REEVALUATING FLOOD PROTECTION LEVEL OF SERVICE

FLORIDA STORMWATER ASSOCIATION
2022 ANNUAL CONFERENCE

Akintunde Owosina P.E.
Chief, Hydrology and Hydraulics Bureau
South Florida Water Management District

Michael J. DelCharco, P.E., CFM
Taylor Engineering
Sr. Vice President of Water Resources

Matahel Ansar Ph.D., P.E.
Chief, Hydrology and Hydraulics Bureau
South Florida Water Management District

FLOOD PROTECTION LEVEL OF SERVICE PROGRAM

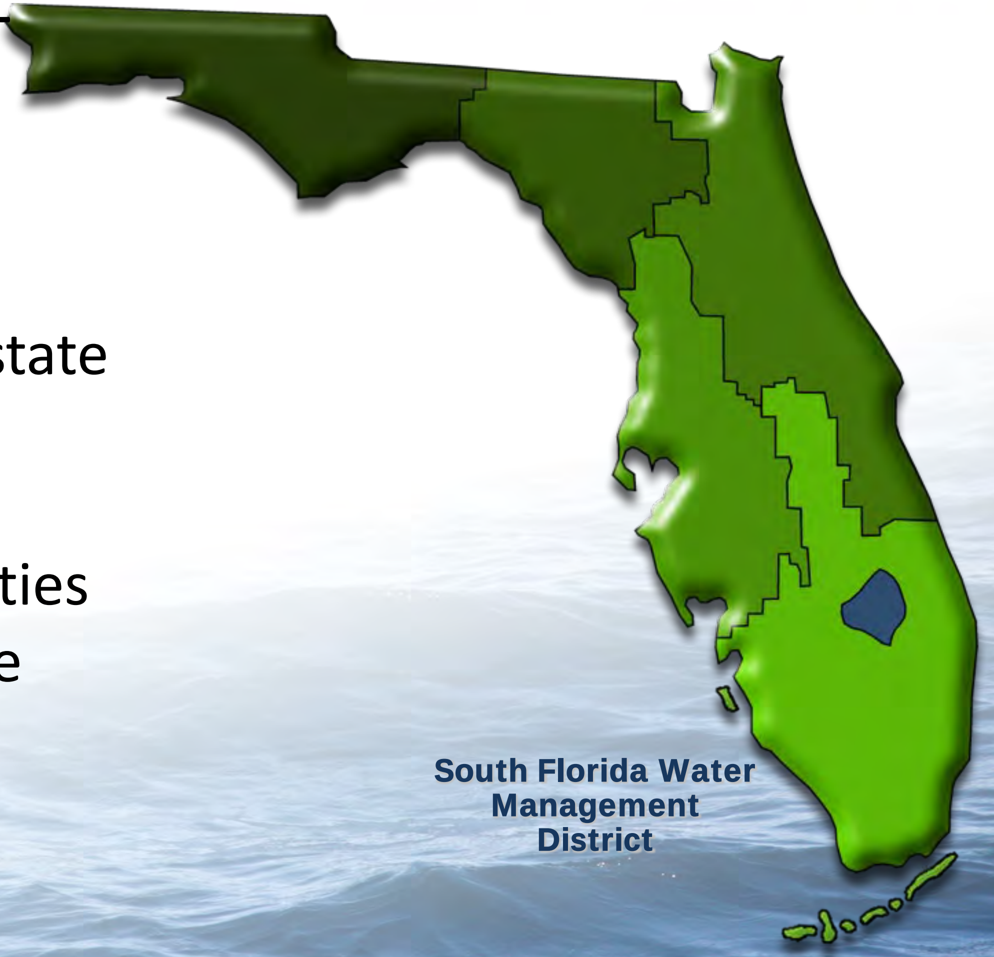
A KEY TO FLOOD RESILIENCY IN SOUTH FLORIDA

Akintunde Owosina P.E.
Chief, Hydrology and Hydraulics Bureau
South Florida Water Management District

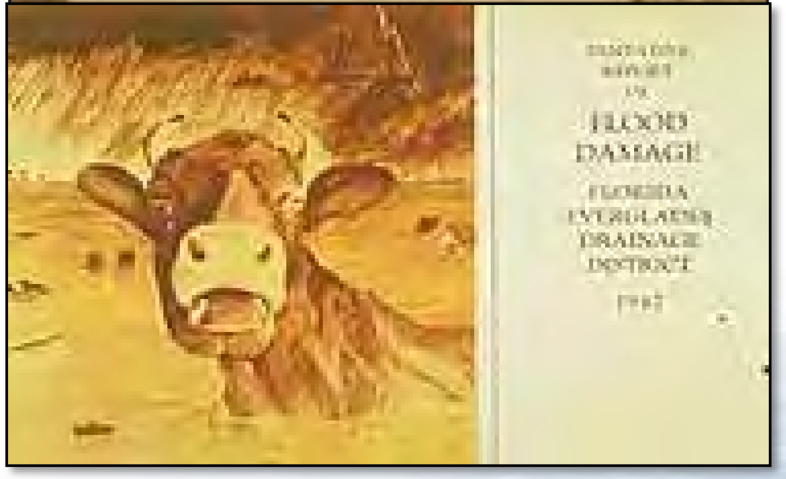
SFWMD - Who we are and what we do

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

- Oldest and largest of the state's five regional water management districts
- Protecting water resources in the southern half of the state since 1949
- Our mission: To safeguard and restore South Florida's water resources and ecosystems, protect our communities from **flooding**, and meet the region's water needs while connecting with the public and stakeholders



FLOOD CONTROL: Central & Southern Florida Project

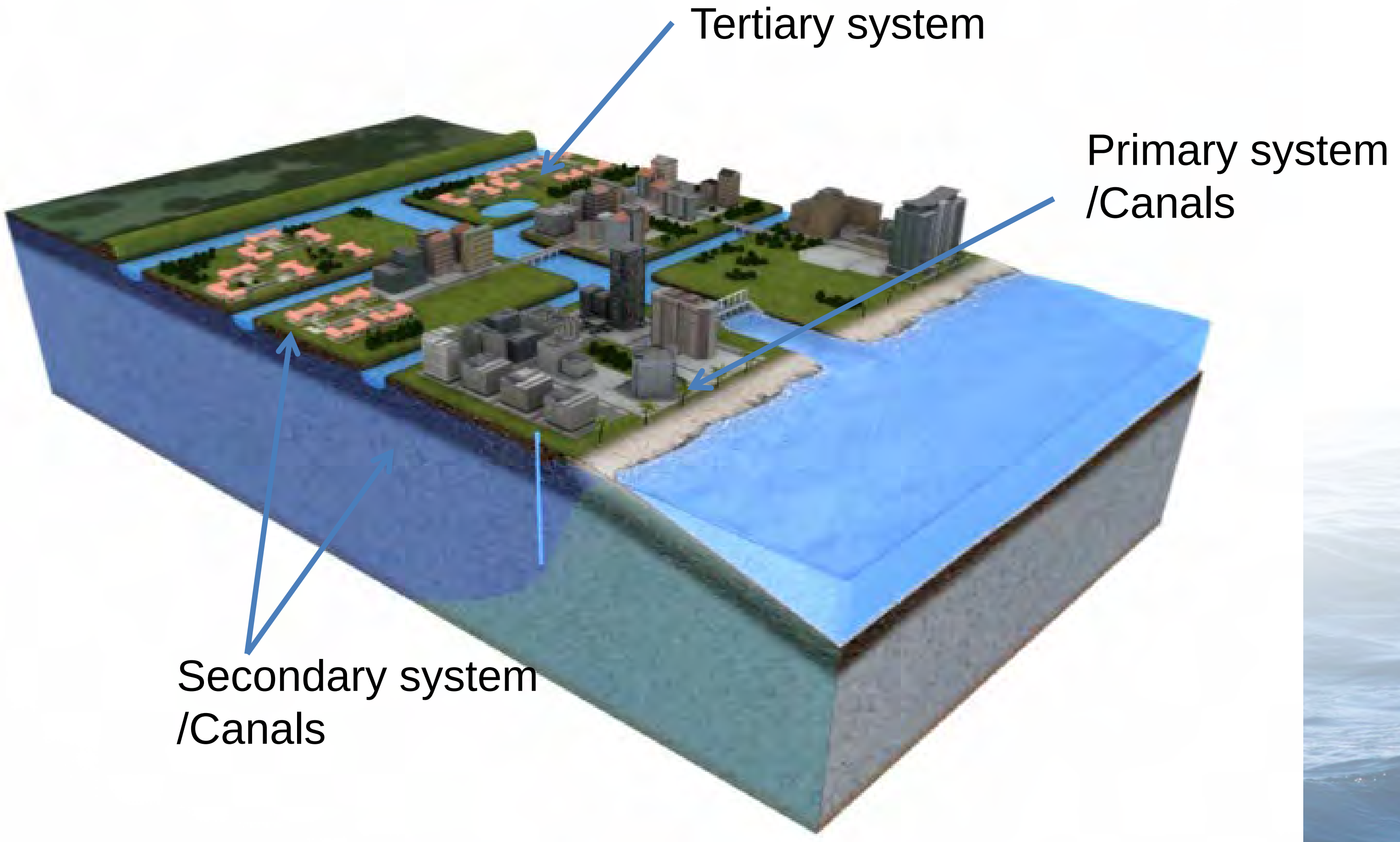


Water Management System

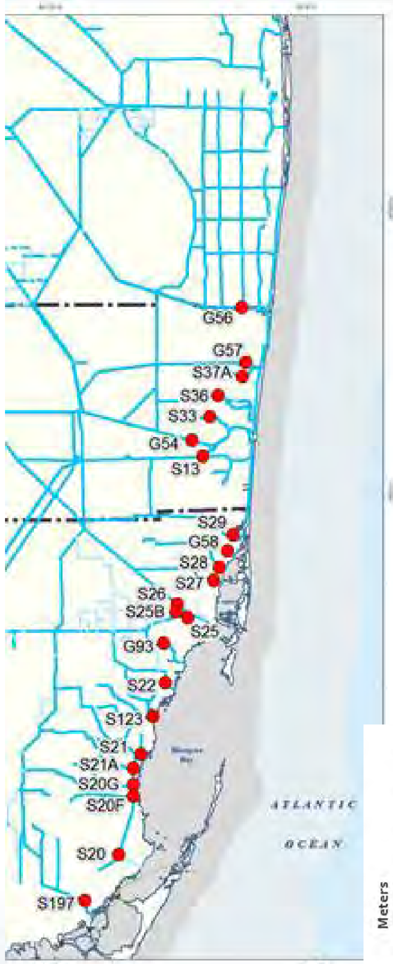
- 2,060 miles of canals
- 2,028 miles of levees
- 160 major drainage basins
- 1,413 water control **structures**
- 71 pumping stations
- 60,000 acres of regional wetland Stormwater Treatment Areas
- Lake Okeechobee
  - 450,000 acre water storage area
- Water Conservation Areas
  - 959,000 acre water storage

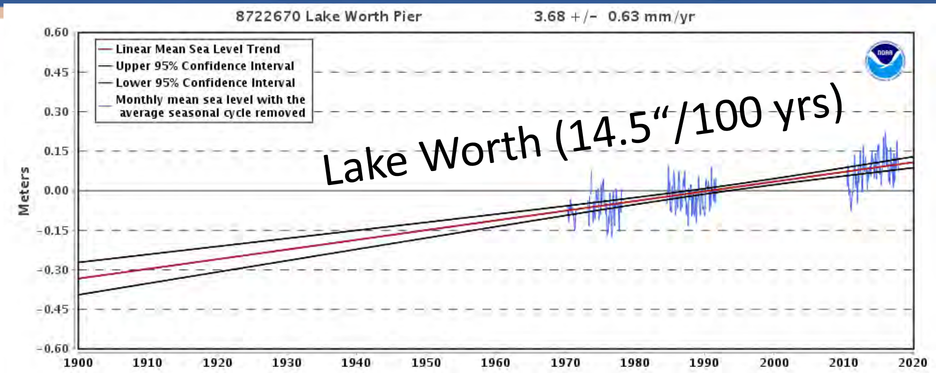
Flood Protection Responsibility

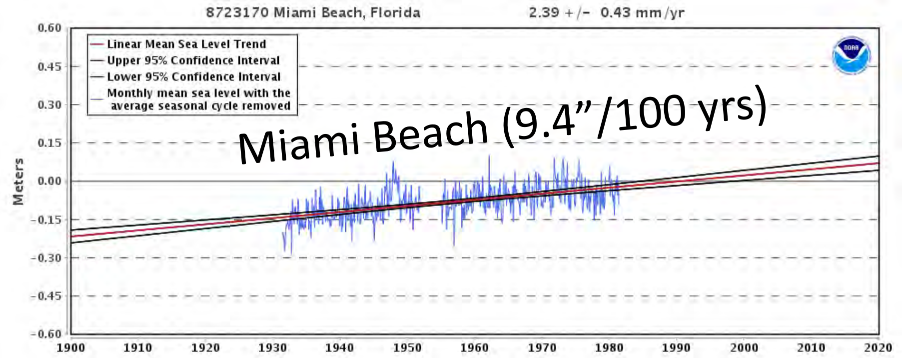
- Primary
  - **USACE**
  - **SFWMD**
- Secondary
  - Local Governments
  - Special Districts
- Tertiary
  - Home Owners Associations
  - Private Land Owners

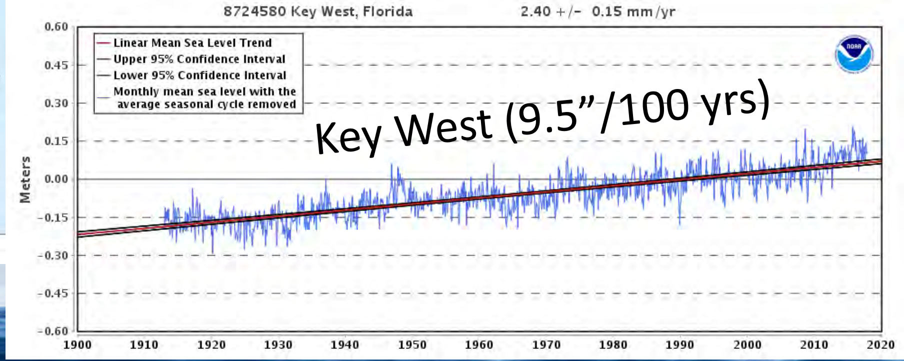


Sea Level Rise Trends in South Florida (NOAA)



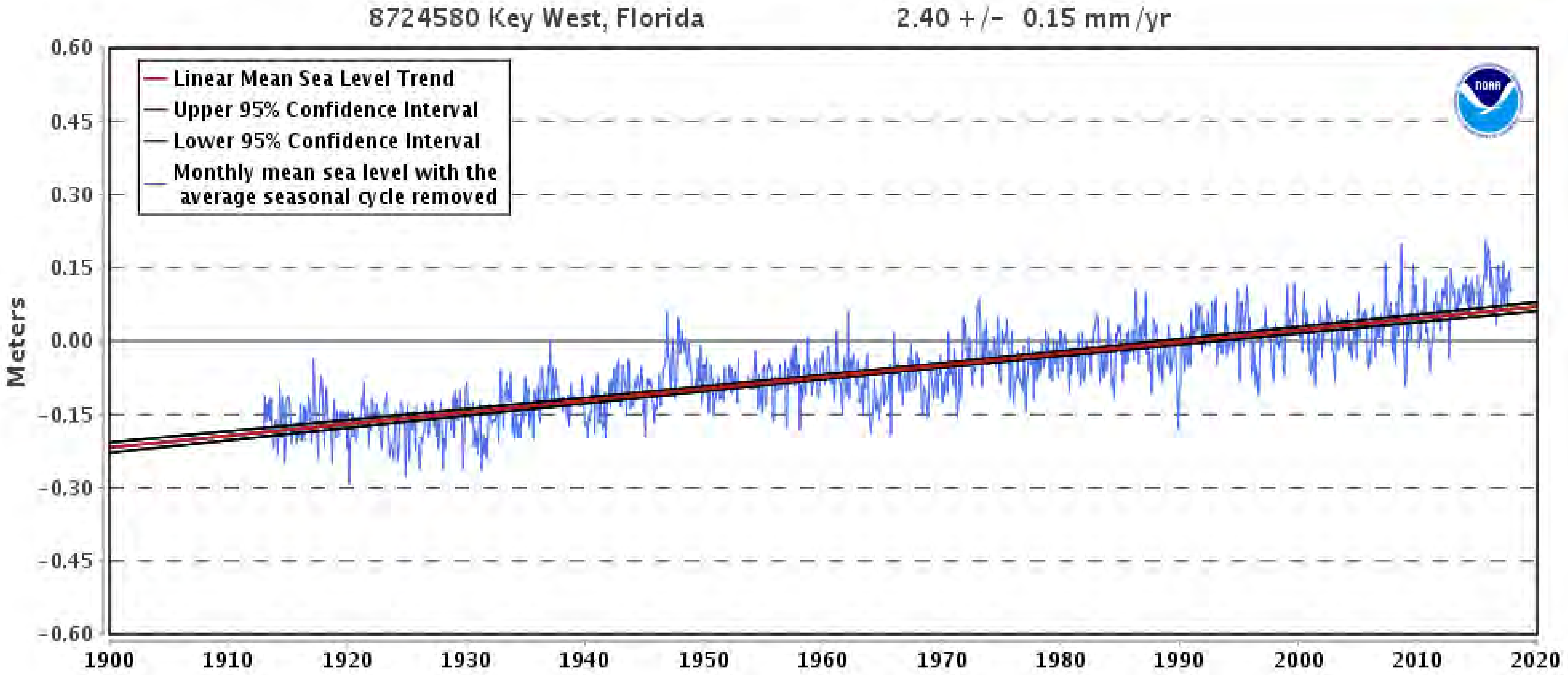






Linear Mean Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed

Sea Level Rise Trends in South Florida (NOAA)



EFFECT OF HIGH TAILWATER CONDITION

Learn more about how sea level rise and other climate change impacts are affecting water resources management and flood protection in South Florida:

https://vimeo.com/416090381/a11cead328

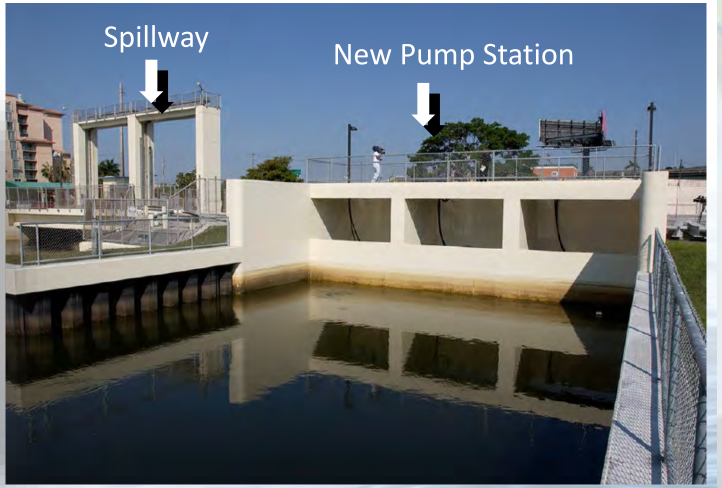
… The Manager's Question …

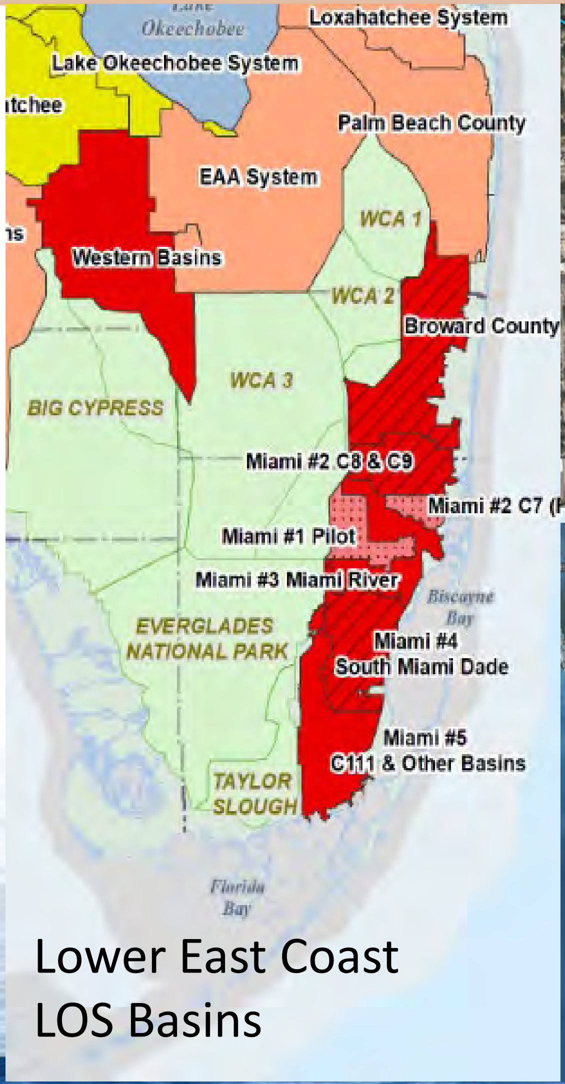
We have the aging infrastructure approaching or past design end of life:

- Do I replace them and if so When do I replace them ?
- What do I replace them with ?
  - In kind - same as it was? or
  - Different to accommodate known changes since design and projected changes?
- Where and how ?
  - What goes first, what happens next?
  - What happens downstream of our current assets?
- What liability or risk am I exposed to – due to action or inaction
- Who pays for the fix ?
- What assurances do I have ? (responsibility to manage public funds) considering high uncertainty

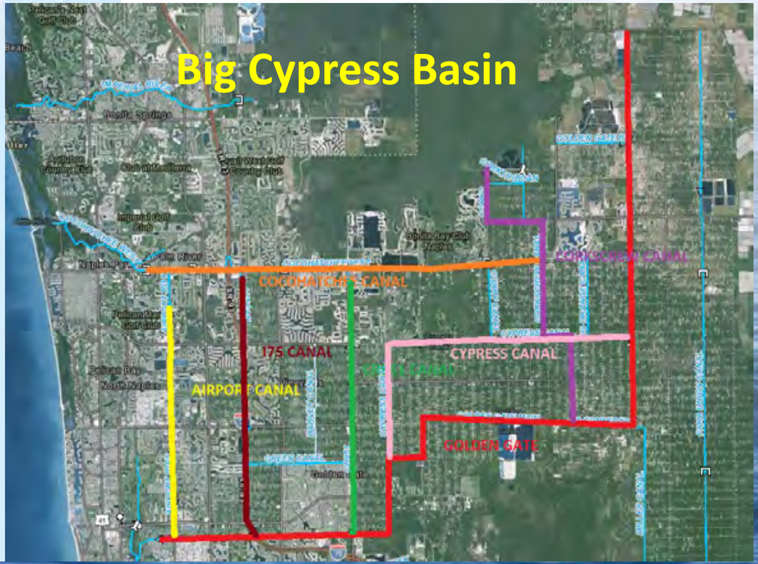
Flood Protection Response

- **Flood Protection Level of Service program:**
  - Assess flood protection performance of flood control infrastructure
  - Support decision making on prioritizing improvements and adaptation



