South Florida’s Response to Predicted Sea Level Rise

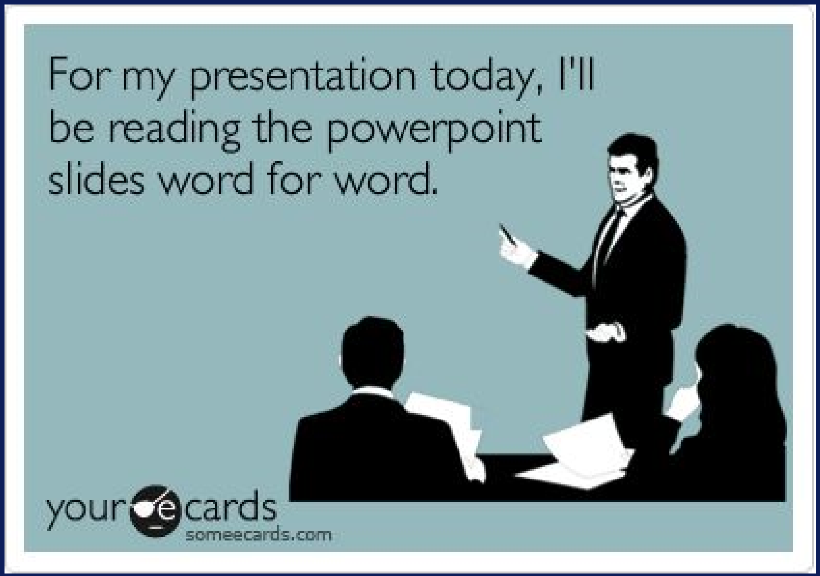
S-29 Forward Pump Station (North Miami Beach)

Garrett Litteken, P.E., CFM

Special Mention: Brian Wozniak, P.E., CFM

Presentation Outline

- Project Background
- Project Scope
  - 2-D Modeling Approach (Original)
- Pump Station Options
- Preliminary Results
- Hydrographs and Boundaries
  - Project Delays
- Expanded Scope
- Variables (Complex)
- HEC-RAS 2D
- Results and Conclusions
- Upcoming Scope



Unique forward pump stations will boost coastal structures' resiliency for future sea level rise

October 18, 2022

Studies suggest that sea levels will rise by a meter or more by the year 2100, threatening trillions of dollars' worth of assets. Long-term sea level rise is a critical threat to coastal areas and poses severe risks and challenges over the upcoming decades.

South Florida may face the adverse effects of sea level rise in the future, and without adaptation investments, the area's annual flood losses could exceed $25 billion by 2050. The South Florida Water Management District (SFWMD) has been making efforts to address these issues and has prepared a sea level rise and flood resiliency plan.

SFWMD has chosen two pilot locations to evaluate these first-of-their-kind forward pump stations. A team effort including Kimley-Horn and Hanson is designing one of these pilot locations at a gated structure in North Miami Beach, Florida. As part of the preliminary design, Hanson is developing a detailed 2D model to define a broad range of hydraulics that influence conditions leading to the pump intake and the discharge to the canal from a concentrated, high-velocity flow through the structure.

This thorough hydraulic model will provide a comprehensive look at how the flood control infrastructure will handle rising sea levels. Hanson is evaluating the gated structure's capacity and a proposed pump station under current conditions and with the consideration of 1 foot to 3 feet of sea level rise. The model's results will help determine the hydraulic transitions of the proposed intake and outflow channels. The 2D hydraulic model will be used in the project's design to support the inflow assumptions for 3D computational fluid dynamics and in physical models to evaluate more detailed hydraulics within the intake bays and pump station.

Learn about increasing the resiliency of coastal structures from Garrett Litteken at glitteken@hanson-inc.com and Brian Wozniak at bwozniak@hanson-inc.com.


Interstate-95
S-29 Gates
C-9 Canal
Aventura
Ojus
Seguro Social
Saint Lawrence Elementary School
Yeshiva Toras Chaim Toras Emes
Greynolds Park
North Miami Beach Building Department
East Greynolds Park
Judge Arthur Snyder Tennis Center
North Miami Beach Tennis Center
North Miami Beach High School
COLLAB CHURCH
Nova Southeastern University
Snake Creek Park
Planet Fitness
Founders Park
Google
Landsat / Copernicus

Direct Connection to Tide
S-29 Gates
C-9 Canal
Newport Fishing Pier
Haulover Nude Beach
Sunny Isles Beach
Oleta River Outdoor Center
Fish & Wildlife Conservation
Glenn Hubert Library
Oleta River State Park
FIU Biscayne Bay Campus
The Church of Jesus Christ of La
Maule Lake
Valente Brothers
Alyssa's Island
Greynolds Park
East Greynolds Park
North Miami Beach Tennis Center
Judge Arthur Snyder Tennis Center
Google
Imagery date: 12/11/18
Data SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat / Copernicus
300 m
Camera: 979 m 25°55'28"N 80°08'39"W
13 m

https://www.climate.gov/maps-data/dataset/sea-level-rise-map-viewer

- Data Snapshots
- Dataset Gallery
- Climate Data Primer
- Global Climate Dashboard
- Tools & Interactives

Sea Level Rise - Map Viewer

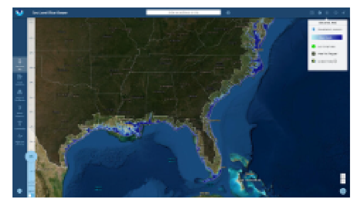
Sea Level Rise and Coastal Flooding Impacts

NOAA's Sea Level Rise map viewer gives users a way to visualize community-level impacts from coastal flooding or sea level rise (up to 10 feet above average high tides). Photo simulations of how future flooding might impact local landmarks are also provided, as well as data related to water depth, connectivity, flood frequency, socio-economic vulnerability, wetland loss and migration, and mapping confidence. The viewer shows areas along the contiguous United States coast, except for the Great Lakes.

Where do these data come from?

The maps are produced using detailed elevation maps with local and regional tidal variability.

EXAMPLE IMAGE



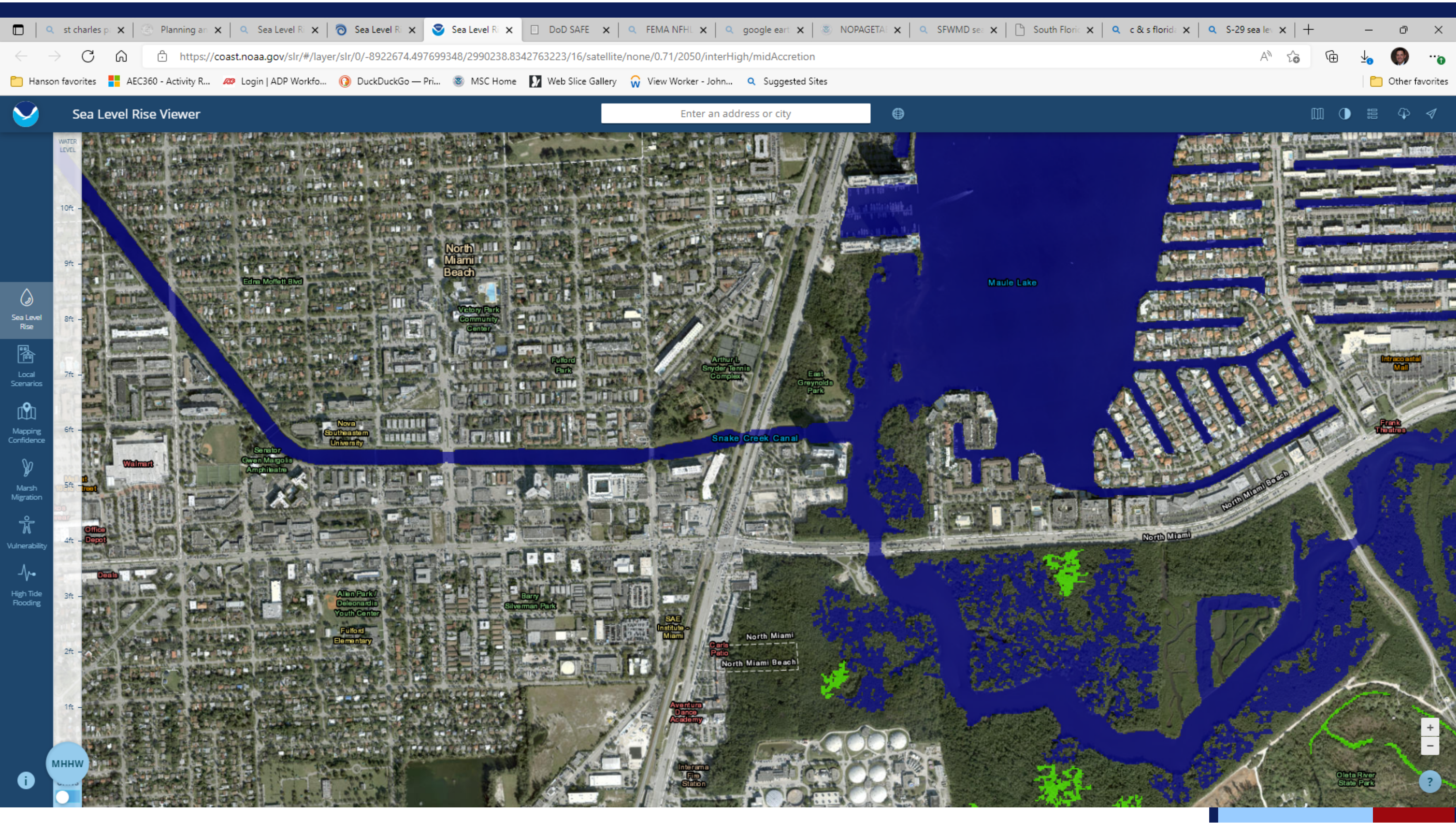
Click to see more detail

DIRECT LINK

Sea Level Rise Map Viewer

COVERAGE

US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Sea Level Rise Viewer
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Sea Level Rise
Local Scenarios
Mapping Confidence
Marsh Migration
Vulnerability
High Tide Flooding
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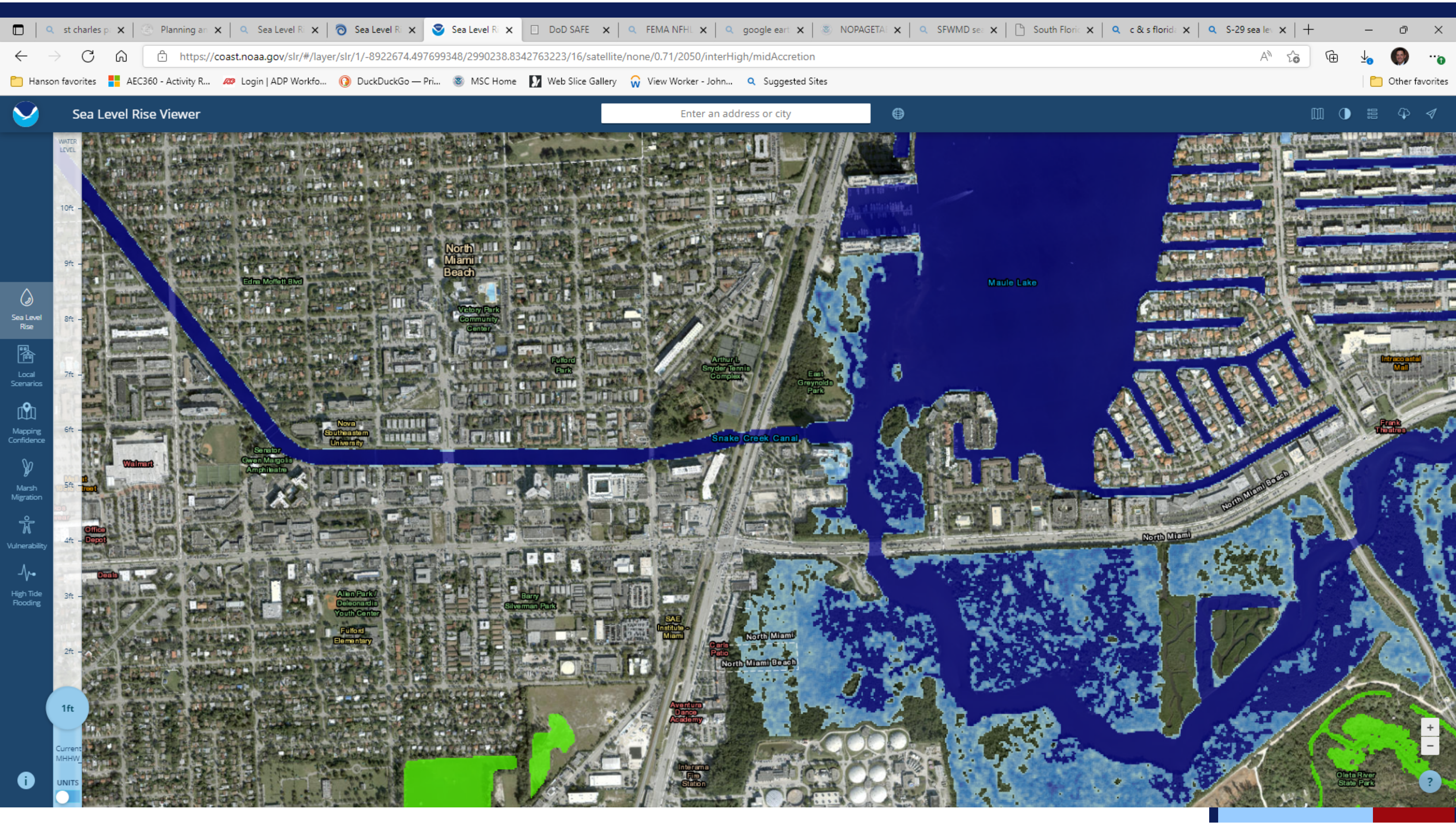
MHHW
North Miami Beach
Edna Moffett Blvd
Victory Park Community Center
Fulford Park
Arthur L Snyder Tennis Complex
East Greynolds Park
Maule Lake
Intracoastal Mall
Frank Theatres
Snake Creek Canal
Nova Southeastern University
Senator Gwen Margolis Amphitheatre
Walmart
Office Depot
North Miami Beach
North Miami
Allen Park / Deleonardis Youth Center
Barry Silverman Park
Fulford Elementary
SAE Institute - Miami
Aventura Dance Academy
Interama Fire Station
Oleta River State Park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Other favorites
Sea Level Rise Viewer
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Sea Level Rise
Local Scenarios
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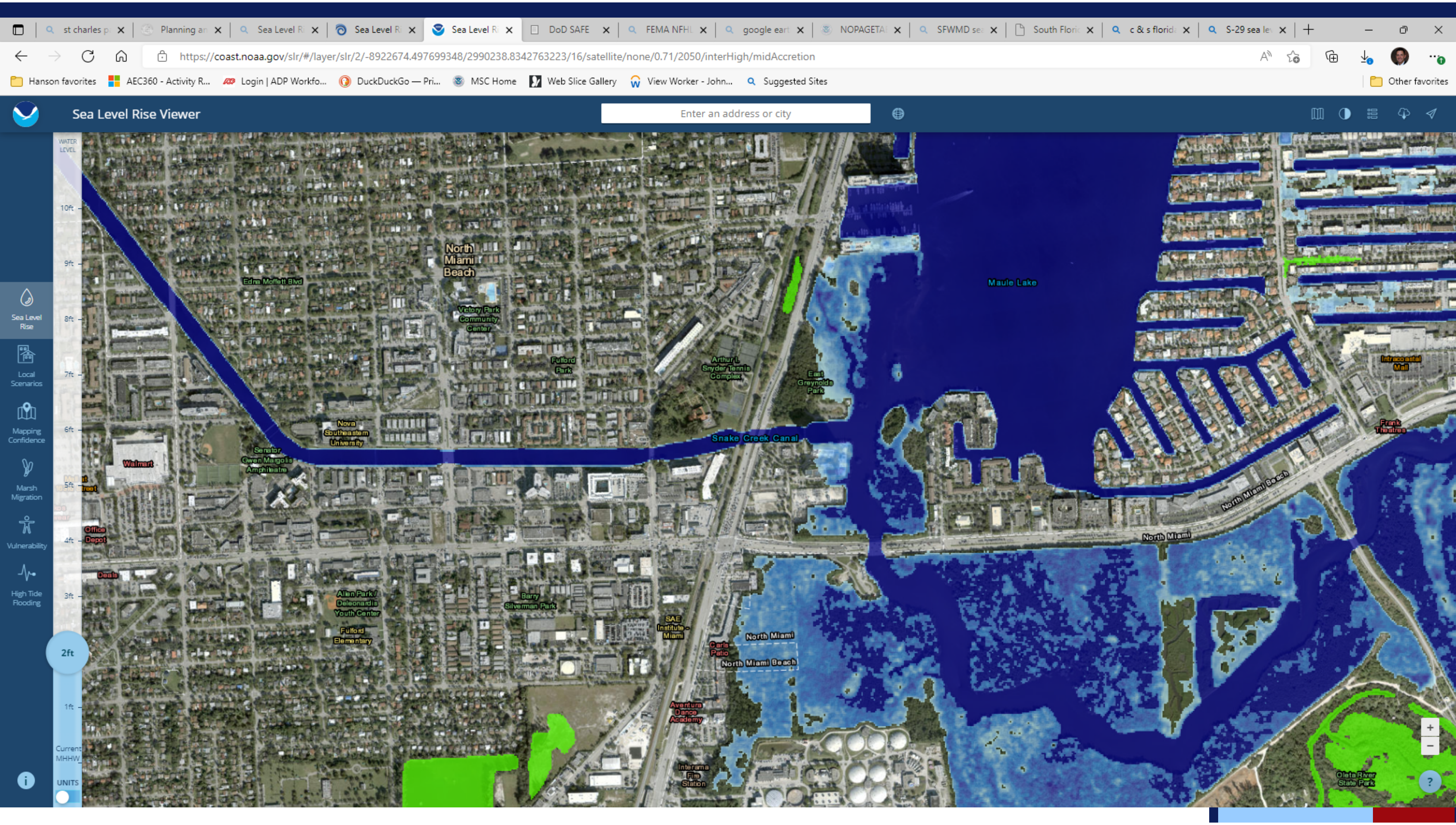
Carla Patio
North Miami
North Miami Beach
Aventura Dance Academy
Interama Fire Station
Oleta River State Park



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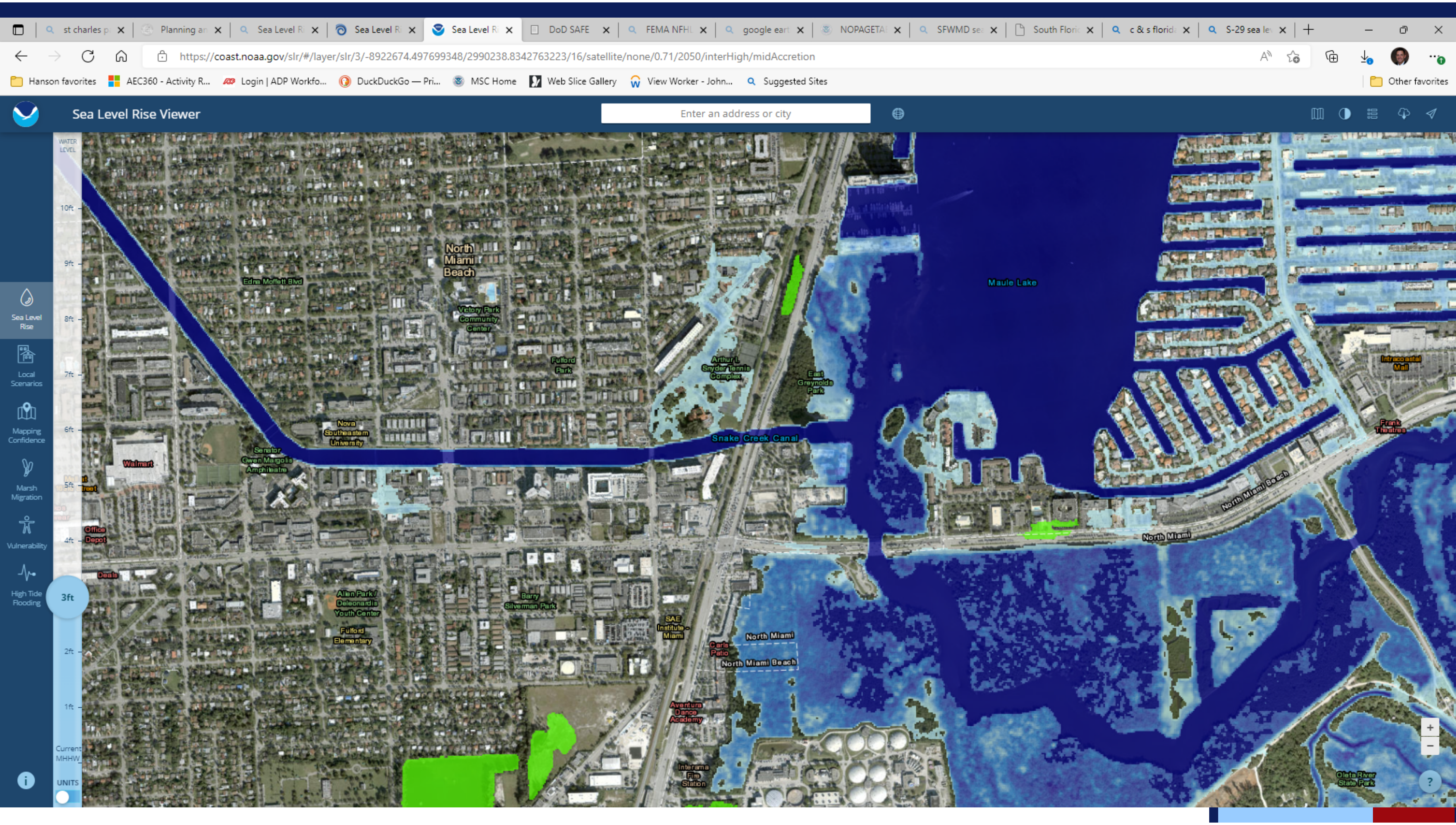
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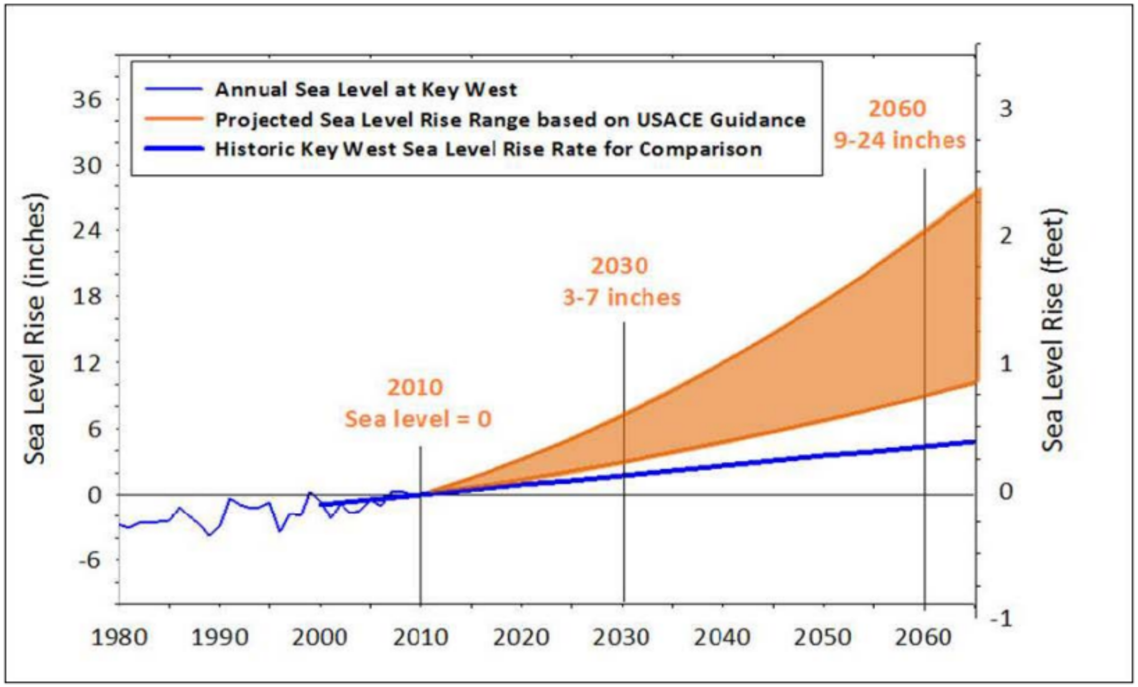
Sea Level Rise Projection



Developed by the Southeast Florida Regional Climate Compact counties and partners, this projection is based on historic tidal information from Key West. It was calculated using U.S. Army Corps of Engineers Guidance Document intermediate and high curves to represent the lower and upper bound for projected sea level rise in Southeast Florida. The rate of sea level rise from Key West over the period of 1913 to 1999 is extrapolated to show how the historic rate compares to projected rates.

