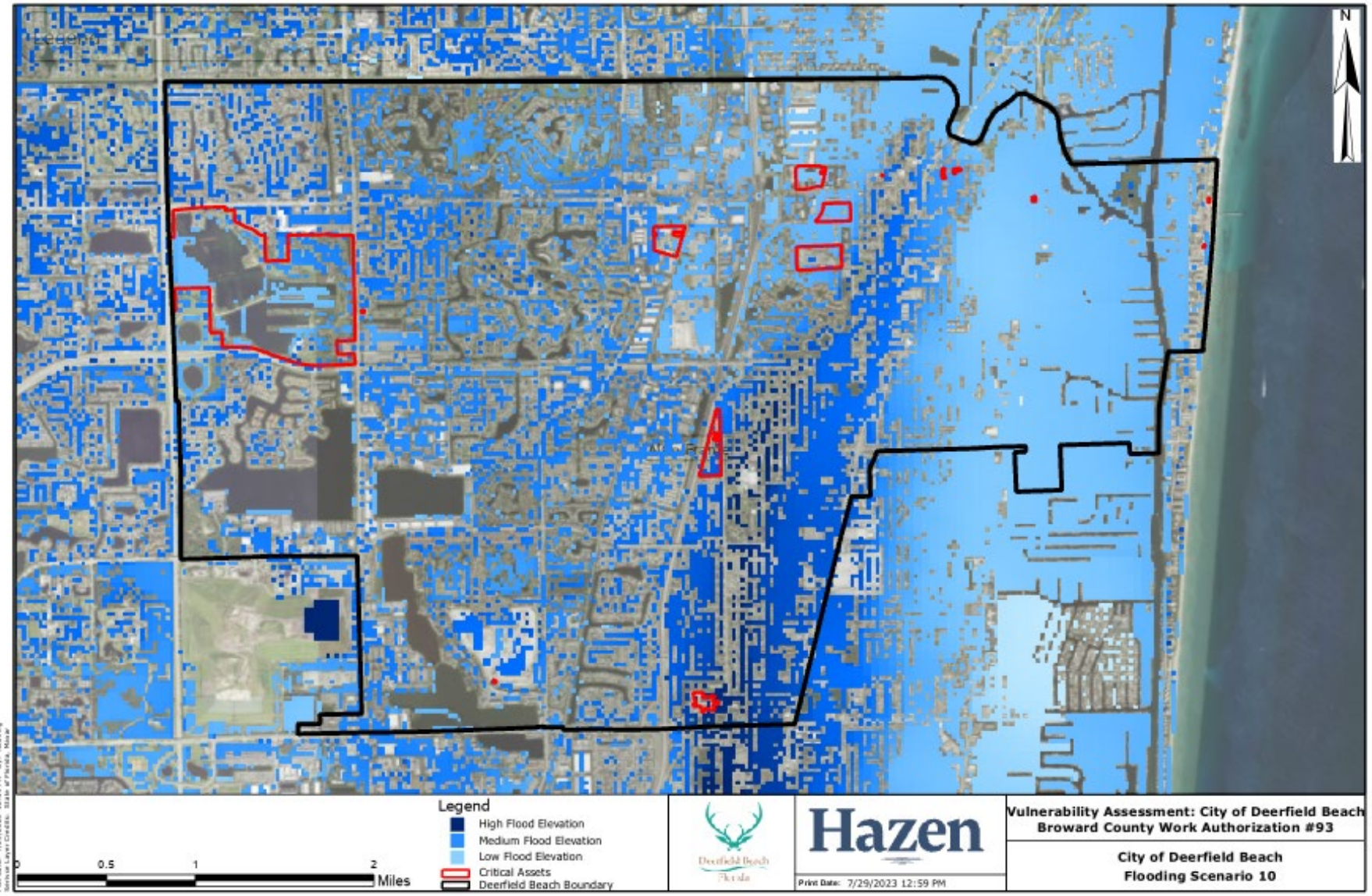
Critical Asset Exposure Analysis Sample

Asset Class	Asset Type	Asset Name	Maximum Flood Depth (in)		
			Scenario 1	Scenario 10	Scenario 18
Critical Infrastructures	Drinking Water Facilities	West Water Plant	16.7	17.0	32.8
		East Water Repump Station	0.0	0.0	0.0
	Electric Production and Supply Facilities	Engineering & Utilities Department	0.0	0.0	0.0
Critical Community and Emergency Facilities	Fire Stations	Fire Station 4	0.0	12.2	29.4
		Fire Station 102	0.0	0.0	0.0
		Fire Station 75	0.0	0.0	0.0
		Fire Station 66	0.0	0.0	0.0
		Fire Station 111	19.3	19.3	34.9
		Fire Station 51	0.0	0.0	0.0
	Law Enforcement Facilities	Broward Sheriff's Office District 10 Station	0.0	0.0	0.0
	Local Government Facilities	City Hall	0.0	0.0	0.0
		Central City Campus	19.8	19.8	41.8
	Hospitals	Broward Health North	0.0	0.0	0.0
	Emergency Operations Centers	Ocean Rescue Headquarters	0.0	0.0	0.0
	Community Centers	Hillsboro Community Center	0.0	0.0	0.0
	Logistical Staging Areas	Hillsboro Technology Staging	17.2	17.3	34.2
		Mitigation Operations Staging	24.5	24.5	42.6
Natural, Cultural, and Historical Resources	Parks	Kirk Cottrell Pavilion	0.0	0.0	0.0
		Oveta McKeithen Recreational Complex	28.3	28.6	44.9
		Quiet Waters Park	51.4	51.4	73.6

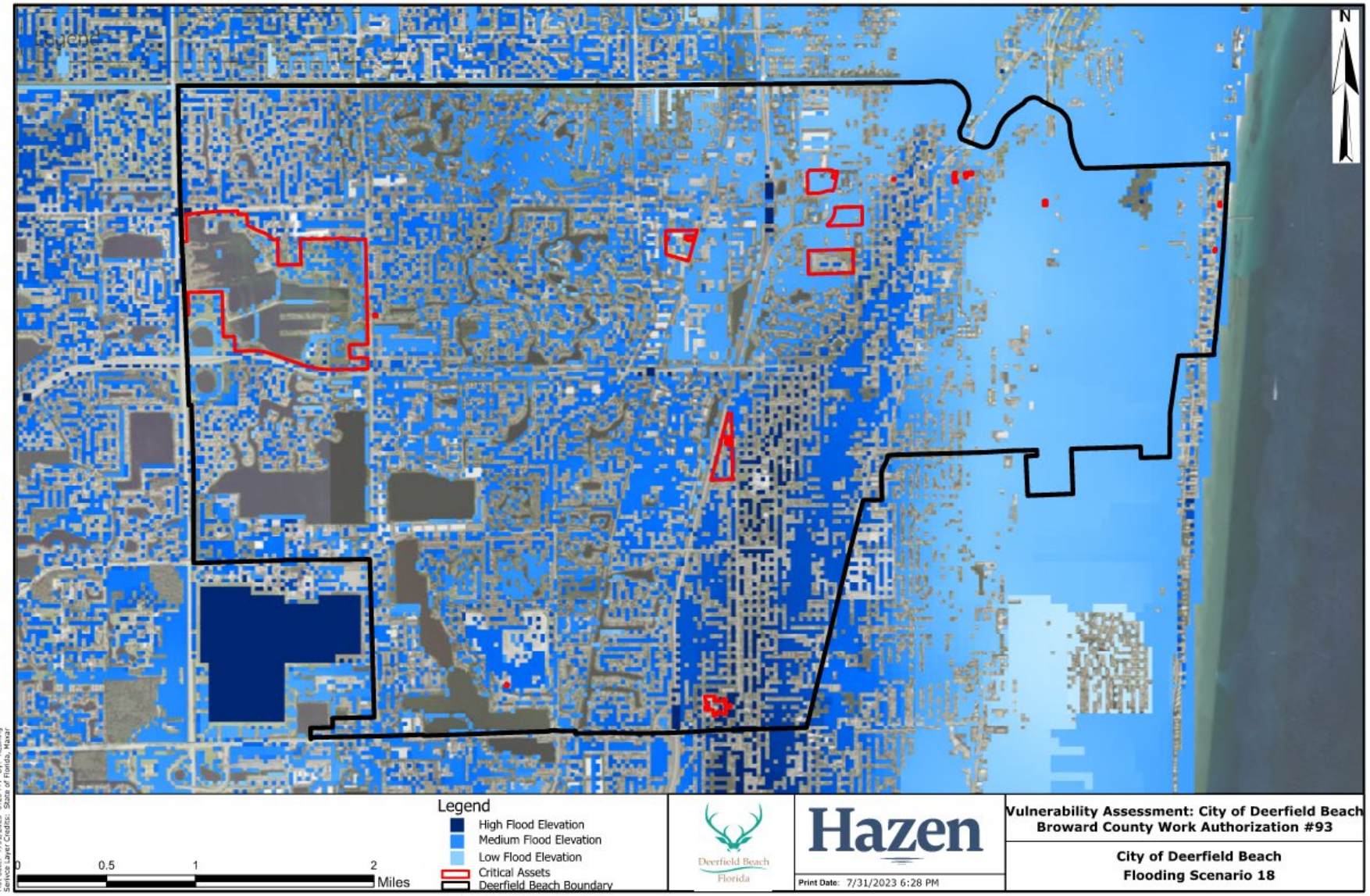
Critical Asset Exposure Analysis – Scenario 1