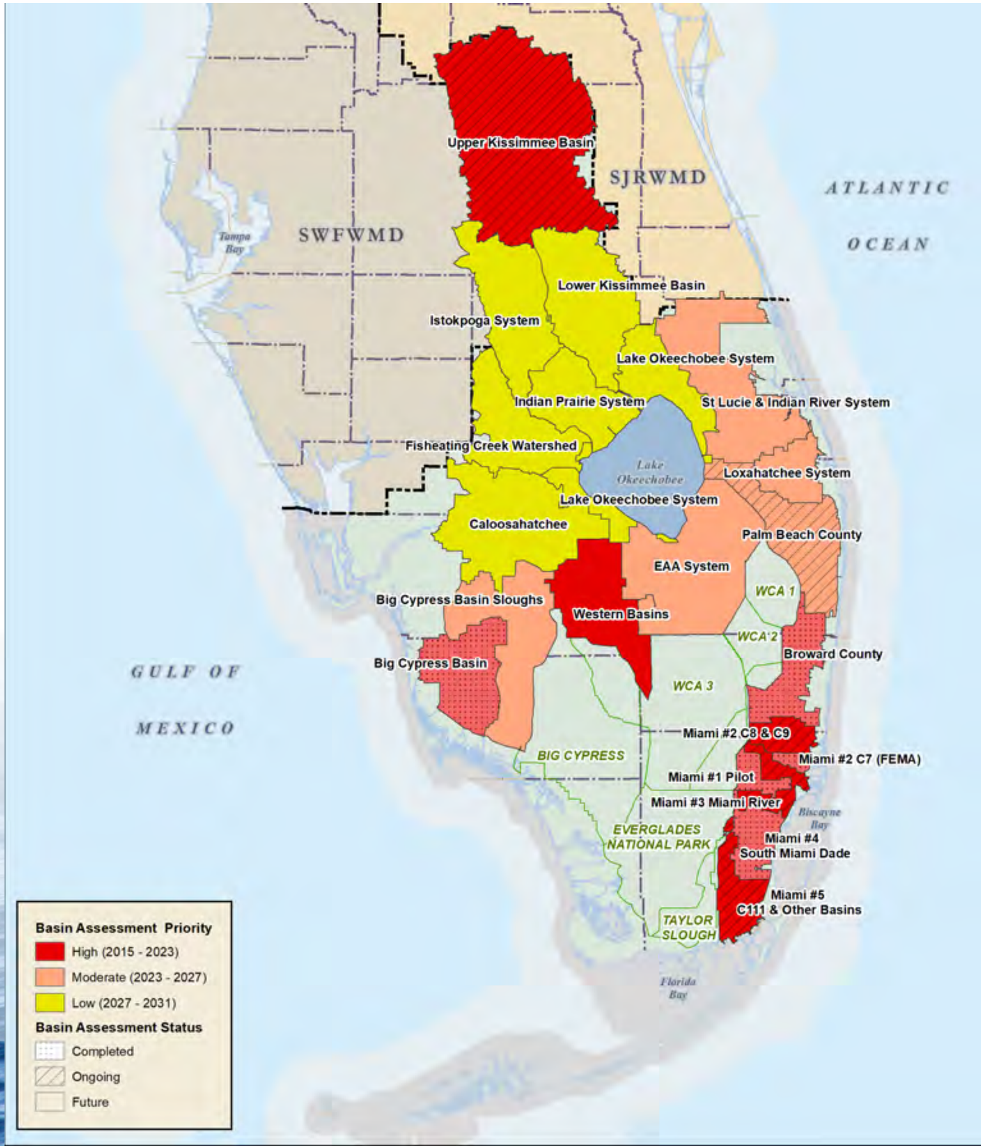


Lower East Coast LOS Basins



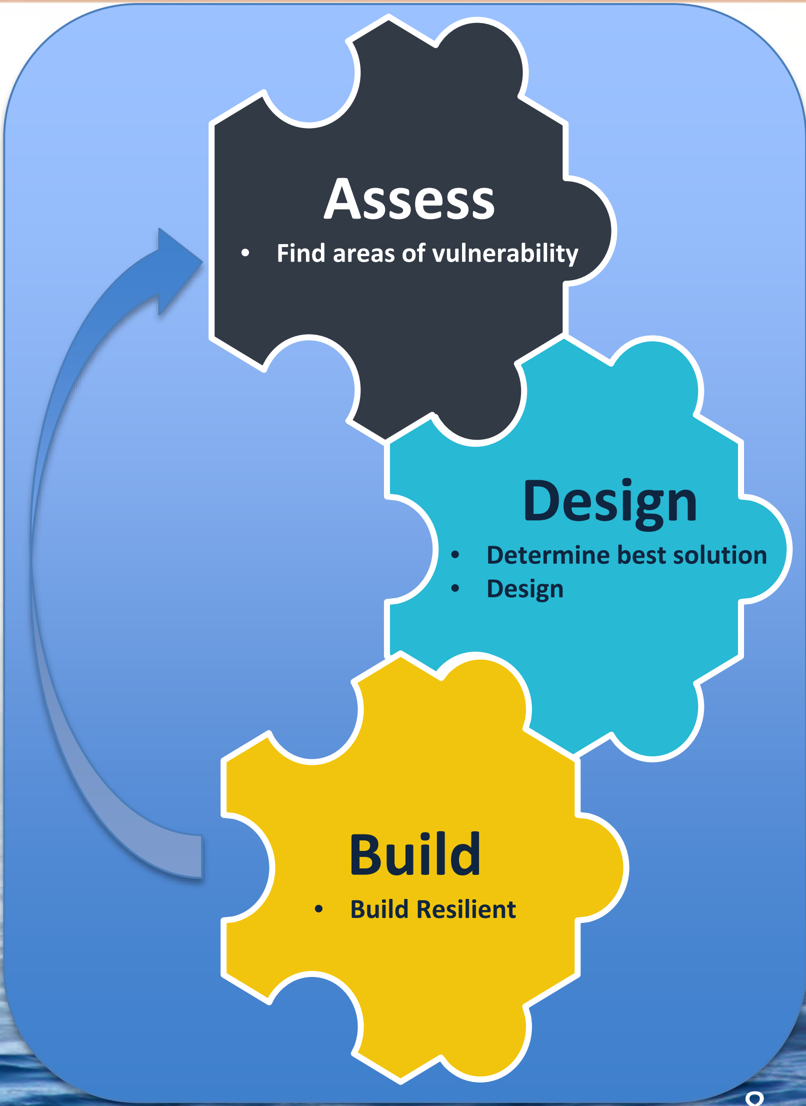
Flood Protection Level of Service Program

- ➢ Identify and prioritize long-term District infrastructure needs.
- ➢ Assess level flood protection throughout the 16-counties of the SFWMD – relative to design
- ➢ Identify at-risk structures and needed improvements to operations, canal conveyance or structures
- ➢ Provide a formal process to initiate retrofit and adaptation efforts for future infrastructure improvements and/or modification of regulatory criteria
- ➢ Incorporate resilient design standards and construction
- ➢ Coordinated with SFWMD Operations, local government entities, drainage districts and other agencies with flood control or related responsibility

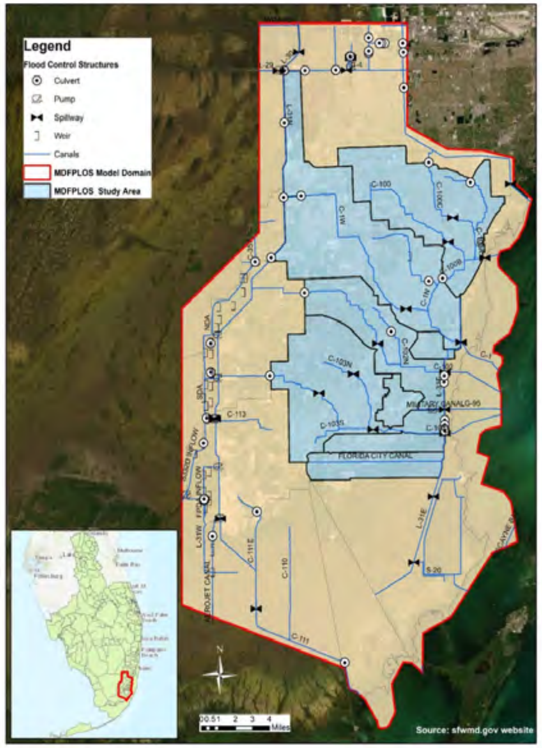


Three Phases of the FPLOS Program

- FPLOS Assessment:
  - Identify location of potential challenge
  - Identify time horizon of potential challenge
  - Prioritize watersheds for detailed resilience studies
- FPLOS Resilience Study and Adaptation Design
  - Based on findings of assessment
  - Detailed study focused on identifying most cost effective adaptation
  - Involves solution search in all three tiers
  - Identification of uncertainties and time horizon for implementation
  - Culminate with preliminary design sufficient for cost development
- Resilient Infrastructure Implementation
  - Include the recommendations in SFWMD Flood Resiliency Plan
  - Final design, permitting and construction of sequenced adaptation

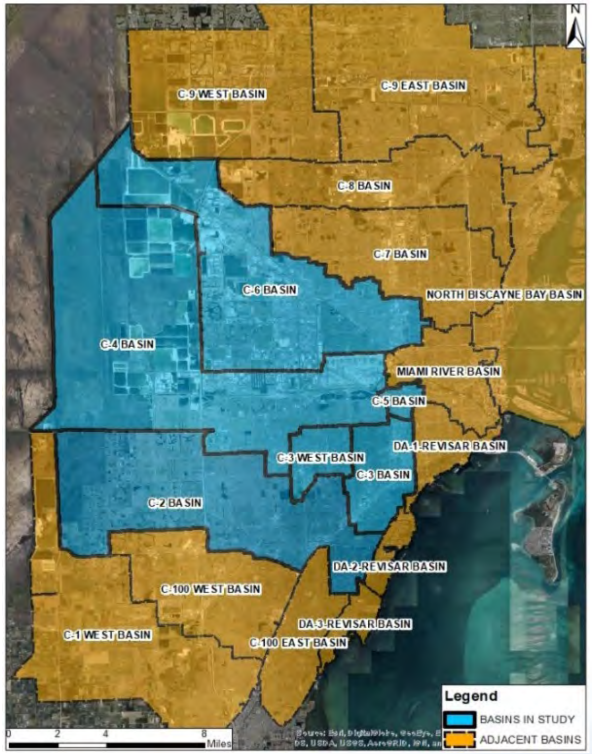


Ongoing and Recently Complete Studies



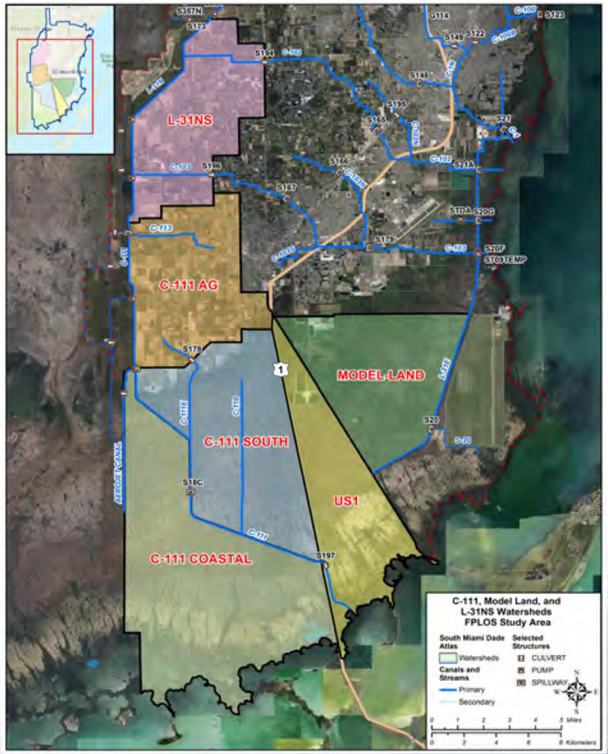
FPLOS for C-1, C-100, C102, and C-103 Watersheds

Completion: May, 2022



C2, C3W, C5 and C6 Watersheds

Completion date: September 2022



C-111, Model Land, and L-31NS Watersheds

Completion date: September 2022

Completed Assessments

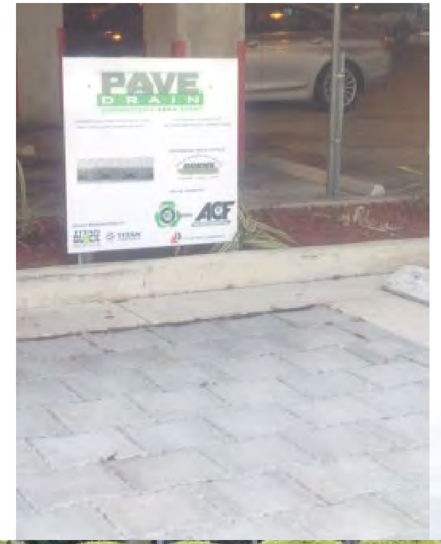
- C4 Basin
- Big Cypress Basin
- C7 Basin
- C8/C9 Basins
- Broward County

New Starts this year:

- Upper Kissimmee Basin
- Palm Beach County

Activities Completed in a Typical FPLOS Adaptation and Mitigation Planning and Design

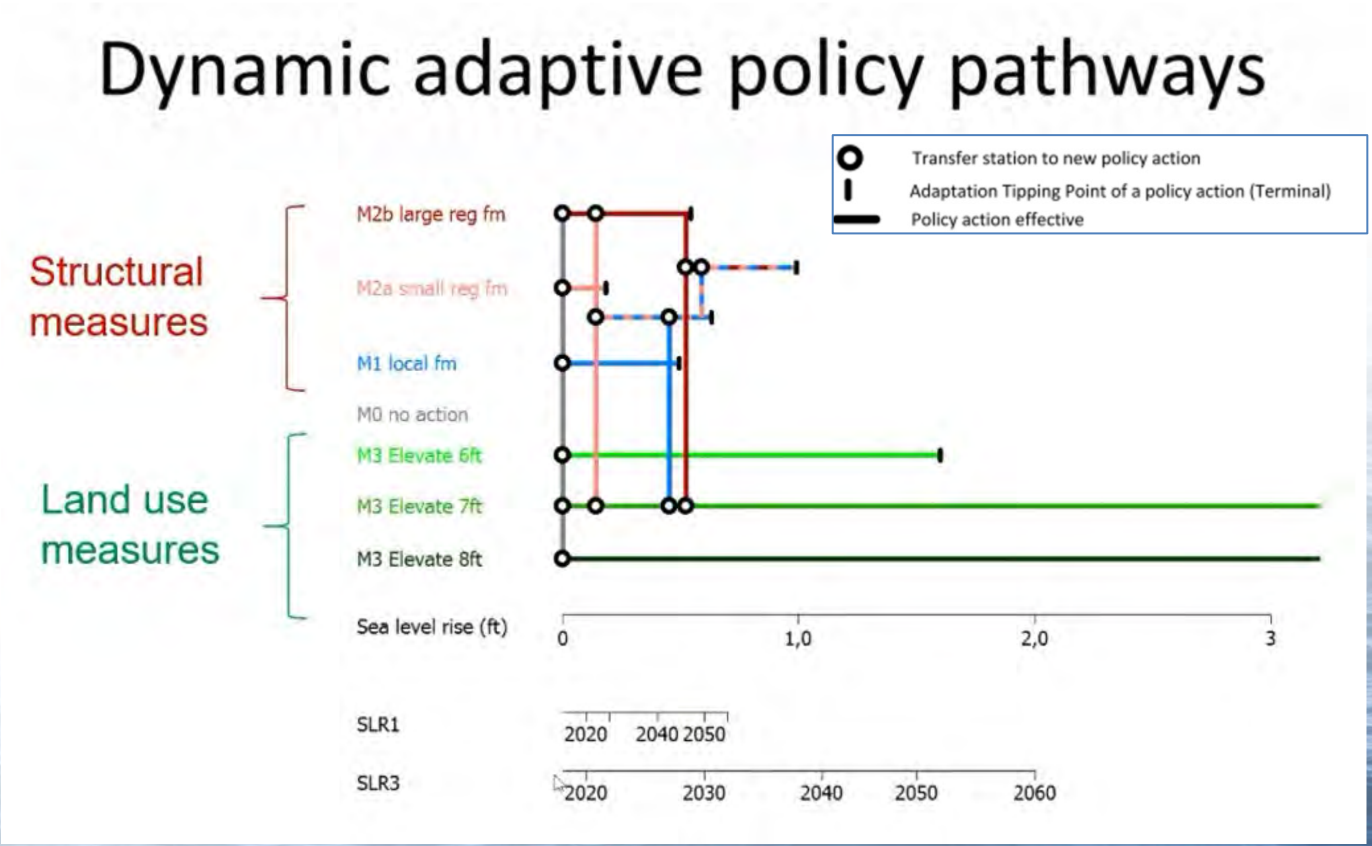
- Plan for future extreme rainfall, SLR and development
- Focus on full system, primary, secondary and tertiary
- Public planning process that integrates input and strategies in all three tiers
- Mitigation and adaptation strategies in all tiers
- Hydraulic and hydrologic model of the strategies
- Damage assessment without adaptation and with each identified strategy or combination of strategies
- Sequencing and combination of courses of action
- Selection of optimal course of action
- Basis of design level evaluation of selected plan



Activities Completed in a Typical FPLOS Adaptation and Mitigation Planning and Design

Supporting Decision Making Under Deep Uncertainty

- Infrastructure cost is high, so is the cost of doing nothing
- There is significant uncertainty
- How to make informed decisions that do not preclude other courses of action
- The difference between a good plan and an implemented plan



Free Book

Some of our Challenges

- Working in an environment with deep uncertainty
  - Future climate scenarios – including rainfall
  - Rate of sea level rise
  - Appropriate initial groundwater levels or antecedent conditions
  - Storm Surge projection at our coastal structures
  - Compound events (rainfall, storm surge and groundwater levels)
- Project funding
- Facilitating decision making

TAYLOR ENGINEERING, INC.

Flood Protection Level of Service Provided by Existing Infrastructure for Current and Future Sea Level Conditions in Nine Broward County Watersheds

Presentation of Major Findings, Current and Future Conditions

8/17/2021

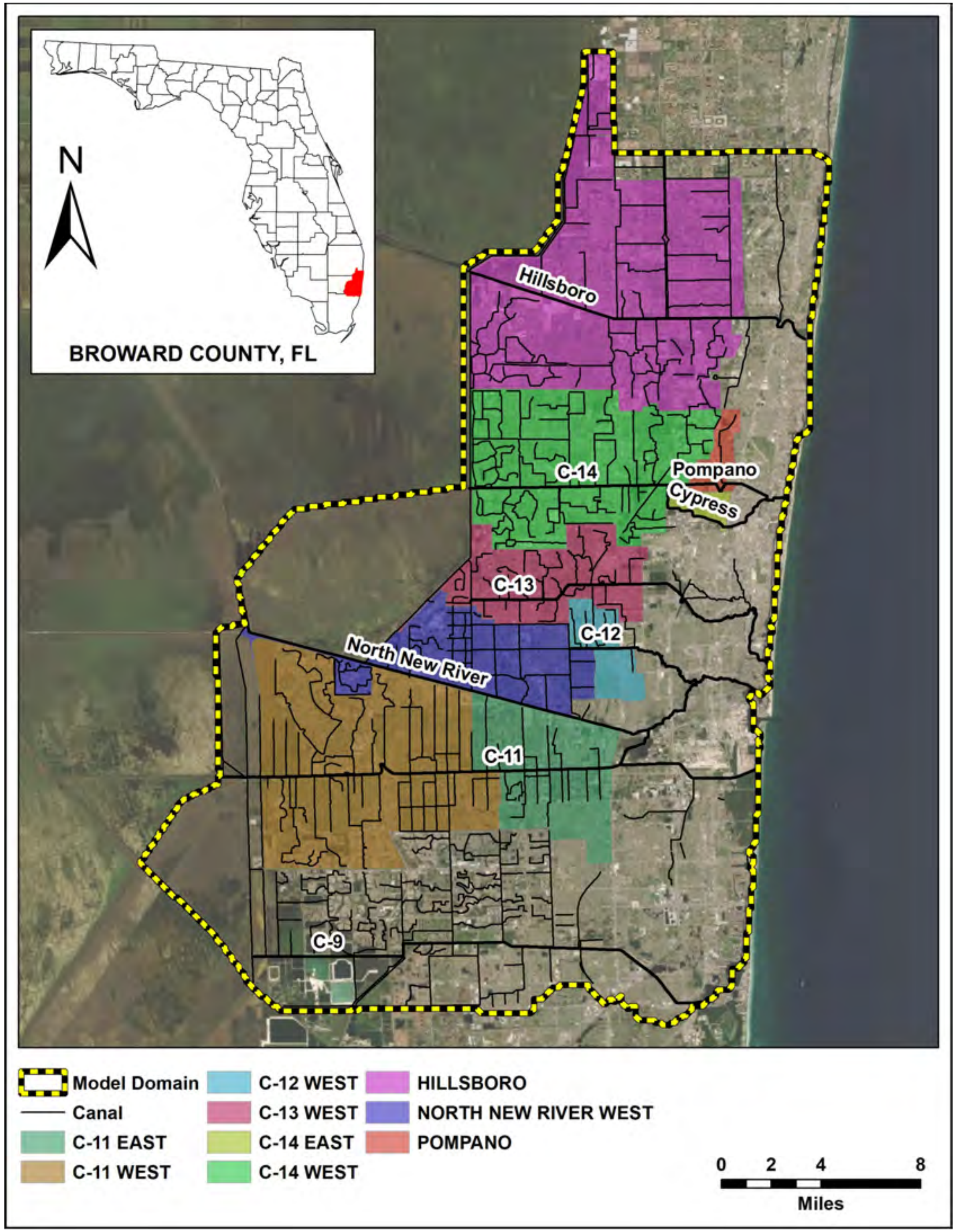
Michael J. DelCharco, P.E., CFM
Taylor Engineering
Sr. Vice President of Water Resources

Overview

- Current Conditions Model Development and Calibration
- Future Conditions Design Storms Setup
- FPLOS Assessments of all Nine Watersheds
- Potential Mitigation Strategies