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 acres water storage area
- Water Conservation Areas
  - 959,000 acre water storage

History How the Program Came About

Aging Infrastructure

- C&SF Project designed and built 60+ years ago
- Approaching end of design life

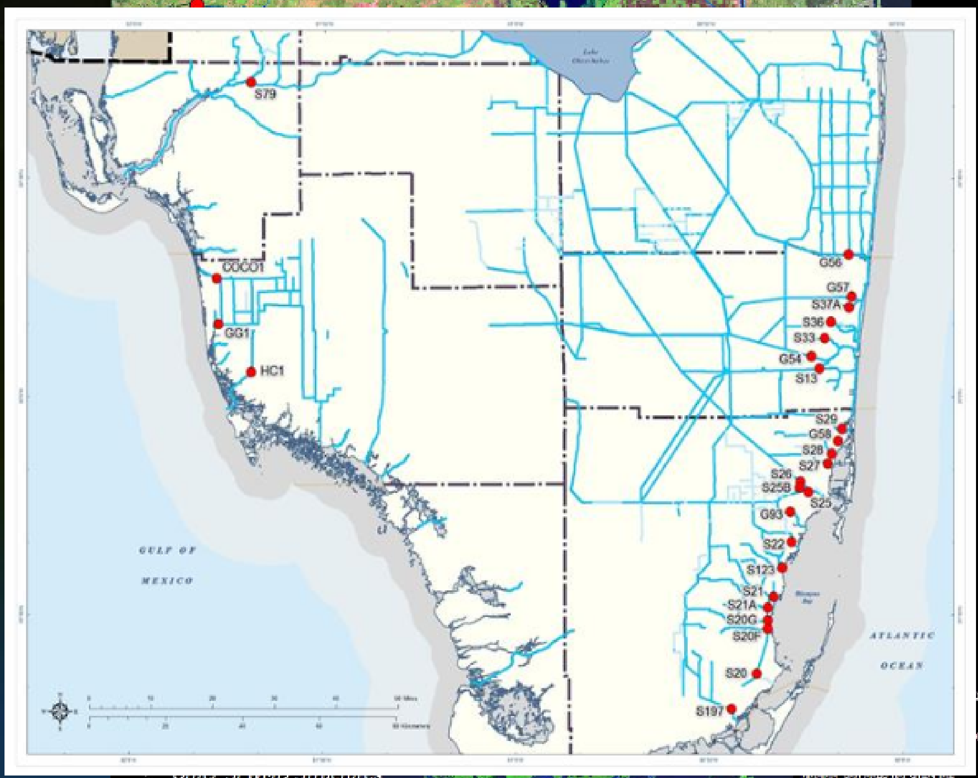
Obsolete Assumptions

- Original design did not account for the sea level rise
- Original design for a population of 2 million people
- Original projections were for less urban development than has occurred over the years

Vulnerable to SLR

- Several low-lying structures determined to be vulnerable to SLR

Low-lying Tidal Structure Assessment

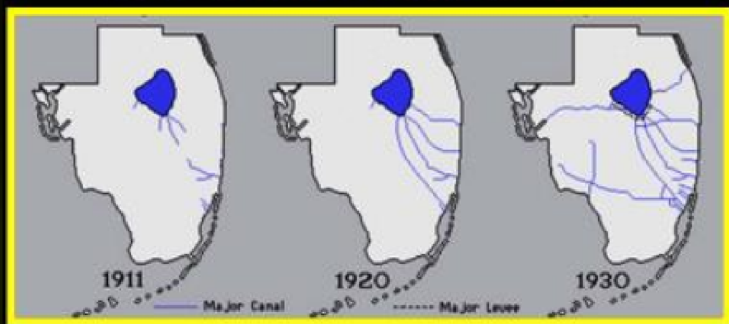


SFWMD Canals

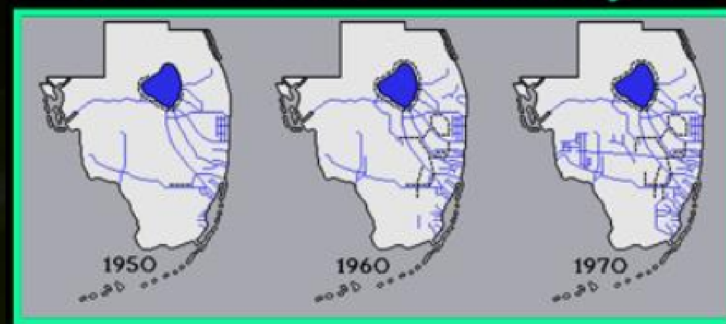
Presenter: Akintunde Owosina

Recognizing Changed Conditions

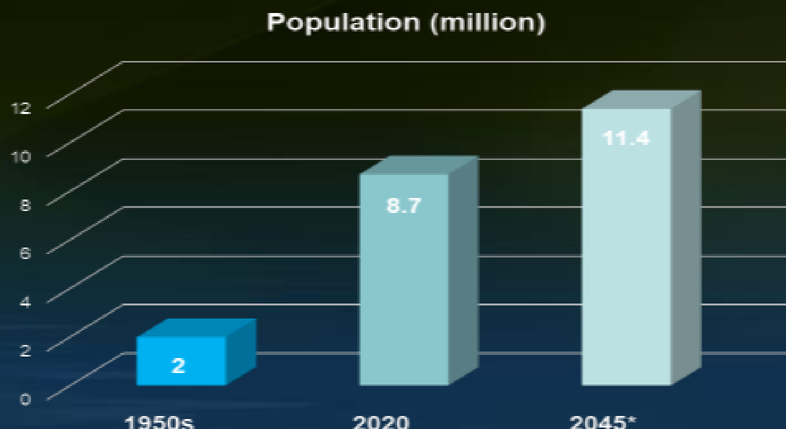
Pre-1948 Drainage Projects



Post-1948 C & S Florida Project



LAND DEVELOPMENT & POPULATION GROWTH



* Estimate taken from BEBR 2017 publication (Median, SFWMD boundaries)

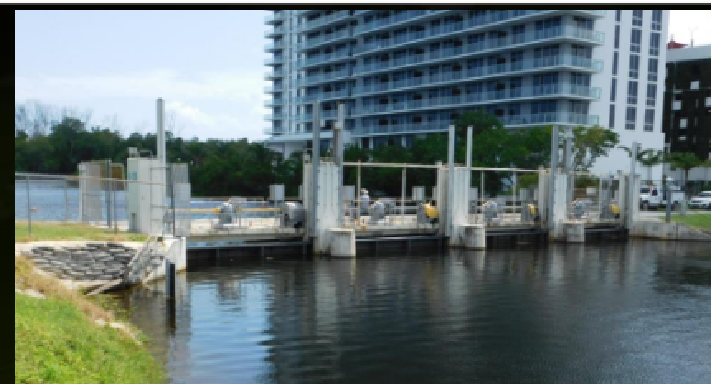
Presenter: Carolina Maran

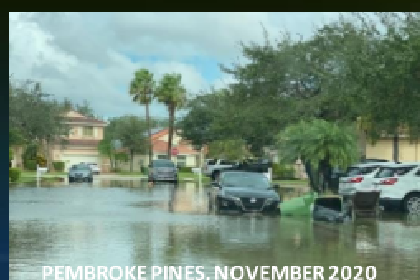
Current Limitations in C&SF Operation

Reduction in Discharge Capacity as a Result of SLR

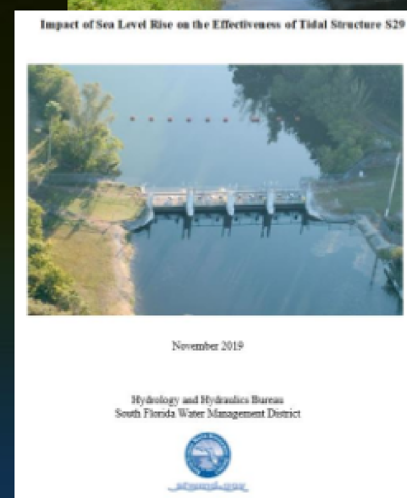
S29 Coastal Structure Resiliency

- Benefiting Broward & Miami Dade Counties
  - C9 Basin: fully developed, primarily residential and commercial uses, 450K people, 100 square miles
- Enhancing Coastal Structure (elevating gates and other equipment)
- Forward pump (2000cfs) and back up generator
- Flood Barrier (tie back to higher land)
- Real Estate Needs
- Currently in Design





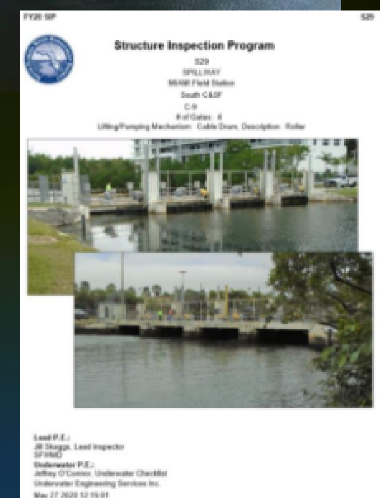
PEMBROKE PINES, NOVEMBER 2020



Impact of Sea Level Rise on the Effectiveness of Tidal Structure S29

November 2019

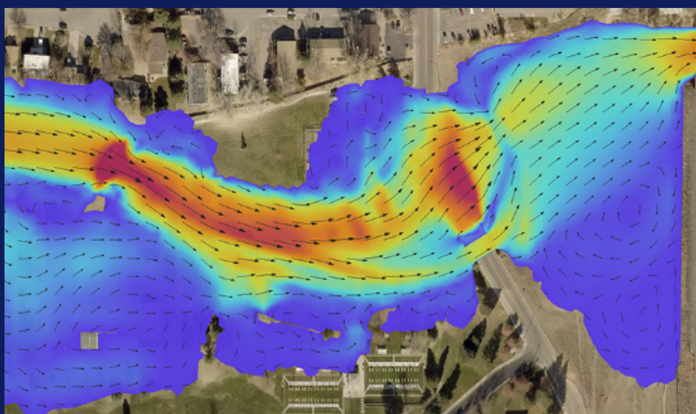
Hydrology and Hydraulics Bureau
South Florida Water Management District

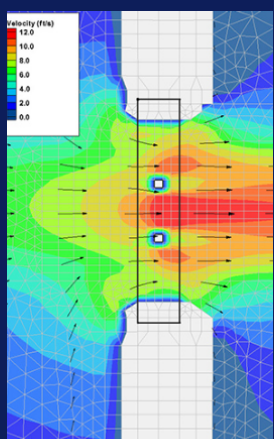


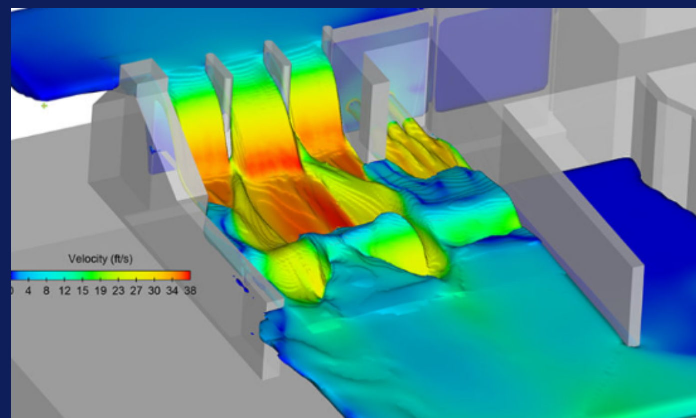
Structure Inspection Program

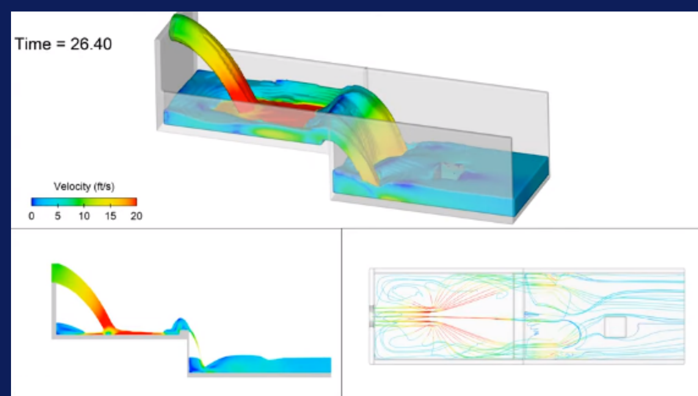
Project Scope

2D (x-y) → 3D (CFD) (x-y-z) → Physical







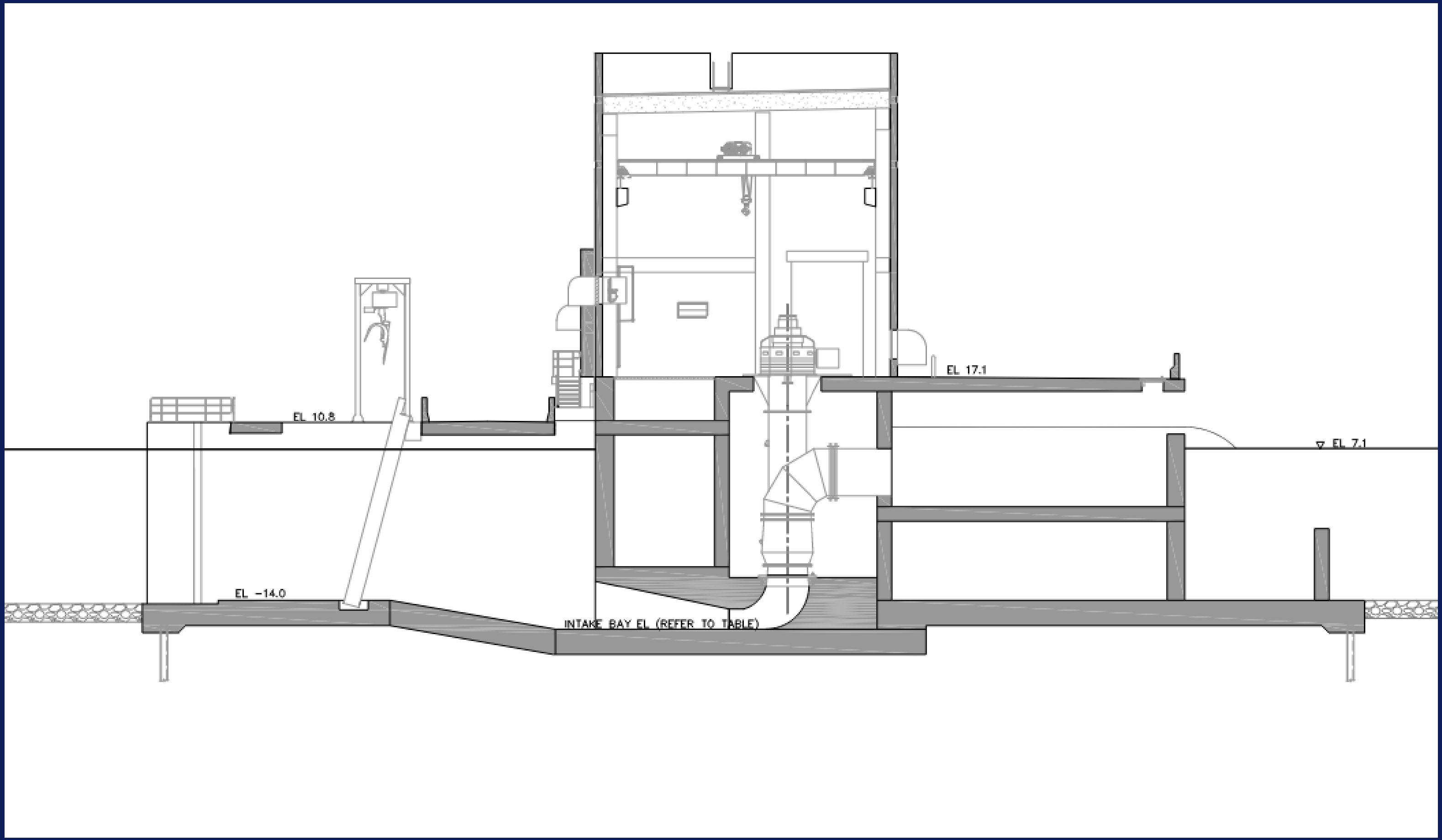


CEH
CLEMSON ENGINEERING HYDRAULICS

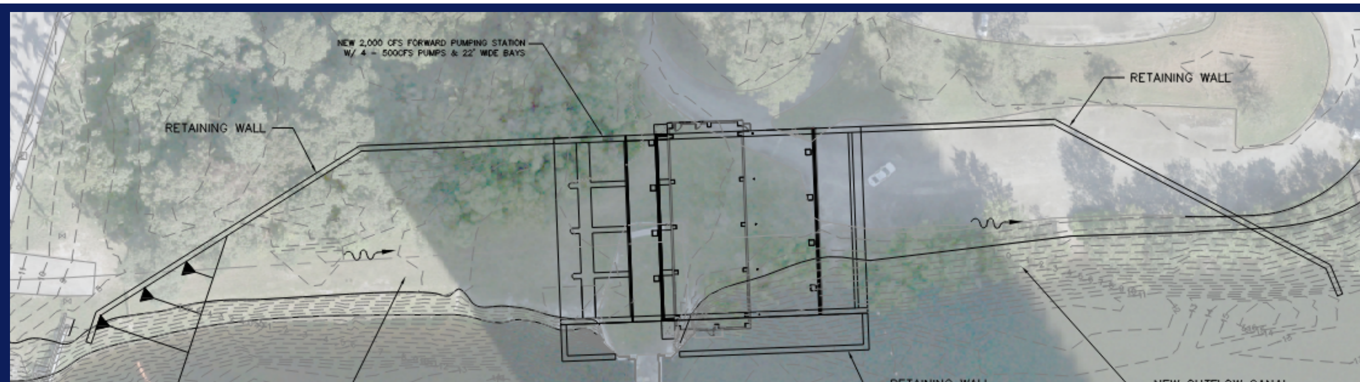
C-9 Canal and S-29 Gates

- C-9 Canal
  - Existing Gates
  - Saltwater Intrusion
- S-29 Pump Station
  - Flood Protection

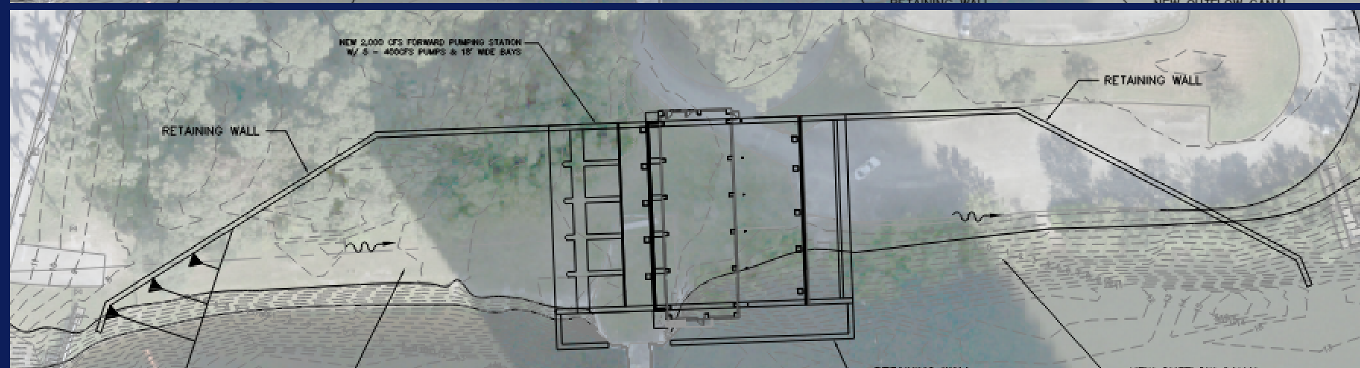
Preliminary Design for Modeling



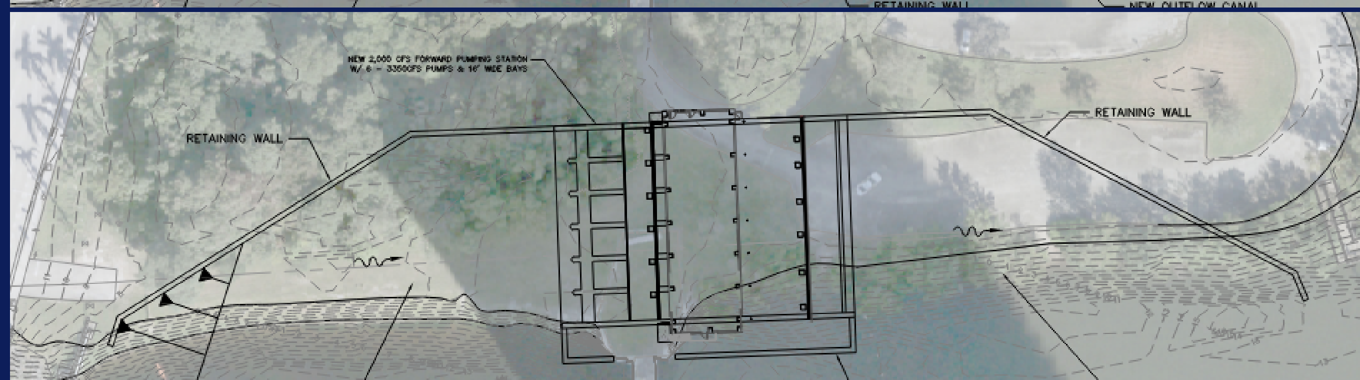
4 Pump Bays – 500-cfs pumps



5 Pump Bays – 400-cfs pumps

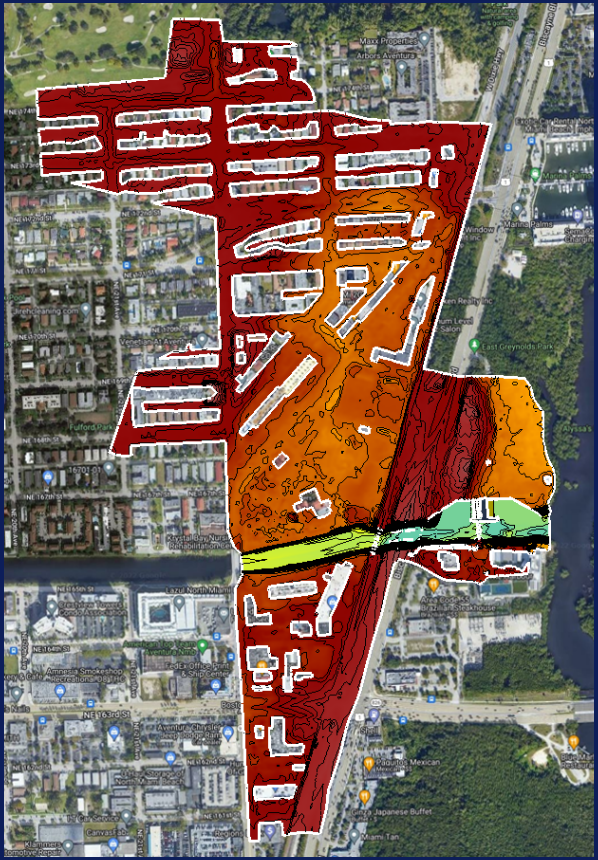


6 Pump Bays – 335-cfs pumps



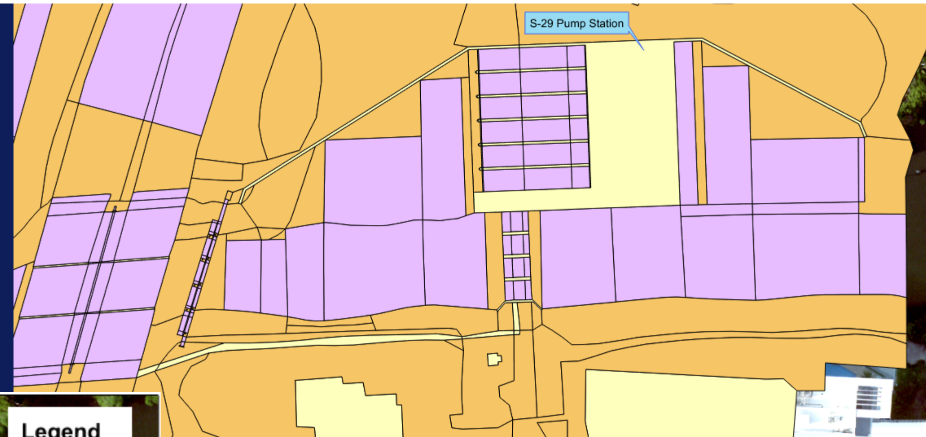
Project Scope – 2D Model

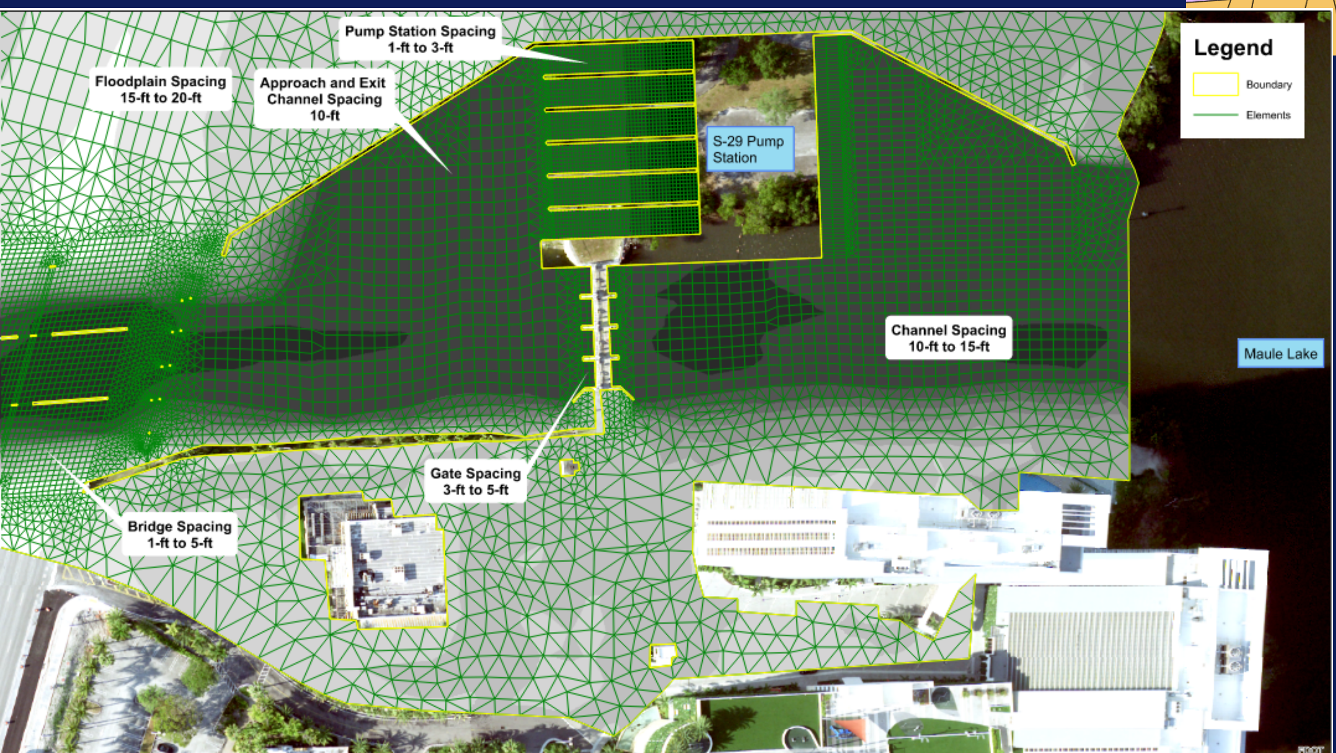
- Develop 2-D Model
  - – Evaluate layout for horizontal eddies and optimize and evaluate bridges and canal impacts leading into/out of proposed pump location
- Model Limits
  - 2100 ft upstream S-29
  - 1400 ft downstream S-29