Critical Asset Exposure Analysis – Scenario 10



Critical Asset Exposure Analysis – Scenario 18

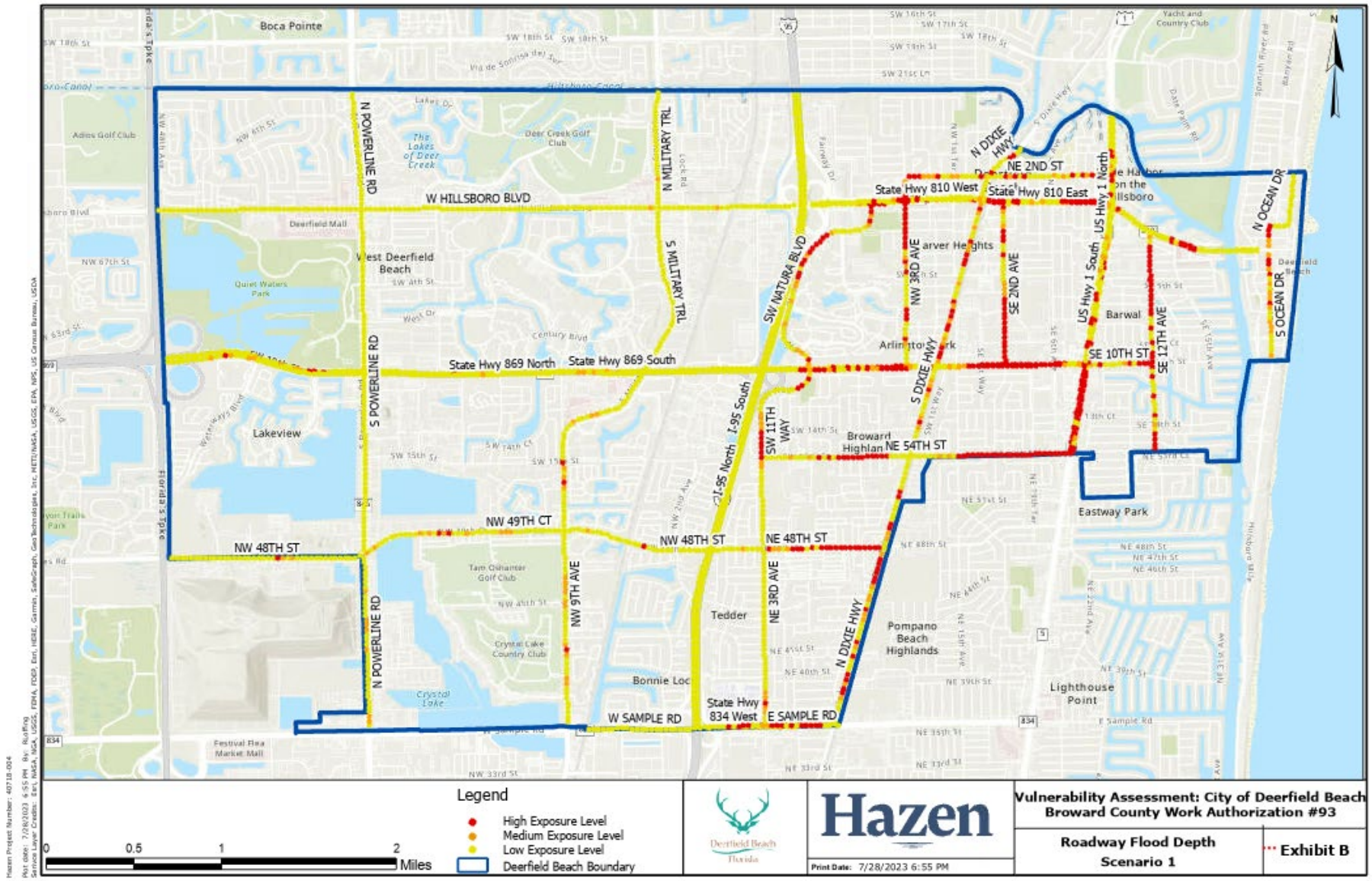


Roadway Exposure Analysis Sample

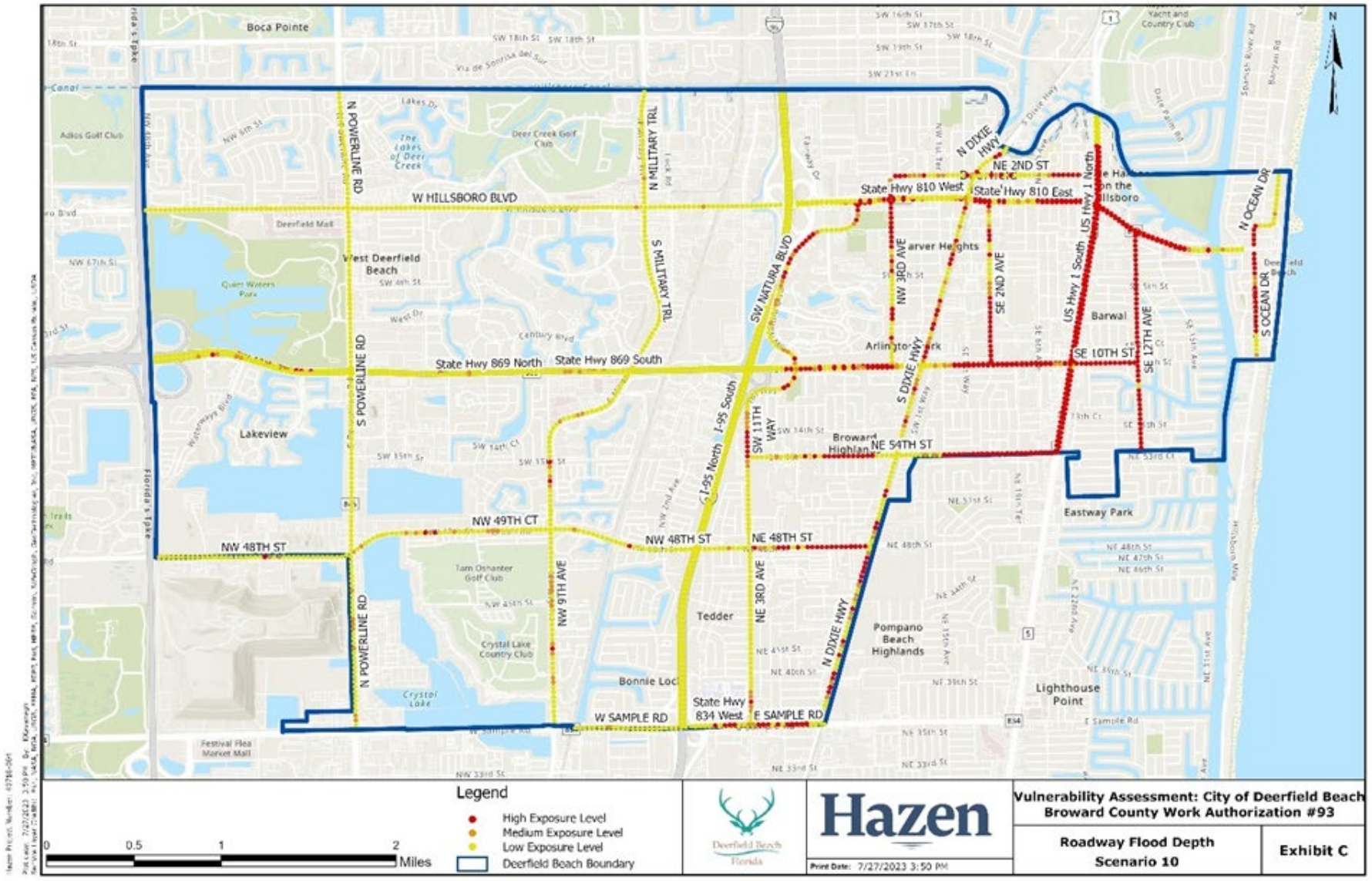
Roadways	Evacuation Route	Approx. Total Roadway Length (ft)	Scenario 1				Scenario 18			
			Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)	Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)
			Flooding Depth >6"	Flooding Depth 0"-6"	Flooding depth -6"-0"		Flooding Depth >6"	Flooding Depth 0"-6"	Flooding Depth -6"-0"	
US Hwy 1 South	Yes	9230	3,770	520	130	4.3	8,580	0	0	35.6
US Hwy 1 North	Yes	9230	2,860	1,300	130	3.8	8,580	0	0	33.5
State Hwy 869 South	Yes	24960	4,810	1,950	1,170	3.1	8,580	260	0	8.4
State Hwy 869 North	Yes	24960	5,070	2,470	1,690	2.9	10,140	650	0	8.9
State Hwy 834 West	Yes	3640	1,690	260	0	5.5	1,950	0	0	13.2
State Hwy 810 West	Yes	12480	3,510	650	0	3.8	7,930	0	0	30.2
State Hwy 810 East	Yes	12480	3,510	1,690	260	4.0	8,450	130	0	30.3
I-95 North	Yes	17550	0	0	130	0.0	910	1,040	260	0.7
I-95 South	Yes	17550	0	0	0	0.0	910	520	260	0.8
E Sample Rd	No	3510	130	780	910	0.2	1,690	0	0	7.3
N Dixie Hwy	No	6760	2,080	1,170	260	4.5	3,250	0	0	13.0
N Military Trl	No	3120	0	130	1,170	-1.4	1,560	130	0	5.6
N Ocean Dr	No	2470	390	260	130	1.9	1,560	0	0	16.5
N Powerline Rd	No	7800	0	910	650	0.0	2,210	0	0	3.7
NE 2nd St	No	5590	1,430	1,430	0	3.3	3,380	0	0	16.2
NE 3rd Ave	No	7020	130	780	390	0.4	910	260	0	2.2
NE 48th St	No	4680	2,340	520	260	7.7	2,860	0	0	15.2

Roadways	Evacuation Route	Approx. Total Roadway Length (ft)	Scenario 1				Scenario 18			
			Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)	Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)
			Flooding Depth >6"	Flooding Depth 0"-6"	Flooding depth -6"-0"		Flooding Depth >6"	Flooding Depth 0"-6"	Flooding Depth -6"-0"	
NE 54th St	No	8320	4,810	520	0	10.2	5,200	0	0	19.3
NW 3rd Ave	No	4940	2,340	650	130	5.7	3,120	0	0	15.4
NW 48th St	No	5980	130	260	390	0.1	1,040	0	0	2.7
NW 49th Ct	No	8580	390	1,300	1,170	0.4	3,640	0	0	6.7
NW 9th Ave	No	7020	390	1,690	910	0.7	3,120	0	0	7.2
S Dixie Hwy	No	9620	2,470	2,340	520	3.0	4,420	0	0	9.1
S Military Trail	No	8190	0	390	0	0.1	1,300	390	130	2.2
S Ocean Dr	No	2860	520	1,300	260	2.4	2,340	0	130	23.0
S Powerline Rd	No	9230	0	0	260	-0.1	1,170	130	0	1.5
SE 10th St	No	1690	650	260	0	4.6	1,690	0	0	61.2
SE 12th Ave	No	5980	3,770	260	130	8.0	5,980	0	0	76.2
SE 2nd Ave	No	4290	2,470	650	0	7.4	2,600	0	0	14.2
SW Natura Blvd	No	5980	1,820	1,430	520	3.1	4,420	130	0	16.7
SW 11th Way	No	3250	1,170	520	260	4.9	1,560	0	0	9.5
W Sample Rd	No	3120	0	0	260	-0.3	780	2	130	3.3
W Hillsboro Blvd	No	17290	0	260	910	-0.1	2,210	260	260	1.5

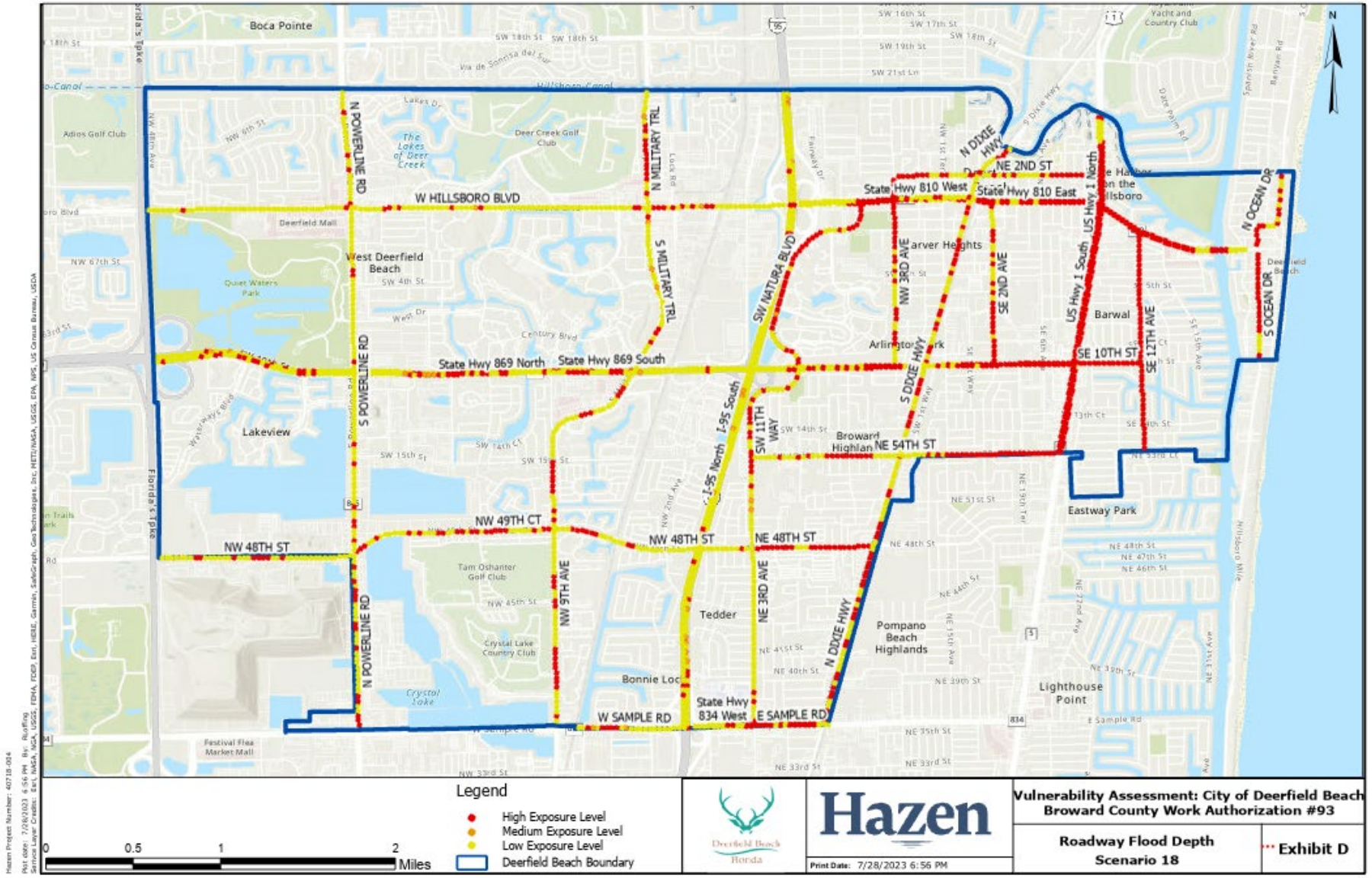
Roadway Exposure Analysis – Scenario 1



Roadway Exposure Analysis – Scenario 10



Roadway Exposure Analysis – Scenario 18



Sensitivity Analysis

- Critical Facility Analysis
  - **Flood depth is the depth of water above the finished floor elevation or the critical flood elevation of the asset**

Critical Facilities Point Values

Exposure Level	Flood Elevation	Point Value
High	>FFE/CFE	3
Medium	0”-12” from FFE/CFE	2
Low	12+” from FFE/CFE	1

Adjusted Point Values for Parks

Exposure Level	Flood Elevation	Point Value
Medium	>FFE/CFE	2
Low	0-6” from FFE/CFE	1

- Roadway Analysis
  - **The length of roadway within each exposure category was divided by the approximate total length and multiplied**
  - **Evacuation routes were multiplied by a factor of 1.5**

Major Roadways Point Values

Exposure Level	Flood Depth	Point Value	Evacuation Route Factor
High	>6”	3	x1.5
Medium	>0 and ≤6”	2	
Low	>-6” and ≤0”	1	

Critical Asset Sensitivity Analysis

Asset Name	Total Sensitivity Analysis Score (Out of 54)
West Water Plant	54
Fire Station 111	54
Central City Campus	54
Hillsboro Technology Staging	54
Mitigation Operations Staging	54
Fire Station 4	45
Oveta Mckeithen Recreational Complex	36
Quiet Waters Park	36
City Hall	26
Broward Health North	26
Fire Station 51	19
Hillsboro Community Center	19
Engineering & Utilities Department	18
Fire Station 102	18
Fire Station 75	18
Fire Station 66	18
Broward Sheriff's Office District 10 Station	18
Ocean Rescue Headquarters	18
Kirk Cottrell Pavilion	18
East Water Repump Station	18

Sensitivity Analysis Score Matrix

Exposure Level	Total Sensitivity Analysis Score
High	41+
Medium	21-40
Low	0-20

- Assets in the high range deserve further attention
- Most notable are:
  - **The West Water Plant**
  - **Fire Station 11**
  - **Central City Campus**

Roadway Sensitivity Analysis

Roadways	Evacuation Route	Overall Sensitivity Analysis Score
US Hwy 1 South	Yes	47.0
US Hwy 1 North	Yes	46.4
SE 12th Ave	No	44.3
State Hwy 834 West	Yes	42.3
State Hwy 810 East	Yes	40.0
SE 10th St	No	38.8
State Hwy 810 West	Yes	35.1
SE 2nd Ave	No	34.8
NE 54th St	No	33.3
S Ocean Dr	No	32.7
NE 48th St	No	32.4
SW Natura Blvd	No	31.7
NW 3rd Ave	No	31.7
State Hwy 869 North	Yes	27.9
SW 11th Way	No	25.4
NE 2nd St	No	24.5
N Dixie Hwy	No	24.3
S Dixie Hwy	No	23.9
State Hwy 869 South	Yes	23.5
N Ocean Dr	No	22.1
E Sample Rd	No	19.7
NW 9th Ave	No	18.4
N Military Trl	No	16.8
NW 49th Ct	No	15.9
N Powerline Rd	No	10.0
W Sample Rd	No	7.2
NE 3rd Ave	No	7.0
NW 48th St	No	6.3
S Military Trail	No	5.7
W Hillsboro Blvd	No	4.3
I-95 North	Yes	3.6
S Powerline Rd	No	3.5
I-95 South	Yes	2.8

Sensitivity Analysis Score Matrix

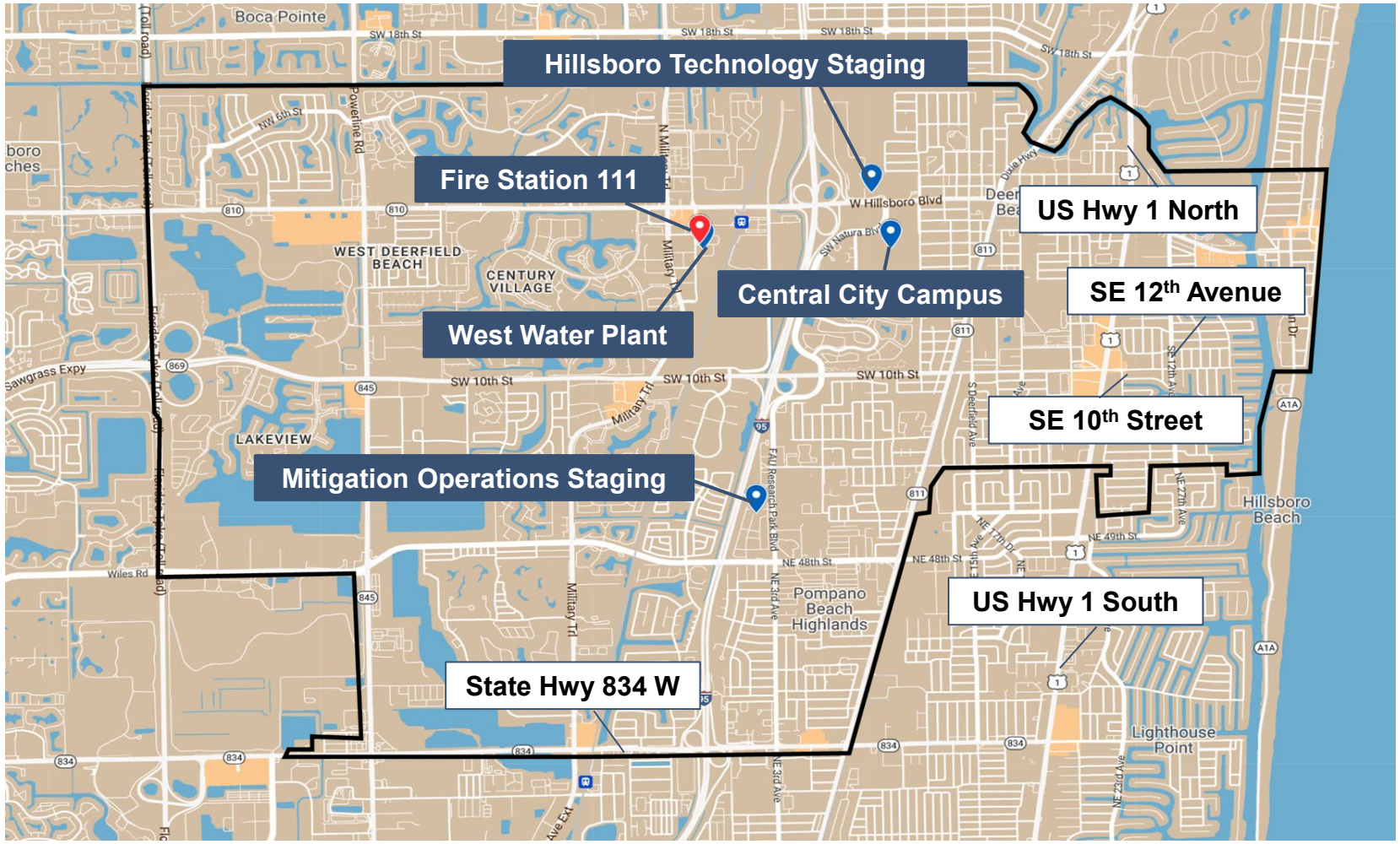
Exposure Level	Total Sensitivity Analysis Score
High	41+
Medium	21-40
Low	0-20

