Evaluation of Strategies for Mitigating Coastal Riverine Flooding

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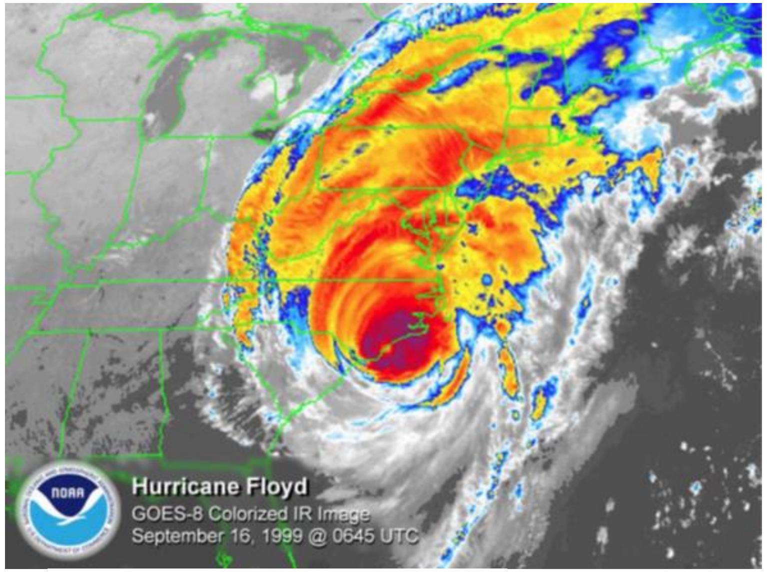

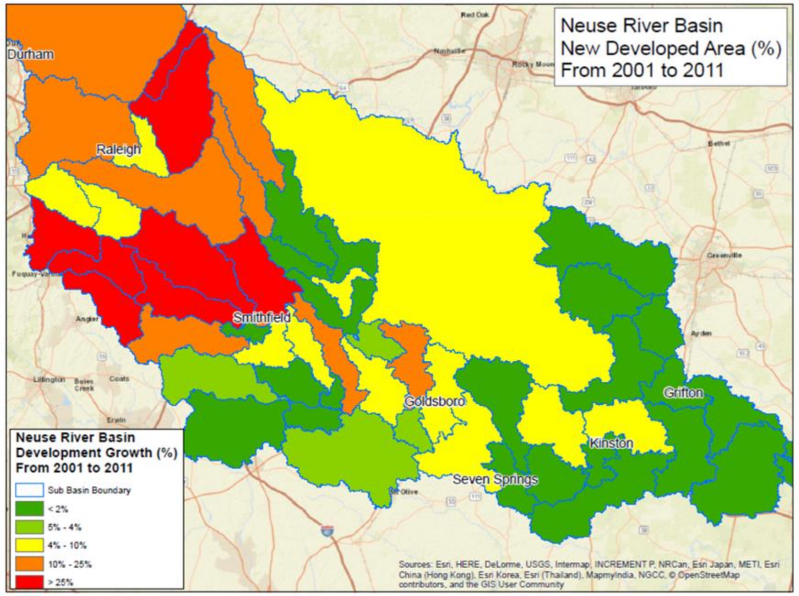

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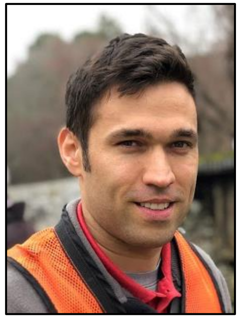
Purpose:

- Identify **flood mitigation** options for communities in eastern NC
- Assist DOT with improving infrastructure resilience
- Evaluate flood mitigation potential of **natural infrastructure**

Approach:

- Understand why it floods
- Determine if there is anything we can do about it



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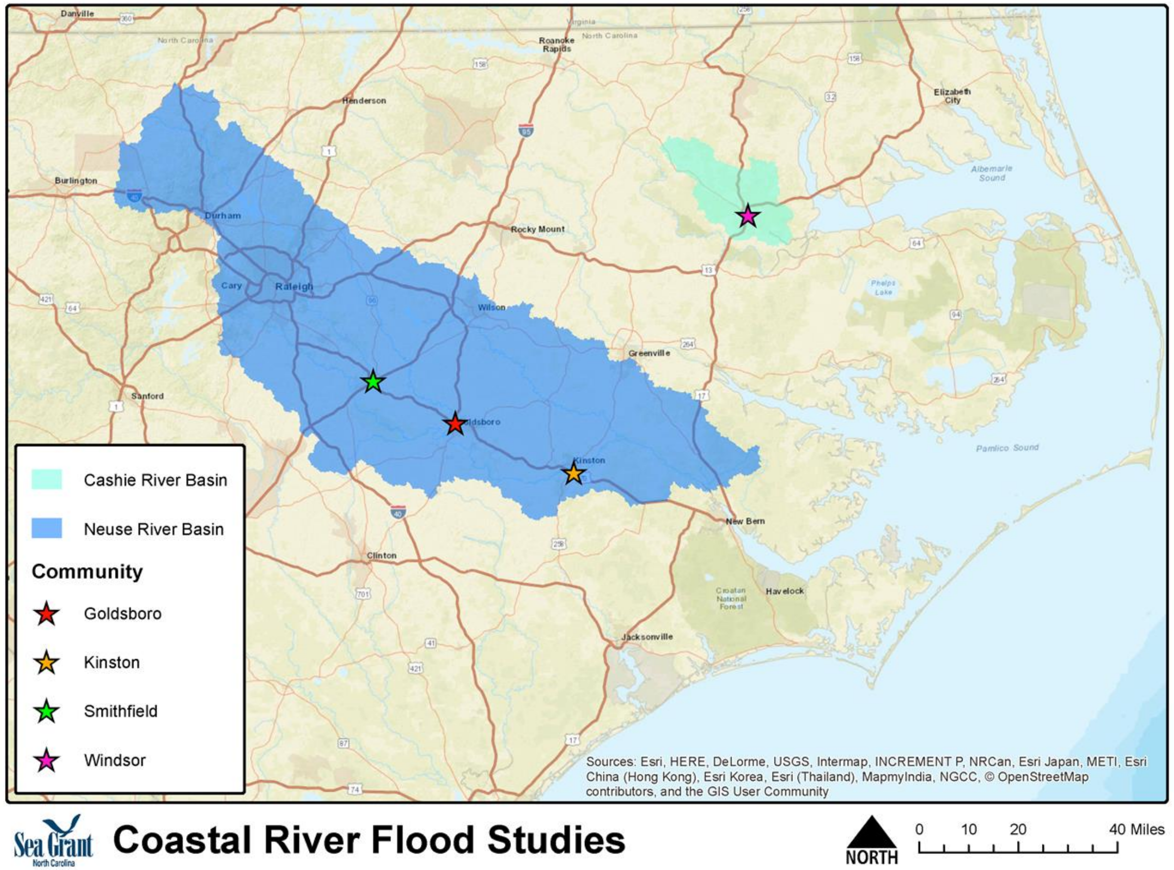
Watershed Modeling
NCSU BAE



NC DOT Neuse River Flood Mitigation Study

Community Workshops
(*Smithfield, Goldsboro and Kinston***)**

Purpose:

- Gather relevant information about flooding and flood-related impacts

Stakeholders:

Emergency responders

Public works

Engineering

Mayor

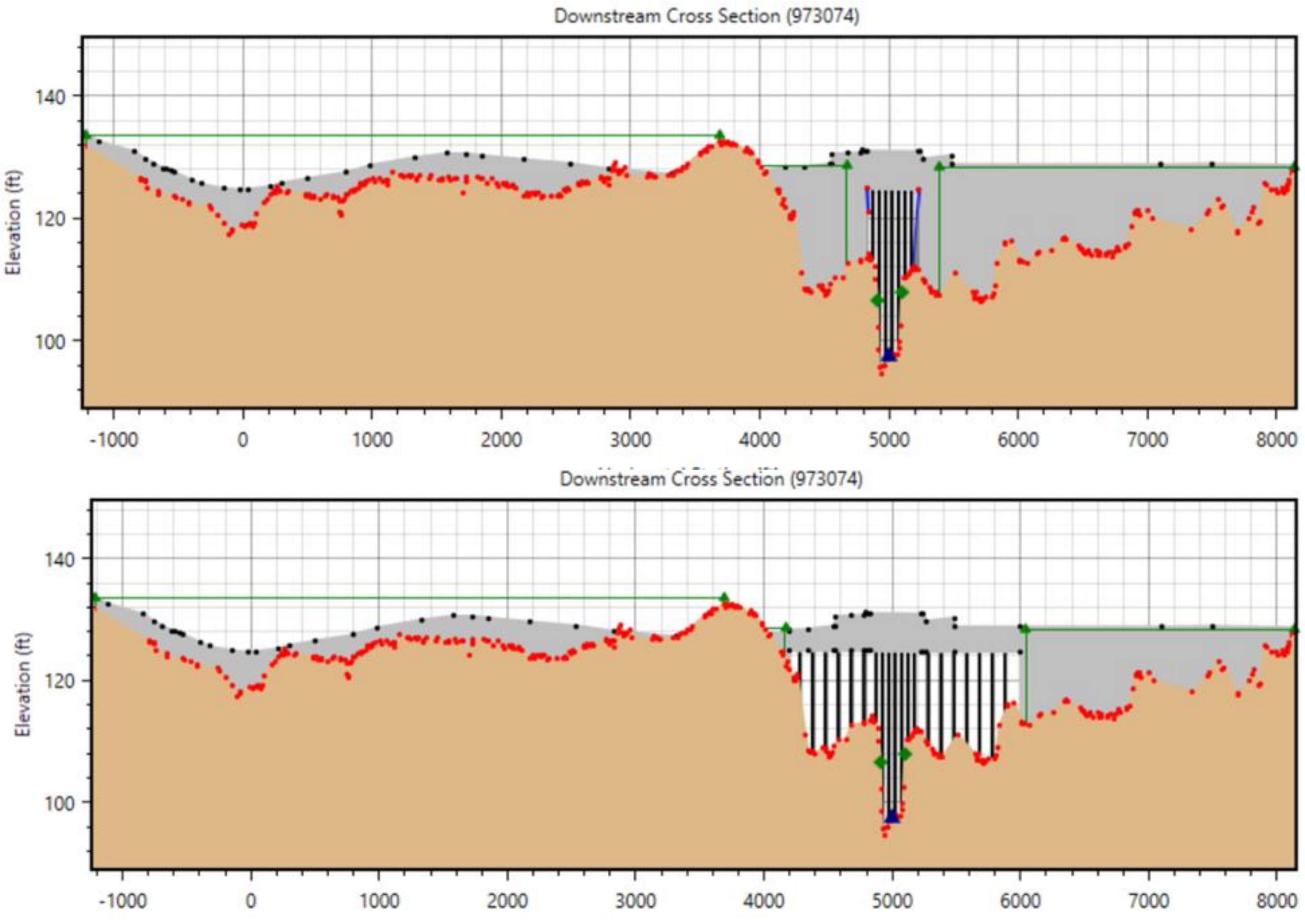
City manager

Planners

What we heard from stakeholders:

- Bridges are undersized
- Falls Dam releases
- Urban areas upstream (Raleigh!)
- Flash flooding of tributaries prior to the river flooding
- Early warning is critical to preparedness
- Continued development in the floodplain

Model river crossings suspected of exacerbating flooding



Example I-95 Bridge Existing and Modified Crossing, Smithfield, N.C.

Smithfield

- US 301 (Brightleaf Blvd)
- Railroad bridge
- I-95

Goldsboro

- Arrington Bridge Rd

Kinston

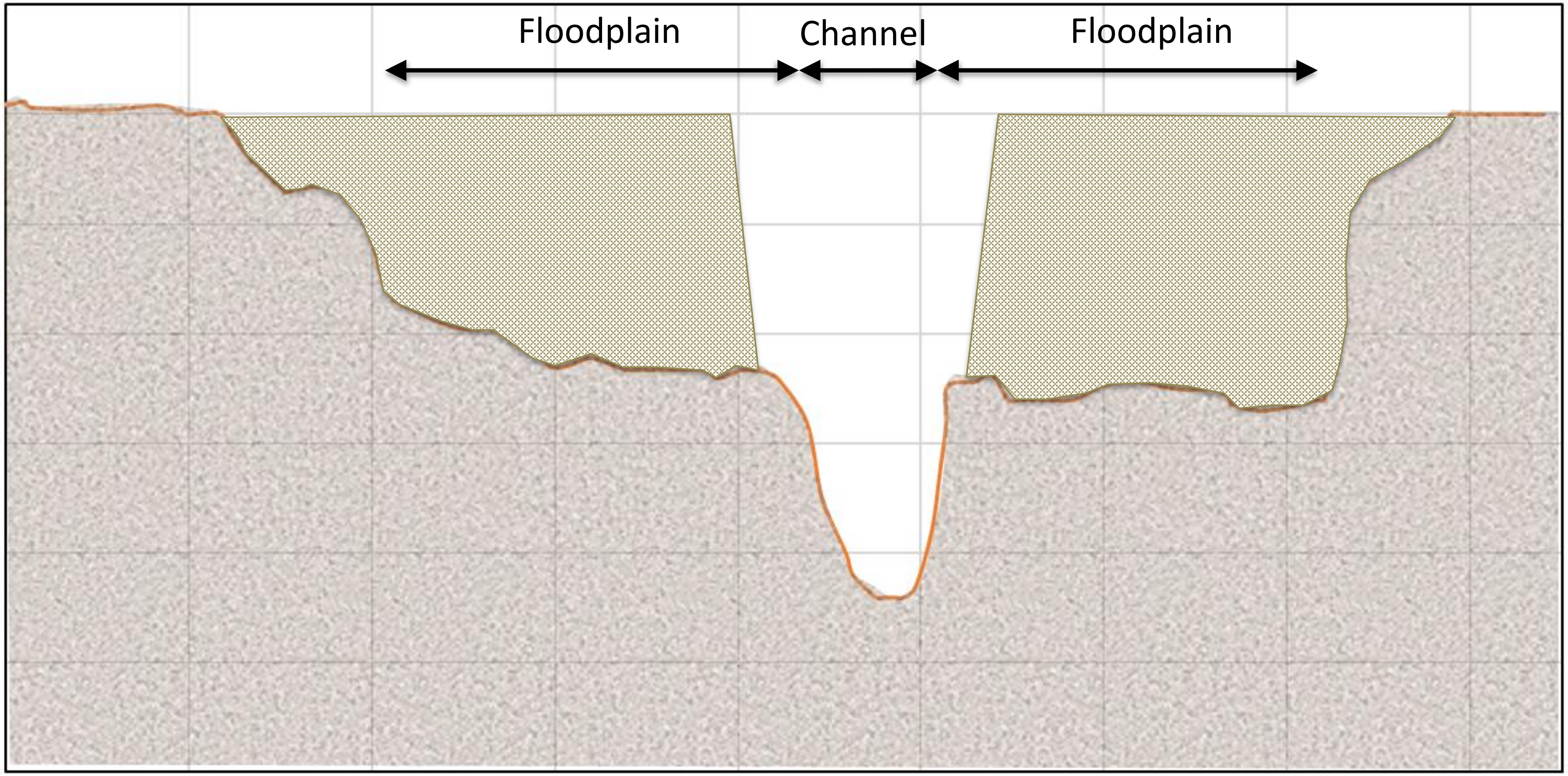
- US 70 (New Bern Ave)
- King St. (NC 11)
- Queen St. (US 258)
- Railroad