SRH-2D Model Documentation

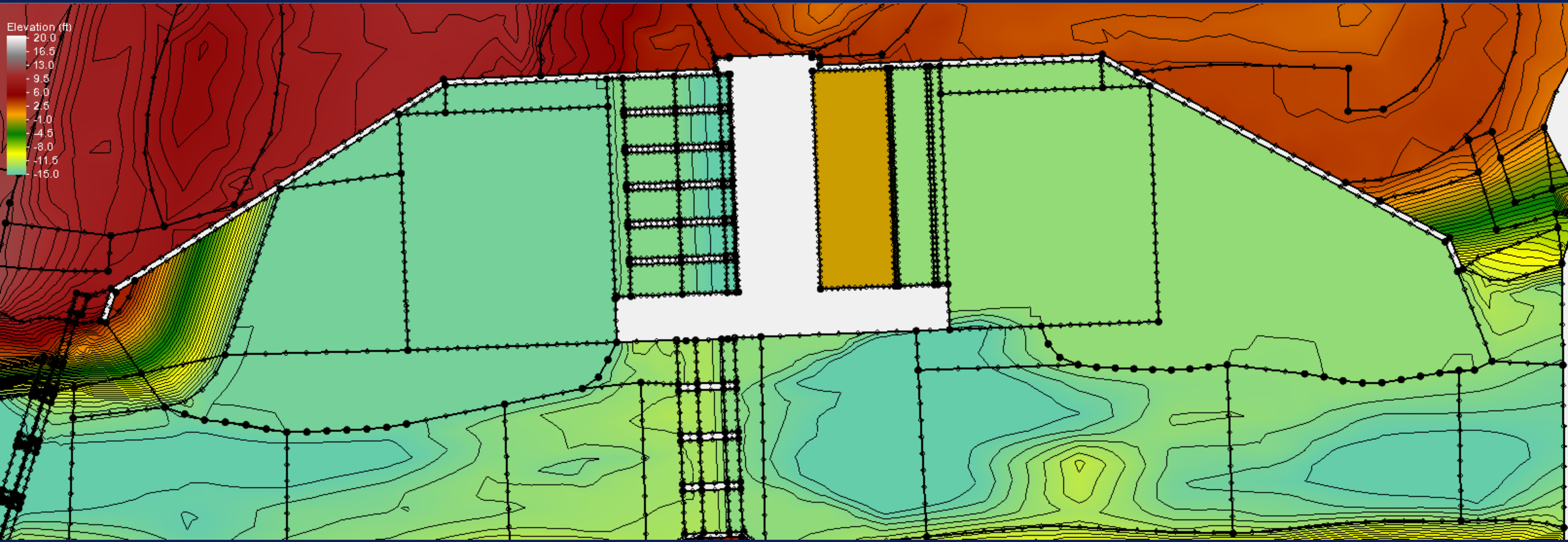
Computational Node and Elements	
Number of Elements	35124
Number of Nodes	23142
Element Type	linear
Number of Triangular Elements	27653
Number of Quadrilateral Elements	7471





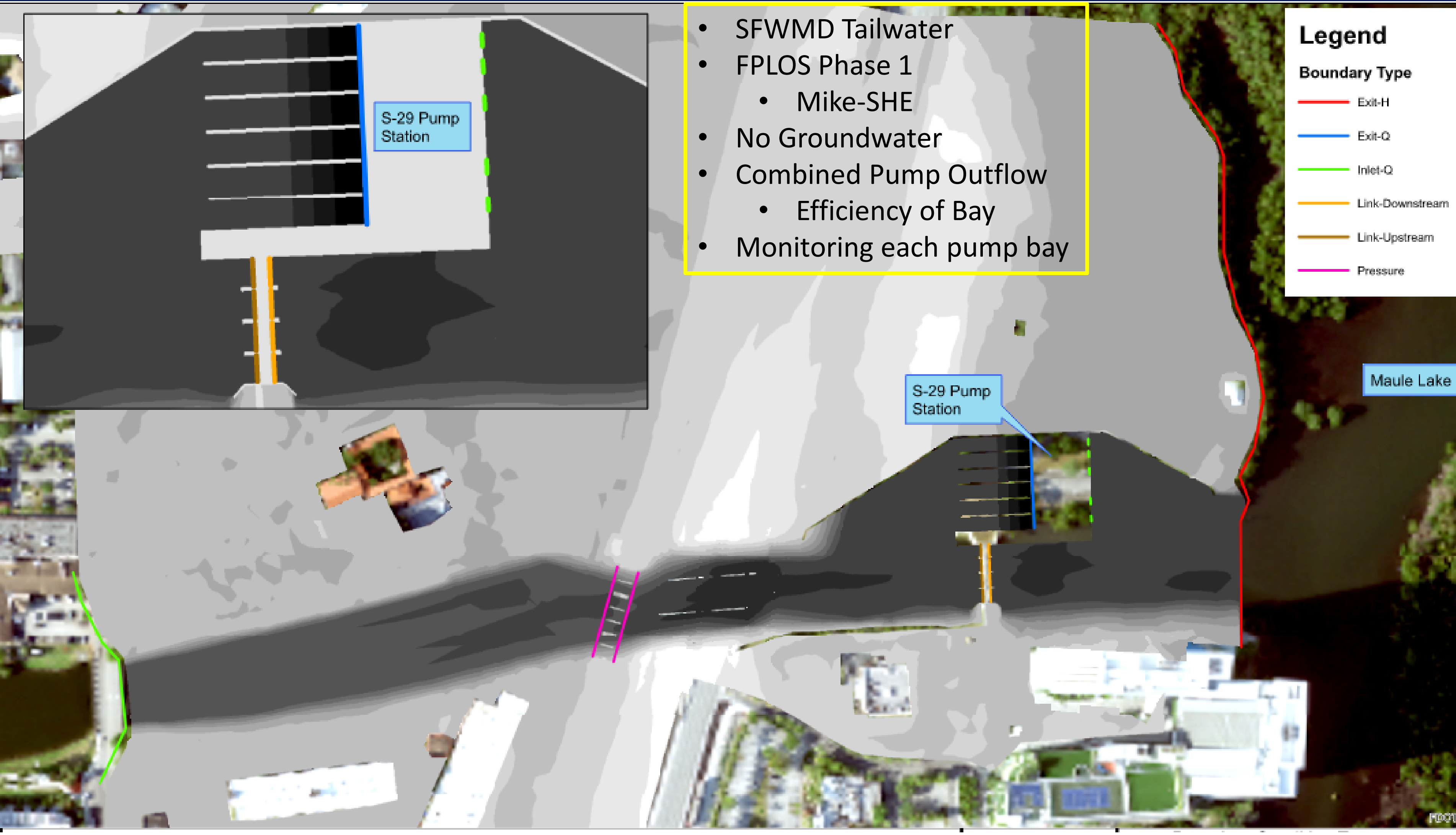
SRH-2D

- Each option requires unique mesh, terrain, and boundary conditions

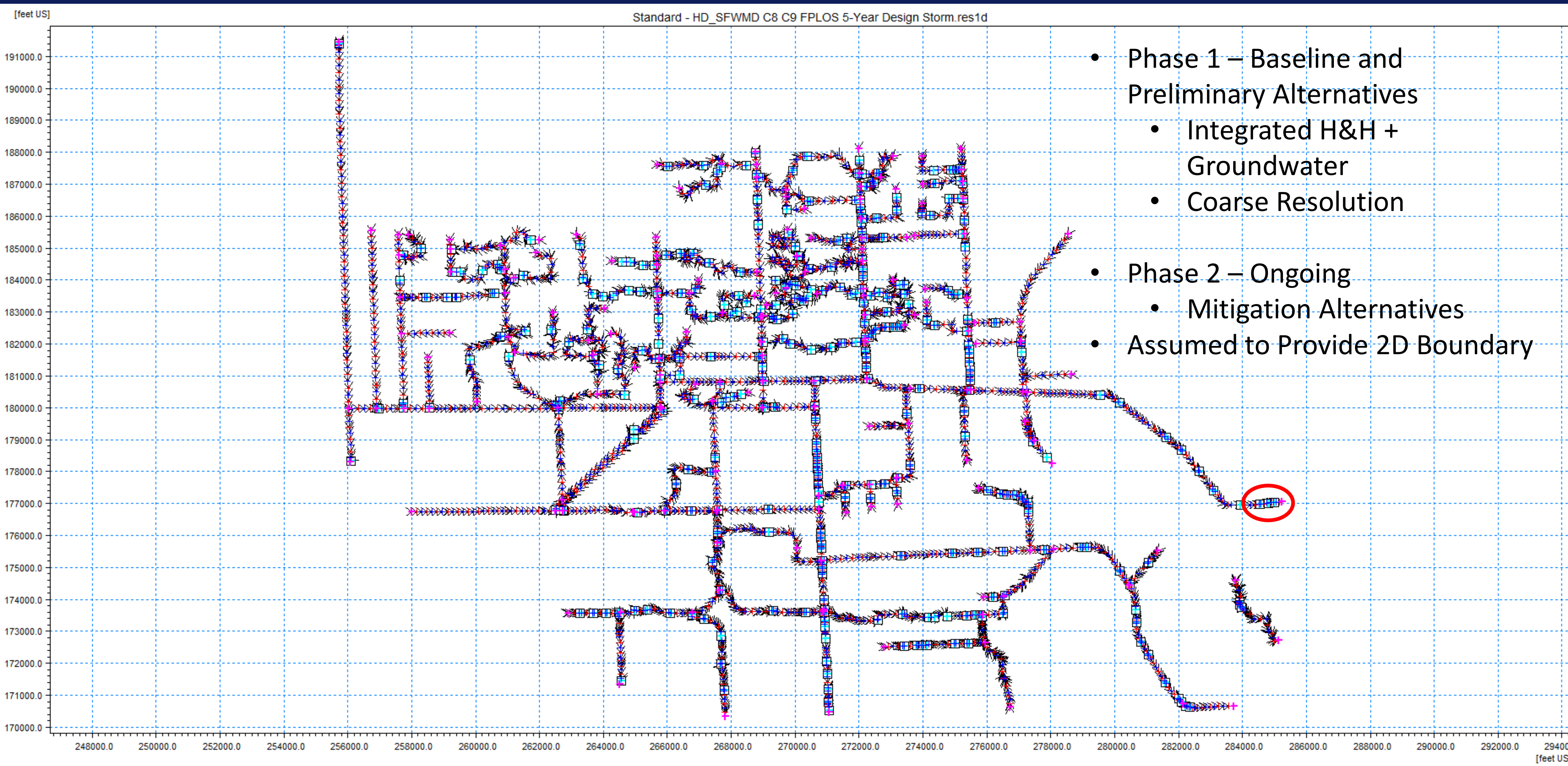


Boundary Conditions

- SFWMD Tailwater
- FPLOS Phase 1
  - Mike-SHE
- No Groundwater
- Combined Pump Outflow
  - Efficiency of Bay
- Monitoring each pump bay



Mike-She & FPLOS



- Phase 1 – Baseline and Preliminary Alternatives
  - Integrated H&H + Groundwater
  - Coarse Resolution
- Phase 2 – Ongoing
  - Mitigation Alternatives
- Assumed to Provide 2D Boundary

FPLOS Boundary Conditions

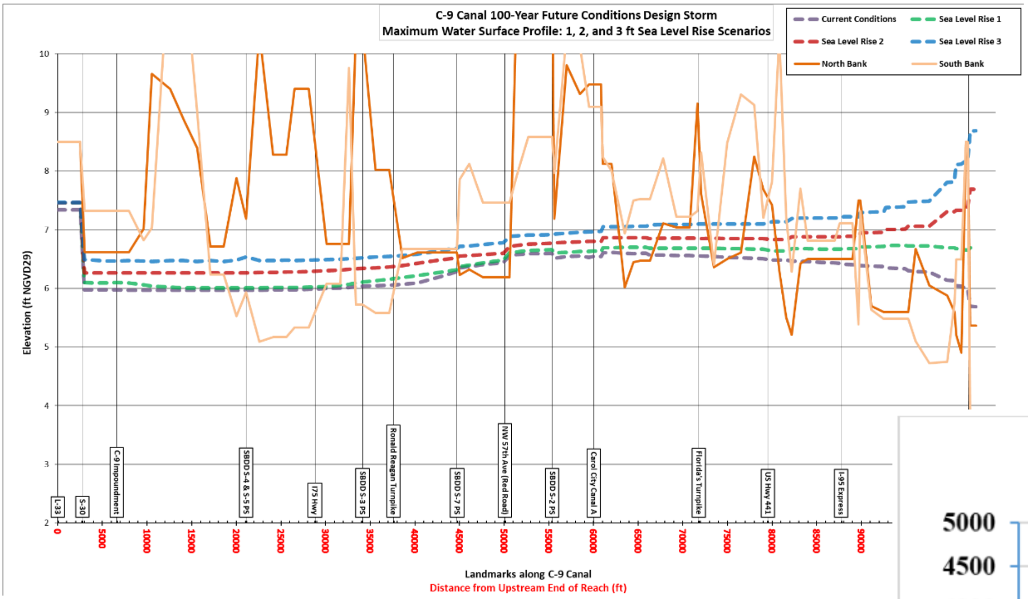


Figure 10.1-9: C-9 Canal Peak Stage Profiles for 100-Year Design Storm – Current vs Future Sea Level Rise Scenarios

- 5-year thru 100-year
  - Current thru SLR3
  - 16 runs per alternative

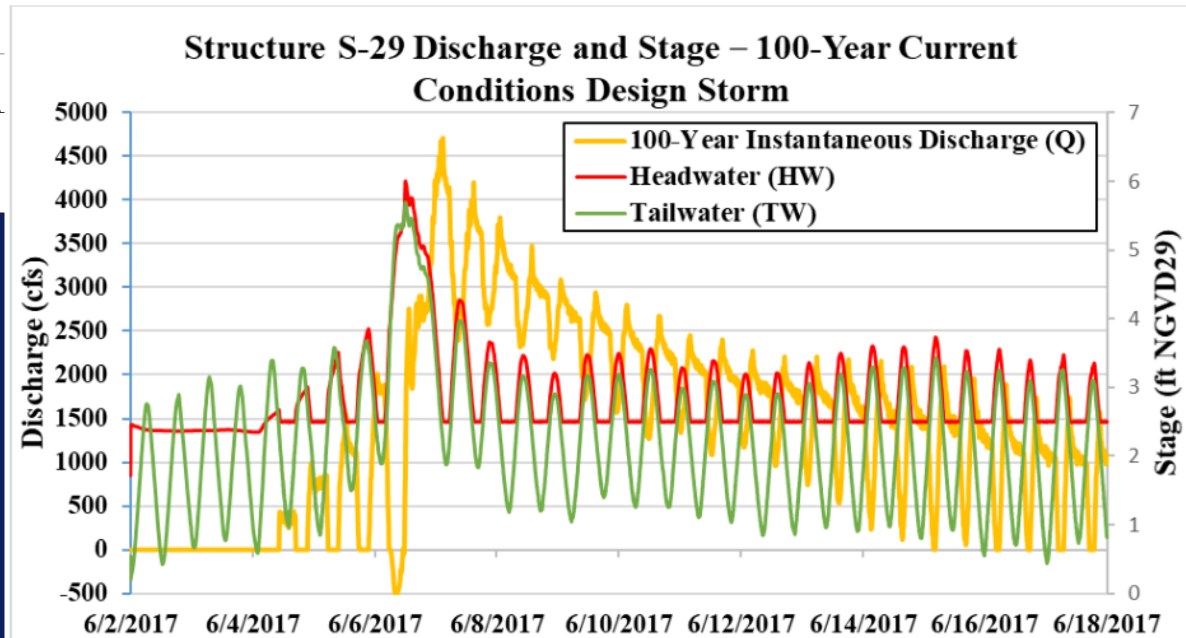
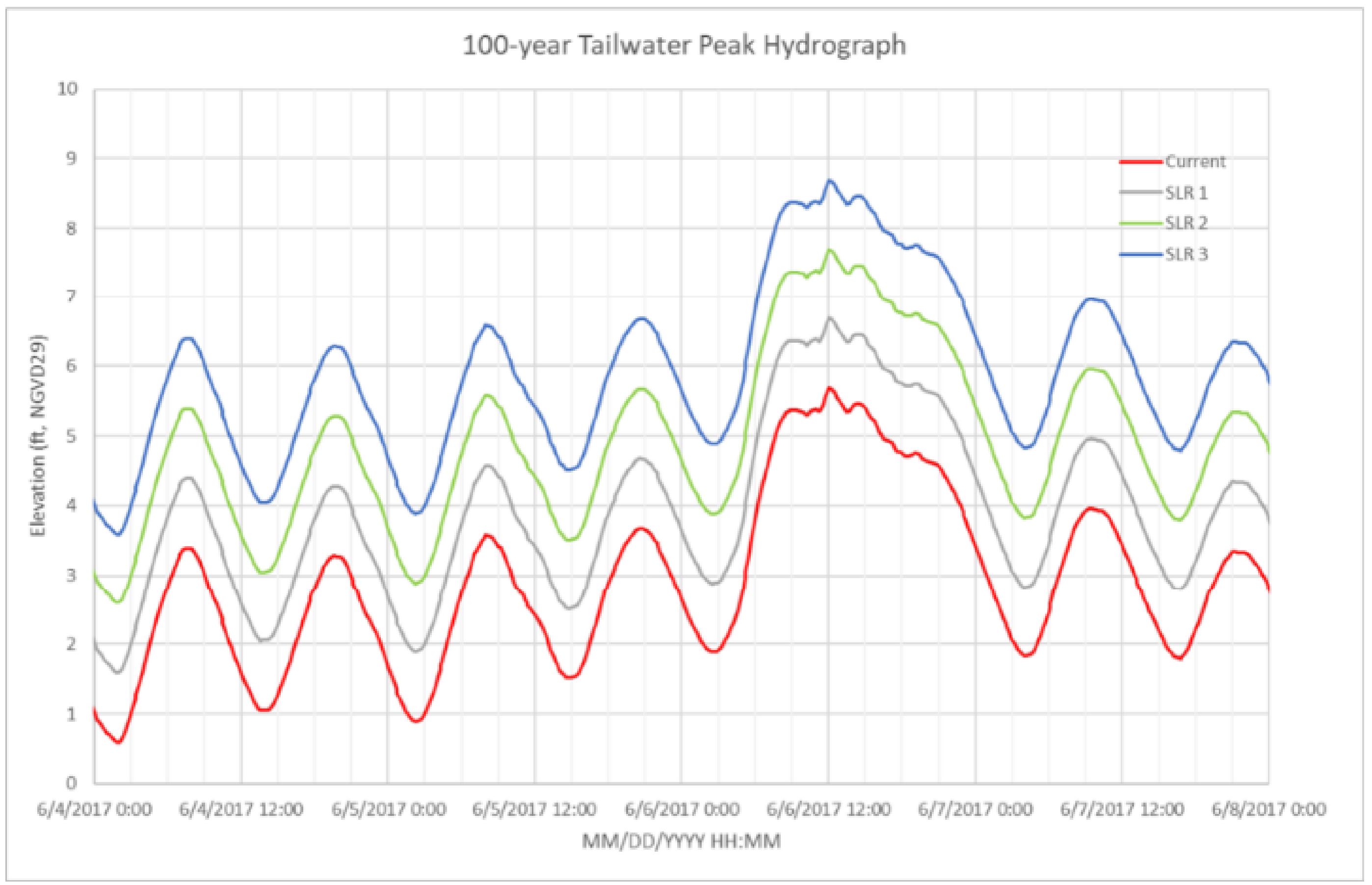
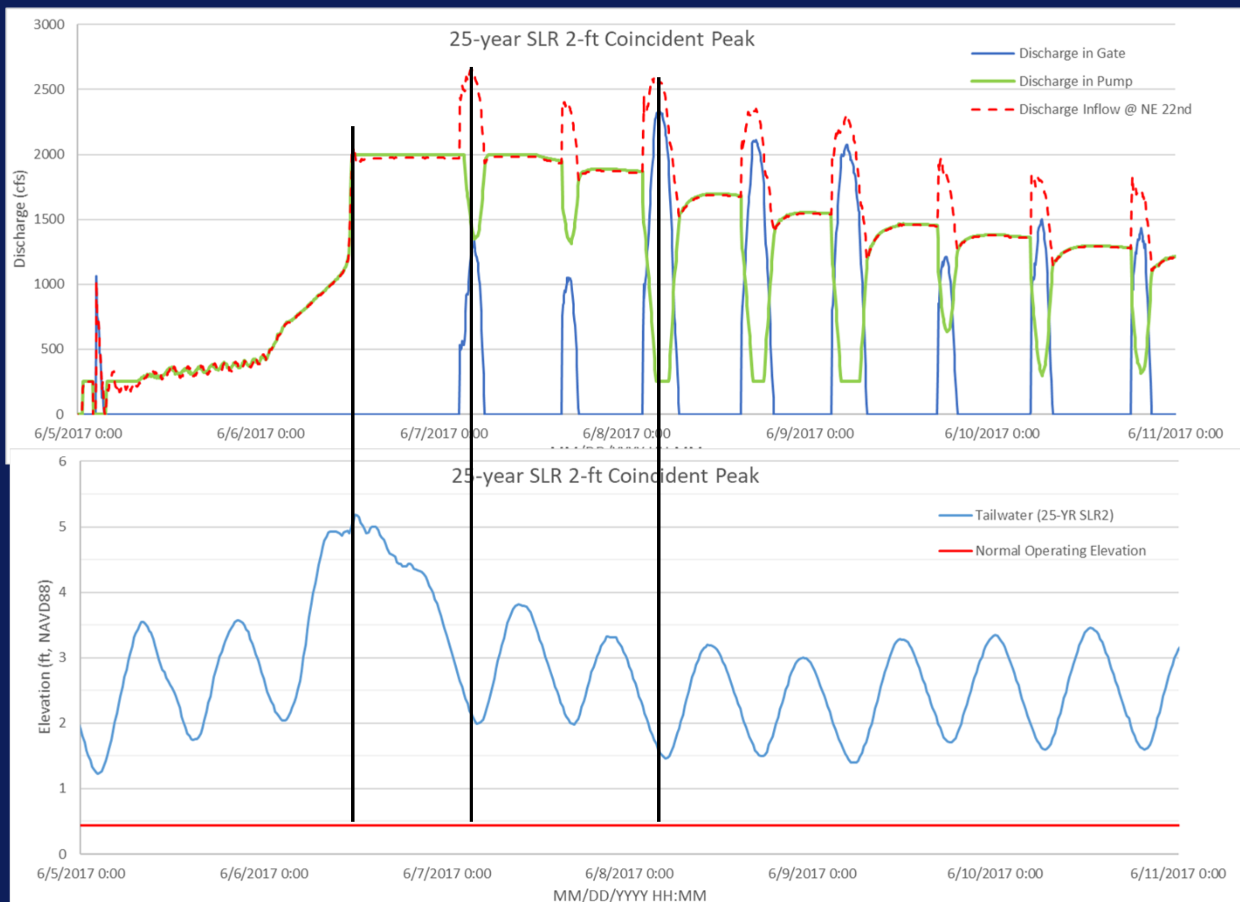


Figure 8.3-7: Instantaneous Discharge and Stage at S-29 Structure for 100-Year Current Conditions Design Storm

Tailwater Boundaries



SRH-2D Boundary Curves



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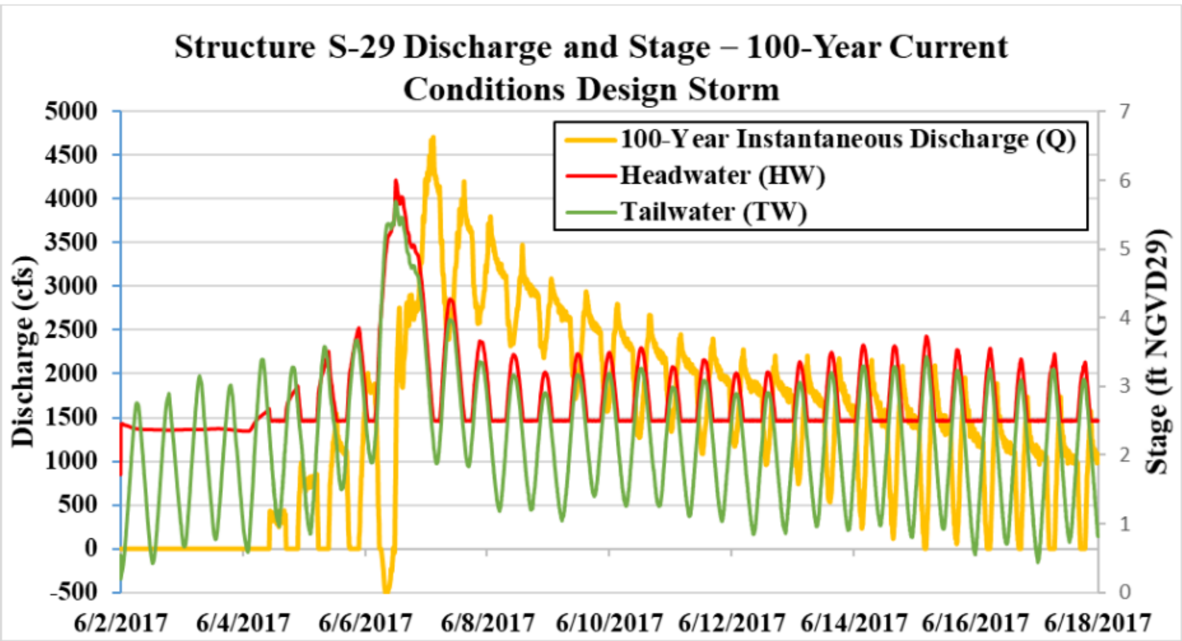
Model Going Dry – Why?



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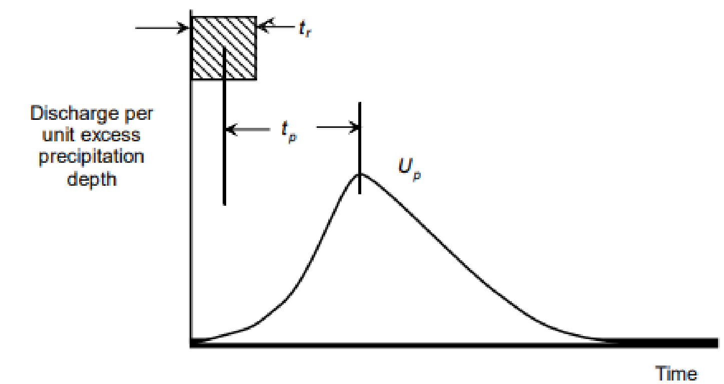


Figure 17. Snyder's unit hydrograph.