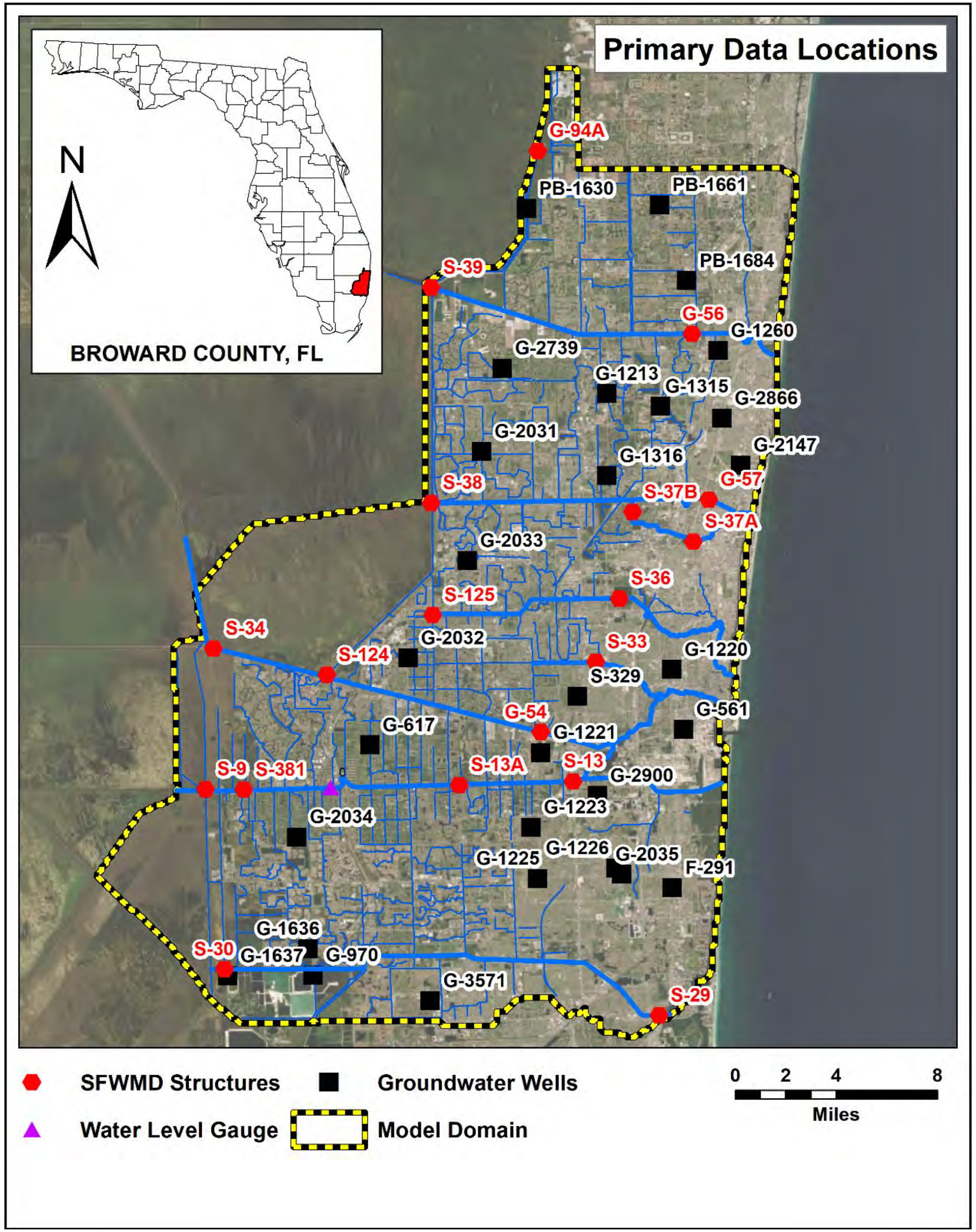
Nine Watersheds Represented in MIKE SHE and MIKE HYDRO

- Hillsboro
- C-14 West
- C-14 East
- Pompano
- C-13 West
- C-12 West
- North New River West
- C-11 West
- C-11 East



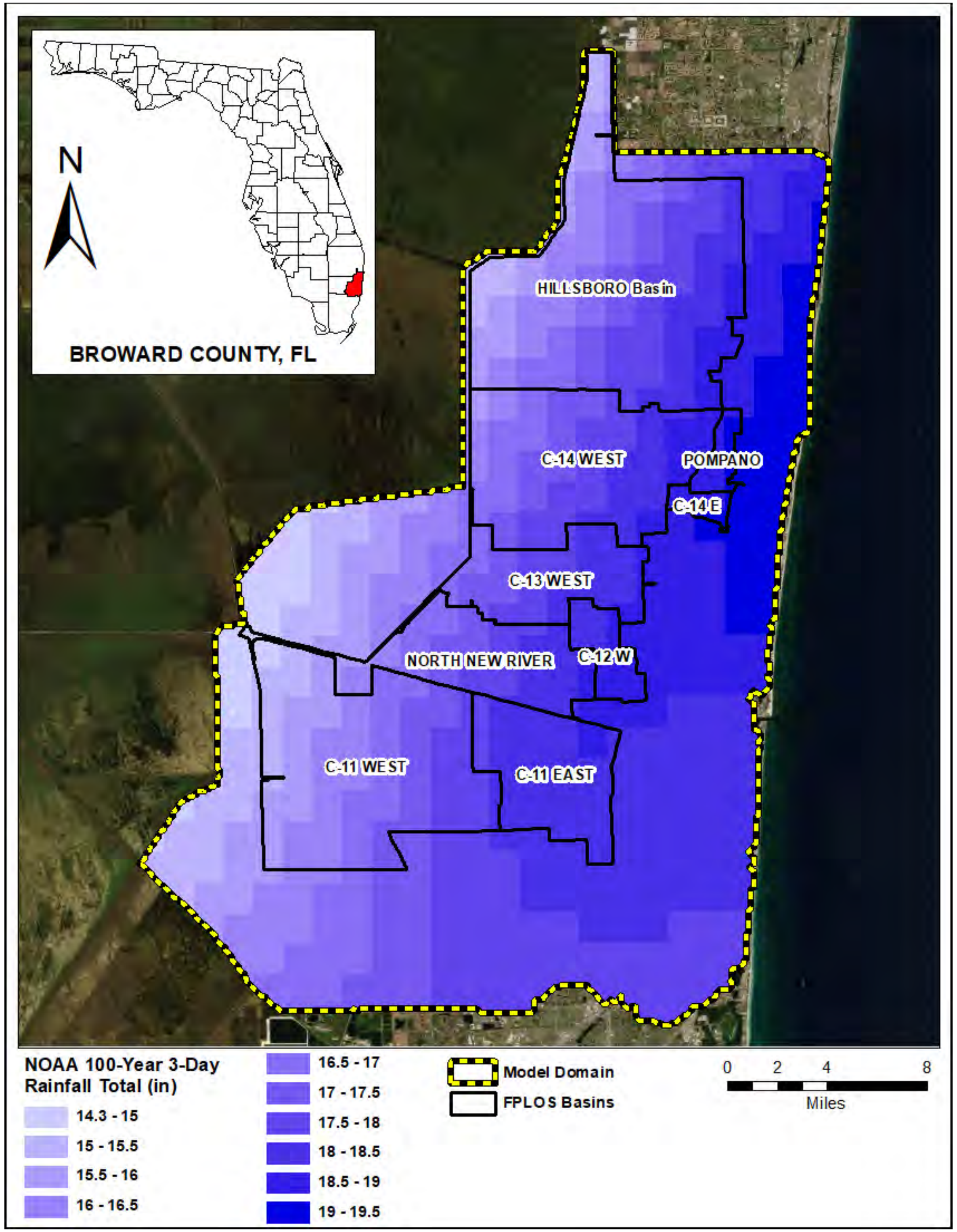
Model Calibration and Validation

- Calibrated to “No-name” rainfall event June 5-7, 2017
  - 4 inches in the southeast to 16 inches in the northwest
- Calibration Target:
  - +/- 10% to 20% peak discharge and total discharge volume
  - +/- 0.5 ft headwater/tailwater and groundwater elevation
- NEXRAD 15-minute rainfall data 2 km x 2 km pixel resolution
- Recorded operations used for gates and pumps
- Tidal structure tailwater forced based on observed data
- Validated to Hurricane Irma rainfall event from September 9-11, 2017
  - 6 inches in the east to 10 inches in the west



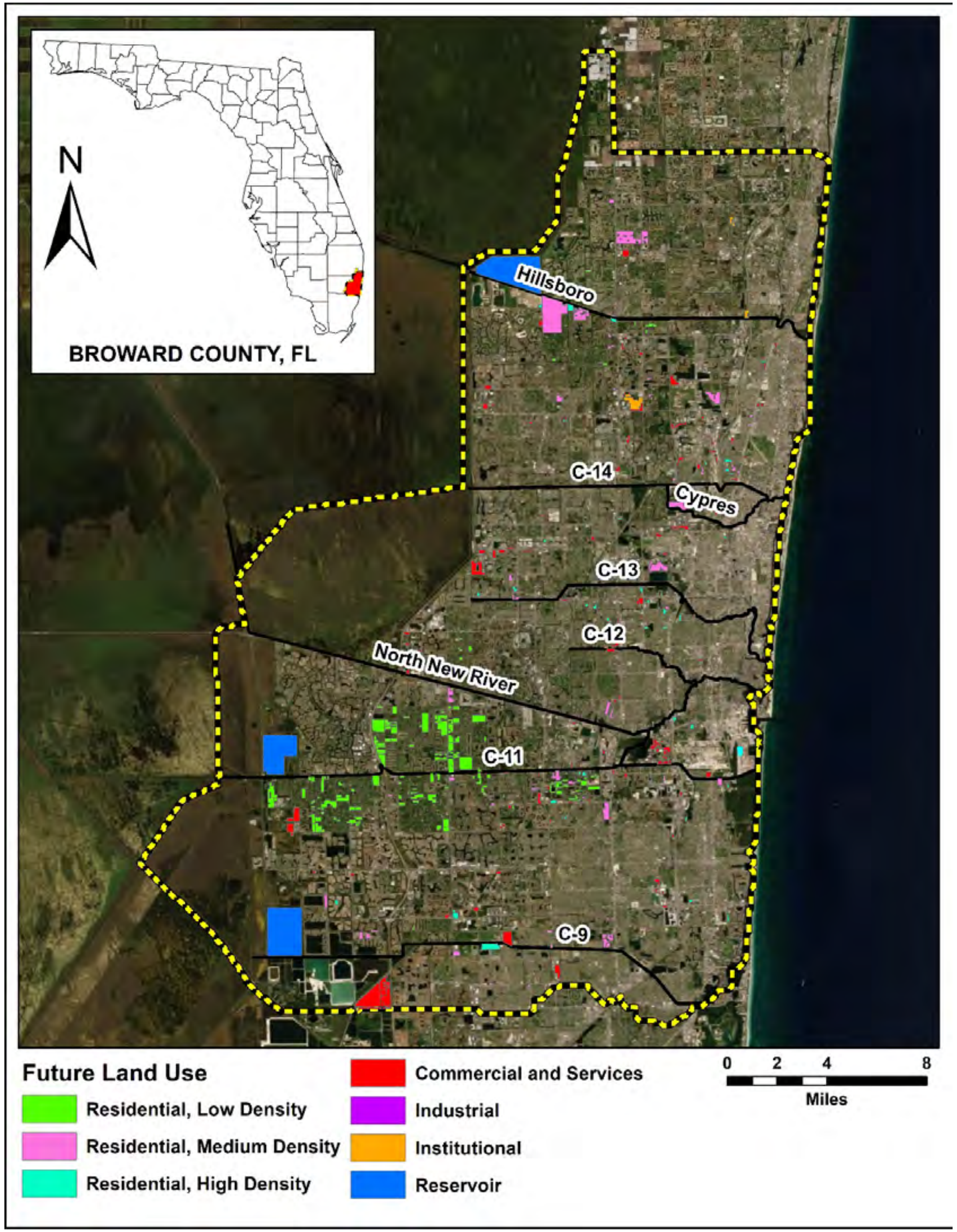
Current Conditions Model Setup

- Rule Based Structure Operations
- Gridded NOAA Atlas 14 rainfall Depths
- SFWMD-provided storm surge tidal boundaries
- “Full-bowl” initial surface water conditions
- Peak rainfall and peak surge occur at same time
- 5-year, 10-year, 25-year, and 100-year storm events

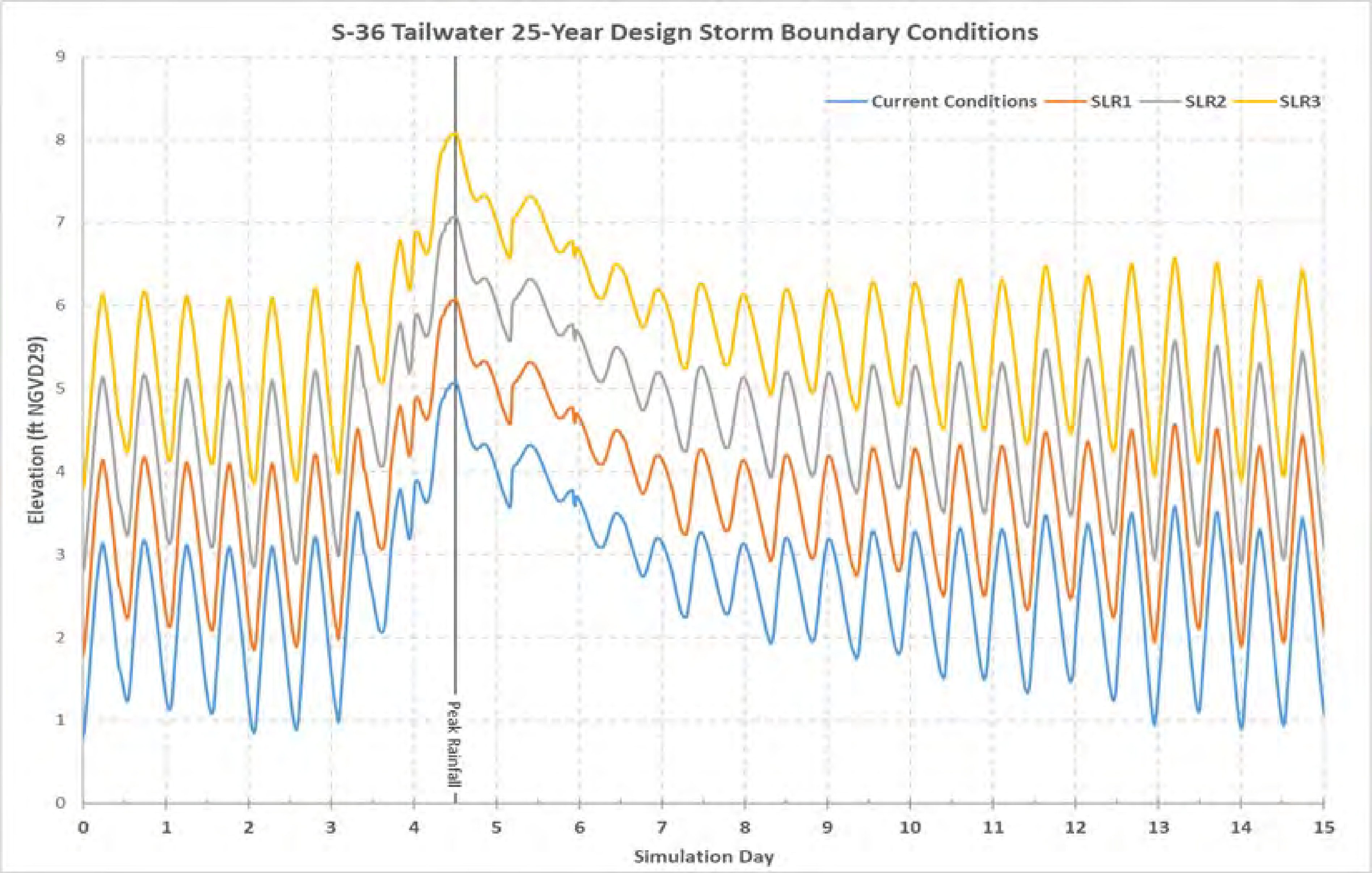


Future Conditions Model Setup

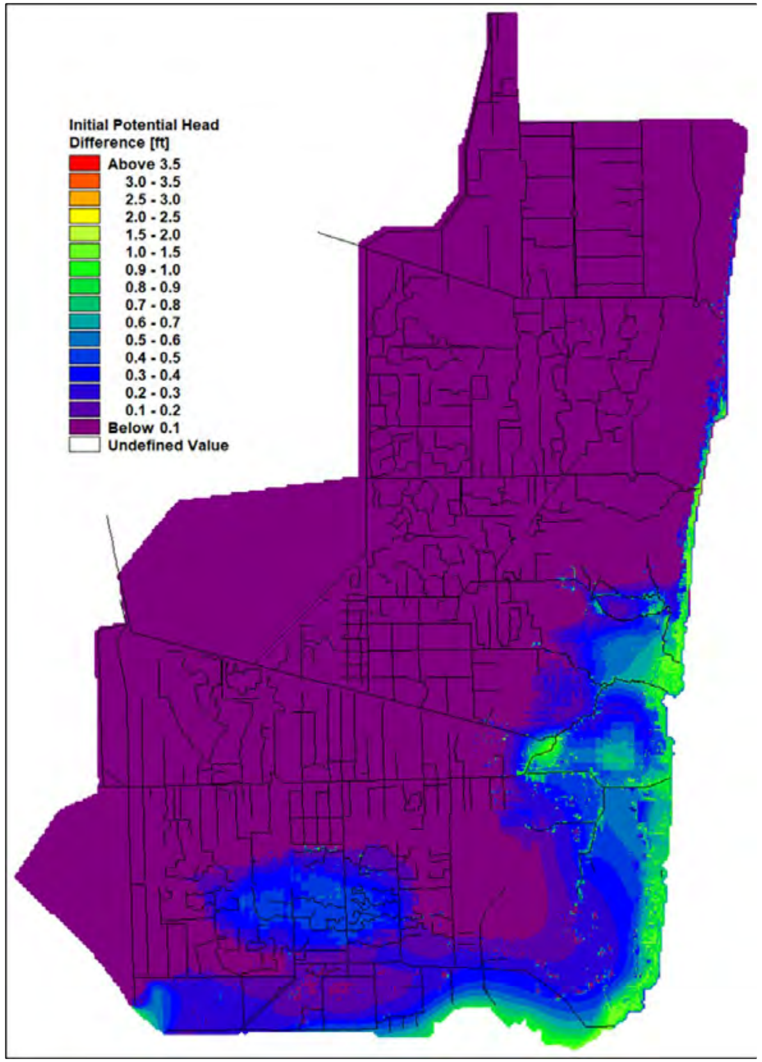
- 13,650 acres identified for land use change. Parameters affected:
  - Topography
  - Overland Manning's Roughness
  - Detention Storage
  - Paved Area Runoff Coefficient
- C-9 & C-11 Impoundments represented
- SFWMD-provided storm surge tidal boundaries with 1, 2, and 3 ft SLR on 2019 sea level
- Future conditions initial groundwater elevations, influenced by SLR



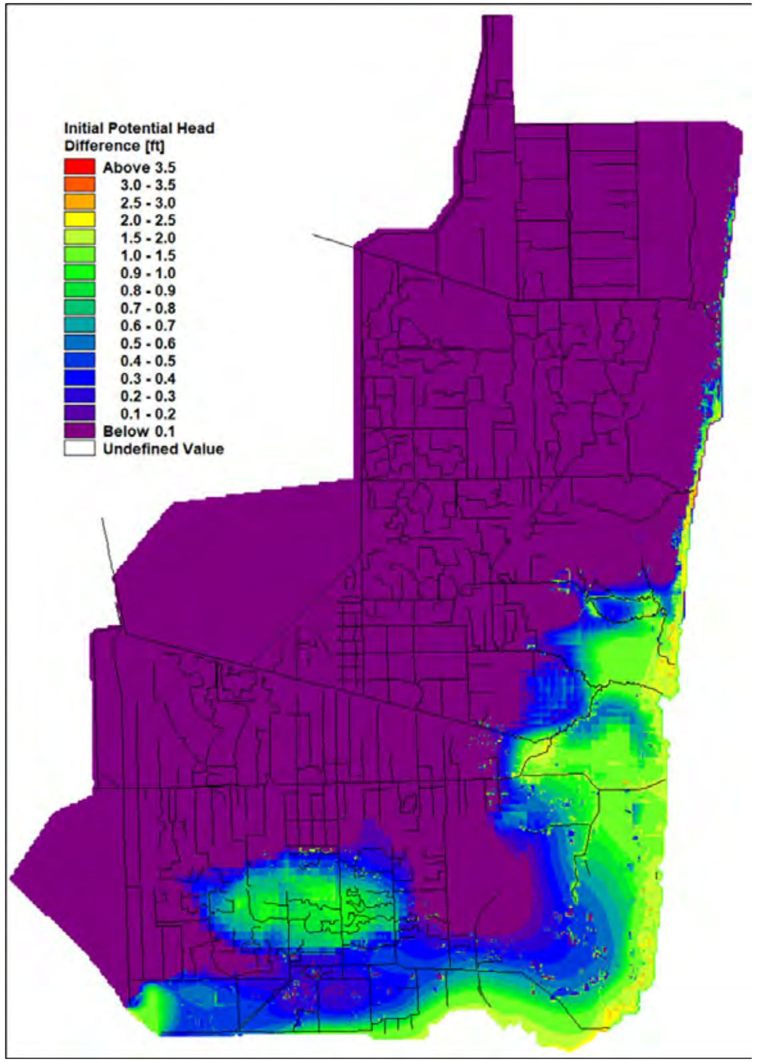
SFWMD-Generated Tidal Boundaries Applied at 7 Tidal Outfalls



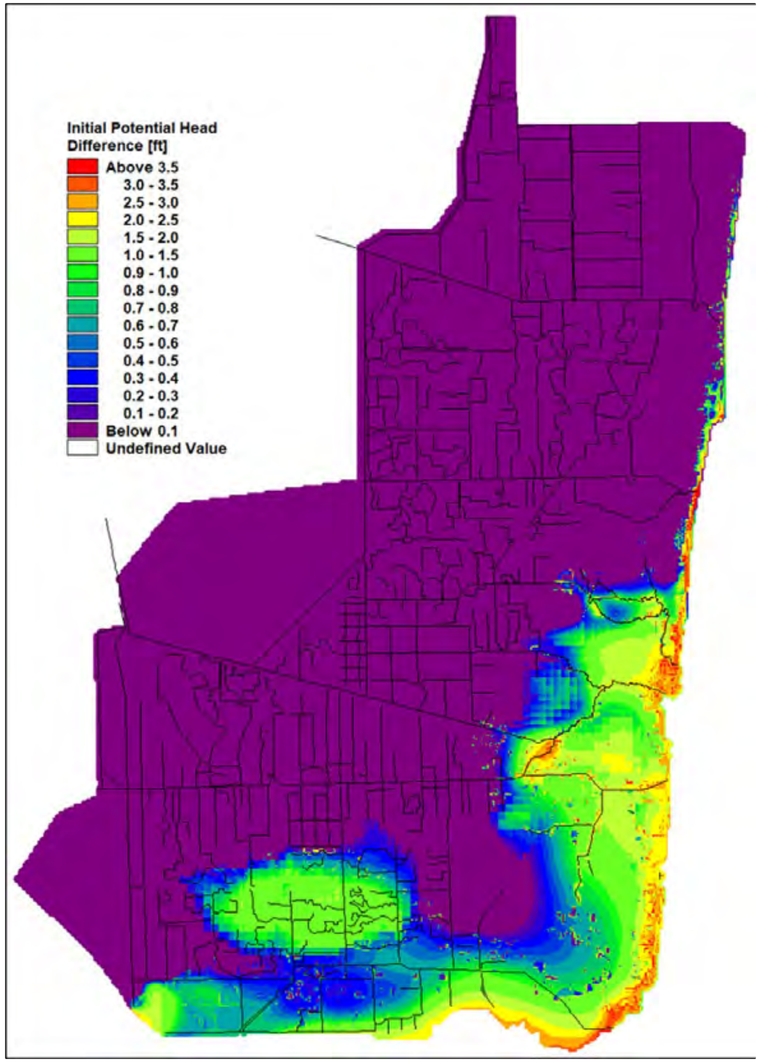
Future Initial Groundwater Elevation Difference Maps