Craven County

- NC 43 – Neuse River
- NC 43 – Swift Creek

Example Bridge Evaluation

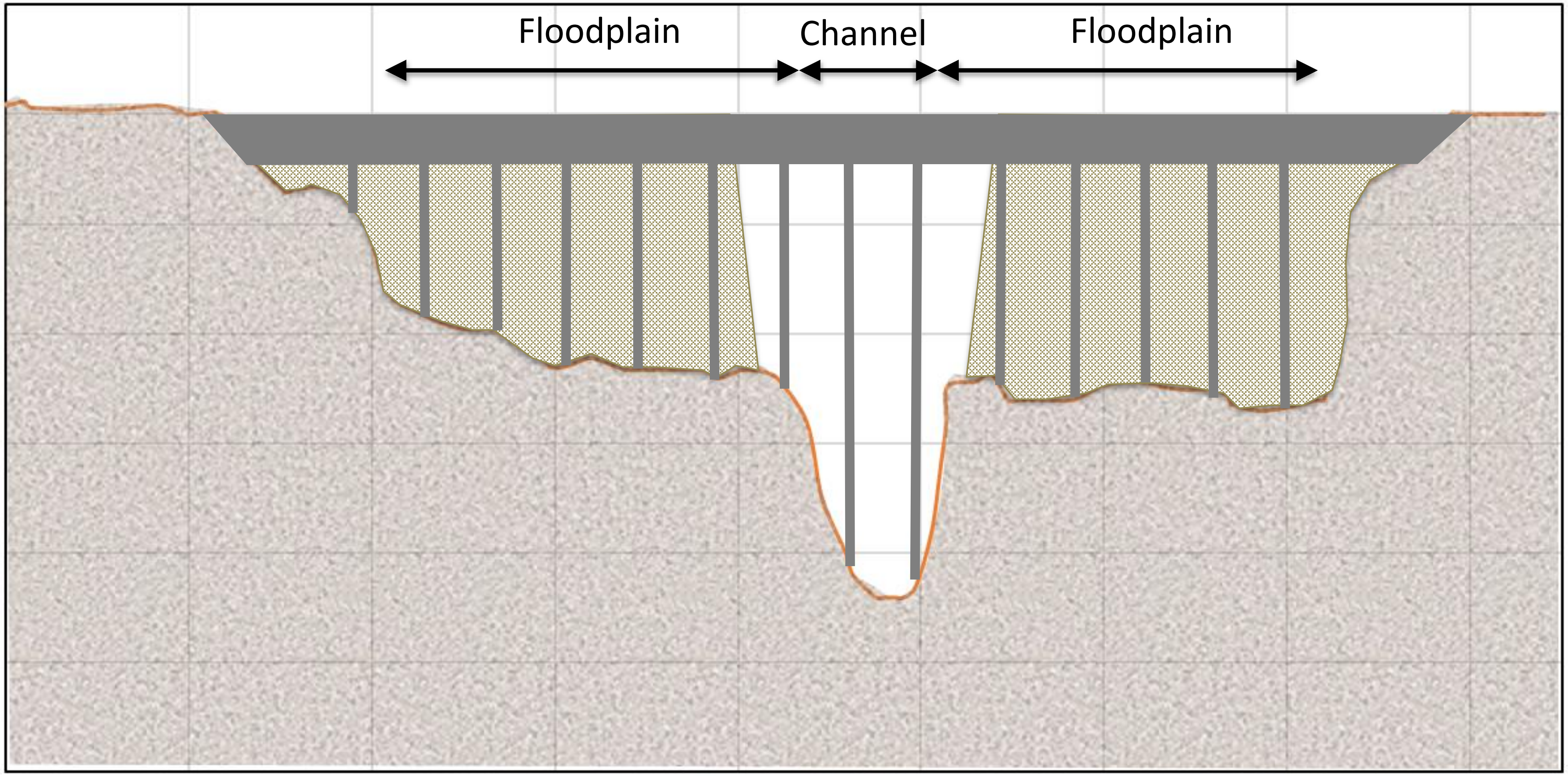
Roadway Constructed – Embankment Added



Cross section (looking downstream)

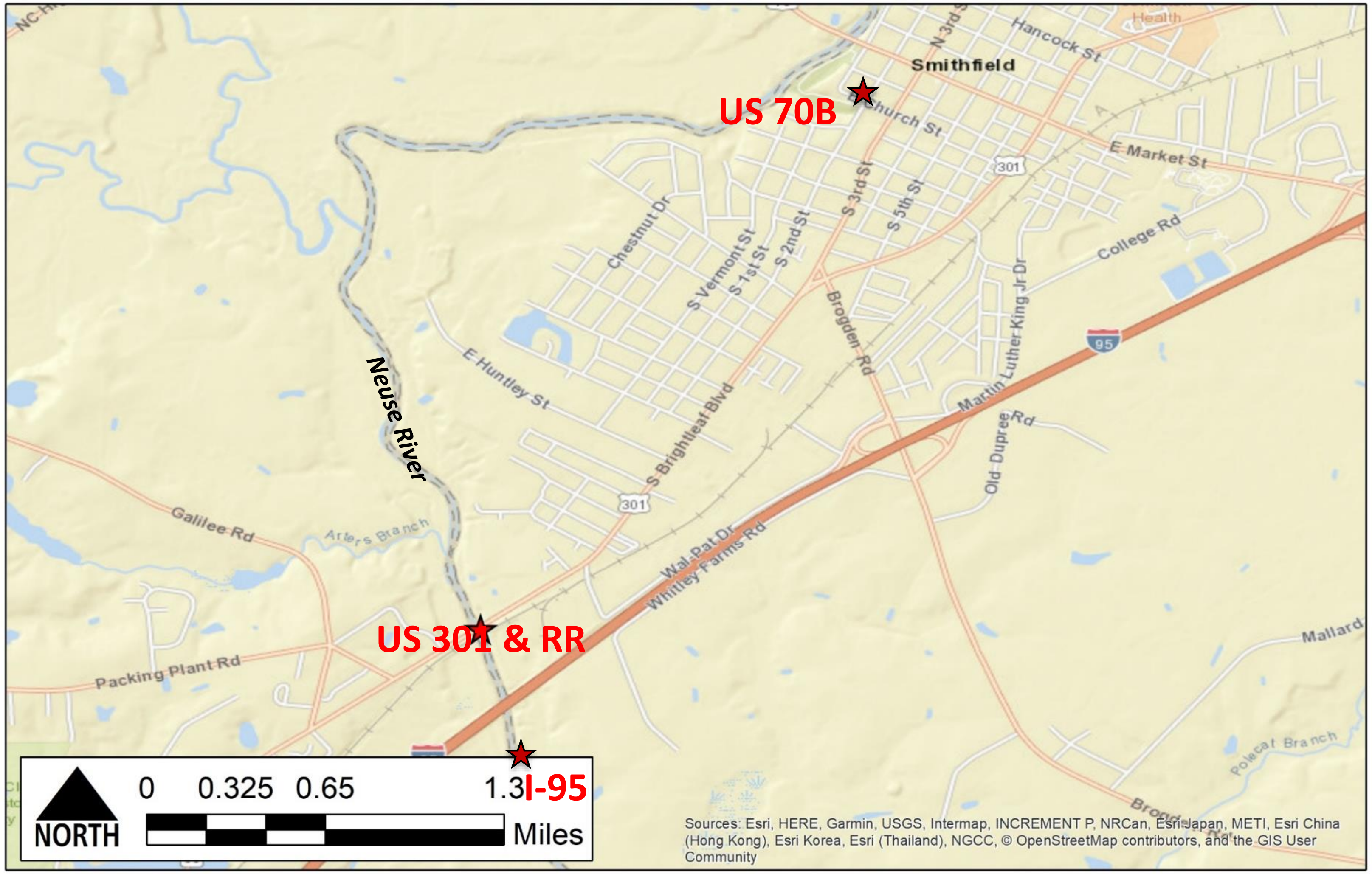
Example Bridge Evaluation

Proposed Scenario to Increase Floodplain Conveyance



Cross section (looking downstream)

Smithfield Bridge Evaluations



Neuse River Flood Mitigation Bridge Modification Evaluation

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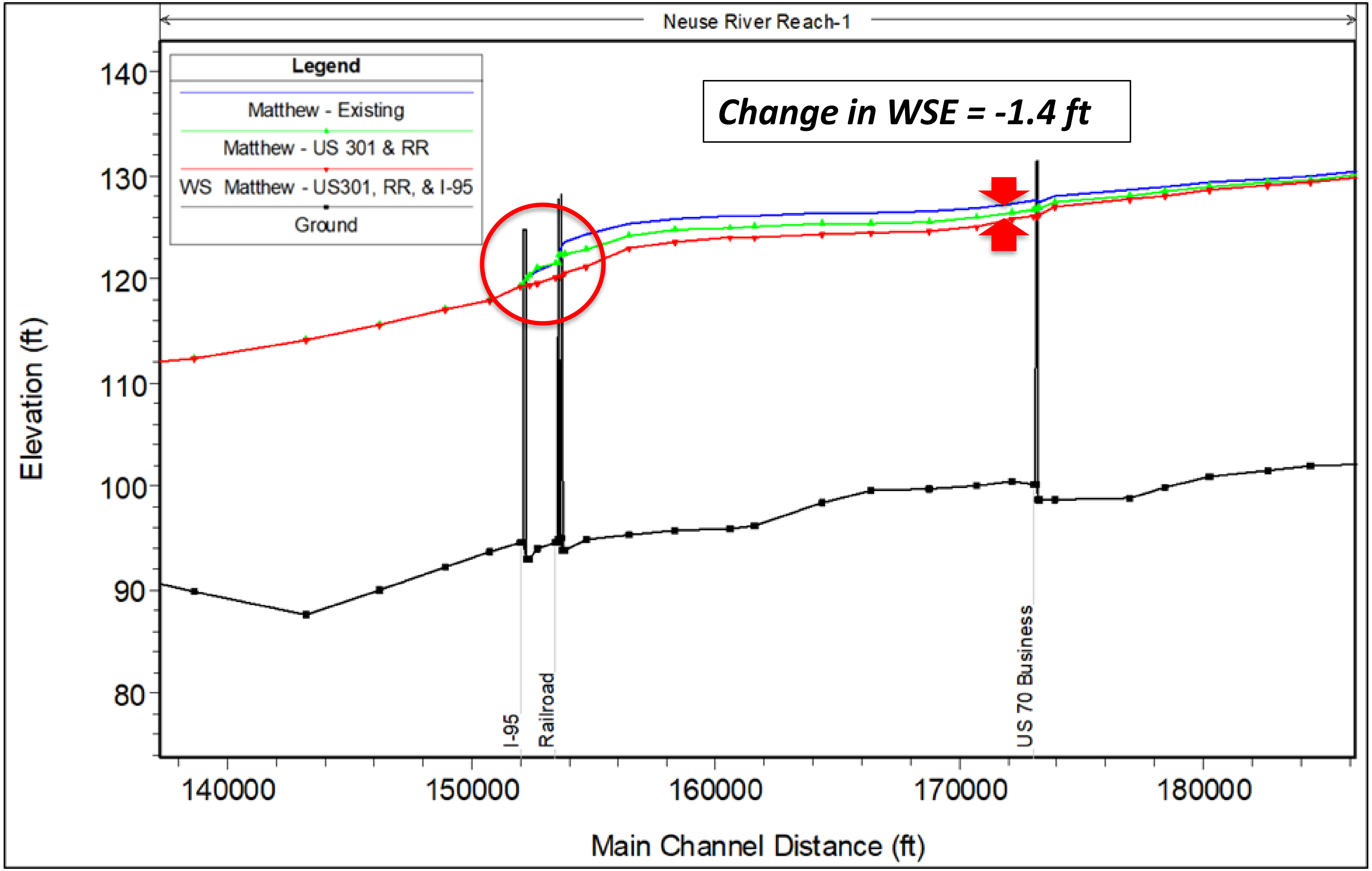
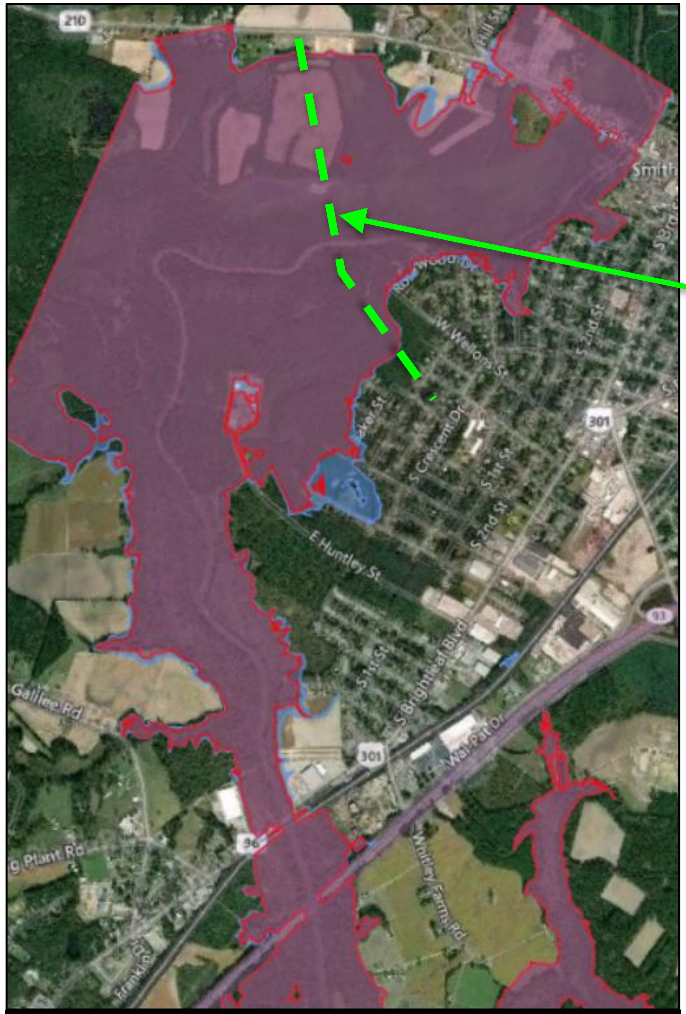
Smithfield- HEC-RAS Results



Smithfield- HEC-RAS Results (Hurricane Matthew)