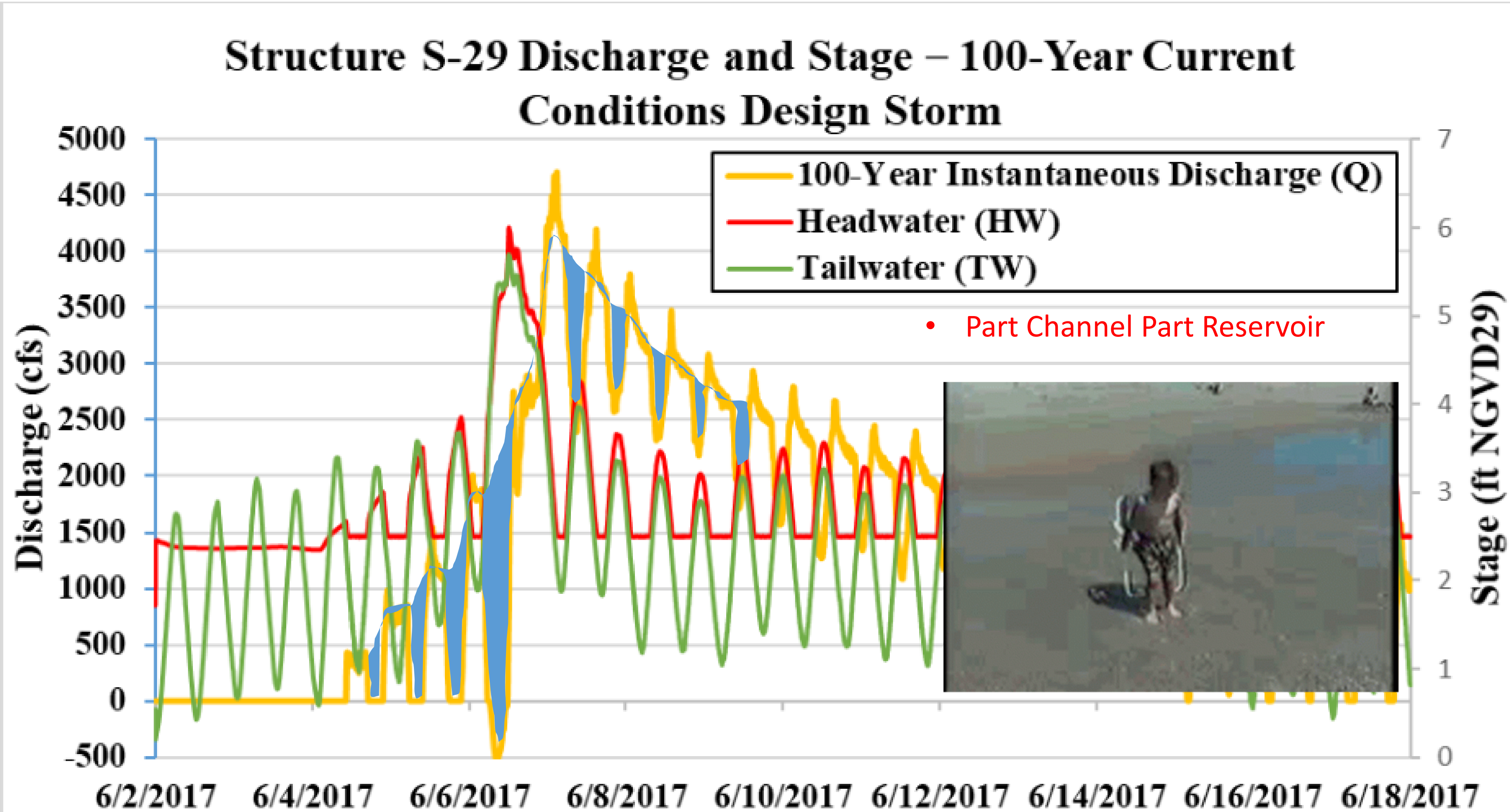
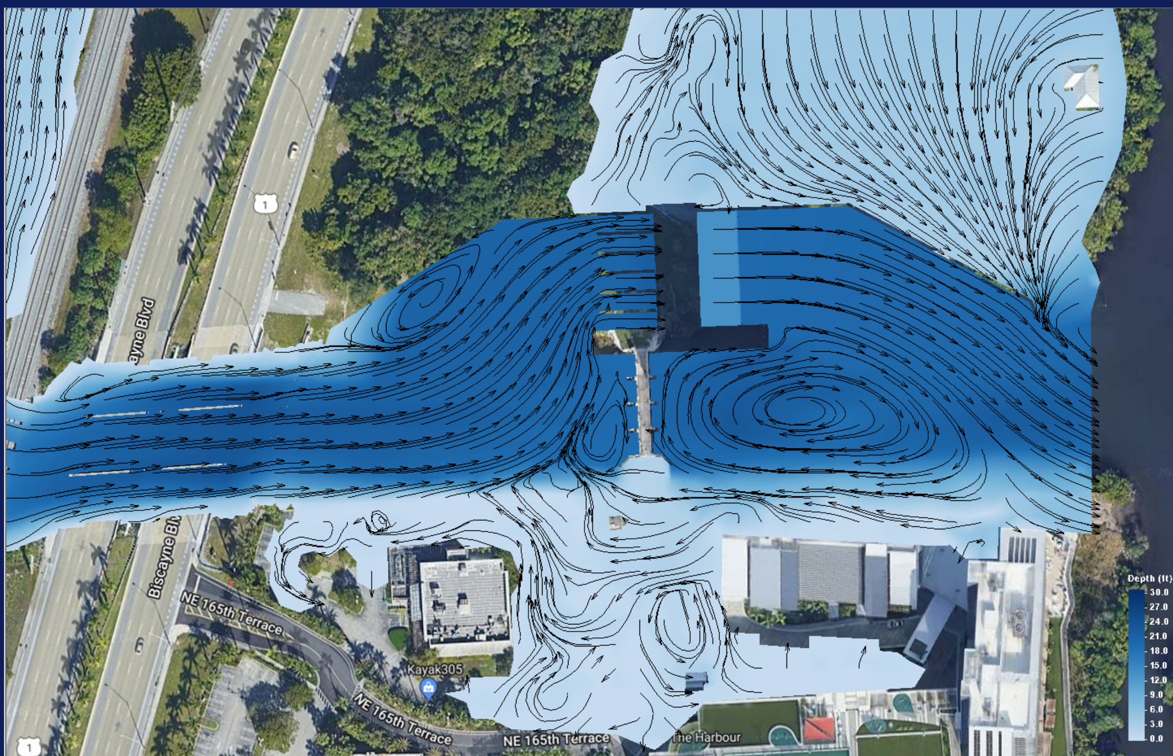


Figure 8.3-7: Instantaneous Discharge and Stage at S-29 Structure for 100-Year Current Conditions Design Storm

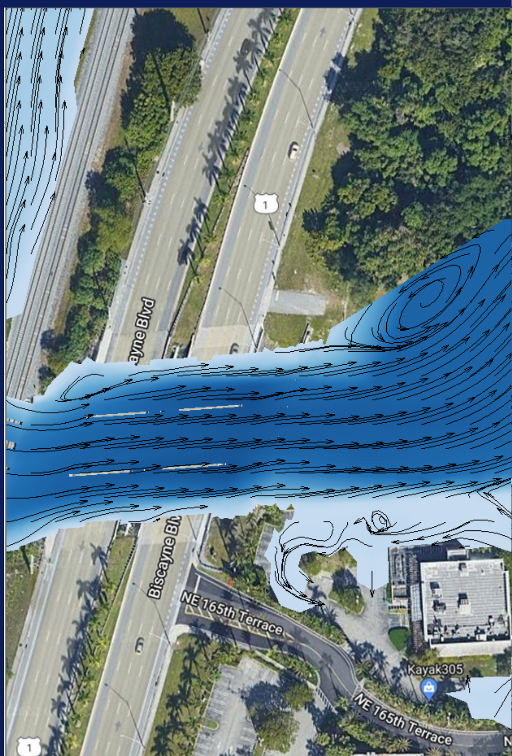
Preliminary Results

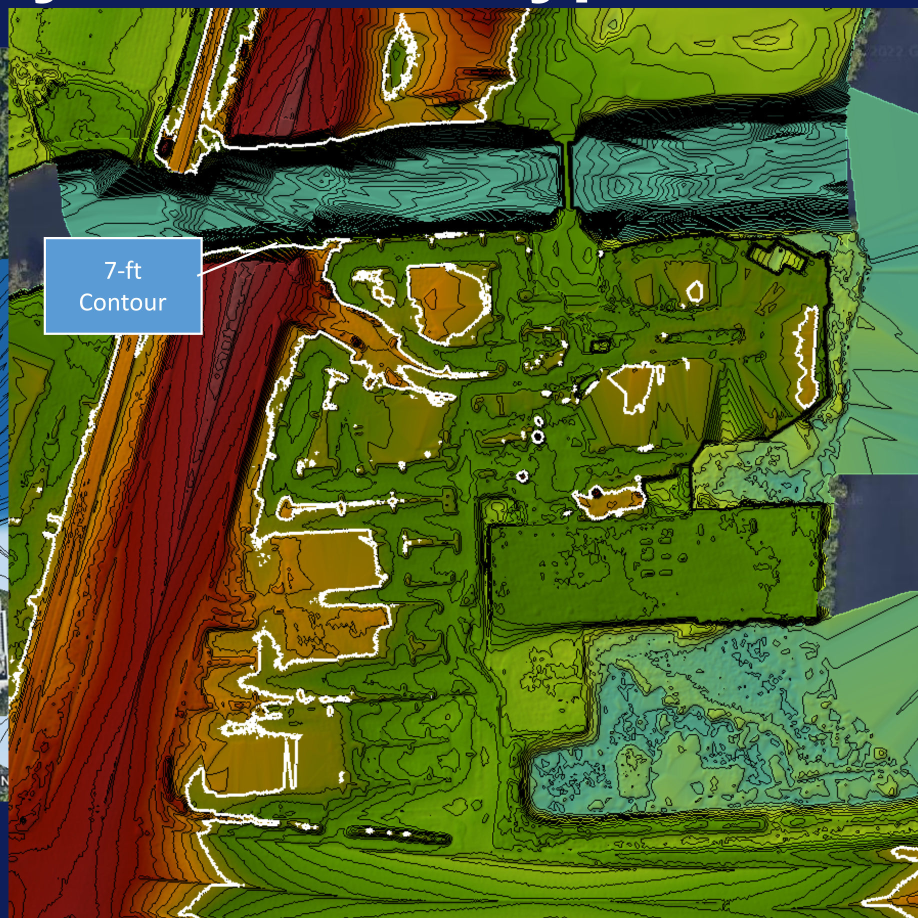
- No Hydrology – Scope Assumption
- Proceed with Steady State
  - Temporarily
- Control WS and Discharge
- Testing 3 Pump Options
  - Flow Patterns and Distribution
    - Low WS
    - High WS
    - Gate Open vs Closed