SLR1



SLR2



SLR3

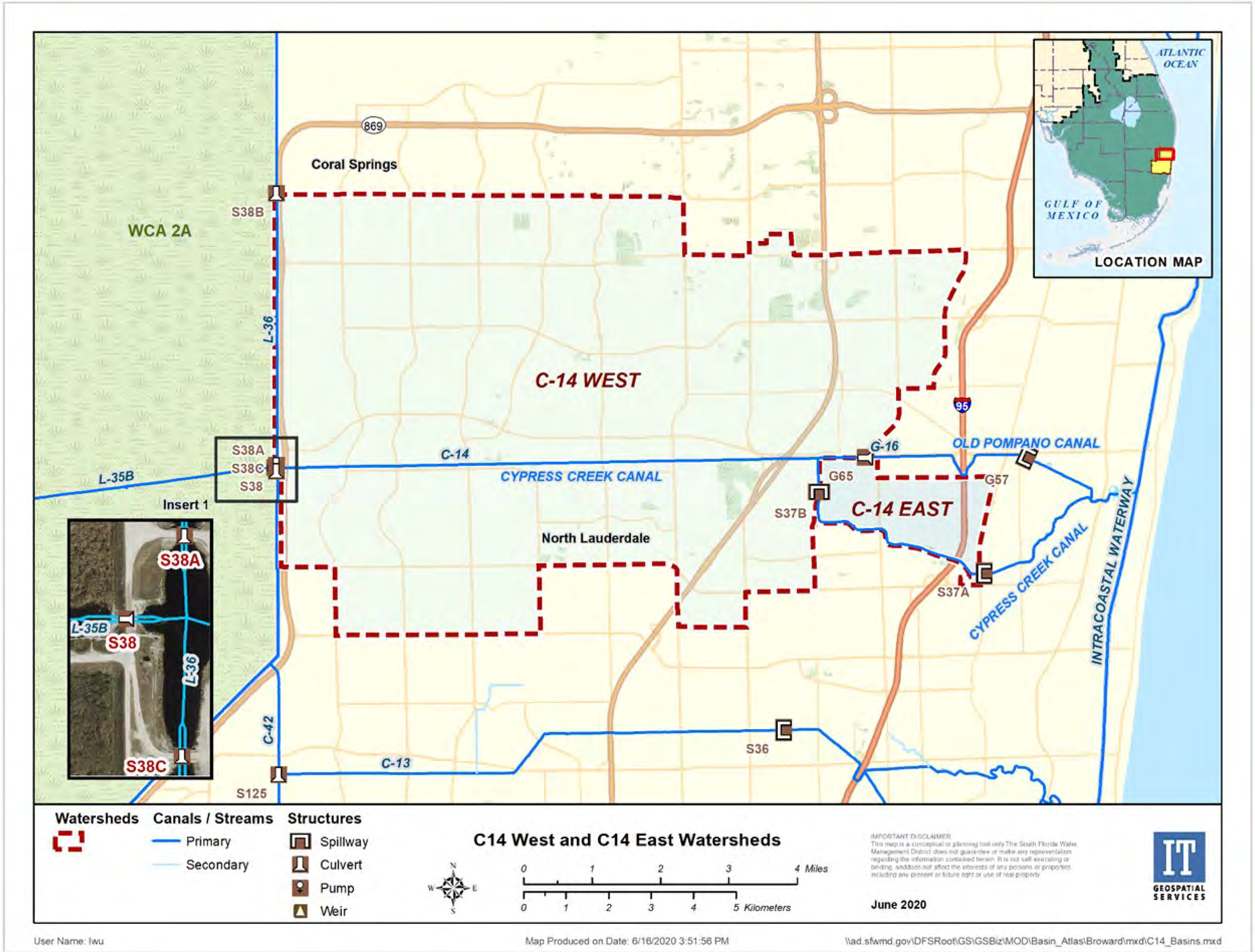
FPLOS Performance Measures Evaluated

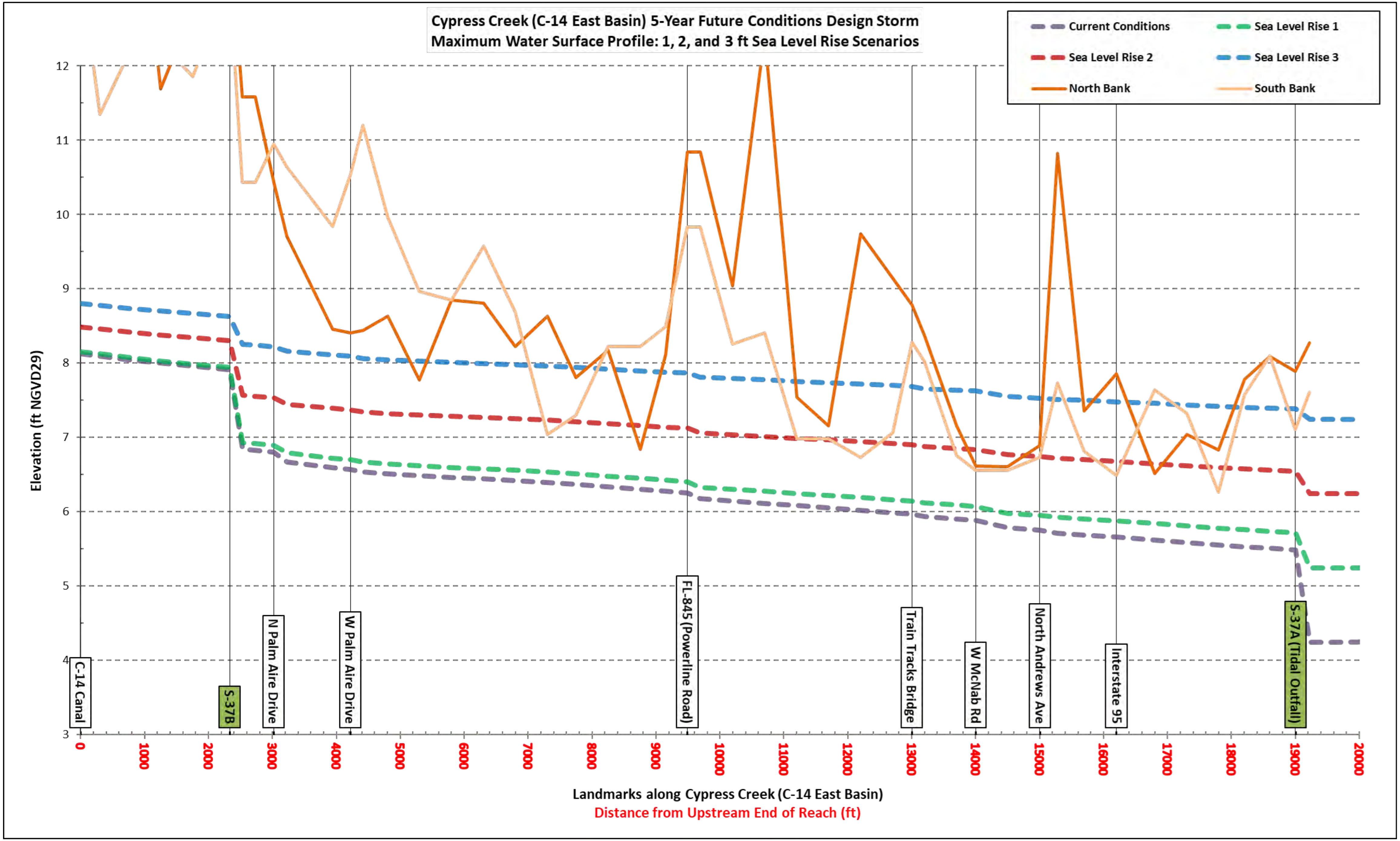
For 5-Year, 10-Year, 25-Year, and 100-Year Design Storms:

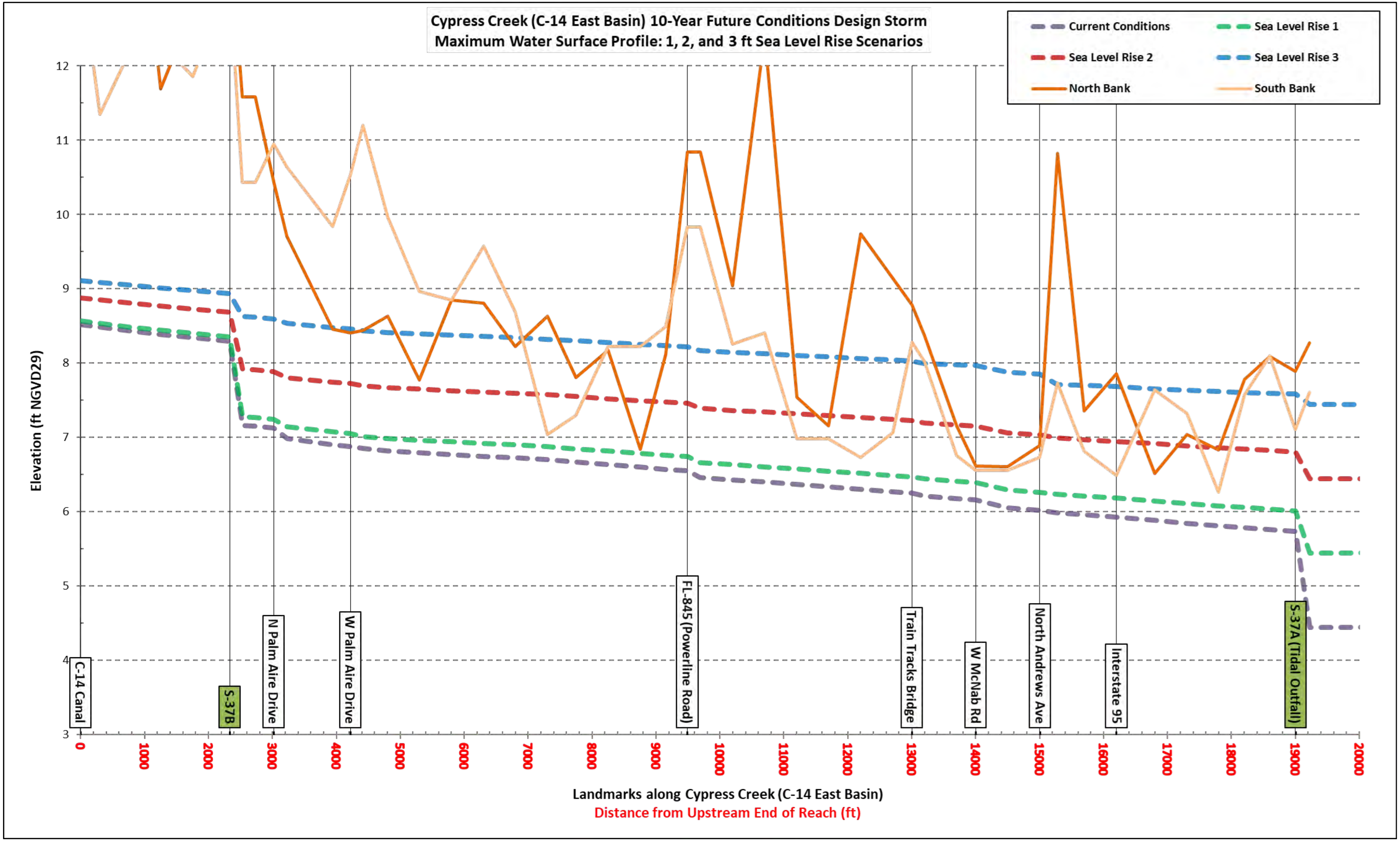
- PM #1 – Maximum Stage Profiles for Primary Canals
- PM #2 – Maximum Area-Weighted Discharge, filtered to remove tide
- PM #3 – Structure Performance – Effects of Sea Level Rise
- PM #4 – Maximum Conveyance Capacity at tidal structures (filtered)
- PM #5 – Frequency of Inundation (Flood Inundation Maps)
- PM #6 – Duration of Flooding Maps (Overland) and Duration for Primary Canals to Recede to Reference Elevation

C-14 East Basin

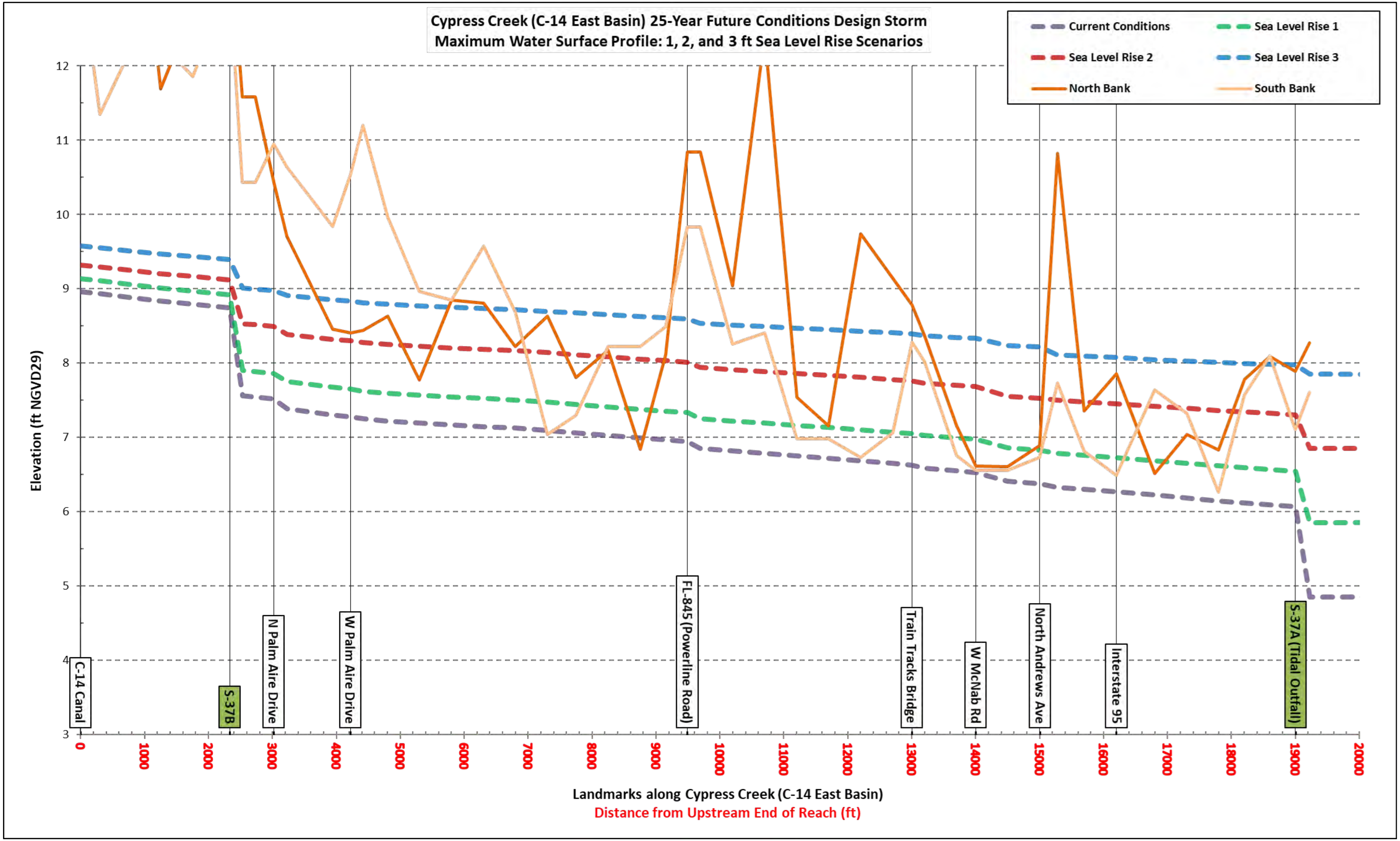
- 10-yr FPLOS for SLR1 and less than 5-yr FPLOS for SLR2 and SLR3
- 25-Yr SLR1 and 5-Yr SLR2/SLR3 results in several bank exceedances
  - Elevated stages & bank exceedances directly contributes to flooding of urban areas



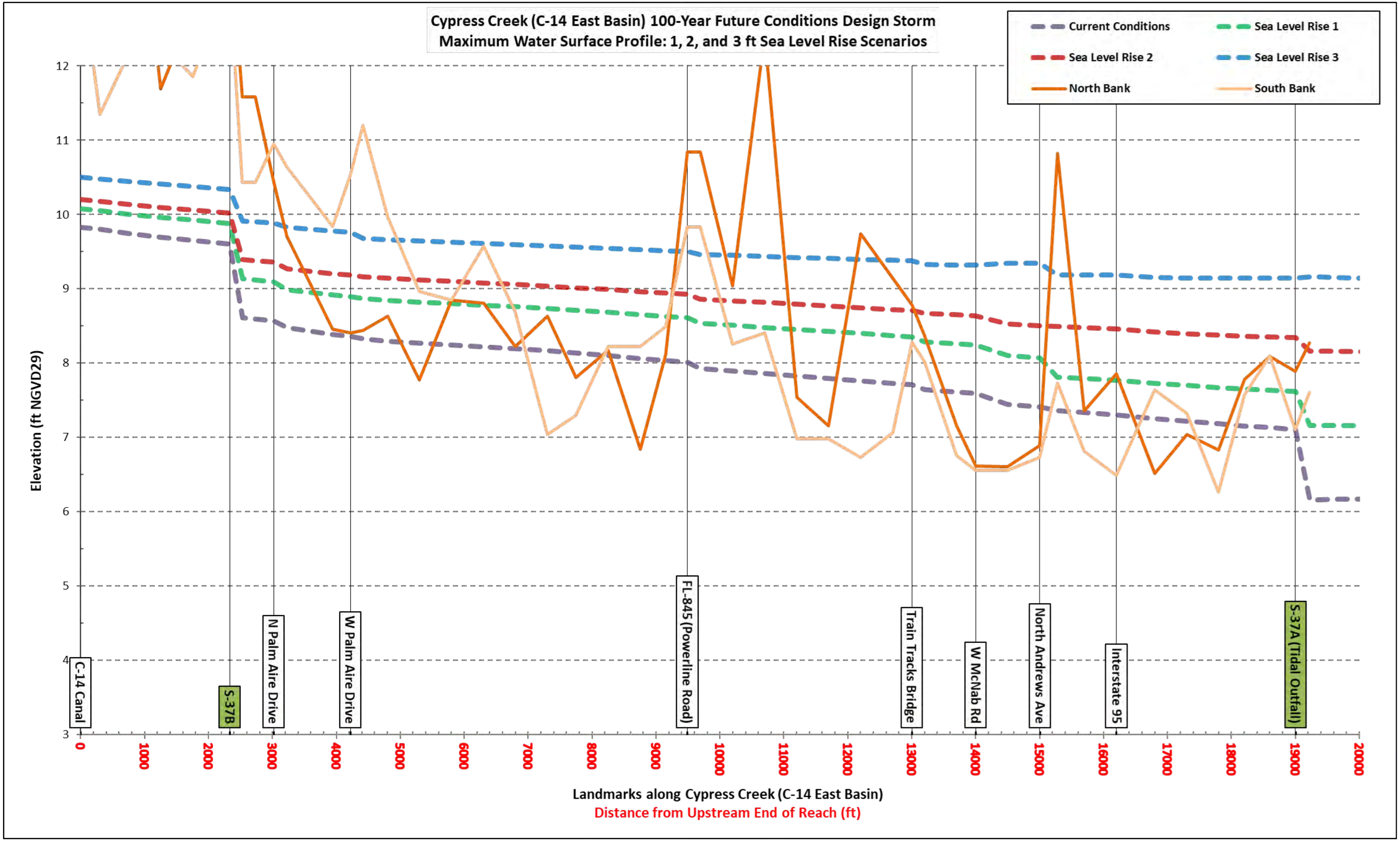

Cypress Creek (C-14 East Basin) 5-Year Future Conditions Design Storm
Maximum Water Surface Profile: 1, 2, and 3 ft Sea Level Rise Scenarios
Current Conditions
Sea Level Rise 1
Sea Level Rise 2
Sea Level Rise 3
North Bank
South Bank
Elevation (ft NGVD29)
3
4
5
6
7
8
9
10
11
12
C-14 Canal
S-37B
N Palm Aire Drive
W Palm Aire Drive
FL-845 (Powerline Road)
Train Tracks Bridge
W McNab Rd
North Andrews Ave
Interstate 95
S-37A (Tidal Outfall)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
Landmarks along Cypress Creek (C-14 East Basin)
Distance from Upstream End of Reach (ft)



Cypress Creek (C-14 East Basin) 10-Year Future Conditions Design Storm
Maximum Water Surface Profile: 1, 2, and 3 ft Sea Level Rise Scenarios
Current Conditions
Sea Level Rise 1
Sea Level Rise 2
Sea Level Rise 3
North Bank
South Bank
Elevation (ft NGVD29)
C-14 Canal
S-37B
N Palm Aire Drive
W Palm Aire Drive
FL-845 (Powerline Road)
Train Tracks Bridge
W McNab Rd
North Andrews Ave
Interstate 95
S-37A (Tidal Outfall)
Landmarks along Cypress Creek (C-14 East Basin)
Distance from Upstream End of Reach (ft)



Cypress Creek (C-14 East Basin) 25-Year Future Conditions Design Storm
Maximum Water Surface Profile: 1, 2, and 3 ft Sea Level Rise Scenarios
Current Conditions
Sea Level Rise 1
Sea Level Rise 2
Sea Level Rise 3
North Bank
South Bank
Elevation (ft NGVD29)
C-14 Canal
S-37B
N Palm Aire Drive
W Palm Aire Drive
FL-845 (Powerline Road)
Train Tracks Bridge
W McNab Rd
North Andrews Ave
Interstate 95
S-37A (Tidal Outfall)
Landmarks along Cypress Creek (C-14 East Basin)
Distance from Upstream End of Reach (ft)



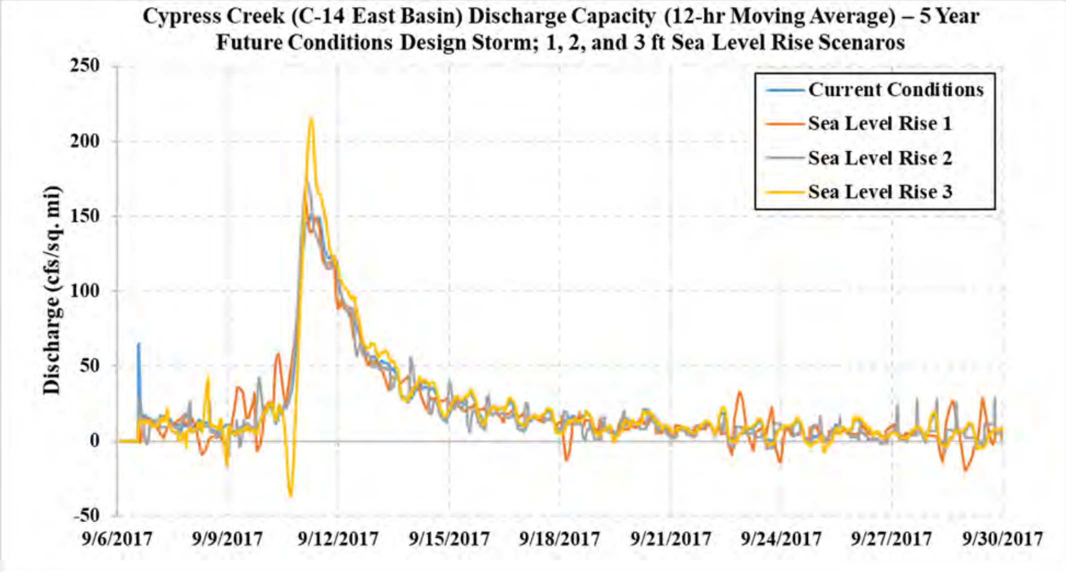
Cypress Creek (C-14 East Basin) 100-Year Future Conditions Design Storm
Maximum Water Surface Profile: 1, 2, and 3 ft Sea Level Rise Scenarios
Current Conditions
Sea Level Rise 1
Sea Level Rise 2
Sea Level Rise 3
North Bank
South Bank
Elevation (ft NGVD29)
C-14 Canal
S-37B
N Palm Aire Drive
W Palm Aire Drive
FL-845 (Powerline Road)
Train Tracks Bridge
W McNab Rd
North Andrews Ave
Interstate 95
S-37A (Tidal Outfall)
Landmarks along Cypress Creek (C-14 East Basin)
Distance from Upstream End of Reach (ft)