HEC-RAS Model Results – 301, RR, & I95 Embankments Removed

Existing Conditions

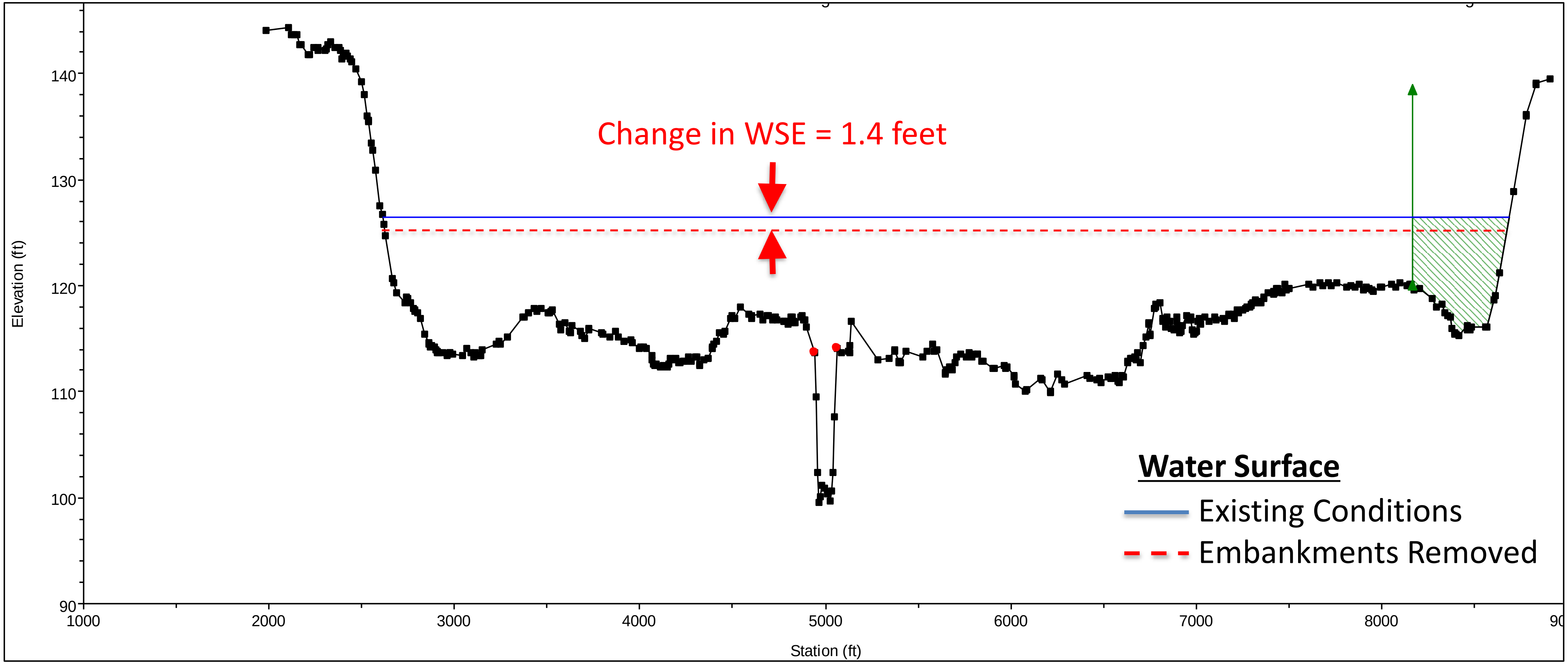


Cross section

Embankments Removed

Smithfield- HEC-RAS Results (Hurricane Matthew)

HEC-RAS Model Results – 301, RR, & I95 Embankments Removed



Bridge Evaluation Summary

Community	Single Bridge	Multiple Bridges
Smithfield	0.0 ft	**1.0 - 1.4 ft**
Goldsboro	0.0 ft	-
Kinston	0.2 – 0.7 ft	**0.9 - 1.2 ft**
Craven County	0.0 - 0.3 ft	0.0 - 0.9 ft

- Relatively large modifications were modeled to determine maximum potential drop in WSE

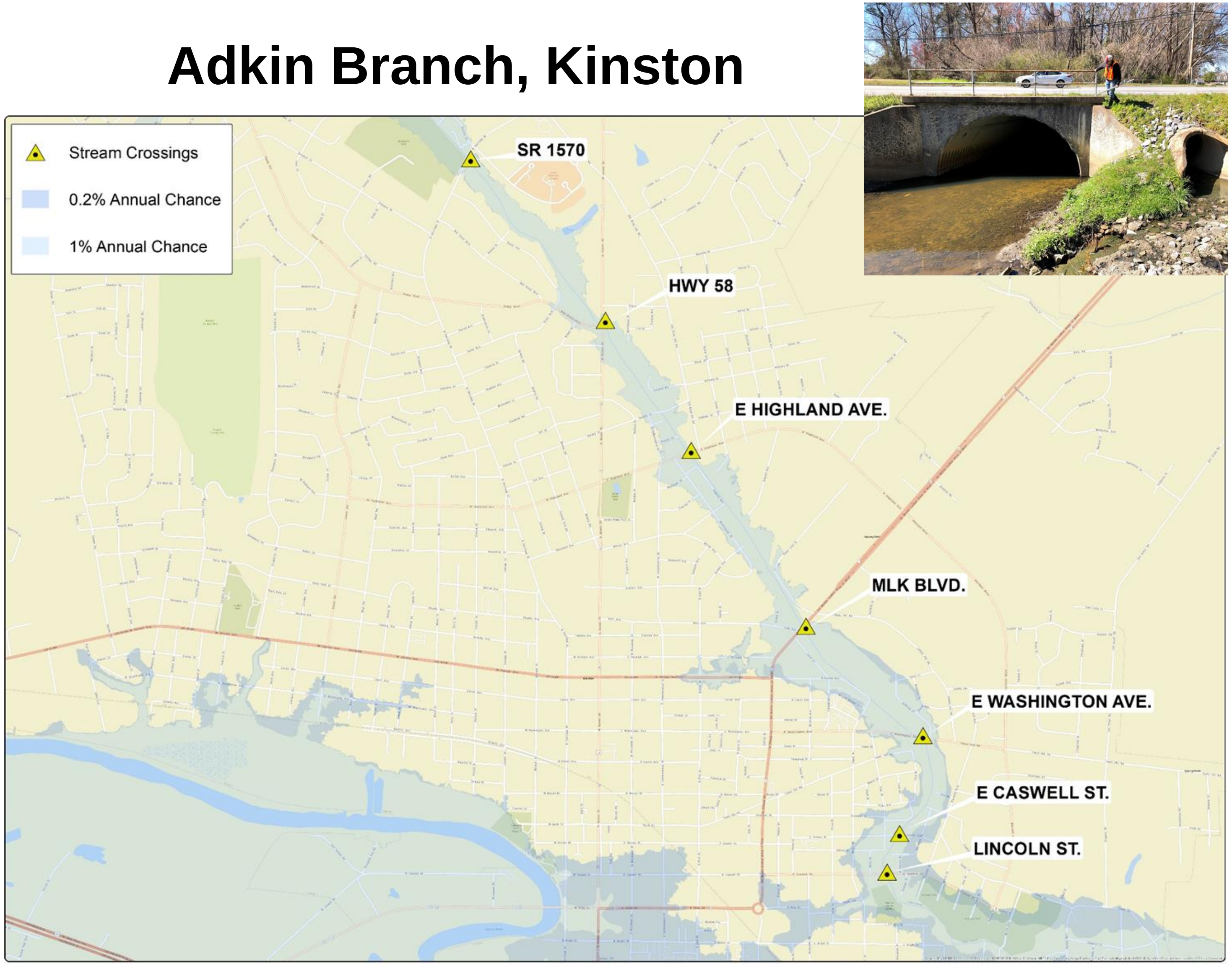

301, Smithfield


RR, Smithfield

Tributary Flash Flooding

- Inventory crossings
- Evaluate size & condition
- Obtain existing hydraulic
- Prioritize transportation importance
- Develop enlargement alternatives for under-sized crossings
- Develop a decision matrix for prioritizing replacement or improvement

Adkin Branch, Kinston

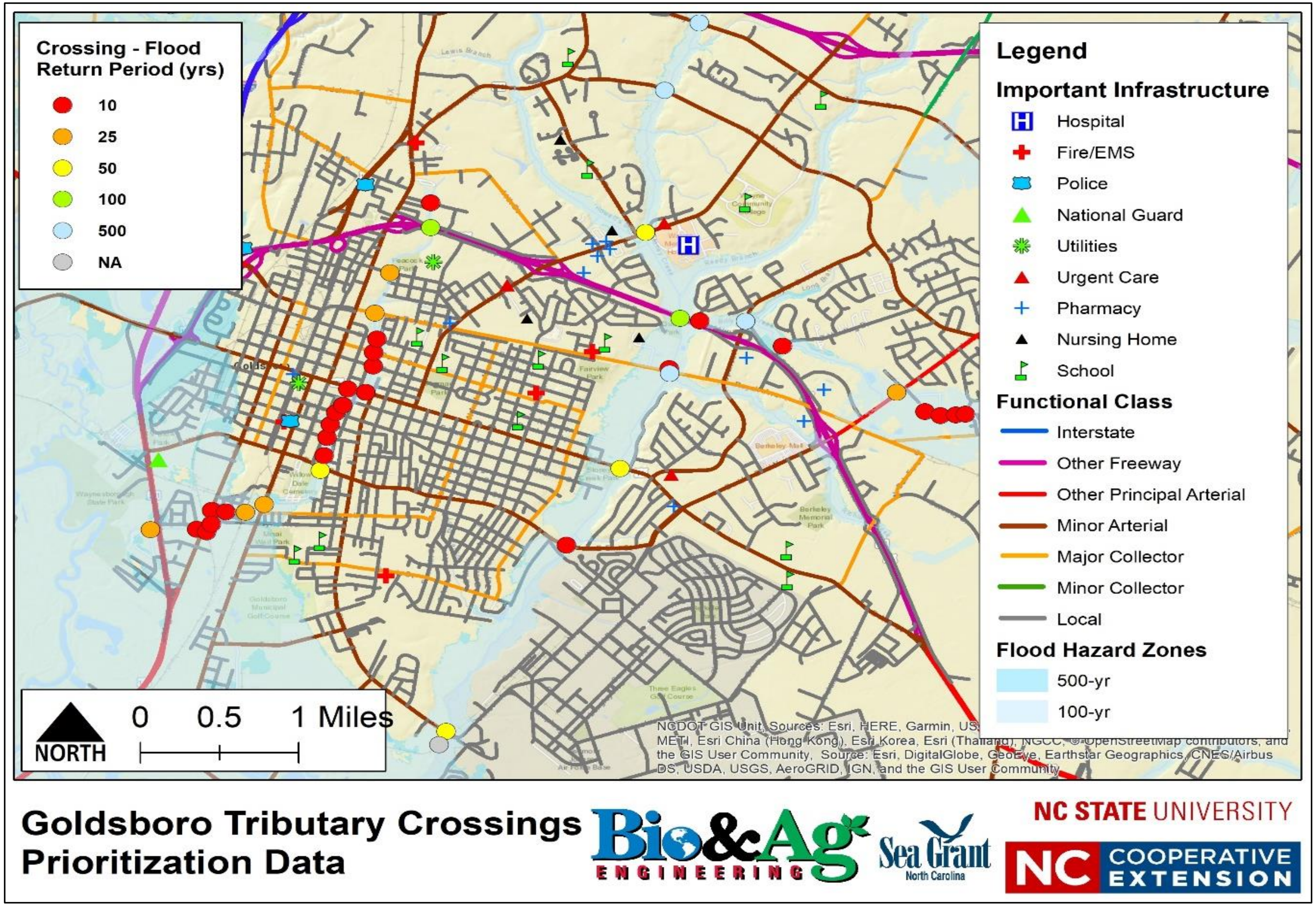


NC 11 south of Kinston (WITN)