Preliminary Results – Bypass Flow

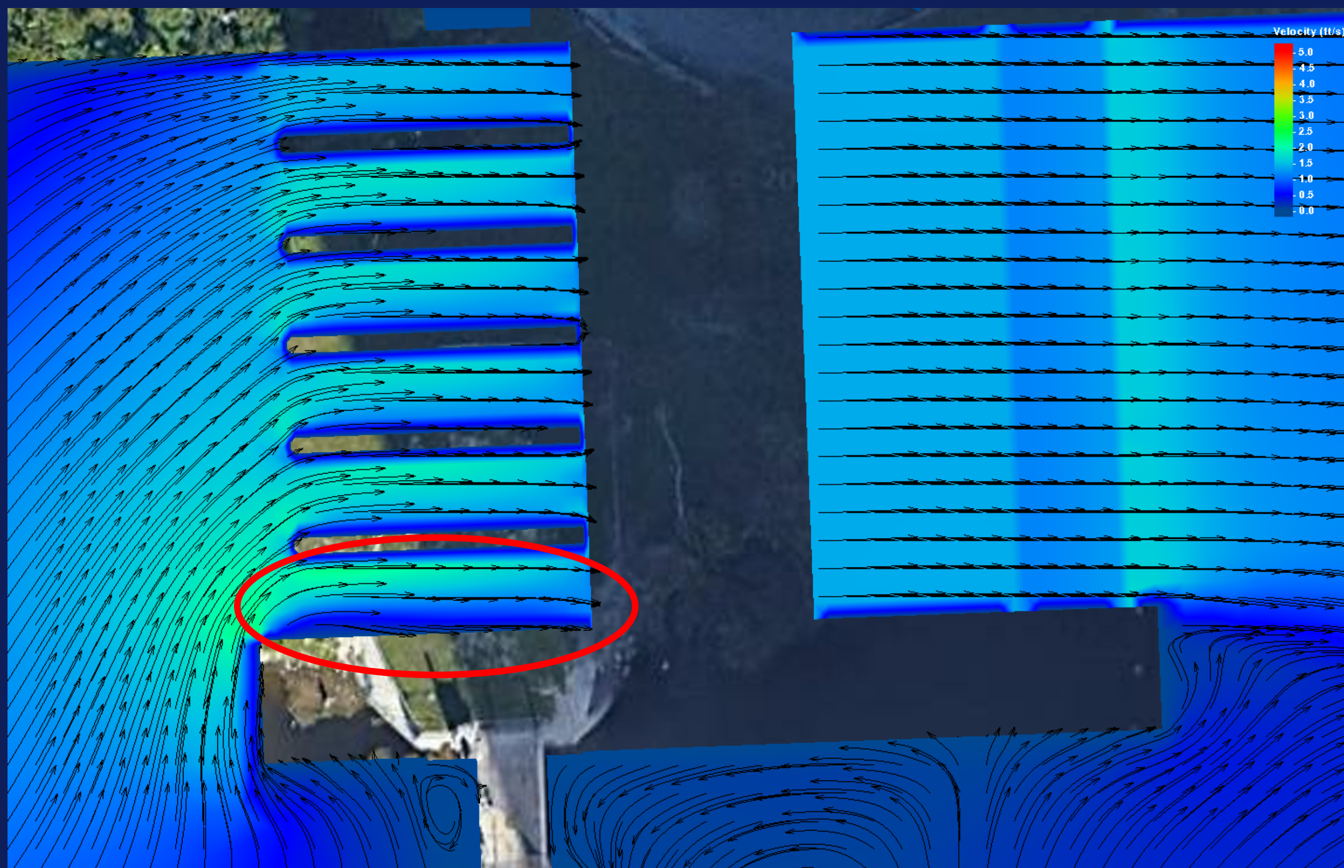


Preliminary Results – Bypass Flow

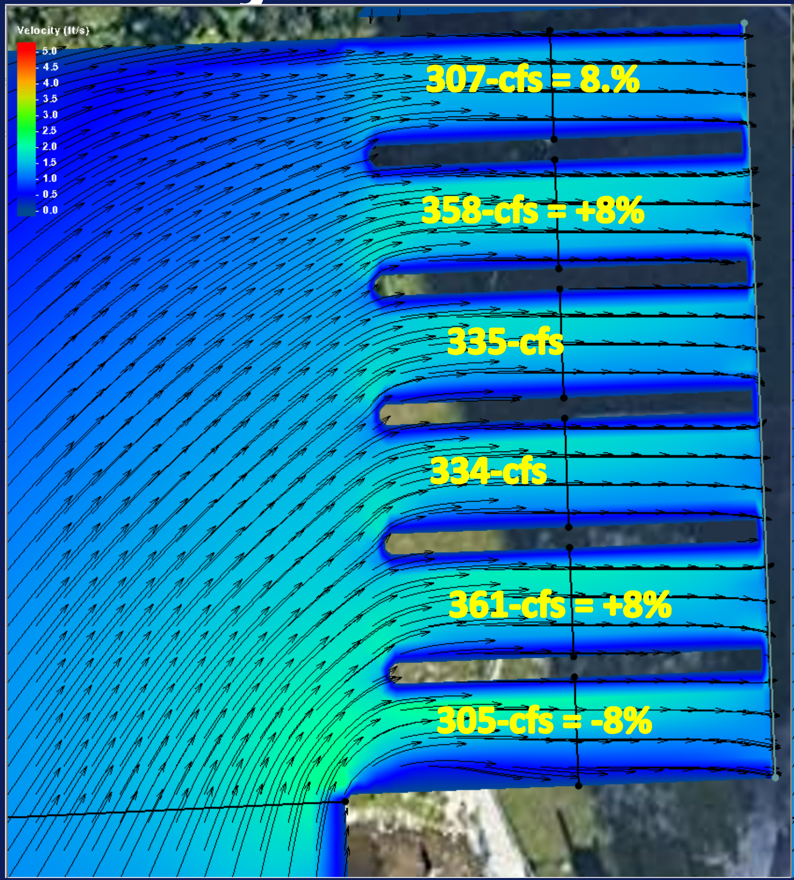


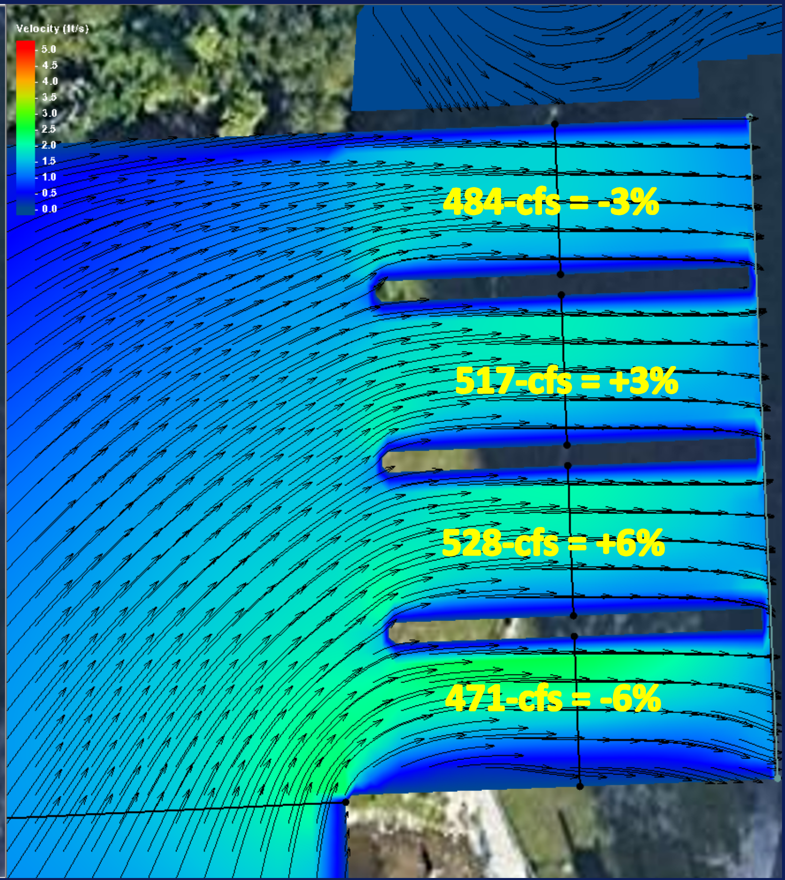


Preliminary Results – Flow Distribution



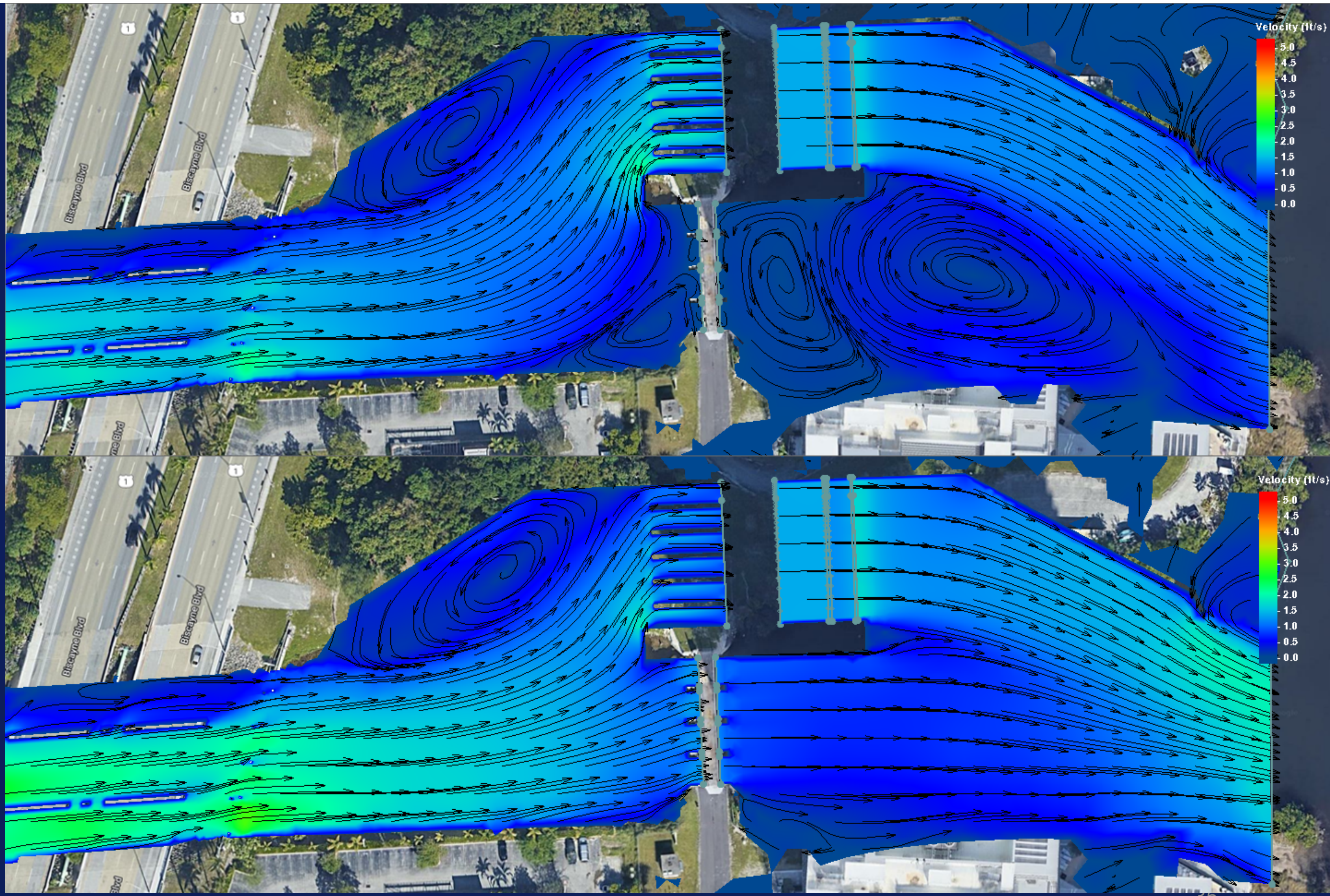
Preliminary Results – Flow Distribution



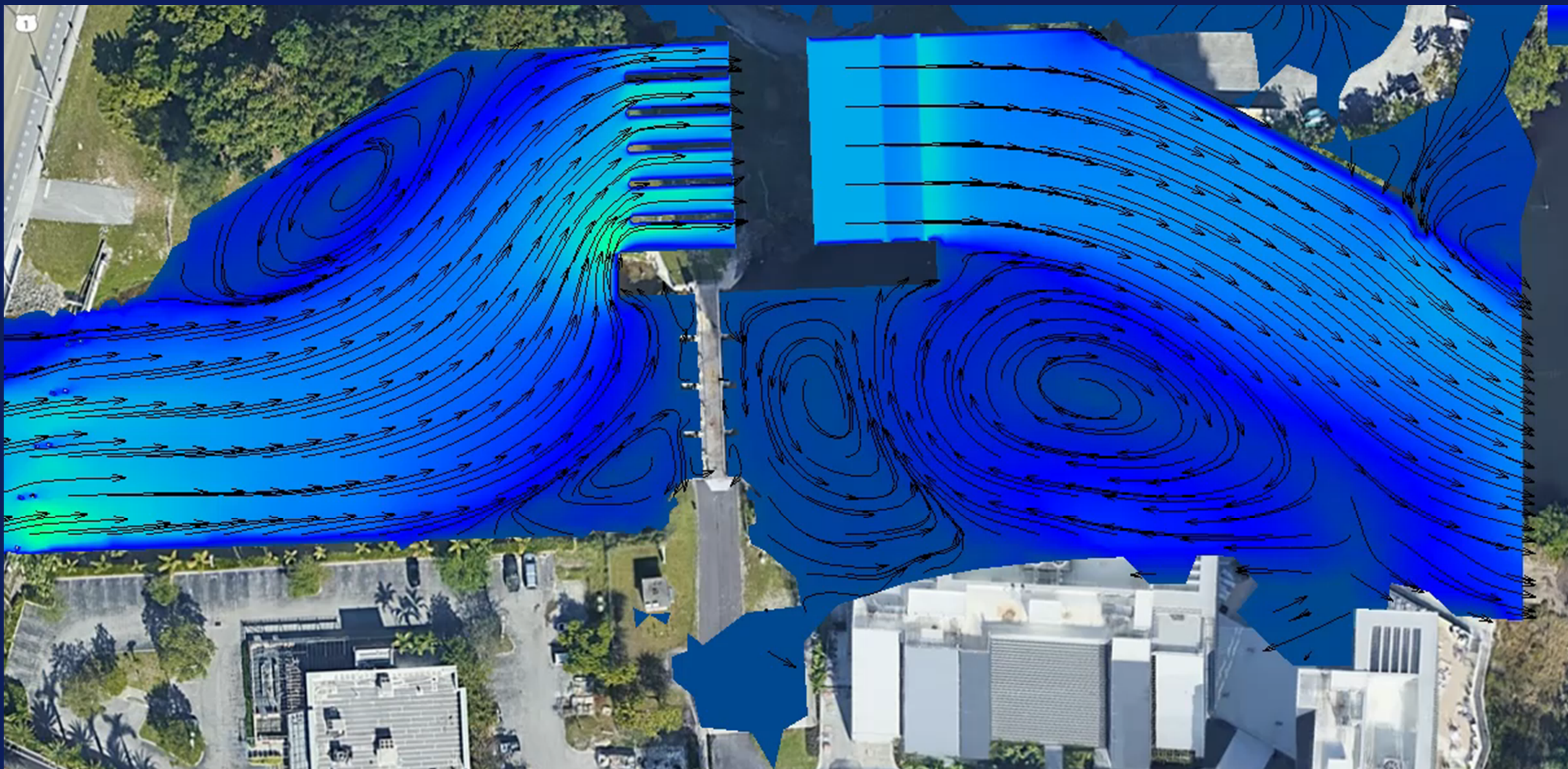


35

Gate Open vs Closed

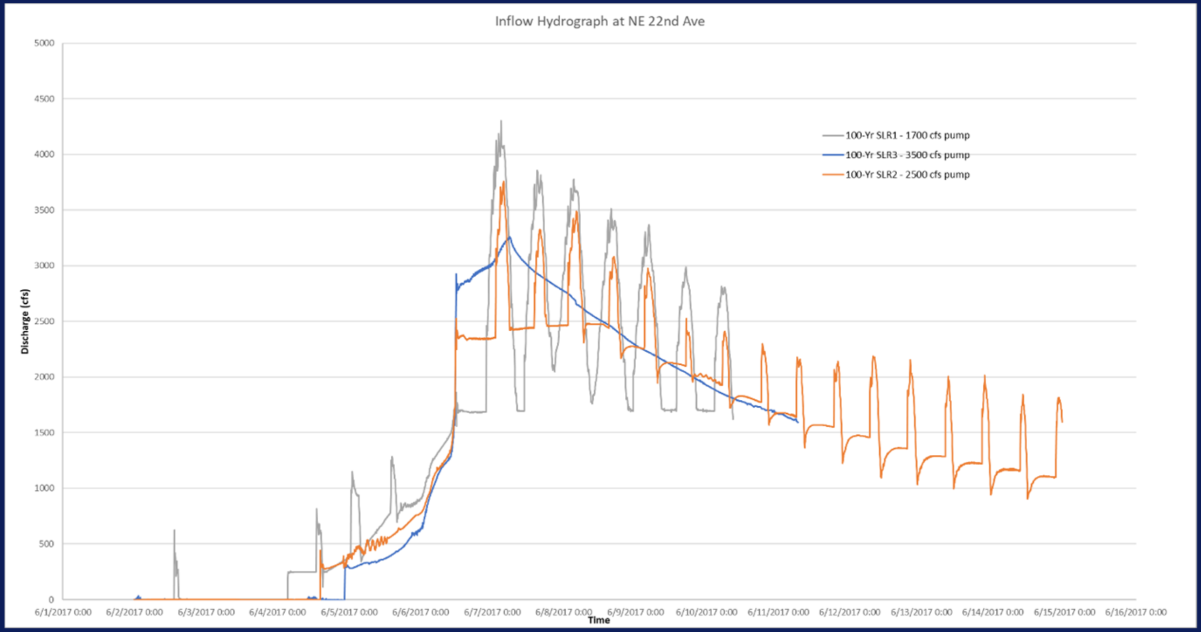


Gate Open vs Closed



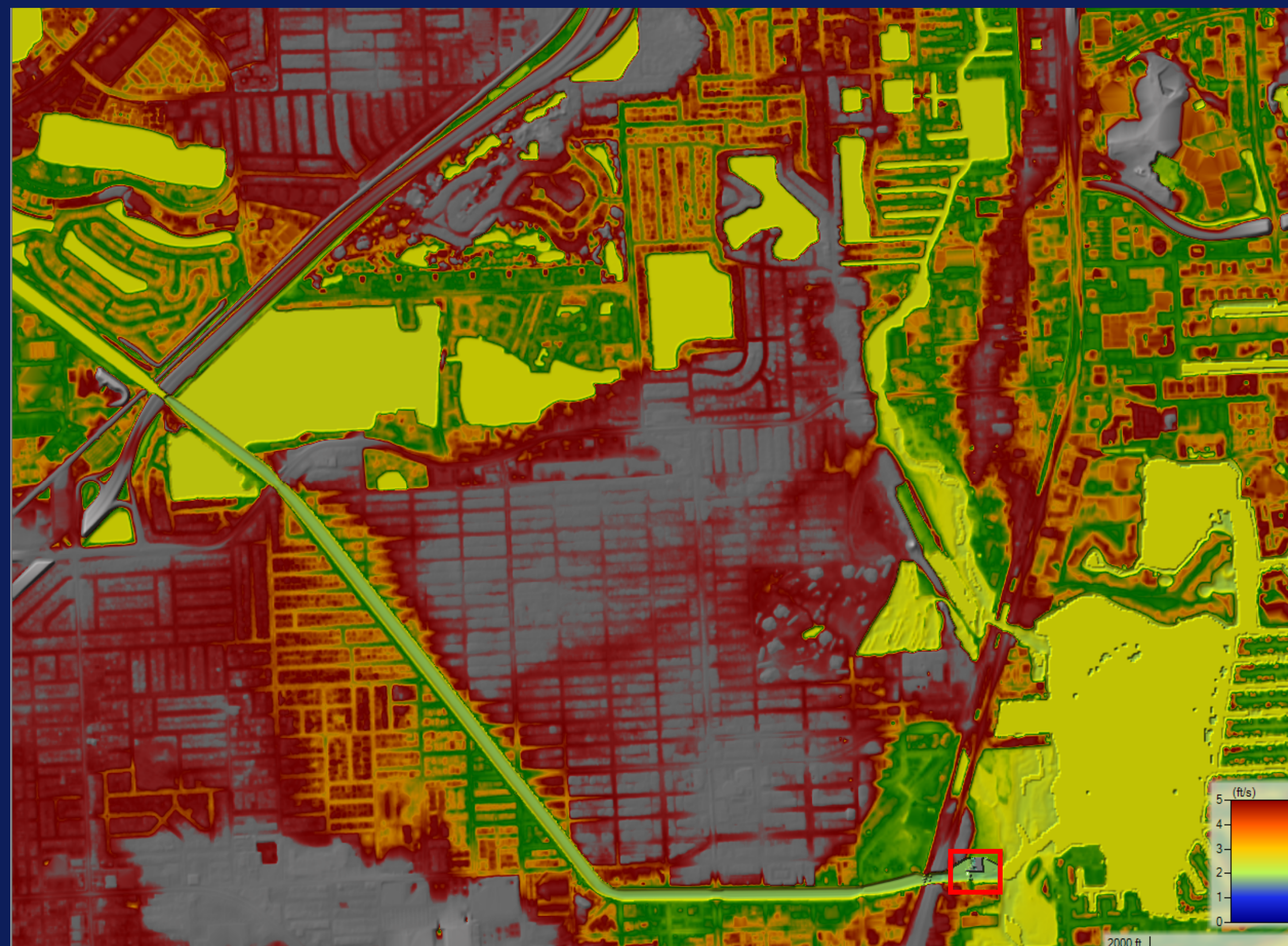
Expanded Scope

- Determine Pump Type & Sequencing
- Can't rely on FPLOS Study
- Need to Capture Volume
  - Schedules Don't Align



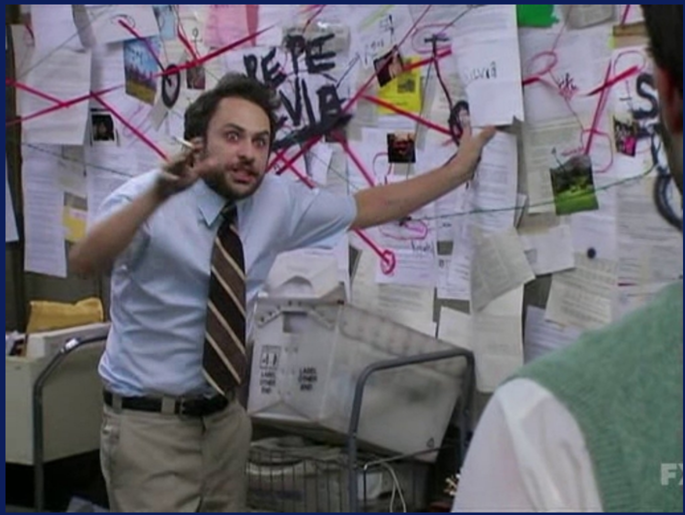
FPLOS Study Limitations

- FPLOS Doesn’t Include Storage (Outside of Channel)
  - Tested Adding Upstream Lake
    - Major Impacts
  - Still Missing Floodplain Storage
  - Static Peak Pump rate



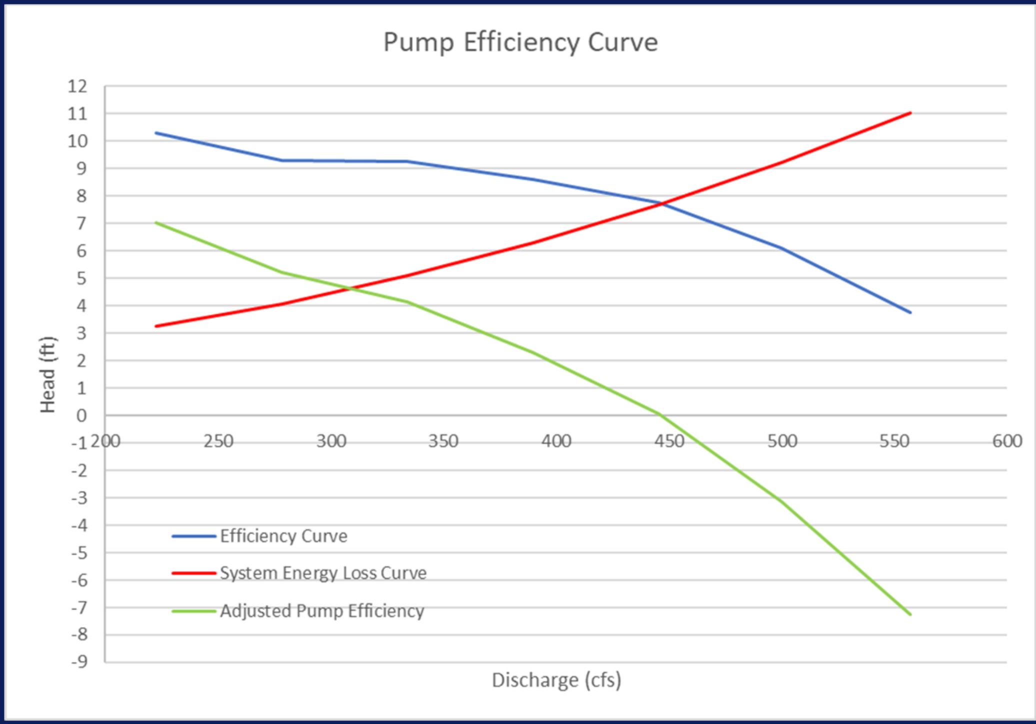
Identify Variables

- Groundwater
  - Influenced by head
- Tide/SLR impacts gates
- Headwater impacts gates
- Different Pumps = Different Efficiency = Variable Discharge
  - Pump selection informed by HW
  - Pump type changes Bay
- On/Off Elevation
- Sequencing
  - 5 pumps turn on independently
- **Changes to WS impact inflow hydrograph!**



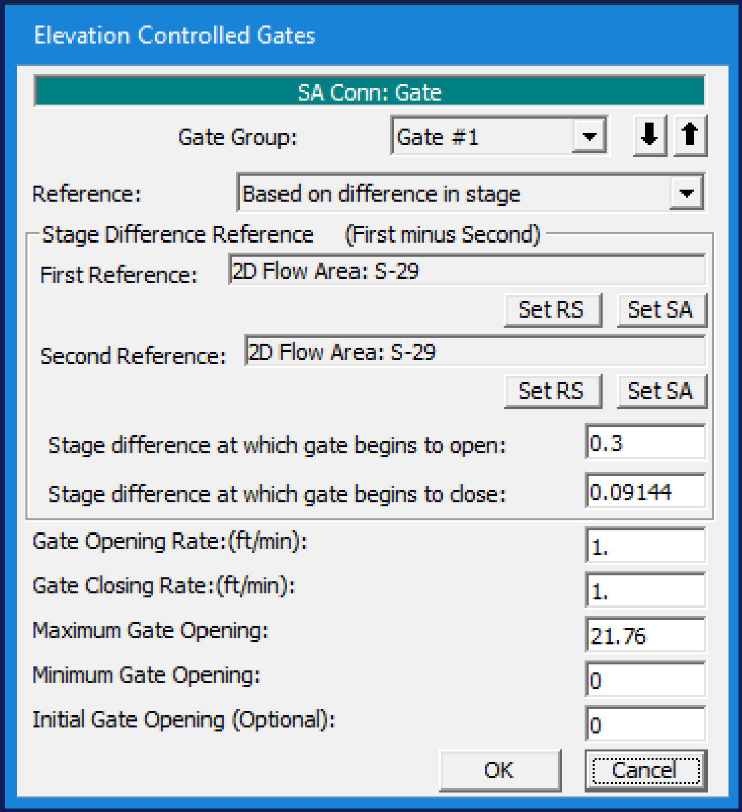
Reduce Variables

- 4 flows with 4 SLR
  - 16 Runs per Alternative
- Narrowed to 500-cfs option
- Supplement FPLOS hydrographs
  - HEC-RAS 2D
- Pick 1 Pump type
  - Efficiency doesn't change
  - Still iterate on/off
- New pump station geometry
  - Modeling start over

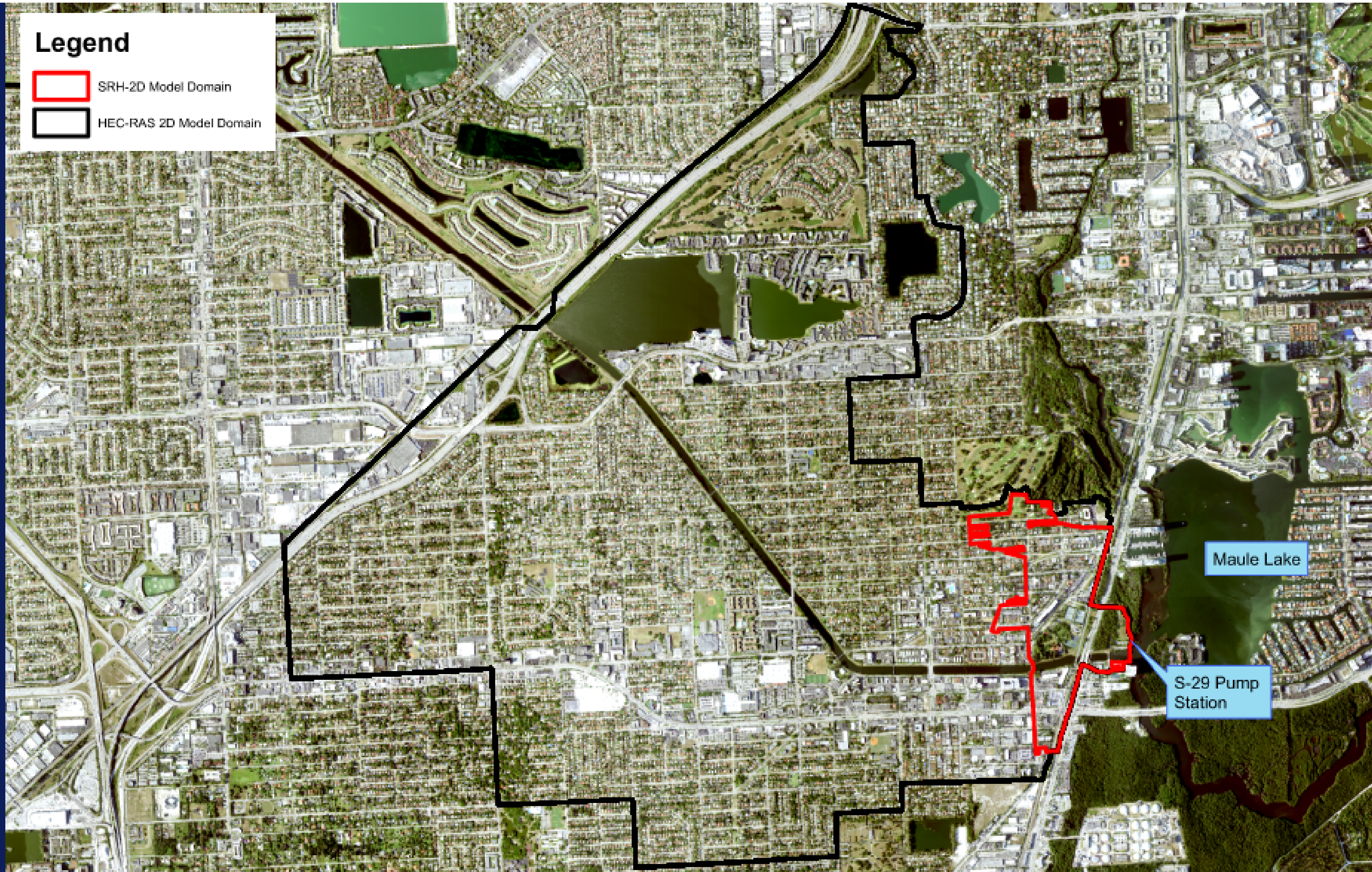


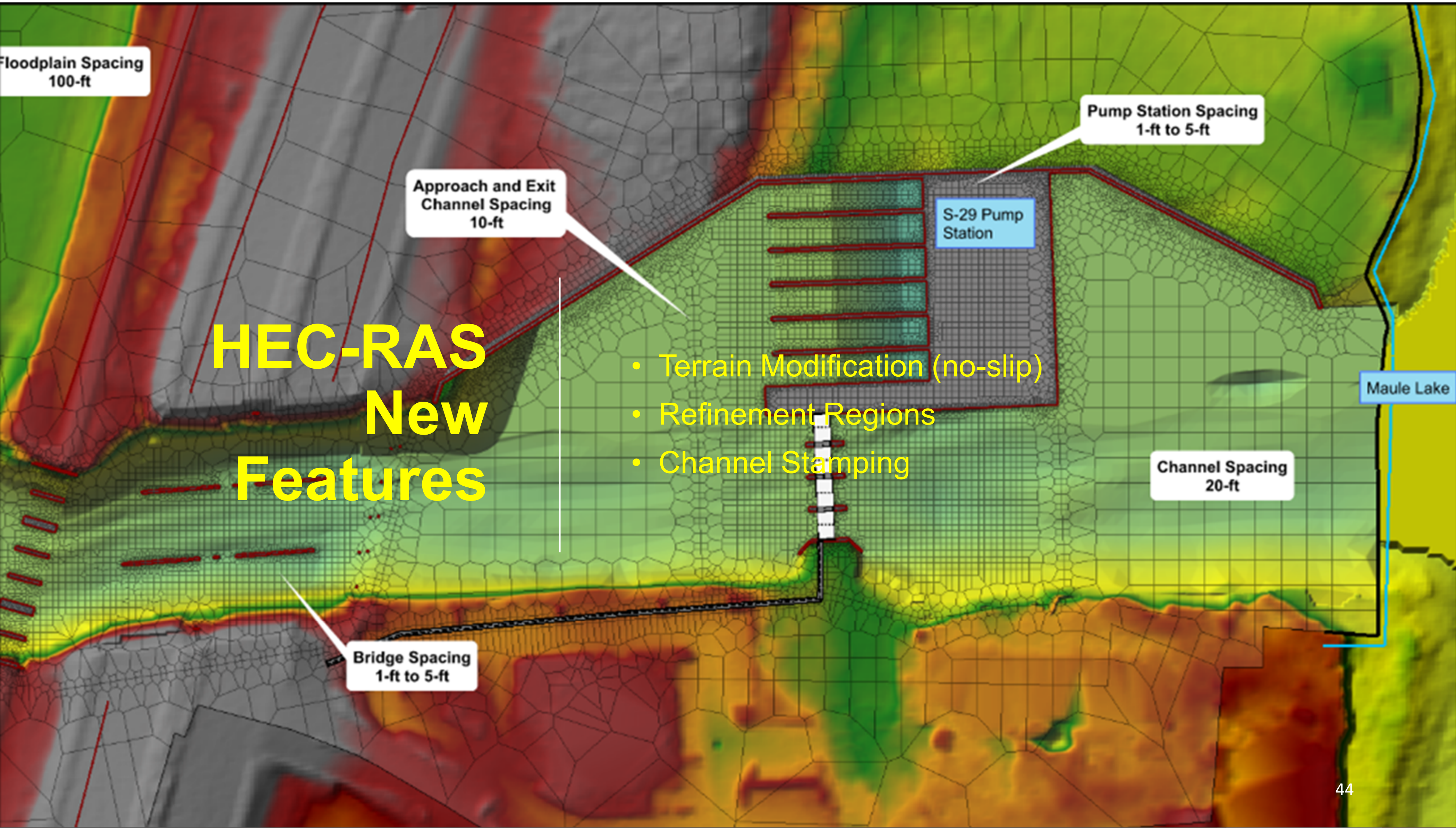
HEC-RAS 2D

- Larger Domain
  - Capture Storage
  - Reduce HW influence on inflow
- Better Control of Boundaries
  - Pump Boundary
  - Gate Boundary
  - Rules
- Inform SRH-2D Model



- Capture Volume
- Key to On/Off



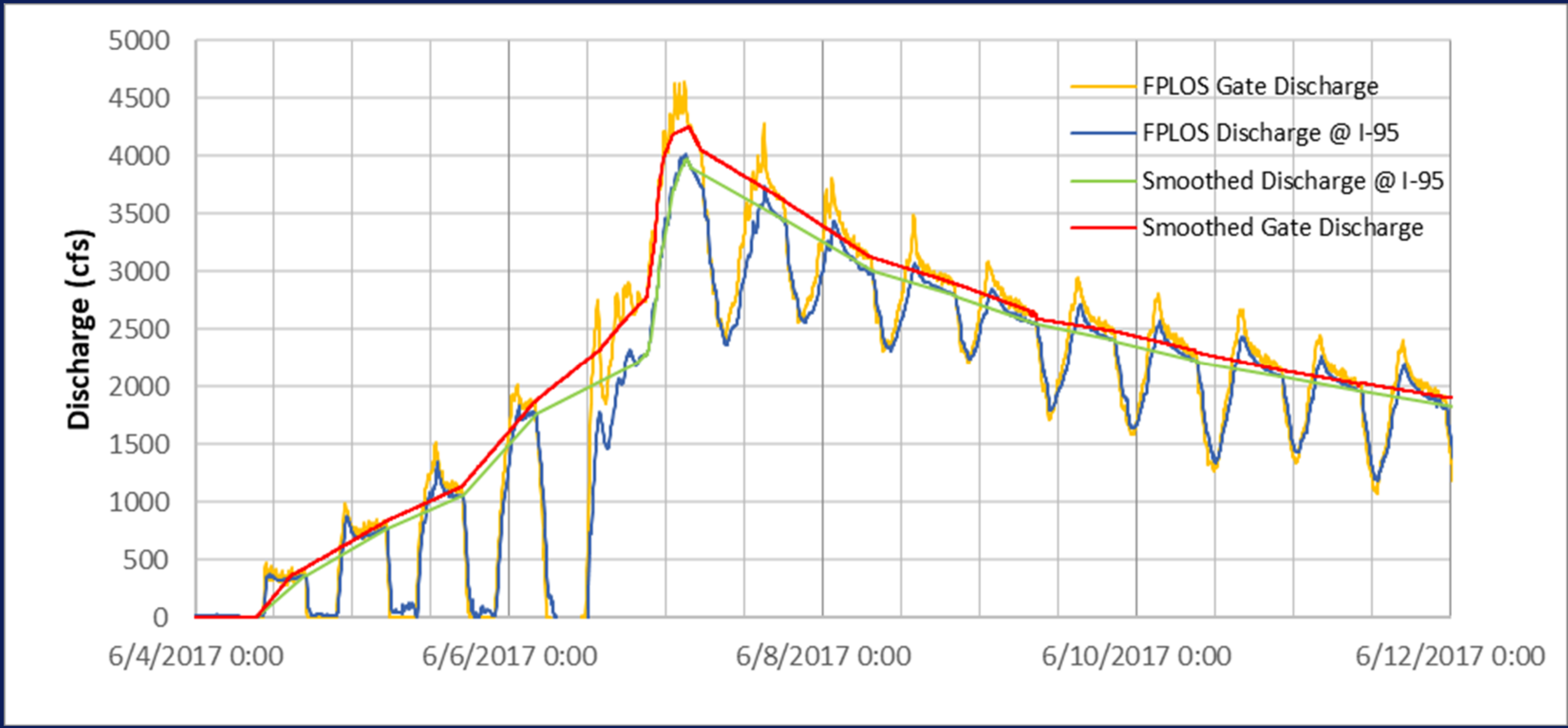


HEC-RAS New Features

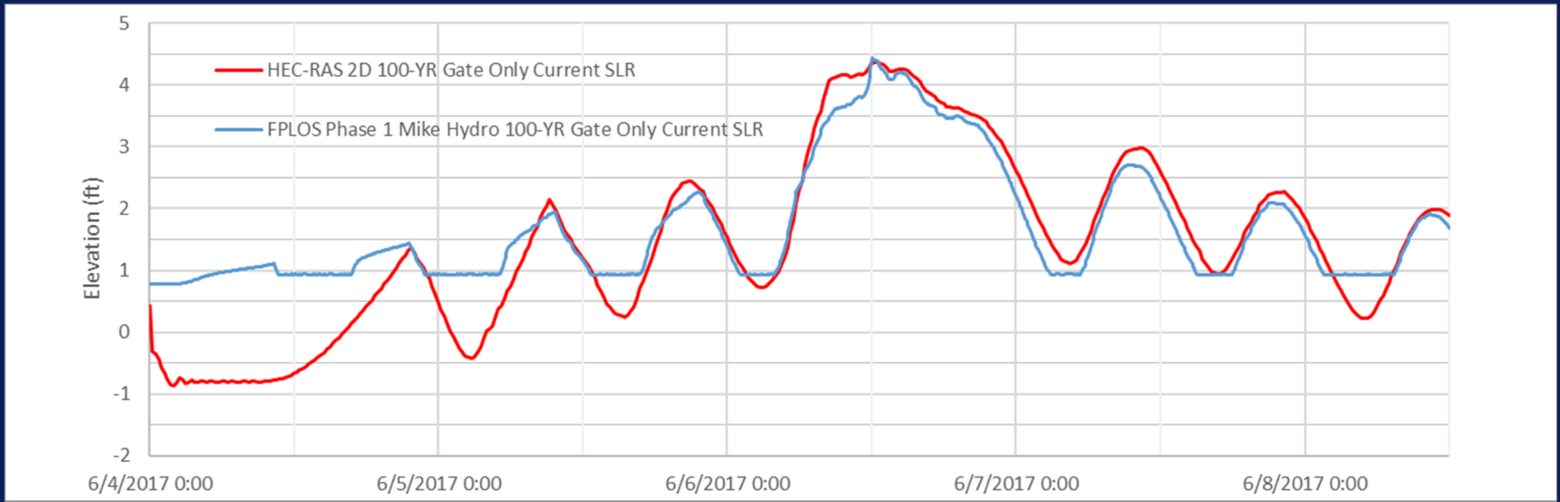
- Terrain Modification (no-slip)
- Refinement Regions
- Channel Stamping