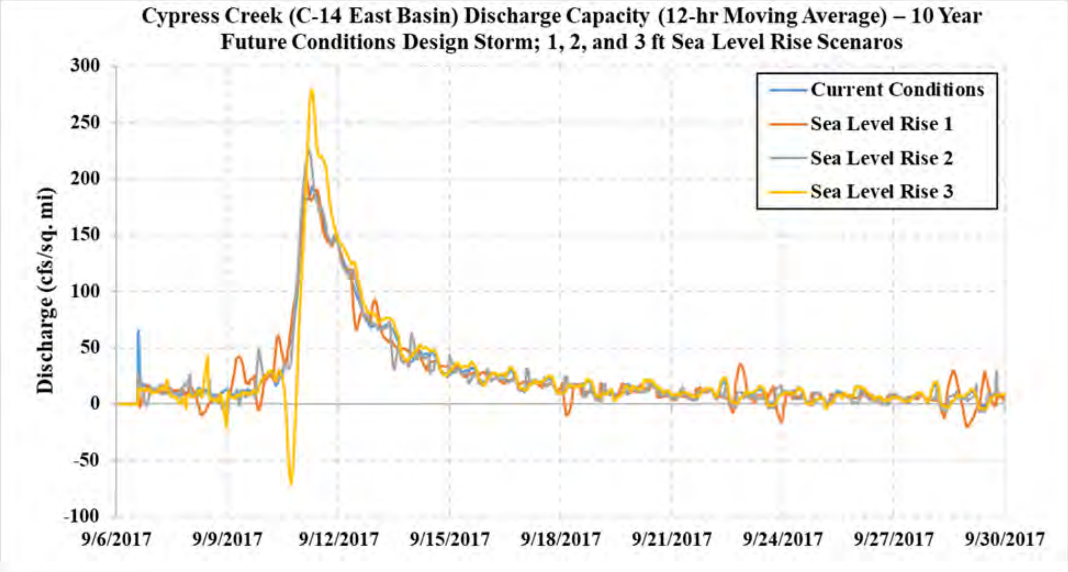
PM #2- Maximum Discharge Capacity through the Primary Canal

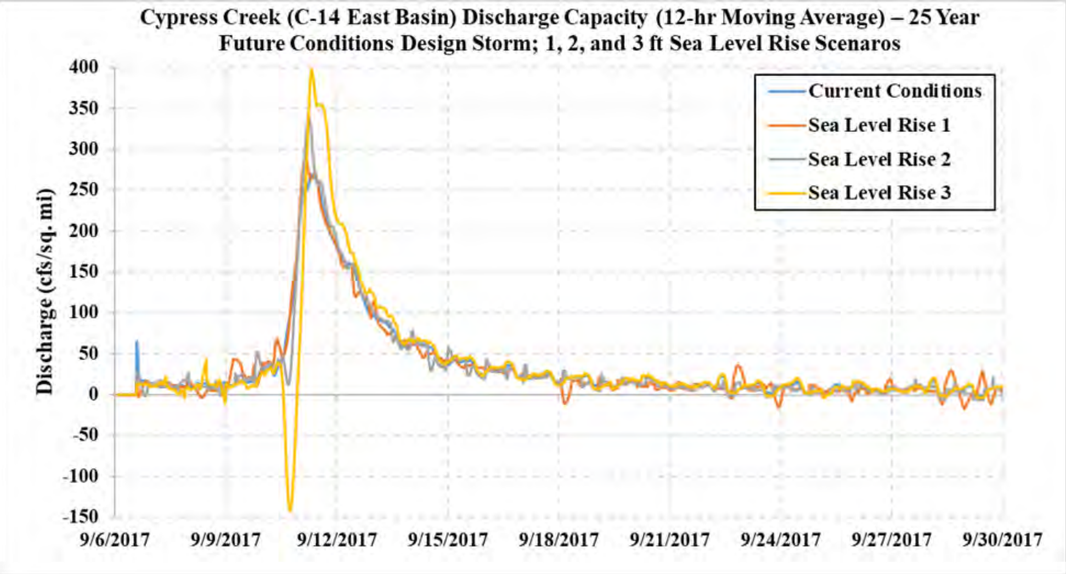
- Allowable discharge rate of 69.2 CSM (25-year design frequency) for C-14 (whole basin)
- 25-year CSL discharge rate = 270.1 CSM
  - 7% to 47% increase under future SLR
- CSM increases as sea level rise increases
  - Increased TW and reverse discharge cause increased HW
  - Continuous discharge into Cypress Creek through Structure S-37B
    - Stages stay elevated and do not drop as quick as the tide after storm surge has passed
    - Increased discharge due to head difference across the structure / timing of gate / flow regime

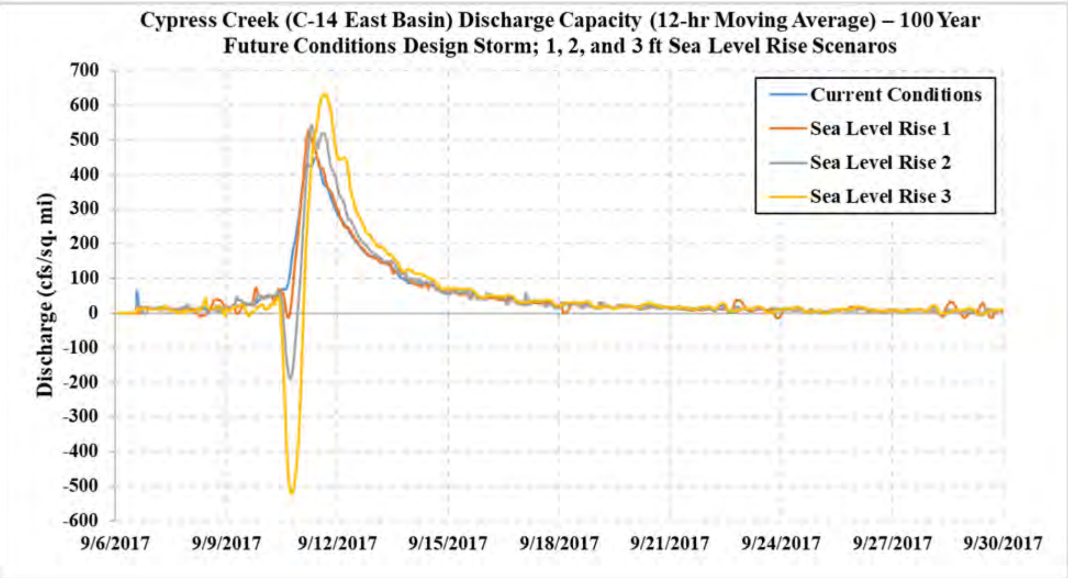
Drainage Basin	Inflow	Outflow	Water Control Catchment Area (sq.mi)	Design Storm	Peak 12-Hour Moving Average Discharge from the Contributing Drainage Area (cfs/sq.mi)			
					CSL	SLR1	SLR2	SLR3
C-14 East	S-37B	S-37A	2.69	5-Year	151.3	161.1	172.1	214.2
				10-Year	192.8	202.9	225.7	279.3
				25-Year	270.1	288.2	338.3	397.1
				100-Year	448.0	527.4	542.9	633.2

PM #2- Maximum Discharge Capacity through the Primary Canal



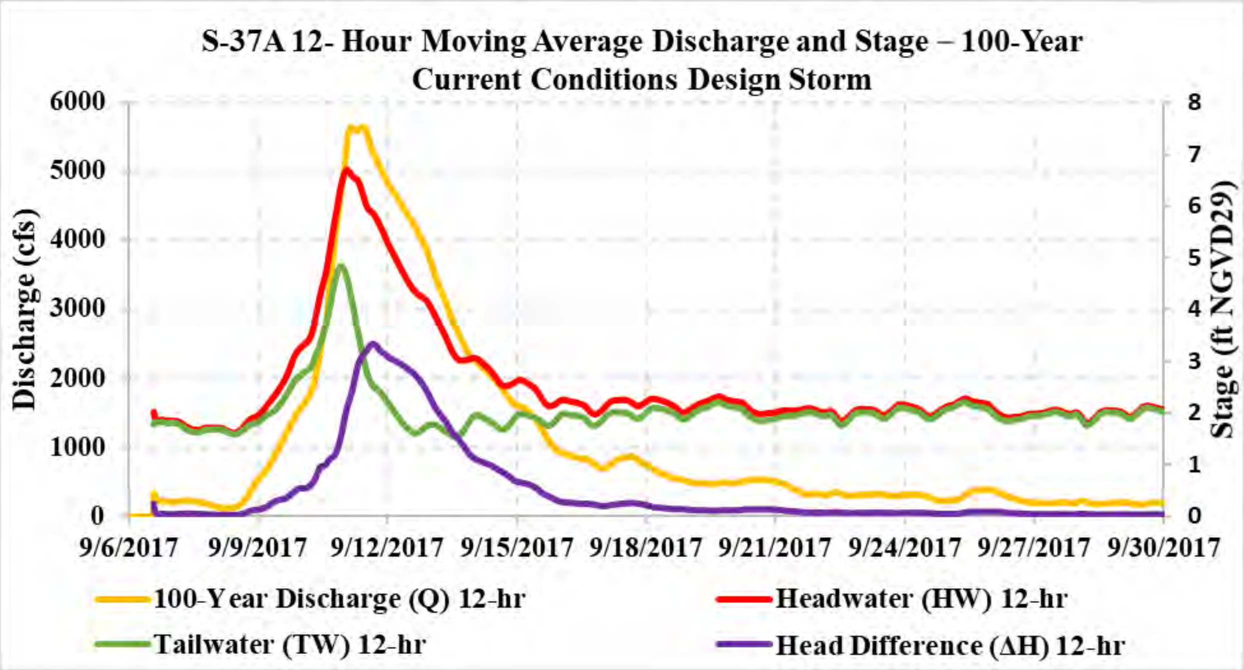


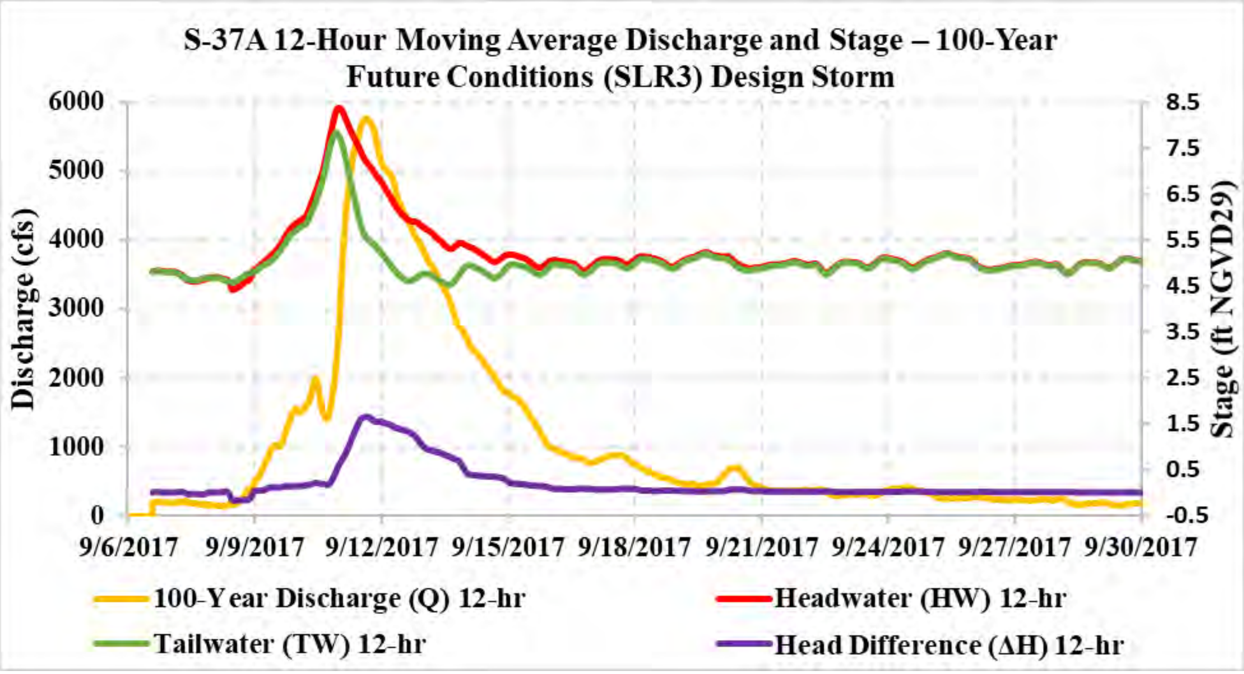




PM #3- Structure Performance

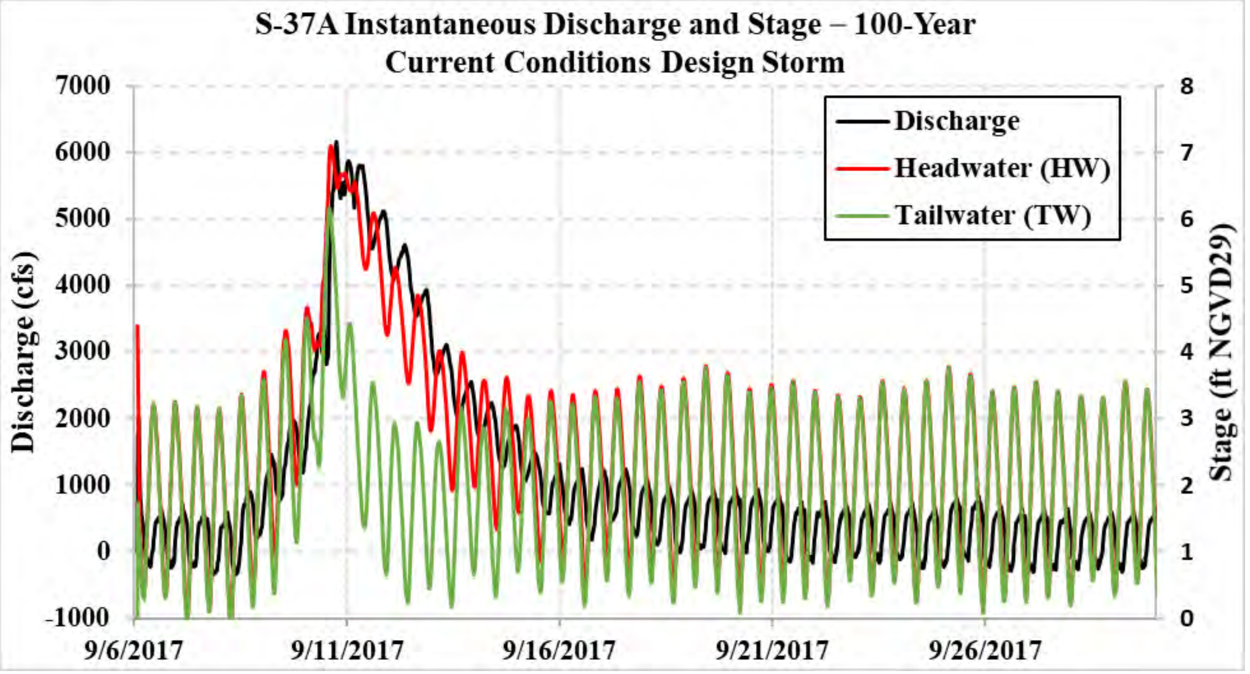
- Design discharge of 3890 cfs exceeded for all but the 5-year SLR scenarios
- S-37A predicted to be sensitive to SLR:
  - Peak 12-hour discharges changing by +/- 0 % to 3%
  - Peak HW increasing by:
    - 4% to 8% (SLR1)
    - 17% to 20% (SLR2)
    - 29% to 35% (SLR3)

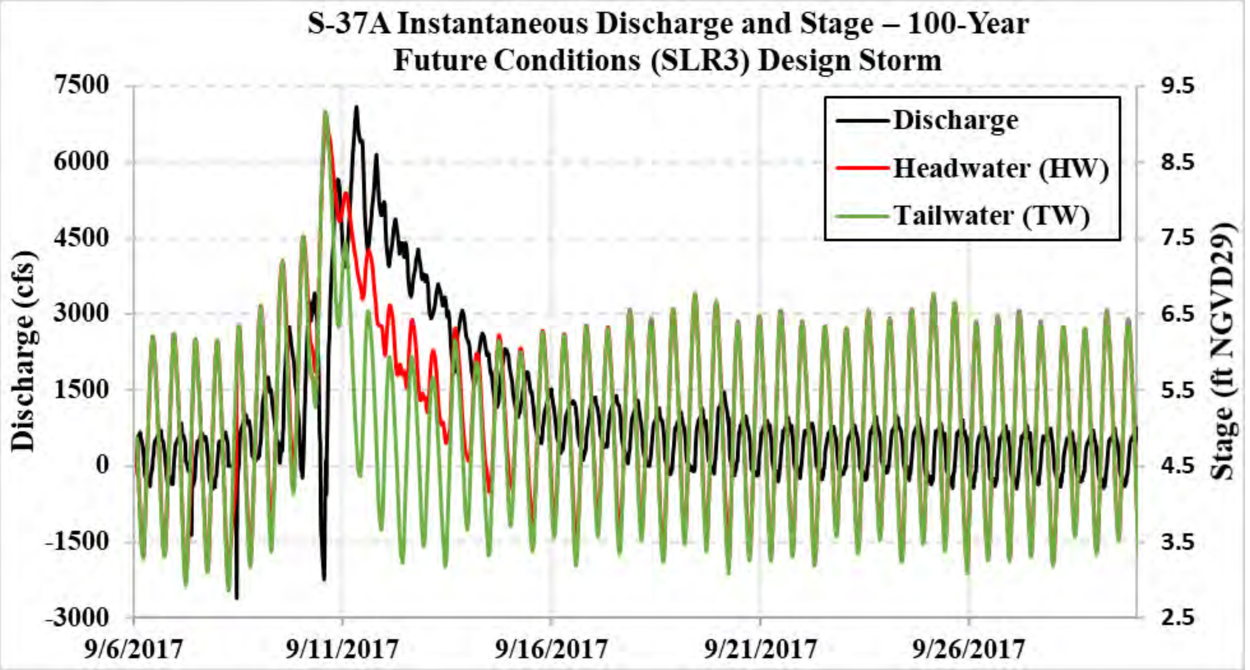




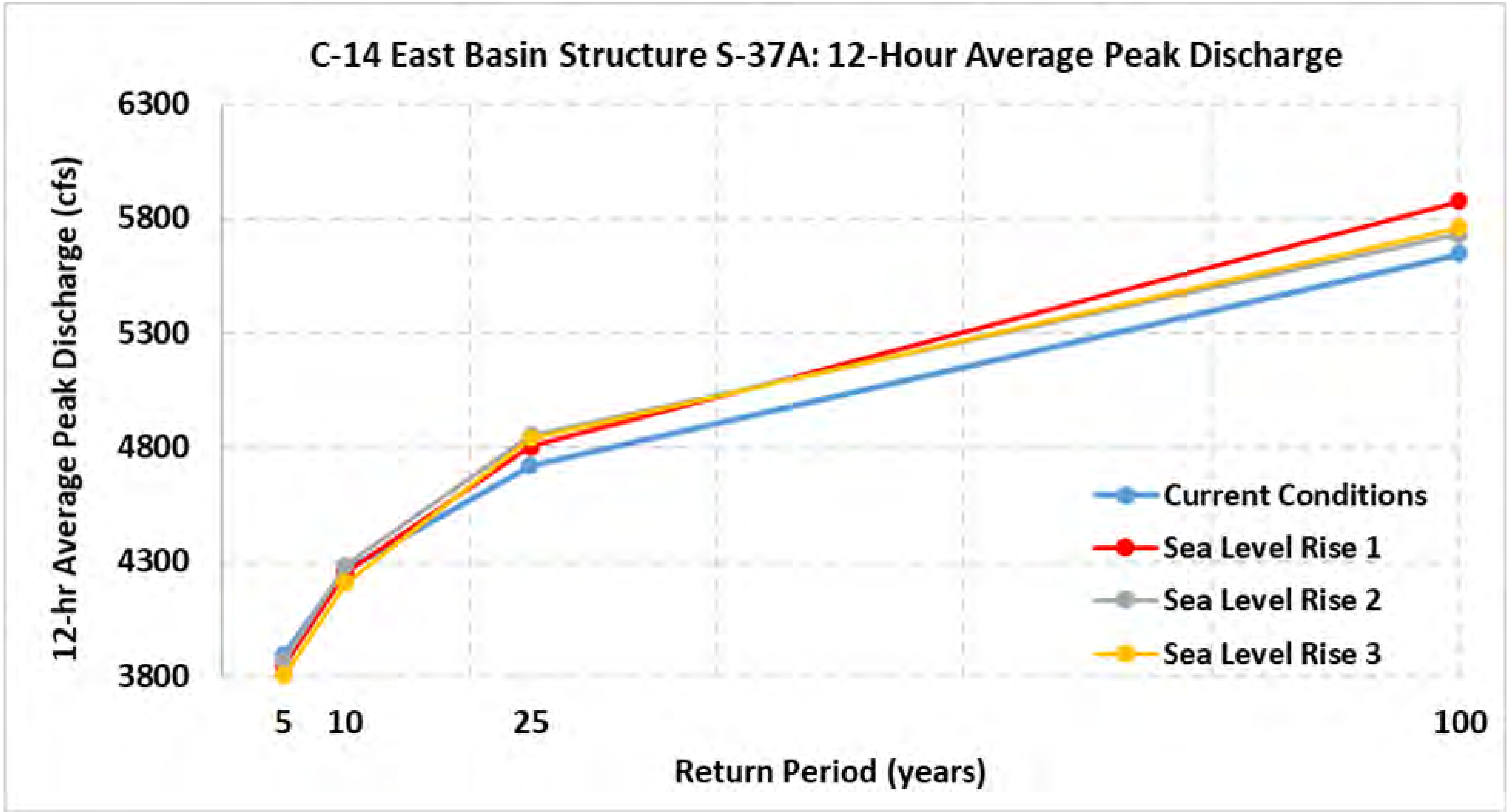
PM #3- Structure Performance

- Peak stages exceed the static HW/TW design assumptions:
  - 3.2 ft design HW
    - Simulated peak 5.7 ft to 9.2 ft
    - 2.5 ft to 6.0 ft violation
  - 2.2 ft design TW
    - Simulated peak 5.2 ft to 9.2 ft
    - 3.0 ft to 7.0 ft violation