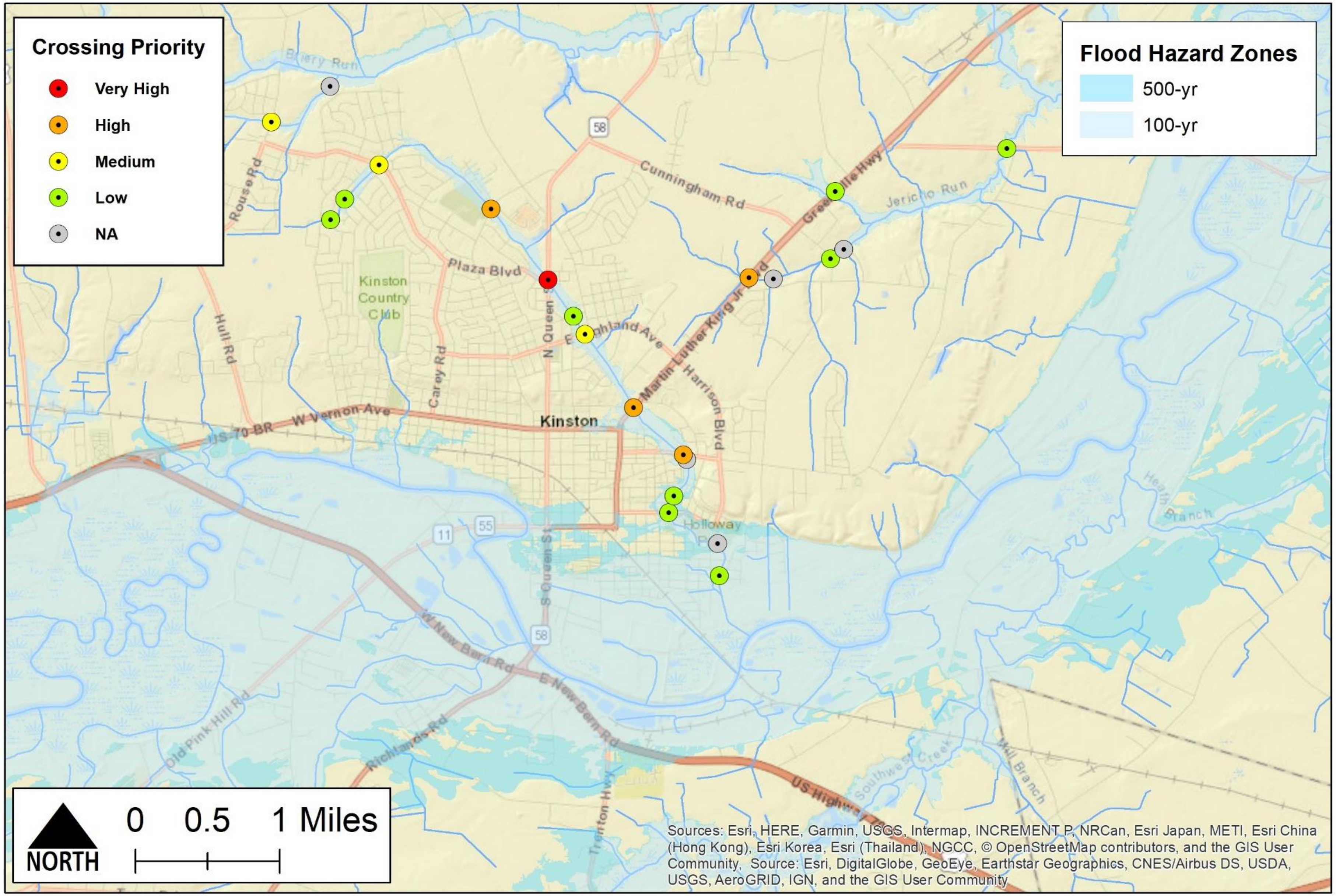
Tributary Crossings – Condition

Culverts under Beech St., Goldsboro

Tributary Crossings – Critical Transportation Importance



Tributary Crossings – Replacement Priority Maps

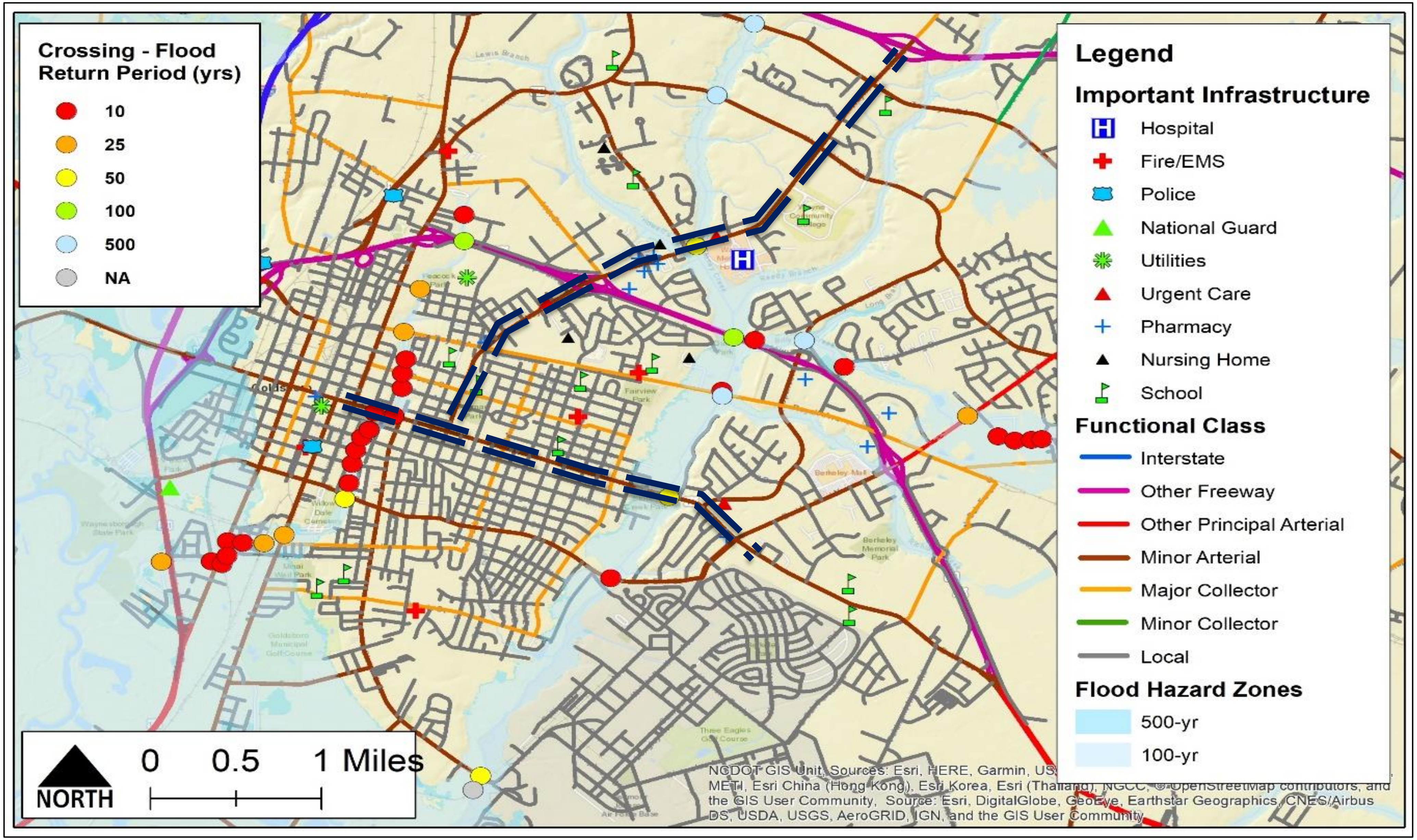


Multi Criteria Decision Analysis (MCDA)

Factors Evaluated:

- Replacement Costs
- Roadway Use Designation
- Crossing Condition
- Critical Transportation Importance
- Flooding Risks

“Safe” Routes

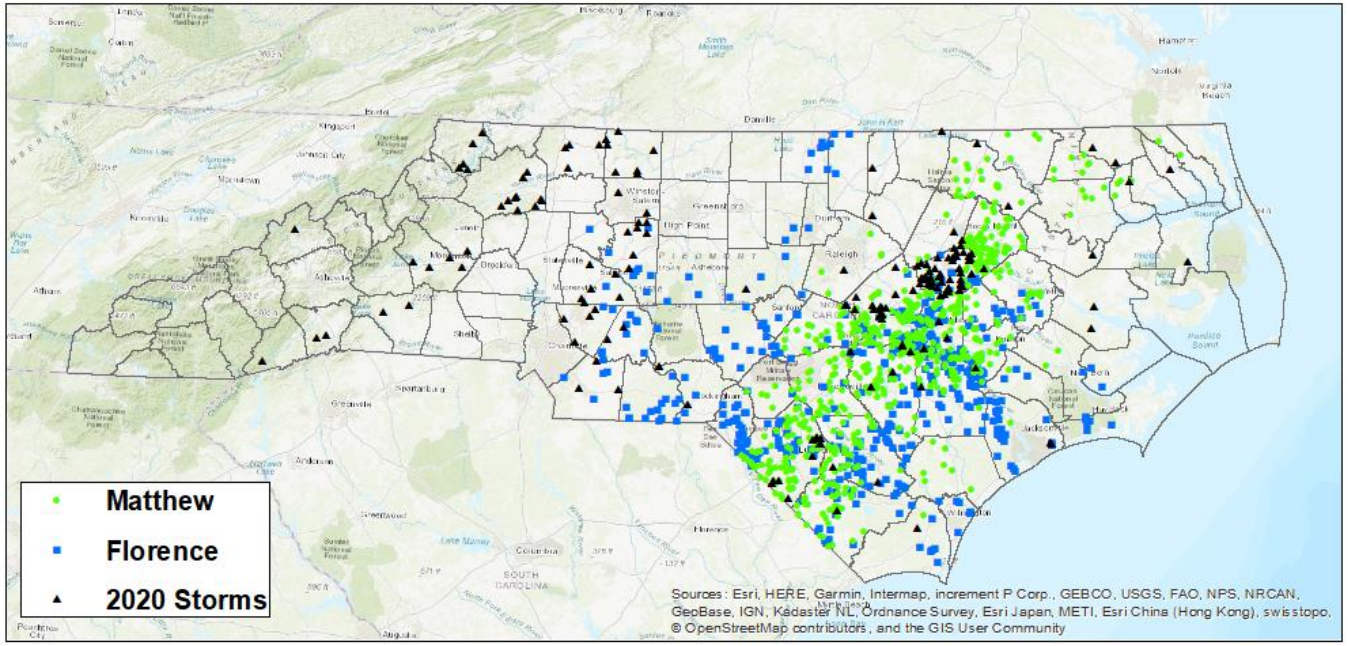


Crossing - Flood Return Period (yrs)
10
25
50
100
500
NA
Legend
Important Infrastructure
Hospital
Fire/EMS
Police
National Guard
Utilities
Urgent Care
Pharmacy
Nursing Home
School
Functional Class
Interstate
Other Freeway
Other Principal Arterial
Minor Arterial
Major Collector
Minor Collector
Local
Flood Hazard Zones
500-yr
100-yr
NORTH
0 0.5 1 Miles
NCDOT GIS Unit, Sources: Esri, HERE, Garmin, USGS, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Road Washouts

- 1177 crossing washouts (Hurricane Matthew and Florence)
- Also during localized flash flood events
- Poses a significant threat to human life
- Incidents more common with climate change
- Current response is mostly reactionary

25th Ave Dr NW in Hickory June 9, 2019 (Source: John Sparks, WECT News 6)



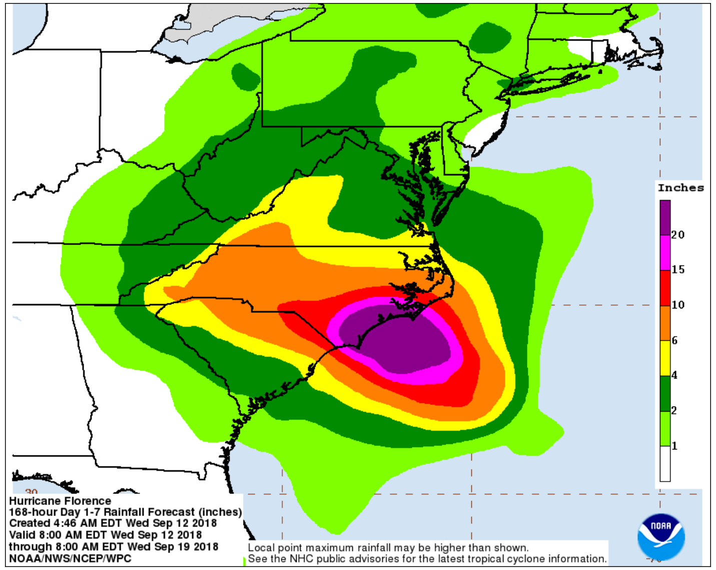
Goal - Predict crossing overtopping and potential washout based on forecasted rainfall depths

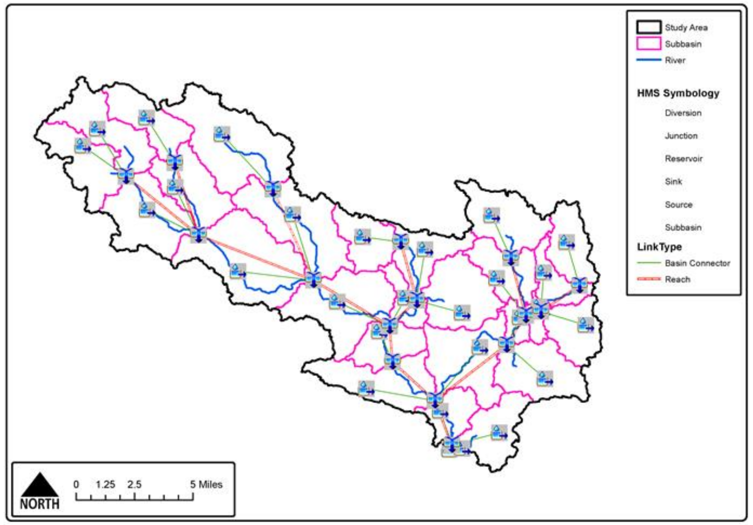
Approach:

Rainfall Depths

Hydrology Model (Q)

Output a map of culvert locations at risk of overtopping and road washout





Natural & Green Infrastructure

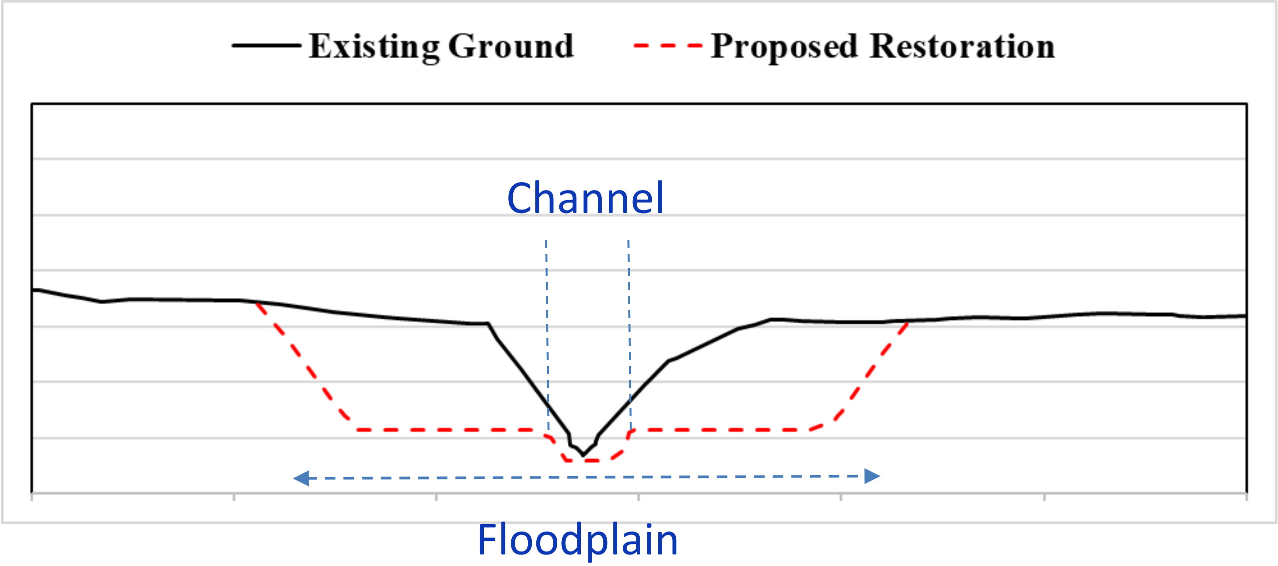
- Wetland restoration
- Stream restoration
- Floodplain expansion
- Reforestation
- Two-Stage Ditches
- Vegetated Filter Strips

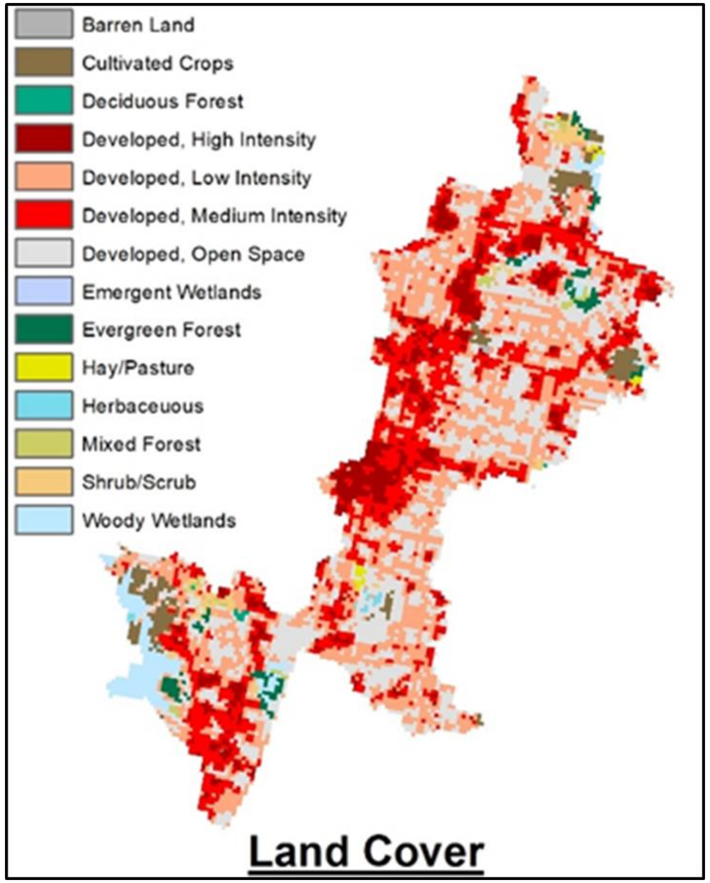
Indiana Watershed Initiative

The Ohio State University

Big Ditch, Goldsboro

Conducted hydraulic modeling to compare stream restoration to enlarging bridges and culverts