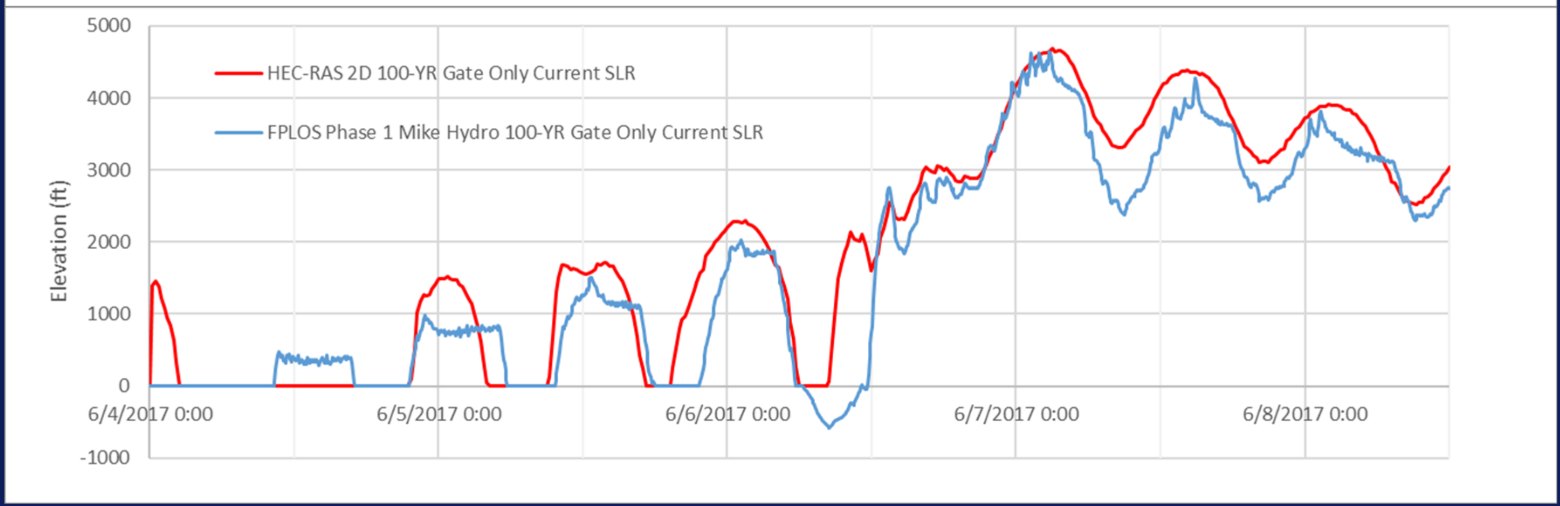
Smoothed Inflow Hydrographs

- Capture Volume
  - Conservative
- FPLOS
  - Ongoing
  - Coordination



Calibration





Running The Model

- 4 flood frequencies, 4 sea level rise conditions = 16 runs
  - 19 total with calibration
- 1-2days per simulation
- 6 computers running models
  - Special thanks to:
    - Kurtis Duemler
    - Matthew Kuechenberg
    - Kush Paliwal
    - Mason Johnson

On/Off

- Iterative Approach
- Start with 100-year
  - Max SLR
- Need Minimum Flow
  - Can't go dry
- SFWMD Operations
- No Significant Changes
  - Variables Reduced

Normal Range

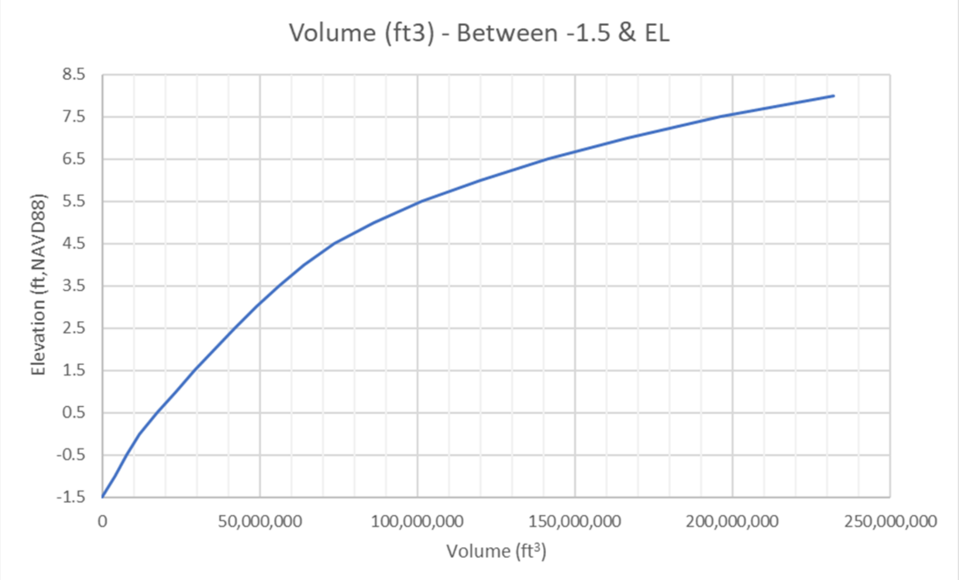
Normal operational range is from 1.5 to 2.5 feet NGVD29.
During very dry conditions, normal operational range may be raised by 0.2 feet to prevent saltwater intrusion.

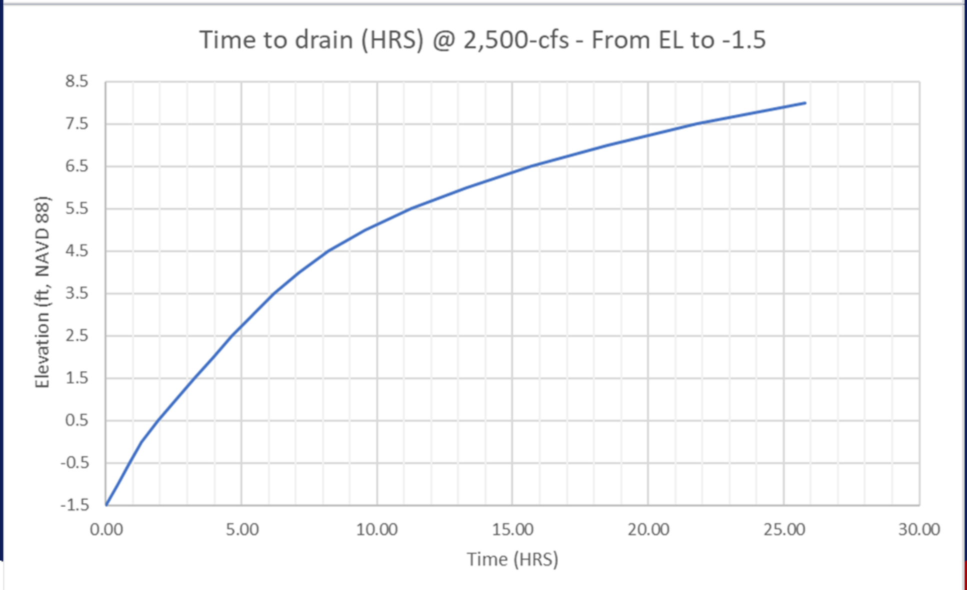
Low Range

A low range of 1.0 to 1.5 feet NGVD29 is used when additional drainage is required.
During very wet conditions in the C-9 basin an operational range of 0.0 to 1.0 feet NGVD29 may be used.
When the tailwater at S-30 culvert (about 19.0 miles upstream of the S-29 on C-9 Canal) rises above 3.3 feet NGVD29, S-29 is placed on low range until the tailwater at S-30 recedes to 2.7 feet NGVD29 at which time normal operation is resumed at S-29.

HEC-RAS Results – On/Off Elevations

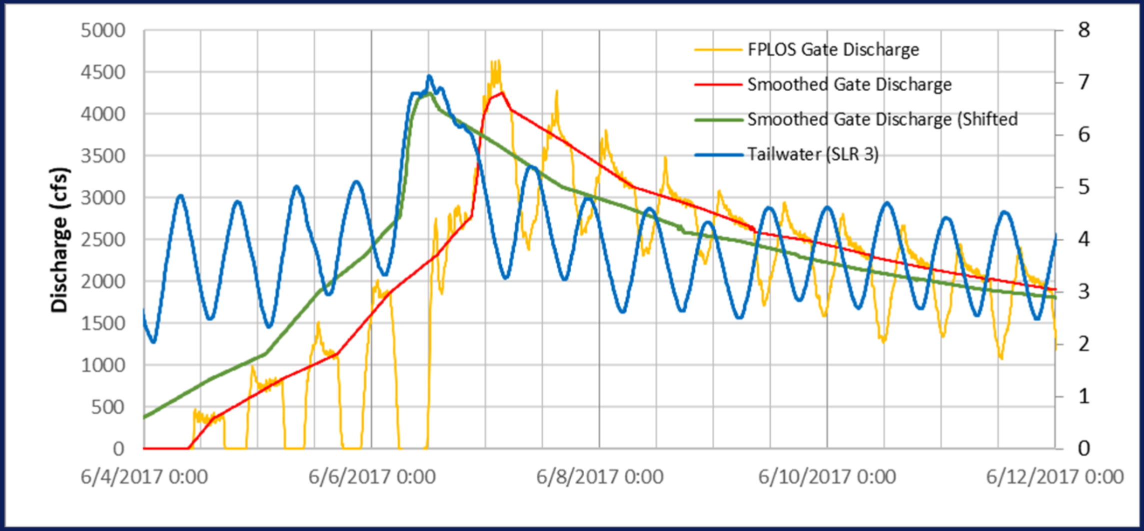
Elevation (EL)	Volume (ft^3) - Between -1.5 & EL		Time to drain (HRS) @ 2,500-cfs	
	Total	Incremental	Incremental	to EL -1.5
-1.5	0	0	0.00	0.00
-1	3,863,494	3,863,494	0.43	0.43
-0.5	7,743,280	3,879,785	0.43	0.86
0	11,673,982	3,930,702	0.44	1.30
0.5	17,242,499	5,568,517	0.62	1.92
1	23,234,120	5,991,621	0.67	2.58
1.5	29,331,772	6,097,652	0.68	3.26
2	35,572,428	6,240,656	0.69	3.95
2.5	42,013,675	6,441,247	0.72	4.67
3	48,763,142	6,749,467	0.75	5.42
3.5	56,024,536	7,261,394	0.81	6.22
4	64,087,823	8,063,287	0.90	7.12
4.5	73,738,291	9,650,468	1.07	8.19
5	86,059,444	12,321,153	1.37	9.56
5.5	101,347,391	15,287,947	1.70	11.26
6	119,740,484	18,393,093	2.04	13.30
6.5	141,378,863	21,638,379	2.40	15.71
7	166,501,124	25,122,261	2.79	18.50
7.5	196,110,369	29,609,246	3.29	21.79
8	231,993,347	35,882,978	3.99	25.78

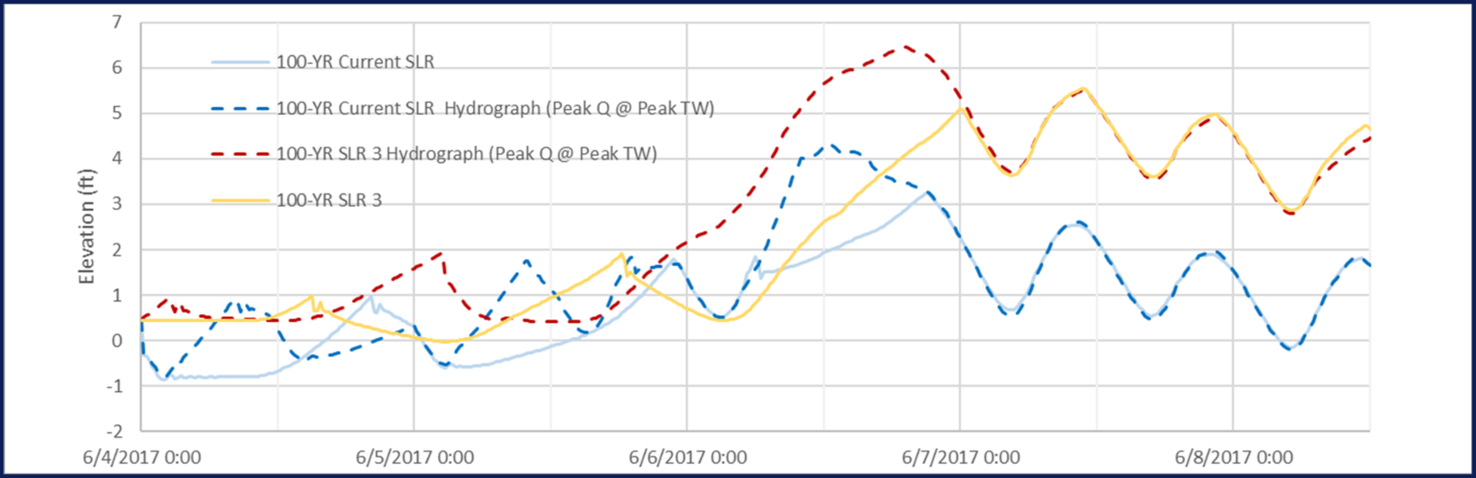


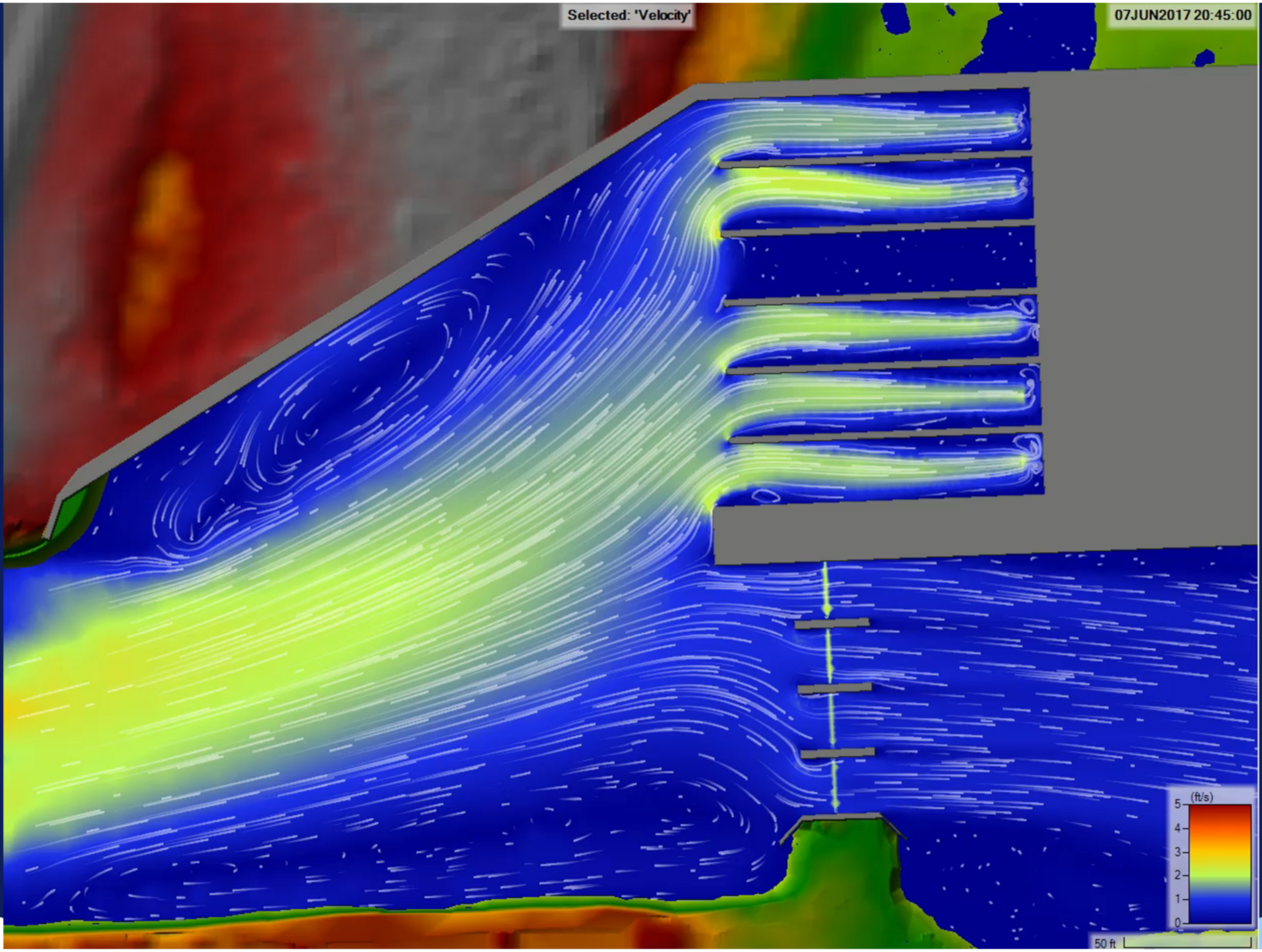


Sensitive to Tailwater

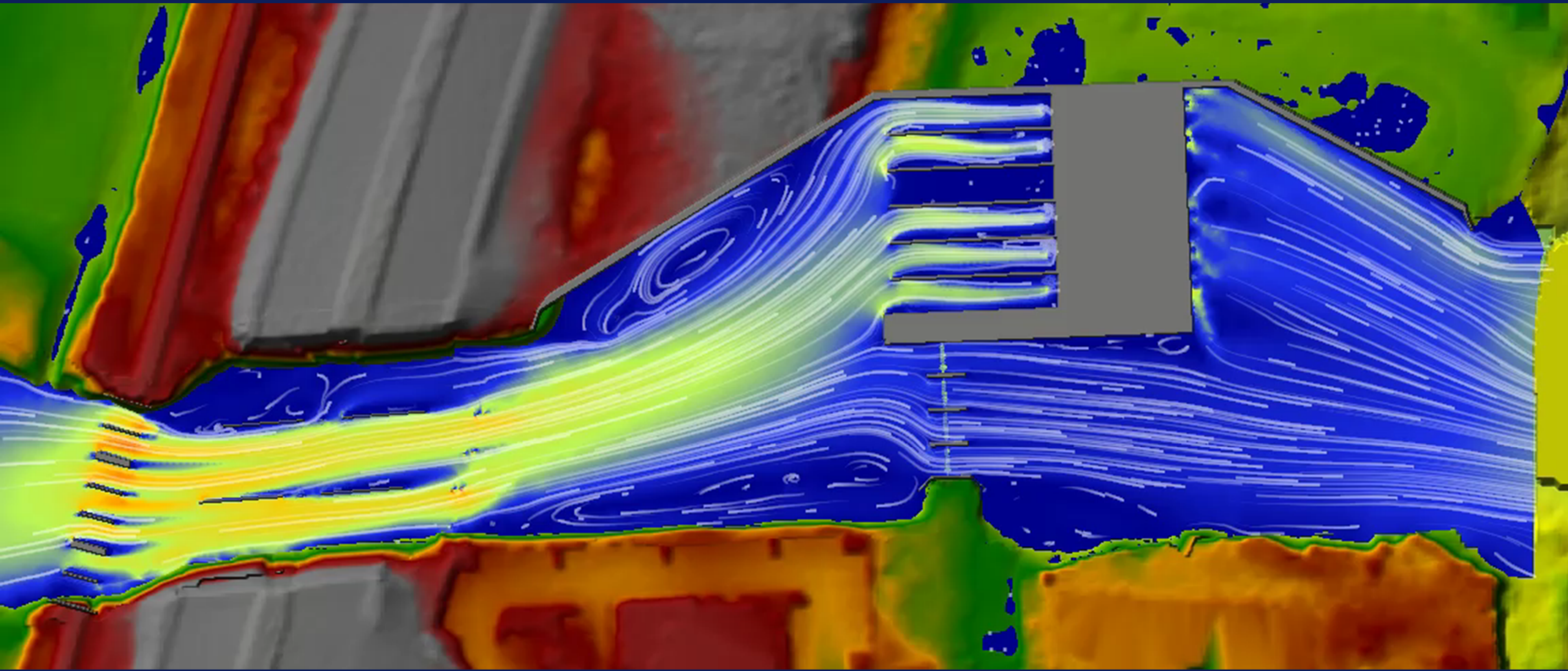
- FPLOS
  - Peak Rainfall at Max TW
- Peak Q at Max TW?





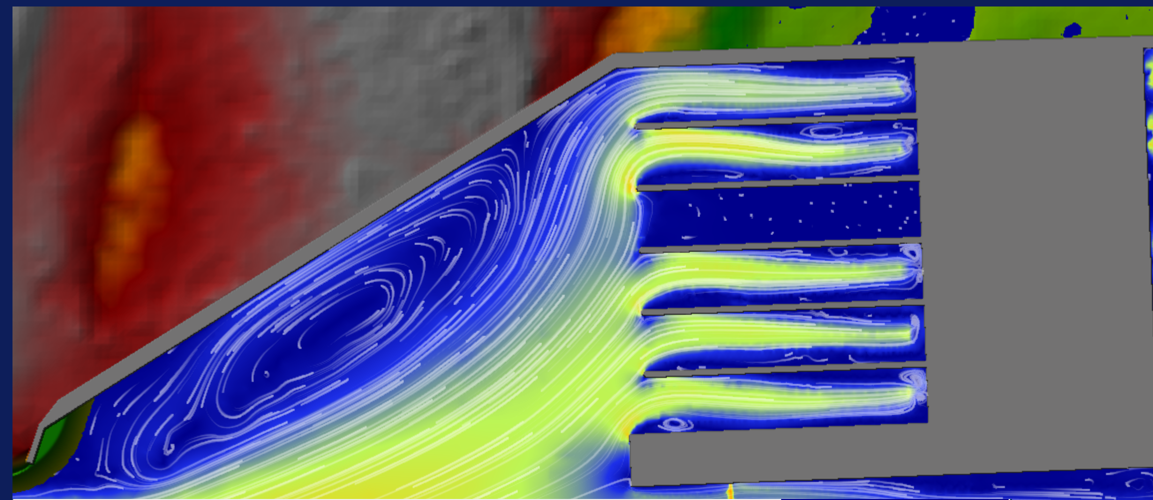


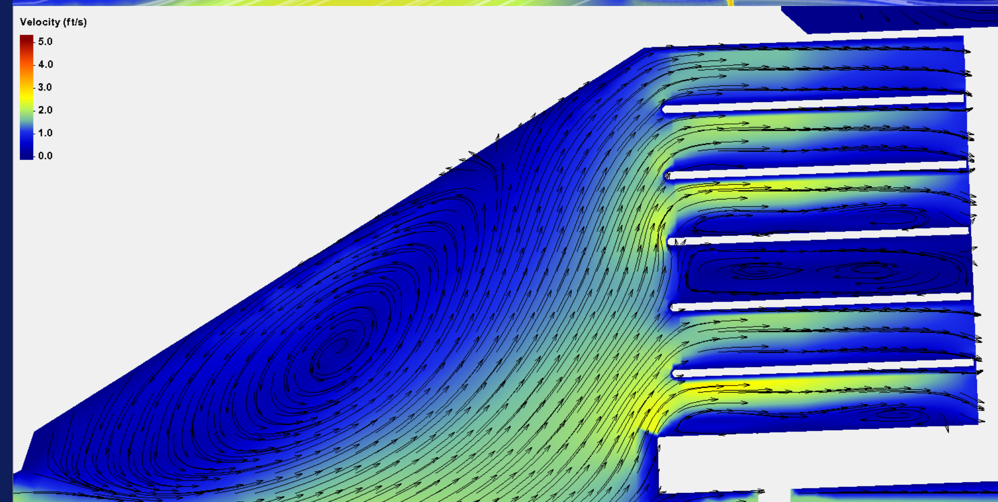
Selected: 'Velocity'
07JUN2017 20:45:00
(ft/s)
5
4
3
2
1
0
50 ft



Back to SRH-2D

- Original Scope
- Results from HEC-RAS
  - Inform Boundaries
- Full St. Venant, Finite Volume, High Density
- No WS comparison





