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FT. Myers, Florida

Navigating FEMA Standards: Mill Creek's Success using 1D/2D Modeling for Floodplain and Floodway Development

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Mill Creek Watershed

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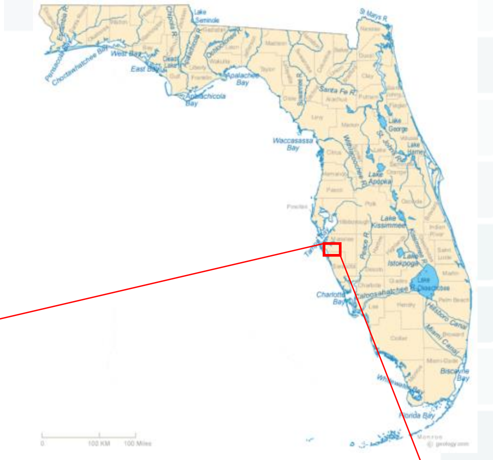
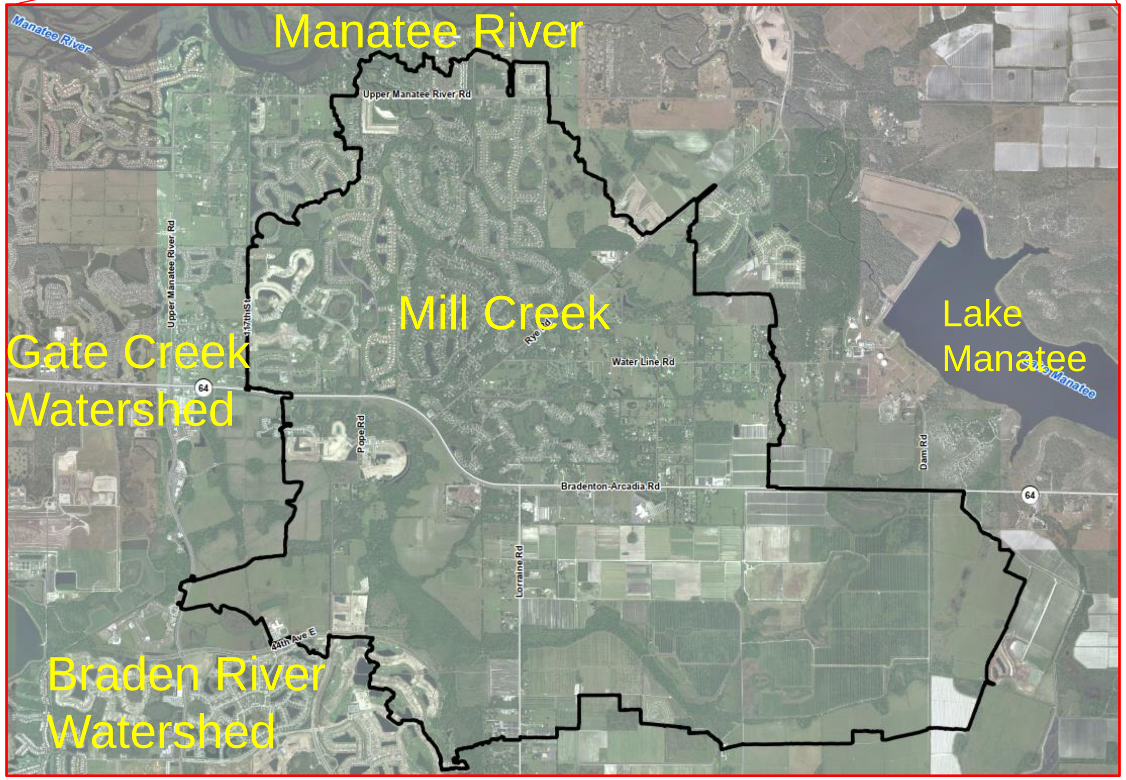
MILL CREEK WATERSHED



- **About watershed**
  - Total Drainage Area: 16 mi^2
  - Elevation: Starts from (-) 7' at the north to over 70' in southeast
  - Lake Manatee to the east, Manatee River to the north, Braden River watershed to the south, and Gates Creek watershed to the west
    - Manatee Dam regulates downstream flow
    - Tidal condition downstream of Manatee River after Mill Creek junction
  - Average annual rainfall: 52"
  - Original model available HEC-1 and HEC-2



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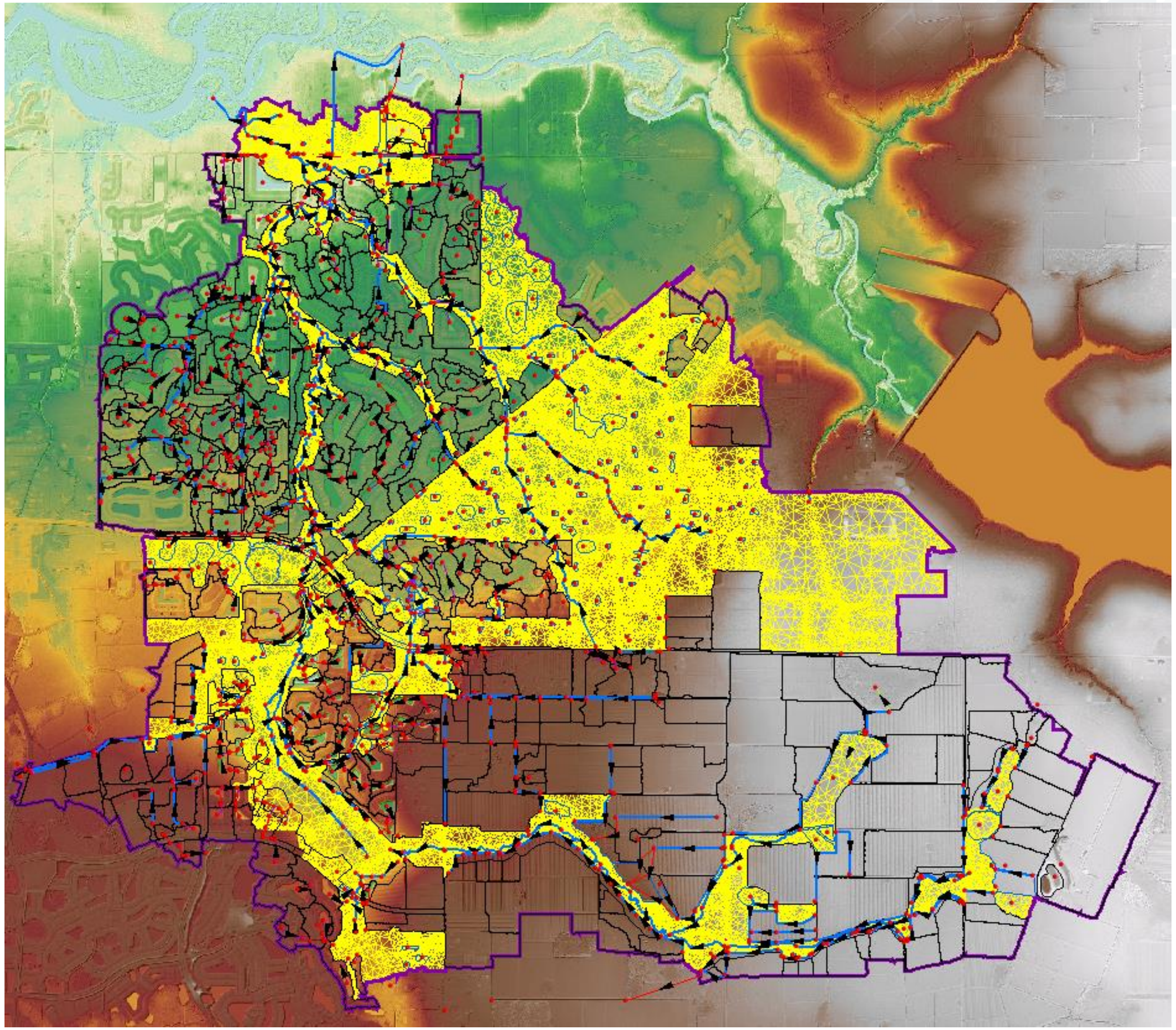
HISTORICAL FLOODING

Model Approach and Input Data

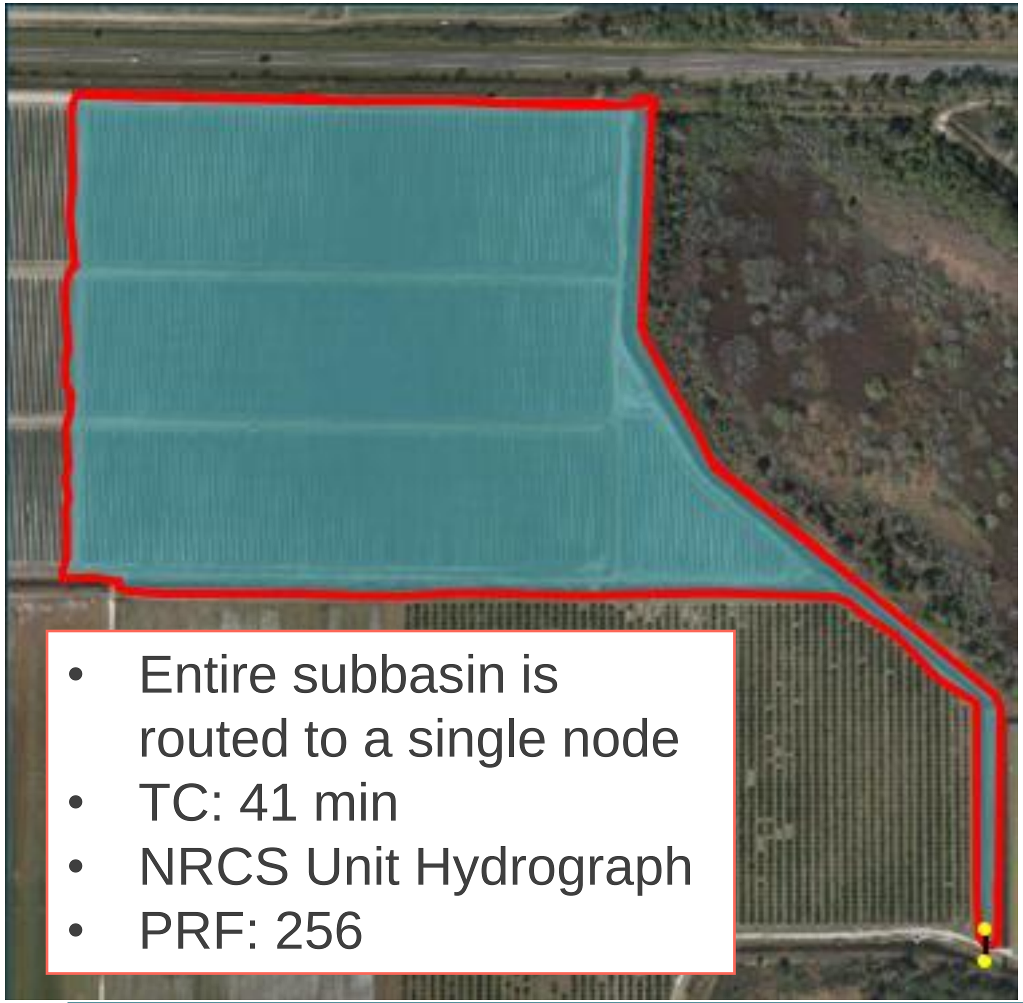
MODEL APPROACH

- Model was developed within ICPRv4 (now known as StormWise)
- 1-Dimension (1D) approach for developed & agricultural areas; areas with unrepresentative DEM
  - Developed areas modeled from ERP data and field reconnaissance
  - Agriculture area : Communication with stakeholders to understand the operation of some pump stations and related drainage system
- 2-Dimnesion (2D) approach for riverine sections where flow meanders or goes in multiple direction; undeveloped area with minimal subsurface conveyance
  - Modeled using ERP data, field reconnaissance, aerial imagery, and the project DEM



AGRICULTURAL AREA – PILOT STUDY

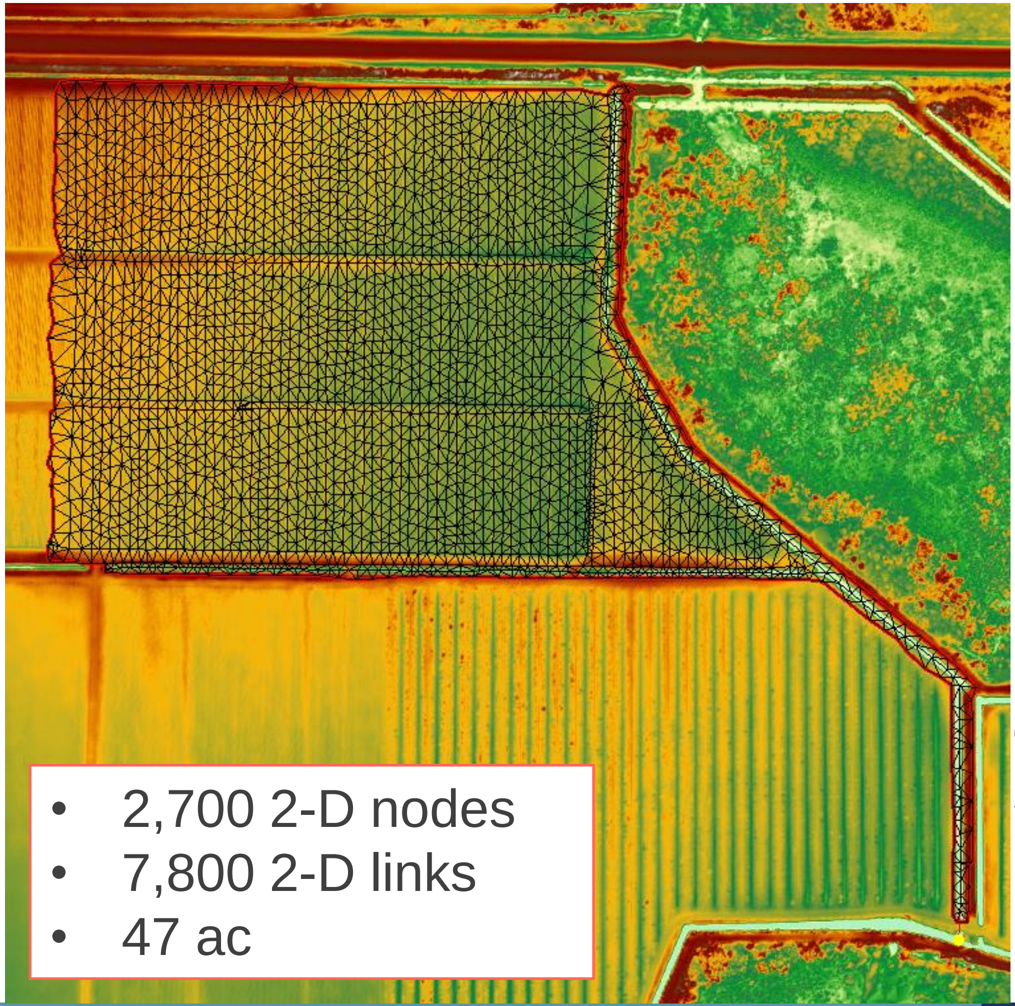
- **1D Approach :**Entire subbasin is routed to a single node



- Entire subbasin is routed to a single node
- TC: 41 min
- NRCS Unit Hydrograph
- PRF: 256