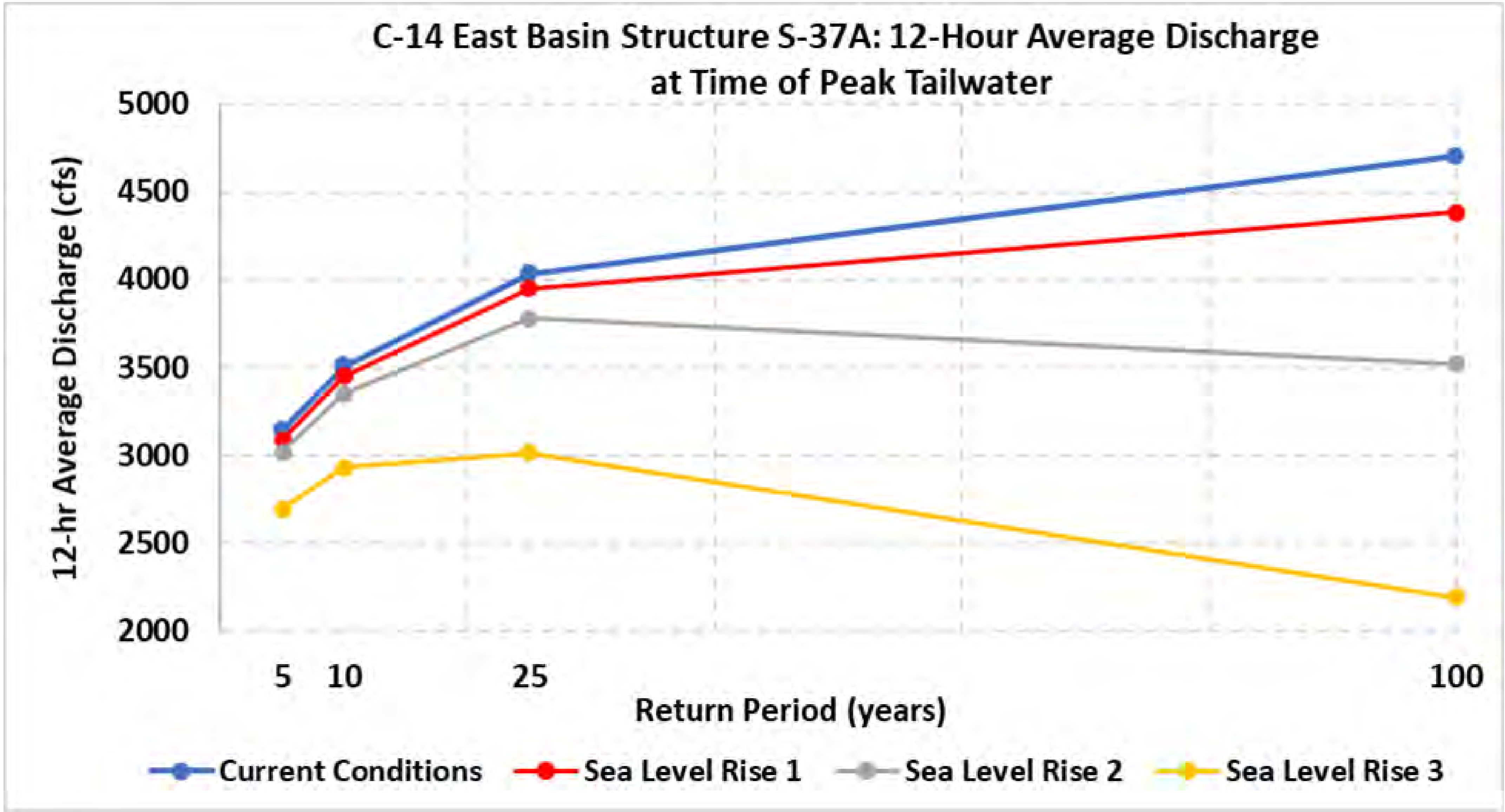




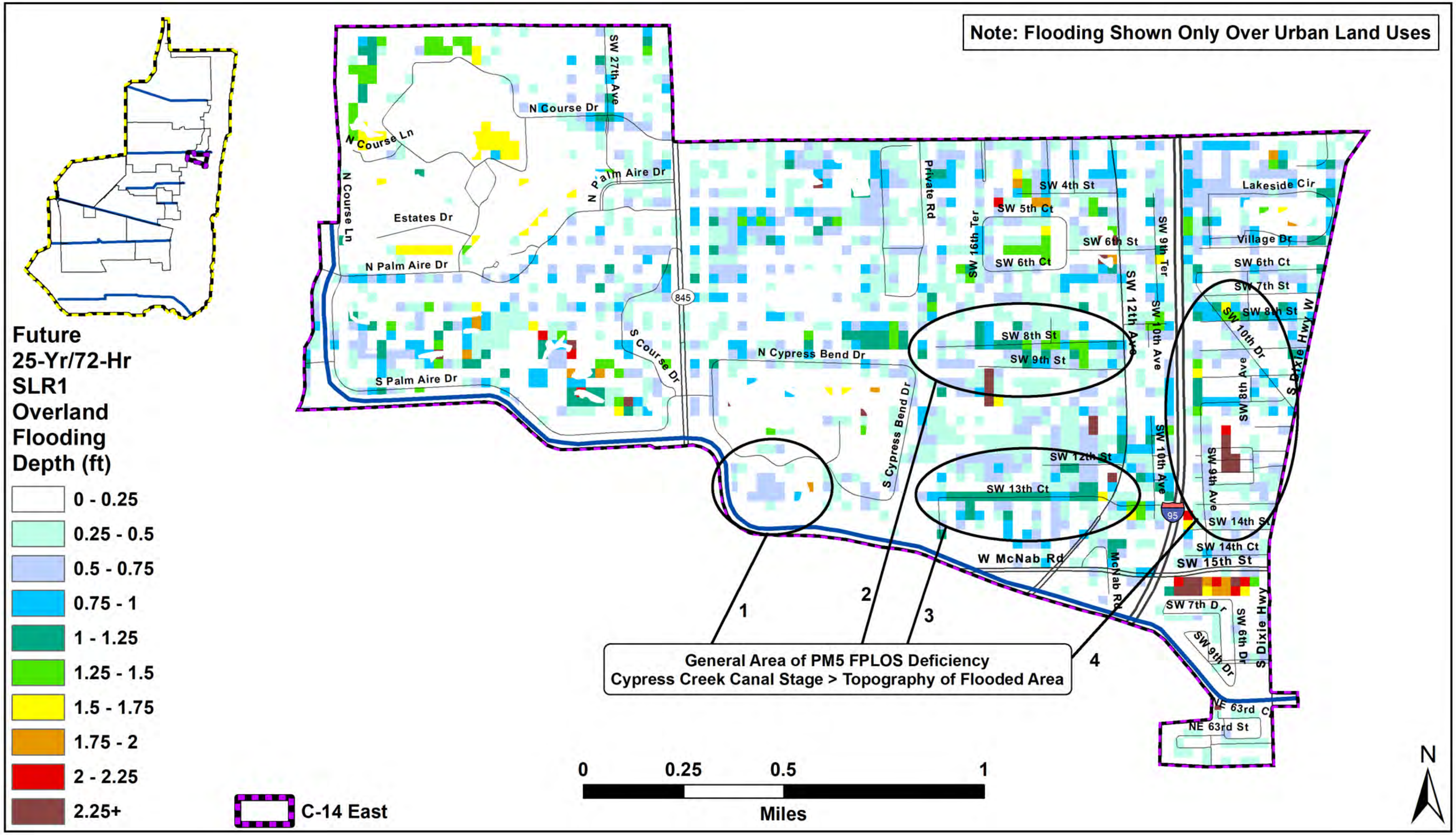
PM #4- Peak Storm Runoff



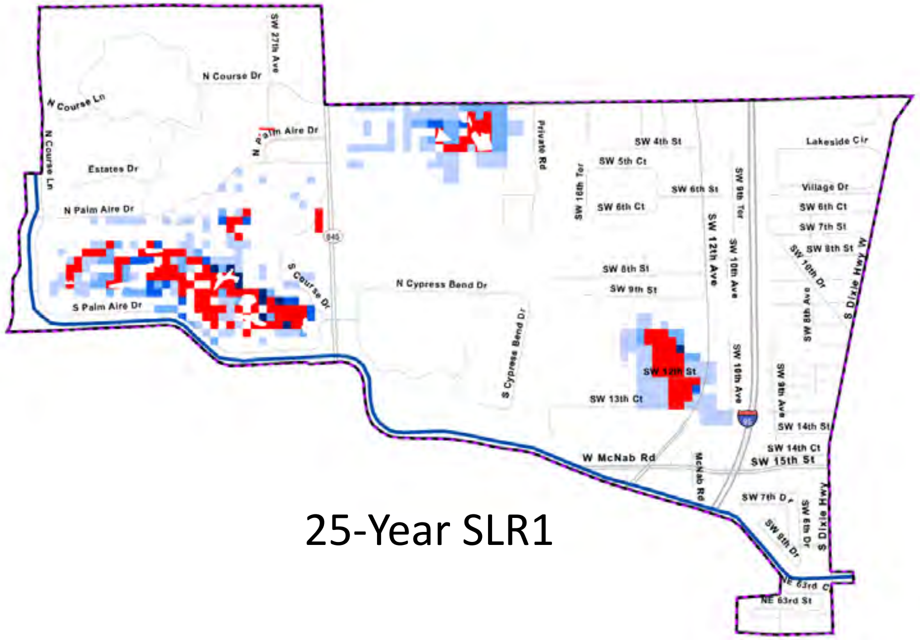
PM #4- Peak Storm Runoff



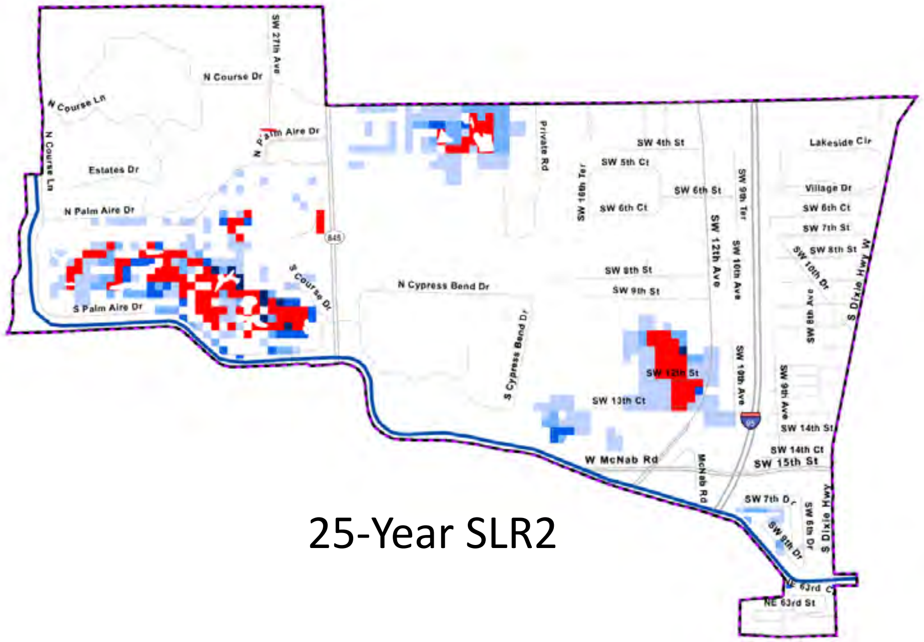
PM #5- Flood Inundation Maps



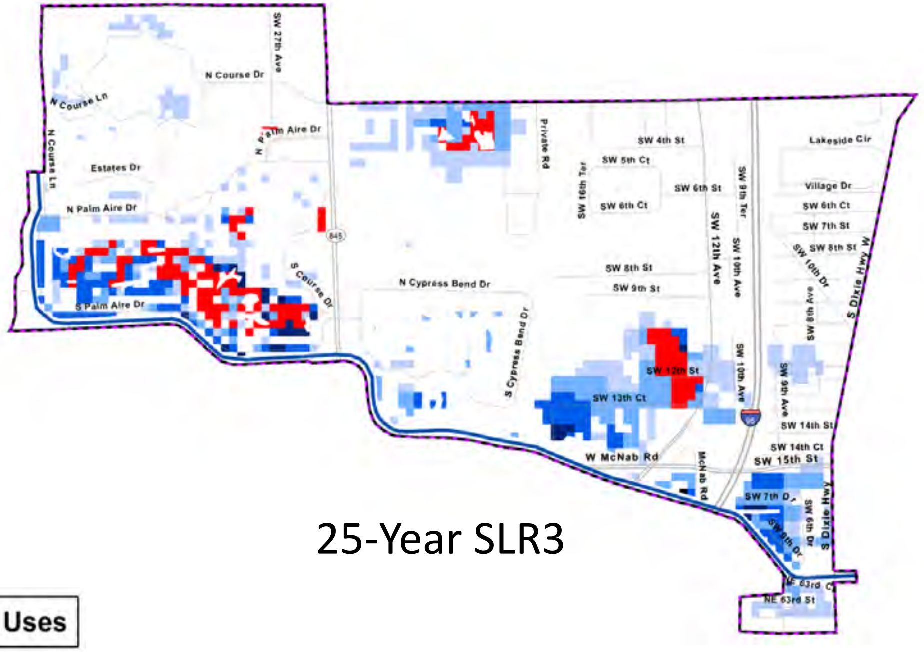
PM #5- Flood Depth Difference Maps: Future minus Current Conditions



25-Year SLR1



25-Year SLR2



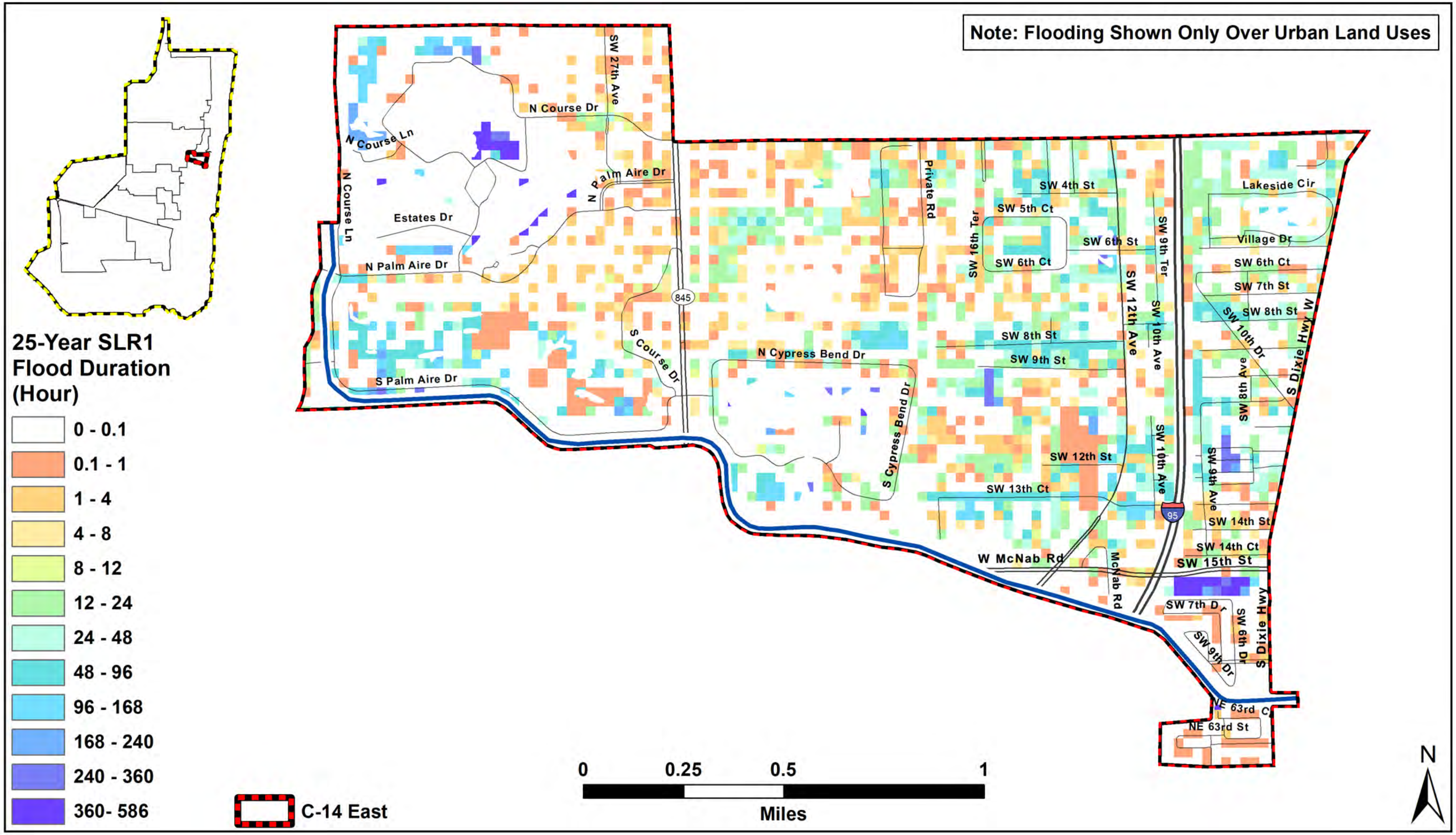
25-Year SLR3

Flooding Depth Difference (ft)

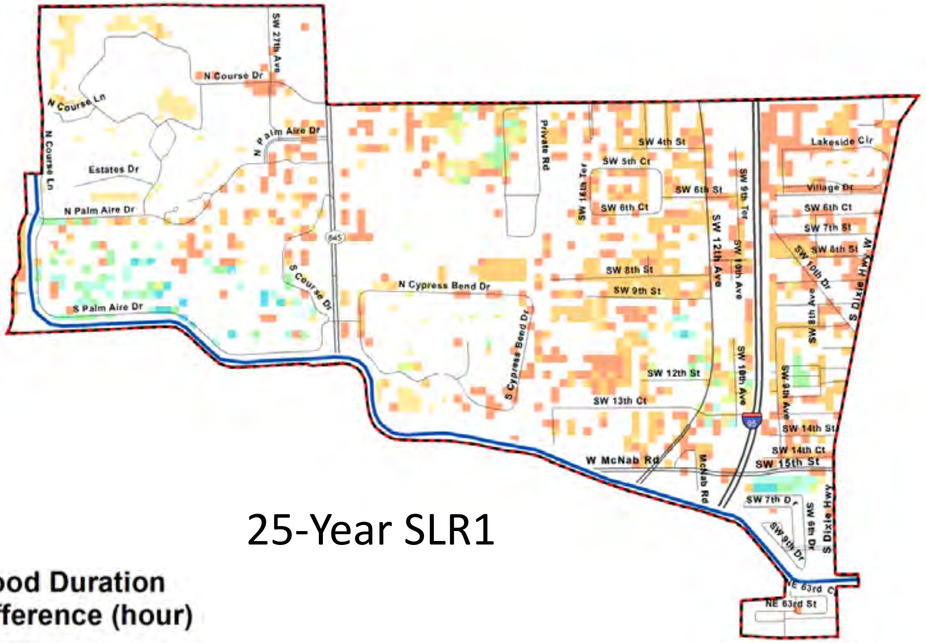
- Less than -0.1
- -0.1 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1.0 - 1.5
- 1.5 - 2

Note: Flooding Shown Only Over Urban Land Uses

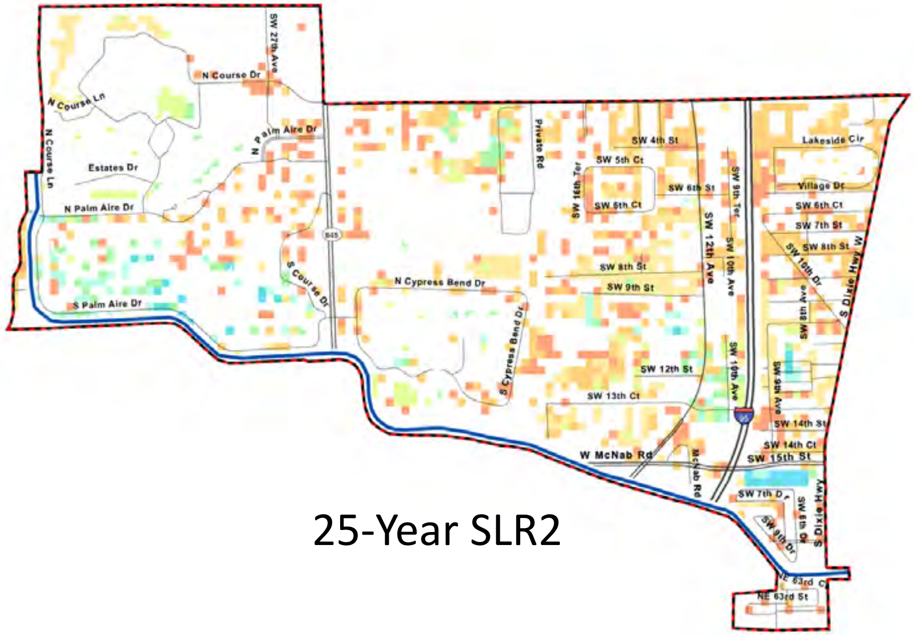
PM #6- Flood Duration Maps



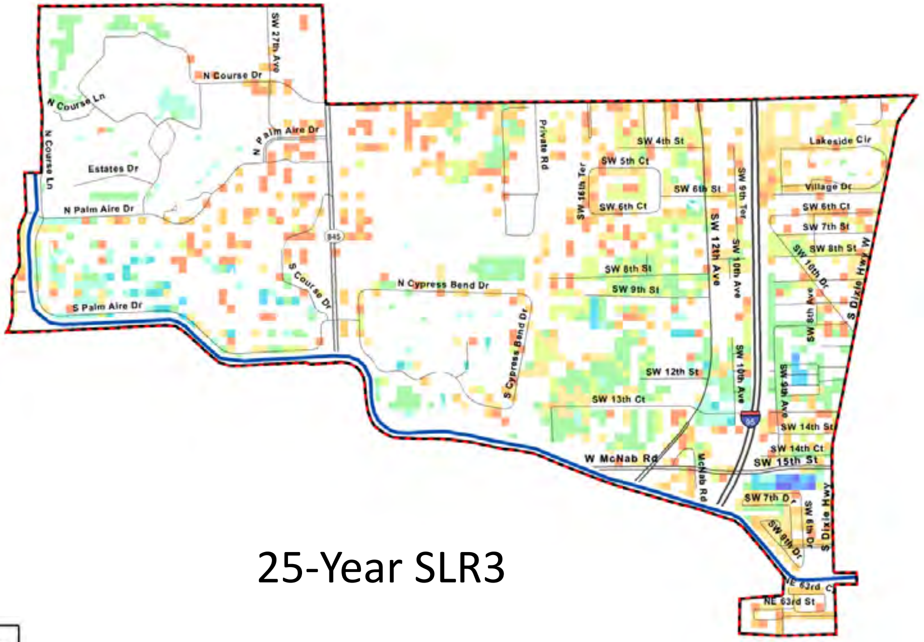
PM #6- Flood Duration Difference Maps: Future minus Current Conditions



25-Year SLR1



25-Year SLR2



25-Year SLR3

Flood Duration Difference (hour)

- 0 - 0.1
- 0.1 - 1
- 1 - 4
- 4 - 8
- 8 - 12
- 12 - 24
- 24 - 48
- 48 - 96
- 96 - 168
- 168 - 240
- 240 - 360
- 360- 586