SRH-2D Results – Gate Operation

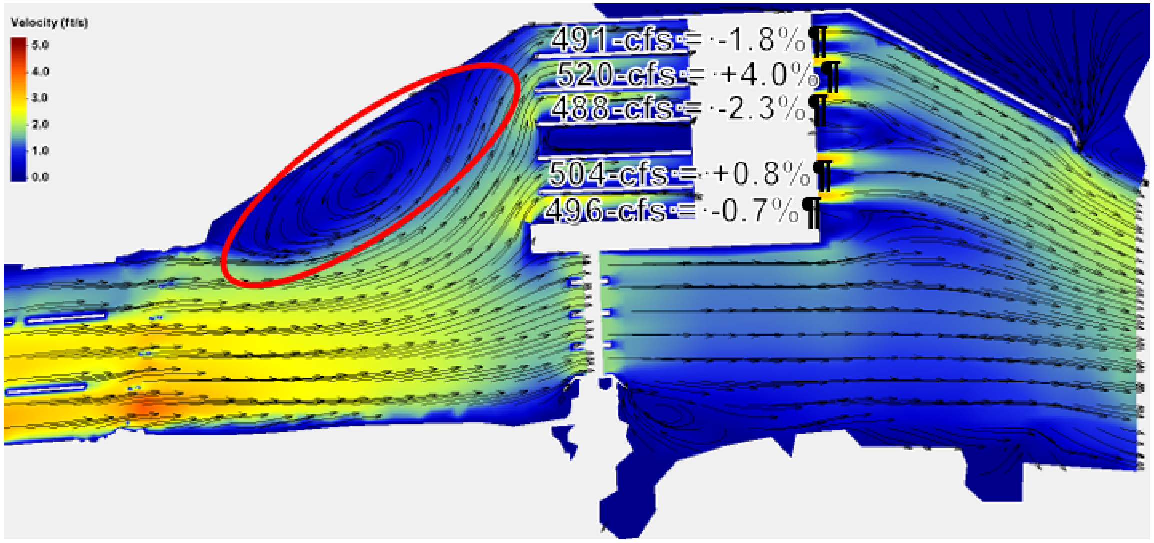


Figure 22: 100-year Maximum Discharge

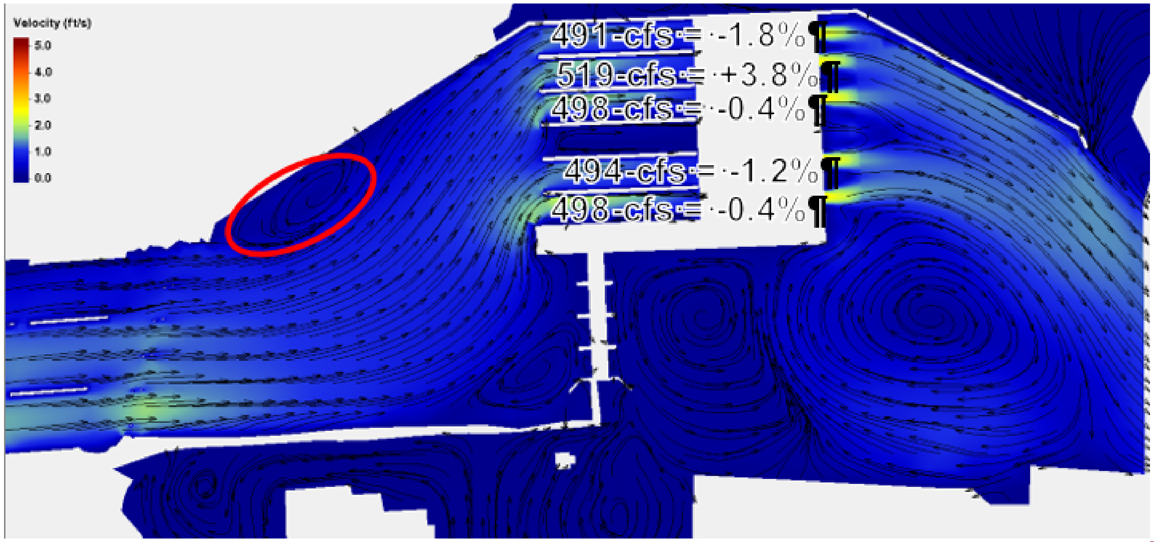


Figure 23: 100-year Maximum Headwater

SRH-2D Results – Headwater

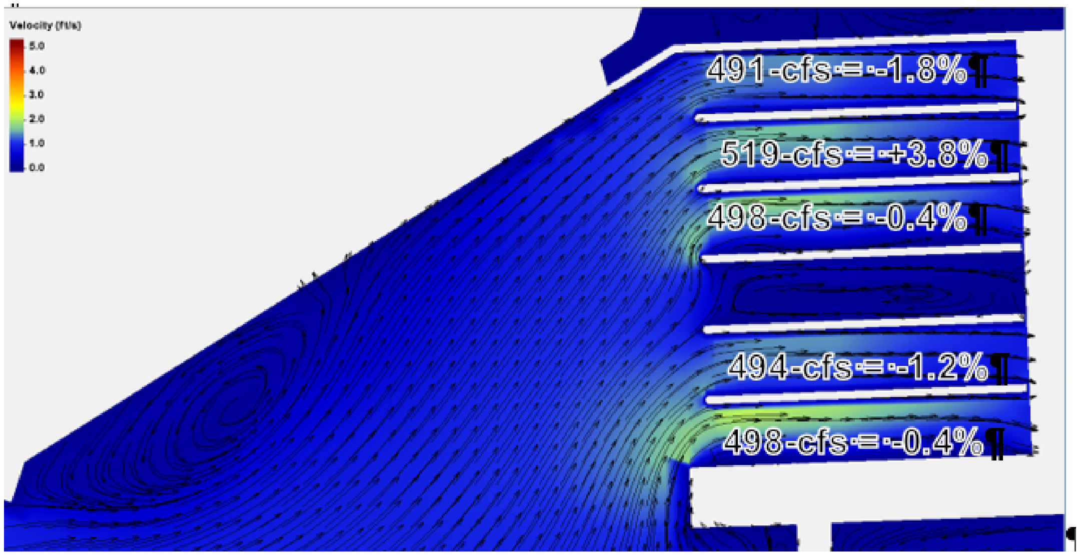


Figure 26: Flow patterns for 100-year maximum headwater

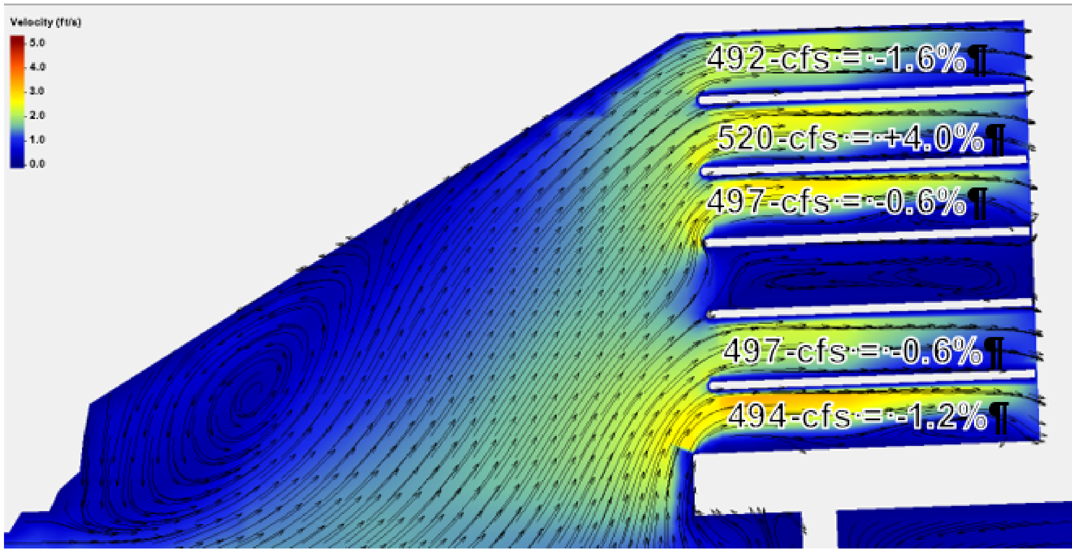


Figure 27: Flow patterns for 100-year minimum headwater

SRH-2D Results – Pump Bays

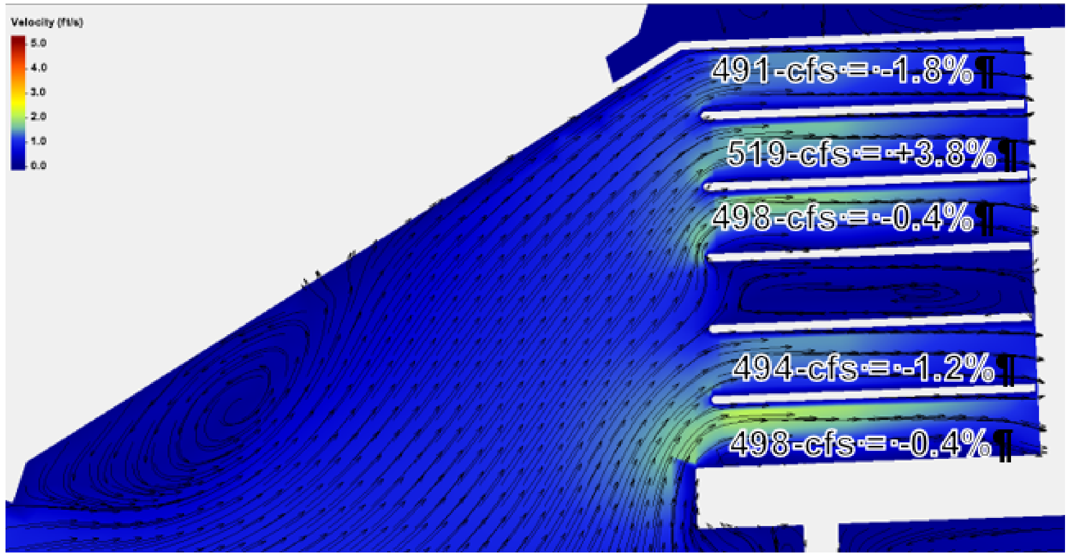


Figure 30: 100-year maximum headwater (Bays 1, 2, 3, 5, and 6)

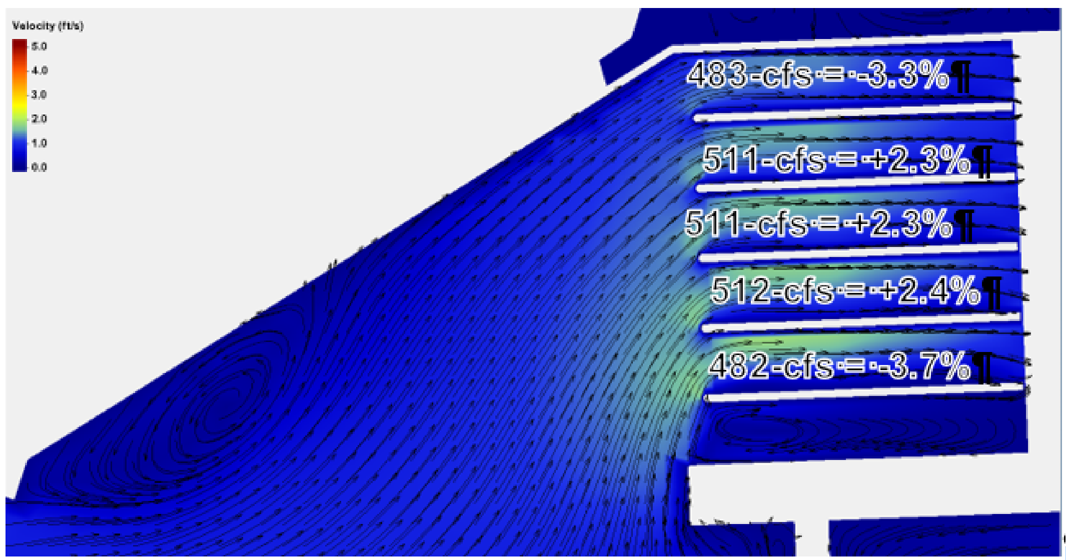
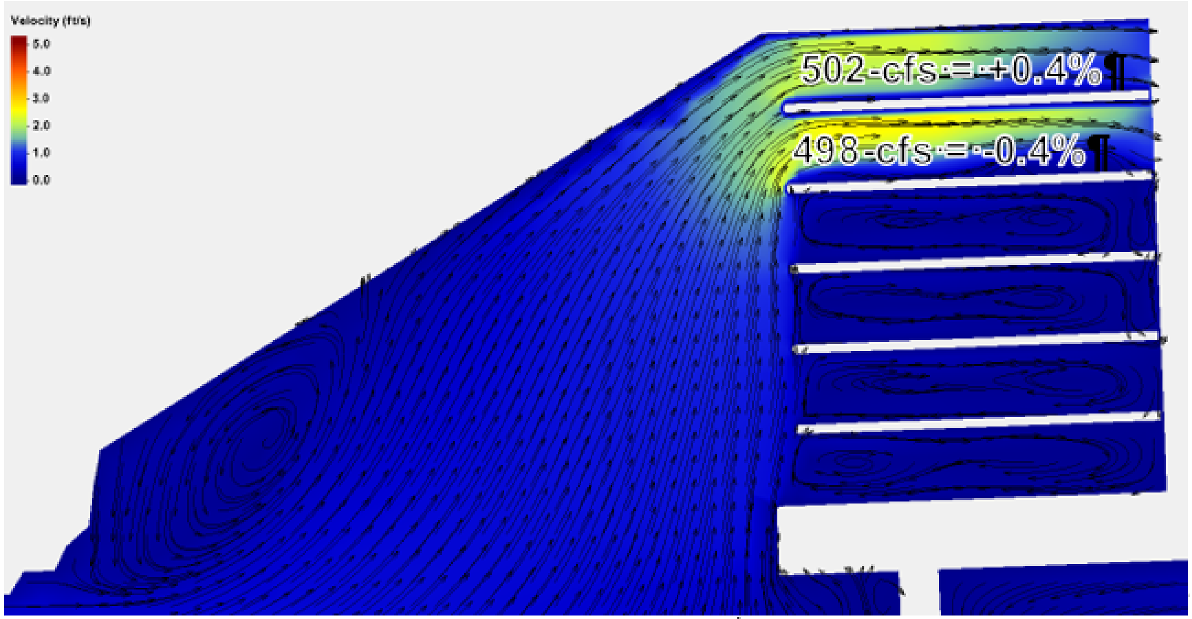


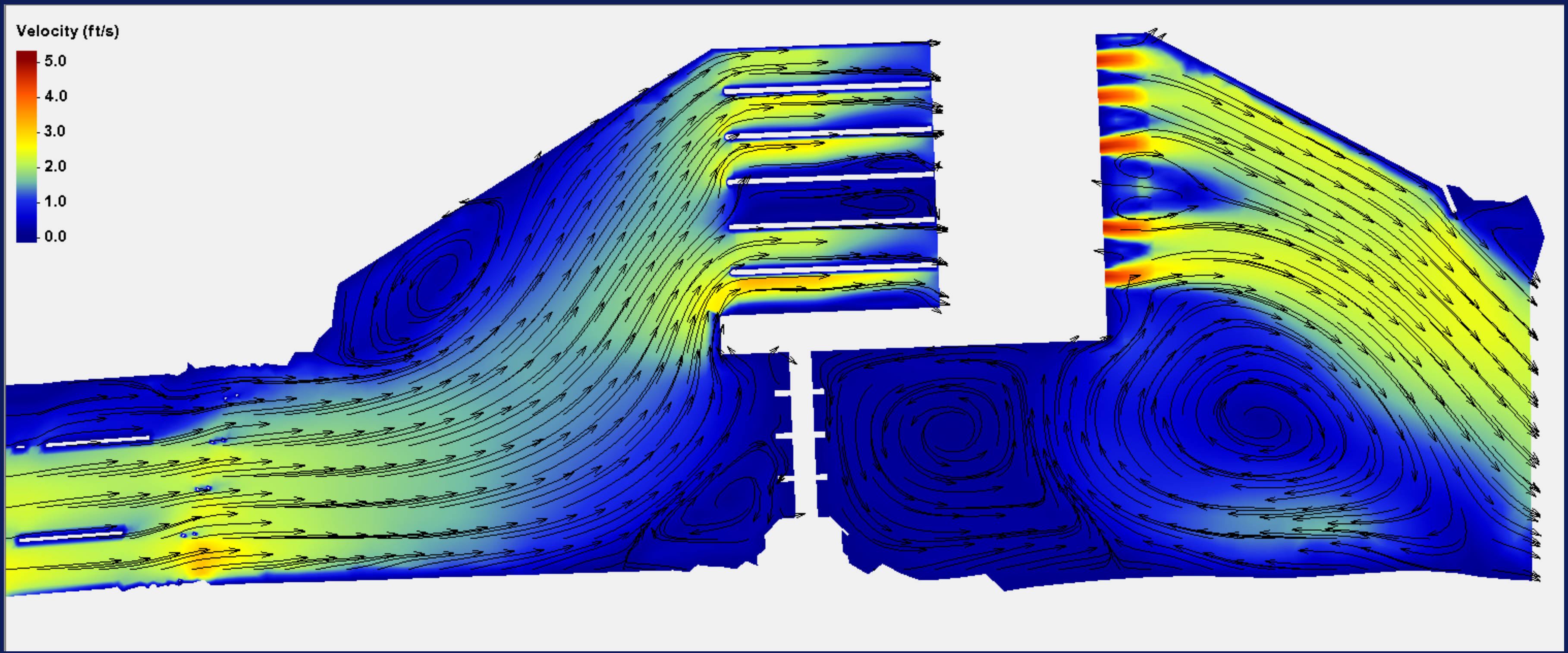
Figure 31: 100-year maximum headwater (Bays 1, 2, 3,4, and 5)

SRH-2D Results – Pump Bays



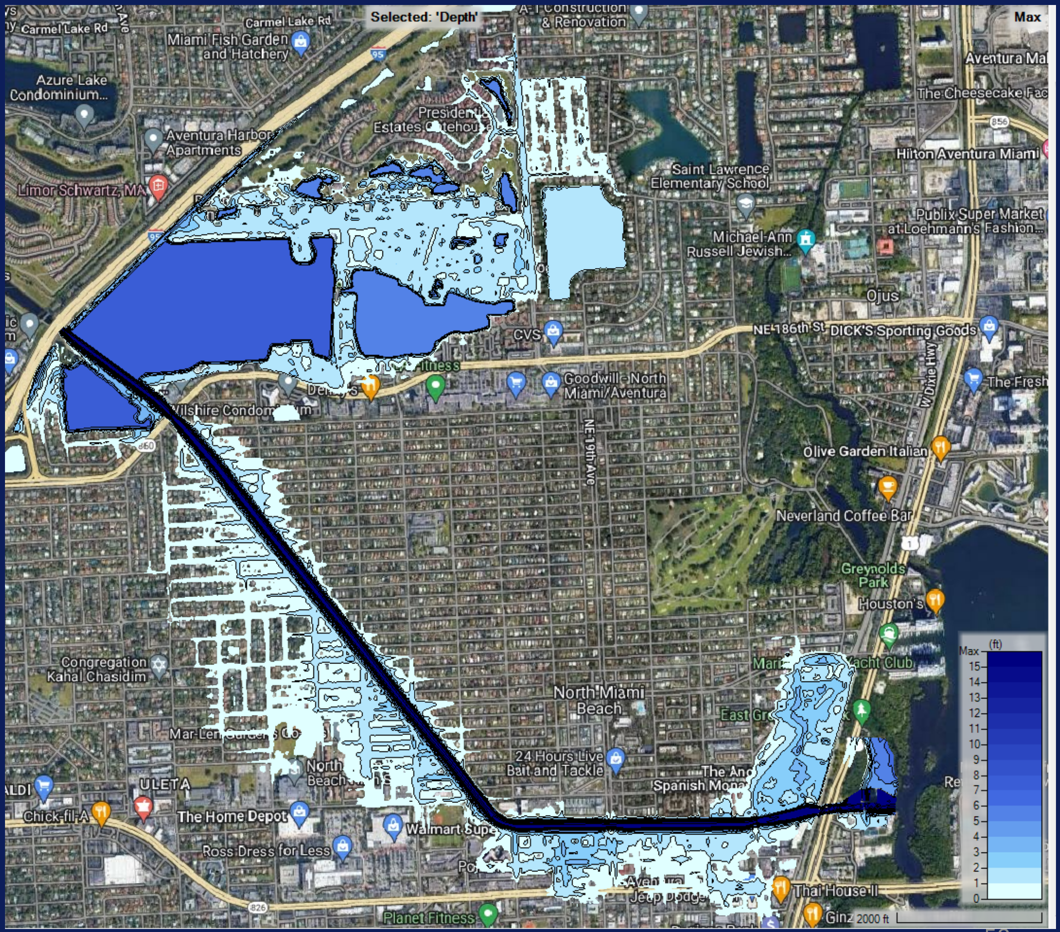
Figure·33:··100-year·maximum·headwater·(Bays·1·and·2)¶

Low Headwater - Velocity



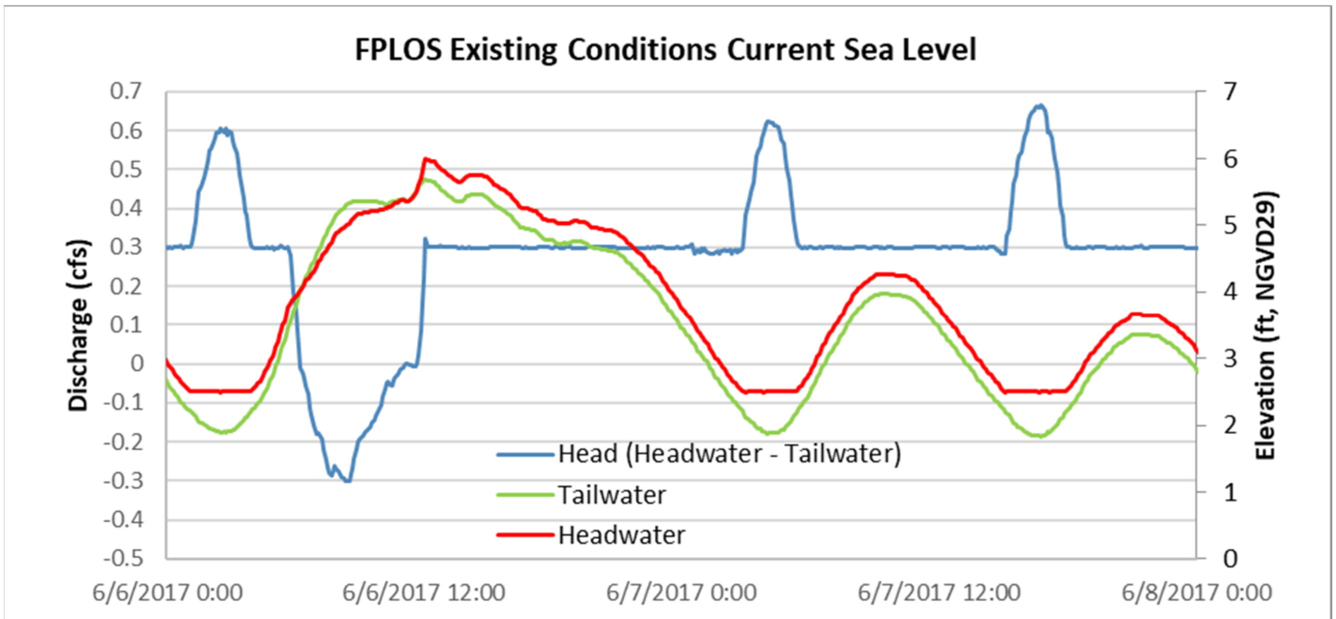
Results and Observations

- Risk of Bypass Flow
- Flow Concentrates Against Bay Wall
- Low Upstream Shear
- High Outlet Velocity
- Simultaneous Gate and Pump
- Pump On/Off
- Coincident Peak
- TW WSEL Control



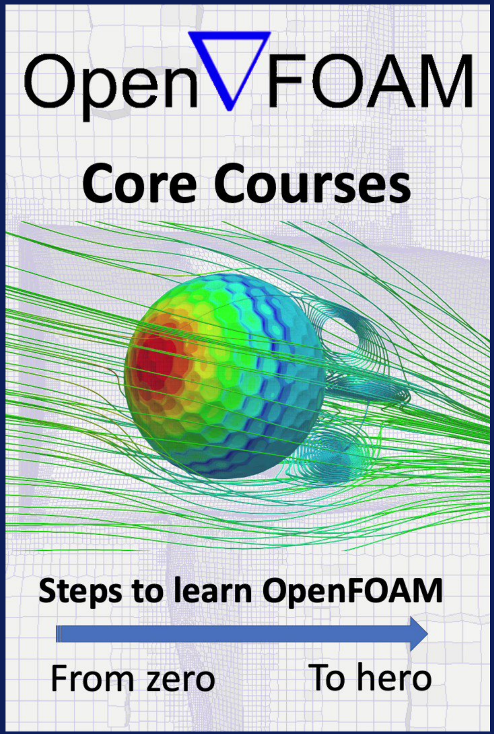
Results and Observations

Gates Equalize Quickly



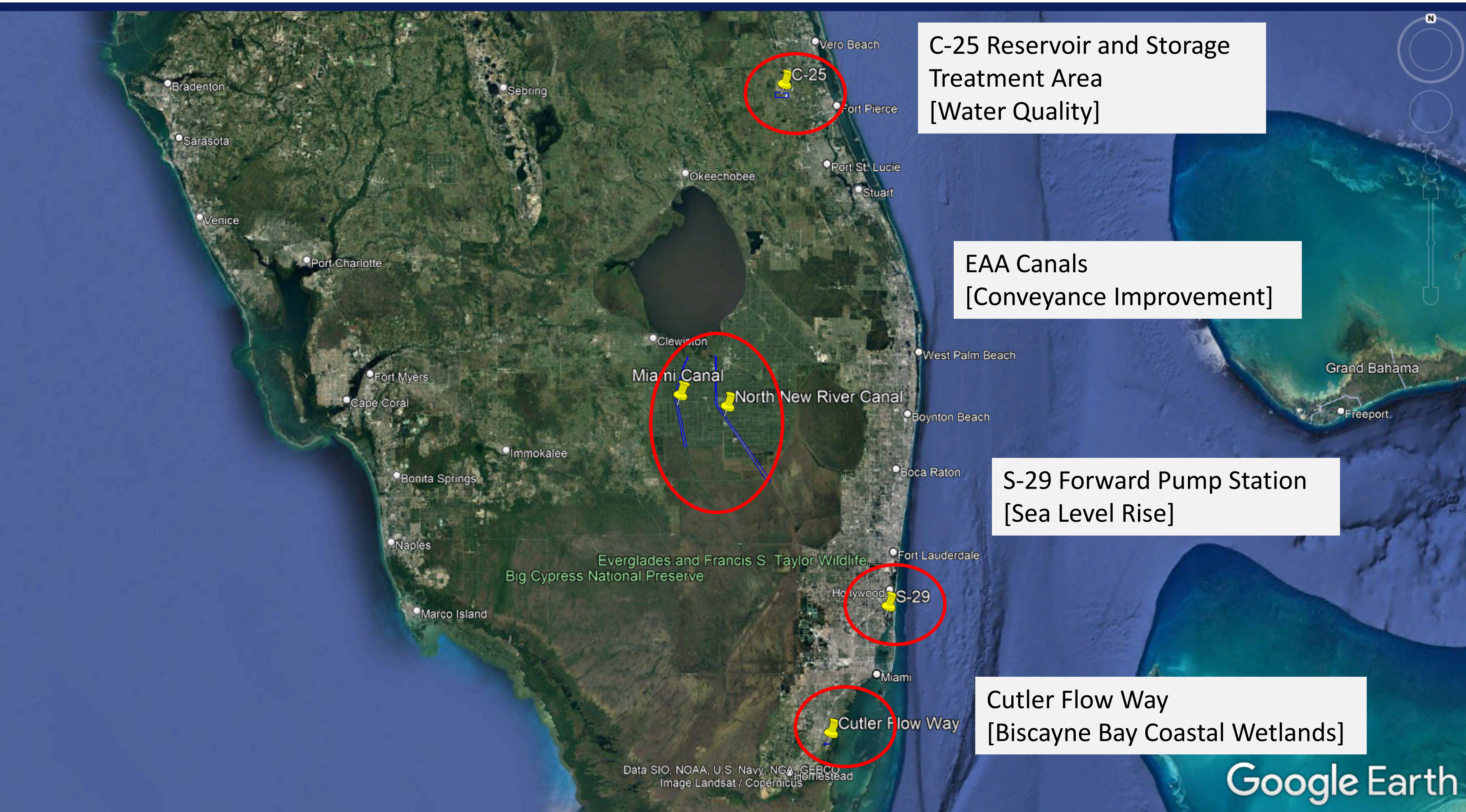
Questions?