Outlet: 36" CMP

- **2D Approach:** Furrows modeled by breaklines and mesh

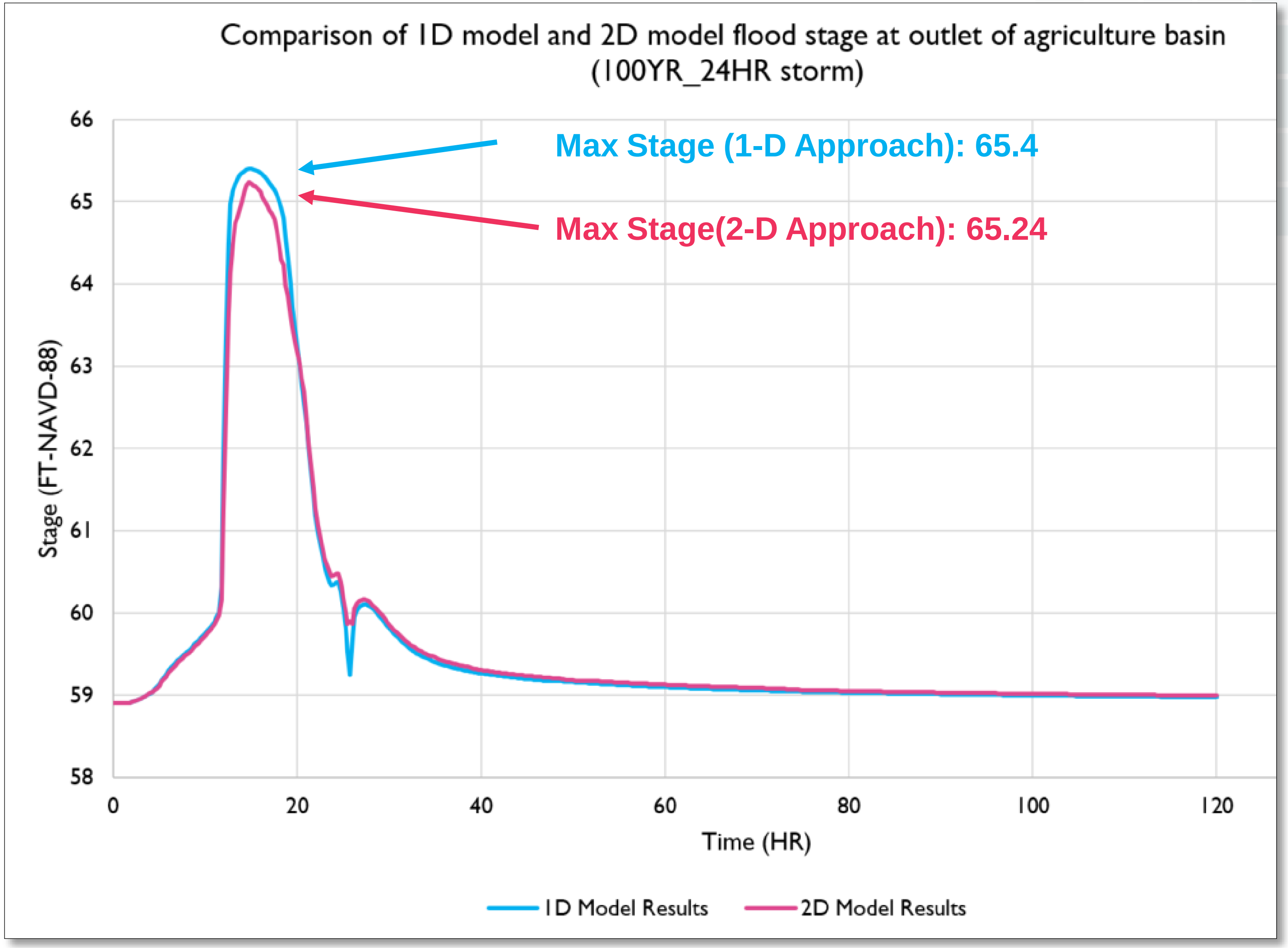


- 2,700 2-D nodes
- 7,800 2-D links
- 47 ac

Outlet: 36" CMP

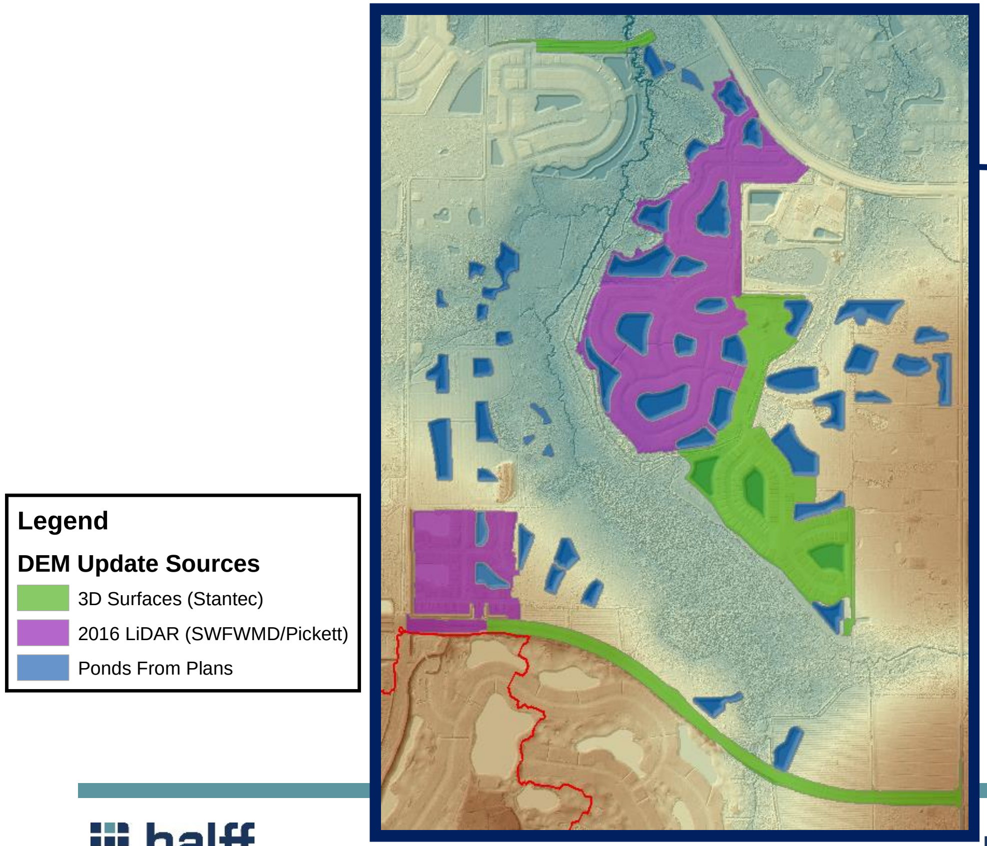
AGRICULTURAL AREA – PILOT STUDY

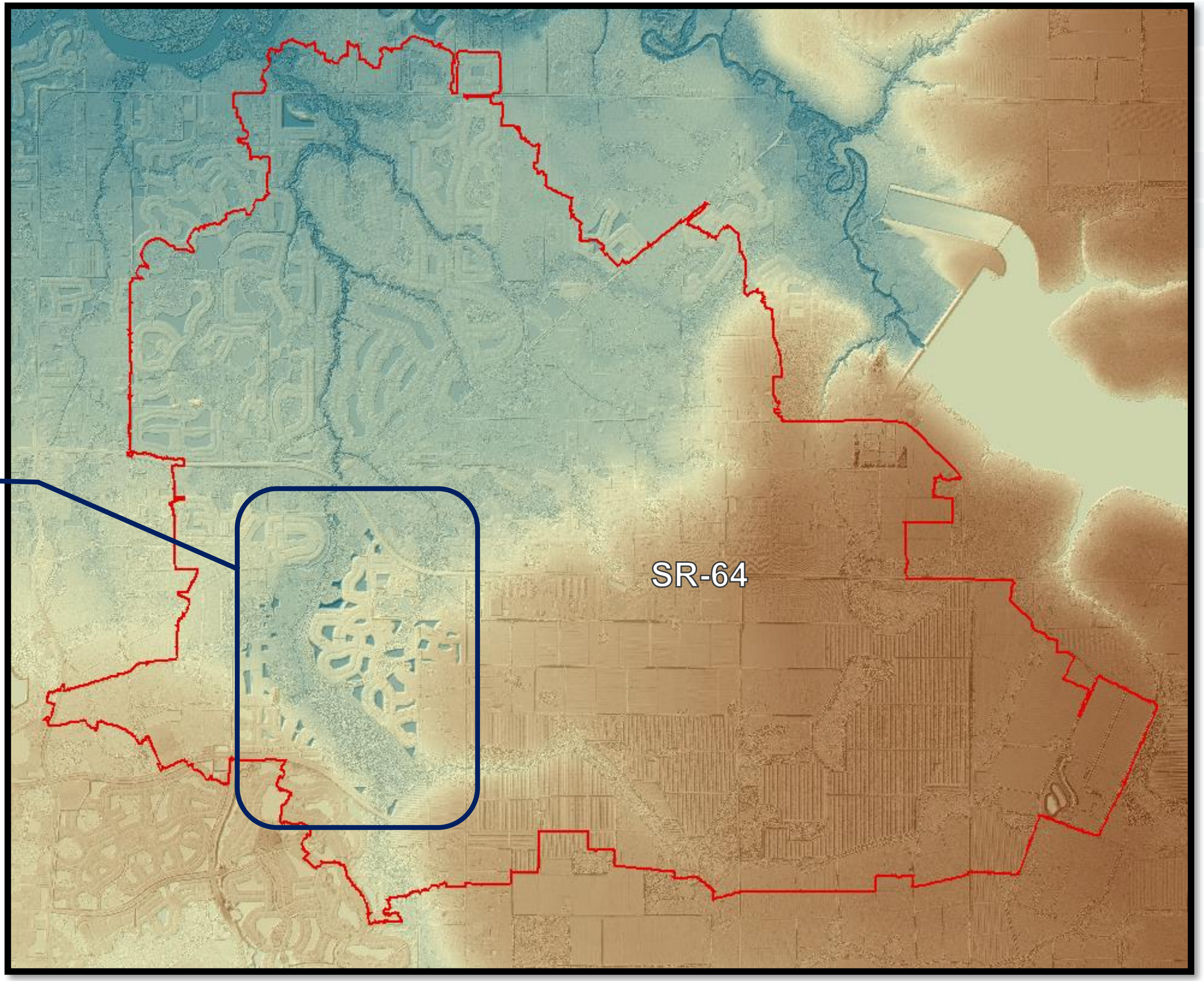
- **1D vs 2D Approach –Comparison**
  - Additional effort: 15-25 hours per mi^2
  - More computationally intensive (>7,000 links)
  - Calibration of 1D parameters using 2D "pilot" area results



INPUT DATA

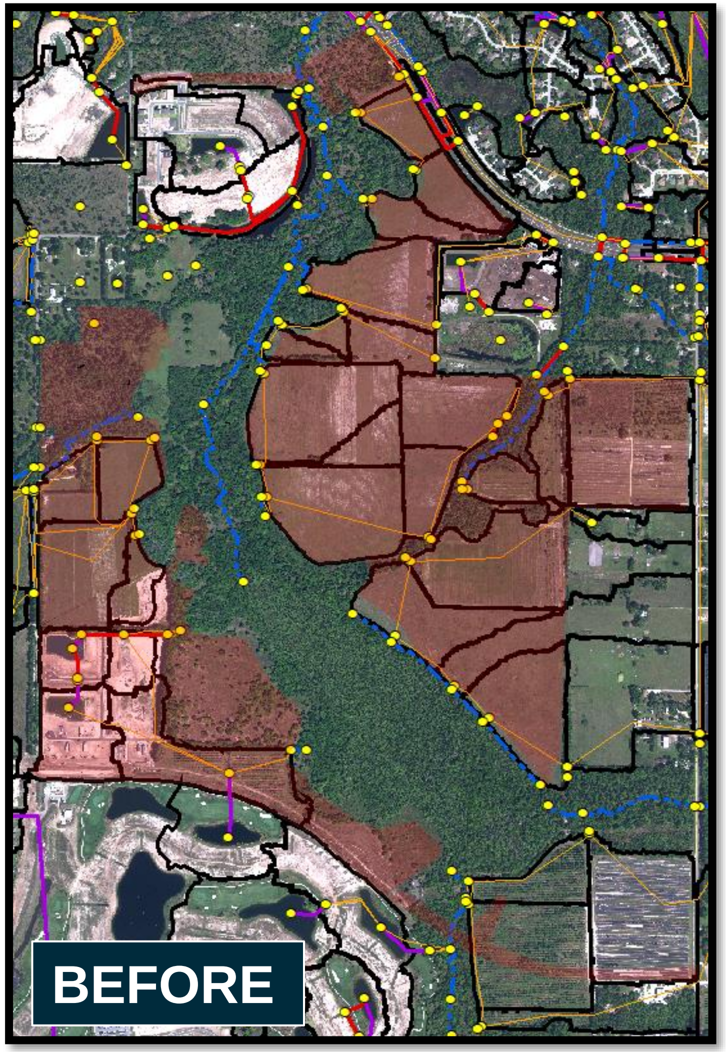
- **Terrain – March 2015**
  - DEM voids were revised using new LiDAR data, surfaces from the developer, and construction plans

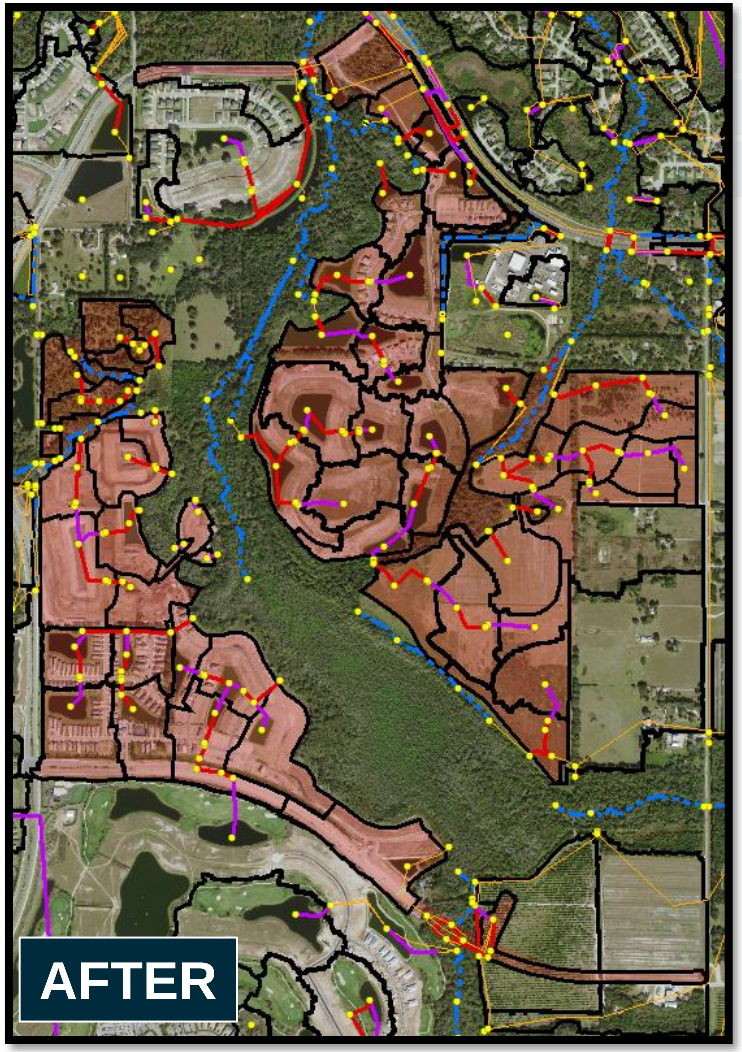




INPUT DATA – NEW DEVELOPMENT

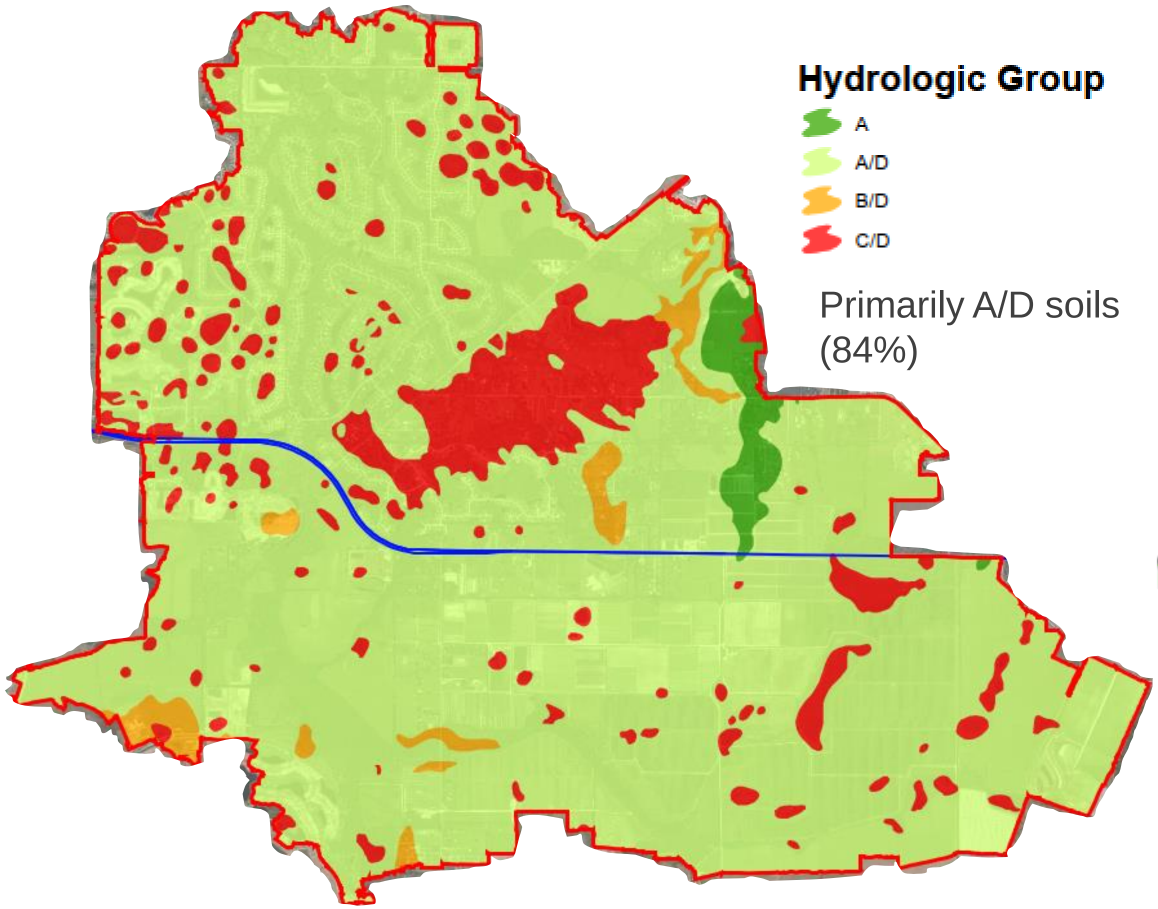
- Project Date Certain: 2015
- Modeled 4 new developments that were considered critical to the County & to allow for calibration to Hurricane Irma
- Partially constructed in 2017





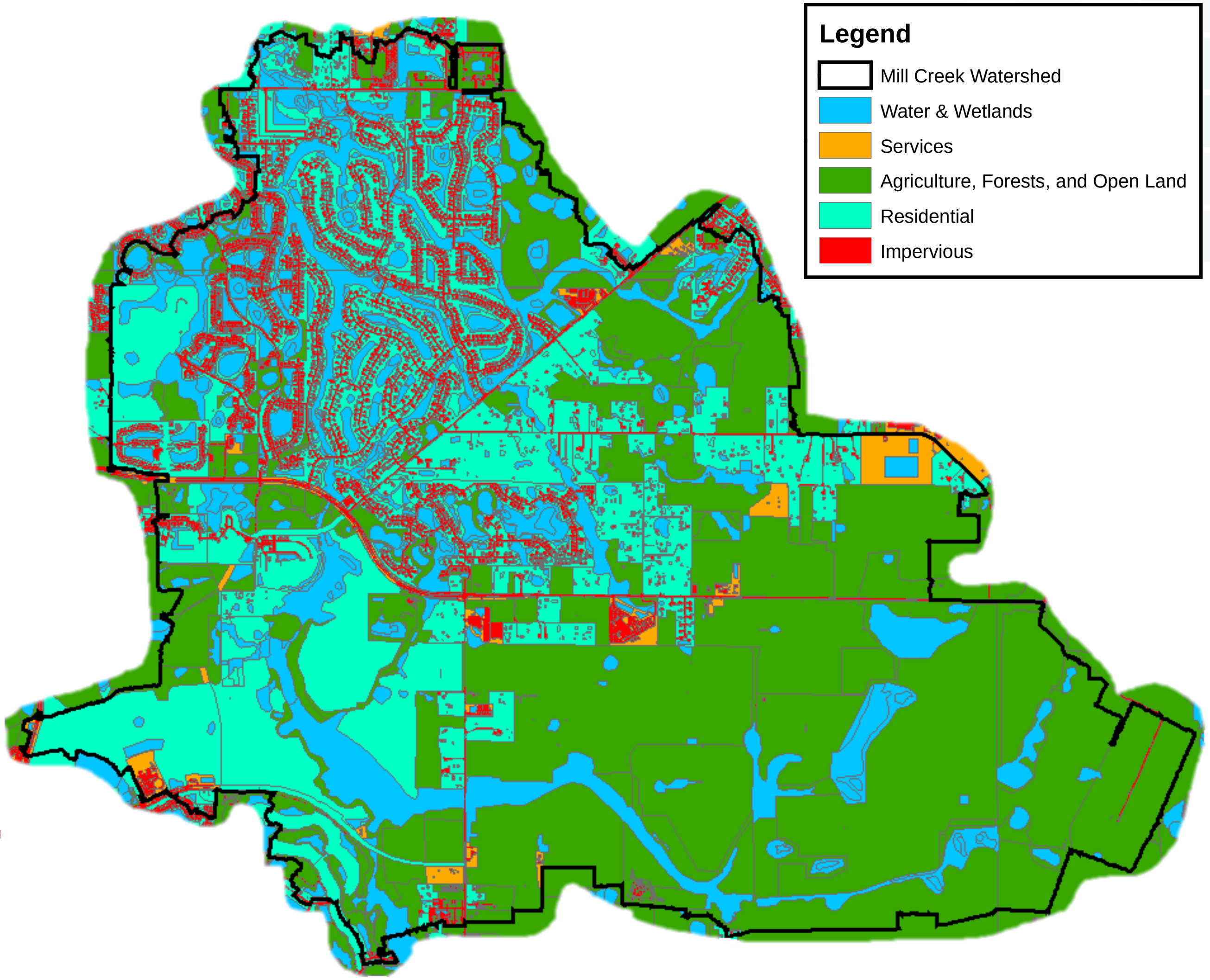
INPUT DATA

Soils Map



Primarily A/D soils (84%)

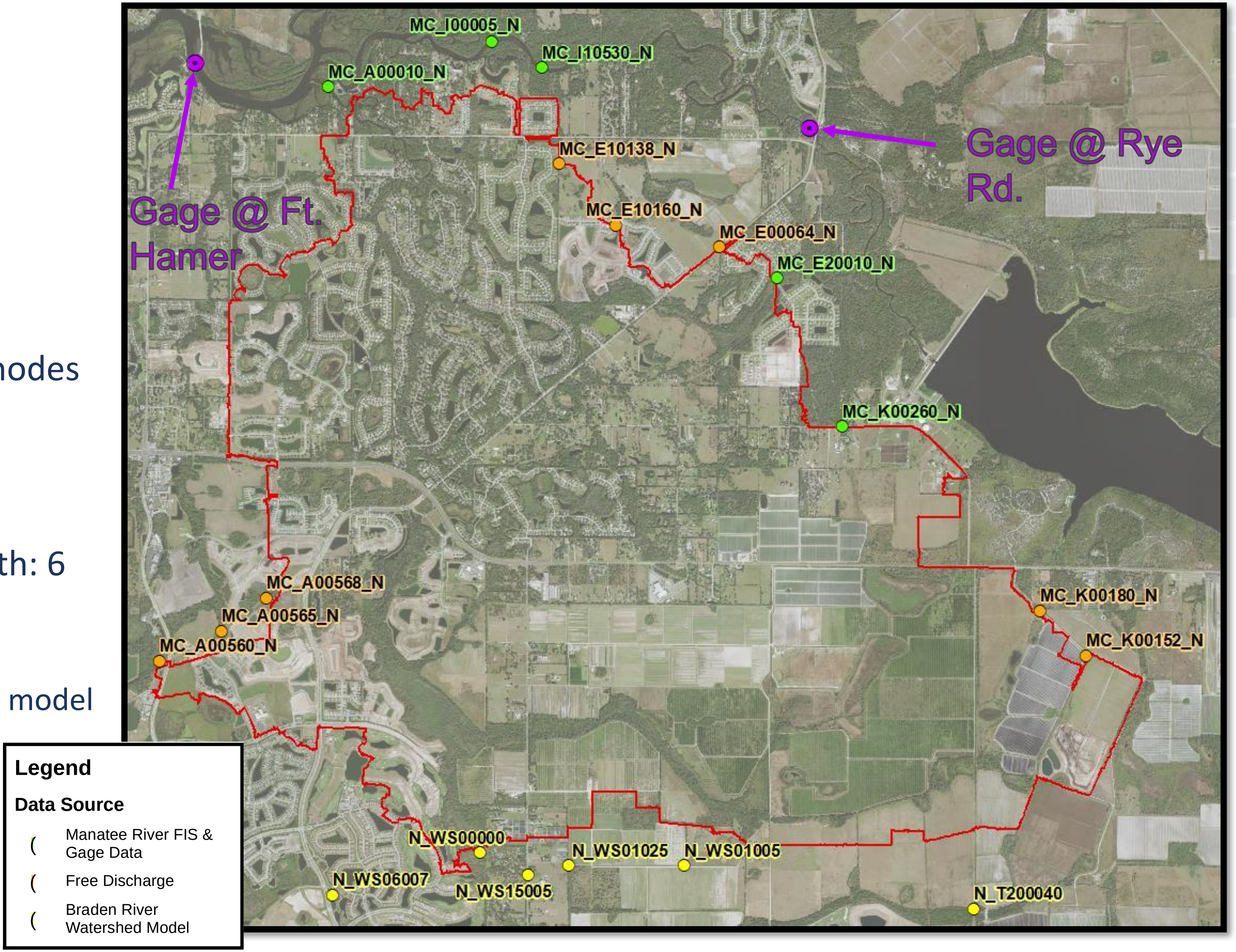
Land Use Map



Boundary Condition and Starting Condition

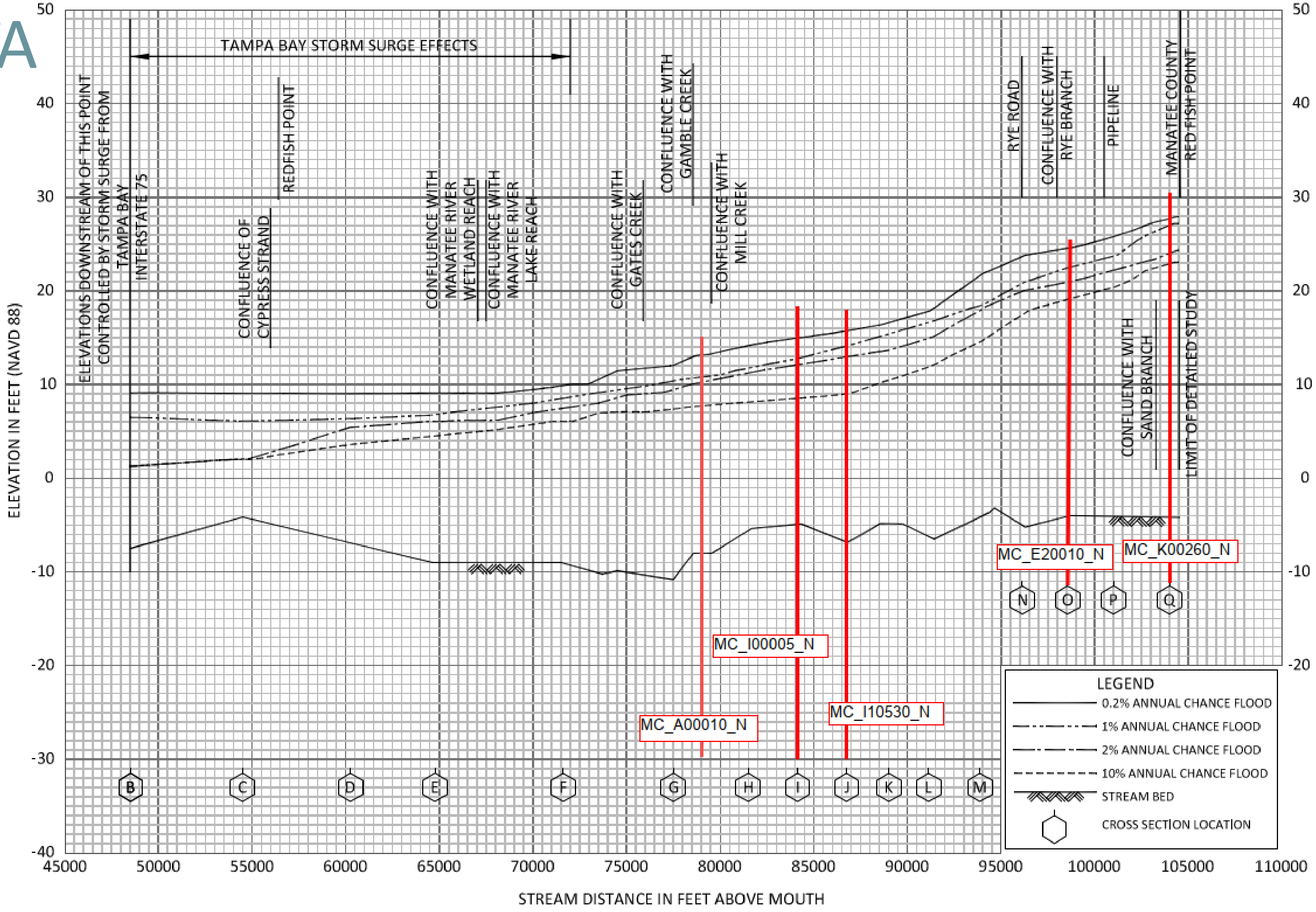
BOUNDARY DATA

- **Total boundary nodes: 19**
  - Free discharge : 8 nodes
    - Fixed time/stage data
  - Manatee River FIS profile, north: 5 nodes
    - Varied time/stage data
    - Calculated from statistical analyses
  - Braden River watershed model, south: 6 nodes
    - Varied time/stage data
    - Simulated results from an adjacent model