Summary of Results for Deerfield Beach VA

Focus Areas

- Critical assets identified as vulnerable to flooding:
  1. West Water Plant
  2. Fire Station 111
  3. Central City Campus
  4. Further investigation to flooding of the two staging sites is recommended
     - *Hillsboro Technology Staging*
     - *Mitigation Operations Staging*

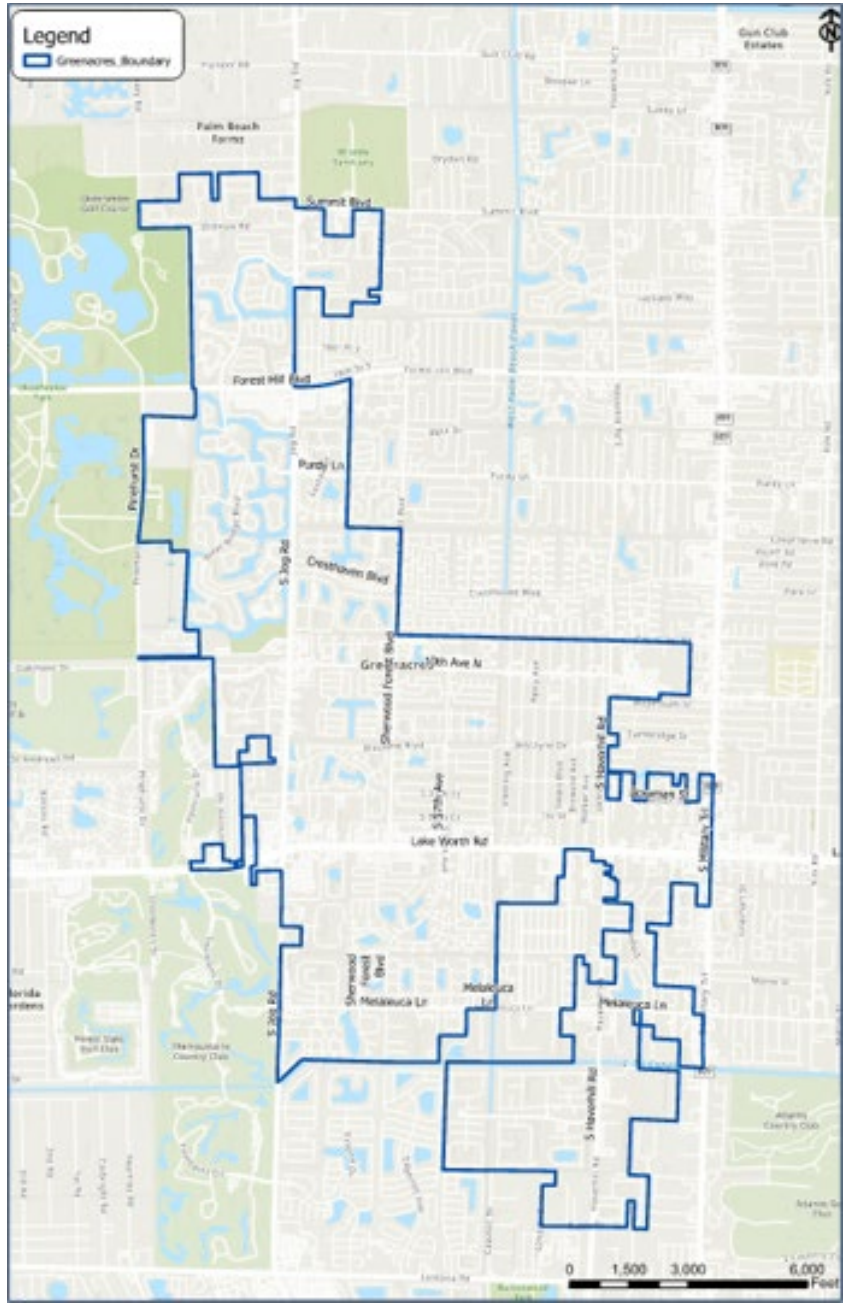
- Major roadways most vulnerable to flooding:
  1. US Hwy 1 South
  2. US Hwy 1 North
  3. SE 10th Street
  4. State Highway 834 West
  5. SE 12th Avenue



3 – Best Practices

Example of a VA Performed with a Simplified Approach

The City of Greenacres is used as the example for application of a simplified model



Critical Assets

31

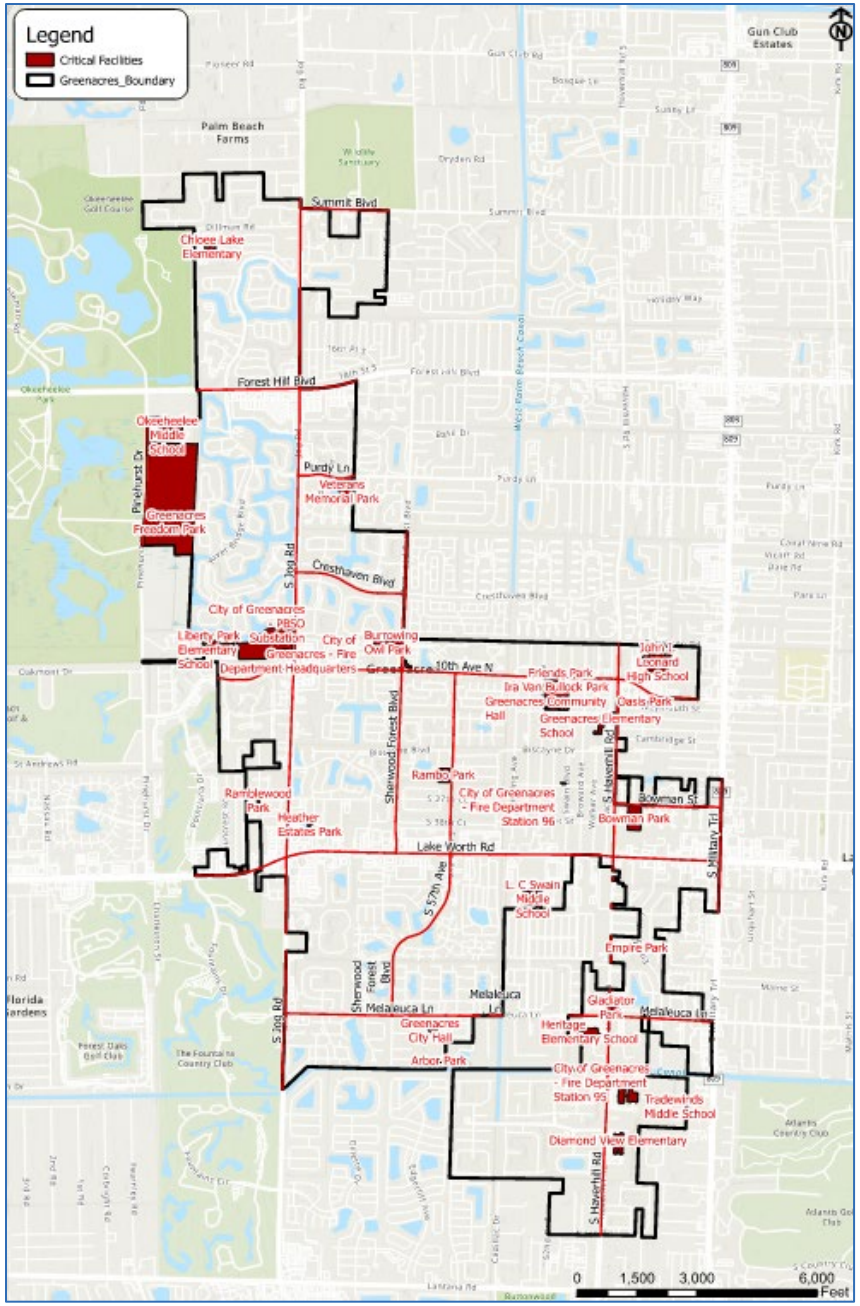
critical facilities

and

14

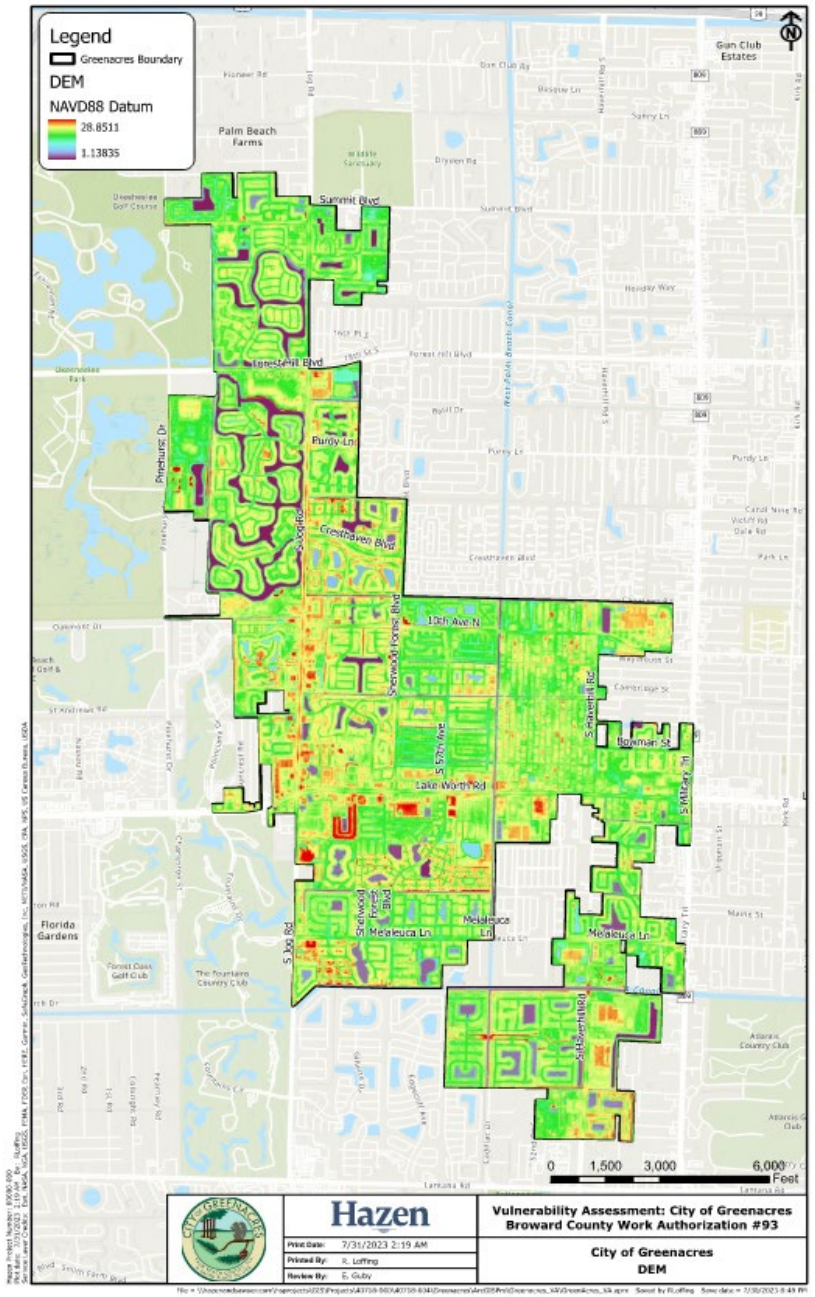
major roadways

were included in the VA



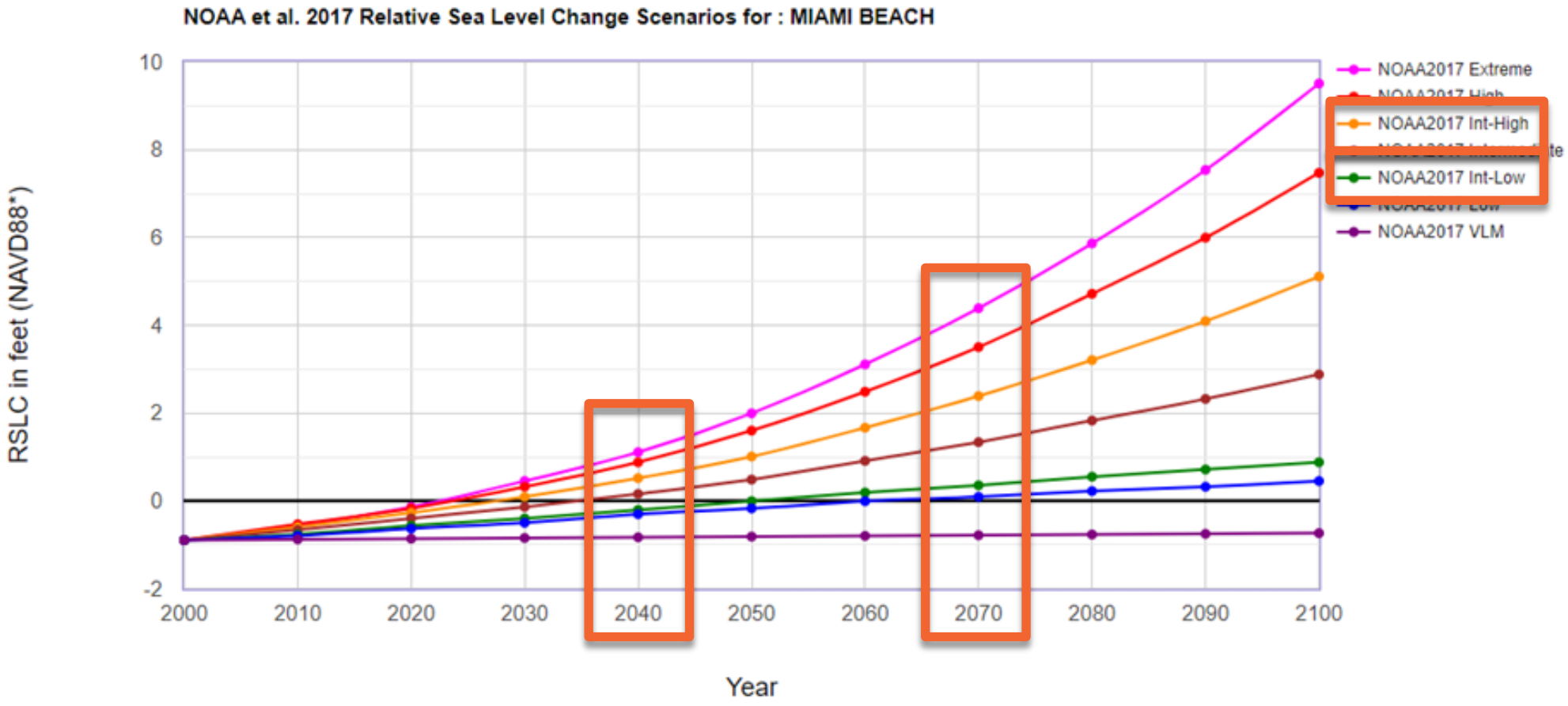
DEM – Developed in 2022 and sourced from Palm Beach County