3D & Physical Modeling



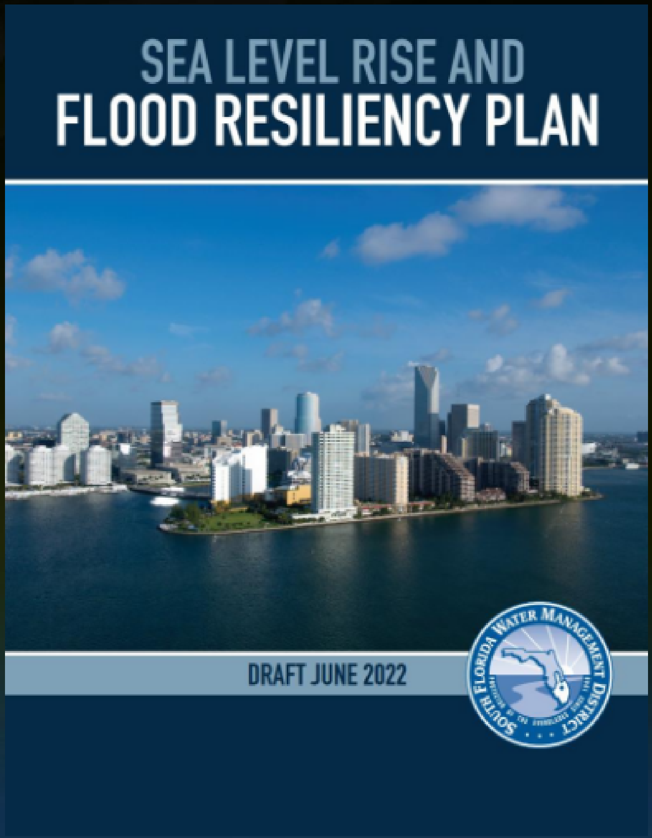
Brian Wozniak, P.E., CFM
bwozniak@hanson-inc.com

Garrett Litteken, P.E., CFM
glitteken@hanson-inc.com


C-25 Reservoir and Storage Treatment Area [Water Quality]
EAA Canals [Conveyance Improvement]
S-29 Forward Pump Station [Sea Level Rise]
Cutler Flow Way [Biscayne Bay Coastal Wetlands]
C-25
Miami Canal
North New River Canal
S-29
Cutler Flow Way
Vero Beach
Fort Pierce
Port St. Lucie
Stuart
Okeechobee
Sebring
Bradenton
Sarasota
Venice
Port Charlotte
Clewiston
West Palm Beach
Boynton Beach
Boca Raton
Fort Lauderdale
Hollywood
Miami
Homestead
Fort Myers
Cape Coral
Immokalee
Bonita Springs
Naples
Marco Island
Everglades and Francis S. Taylor Wildlife
Big Cypress National Preserve
Grand Bahama
Freeport
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth

Planning for System Enhancements
Our Resiliency Vision

- Risk Reduction / Effectiveness
- Implementation Resources
- Anticipated Future Conditions
- Vulnerable Population and Critical Infrastructure
- Leveraging Partnerships and Public Engagement
- Ongoing Ecosystem Restoration Efforts
- Innovative Green/Nature-Based Solutions
- Offsetting New Energy Demands with Sustainable Sources



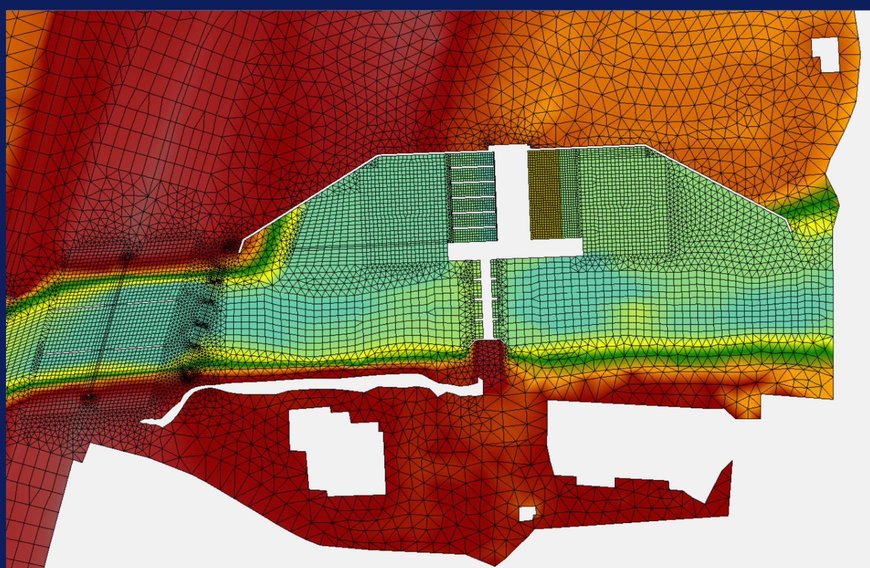
Project Background

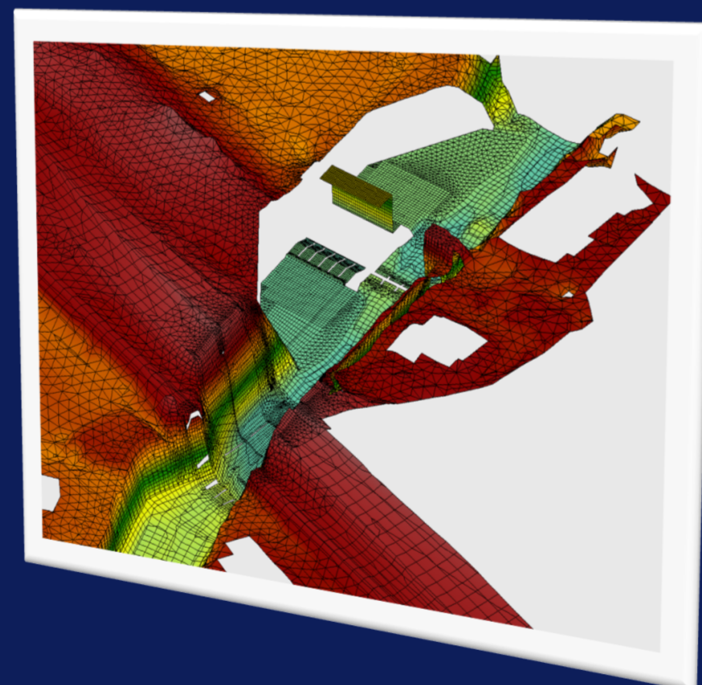
- Sea Level Rise
  - 3-ft by 2100
- Annual Flood Losses
  - $25 Billion by 2050
- SFWMD
  - Forward Pump Stations
  - Pilot Projects

C-9 Canal and S-29 Gates

SRH-2D Model Documentation

- Holes in mesh
- 0.5-ft to 25-ft





Inflow Hydrographs?

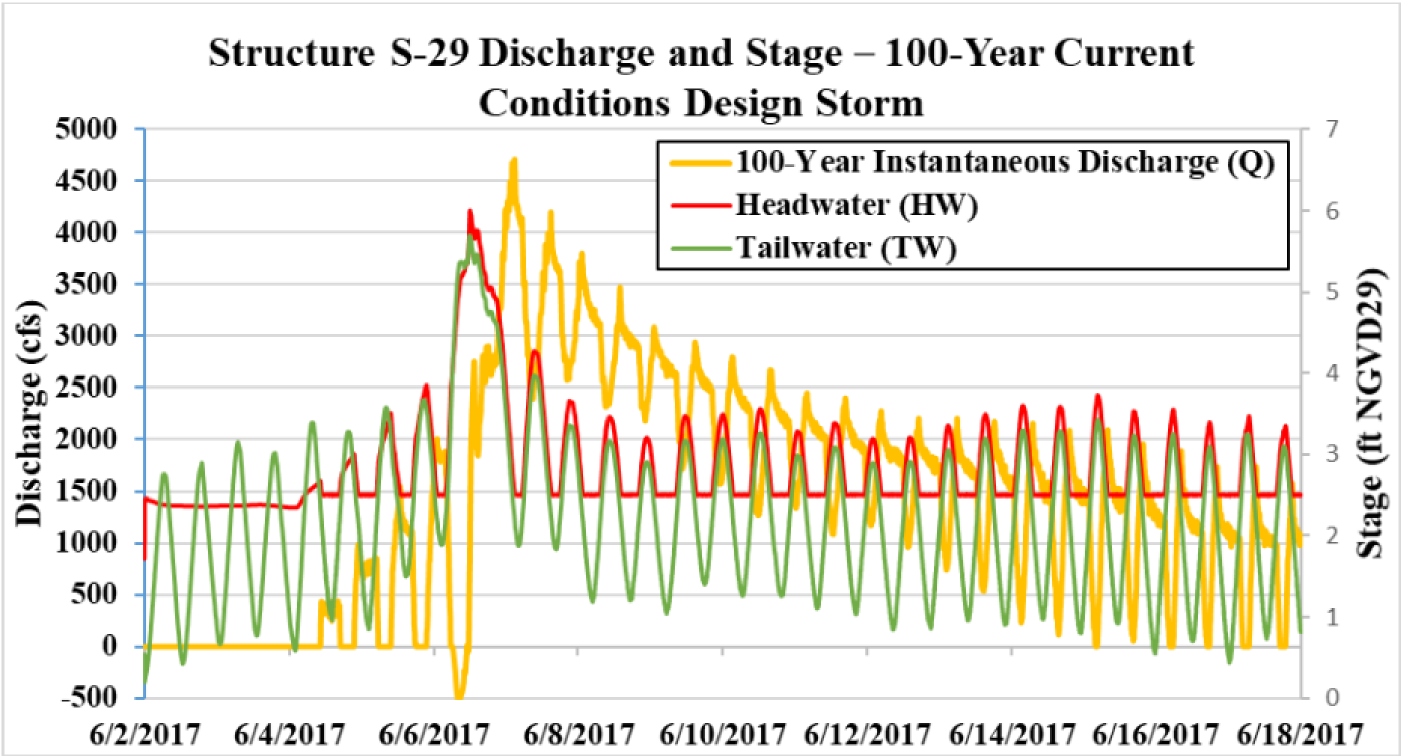
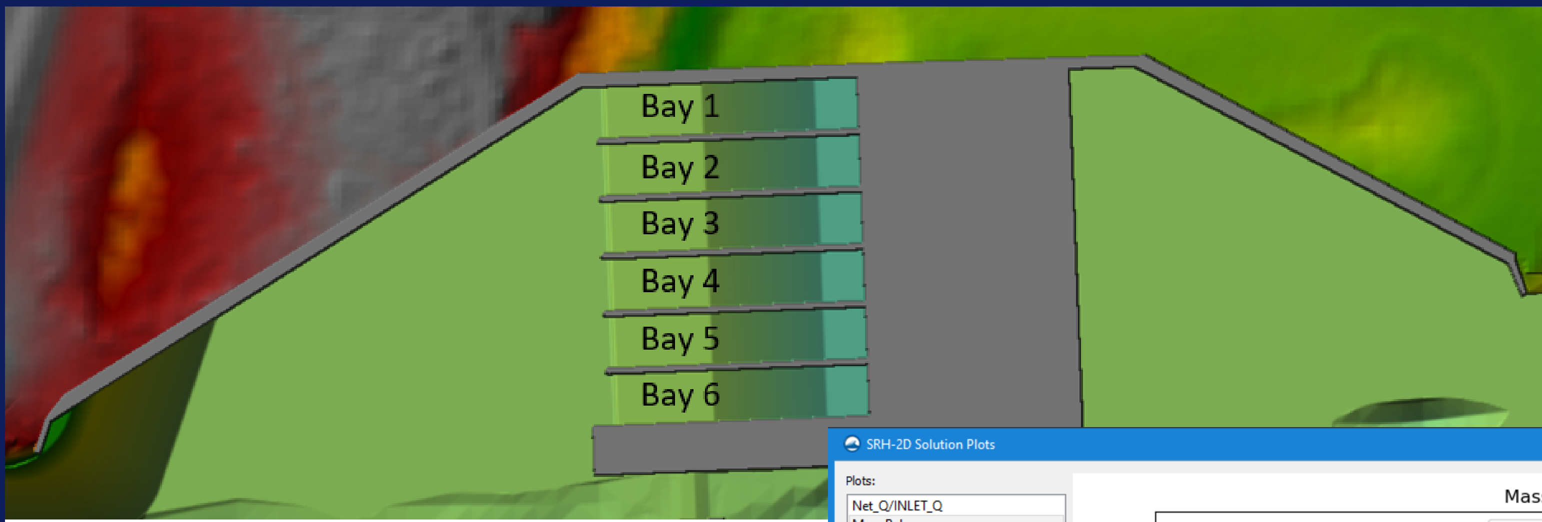
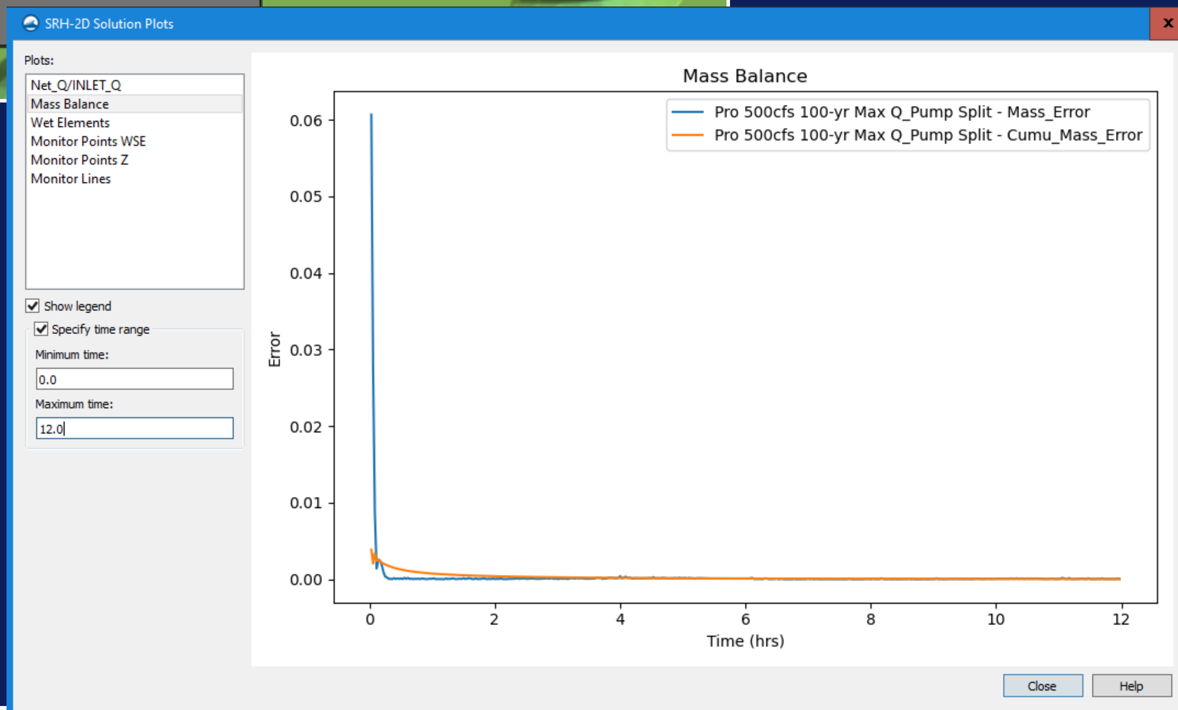


Figure 8.3-7: Instantaneous Discharge and Stage at S-29 Structure for 100-Year Current Conditions Design Storm



- Observe Results in Each Bay
- Stability



SRH-2D Results – Discharge Magnitude

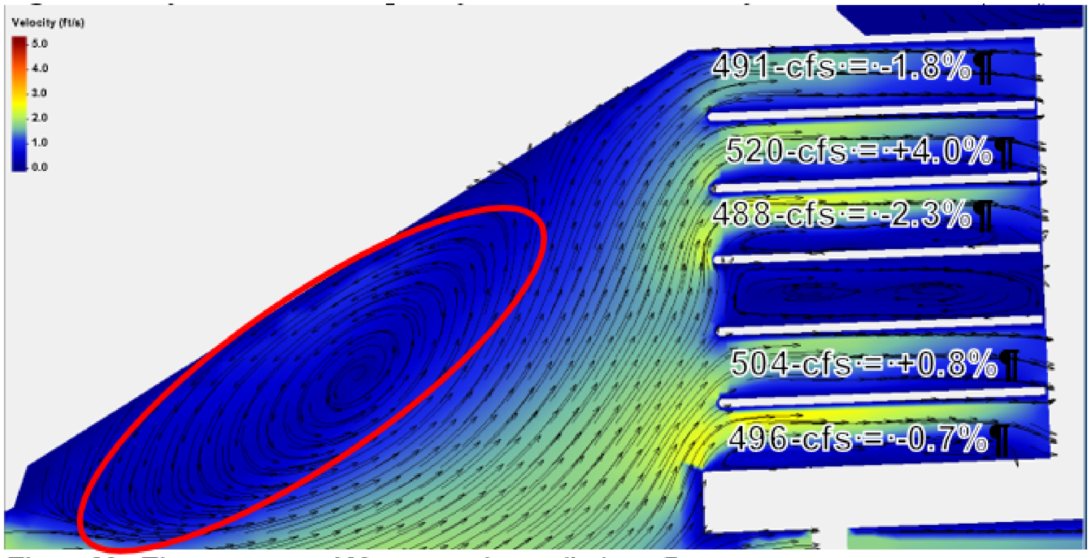


Figure 20: Flow patterns at 100-year maximum discharge

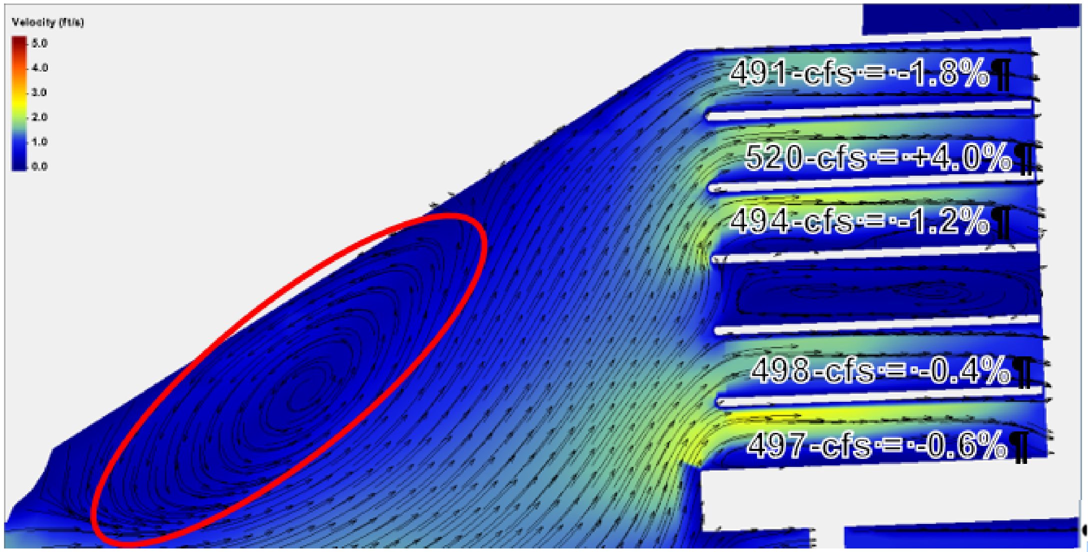


Figure 21: Flow patterns at 25-year maximum discharge

SRH-2D Results – Headwater & Discharge

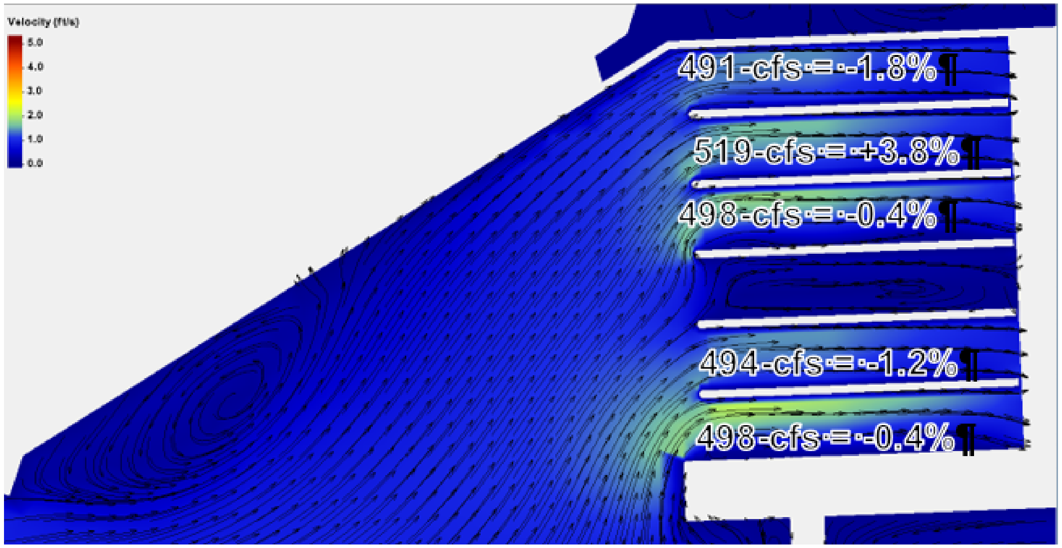


Figure 24: Flow patterns for 100-year maximum headwater

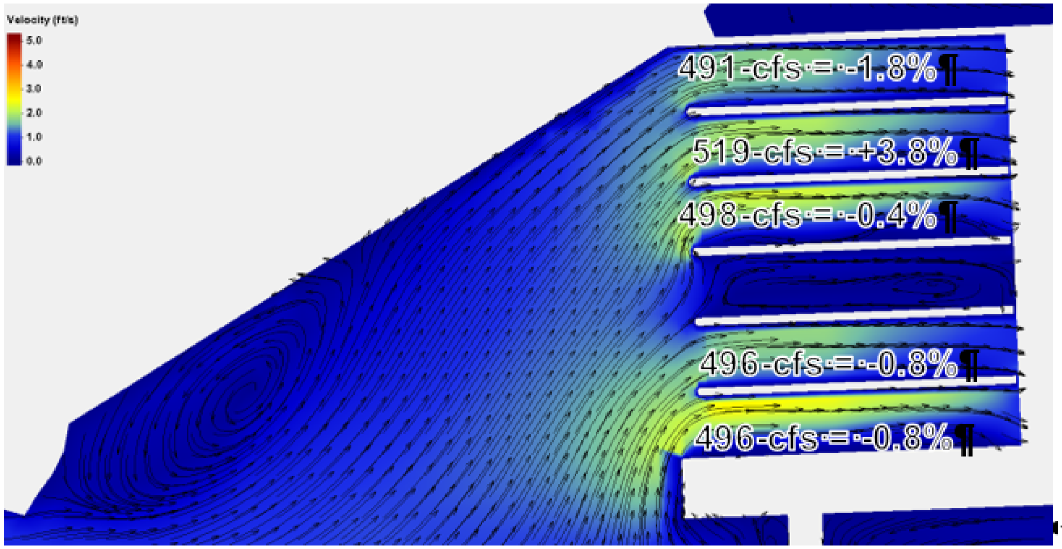
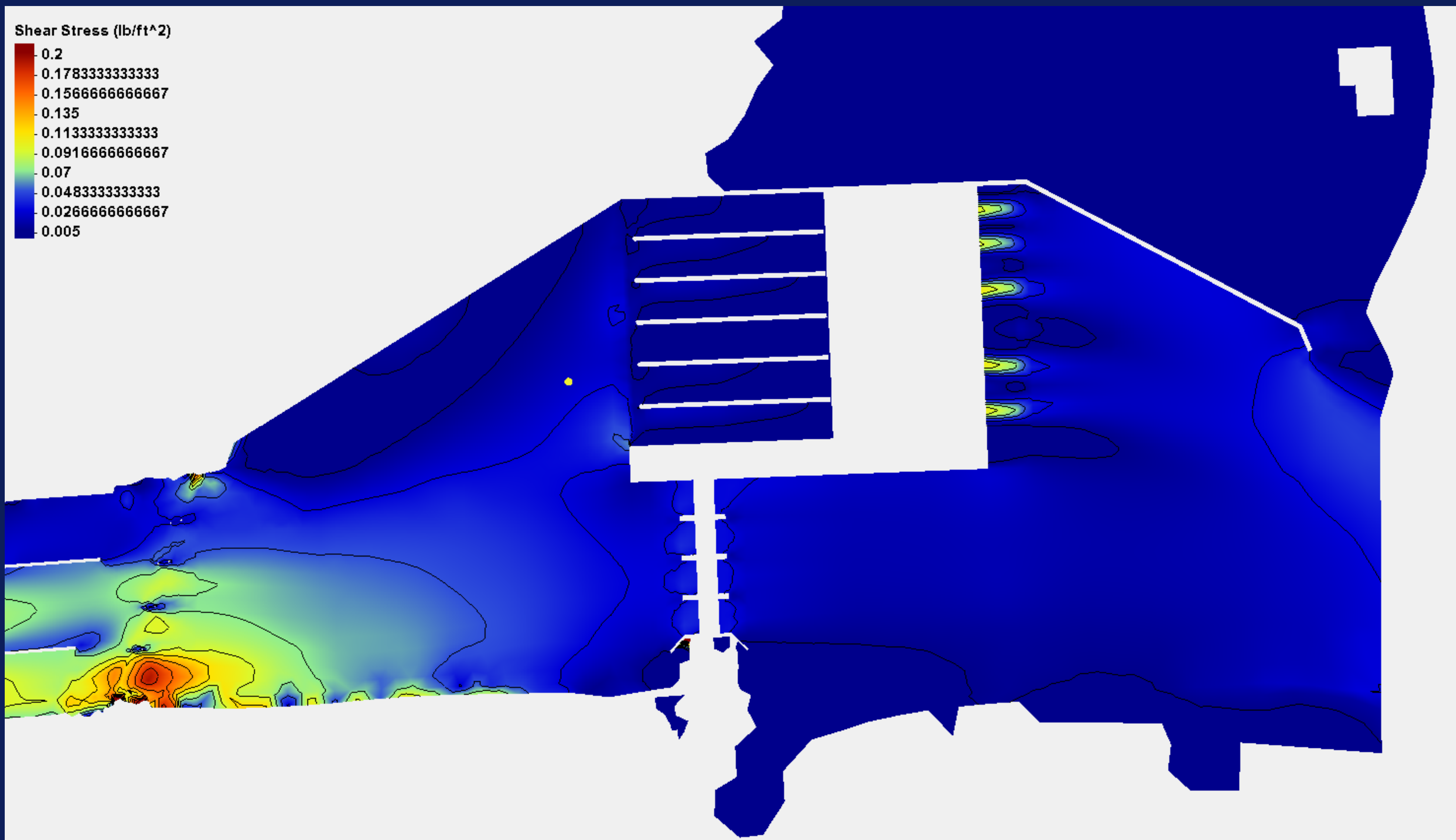


Figure 25: Flow patterns for 5-year maximum headwater

Shear Stress



Water Surface