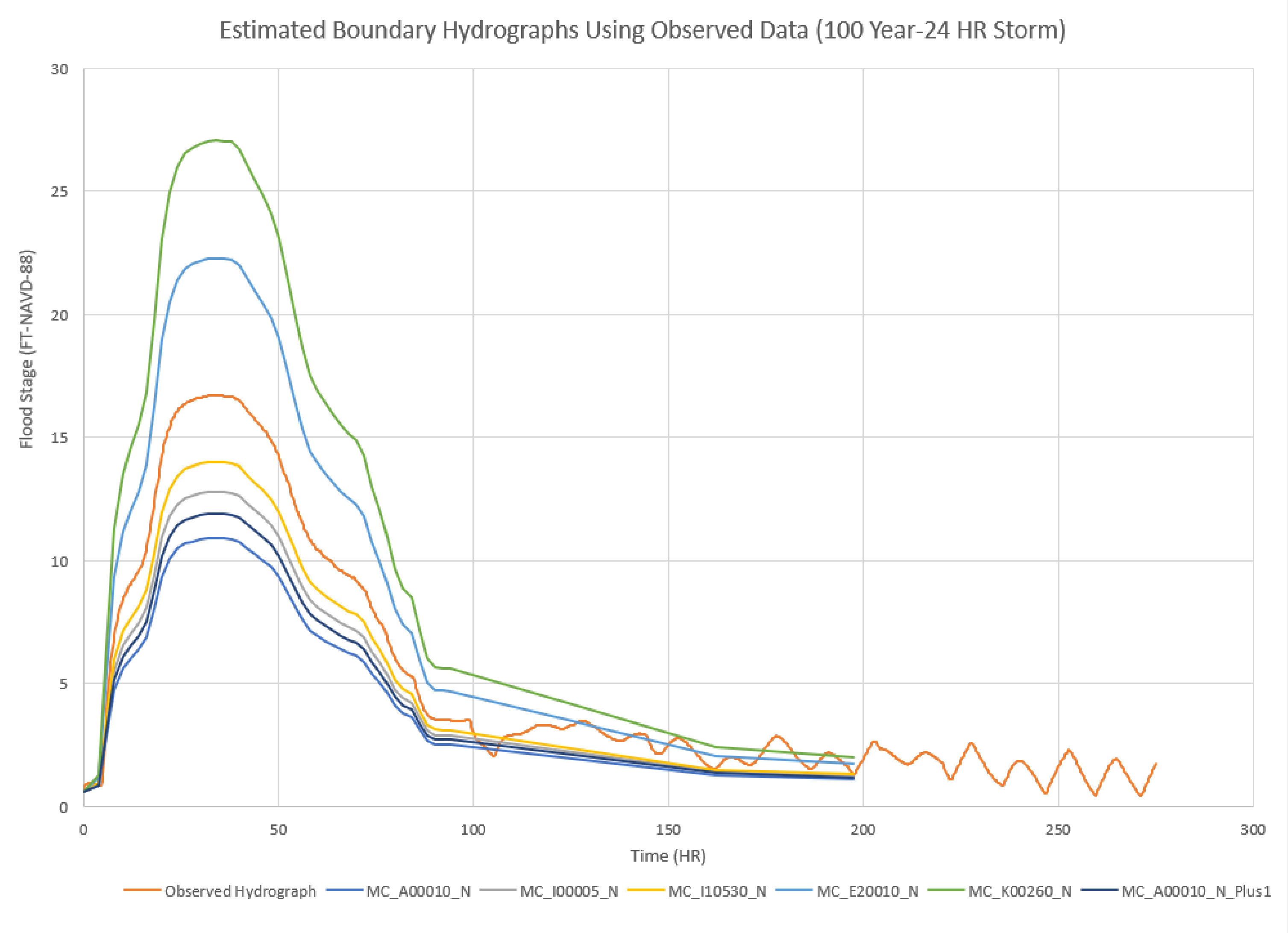
BOUNDARY DATA

- **Estimation of maximum stage using FIS profile**
  - Interpolated maximum stage using probability graph for missing frequencies
  - Frequency analysis of observed gage data



BOUNDARY DATA

- **Generated unit hydrograph**
  - Generating dimensionless hydrographs for different storm durations using Manatee River gage data
  - Generating varied boundary using unit hydrographs and peak stage for different storm frequency (e.g., 5, 10, 25 year) and durations (e.g., 24, 72, and 168 hour)

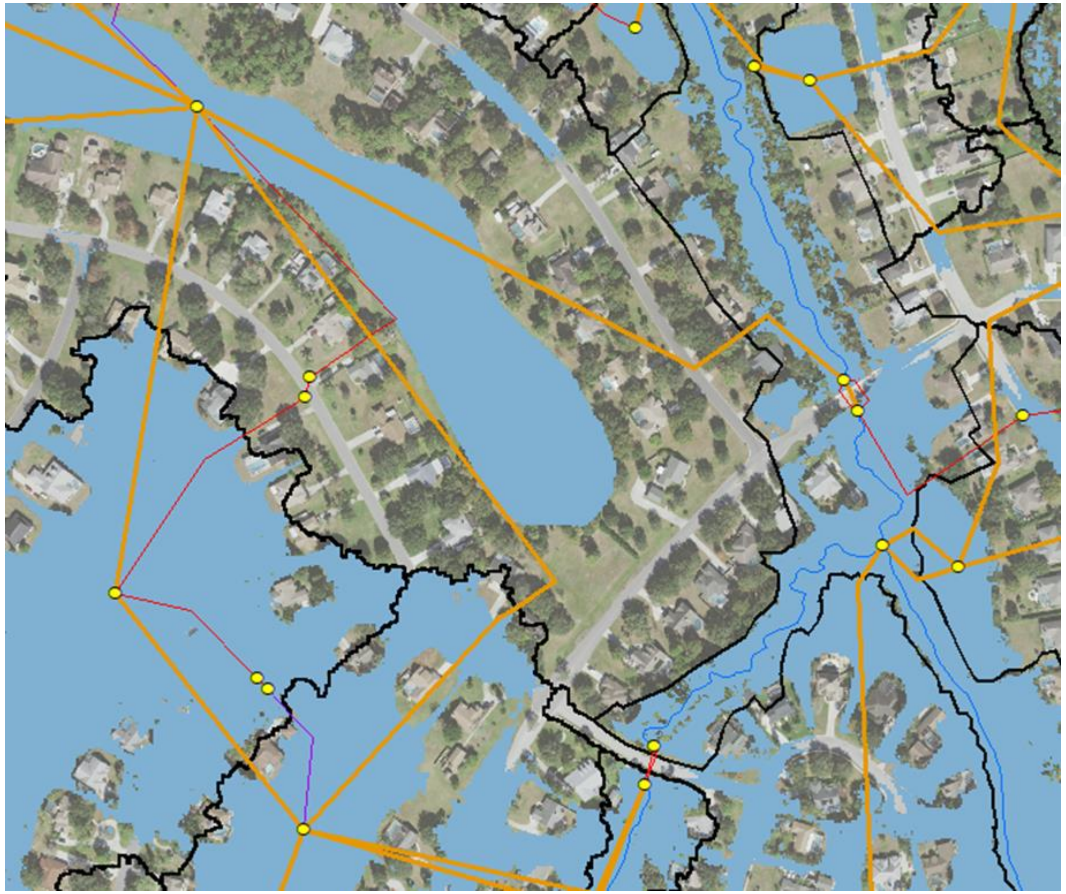


Model Parametrization

MODEL PARAMETRIZATION

- **Rainfall Excess Method**
  - Three methods were evaluated - Curve Number (CN), Green-Ampt, and Vertical Layer; CN method was selected during calibration
- **SCS Unit Hydrograph**
  - PRF=323 (Developed Areas)
  - PRF= 256 (Remaining Areas)
- **Initial Conditions for 1D and 2D area**
  - Established based on drawdown analysis of 100-year storm simulated to 500-hours

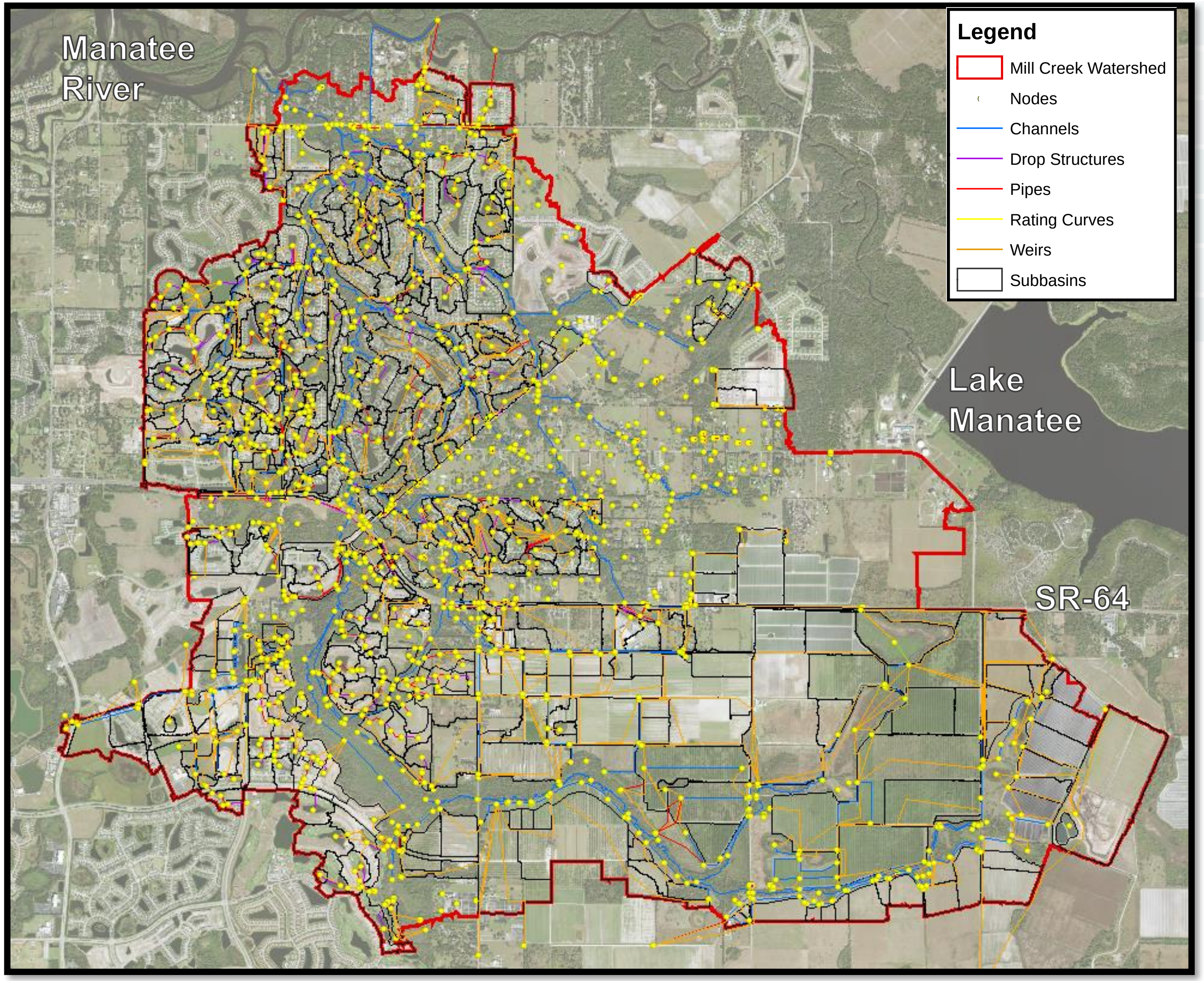
- **Overland Flow Weirs**



  - Modeled at glass walls in floodplain
  - Developed at basin lines from the project DEM; excludes buildings and channels from XSEC

MODEL NETWORK

- **1D Link Quantities**
  - Channels: 325
  - Culverts: 569
  - Drop Structures: 211
  - Weirs: 1,231
  - Rating Curves: 12 (3 pumps)
- **2D Node/Link Quantities**
  - Links: 178,132
  - Nodes: 84,771



2D Parameters and challenges

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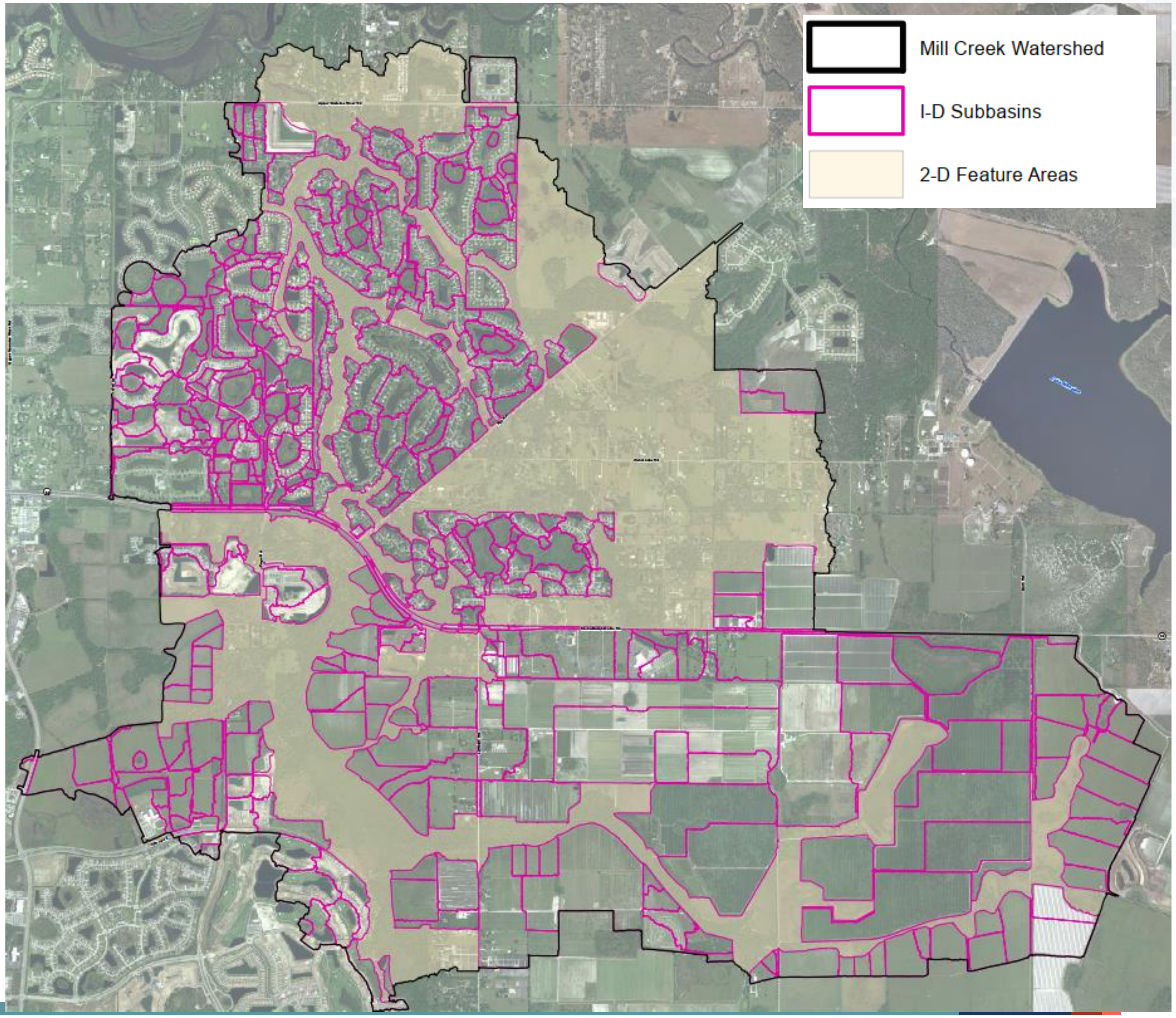
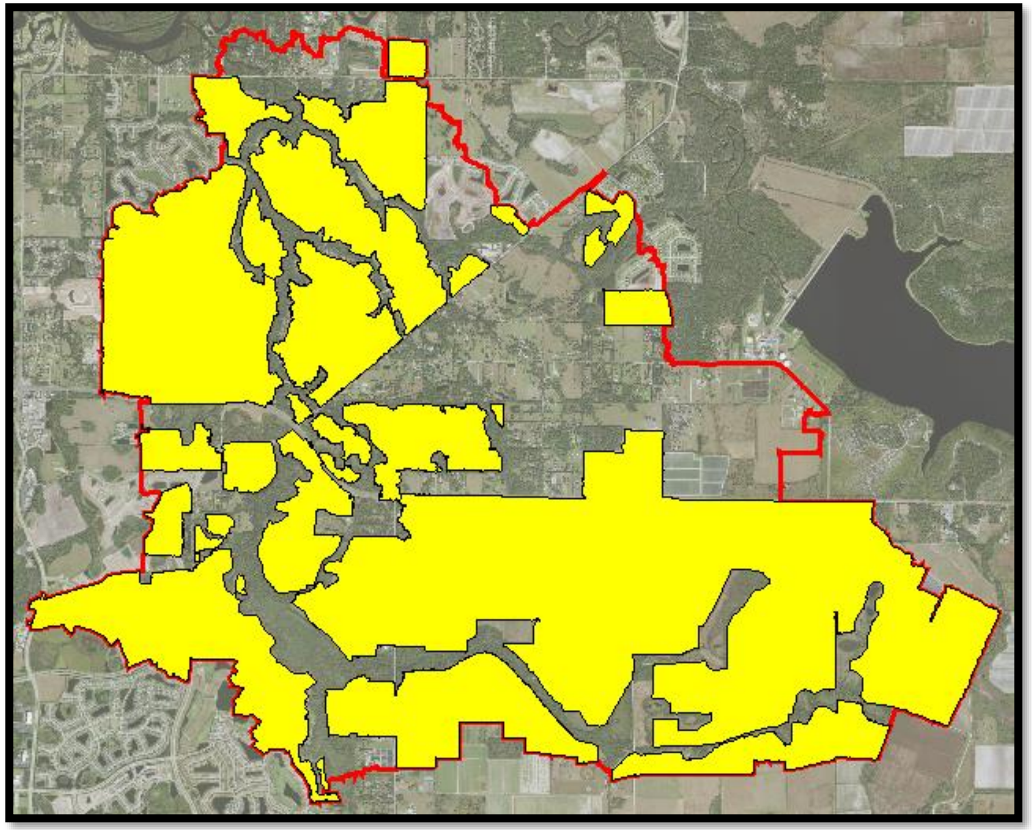
2D FEATURES AND CHALLENGES

- **Pros**
  - No need to delineate subbasin boundaries or estimate related parameters
  - Requires less time to model undeveloped areas
  - Suitable for areas where runoff does not follow a single direction
  - Faster and easier to set up (in some cases)
  - No need to define overland flow links or cross sections
- **Cons**
  - Higher computational time in the model
  - Significantly larger model file size
  - For developed areas, most underground pipes must be modeled; otherwise, results may be unreliable
  - Limited number of examples for floodplain and floodway applications
- **1D vs 2D Modeling**
  - All agricultural and developed areas were modeled using a 1D approach
  - The main river and adjacent meandering zones were modeled using a 2D approach

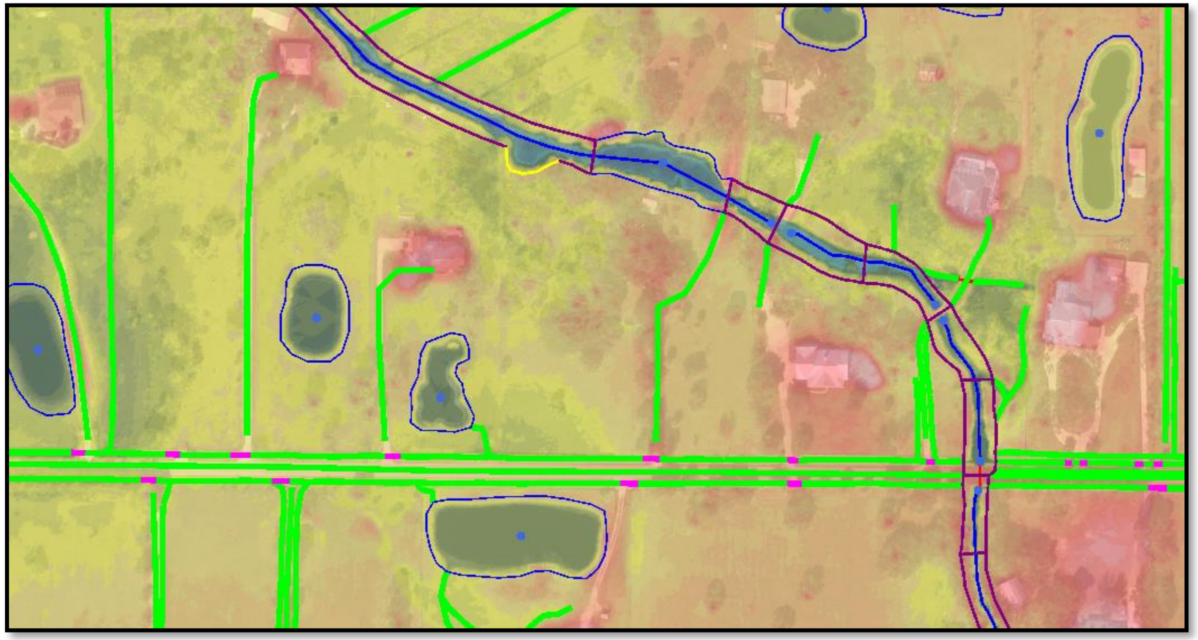


2D FEATURES AND CHALLENGES

- **Mapped basin feature**
  - Used to define 1D areas and prevent mesh generation in those regions