- Provides a topographic ground surface from which depths can be measured
- Publicly available via the SFWMD



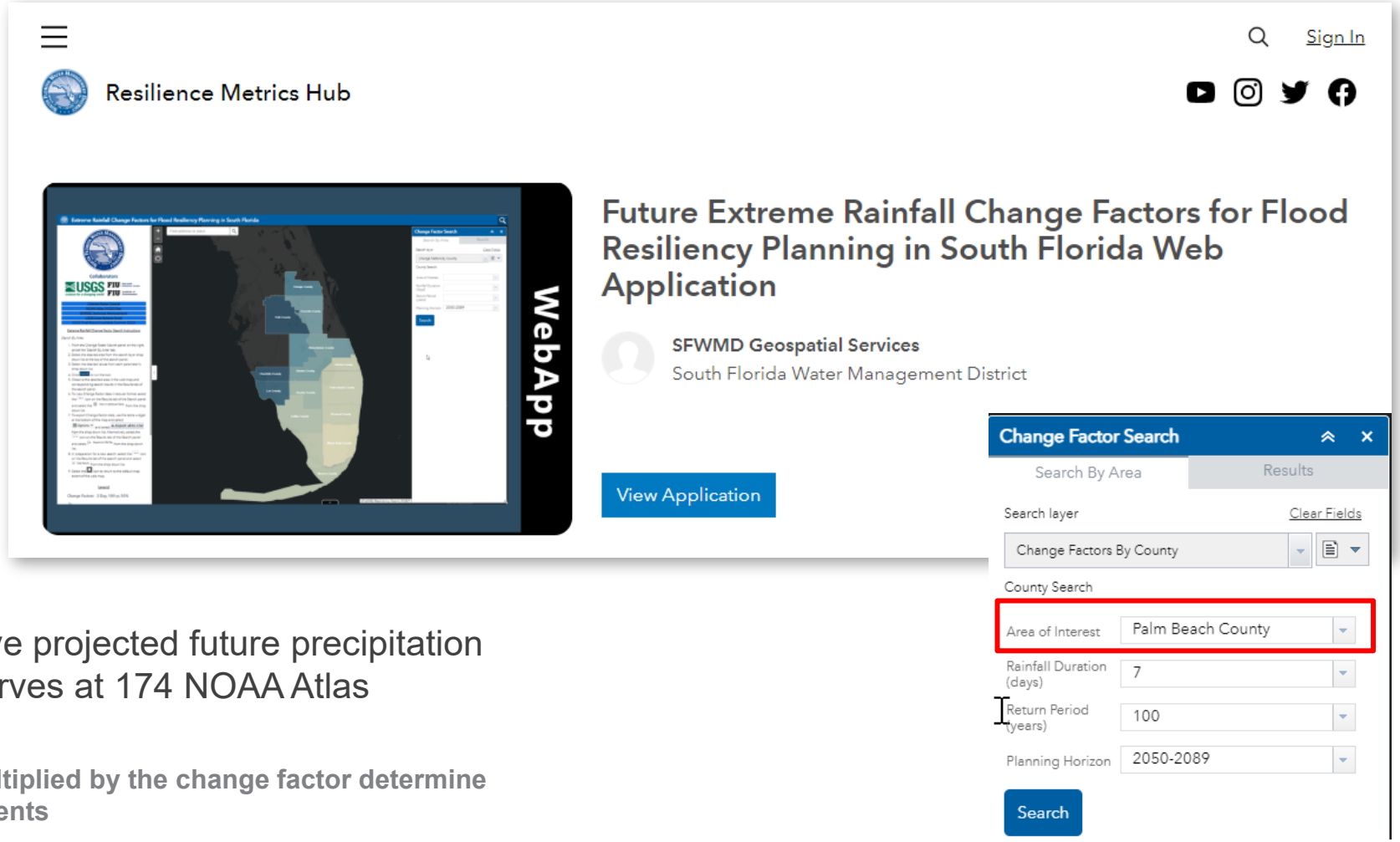
NOAA Sea Level Rise Curves were used per statutory requirements

Planning Horizons for 2040 and 2070 utilized to have a statutorily compliant VA



Rainfall induced Flooding Change Factor was utilized

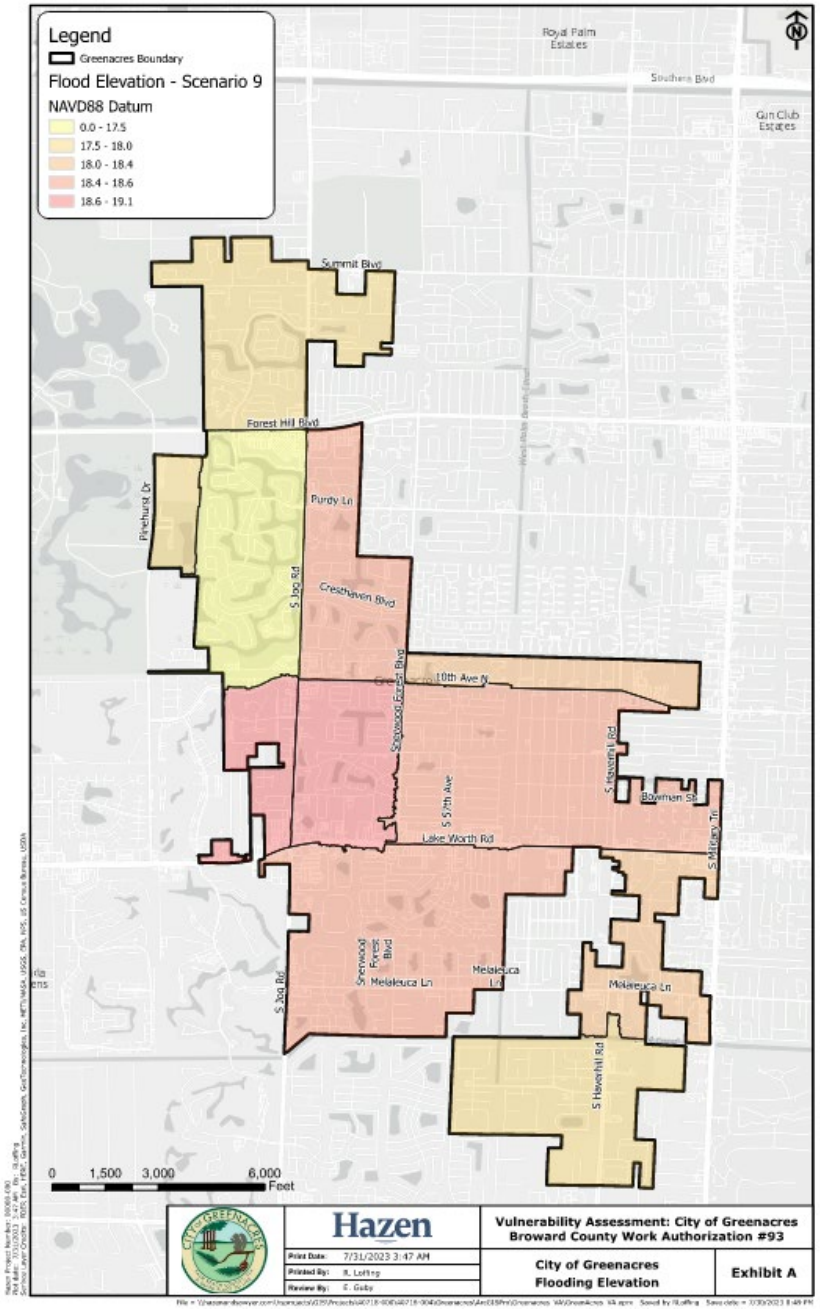
- Compliant with FS, 380.093, F.S. compound flooding or the combination of tidal storm surge, and rainfall-induced flooding should be incorporated into the VA
- Atlas 14 published by NOAA was utilized for extreme rainfall information
  - **Does not include upward trend in rainfall intensity via climate change**
- USGS change factors used to derive projected future precipitation depth-duration-frequency (DDF) curves at 174 NOAA Atlas 14 stations in Florida
  - **Historical NOAA Atlas 14 DDF curves multiplied by the change factor determine projected future extreme precipitation events**



Simplified Approach

Modeling Subbasins with Inundation – Scenario 9

- Subbasins divided based on topographic features
- Hydrologic analyses performed at subbasin level