Watershed

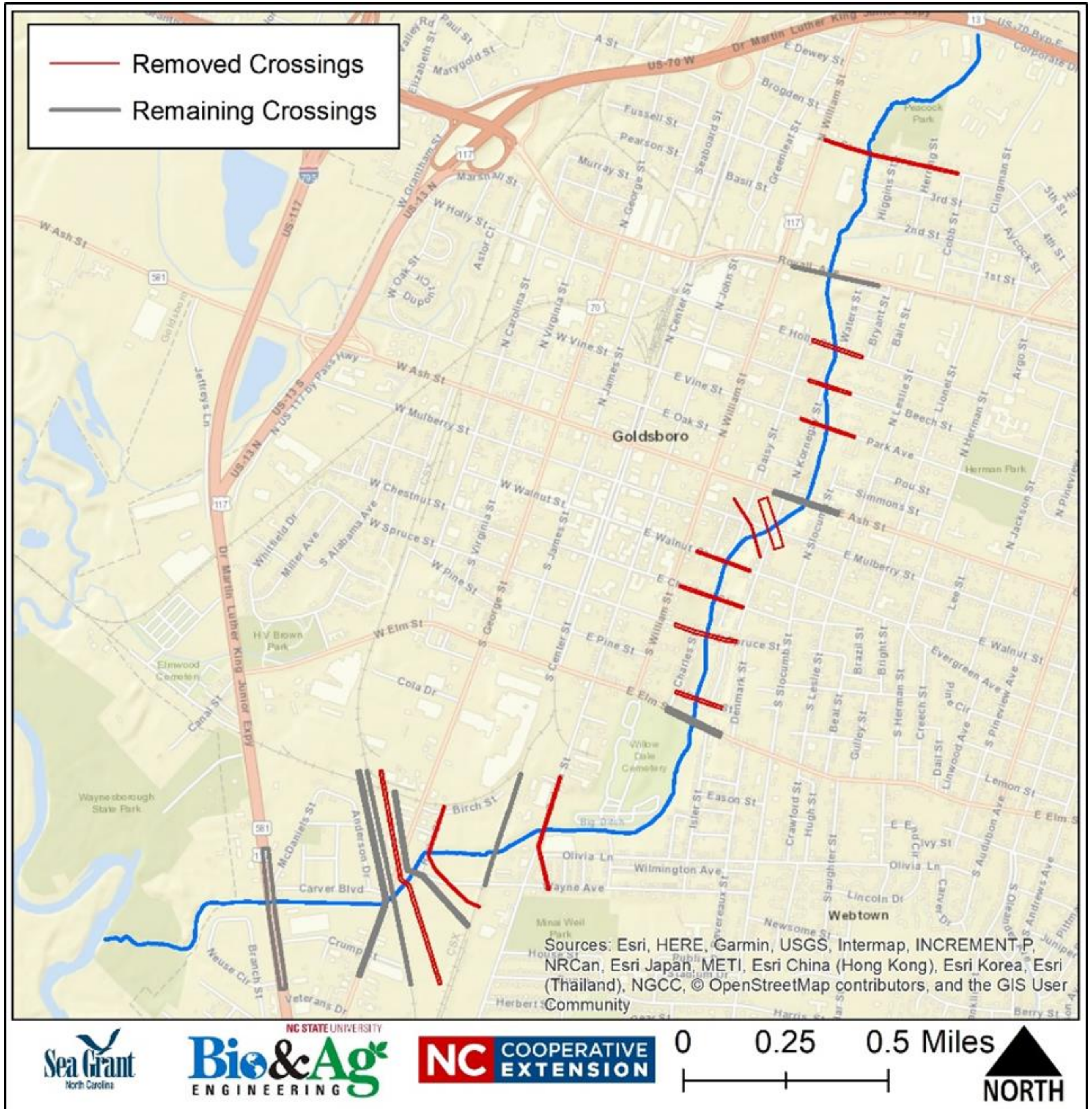
- 3 square miles
- 93% Developed
- 35% Impervious

Stream

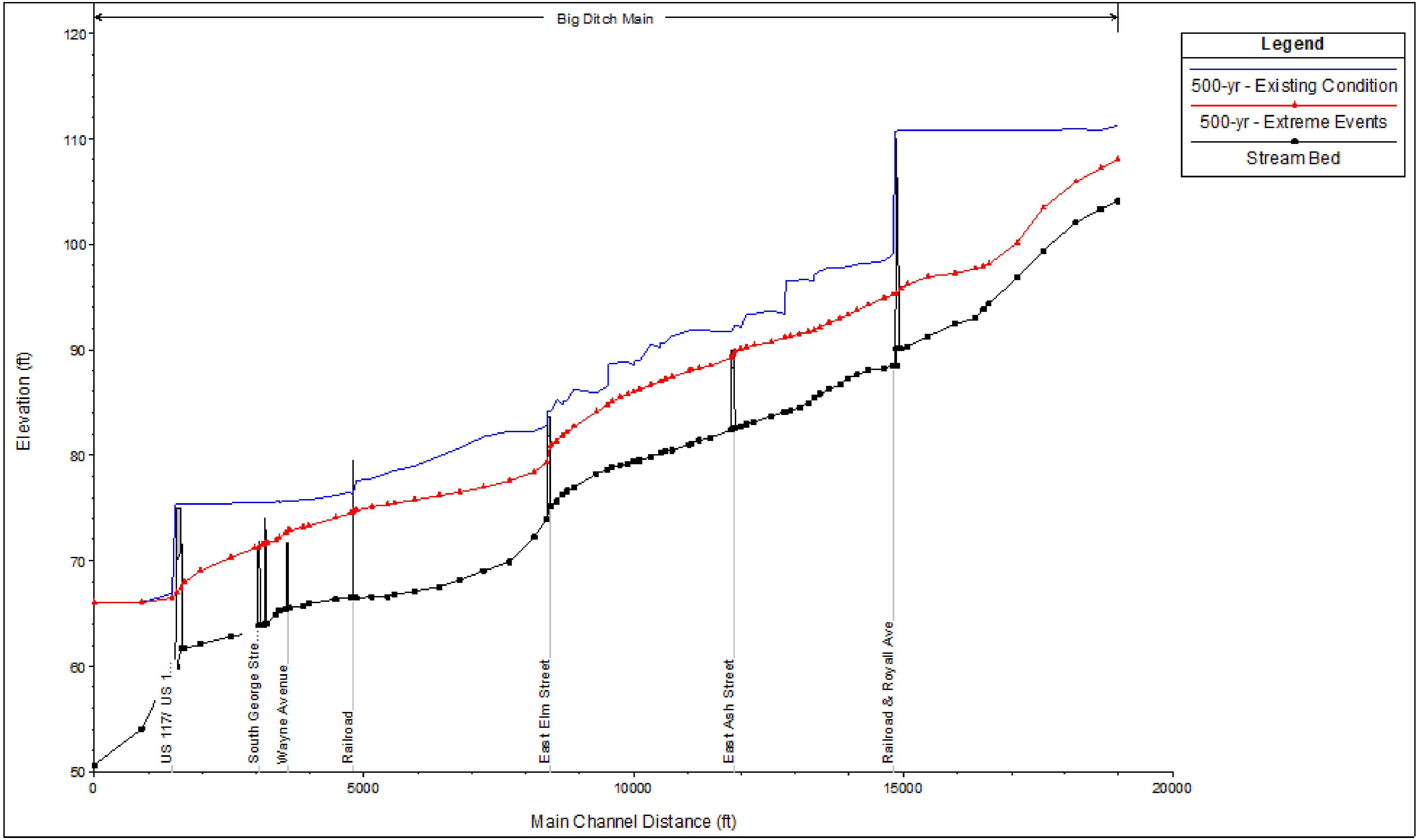
- 22 road crossings
  - Many undersized

Combined Measures

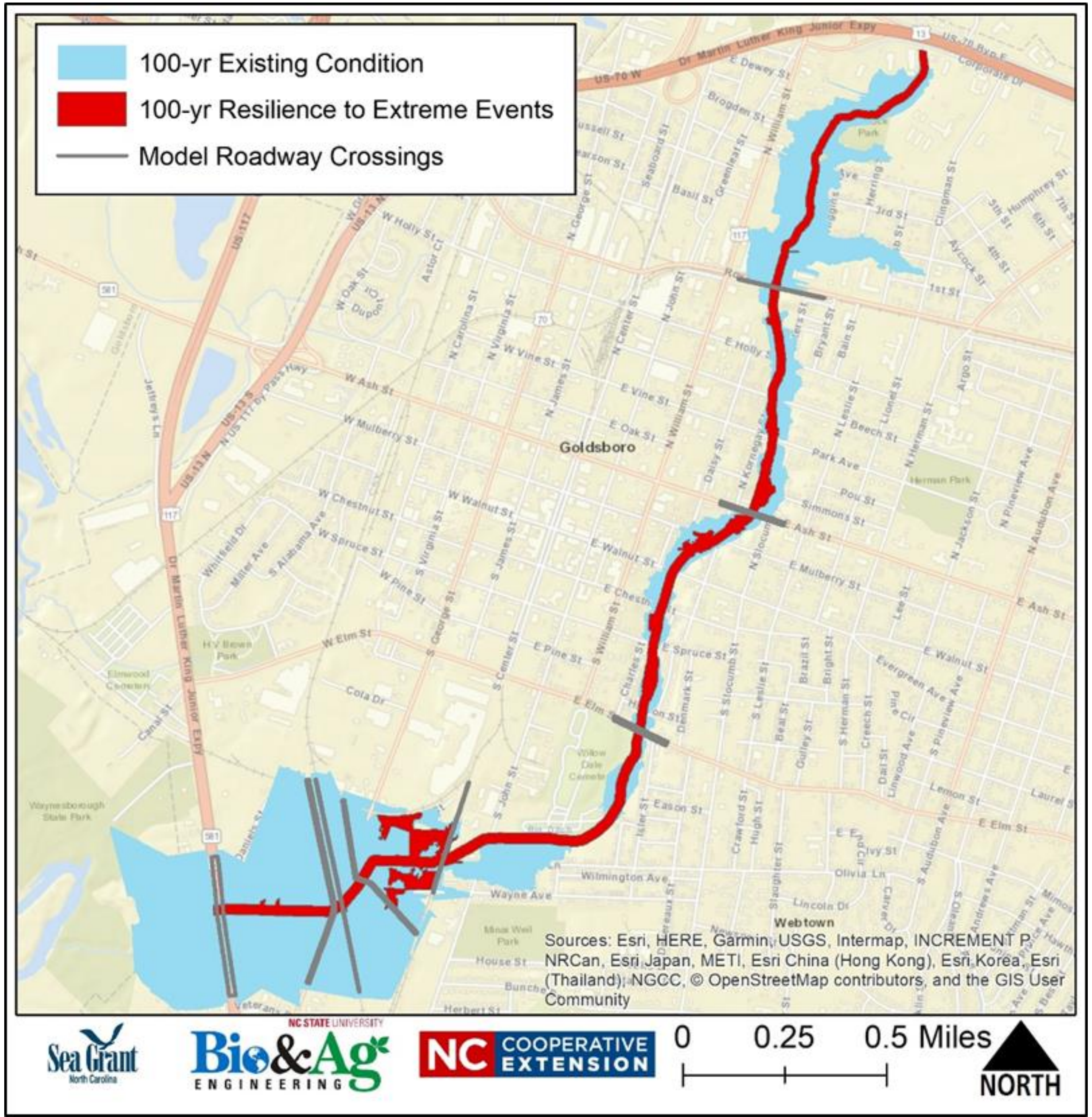
- 7 crossings enlarged
- 13 redundant crossings removed
- Floodplain expanded to 6 x channel width



Combined Measures (500-year storm)

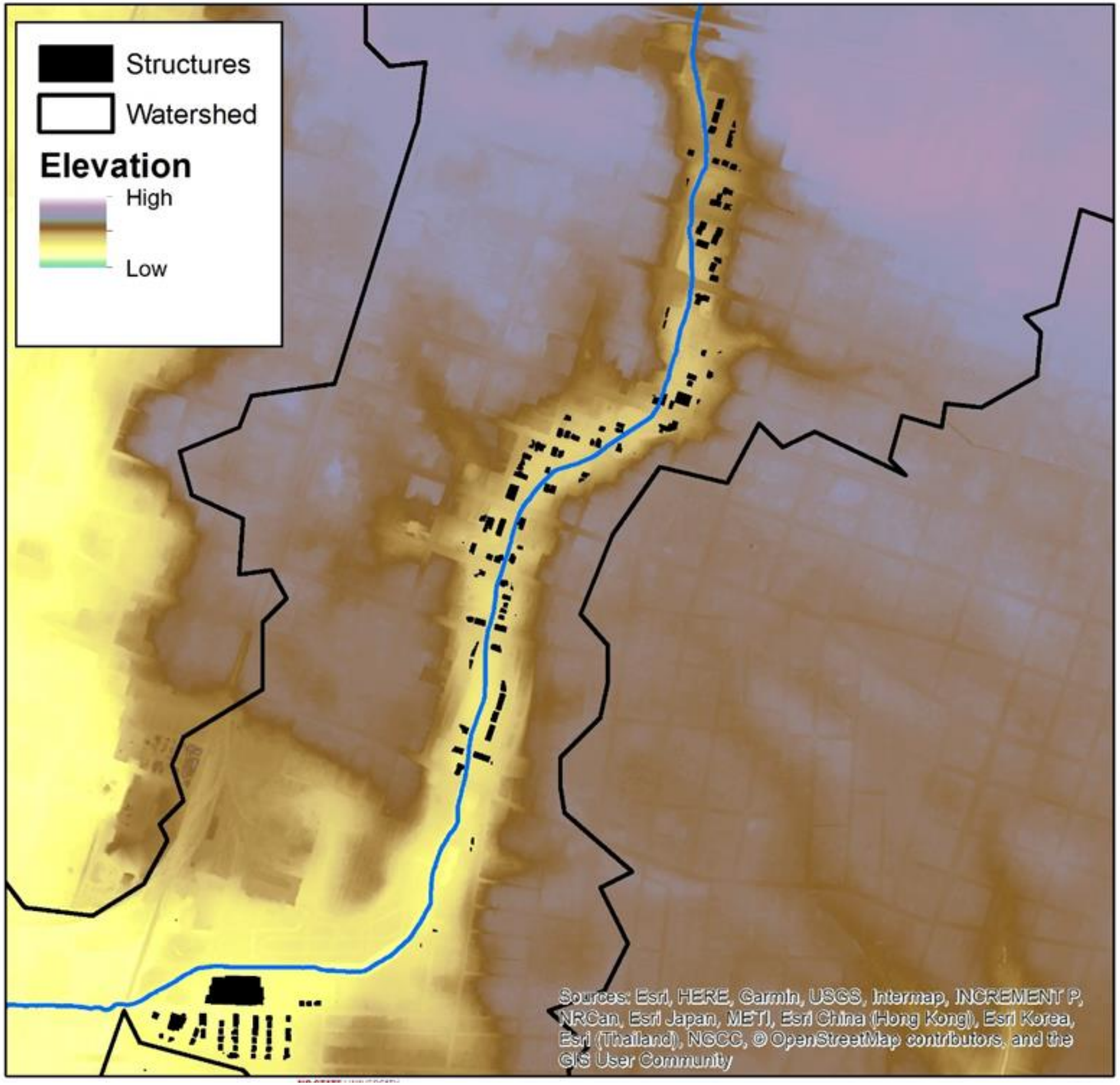


Big Ditch – Combined Measures



Conclusions:

- Neither floodplain restoration nor crossing modifications alone could mitigate flooding problems
- **A combination approach is needed!**



Conclusions Continued

- **Estimated cost = $30 million**
  - Land purchase
  - Demolition
  - Floodplain excavation
  - Utility relocation
  - Bridge construction.
- Recommendation: Optimize combination approach with buy-out of properties in the floodplain

Natural Infrastructure (Nature-based solutions)

Research Question: How can natural Infrastructure mitigate flooding during extreme rainfall events? And what are the cost and benefits environmental & damage reduction?