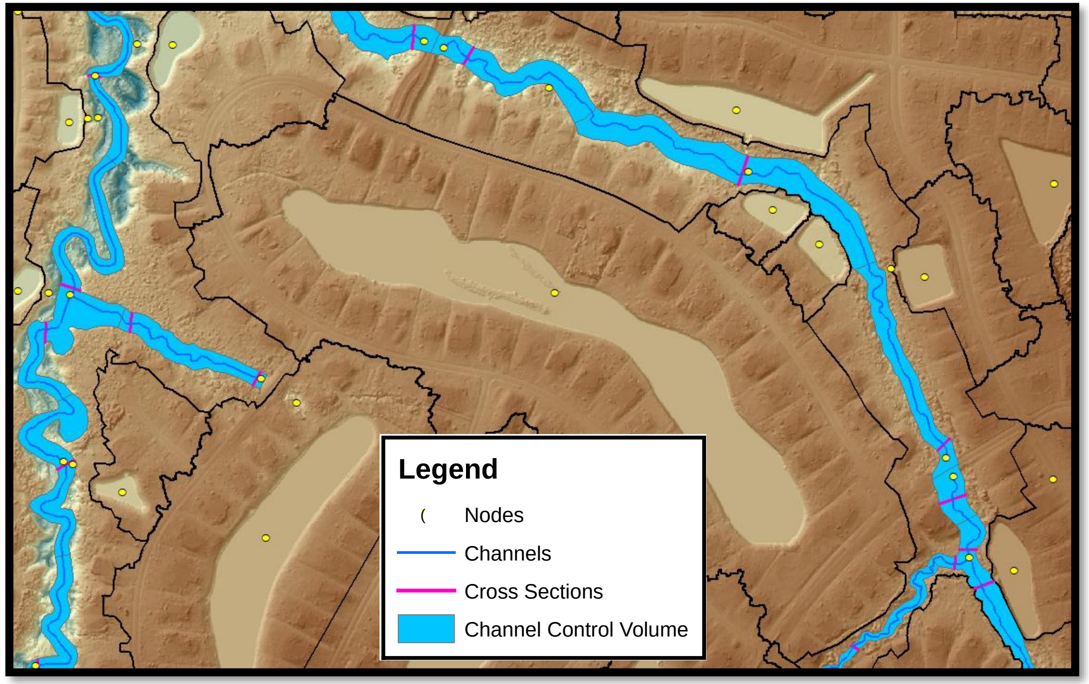


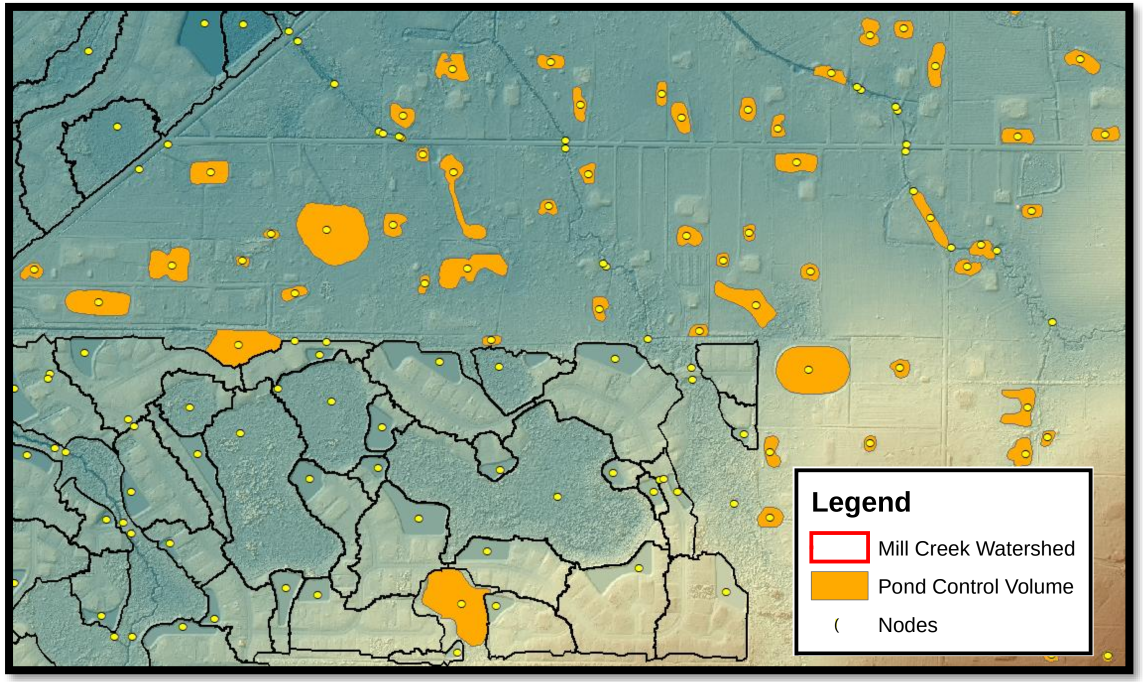
- **Breaklines**
  - Manually developed along roadways, swales/ditches, wetlands, and significant grade breaks.
  - In selected locations, interpolated breaklines are used to represent side ditch culverts.



2D FEATURES AND CHALLENGES

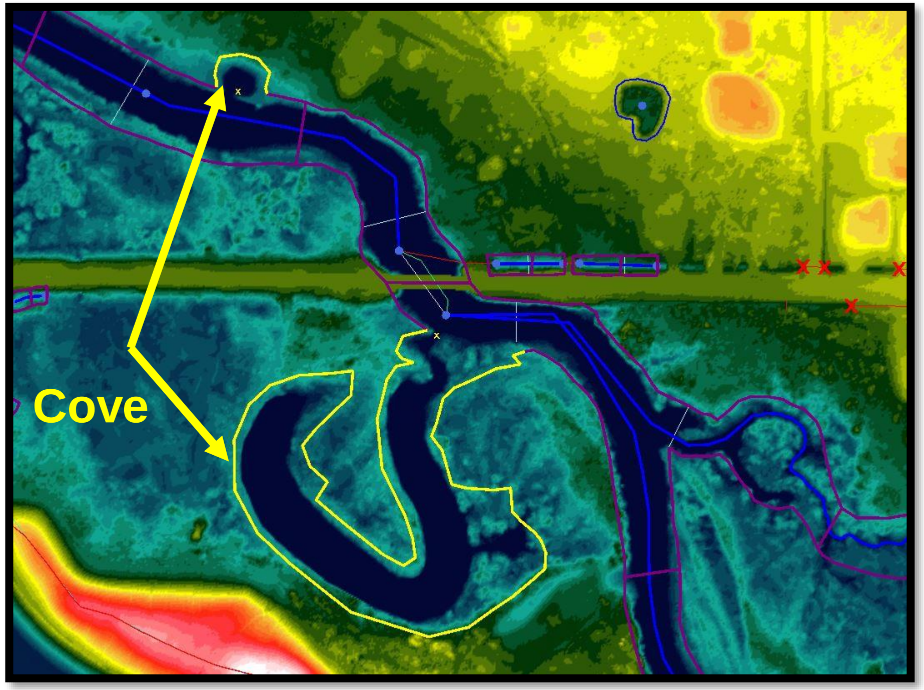
- **Channel Control Volume (CCV)**
  - Developed for each channel link located within the 2D region
  - Covers the full extent of channel cross sections
- **Pond Control Volume (PCV)**
  - Modeled as level pool storage
  - Applied to ponds, lakes, and wetlands



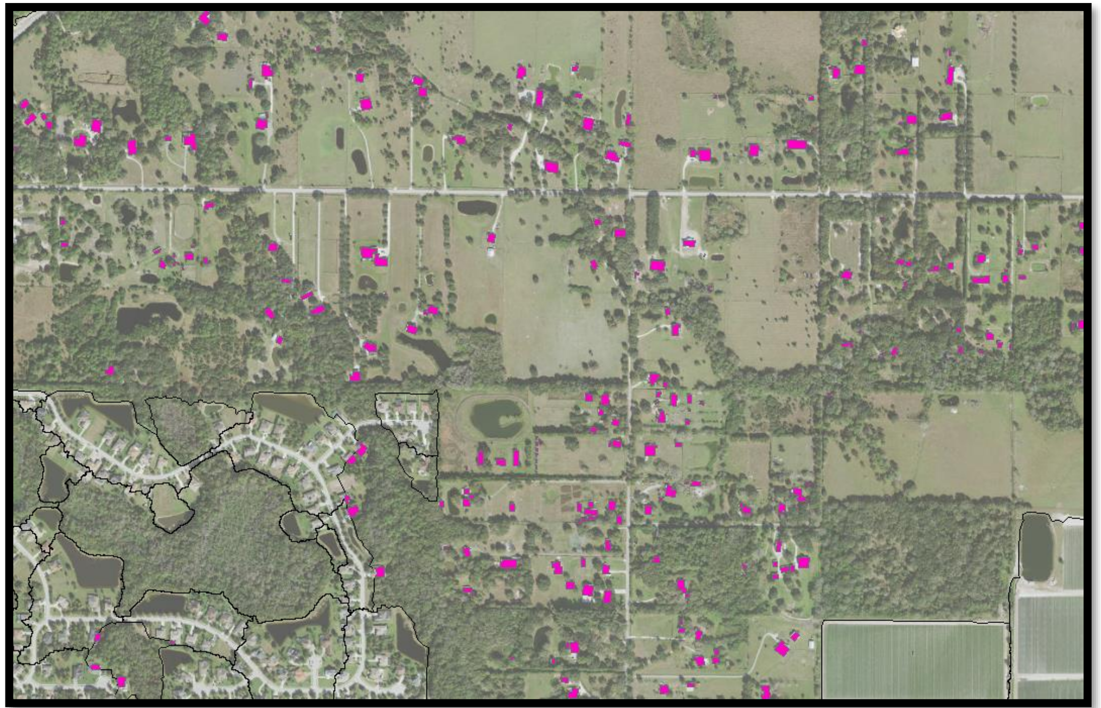


2D FEATURES AND CHALLENGES

- **Coves**
  - Represent level pool areas along a CCV
  - Not suitable for 2D overland flow modeling, yet too small or insignificant for detailed 1D modeling
  - Elevation within the cove is equal to the channel elevation at the point of connection to the CCV

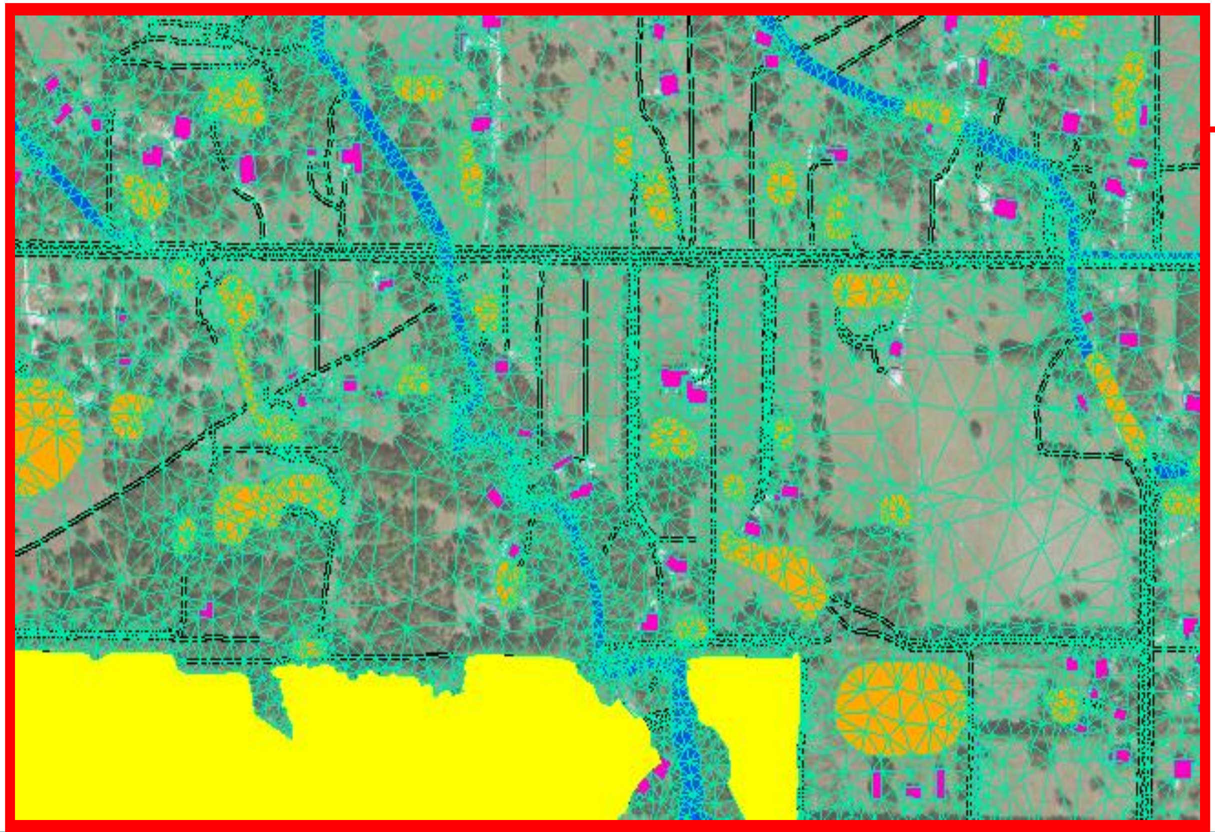


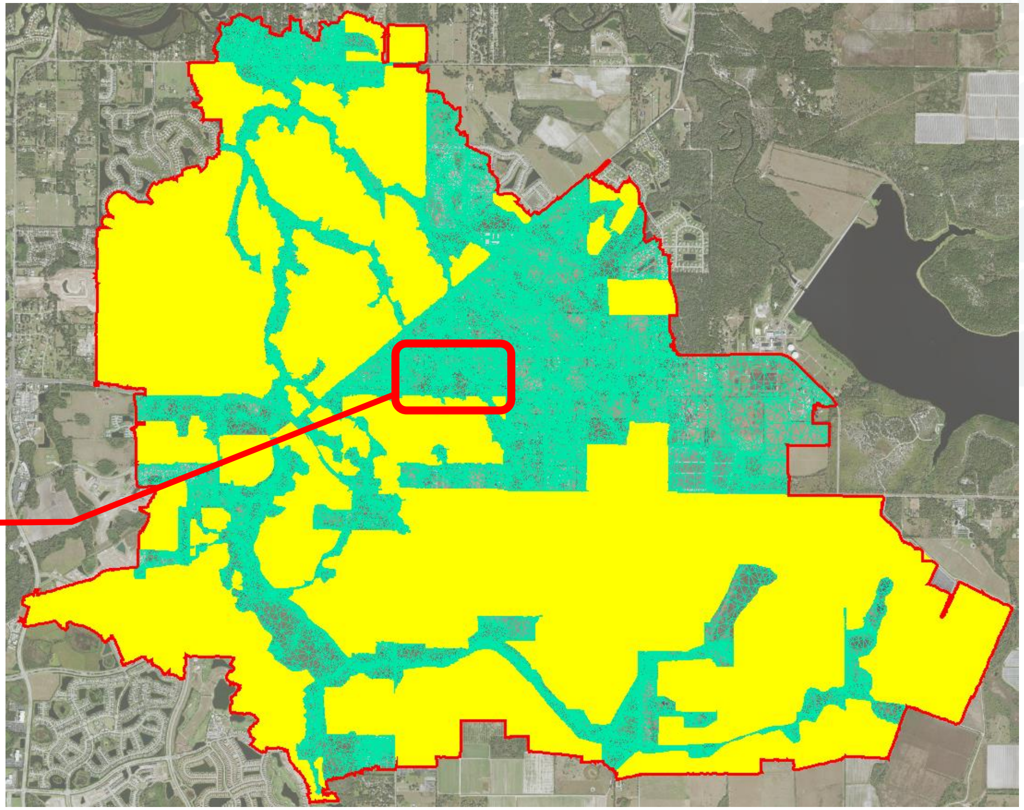
- **Extrusion polygons**
  - Exclude regions within defined polygons from the 2D mesh.
  - Typically used to represent buildings, structures, or other non-hydraulic features
  - Prevent flow from passing over them but allow flow to route around

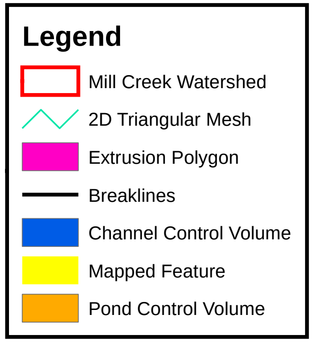


2D FEATURES AND CHALLENGES

- **2D Mesh**
  - Each triangle vertex functions as a node, and each side represents a flow link
  - The mesh is generated using DEM elevations and 2D features such as breaklines, control volumes, and mapped basins

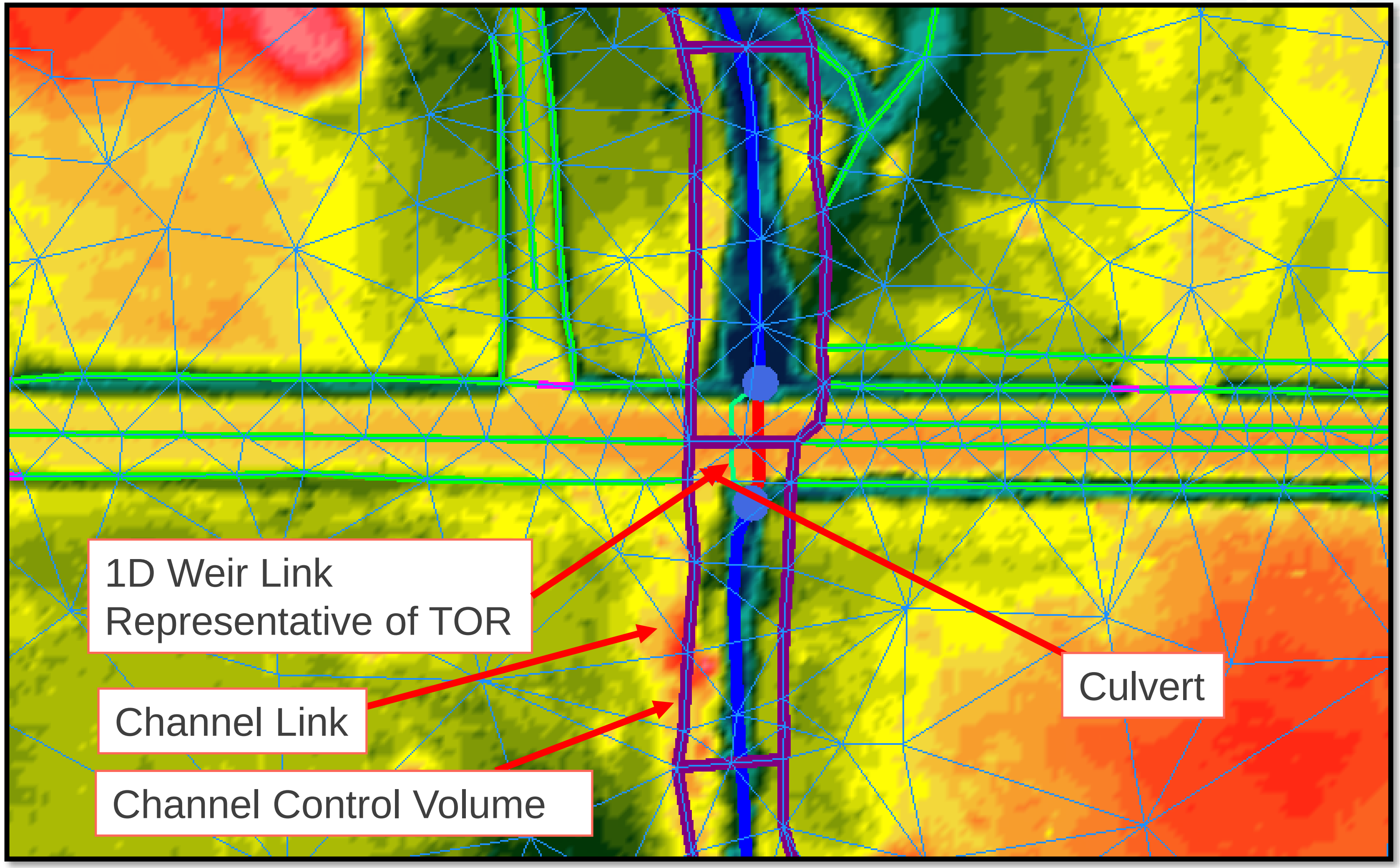






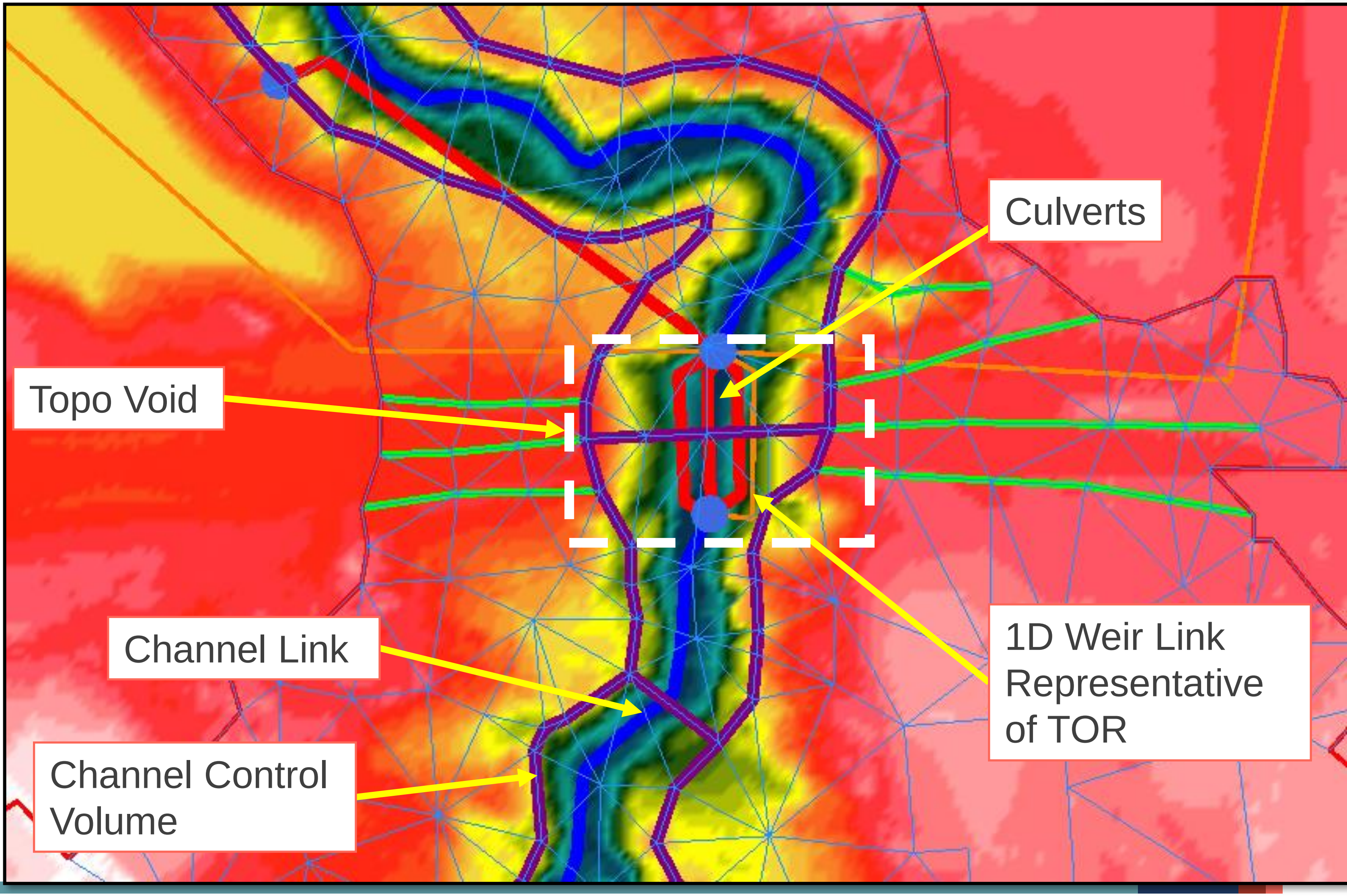
2D FEATURES AND CHALLENGES

- **Special Cases**
  - Approach for simplifying roadway overtopping at culvert crossings in 2D regions