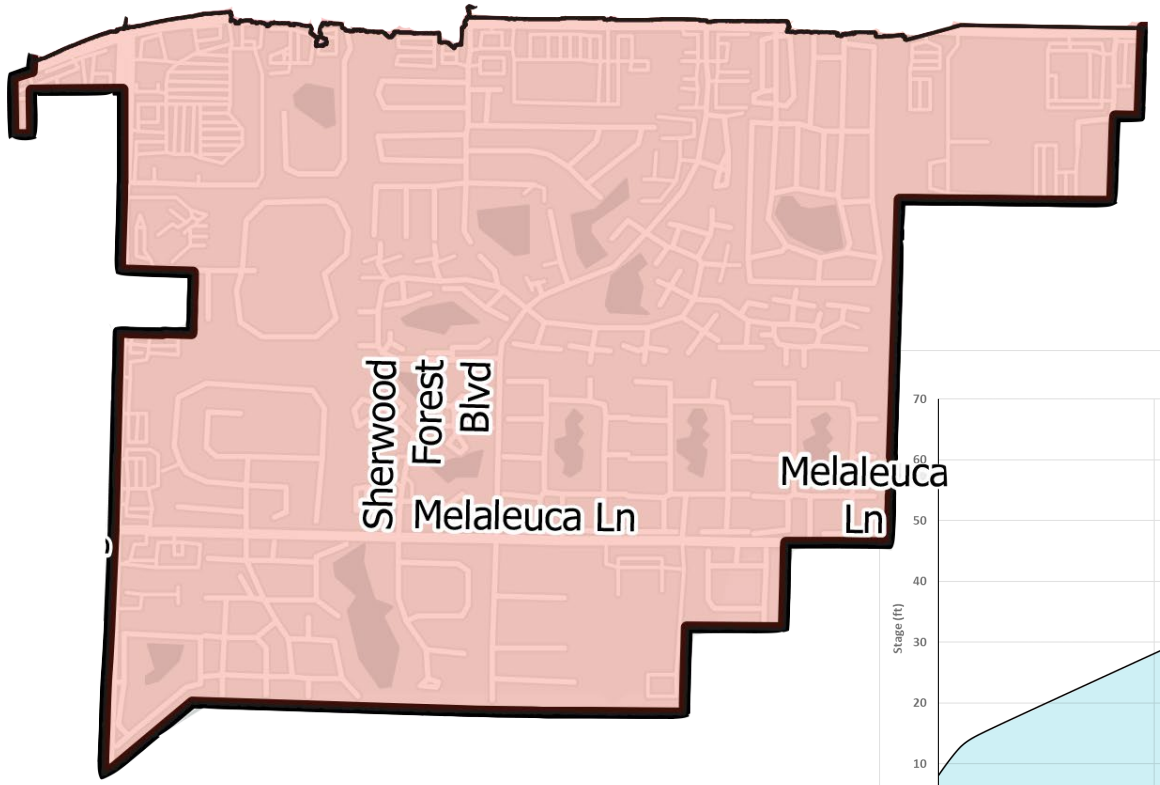


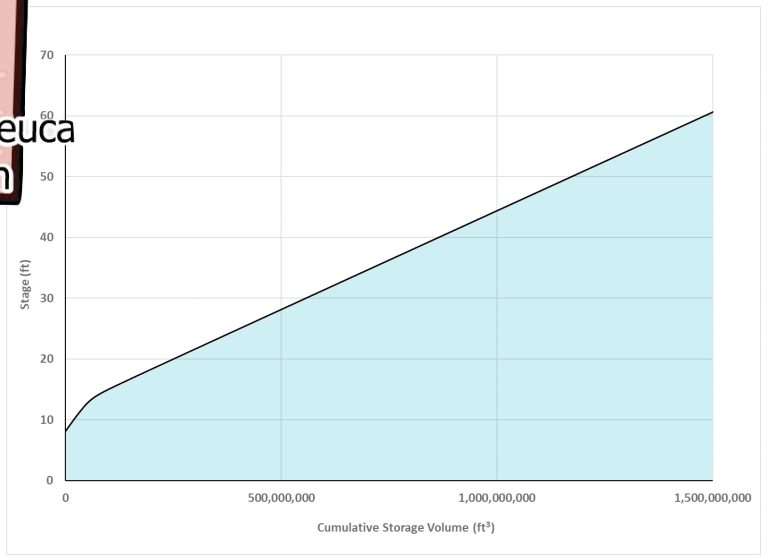
Simplified Approach

Modeling Subbasins with Inundation – Scenario 9

$$S = \frac{1000}{CN} - 10$$

$$Pe = \frac{(P - Ia)^2}{P - Ia + S}$$

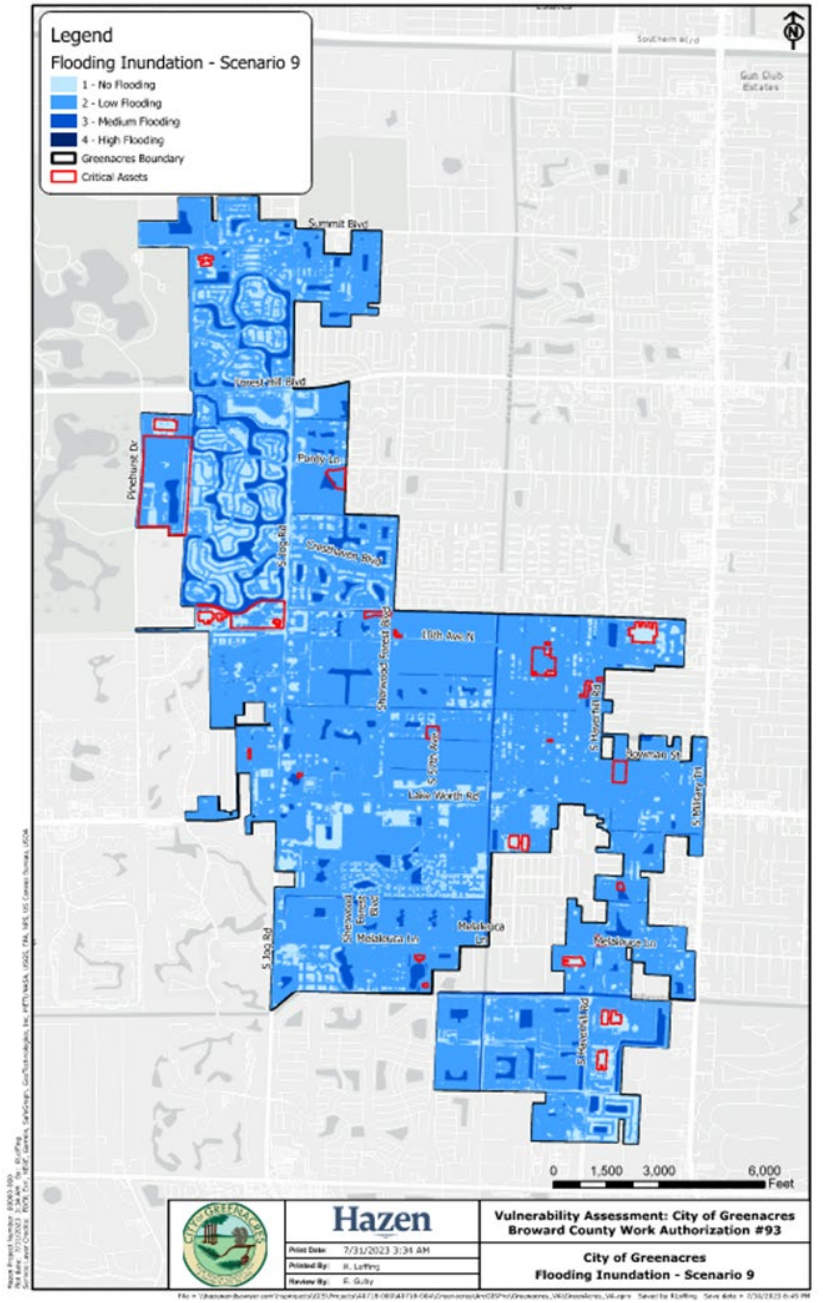




Simplified Approach

Modeling Subbasins with Inundation – Scenario 9

Analysis results can be visually shared via a colorized floodplain map



Exposure Analysis

Flooding Scenarios

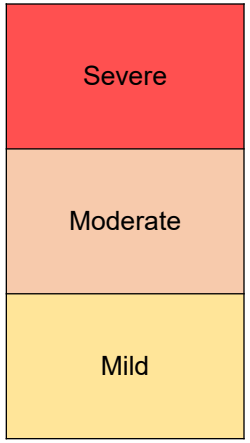
Scenario No.	Rainfall	Sea Level Rise Projection	Planning Horizon	Tidal Condition	Change Factor
1	100-yr	N/A	2021-Current	Normal High Tide	None
2	100-yr	2017 NOAA Intermediate Low	2040	Normal High Tide	None
3	100-yr	2017 NOAA Intermediate High	2040	Normal High Tide	None
4	100-yr	2017 NOAA Intermediate Low	2070	Normal High Tide	None
5	100-yr	2017 NOAA Intermediate High	2070	Normal High Tide	None
6	100-yr	2017 NOAA Intermediate Low	2040	Normal High Tide	50th percentile
7	100-yr	2017 NOAA Intermediate High	2040	Normal High Tide	50th percentile
8	100-yr	2017 NOAA Intermediate Low	2070	Normal High Tide	50th percentile
9	100-yr	2017 NOAA Intermediate High	2070	Normal High Tide	50th percentile

- Critical Facility Analysis
  - **Flood depth is the depth of water above the finished floor elevation or the critical flood elevation of the asset**
- Roadway Analysis

Roadway Exposure Level

Exposure Level	Flood Depth (at centerline of roadway)
High	>6”
Medium	>0 and ≤6”
Low	>-6” and ≤0”

Comparison of Exposure Results



- **Mild and Severe Flooding Scenarios**
  - **Scenario 1** - current planning horizon with no SLR and normal high tide
  - **Scenario 9** - 2070 planning horizon with intermediate-high SLR and the rainfall change factor

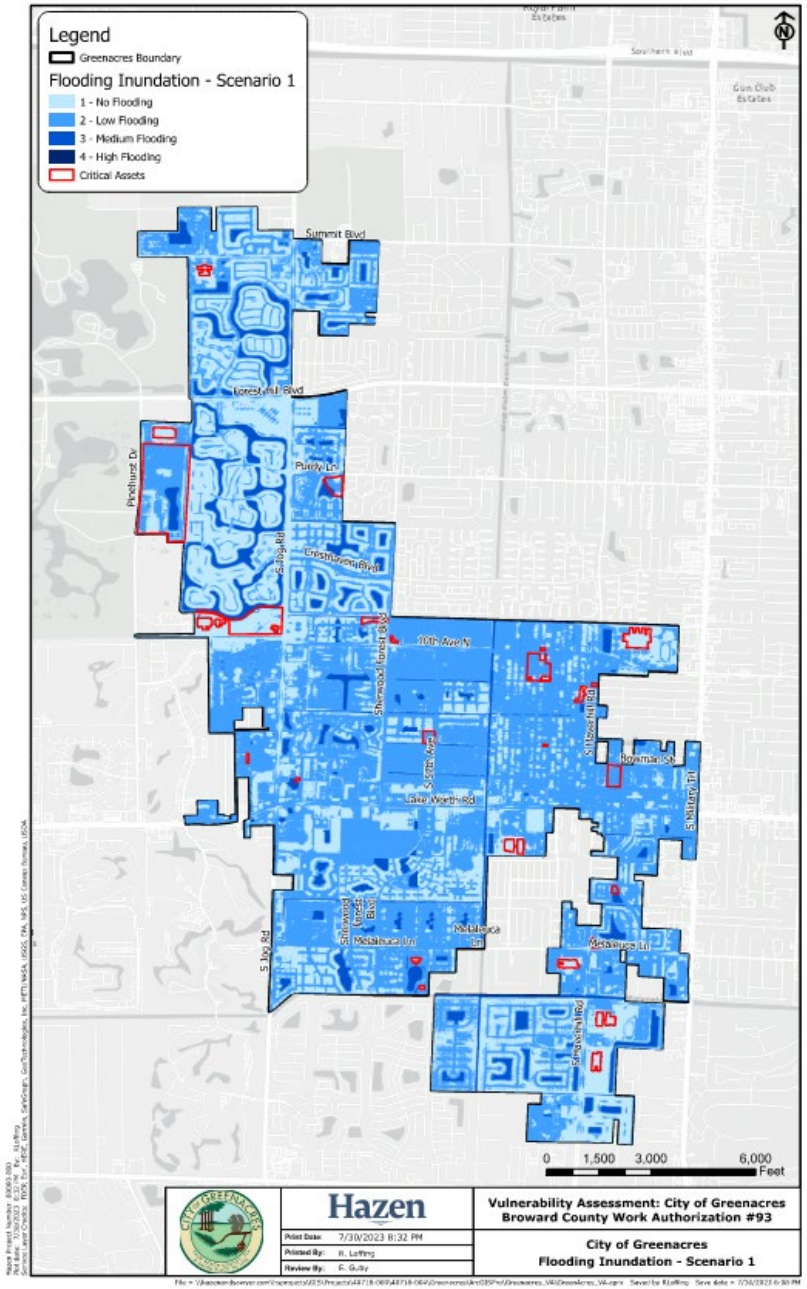
- Scenarios were chosen for comparison to highlight the existing and worst-case flooding conditions based on the modeling parameters

Critical Asset Exposure Analysis Sample

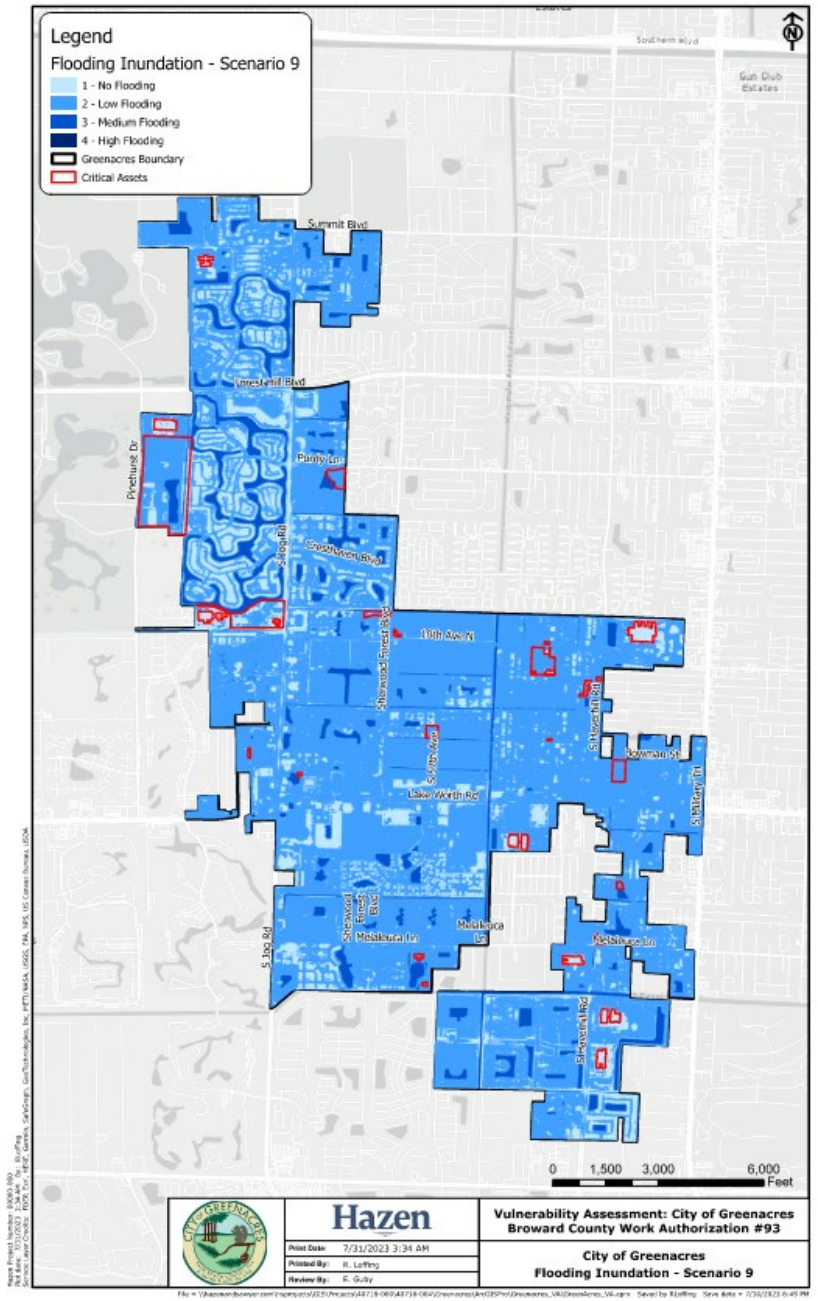
Asset Class	Asset Type	Asset Name	Maximum Flood Depth (in)	
			Scenario 1	Scenario 9
Critical Community and Emergency Facilities	Community Centers	Greenacres Community Hall	0.0	0.0
		City of Greenacres Community Center	0.0	0.0
	Fire Stations	City of Greenacres - Fire Department Headquarters	0.0	0.0
		City of Greenacres - Fire Department Station 95	0.0	0.0
		City of Greenacres - Fire Department Station 96	0.0	5.6
	Law Enforcement Facilities	City of Greenacres - PBSO Substation	0.0	0.0
	Local Government Facilities	Greenacres City Hall	0.0	0.0
	State Government Facilities	State of Florida Department of Health	0.0	0.0
	Schools	Chloee Lake Elementary	0.0	0.0
		Diamond View Elementary	0.0	0.0
		Greenacres Elementary School	0.0	0.0
		Heritage Elementary School	0.0	0.0
		Liberty Park Elementary School	0.0	0.0
		L. C Swain Middle School	0.0	0.0
		Okeeheelee Middle School	0.0	0.0
		John I. Leonard High School	0.0	0.0
		Tradewinds Middle School	0.0	0.0

Asset Class	Asset Type	Asset Name	Maximum Flood Depth (in)	
			Scenario 1	Scenario 9
Natural, Cultural, and Historical Resource	Parks	Greenacres Freedom Park	13.1	20.3
		Veterans Memorial Park	11.0	19.4
		Burrowing Owl Park	5.2	13.6
		Samuel J. Ferreri Community Park	0.0	7.9
		Ramblewood Park	20.9	26.9
		Heather Estates Park	17.0	24.2
		Bowman Park	20.0	26.0
		Empire Park	12.3	19.5
		Friends Park	11.5	17.5
		Ira Van Bullock Park	11.5	17.5
		Gladiator Park	11.2	18.4
		Oasis Park	15.5	21.5
		Rambo Park	11.5	17.5
		Arbor Park	0.0	0.6