Reforestation


Wetland restoration


Stream restoration

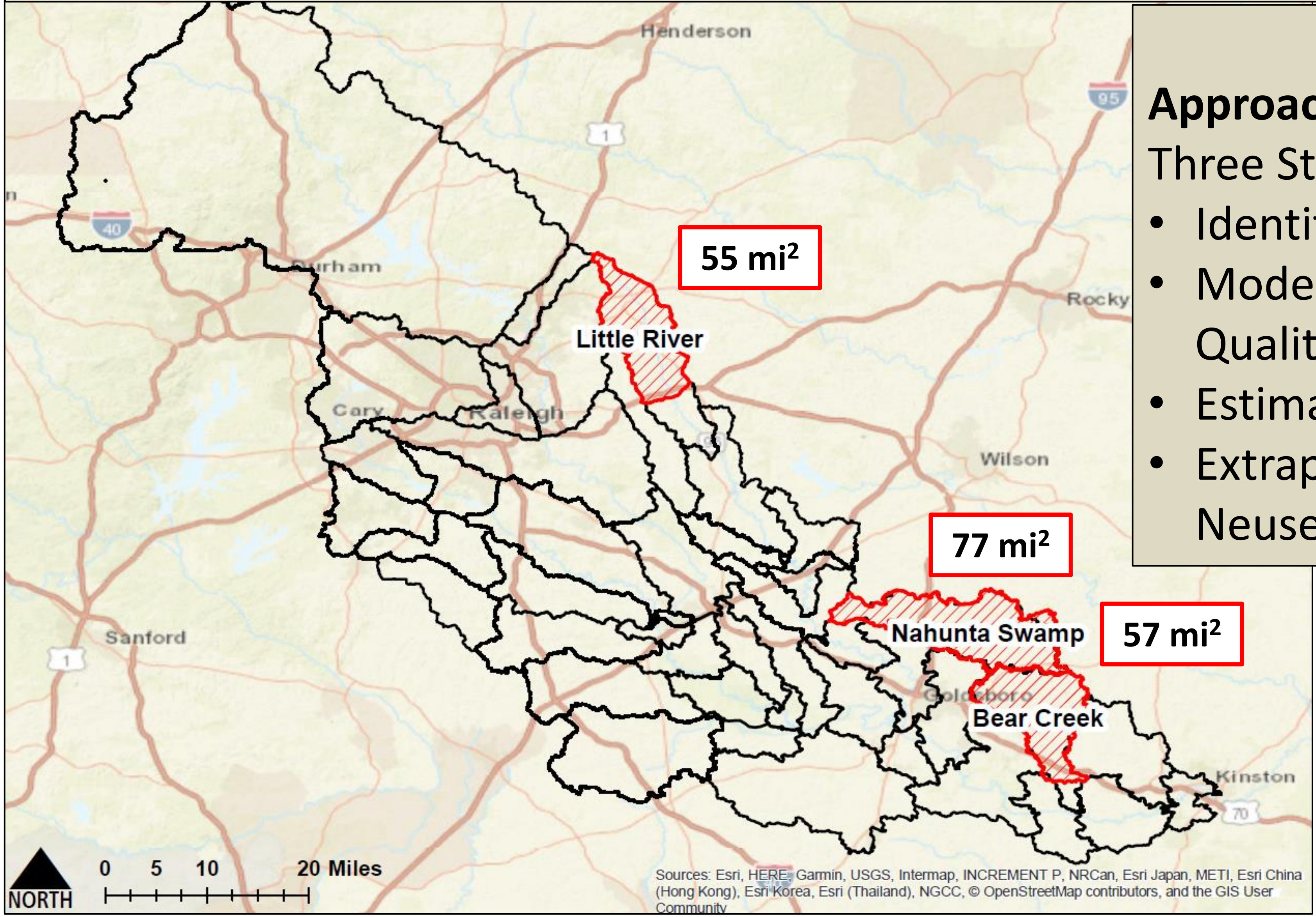

Water Farming

Approach:

1. Identify Opportunity
2. Model watershed hydrology to determine flow reduction
3. Model river hydraulics to estimate the associated flood reduction
4. Model water quality benefit
5. Estimate costs and benefits

Research Question:

How can natural Infrastructure mitigate flooding during extreme rainfall events? And what are the cost and benefits (environmental & damage reduction)?



Neuse Basin Focus:

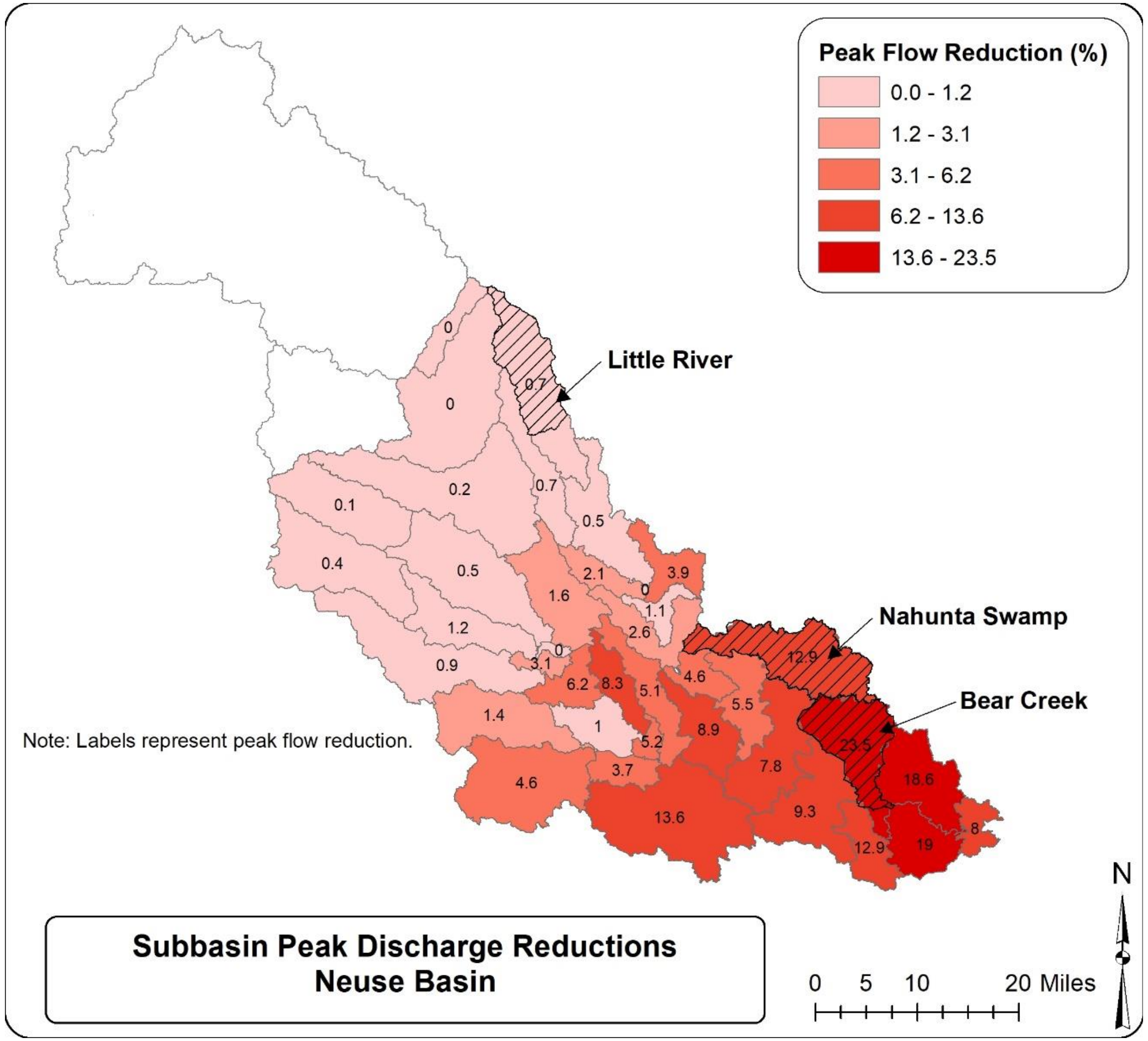
Approach:

Three Study Subbasins (USGS gauges)

- Identified NI Opportunity
- Modeled Hydrology & Water Quality Before & After
- Estimate Reductions
- Extrapolate Results to the Full Neuse Basin

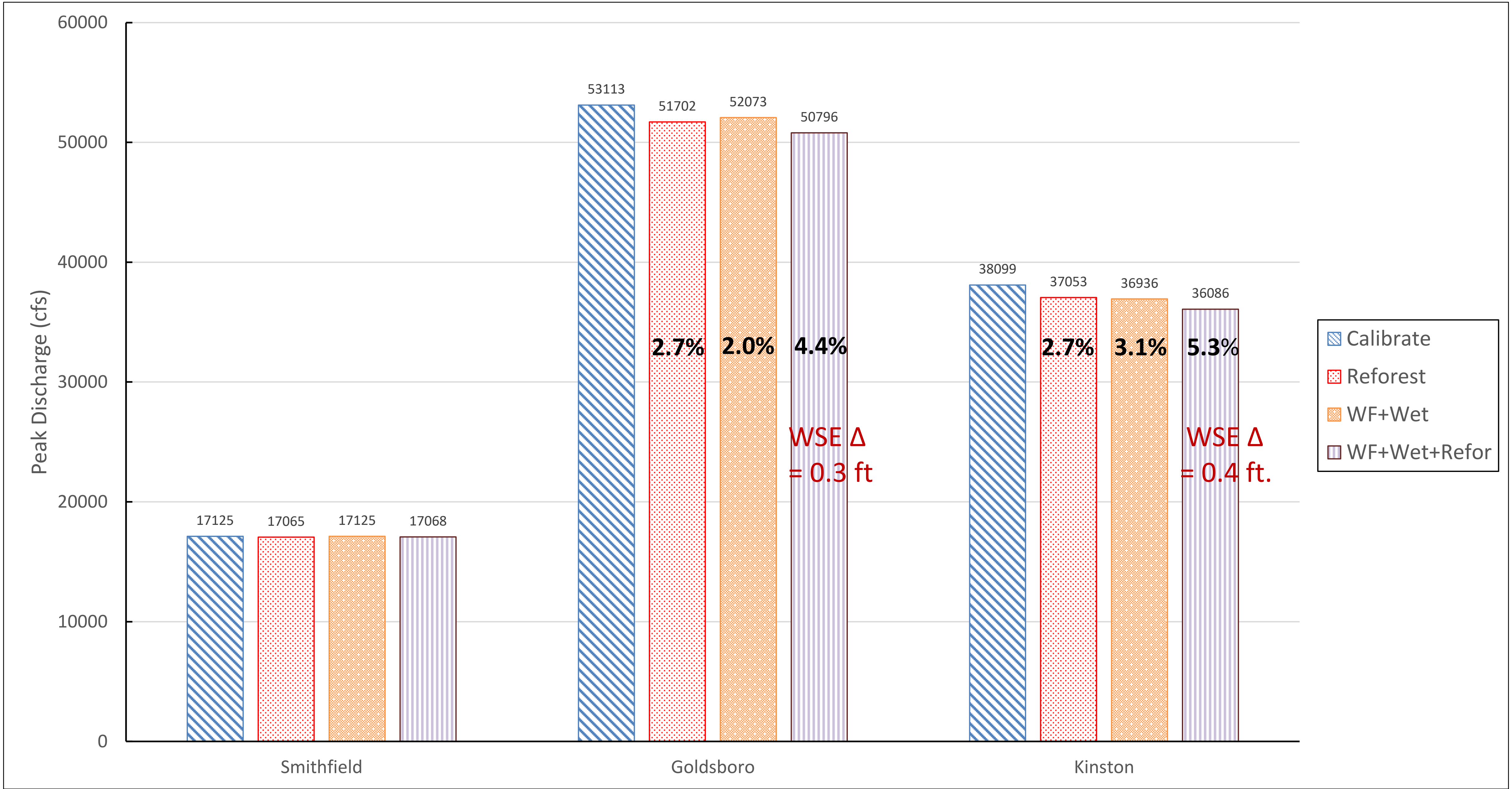
Peak Flow Reductions for the Middle Neuse River Basin Hurricane Matthew

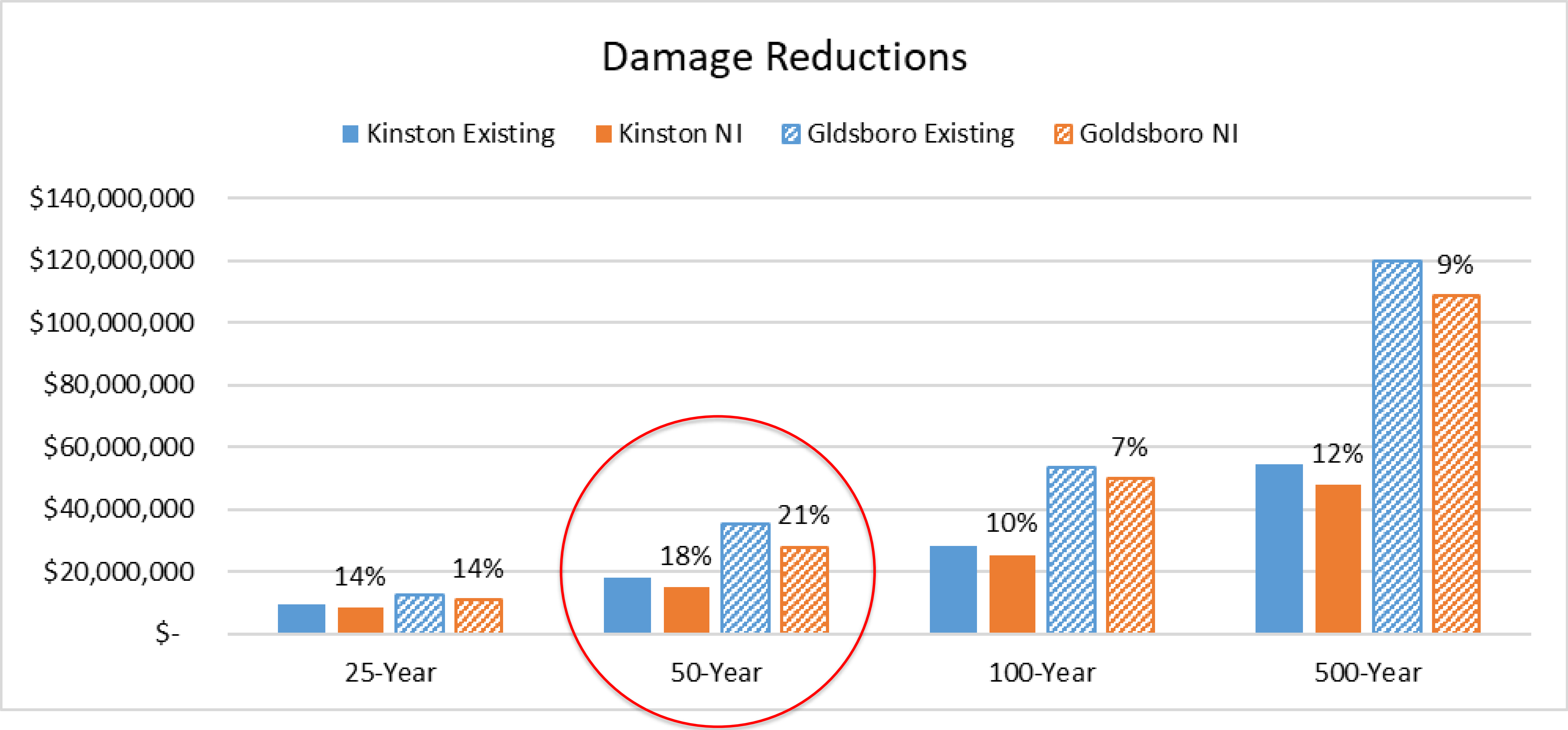
- **<u>Water Farming (WF) + Wetland +Reforestation</u>**