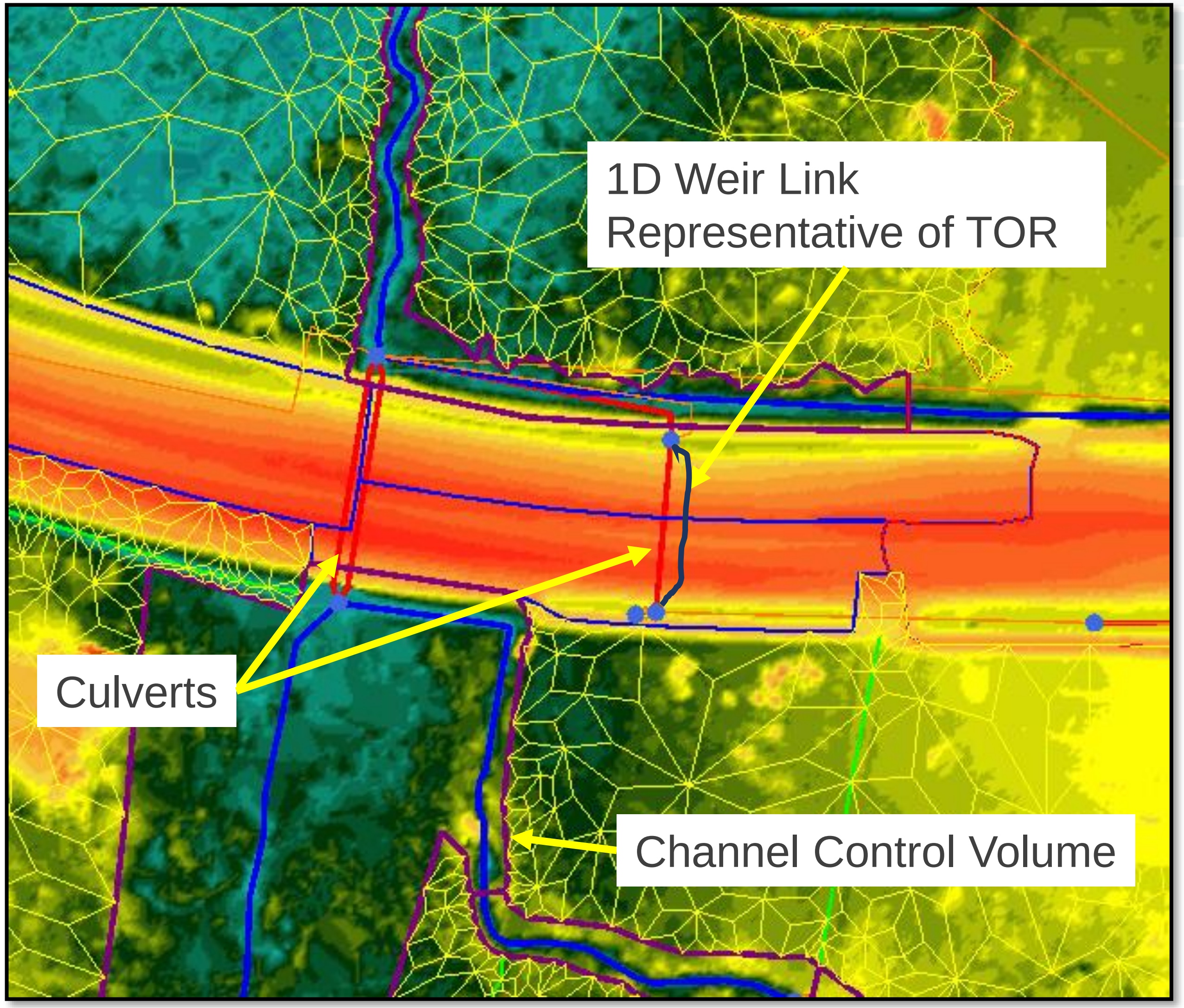
2D FEATURES AND CHALLENGES

- **Special Cases**
  - Addressing "burned areas" at culvert crossings in 2D regions



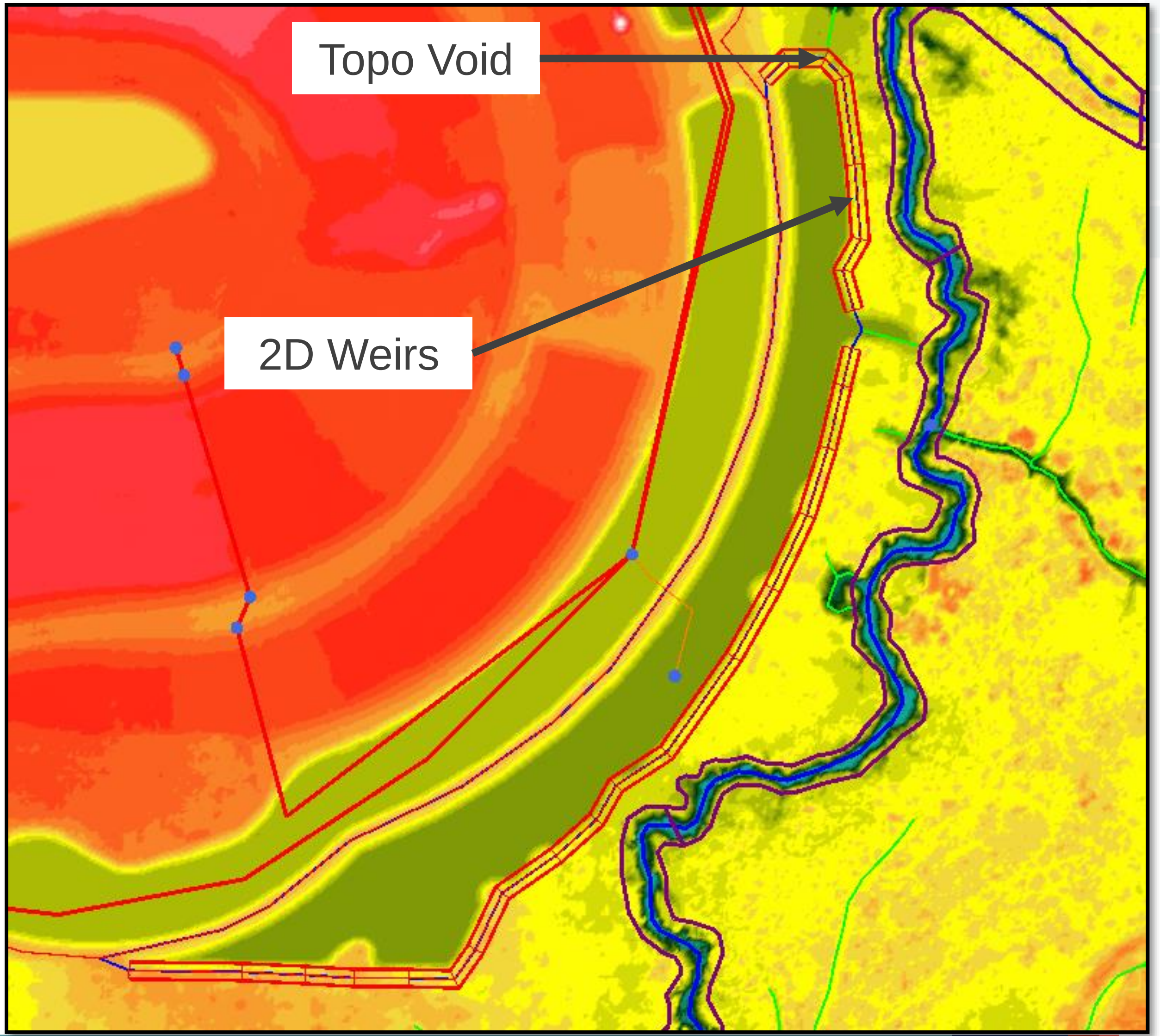
2D FEATURES AND CHALLENGES

- **Modeling roadway overtop with pond control volumes**
  - Pond control volumes added in road right-of-way to avoid 2D links in and over the roadway area
  - Simplifies and reduces run times without compromising results



2D FEATURES AND CHALLENGES

- **Pond berm / DEM adjustment using 2D weirs**
  - Pond construction incomplete at time of LiDAR flight
  - Initial mesh allowed outflow from pond at topo void
  - 2D weir placed along As-Built TOB to correct for DEM issues



Model Calibration and Verification

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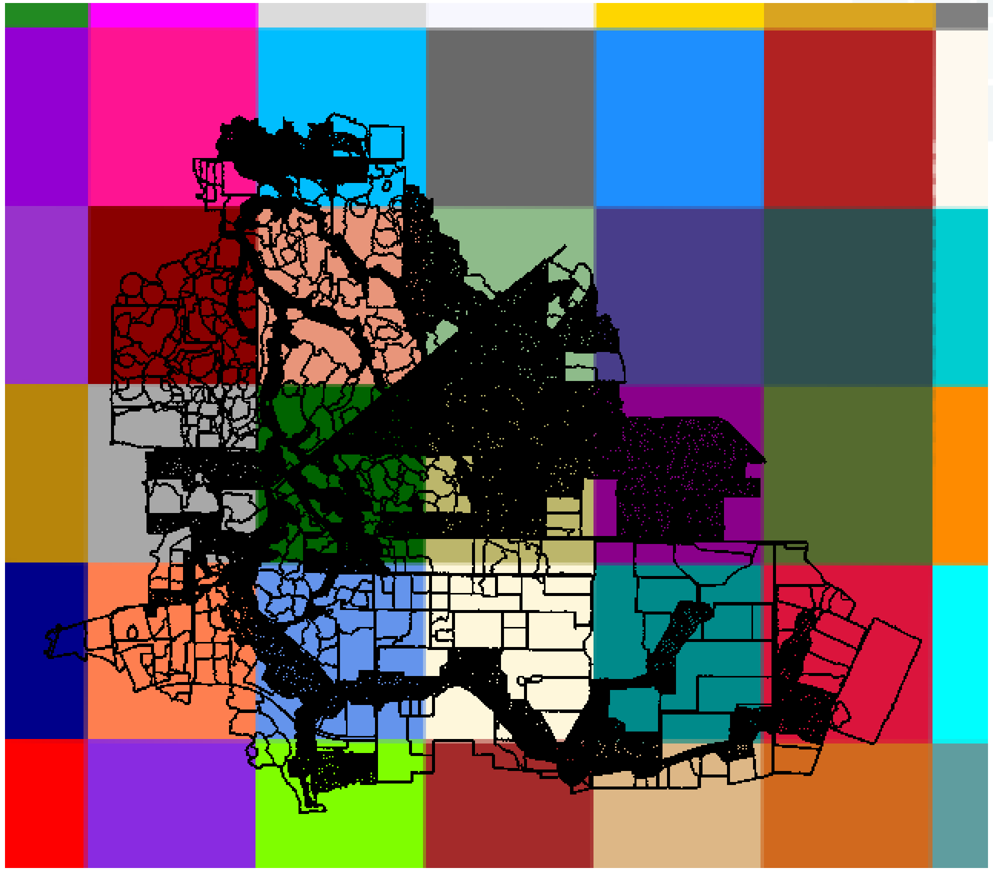
MODEL CALIBRATION AND VERIFICATION

- **Calibration Storm**
  - Hurricane Irma: September 10-11, 2017
  - Rainfall: 7.7” (~ 10-year, 24-hour)
  - 0.9” rainfall prior to the storm (September 3-8, 2017)
- **Verification Storm**
  - Verification Storm: August 26-28, 2017
  - Rainfall: 5.9”
- **Rainfall data source**
  - 15 minutes NEXRAD rainfall

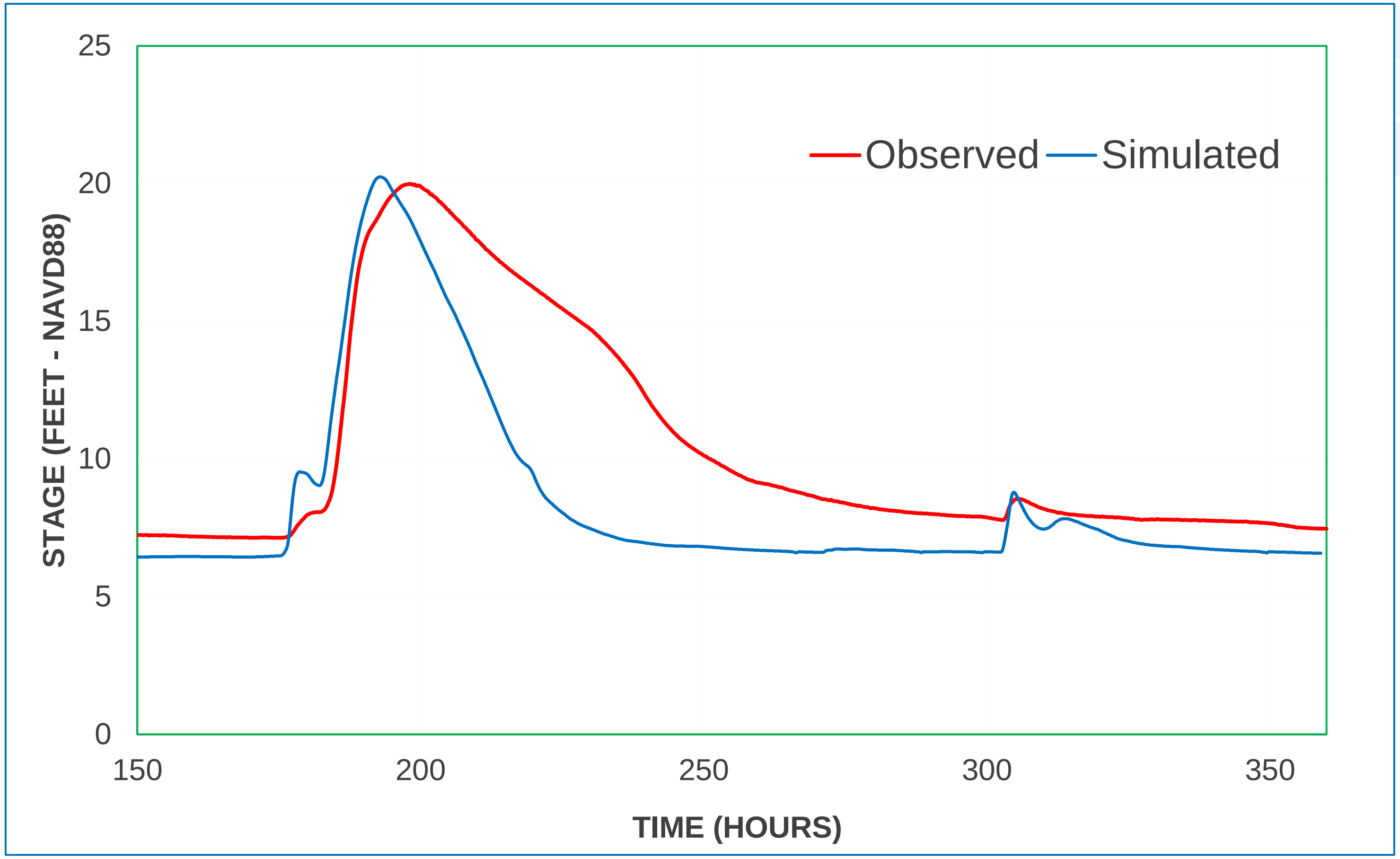


MODEL CALIBRATION AND VERIFICATION

- **Challenges of calibration and verification**
  - New developments present during Hurricane Irma and August 2017 storms were beyond the original modeling cutoff date
  - Added developments to the model to resolve related issues
  - Significant sedimentation found, even at newer crossings like White Eagle Blvd
  - Measured sedimentation during field visits and incorporated into the model

MODEL CALIBRATION

- **Model calibration- 131st Street Gage**
  - Observed Peak Stage: 20.0’
  - Model Peak Stage: 20.2’
  - Receding limb discrepancies possibly due to water “trapped” in soils after runoff calculations



MODEL CALIBRATION

- **Model calibration- White Eagle Blvd**
  - Simulated Peak Stage: 22.7’
  - Estimated Peak Stage using watermark: 22.7’

MODEL CALIBRATION

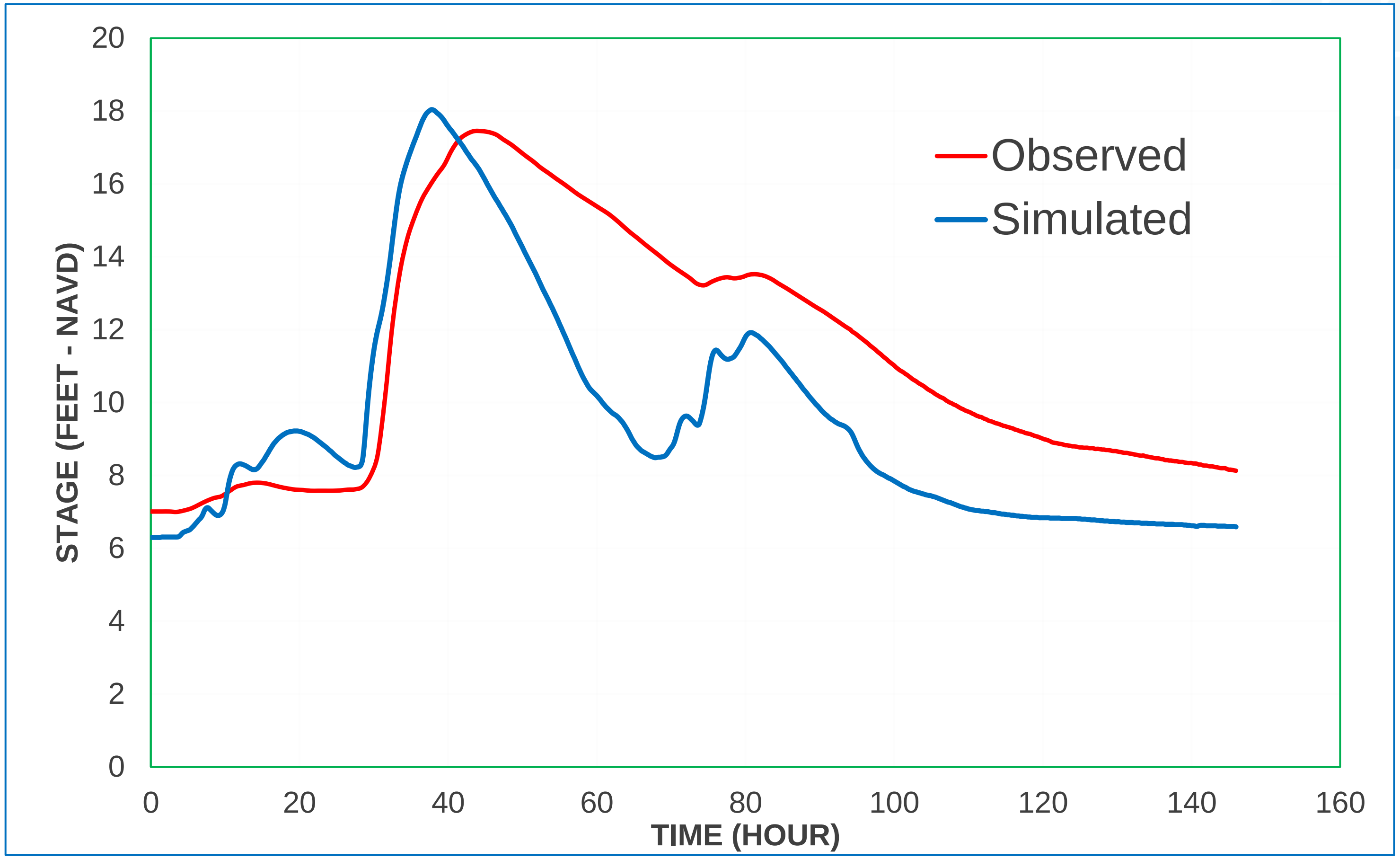
- **Model calibration- White Eagle Blvd**
  - Simulated Peak Stage: 22.1’
  - Estimated Peak Stage using watermark: >20.8’