Critical Asset Exposure Analysis – Scenario 1



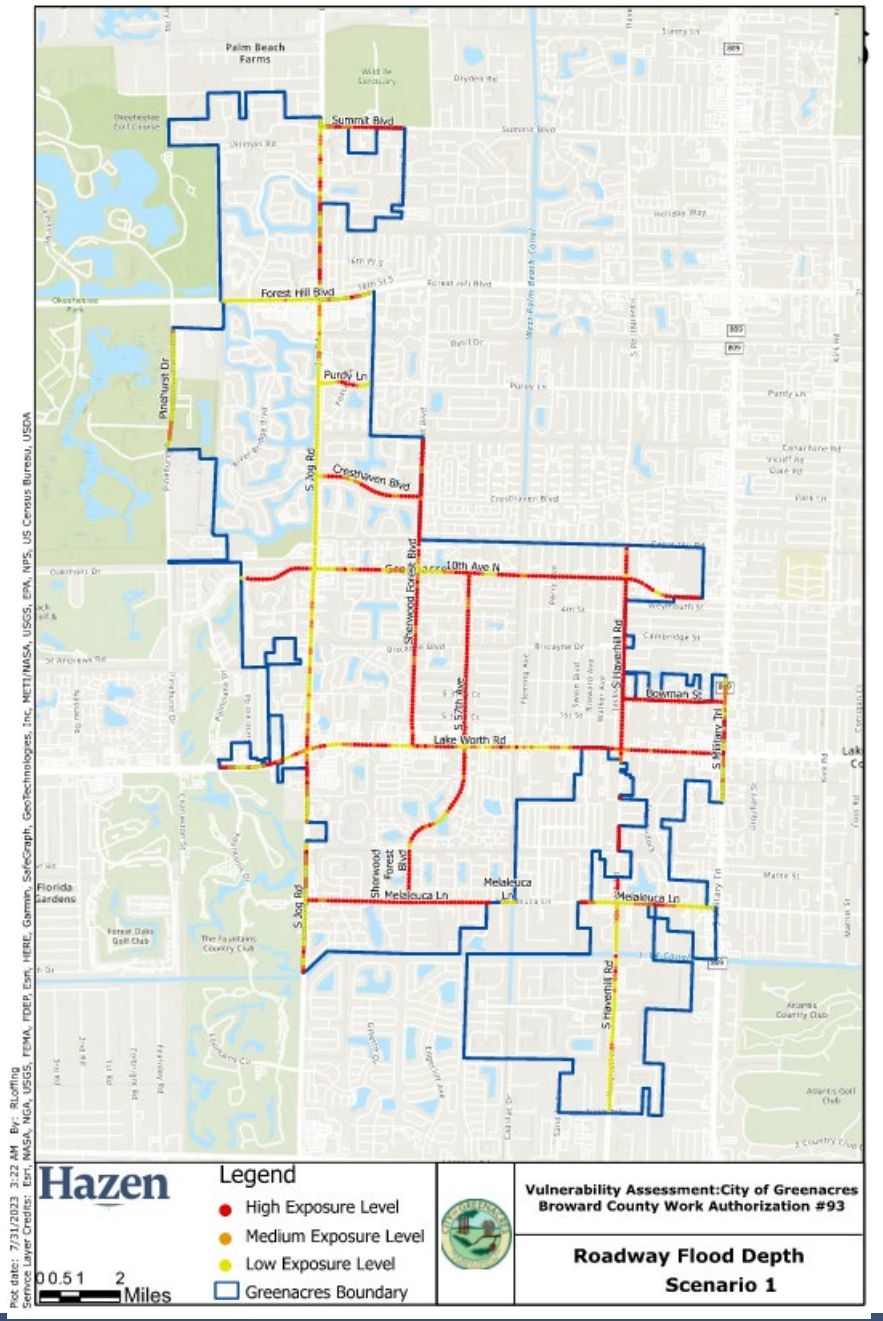
Critical Asset Exposure Analysis – Scenario 9



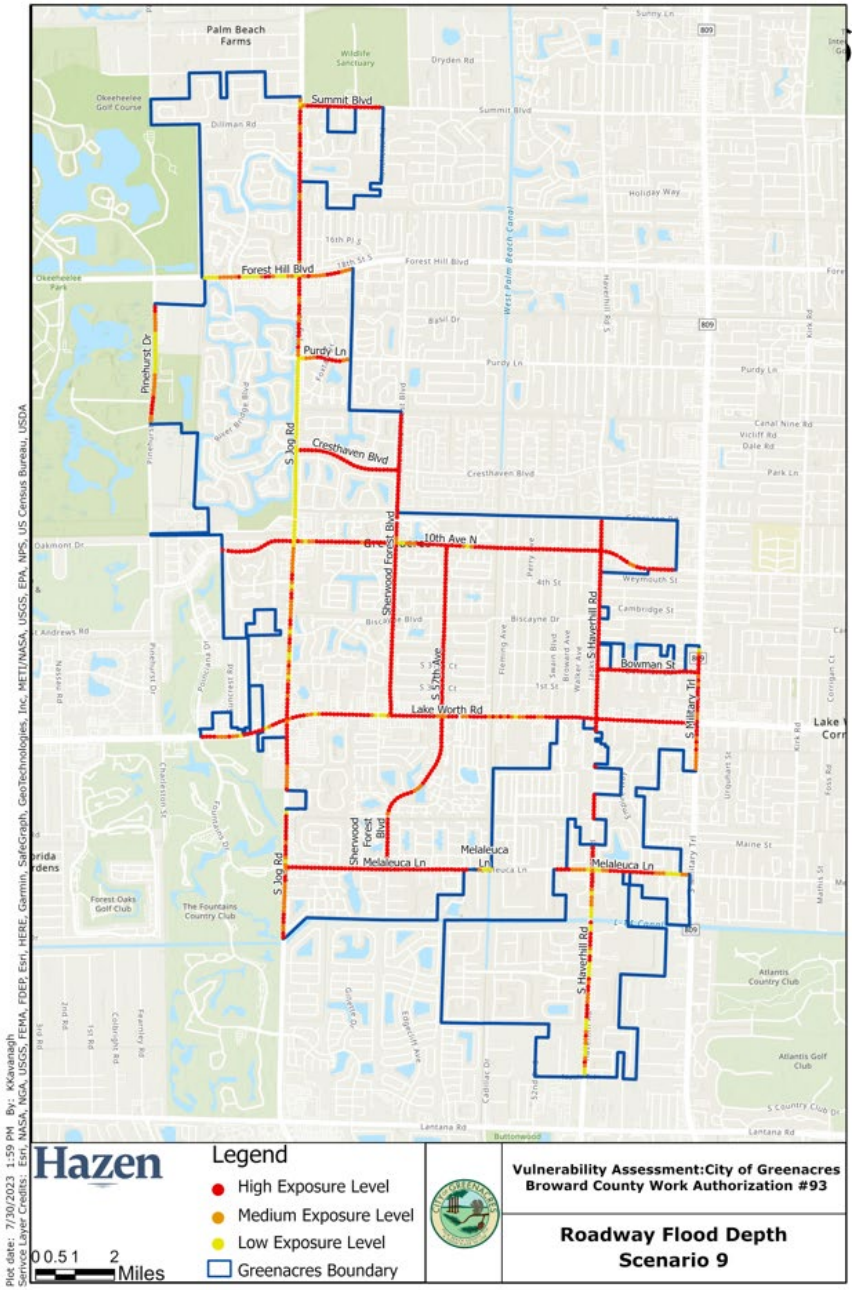
Roadway Exposure Analysis Sample

Roadways	Evacuation Route	Approx. Total Roadway Length (ft)	Scenario 1				Scenario 9			
			Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)	Approximate Length of Roadway Flooded (ft)			Average Depth of Flooding (in)
			Flooding Depth >6"	Flooding Depth 0"-6"	Flooding Depth -6"-0"		Flooding Depth >6"	Flooding Depth 0"-6"	Flooding Depth -6"-0"	
S Jog Rd	No	21,600	2,100	5,600	4,800	0.51	9,500	6,200	1,200	5.6
S Haverhill Rd	No	12,400	6,400	1,500	1,800	9.13	8,900	2,100	1,700	15.1
Lake Worth Rd	Yes	13,000	6,000	4,400	2,700	6.16	9,800	3,000	700	12.0
Melaleuca Ln	No	8,700	5,100	1,300	1,000	9.54	6,400	1,200	1,100	15.5
S 57th Ave	No	7,700	6,100	1,400	400	14.57	7,200	500	0	20.9
Sherwood Forest Blvd	No	9,300	7,800	1,300	200	12.86	9,100	200	0	19.8
S Military Trl	No	3,200	500	1,300	800	1.35	1,900	1,100	100	7.3
10th Ave N	No	11,900	8,000	2,800	1,600	8.70	10,200	1,700	400	15.3
Bowman St	No	2,600	2,600	0	0	19.21	2,600	0	0	25.2
Cresthaven Blvd	No	2,800	1,800	400	100	8.82	2,700	100	100	16.9
Pinehurst Dr	No	3,100	0	100	600	-0.51	700	900	800	2.5
Purdy Ln	No	1,400	400	100	300	1.53	700	300	200	7.6
Forest Hill Blvd	Yes	3,900	100	200	600	-0.98	800	1,100	500	2.4
Summit Blvd	No	2,100	1,500	400	100	8.33	2,000	100	0	16.7

Roadway Exposure Analysis – Scenario 1



Roadway Exposure Analysis – Scenario 9



Sensitivity Analysis

- Critical Facility Analysis
  - Flood depth is the depth of water above the finished floor elevation or the critical flood elevation of the asset

Critical Facilities Point Values

Exposure Level	Flood Elevation	Point Value
High	>FFE/CFE	3
Medium	0”-12” from FFE/CFE	2
Low	12+” from FFE/CFE	1

Adjusted Point Values for Parks

Exposure Level	Flood Elevation	Point Value
Medium	>FFE/CFE	2
Low	0-6” from FFE/CFE	1

- Roadway Analysis
  - The length of roadway within each exposure category was divided by the approximate total length and multiplied
  - Evacuation routes were multiplied by a factor of 1.5

Major Roadways Point Values

Exposure Level	Flood Depth	Point Value	Evacuation Route Factor
High	>6”	3	x1.5
Medium	>0 and ≤6”	2	
Low	>-6” and ≤0”	1	

Critical Asset Sensitivity Analysis

Asset Name	Total Sensitivity Analysis Score (Out of 27)
City of Greenacres - Fire Department Station 96	26
Greenacres Community Hall	18
City of Greenacres Community Center	18
Greenacres Freedom Park	18
Veterans Memorial Park	18
Burrowing Owl Park	18
Ramblewood Park	18
Heather Estates Park	18
Bowman Park	18
Empire Park	18
Friends Park	18
Ira Van Bullock Park	18
Gladiator Park	18
Oasis Park	18
Rambo Park	18
Greenacres City Hall	17
Samuel J. Ferreri Community Park	16
Greenacres Elementary School	13
Heritage Elementary School	12
Arbor Park	12

Asset Name	Total Sensitivity Analysis Score (Out of 27)
City of Greenacres - Fire Department Headquarters	9
City of Greenacres - Fire Department Station 95	9
City of Greenacres - PBSO Substation	9
State of Florida Department of Health	9
Chloee Lake Elementary	9
Diamond View Elementary	9
Liberty Park Elementary School	9
L. C Swain Middle School	9
Okeeheelee Middle School	9
John I. Leonard High School	9
Tradewinds Middle School	9

Facility Sensitivity Analysis Score Matrix

Exposure Level	Total Sensitivity Analysis Score
High	20+
Medium	11-19
Low	0-10

Roadway Sensitivity Analysis

Roadways	Evacuation Route	Overall Sensitivity Analysis Score
Lake Worth Rd	Yes	35.1
Bowman St	No	27.0
Sherwood Forest Blvd	No	26.5
S 57th Ave	No	26.3
Summit Blvd	No	25.4
Cresthaven Blvd	No	25.0
10th Ave N	No	25.0
Melaleuca Ln	No	22.4
S Haverhill Rd	No	21.8
S Military Trl	No	19.4
Purdy Ln	No	15.8
S Jog Rd	No	14.5
Forest Hill Blvd	Yes	11.6
Pinehurst Dr	No	8.3

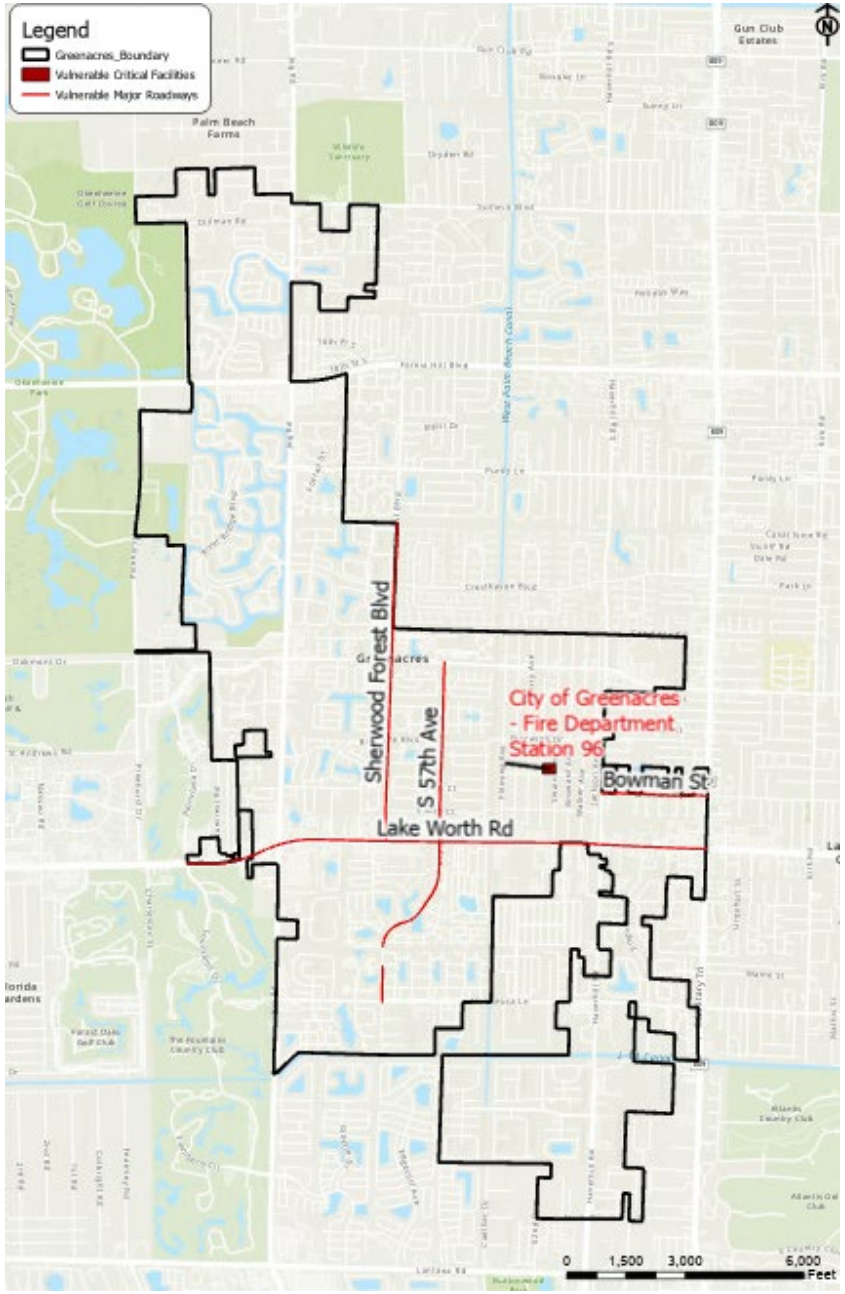
Roadway Sensitivity Analysis Score Matrix

Exposure Level	Total Sensitivity Analysis Score
High	31+
Medium	21-30
Low	0-20

Summary of Results for Greenacres

- Critical assets identified as vulnerable to flooding:
  1. **Fire Station 96**

- Major roadways most vulnerable to flooding:
  1. **Lake Worth Rd. / State Road 802**
  2. **Bowman St.**
  3. **Sherwood Forest**
  4. **S 57th Ave**