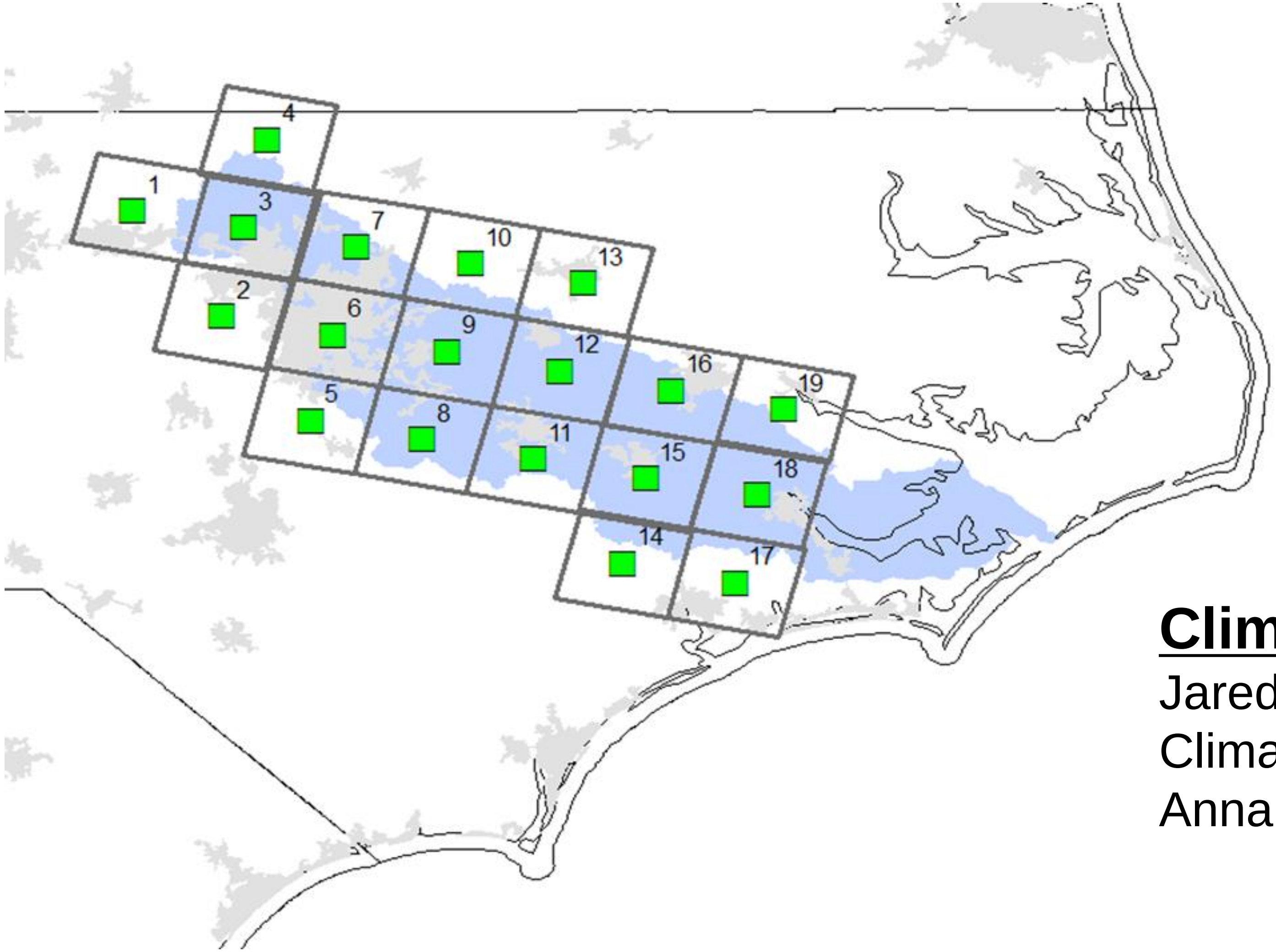
Water Farming -**1.1**%
Wetland – **5.7**%
Reforestation -**8.4**%

Neuse River: Peak Discharge (Hurricane Matthew)




Damage Reductions
Kinston Existing
Kinston NI
Gldsboro Existing
Goldsboro NI
$140,000,000
$120,000,000
$100,000,000
$80,000,000
$60,000,000
$40,000,000
$20,000,000
$-
14%
14%
18%
21%
10%
7%
12%
9%
25-Year
50-Year
100-Year
500-Year

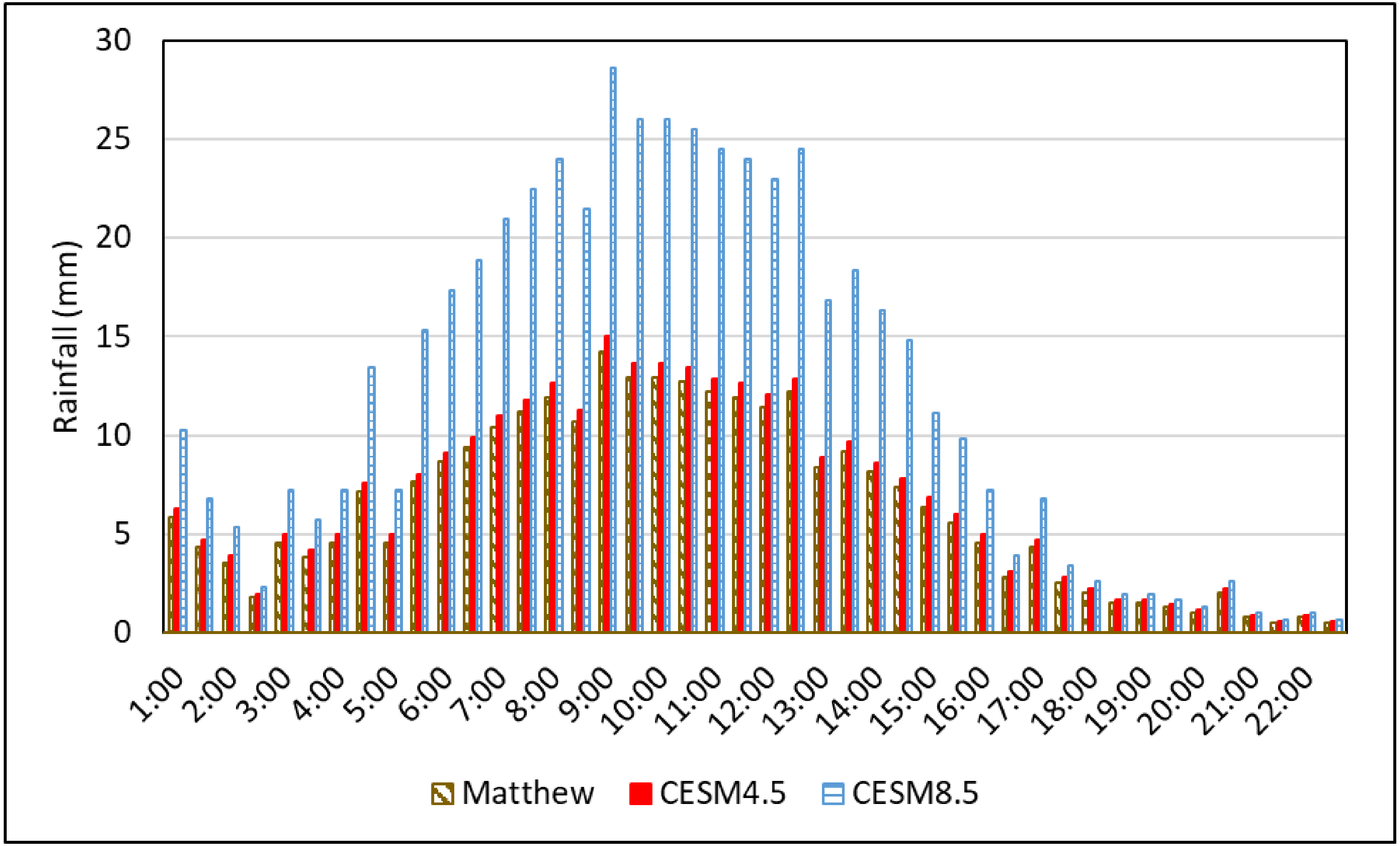
Climate Change – Impact on Extreme Storms



Climate Modeling

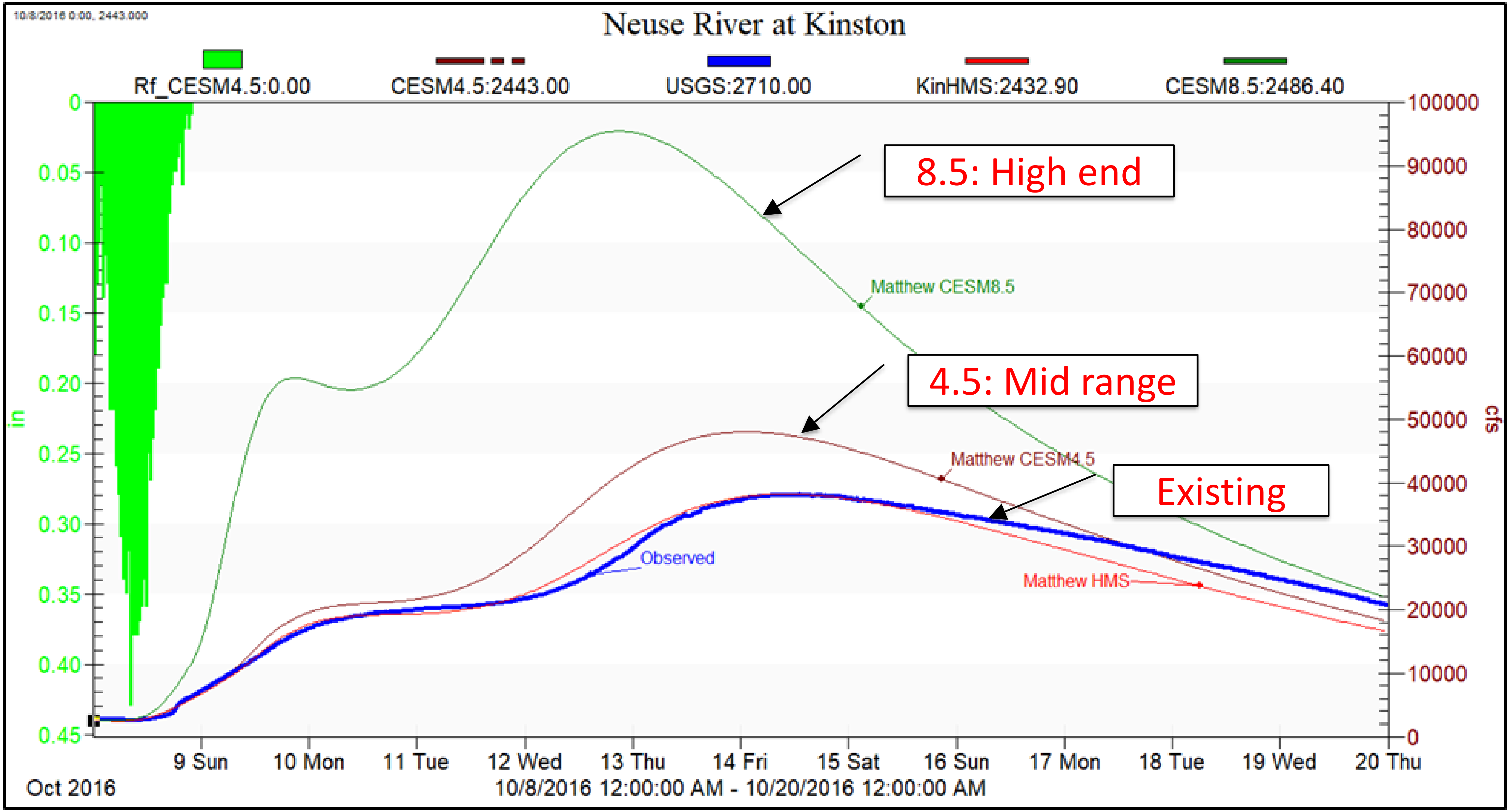
Jared Bowden, NCSU, Southeast Climate Adaptation Science Center
Anna Jalowska, NCSU, EPA

Rainfall Distribution for Hurricane Matthew and Future Storms (Year 2100) for Kinston



CESM 4.5 – Some carbon reduction efforts made

CESM 8.5 – No carbon reduction efforts made (Business as usual)