Note: Flooding Shown Only Over Urban Land Uses

FPLOS Summary- Highest LOS Ratings

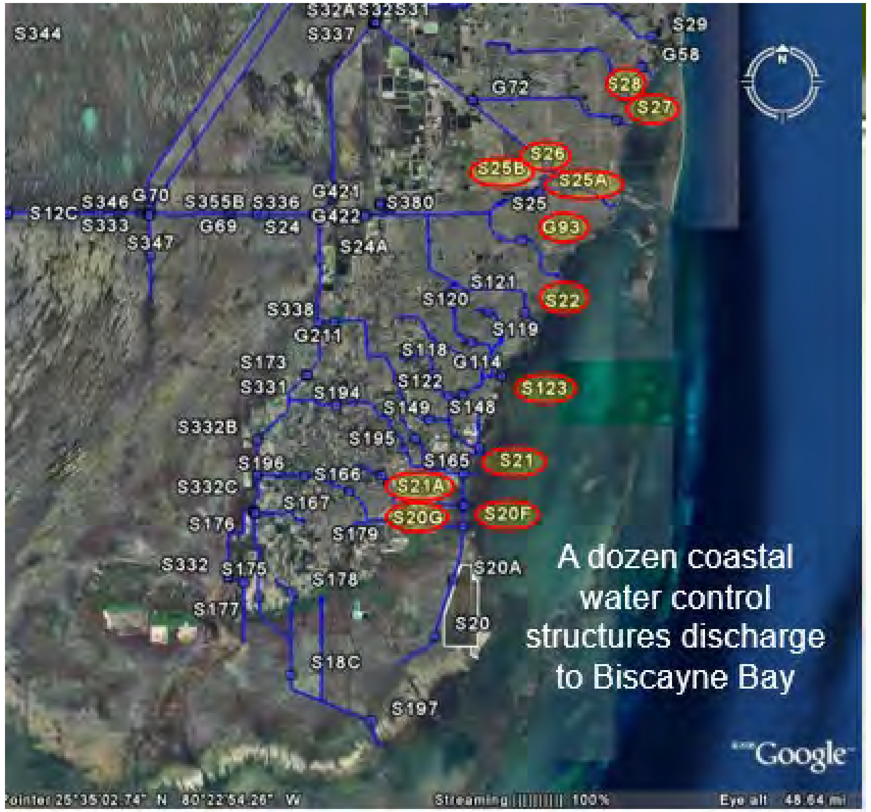
- Hillsboro Basin: 100-yr LOS for all scenarios
- C-13 West: 25-yr CSL, 25-yr SLR1, 10-yr SLR2, LT 5-yr LOS for SLR3
- C-12 West: 25-yr CSL, 10-yr SLR1, less than 5-yr SLR2 & SLR3
- North New River West: 100-yr SLR1, 25-yr SLR2, 10-yr SLR3
- C-11 West: 10-year LOS for all scenarios

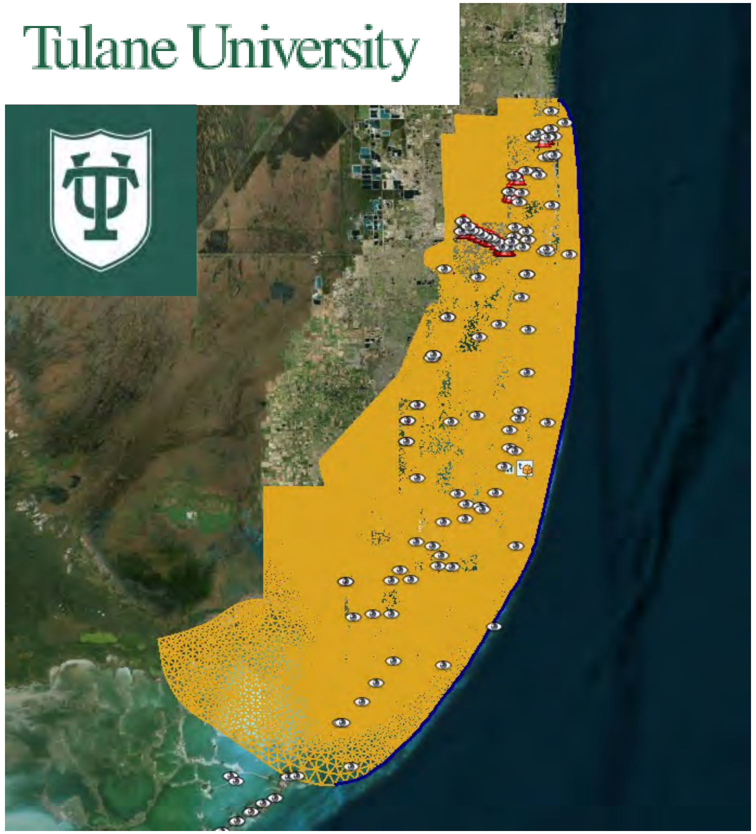
FPLOS Summary- Lowest LOS Ratings

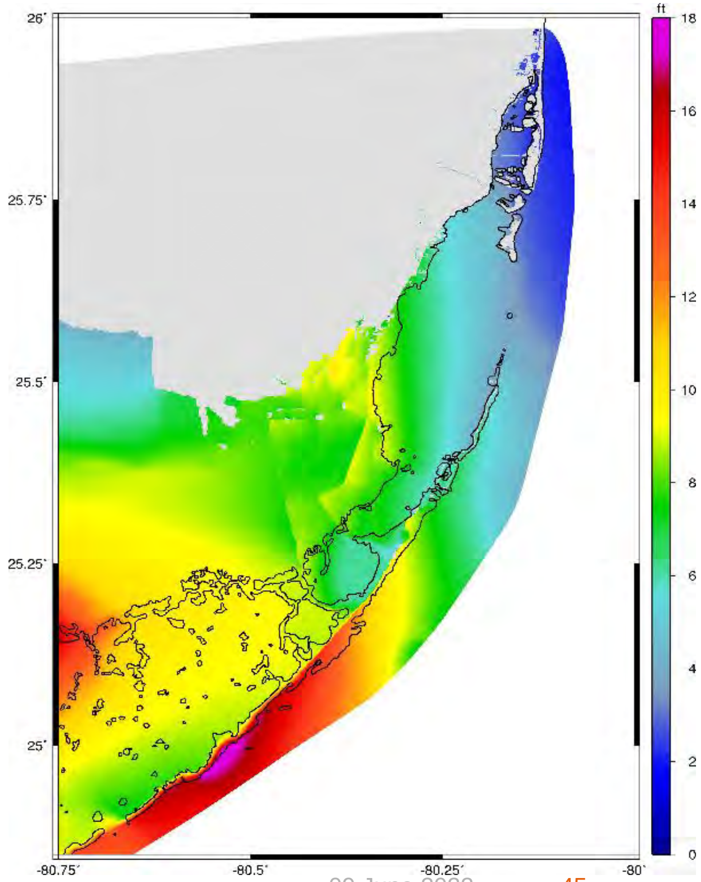
- C-11 East: 10-yr CSL, 5-year LOS for all SLR
- Pompano: 5-yr CSL, less than 5-year LOS for all SLR
- C-14 West: 5-yr CSL, 5-year SLR1, less than 5-yr SLR2 & SLR3
- C-14 East: 25-year CSL, 10-year SLR1, less than 5-yr SLR2 & SLR3

Biscayne Bay Storm Surge Hydrodynamic Models

By Matahel Ansar[1], Ph.D., P.E., Jie Zeng[1], Ph.D., P.E., Akintunde Owosina[1], P.E.
Ehab Meselhe[2], Ph.D., P.E., Kelin Hu[2], Ph.D., P.E.
John Atkinson[3], Zachary Cobell[3]





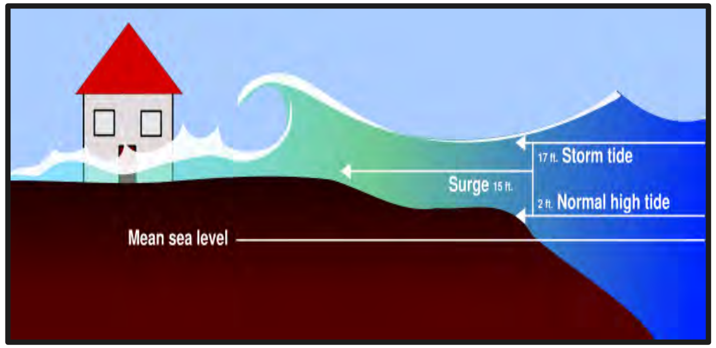


[1]South Florida Water Management District; [2]Tulane University, [3]Arcadis

Project Background

- Original flood protection system designed in the 1950’s
  - Did not account for today’s sea level changes
- Flood Protection Level of Service program (FPLOS) needs tail water data:
  - range of storm frequencies
  - future sea levels
- There are limited gauge data in the region.
- Historical statistics may no longer reflect future conditions.
- Use physically-based computer models to evaluate propagation of storm surge in canals leading up to the structures.

Technical Background

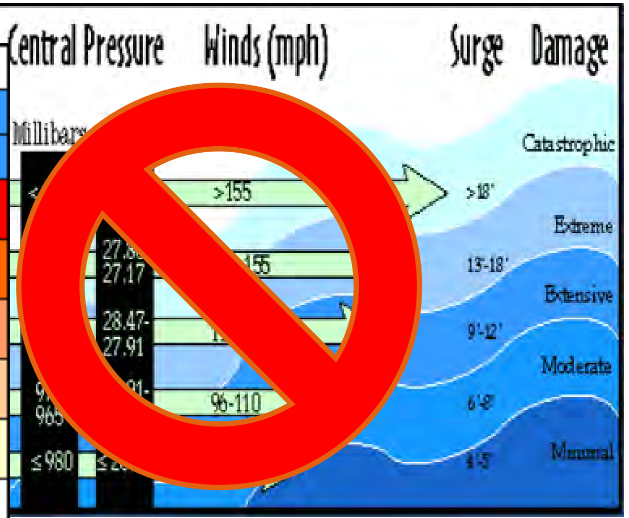


What is Storm Surge?

- Elevated ocean surface due to wind and pressure
- Wind stress pushes water
- Wind stress generates waves
- Wave radiation stresses also push on water column

Factors that influence surge

- Wind speed
- Track angle
- Forward speed
- Radius to maximum wind (size of the storm)



Saffir-Simpson Hurricane Scale

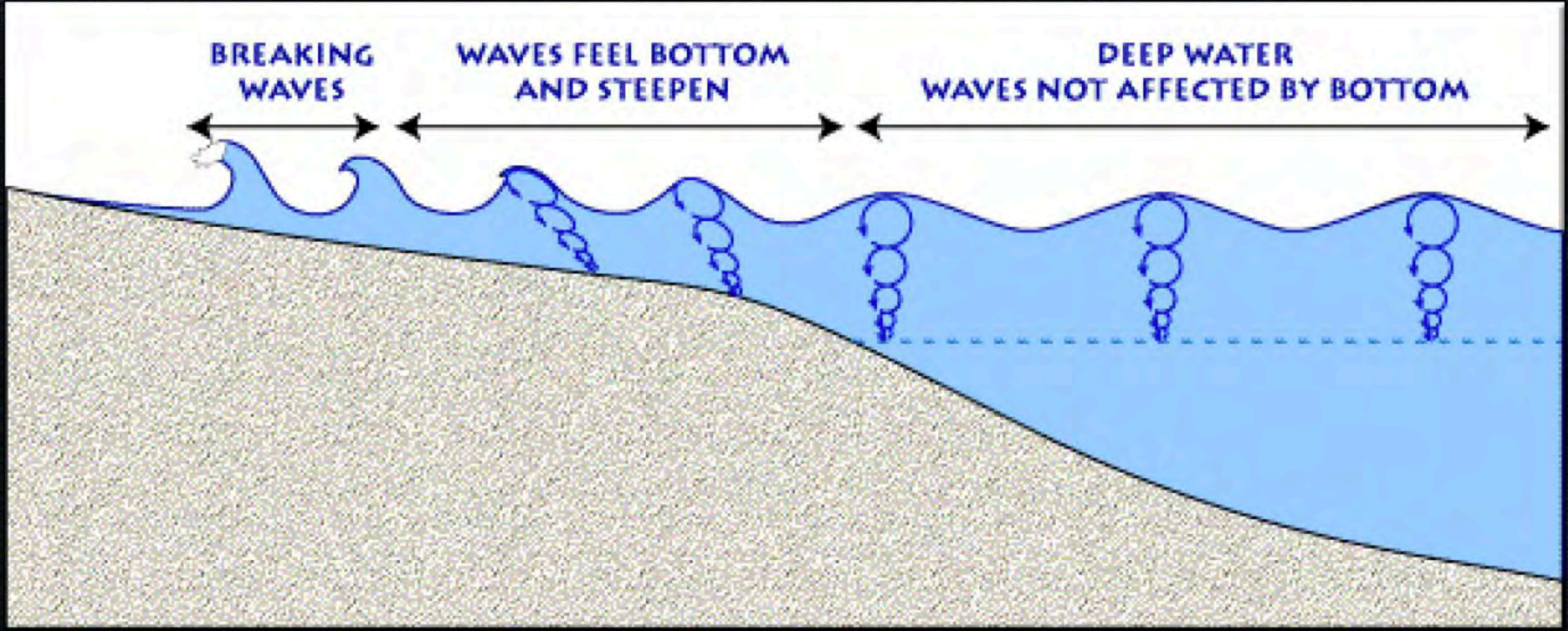
Category	Wind Speed mph	Wind Speed knots
5	≥156	≥135
4	131-155	114-134
3	111-130	96-113
2	96-110	84-95
1	74-95	65-83
Non-Hurricane Classifications		
Tropical Storm	39-73	34-64
Tropical Depression	0-38	0-33

Charley (4) moderate
Katrina (3) catastrophic
Ike (2) catastrophic

Other factors: bottom slope, landfall location

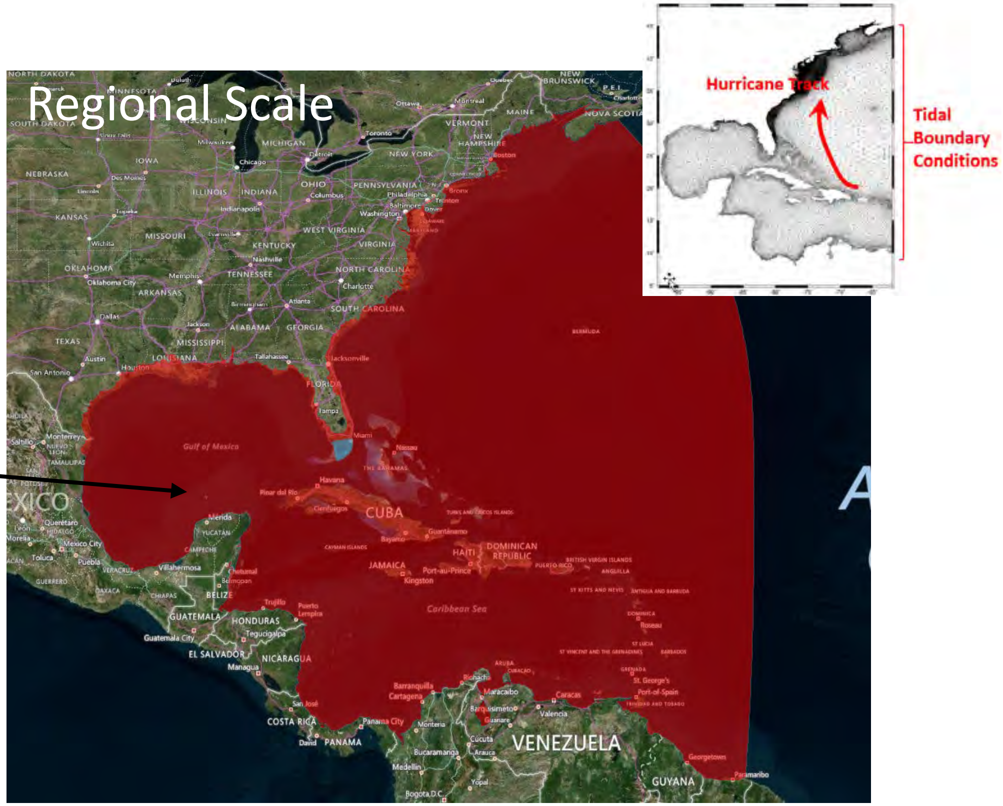
What about Waves?

- Breaking waves also contribute to the total water level through wave runup/setup

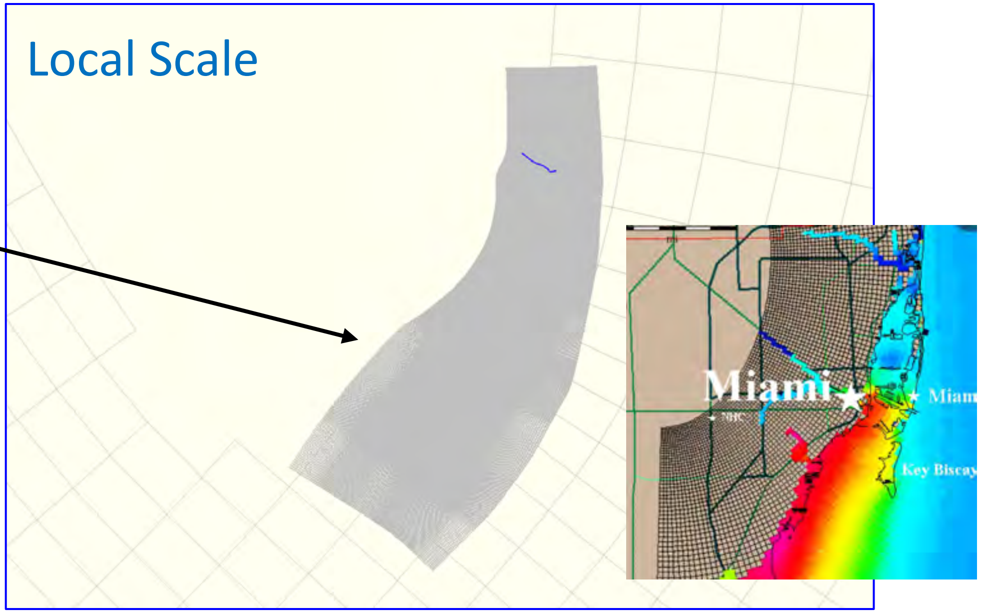


Two Scales of Models Coupling

- **Regional Scale**
  - ADCIRC--2D shallow-water equations based
  - SWAN--spectral wave model
  - Coupled ADCIRC & SWAN
  - Covers the western Atlantic Ocean and Gulf of Mexico
  - Includes Biscayne Bay
  - Some nearshore overland regions

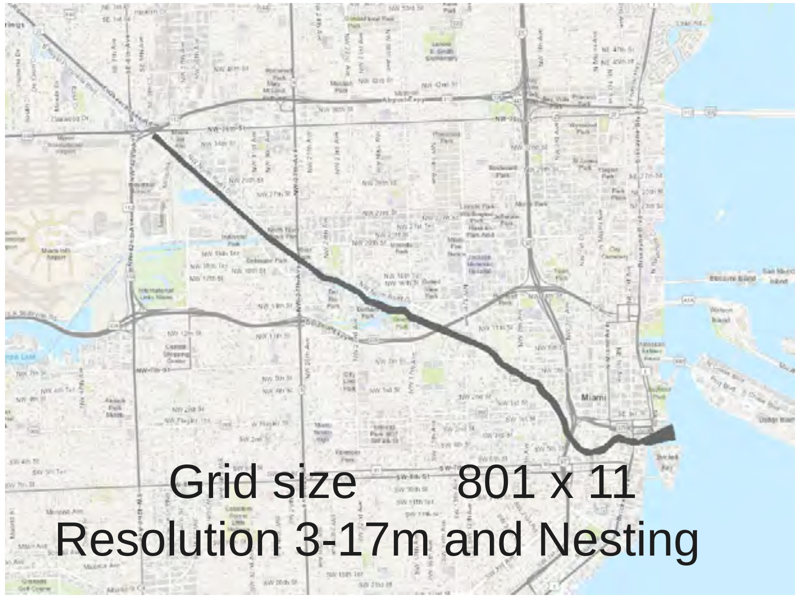


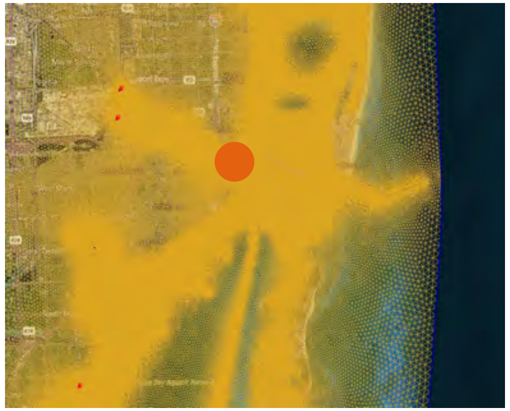
- **Local Scale**
  - DFLOW (Delft3D) FM hydrodynamic model
  - SWAN
  - Coupled DFLOW FM & SWAN
  - Highly refined in Biscayne Bay
  - Includes extensive overland areas
  - SFWMD canal network

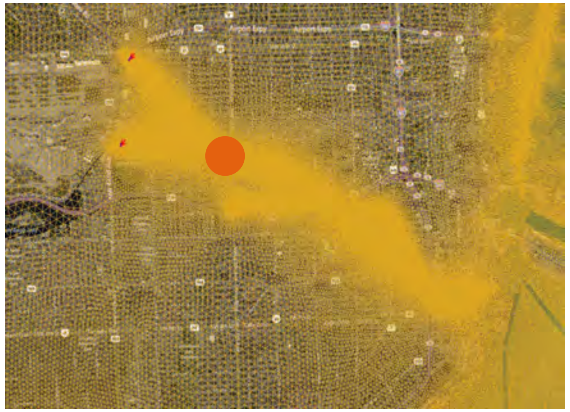


Local Scale Modeling

- D-Flow FM + SWAN (waves set up)
- Unstructured mesh with 1.8 M elements and 940K nodes
- Solves shallow water equations in 2D and 3D
- Adaptive time step
- Resolution 3 m (inland) to 0.5 km (offshore)
- 3D simulation with 7 vertical sigma layers
- Dynamic control of gate structures
- Uses ADCIRC+SWAN results as boundary condition