Summary of Useful GIS Tools

- Zonal Statistics as Table (Spatial Analyst)
  - Used to approximate FFE, CFE and flood elevations
- Generate Points along Line (Data Management)
  - Used to convert roadway centerlines into points separated by a specific distance
- Extract Multi Values to Points (Spatial Analyst)
  - Used to create a new column with raster data at a roadway point
- Resample (Data Management)
  - Used to resample raster cell sizes to effectively capture the zonal statistics for each critical asset
- Extract by Mask (Spatial Analyst)
  - Used to remove water bodies from the DEM when approximating FFE and CFE
- Pairwise Clip
  - Used to clip a large dataset to the municipality boundary
- Pairwise Buffer
  - Used to create a buffer around the municipality boundary

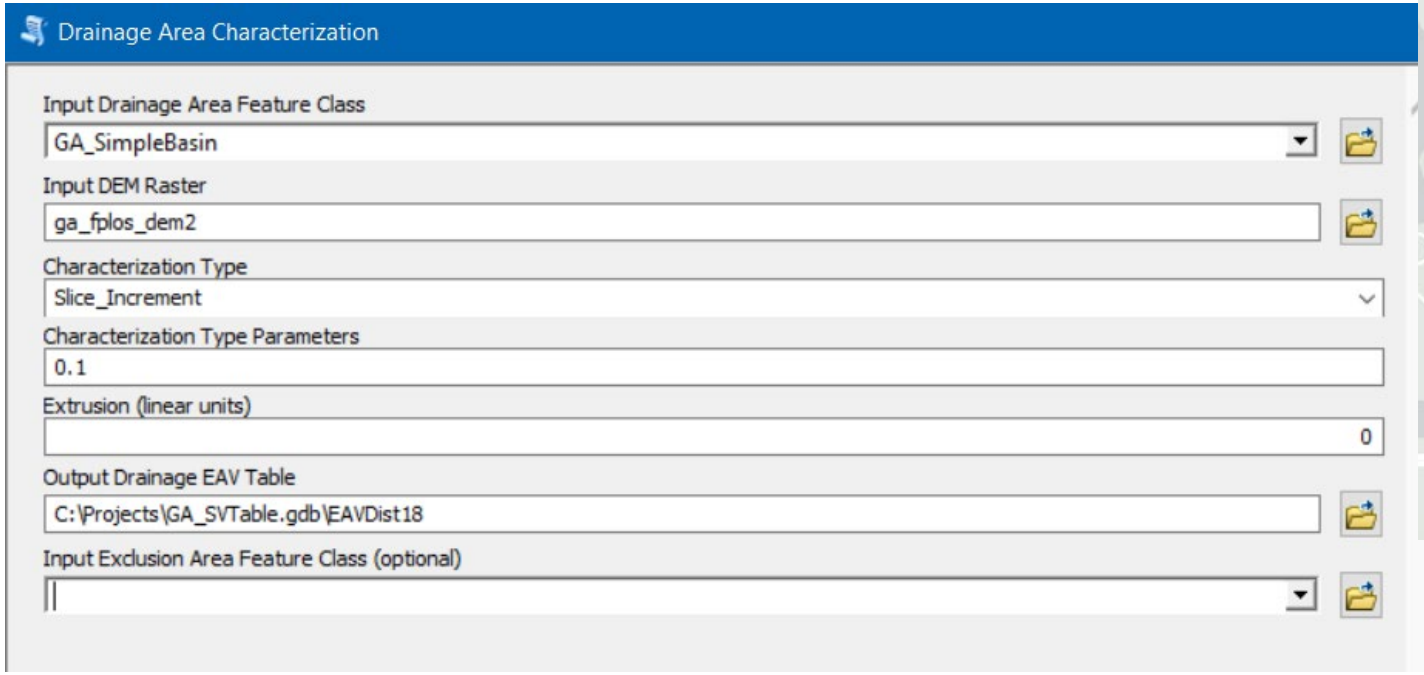
ArcGIS Pro Advanced License needed with ESRI 3D analyst extension

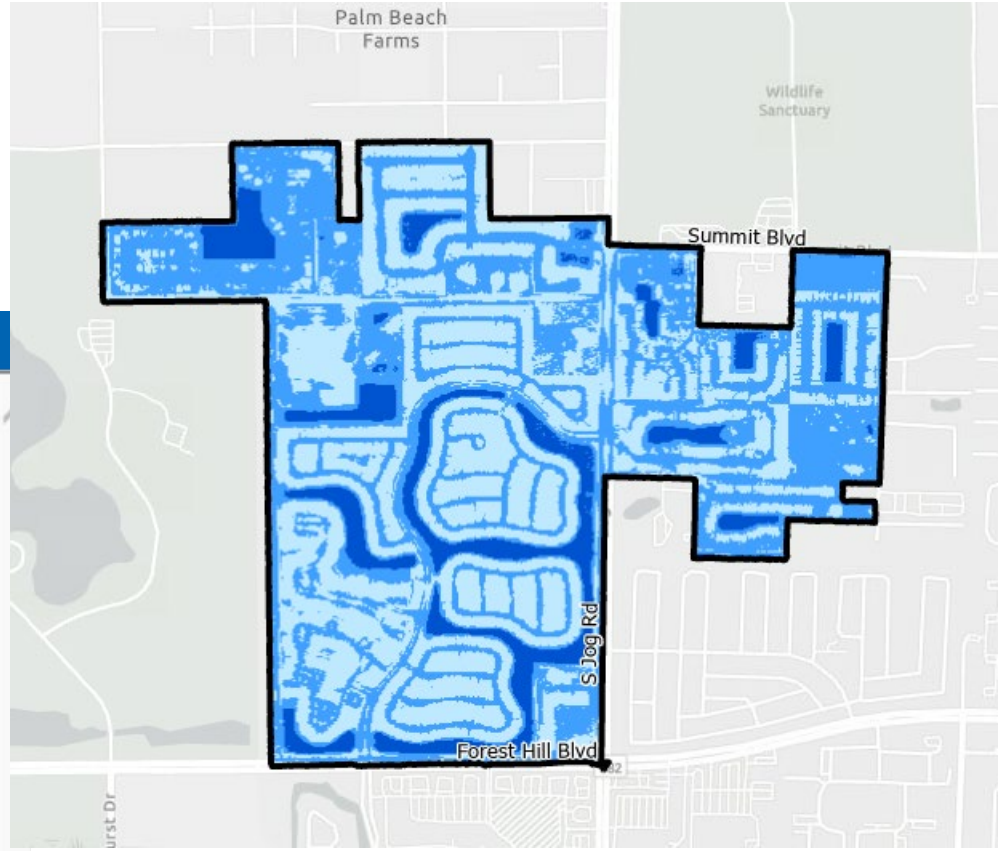
Summary of Useful GIS Tools

Storage within each Subbasin

- ArcHydro Drainage Area Characterization Tool
  - Used to calculate the volume of water stored at a given elevation within a subbasin

ArcHydro Toolbox within ArcGIS is Required

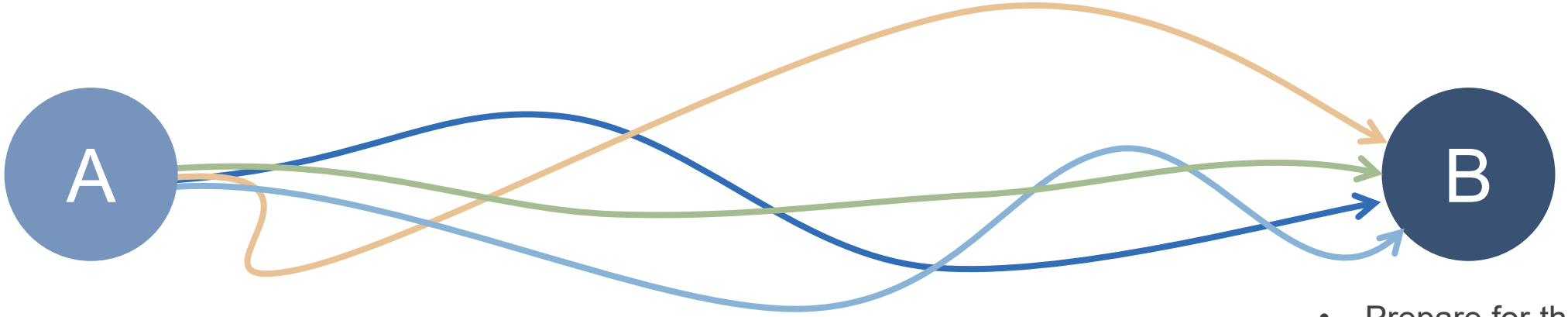




Questions/Discussion

4– Lessons Learned/Key Takeaways

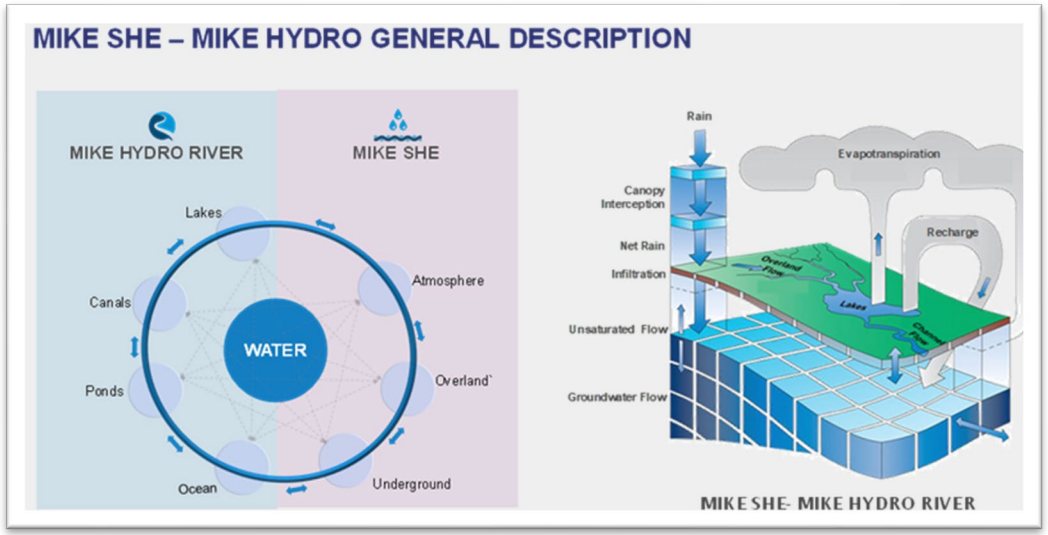
The State has laid out clear goals for resilience planning and vulnerability assessment



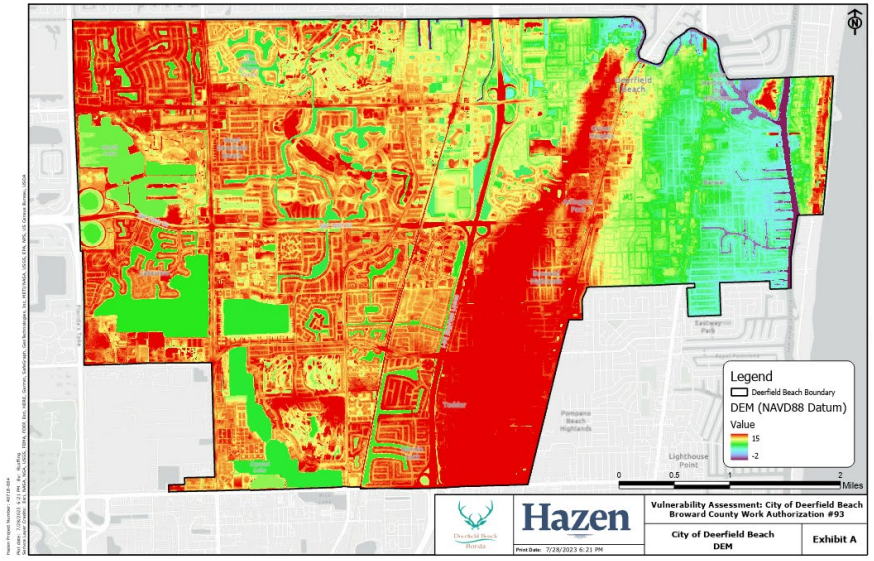
- Prepare for threats
- Critical assets
- Planning horizons