Note: The high watermark was unclear and difficult to measure

Hurricane Irma – 9/11/17 @ 2:50 PM

MODEL VERIFICATION

- **Model verification- 131st Street Gage**
  - Observed Peak Stage: 17.4’
  - Model Peak Stage: 18’
  - Receding limb discrepancies possibly due to water “trapped” in soils after runoff calculations



Floodplain Approach and Development

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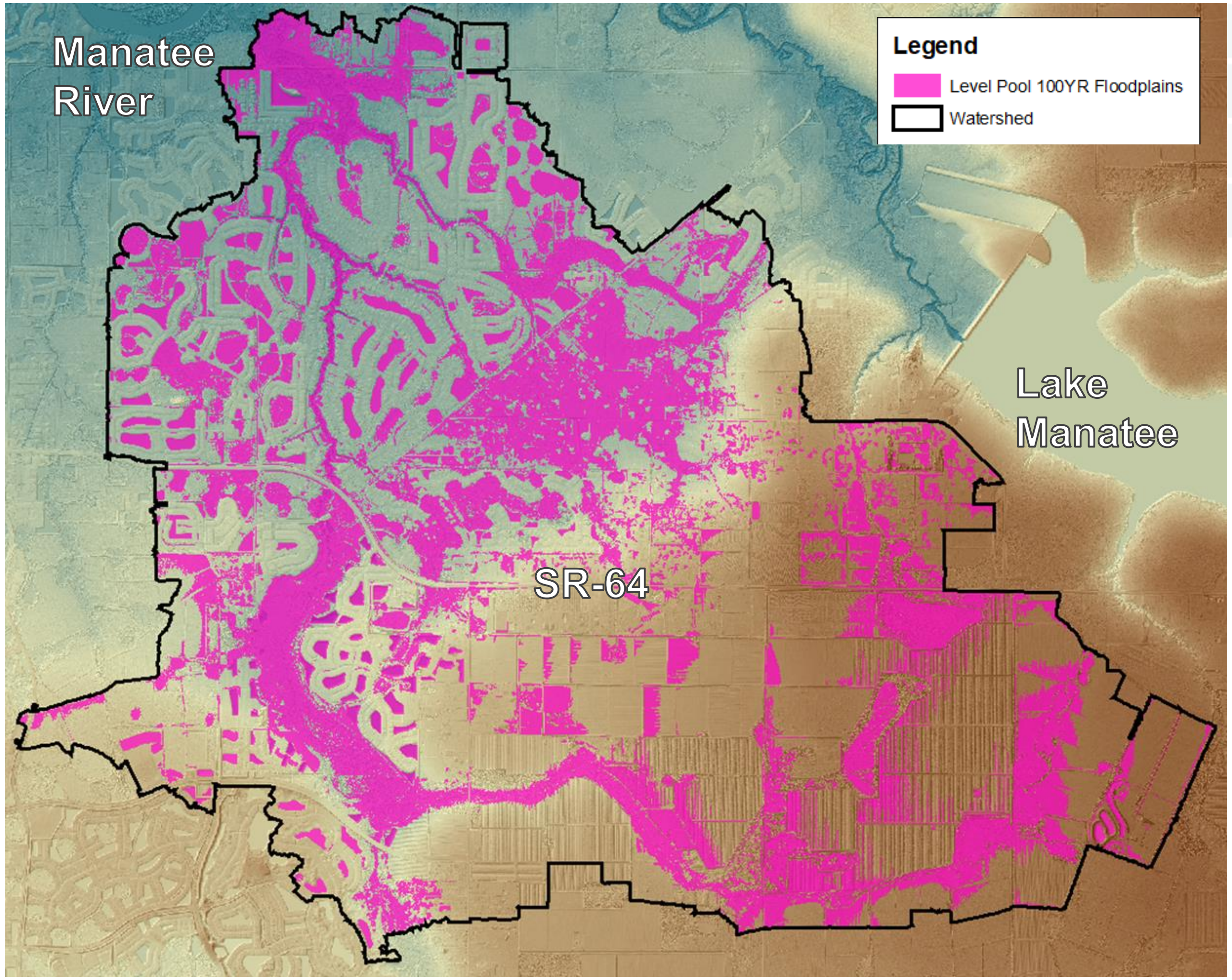
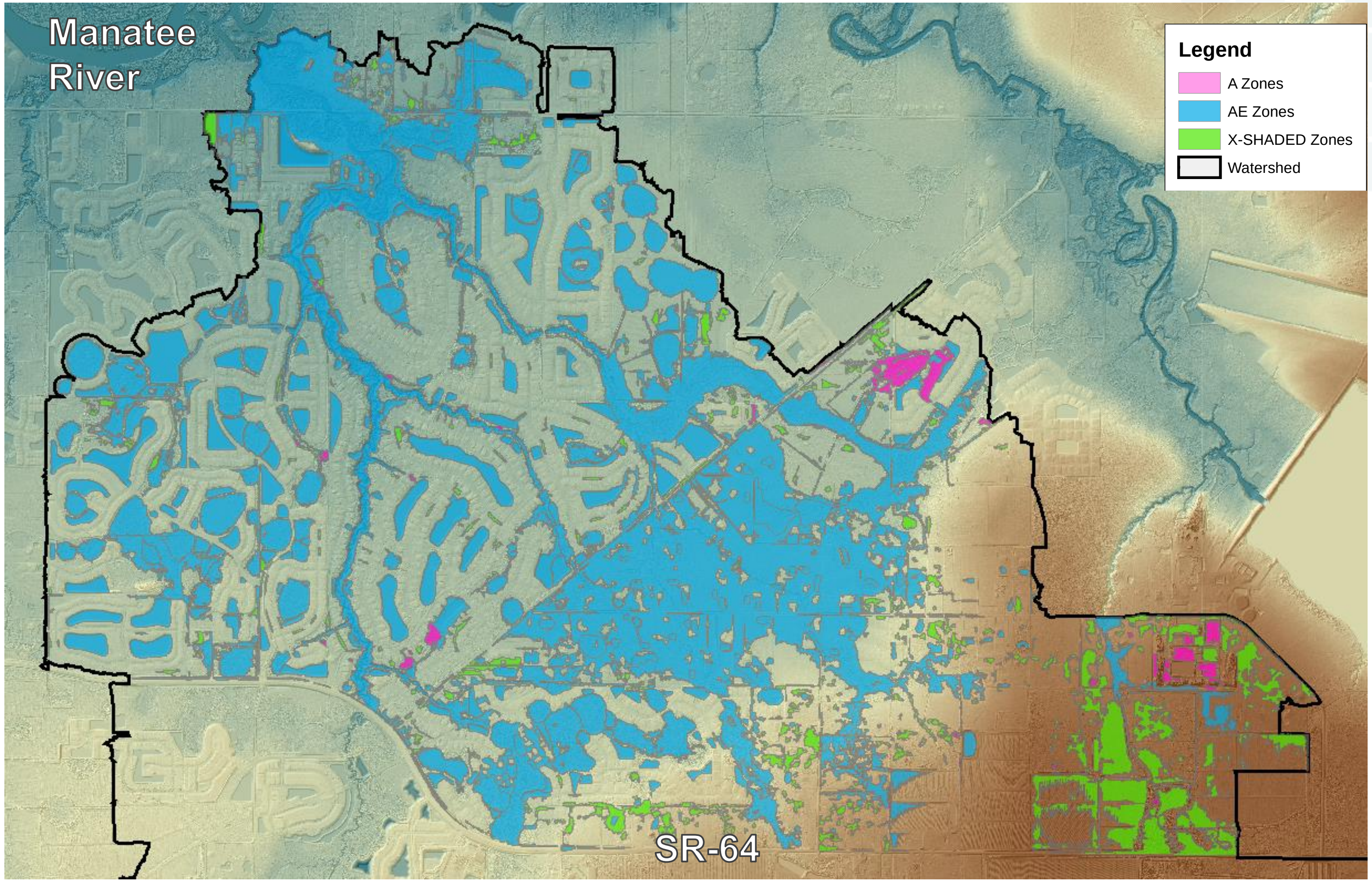
FLOODPLAIN MAPPING APPROACH

- 100-year, 24-hour storm
- 1D floodplains (basins, PCV, CCV) were mapped based on node maximum stage
- 2D floodplains were mapped based on
  - Max elevation surface, mesh-based DEM, and project DEM
  - Flood depths of 3-inches or higher
- All Floodplains were smoothed and simplified with spackle removed (2,500 ft^2)



PRELIMINARY FLOODPLAIN DELINEATION

- AE Zones: Defined BFE associated with a 1D surface water node
- A Zones: Floodplain 1’ or deeper disconnected from a 1D surface water model node
- X (Shaded) Zones: Floodplain less than 1’ deep disconnected from a 1D surface water model node



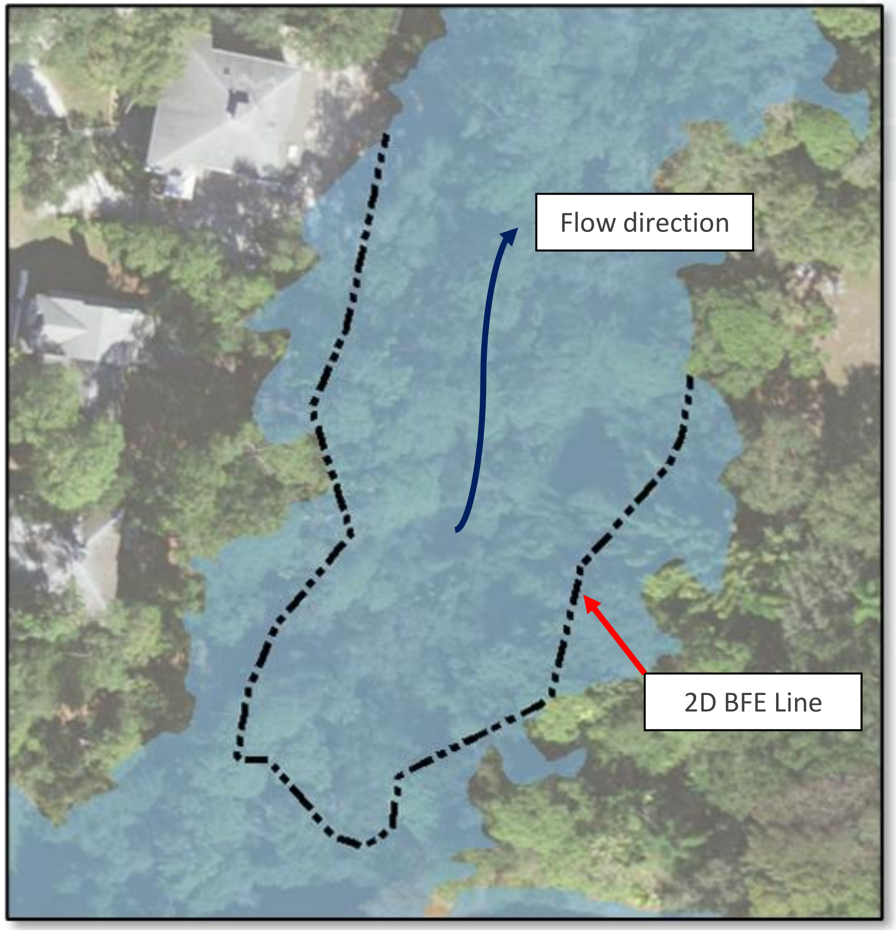
BASE FLOOD ELEVATIONS

Level Pool Flooding

- 1D storage basins & 2D pond control volumes
- AE floodplains assigned a single BFE based on node maximum stage

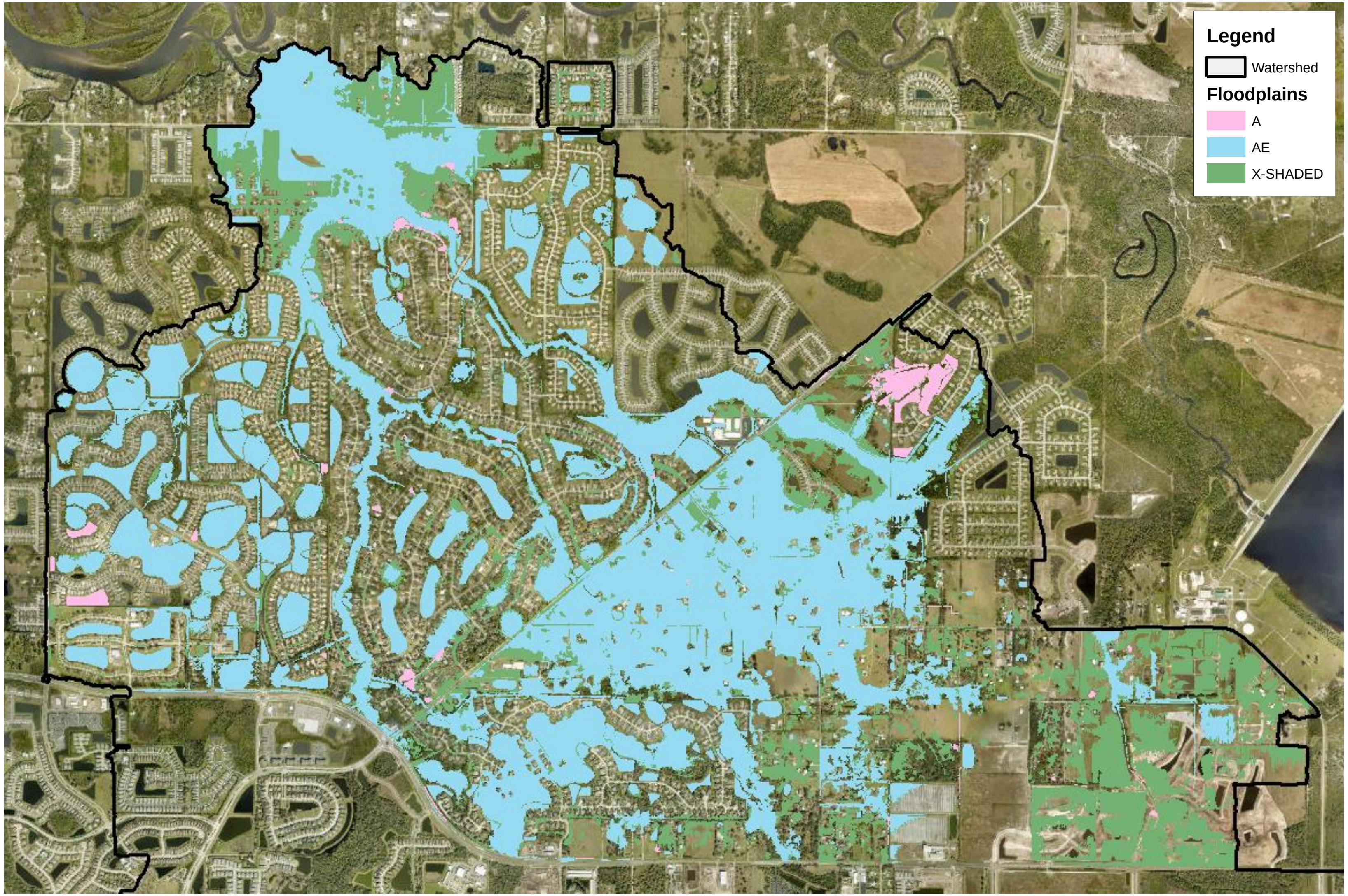
Sloping Water Surfaces

- BFE lines drawn at whole # flood elevations and where additional detail warranted.
- Drawn along channels and 2D sloping water surfaces
- 1D BFE lines – drawn traditionally, straight line perpendicular to channel floodplain
- 2D BFE lines – drawn based on maximum elevation surface
  - Typically only straight through the CCV
  - Drawn similar to contour lines, and tend to “point upstream”



0.2% ANNUAL CHANCE STORM

- 500-year, 24- hour storm
- Mapped as X (Shaded) flood zones outside the 1% annual chance floodplain limit



Floodway Approach & Analysis

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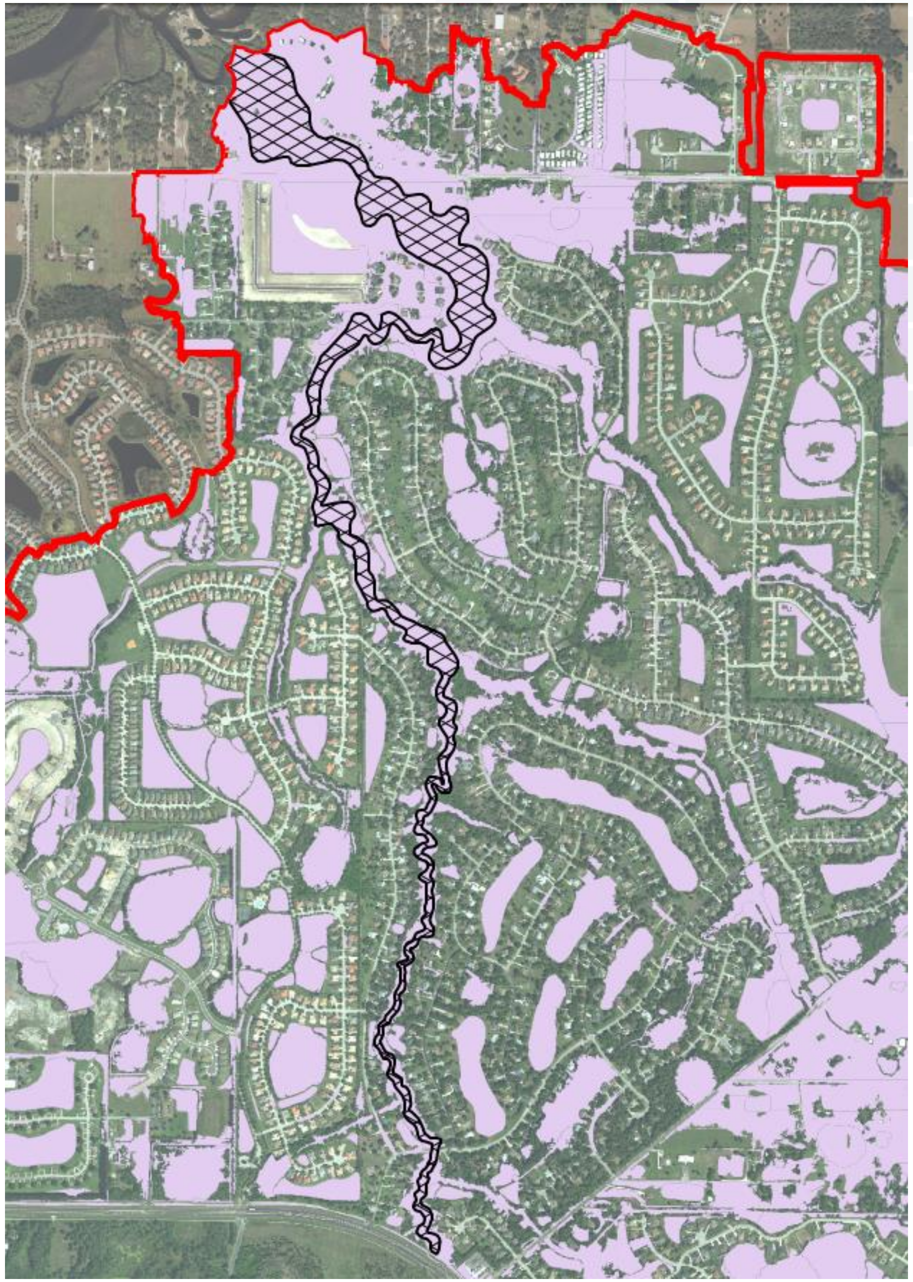
FLOODWAY APPROACH & ANALYSIS

- **Challenges of floodway analysis using ICPRv4 2D**
  - ICPRv4 2D does not support encroachment stations within channel cross sections
  - Each iteration requires significant model build and simulation time
  - Equal conveyance is difficult to achieve without tools to estimate encroached conveyance
  - Few documented examples of floodway analysis using 2D unsteady models
  - SAI-Halff was among the first firms to develop a floodway using ICPRv4 2D, coordinating with FEMA on the approach
  - HEC-RAS 2D supports floodway analysis, but lacks automated encroachment tools like those in 1D steady-state



FLOODWAY APPROACH & ANALYSIS

- **HEC-RAS Steady State 1D Standard Floodway Encroachment Methods**
  - Method 1 -User enters right and left encroachment station
  - Method 2 -User enters a fixed top width
  - Method 3 -User specifies the percent reduction in conveyance
  - Method 4 -User specifies a target water surface increase
  - Method 5 -User specifies target water surface increase and maximum change in energy

- **Notes:**
  - Equal conveyance option is available for the automated methods 3, 4 , 5
  - HEC-RAS attempts to encroach, such that an equal loss of conveyance is provided on both sides of the stream
  - There is option of buffer zone around the main channel for limiting the encroachments (5 to 10')