10/8/2016 0:00, 2443.000
Neuse River at Kinston
Rf_CESM4.5:0.00
CESM4.5:2443.00
USGS:2710.00
KinHMS:2432.90
CESM8.5:2486.40
in
cfs
8.5: High end
4.5: Mid range
Existing
Matthew CESM8.5
Matthew CESM4.5
Observed
Matthew HMS
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9 Sun
10 Mon
11 Tue
12 Wed
13 Thu
14 Fri
15 Sat
16 Sun
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18 Tue
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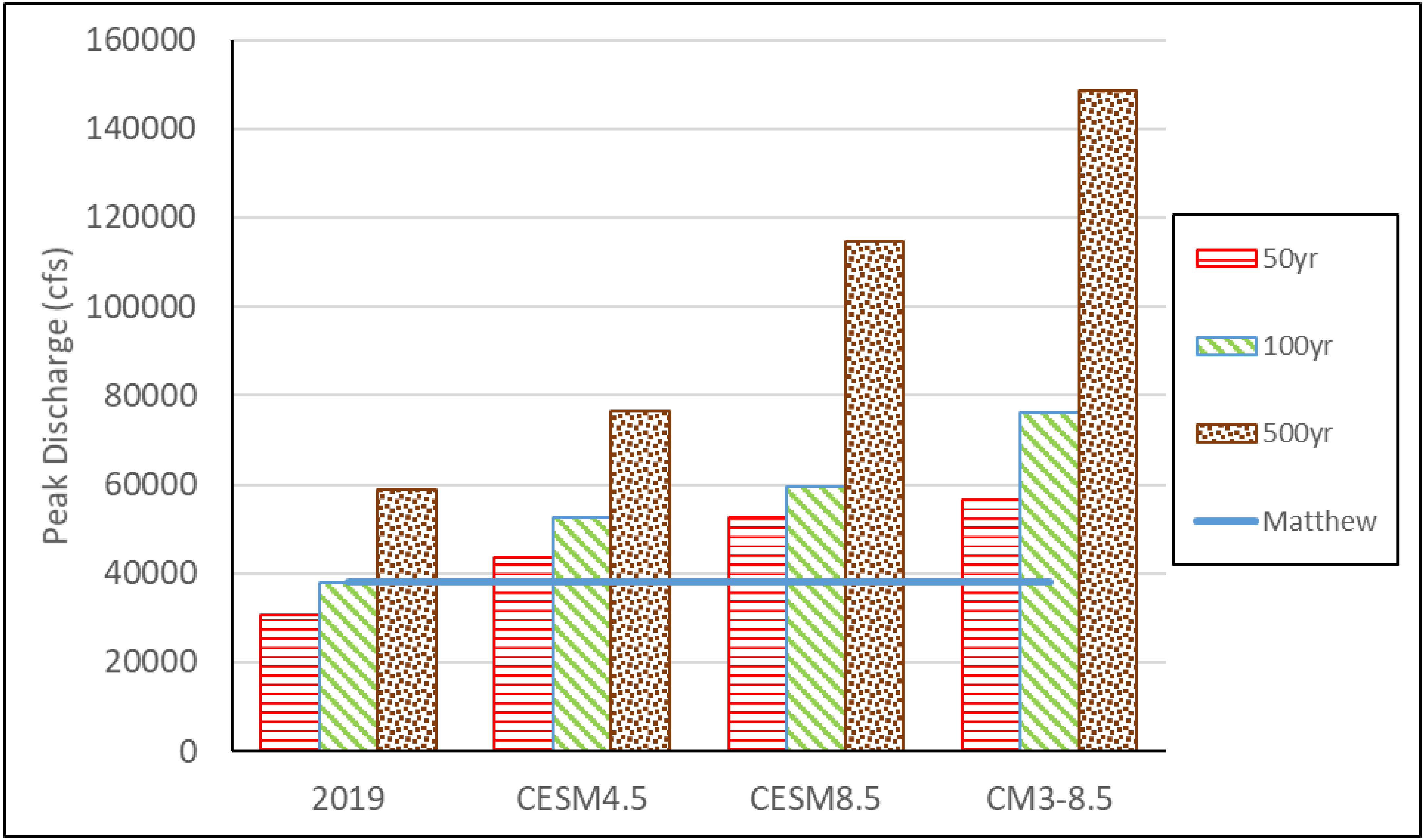
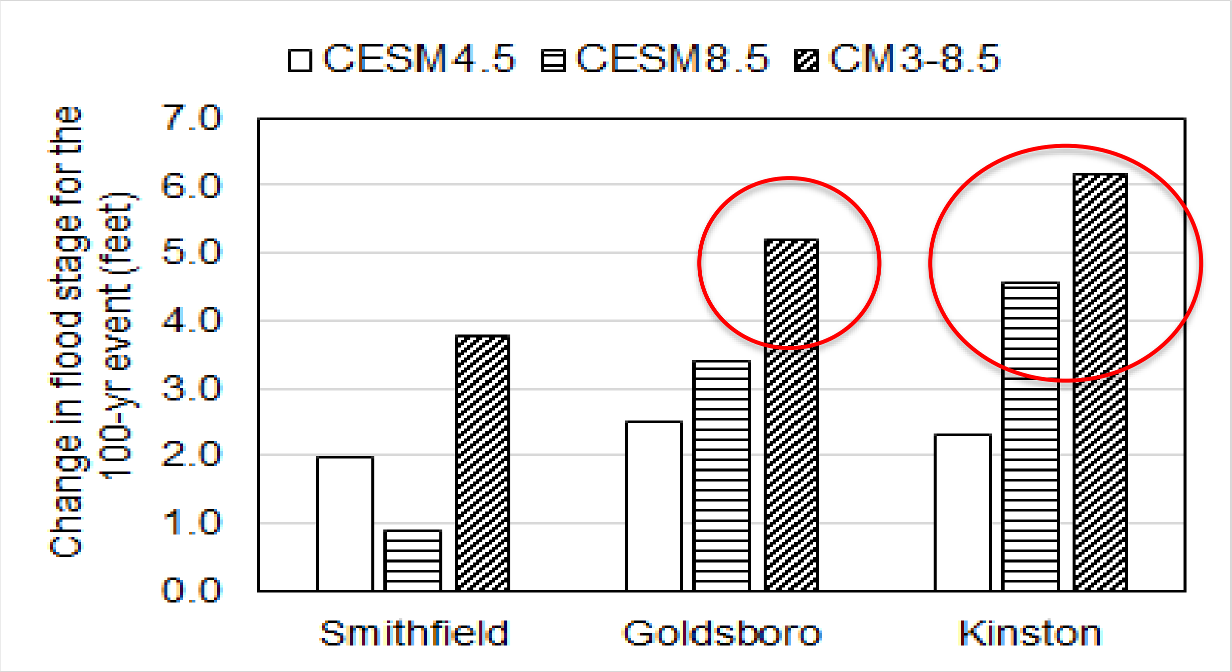
20 Thu
Oct 2016
10/8/2016 12:00:00 AM - 10/20/2016 12:00:00 AM



160000
140000
120000
100000
80000
60000
40000
20000
0
Peak Discharge (cfs)
2019
CESM4.5
CESM8.5
CM3-8.5
50yr
100yr
500yr
Matthew

Estimated Potential Water Surface Elevation Increase 100-Year Storm



****These Values are Not Accurate. The Increase Is Unknown due to Exceeding the Limits of the Model*****

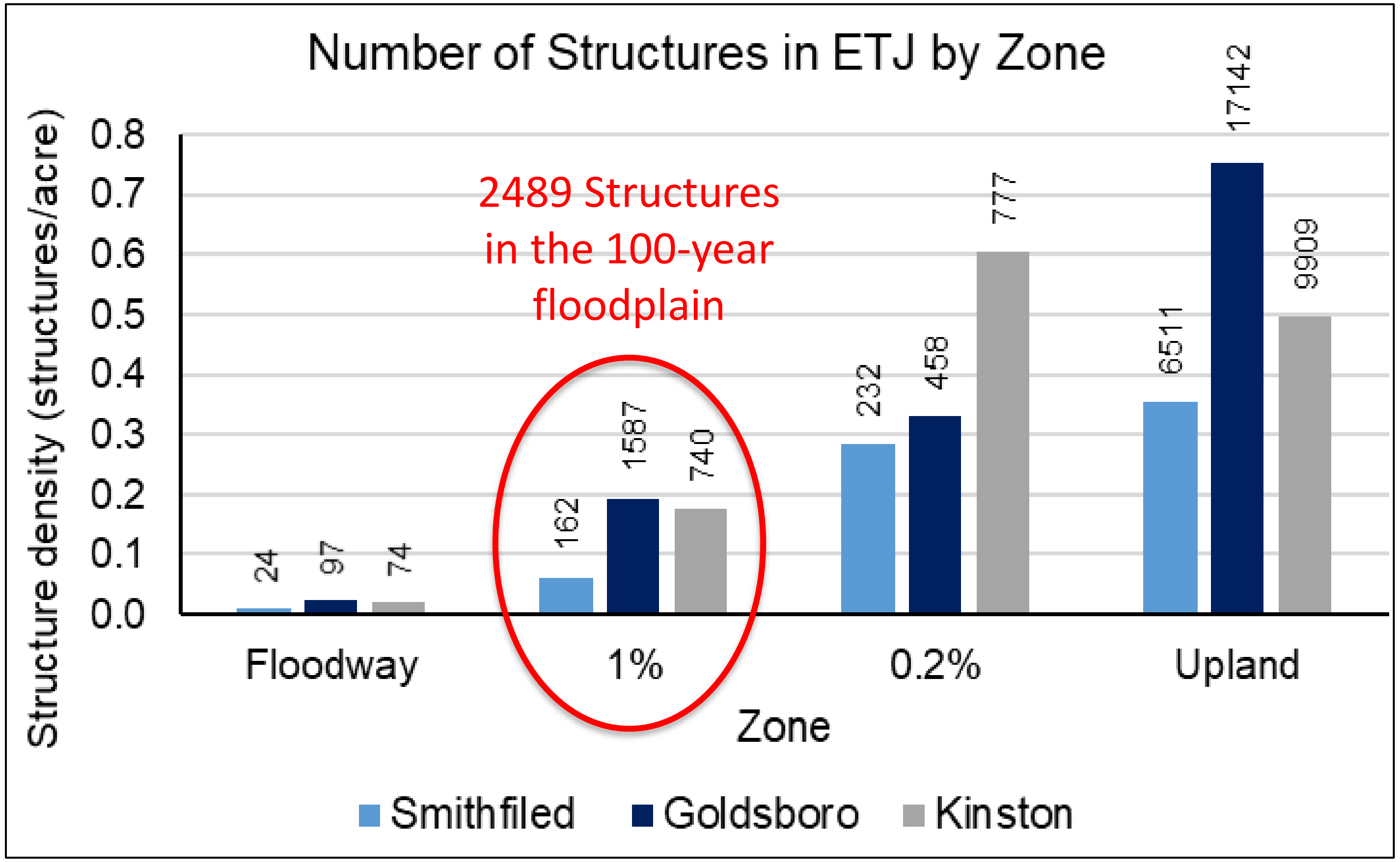
	With Carbon Reduction Efforts	Business as Usual
Community	**Change in 100-yr WSE (feet)**	
Smithfield	+ 2	+1 to + 3.8
Goldsboro	+ 2.4	+ 3.3 to ?
Kinston	+ 2.2	+ 3?

Images Courtesy of Brian Bledsoe, Professor, UGA

100-Year Flood Risk

Time Period (years)	Flood Risks
1	1%
10	9.6%
30	26%
50	39%

Community	Area of Floodplain in ETJ (1% exceedance)	Developed Area (2001)		Developed Area (2016)	
	acres	acres	%	acres	%
Smithfield	5,040	190	4	250	5
Goldsboro	12,300	2670	22	3020	25
Kinston	7,870	1428	18	1525	20

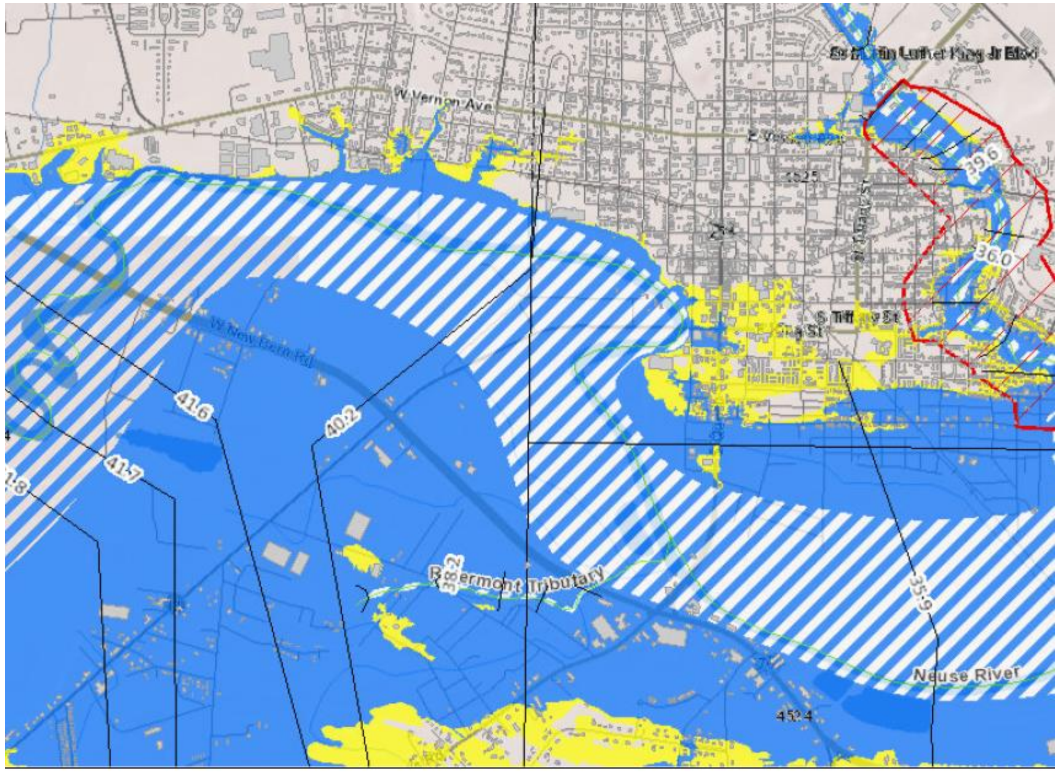


Review of Floodplain Ordinances from 9 NC Communities (UNC-CH)

Conclusion: Municipalities largely use *boilerplate* text (Charlotte-Mecklenburg was the only notable exception)

Recommendations: Cedar Falls, Iowa example

- Define 500-yr floodplain as regulatory floodplain
- Require freeboard *above 500-yr flood elevation* (also adopted by Mexico Beach, FL)
- Prohibit any development or reconstruction in the Floodway
- Further restrict development in 100-yr floodplain
- Compensatory excavation for any fill in floodplain



How can we become more resilient?

(1) absorb stresses and maintain function during future extreme events
(2) adapt, reorganize, and evolve to improve the sustainability of the system

- Remove repetitive loss structures from floodprone areas
- Raise roads, enlarge bridges and improve infrastructure to be more resilient
- Improve early warning and preparedness for future events
- Map the actual flood risk area
- Strengthen floodplain ordinances
- Better communicate flood risks to the public
- Recover floodplains for the river
- Expand natural infrastructure

Aerial photograph of inland flooding caused by Hurricane Floyd. Photographer J. Jordan of the US Army Corps of Engineers

http://go.ncsu.edu/flooding

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N.C. Coastal Rivers Flood Mitigation

On this page:
Major Floods | Transportation Impacts | Future Risks | Improving Resilience | Forecasting and Planning | References

The content below was prepared by J. Jack Kurki-Fox and edited by Barbara Doll, Julie Leibach, and Jonathan Page.

Major storms have exposed glaring vulnerabilities to riverine flooding in many N.C. Coastal Plain communities.

Riverine flooding imperils life, health and livelihoods. It also threatens transportation infrastructure. Road closures and flooding can severely affect the movement of vital goods and services, with crippling effects on local economies and emergency response.