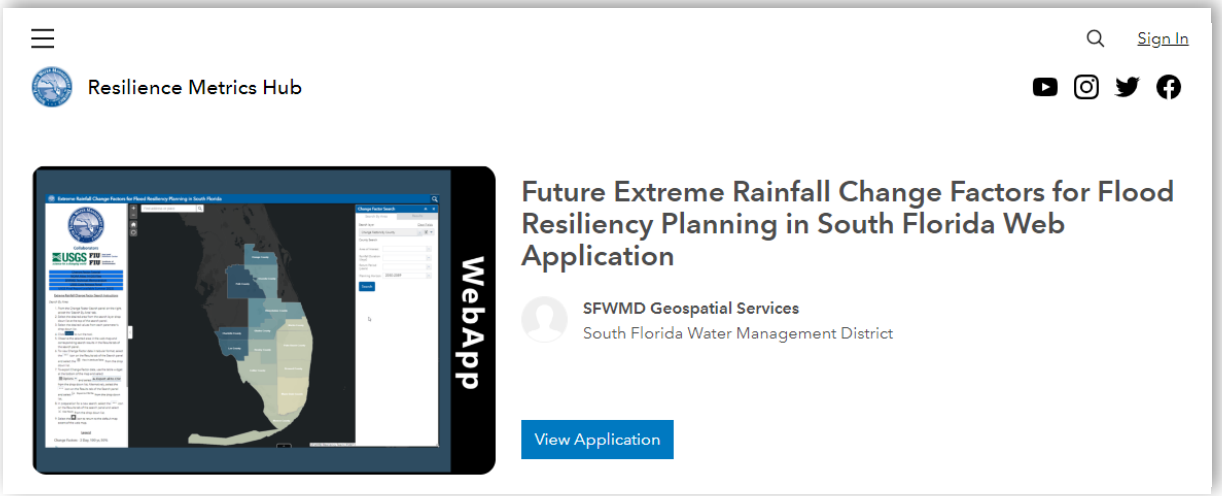
…but with different paths to get there

Regardless of the path, the tools to get there are available



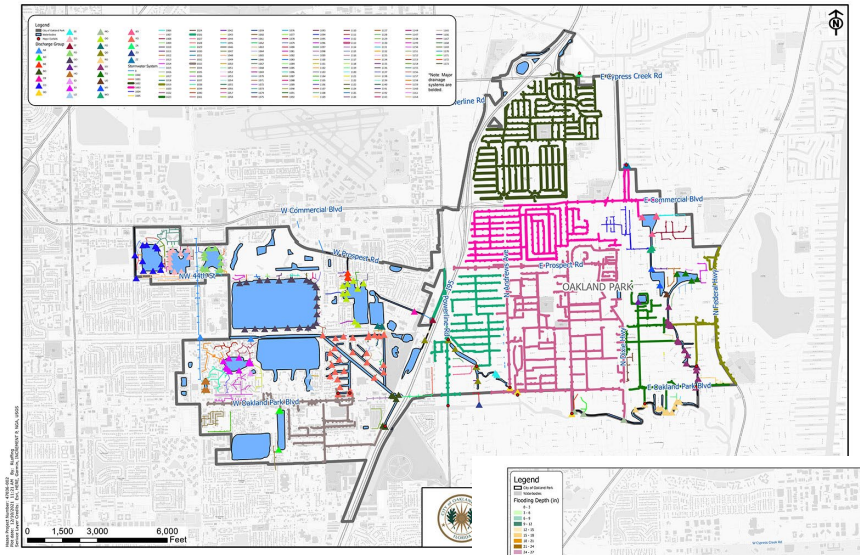
ArcGIS

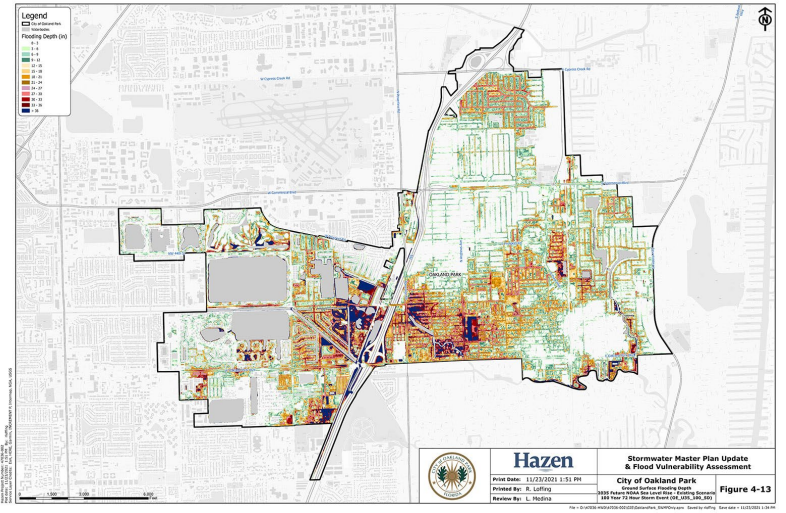




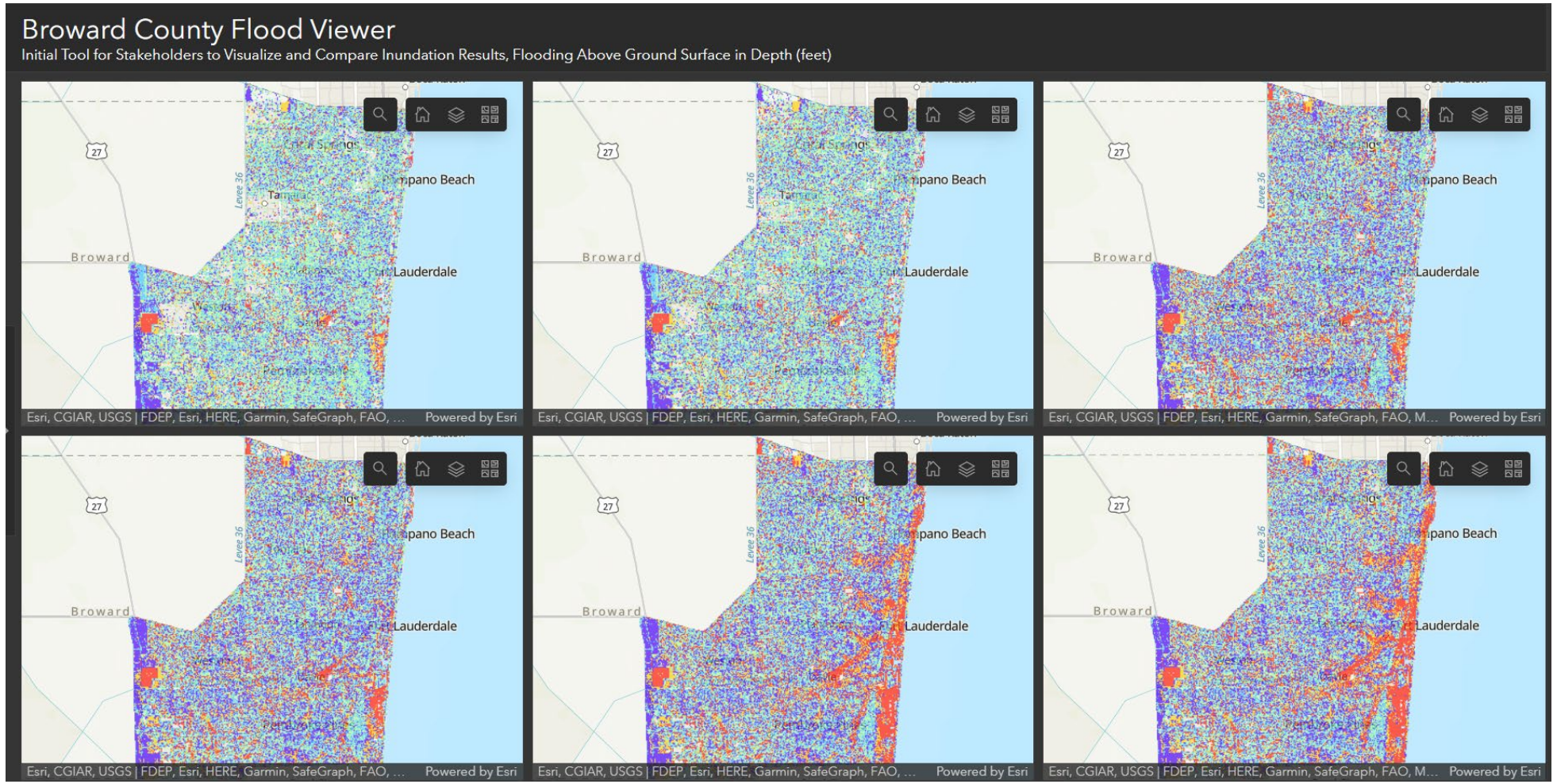
The path and necessary tools may depend on the community's broader goals

- Screening tool for critical asset exposure
- Broader resilience and stormwater management planning
- Design/development of adaptation strategies



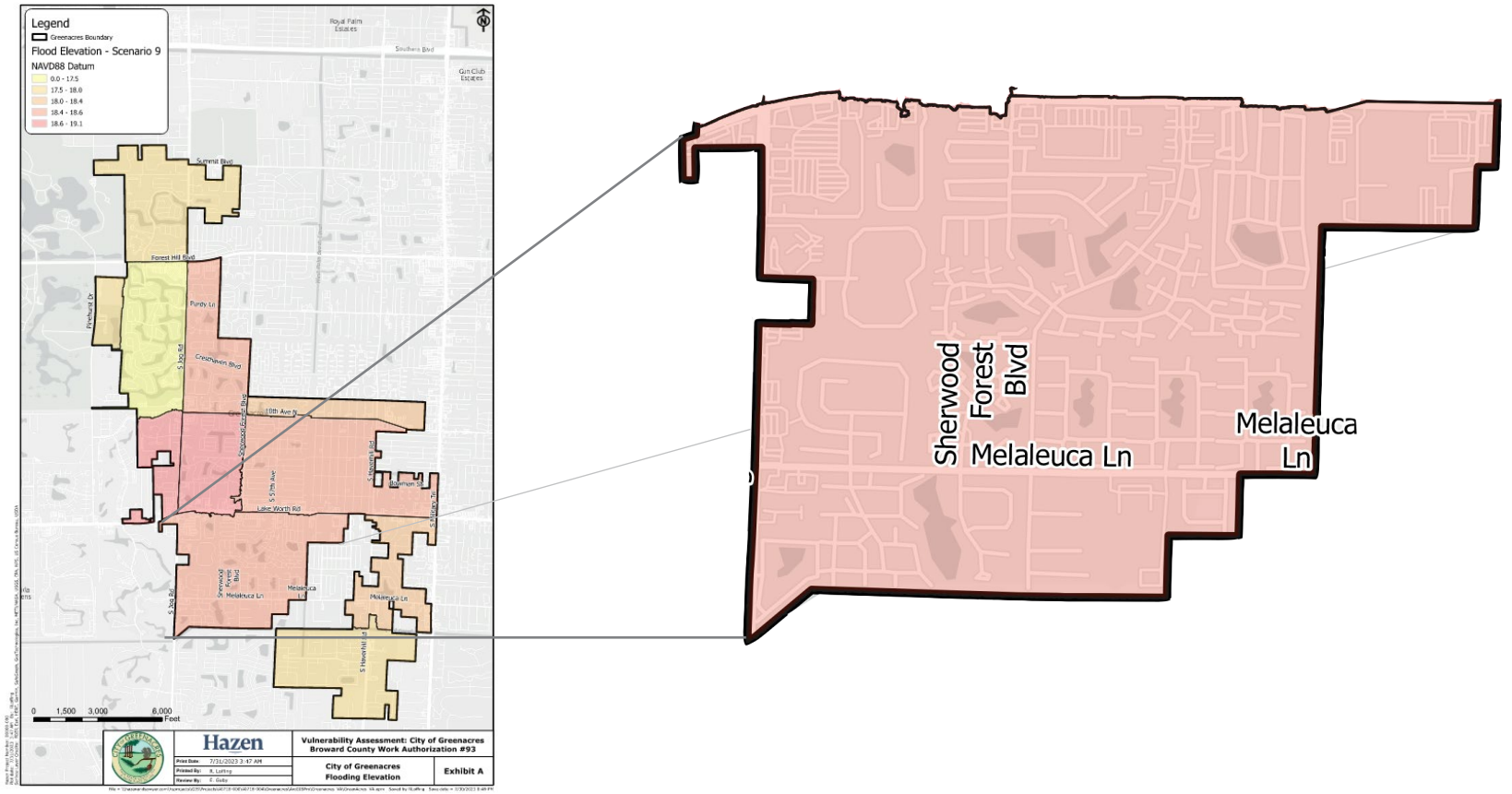


For many communities, very robust tools for exposure analysis are already in place



For others, the simplified methods demonstrated today (or similar) can be used by almost any community

- The data and tools are readily available from public websites and sources
- The equations and techniques used are common amongst engineers and scientists working in the areas of hydrology and /or stormwater management



$$S = \frac{1000}{CN} - 10$$

$$Pe = \frac{(P - Ia)^2}{P - Ia + S}$$

Key Takeaways

VA's don't have to be "perfect", just serve the purpose of ranking the exposure and sensitivity of critical assets.

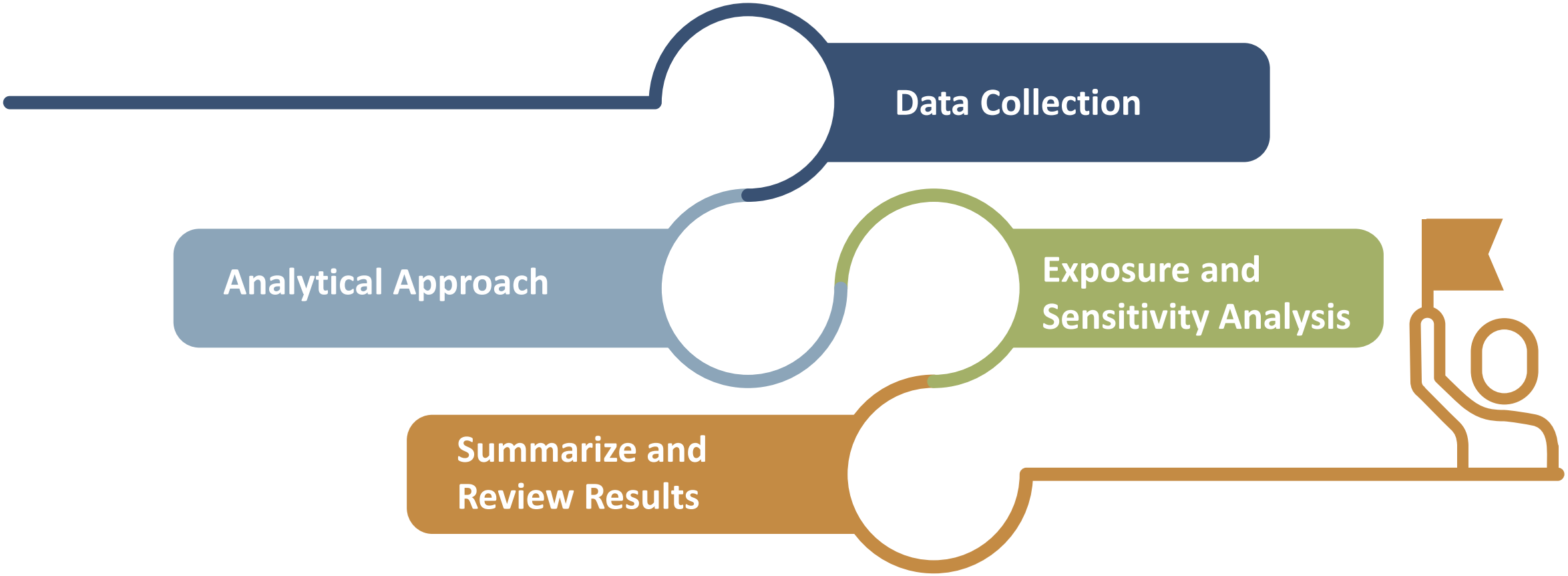
Understand what the broader goals may be, and choose the approach/tools accordingly.

Understand the limitations of the simplified model.

- Is the community flooding impacted by the regional system?
- Understand the spatial nuances of the simplified model.

Compare simplified model results to adjacent “regional system” modeling results, where possible.

It's time to get started!



Questions?

Hazen

FDEP Resilient Florida Program Open House Dates

Pensacola
Day/time: Monday, August 7, 12:00 – 3:00 PM, CDT
Location: DEP Northwest District Office; 502 Conference Room, 160 W. Government Street, Suite 502, Pensacola, FL 32502

Orlando
Day/time: Monday, August 7, 1:00 – 4:00 PM, EDT
Location: DEP Central District Office, 3319 Maguire Boulevard, Orlando, FL 32803

Tallahassee
Day/time: Tuesday, August 8, 9:00 AM – 12:00 PM EDT
Location: Marjory Stoneman Douglas Building, Room 137, 3900 Commonwealth Blvd., Tallahassee, FL 32399

Temple Terrace
Day/time: Tuesday, August 8, 1:00 – 4:00 PM, EDT
Location: DEP Southwest District Office; Main Conference Room, 13051 N. Telecom Parkway, Suite 101, Temple Terrace, FL 33637

Fort Myers
Day/time: Wednesday, August 9, 1:00 – 4:00 PM, EDT
Location: DEP South District Office, 2295 Victoria Avenue, Suite 364, Fort Myers, FL 33901

Jacksonville
Day/time: Thursday, August 10, 1:00 – 4:00 PM, EDT
Location: DEP Northeast District Office, 8800 Baymeadows Way West, Suite 100, Jacksonville, FL 32256

West Palm Beach
Day/time: Thursday, August 10, 1:00 – 4:00 PM, EDT
Location: DEP Southeast District Office, 3301 Gun Club Rd, MSC 7210-1, West Palm Beach, FL 33406

Hazen