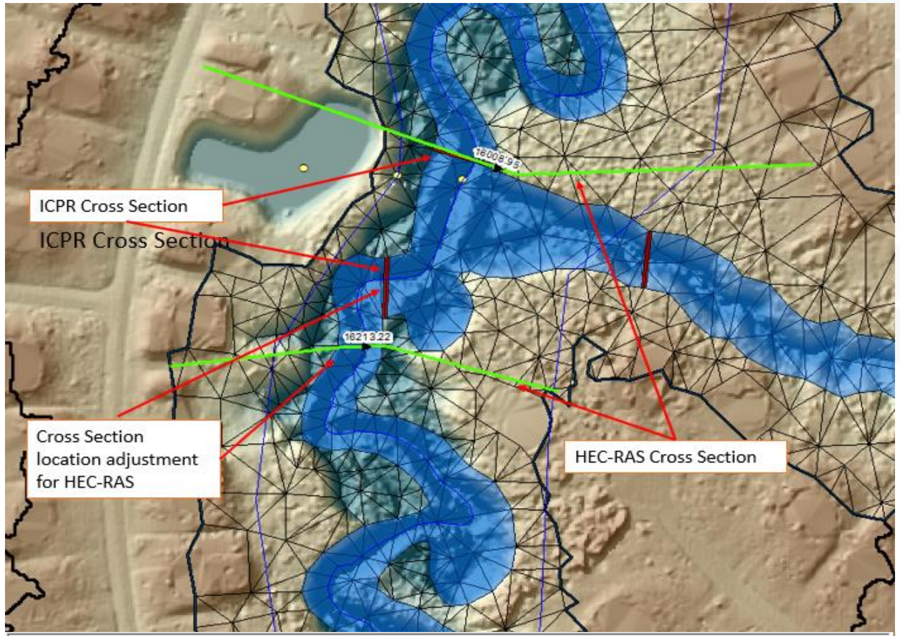
FLOODWAY APPROACH & ANALYSIS

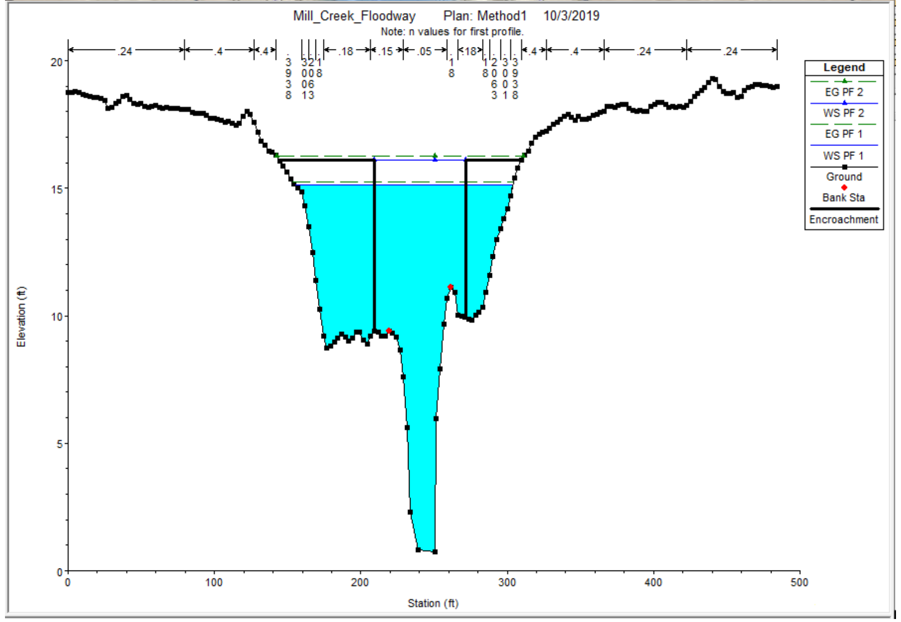
- **Developed a steady state HEC-RAS model**
  - Converted ICPRv4 2D unsteady floodplain model to a HEC-RAS 1D steady-state model

    Note: This was a manual process – no direct conversion exists.
  - HEC-RAS model is calibrated to ICPR floodplain model (vertical varied Manning's value is considered)
  - HEC-RAS allows for faster iterations and provides equal conveyance
  - Provides automatic optimization to get the best target surcharge
  - Performed floodway analysis (Method 4 and Method 5) multiple times in HEC-RAS, including optimization for equal conveyance
  - Imported encroachment stations into Method 1 (manual method) and made minor refinements

- **Final floodway analysis in the ICPRv4 model**
  - Encroachment stations from HEC-RAS model are used in ICPRv4
  - 2D mesh in encroached area is replaced with mapped basin to remove the conveyance and allow local runoff into the channel
  - Final floodway analysis (in ICPRv4) using fewer iterations

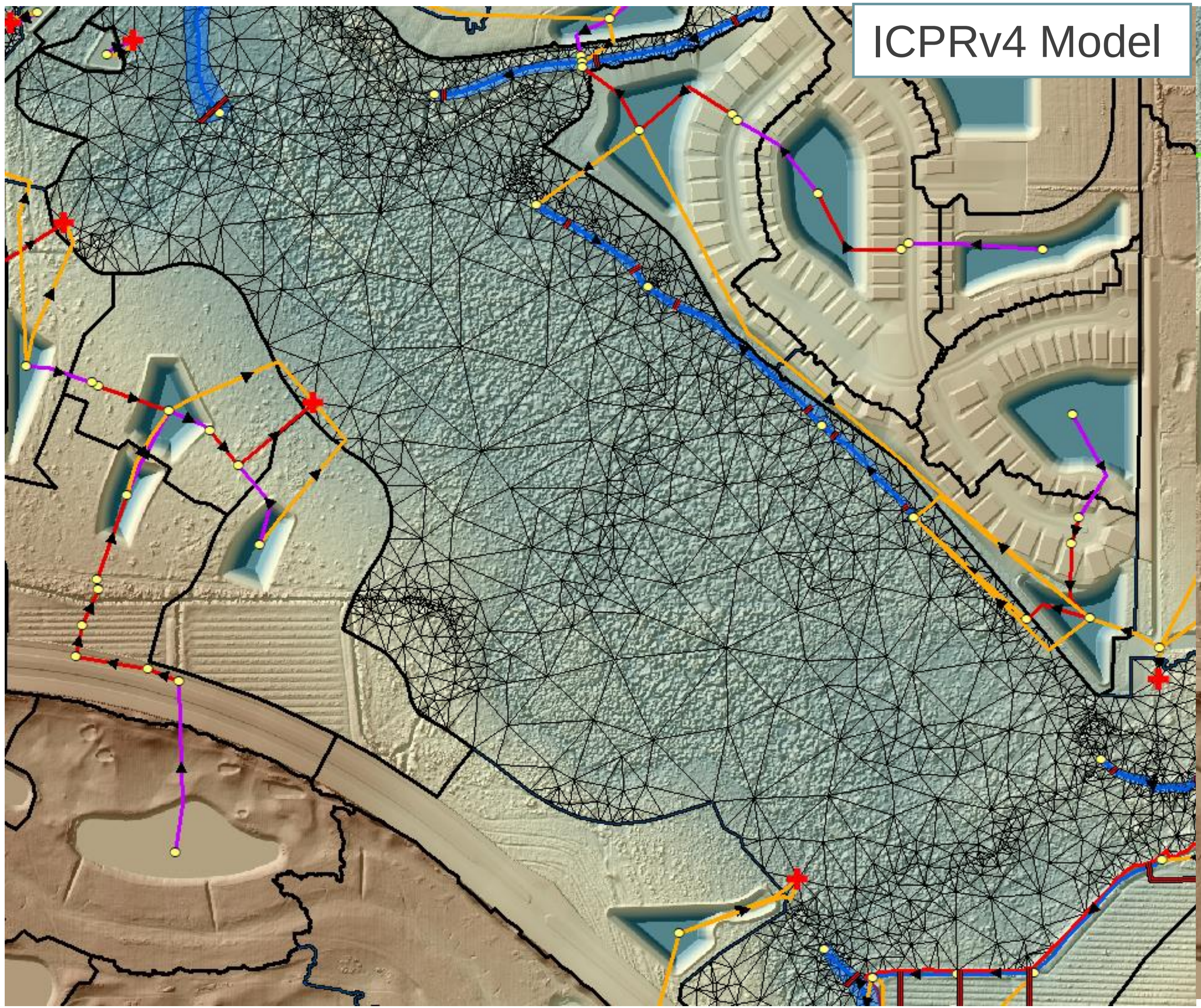
- **Mapped floodway in ArcGIS model**

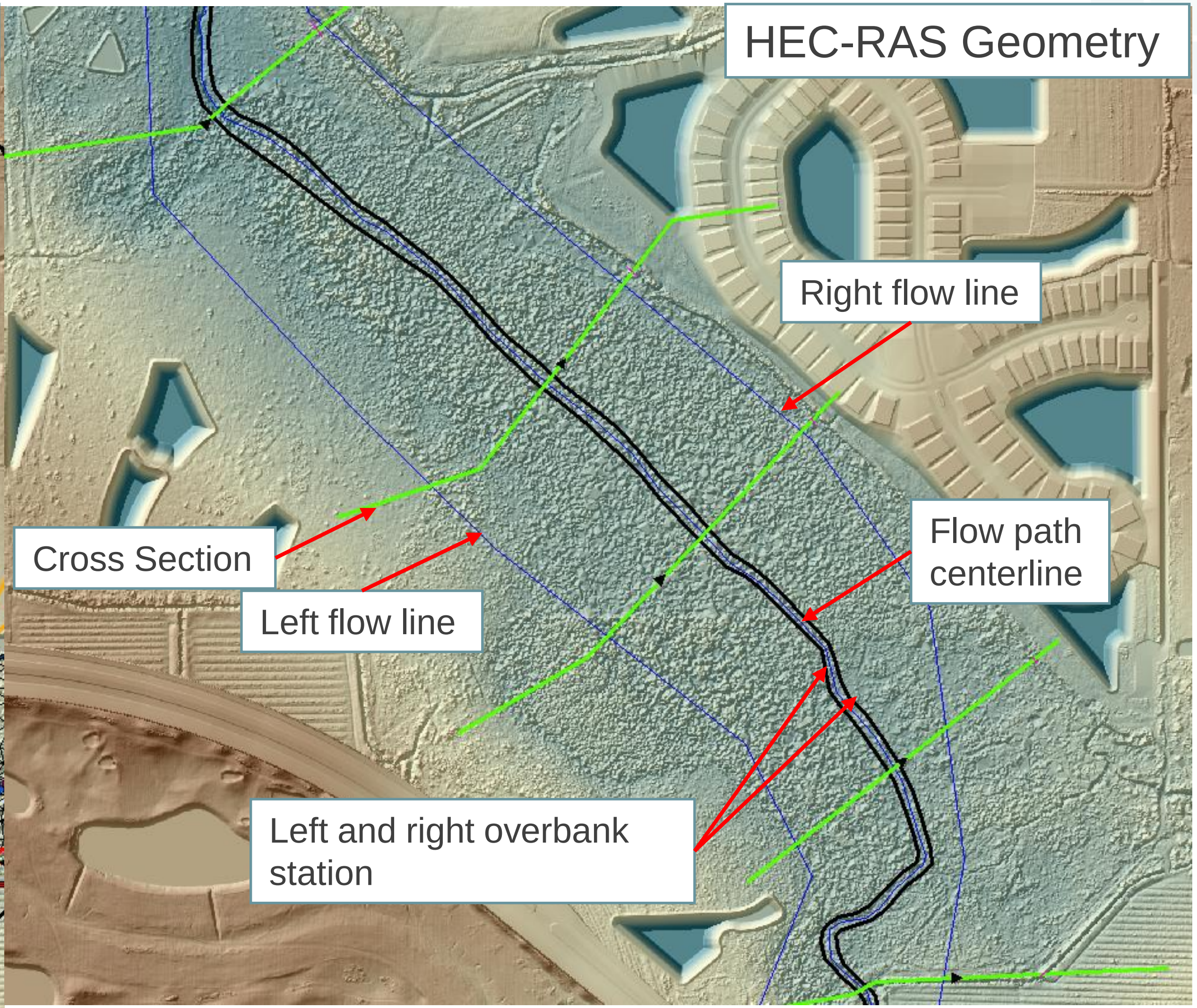




FLOODWAY APPROACH & ANALYSIS

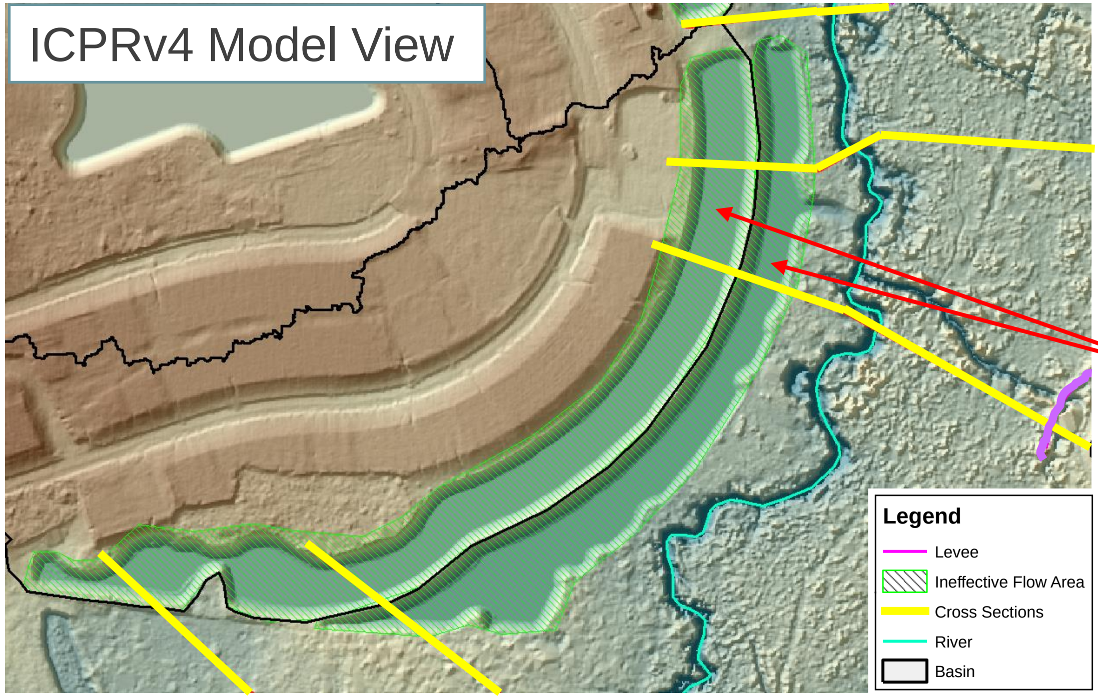
- **Conversion of 1D/2D ICPRv4 unsteady to 1D HEC-RAS steady state**

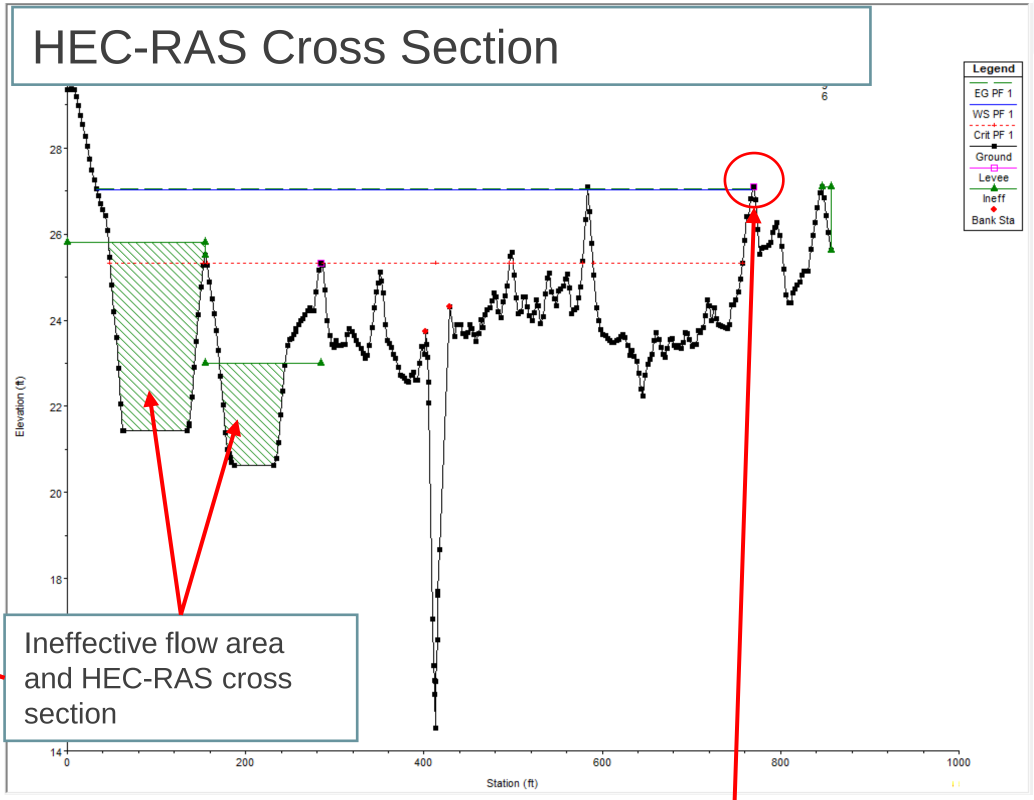




FLOODWAY APPROACH & ANALYSIS

- **Conversion of 1D/2D ICPRv4 unsteady to 1D HEC-RAS steady state**





FLOODWAY APPROACH & ANALYSIS

- **Vertical varied Manning Roughness Value**
  - ICPRv4 uses an exponential decay function to vertically transition between a shallow-condition Manning's value and a deep-condition value

$$N = N_{shallow} e^{(k)(d)}$$

$$k = \frac{\ln\left(\frac{N_{deep}}{N_{shallow}}\right)}{d_{max}}$$

d: depth of flow (ft)

n: Manning's roughness coefficient at depth d

$n_{shallow}$: Manning's roughness coefficient at ground surface

d_{max}: transition depth (depth range) to n_{deep} (ft)

n_{deep}: Manning's roughness coefficient at d_{max} or greater

k: exponential decay factor (f^{-1})

ICPRv4 Roughness look-up table

Roughness Set Data

Menu

Roughness Zone	Shallow Manni...	Deep Mannin...	Depth Range	Damping Thre...	Area Reduction ...
BAYS AND ESTUARIES	0.03	0.01	3	0.075	1
COMMERCIAL AND SERVICES	0.24	0.1	3	0	1
COMMUNICATIONS	0.24	0.1	3	0	1
CROPLAND AND PASTURELAND	0.13	0.03	3	0	1
CYPRESS	0.4	0.2	3	0	1
DISTURBED LAND	0.13	0.03	3	0	1
EMERGENT AQUATIC VEGETATION	0.2	0.18	3	0	1
FEEDING OPERATIONS	0.15	0.03	3	0	1
FRESHWATER MARSHES	0.2	0.18	3	0.075	1
GOLF COURSES	0.2	0.1	3	0	1
HARDWOOD CONIFER MIXED	0.4	0.2	3	0	1
INDUSTRIAL	0.24	0.1	3	0	1
INSTITUTIONAL	0.24	0.1	3	0	1
INTERMITTENT PONDS	0.01	0.01	3	0	1

HEC-RAS vertical varied Manning's N

Row 0: Starting Stations Rows 1-20: Mannings n Values

		Station1	Station2	Station3	Station4	Station5	Station6	Station7
0	Elev\Sta	226.25	271.9	442.33	480.6	497.51	576.5	602.69
1	20	0.013	0.24	0.15	0.05	0.15	0.4	0.24
2	20.5	0.013	0.24	0.15	0.05	0.15	0.35	0.24
3	21	0.013	0.24	0.15	0.05	0.15	0.31	0.24
4	21.5	0.013	0.24	0.15	0.05	0.15	0.27	0.21
5	22	0.013	0.24	0.15	0.05	0.15	0.23	0.18
6	22.5	0.013	0.24	0.15	0.05	0.15	0.21	0.15
7	23	0.013	0.24	0.15	0.05	0.15	0.18	0.13
8	23.5	0.013	0.21	0.15	0.05	0.15	0.18	0.12
9	24	0.013	0.18	0.15	0.05	0.15	0.18	0.1
10	24.5	0.012	0.15	0.15	0.05	0.15	0.18	0.1
11	25	0.011	0.13	0.15	0.05	0.15	0.18	0.1
12	25.5	0.01	0.12	0.15	0.05	0.15	0.18	0.1
13	26	0.01	0.1	0.15	0.05	0.15	0.18	0.1
14	26.5	0.01	0.1	0.15	0.05	0.15	0.18	0.1
15	27	0.01	0.1	0.15	0.05	0.15	0.18	0.1
16	27.5	0.01	0.1	0.15	0.05	0.15	0.18	0.1
17	28	0.01	0.1	0.15	0.05	0.15	0.18	0.1
18	28.5	0.01	0.1	0.15	0.05	0.15	0.18	0.1
19	29	0.01	0.1	0.15	0.05	0.15	0.18	0.1
20	29.5	0.01	0.1	0.15	0.05	0.15	0.18	0.1