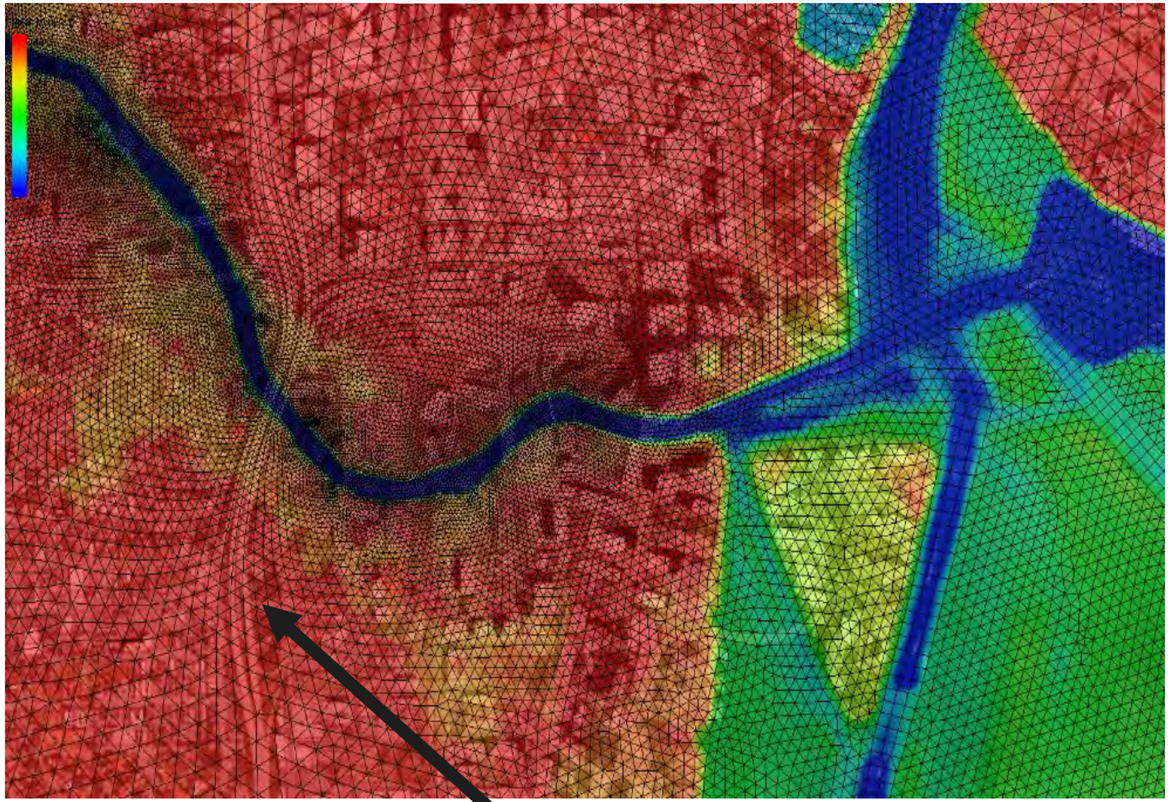




Zoom in

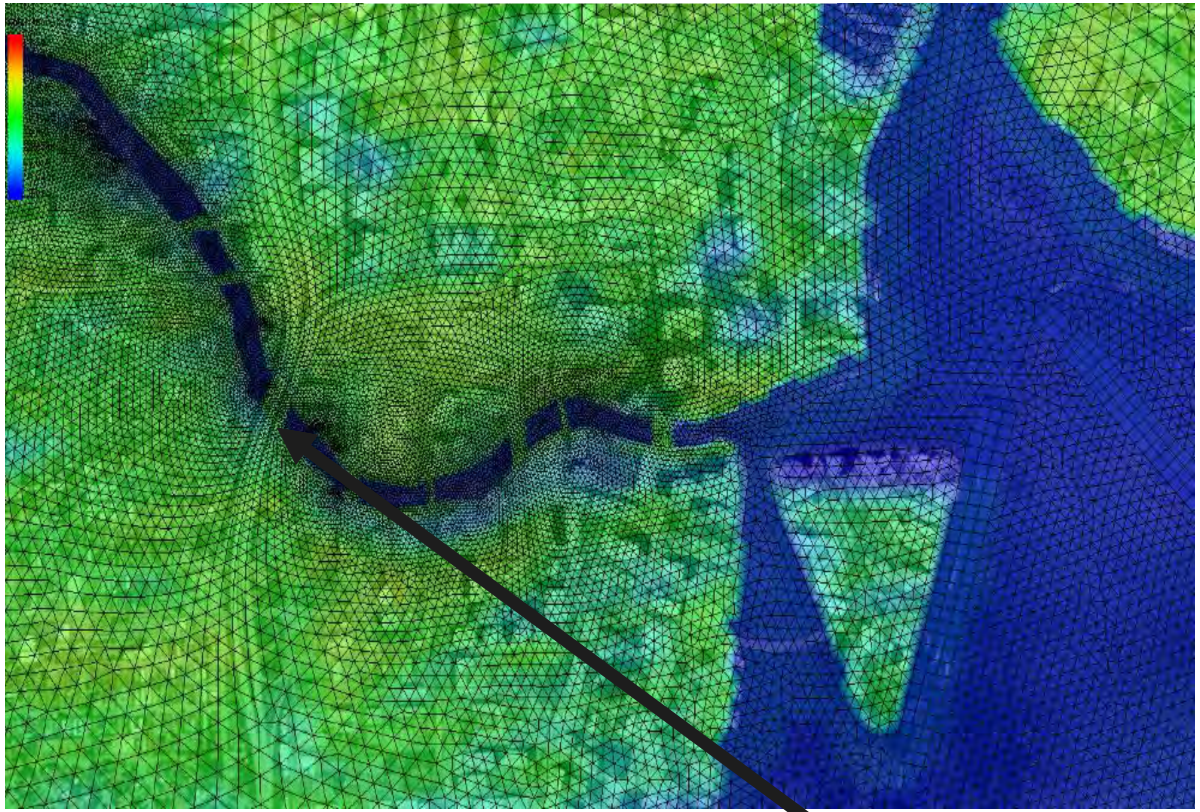
Model Topo and Friction

Topography



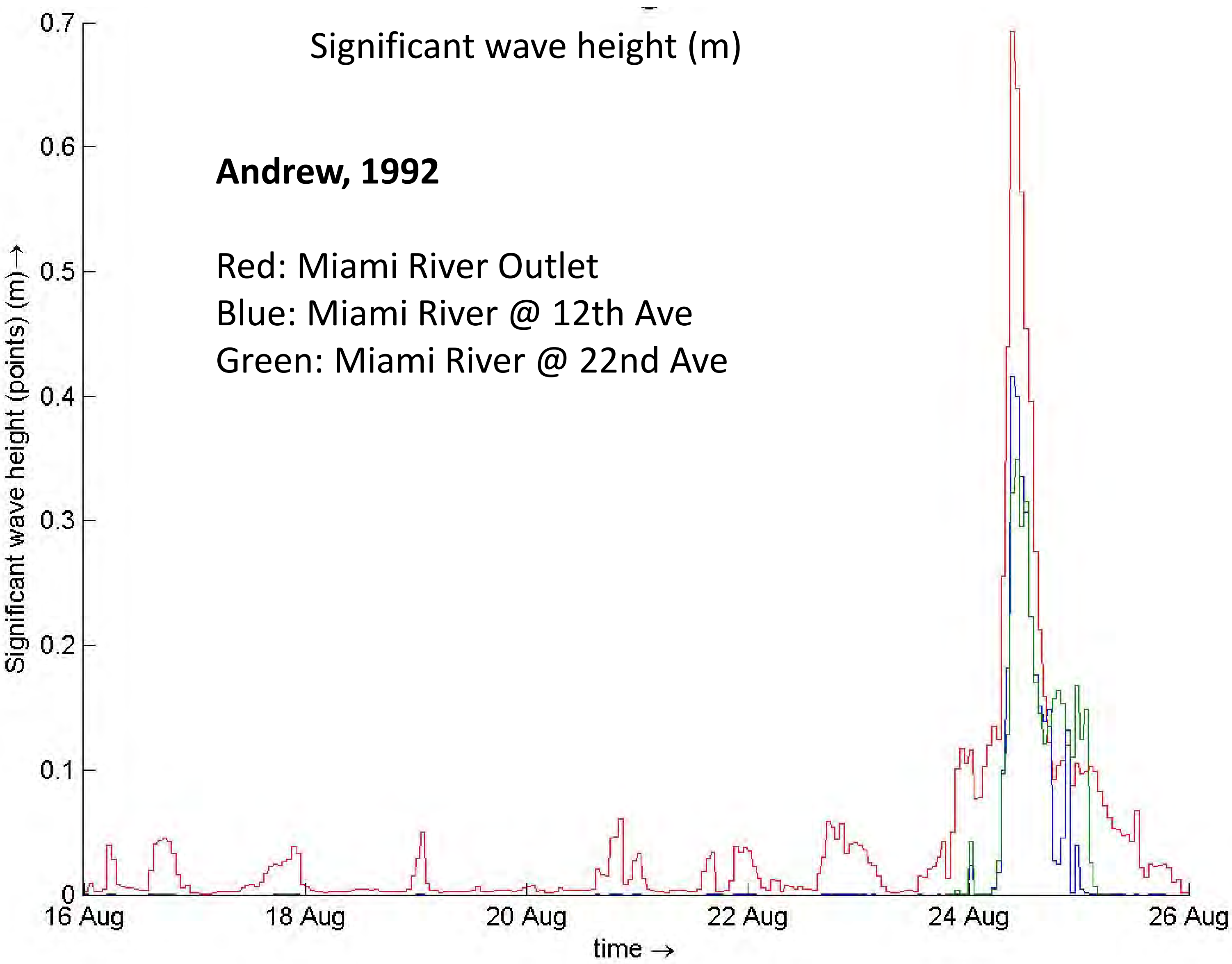
Mesh edges follow critical geometries

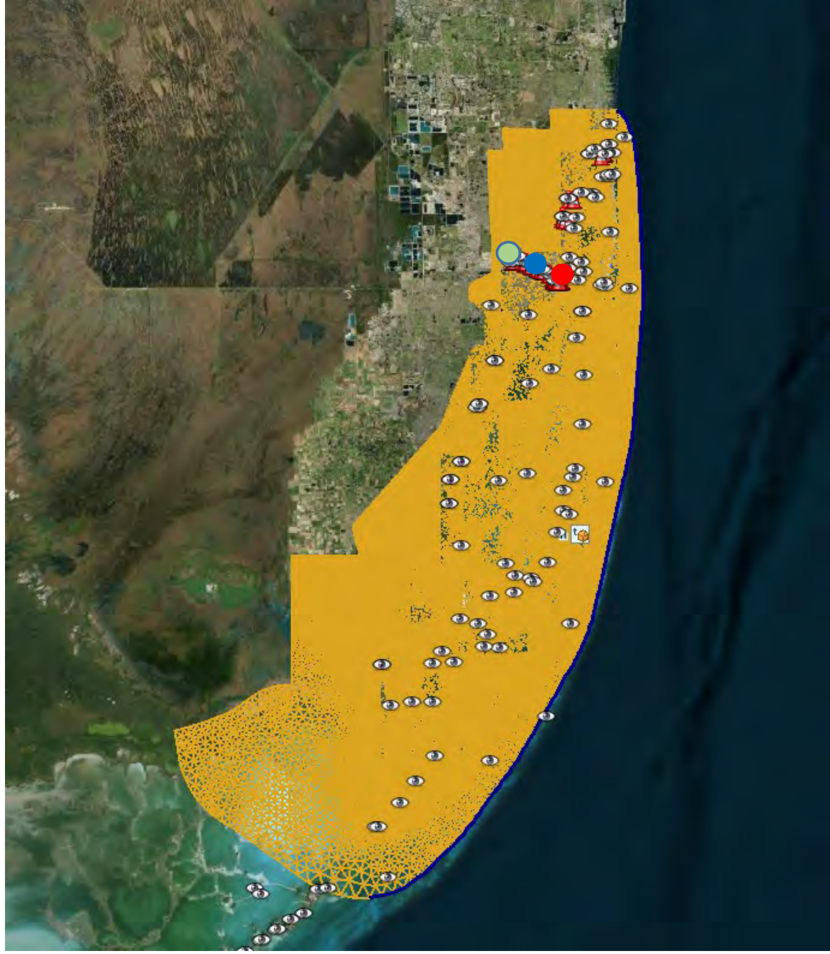
Bottom Friction



Frictional resistance and dry cells added at bridge crossings

Hurricane-induced wave height along Miami River



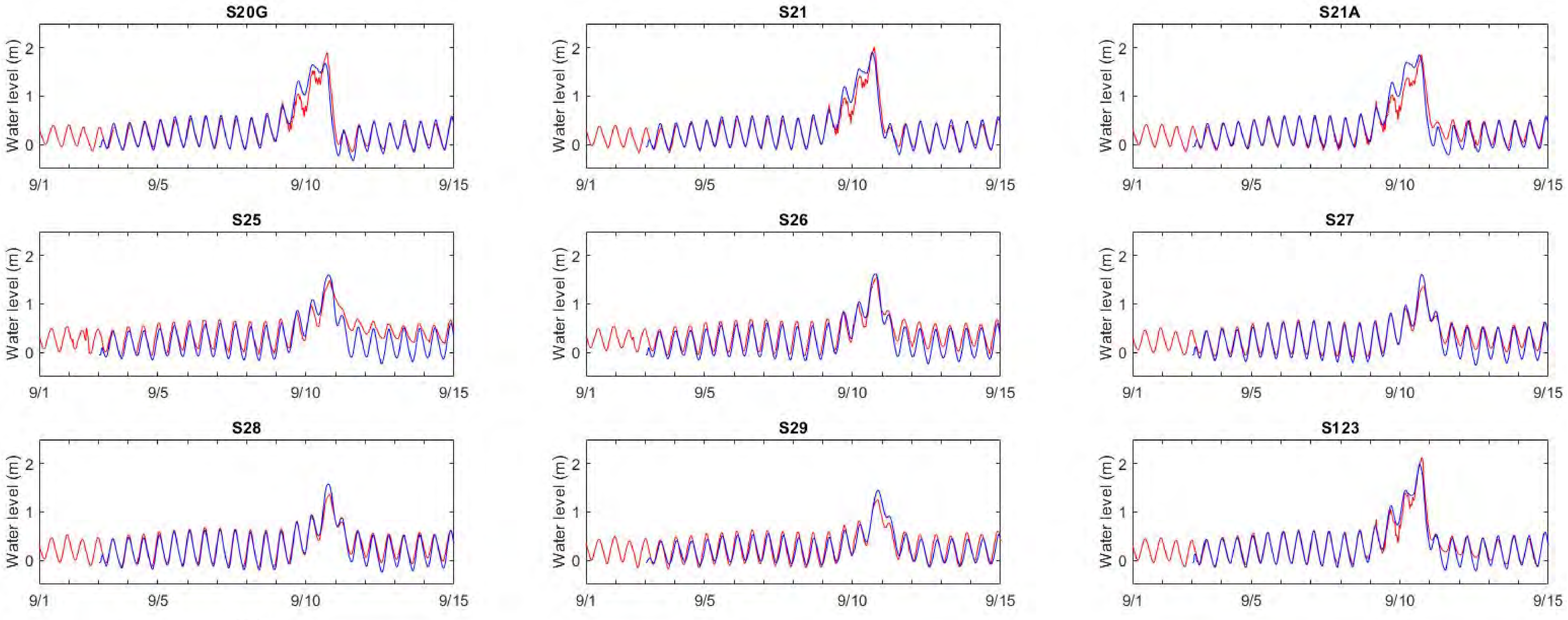


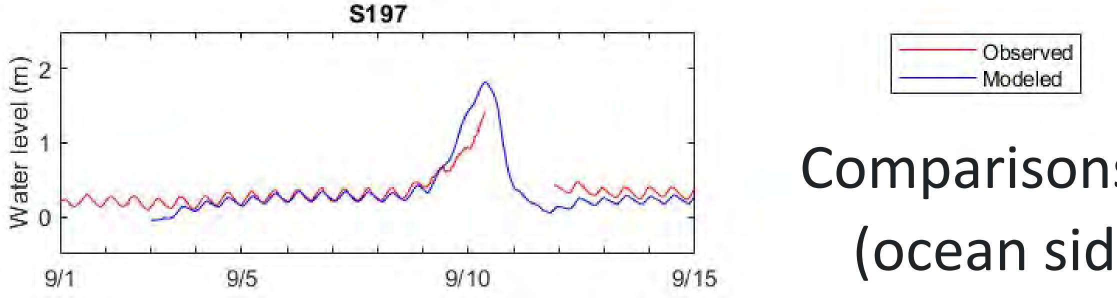
Model Application -- Hurricane Irma (2017)

Tropical depression(≤38 mph) Tropical storm(39–73 mph) Category 1 (74–95 mph) Category 2 (96–110 mph) Category 3 (111–129 mph) Category 4 (130–156 mph) Category 5 (≥157 mph)

The track of Hurricane Irma (2017). (Source: https://en.wikipedia.org/wiki/Hurricane_Irma#/media/File:Irma_2017_track.png

Irma (2017)

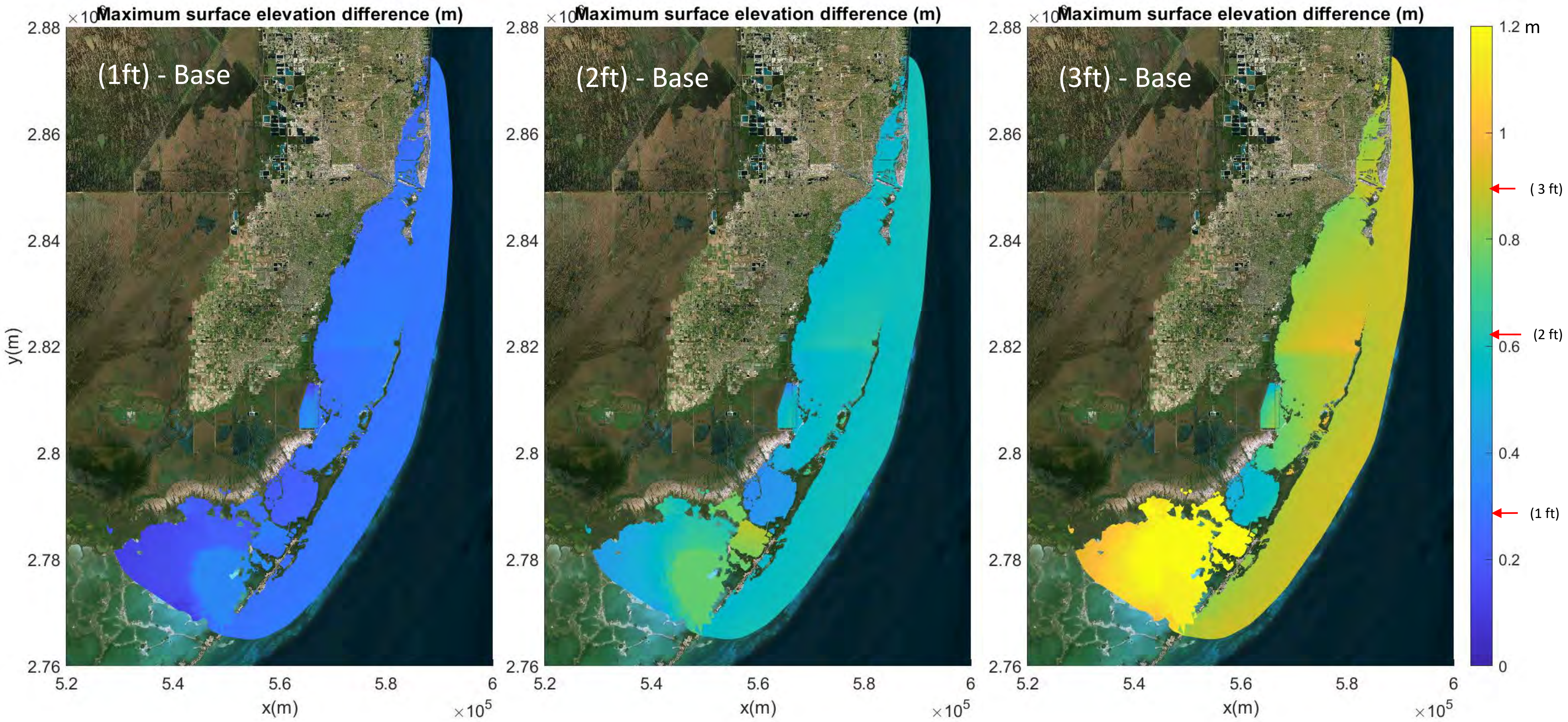




Comparisons of tailwater level (m) at ten gates (ocean side) during Hurricane Irma (2017).

Model Application -- Sea level rise scenarios (1ft, 2ft & 3ft)

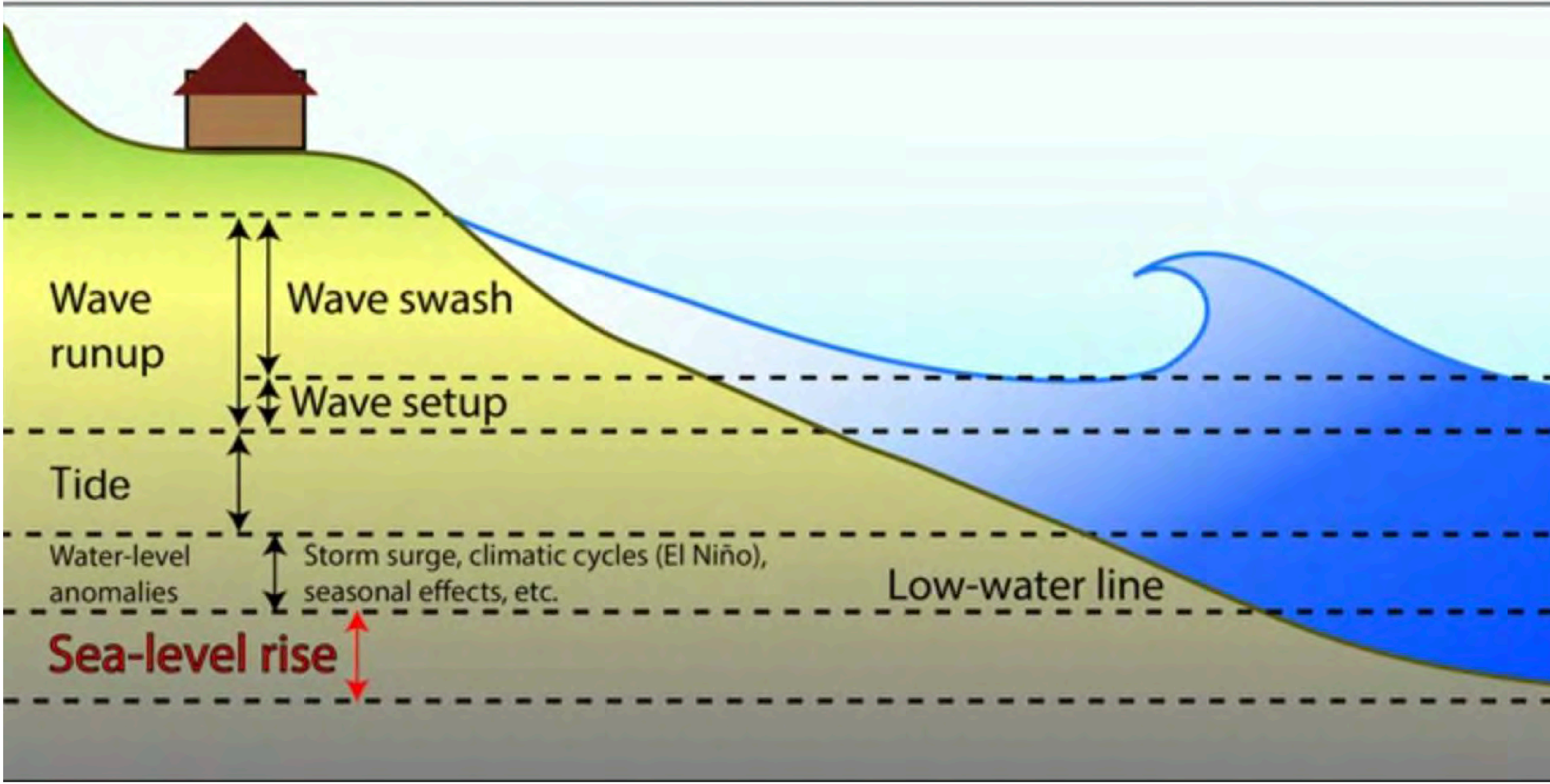
Tulane University



Summary

- Biscayne Bay Storm Surge Model has been calibrated and validated.
- The model has successfully been applied to Irma (2017) and Bertha (2020) hindcast storm surge studies for FPLOS project
- The model is ready for use to examine individual regions in more detail or to look at wider range of return periods as well as land use planning and to support other resiliency projects
- This model can further be extended to other regions such as coastal Broward county, and also to dynamically simulate gate operations and resulting flows.

QUESTIONS ?


Wave runup
Wave swash
Wave setup
Tide
Water-level anomalies
Storm surge, climatic cycles (El Niño), seasonal effects, etc.
Low-water line
Sea-level rise

Questions?