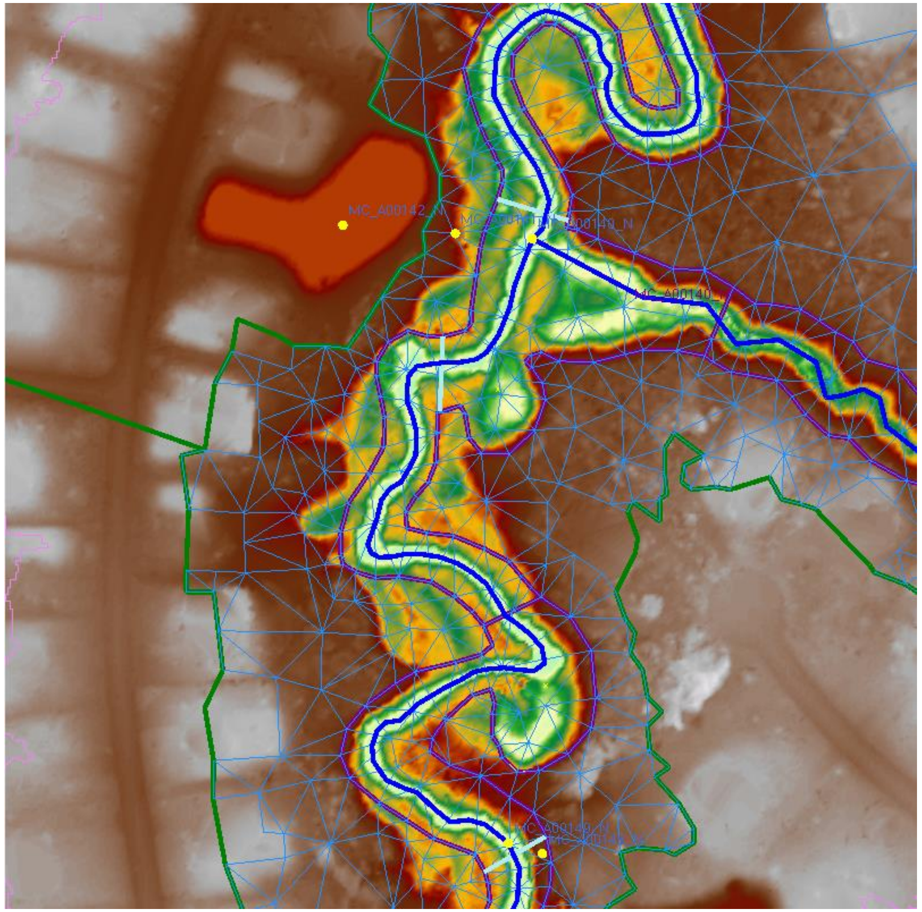
FLOODWAY APPROACH & ANALYSIS

- **Calibrated HEC-RAS Model vs ICPR maximum stage**

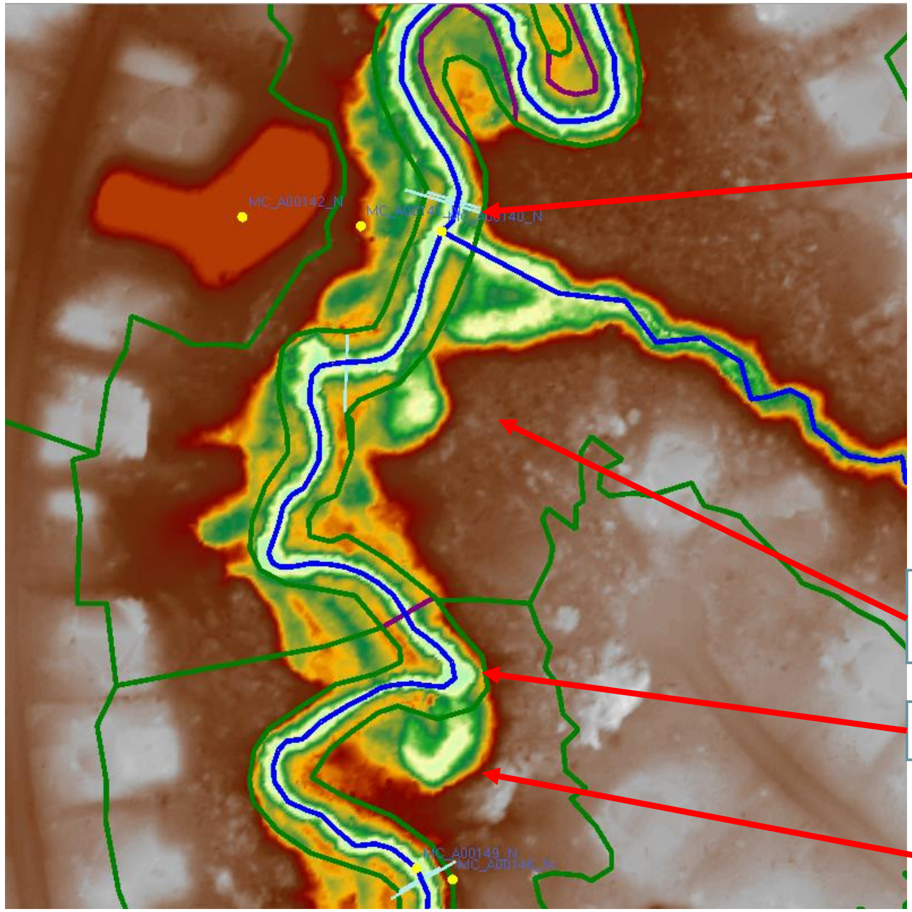
HEC-RAS Station	ICPR4 Node	Max stage HEC-RAS	Max Stage ICPR4	Discrepancies
22928.35	MC_A00180_N	23.7	23.27	0.4
22072.74	MC_A00178_N	22.78	22.43	0.4
21301.71	MC_A00174_N	22.06	21.95	0.1
21213.85	MC_A00170_N	21.78	21.38	0.4
20551.7	MC_A01060_N	21.16	20.64	0.5
19699.09	MC_A00155_N	18.72	18.6	0.1
18150.73	MC_A00150_N	16.52	16.64	-0.1
17094.34	MC_A00149_N	15.54	15.52	0.0
16008.69	MC_A00140_N	14.95	15.03	-0.1
14730.71	MC_A00139_N	14.29	14.28	0.0
13732.2	MC_A00130_N	13.73	13.66	0.1
12523.96	MC_A00120_N	13.13	12.68	0.5
12022.08	MC_A00110_N	12.83	12.33	0.5
11530.76	MC_A00105_N	12.68	12.06	0.6
10170.78	MC_A00090_N	12.12	11.58	0.5
9672.744	MC_A00085_N	11.56	11.38	0.2
8624.181	MC_A00080_N	11.08	11.23	-0.2
7748.269	MC_A00078_N	10.99	11.19	-0.2
6750.74	MC_A00070_N	10.93	11.16	-0.2
5614.271	MC_A00060_N	10.9	11.13	-0.2
4565.528	MC_A00040_N	10.9	11.1	-0.2
3801.963	MC_A00031_N	10.9	11.06	-0.2
3070.272	MC_A00030_N	10.9	11.05	-0.2
2798.708	MC_A01030_N	10.9	11.05	-0.2
2080.371	MC_A01010_N	10.9	10.99	-0.1
1784.419	MC_A00020_N	10.9	10.93	0.0
760.2167	MC_A00010_N	10.9	10.9	0.0

FLOODWAY APPROACH & ANALYSIS

Floodplain Model



Floodway Model



Adjusted and original cross sections

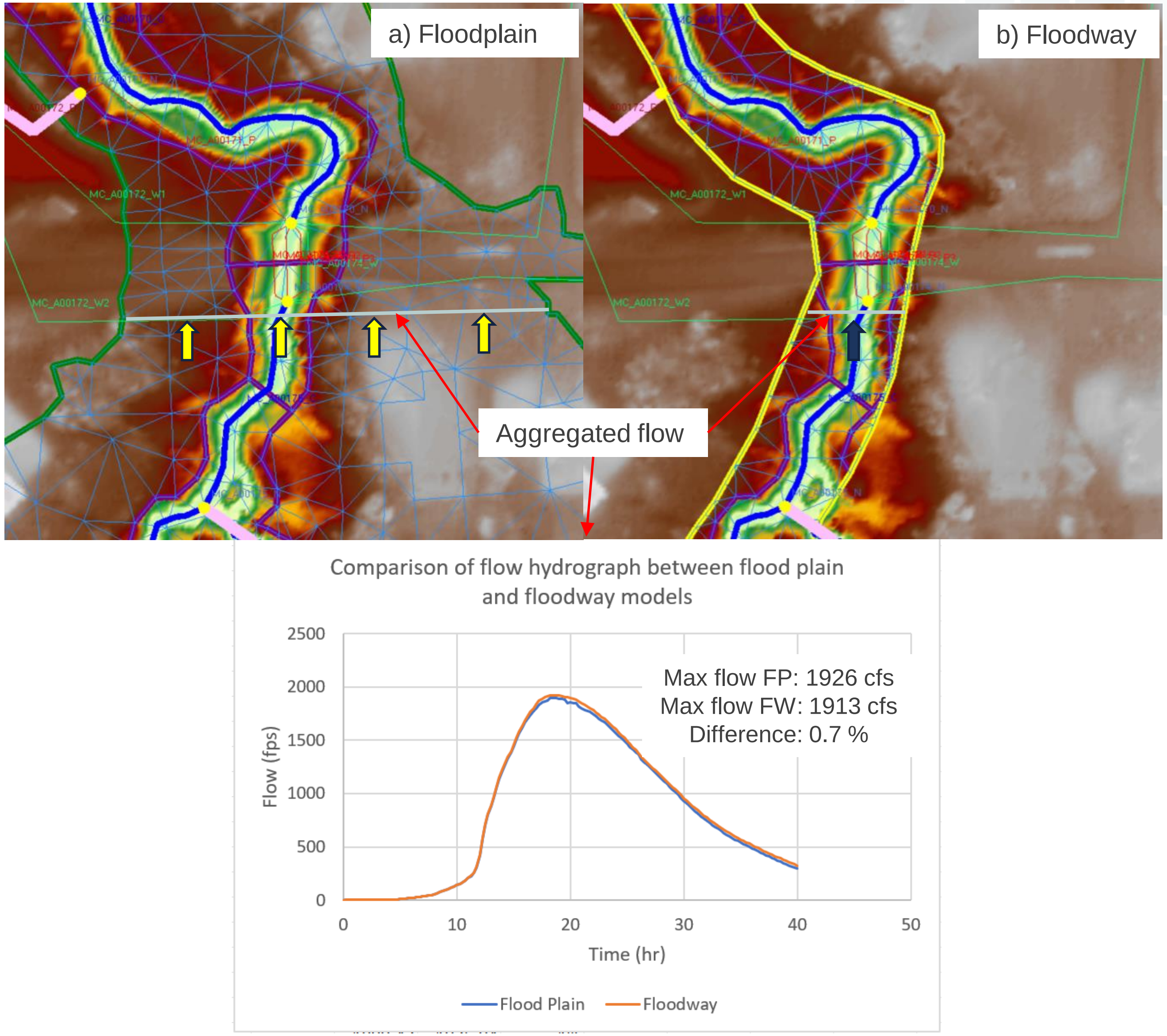
Encroached area or flood fringe

Floodway

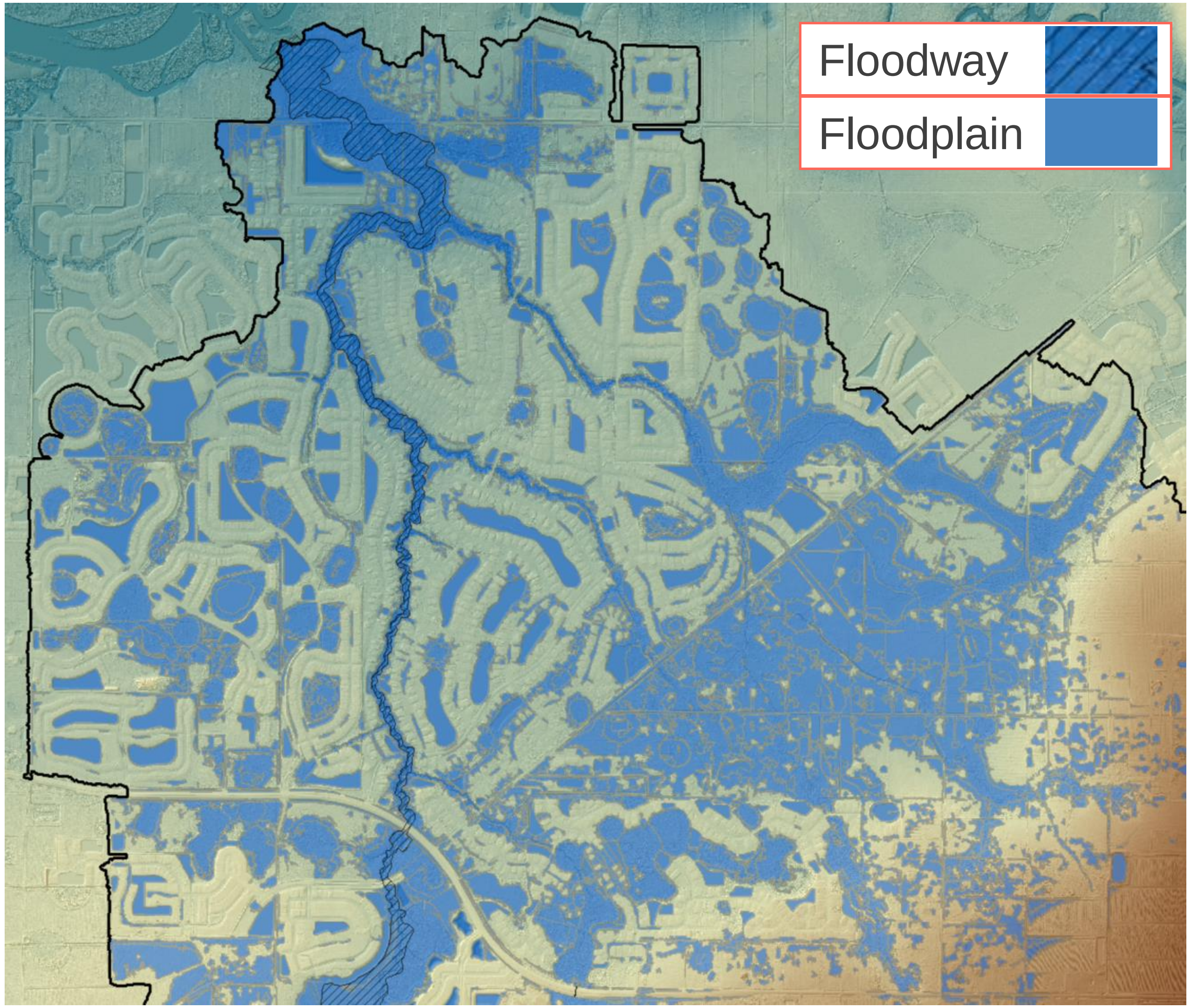
Mapped basin to account for local runoff

MILL CREEK WATERSHED

- **Consistency of maximum flow between models**
  - Aggregated maximum flows from the 2D ICPRv4 floodplain model were calculated and specified as the steady state maximum flow within HEC-RAS
  - Maximum flow from 2D ICPRv4 floodplain model was checked for consistency with the 2D ICPRv4 floodway model



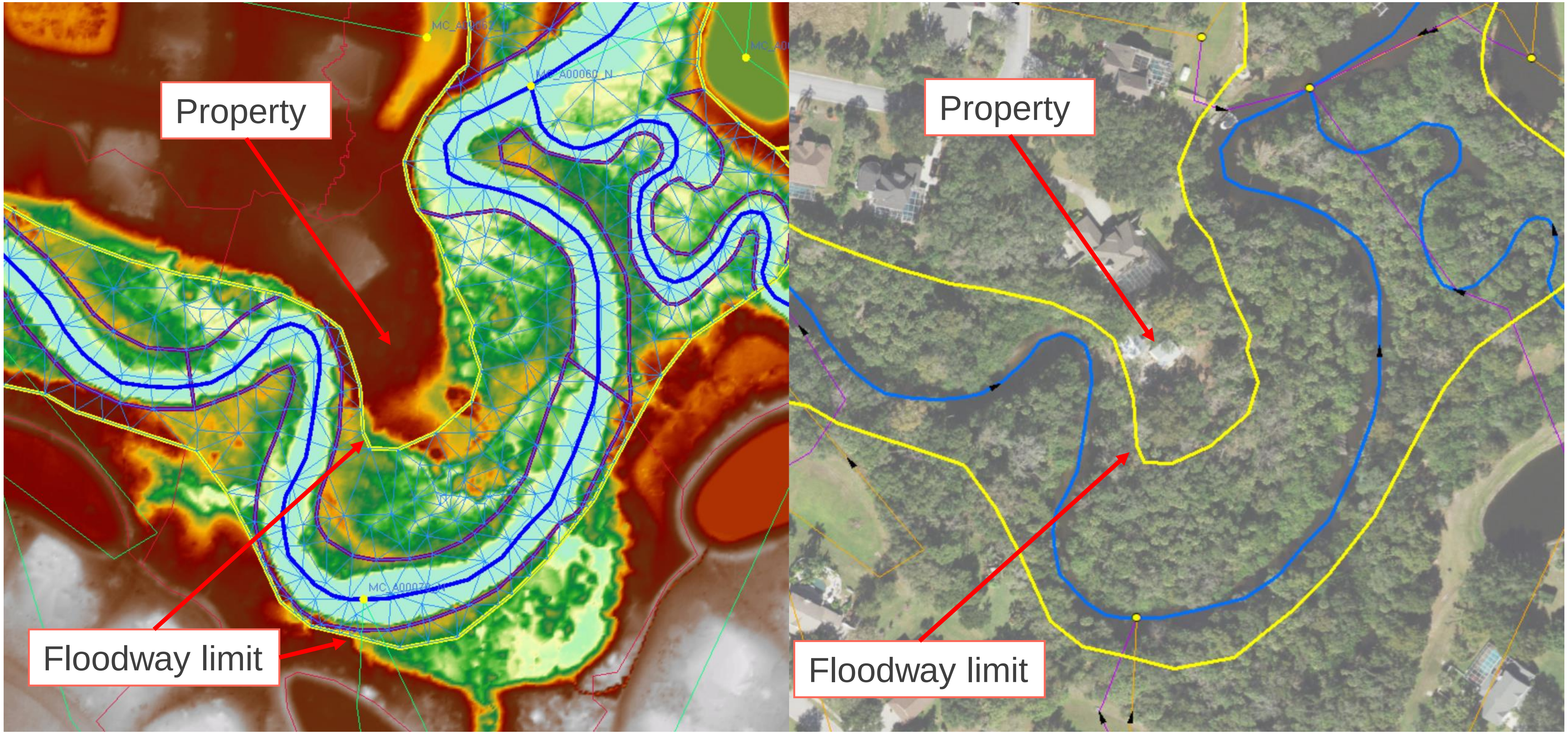
FLOODWAY ANALYSIS



Station #	Node	Max Stage No Floodway	Max Stage with Floodway	Stage Difference
1	MC_A00010_N	10.9	11.9	1.00
2	MC_A00020_N	10.92	11.92	1.00
3	MC_A01010_N	10.96	11.96	1.00
4	MC_A01020_N	10.982	11.986	1.00
5	MC_A01030_N	11.013	12.016	1.00
6	MC_A00030_N	11.05	12.05	1.00
7	MC_A00031_N	11.06	12.06	1.00
8	MC_A00040_N	11.11	12.1	0.99
9	MC_A00060_N	11.14	12.14	1.00
10	MC_A00070_N	11.17	12.17	1.00
11	MC_A00078_N	11.2	12.2	1.00
12	MC_A00080_N	11.232	12.237	1.01
13	MC_A00085_N	11.37	12.36	0.99
14	MC_A00090_N	11.56	12.53	0.97
15	MC_A00100_N	11.94	12.81	0.87
16	MC_A00105_N	12.04	12.9	0.86
17	MC_A00110_N	12.33	13.21	0.88
18	MC_A00120_N	12.68	13.49	0.81
19	MC_A00130_N	13.64	14.34	0.70
20	MC_A00139_N	14.26	15.01	0.75
21	MC_A00140_N	15.05	15.77	0.72
22	MC_A00149_N	15.56	16.38	0.82
23	MC_A00150_N	16.66	17.36	0.70
24	MC_A00155_N	18.57	18.78	0.21
25	MC_A00160_N	20.04	20.28	0.24
26	MC_A01060_N	20.6	20.61	0.01
27	MC_A00170_N	21.32	21.54	0.22
28	MC_A00174_N	21.89	22.1	0.21
29	MC_A00175_N	22.03	22.24	0.21
30	MC_A00178_N	22.37	22.71	0.34
31	MC_A00180_N	23.23	23.55	0.32

FLOODWAY APPROACH & ANALYSIS

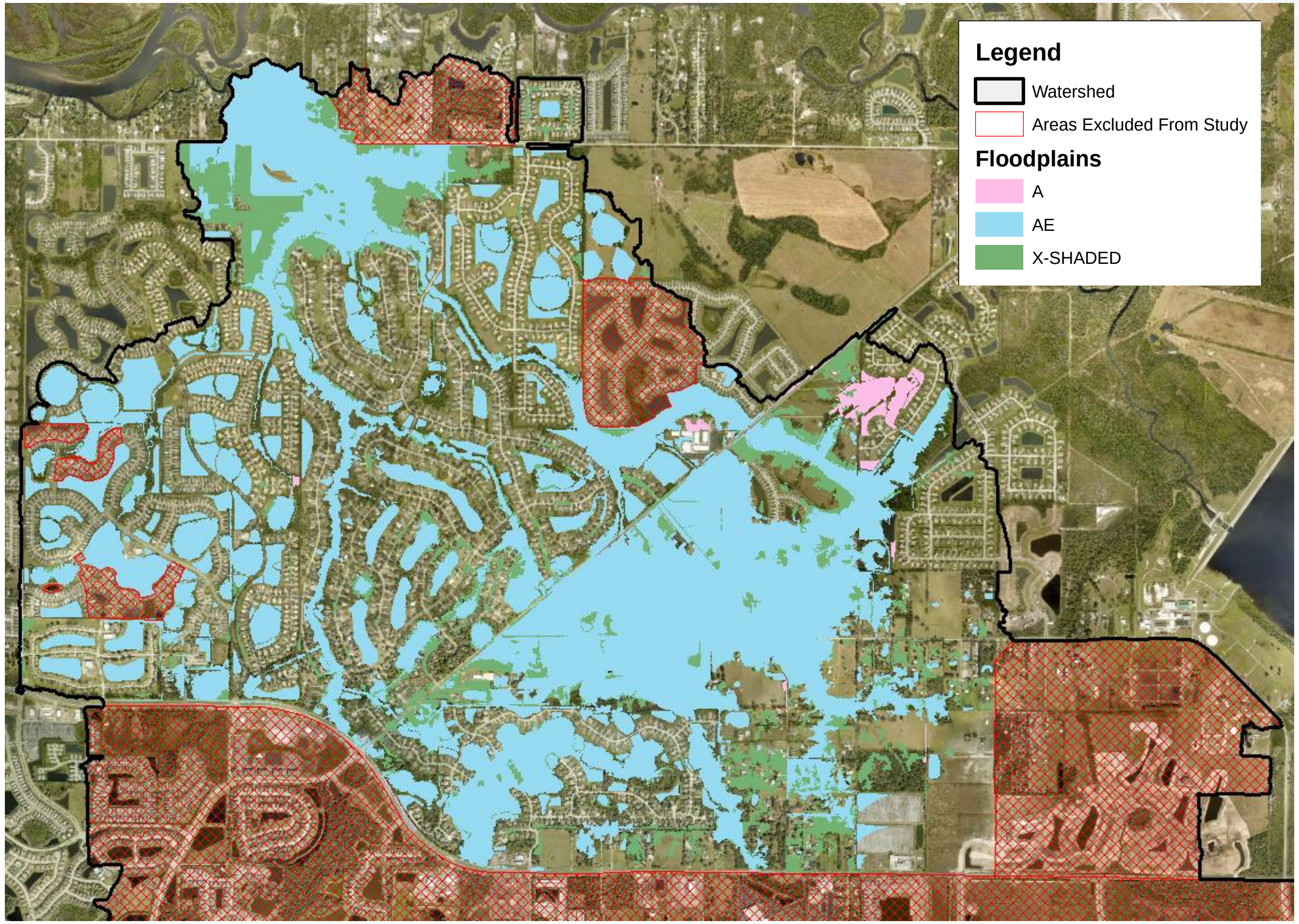
Importance of equal conveyance



Physical Map Revision

PHYSICAL MAP REVISIONS

- **PMR vs LOMR**
  - MT2 Application submitted for LOMR
  - FEMA and community agreed PMR would be preferred
- **RAIs**
  - Fee exemption – Excluded areas of new development
  - Floodway
    - Evaluation lines – Analysis of the floodway in 2D regions
    - Modeling approach discussions
  - Floodplains
    - Fill, spackle, and slivers
    - Backwater in northern community
    - Tie-ins to effective data
- **Pending mapping revisions & community involvement**



Q&A

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