COLLABORATIVE SCIENCE FOR ESTUARIES

WEBINAR SERIES

Rachel Noble

University of North Carolina - Chapel Hill

Whitney Jenkins

North Carolina NERR

Collaborative Research to Manage Stormwater Impacts on Coastal Reserves

National Estuarine
Research Reserve System
Science Collaborative

Date: Tuesday, November 30, 2021
Time: 2:00-3:00 PM ET

National Estuarine Research Reserve System

LIST OF RESERVES

Great Lakes
1. Lake Superior, Wisconsin
2. Old Woman Creek, Ohio

Northeast
3. Wells, Maine
4. Great Bay, New Hampshire
5. Waquoit Bay, Massachusetts
6. Narragansett Bay, Rhode Island

Mid-Atlantic
7. Hudson River, New York
8. Jacques Cousteau, New Jersey
9. Delaware
10. Chesapeake Bay, Maryland
11. Chesapeake Bay, Virginia

Southeast
12. North Carolina
13. North Inlet-Winyah Bay, South Carolina
14. ACE Basin, South Carolina
15. Sapelo Island, Georgia
16. Guana Tolomato Matanzas, Florida

Gulf of Mexico
17. Rookery Bay, Florida
18. Apalachicola, Florida
19. Weeks Bay, Alabama
20. Grand Bay, Mississippi
21. Mission-Aransas, Texas

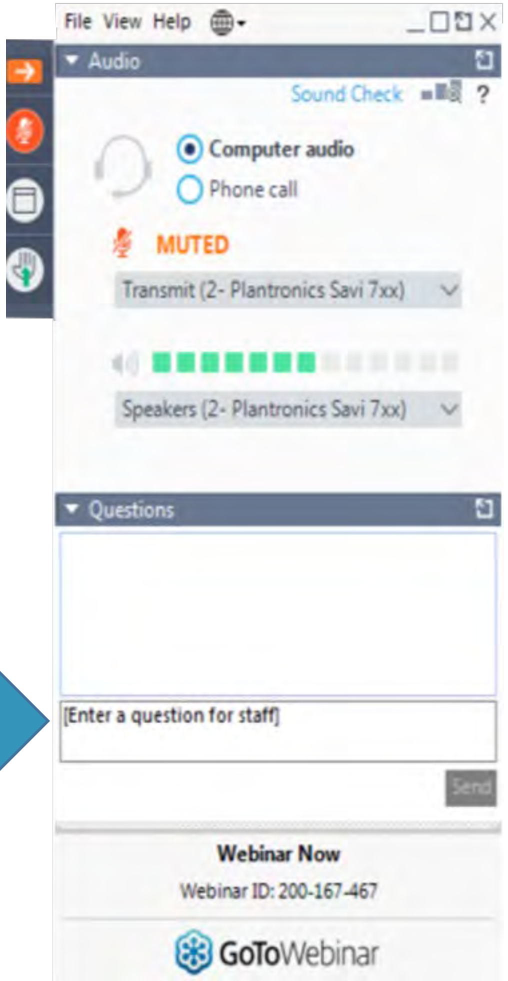
West
22. Tijuana River, California
23. Elkhorn Slough, California
24. San Francisco Bay, California
25. South Slough, Oregon
26. Padilla Bay, Washington
27. Kachemak Bay, Alaska

Pacific
28. He'eia, Hawai'i

Caribbean
29. Jobos Bay, Puerto Rico

Have a question?

Use the “Questions” function to pose questions throughout the webinar.



National Estuarine
Research Reserve System
Science Collaborative

National Estuarine
Research Reserve System
Science Collaborative

Presenters

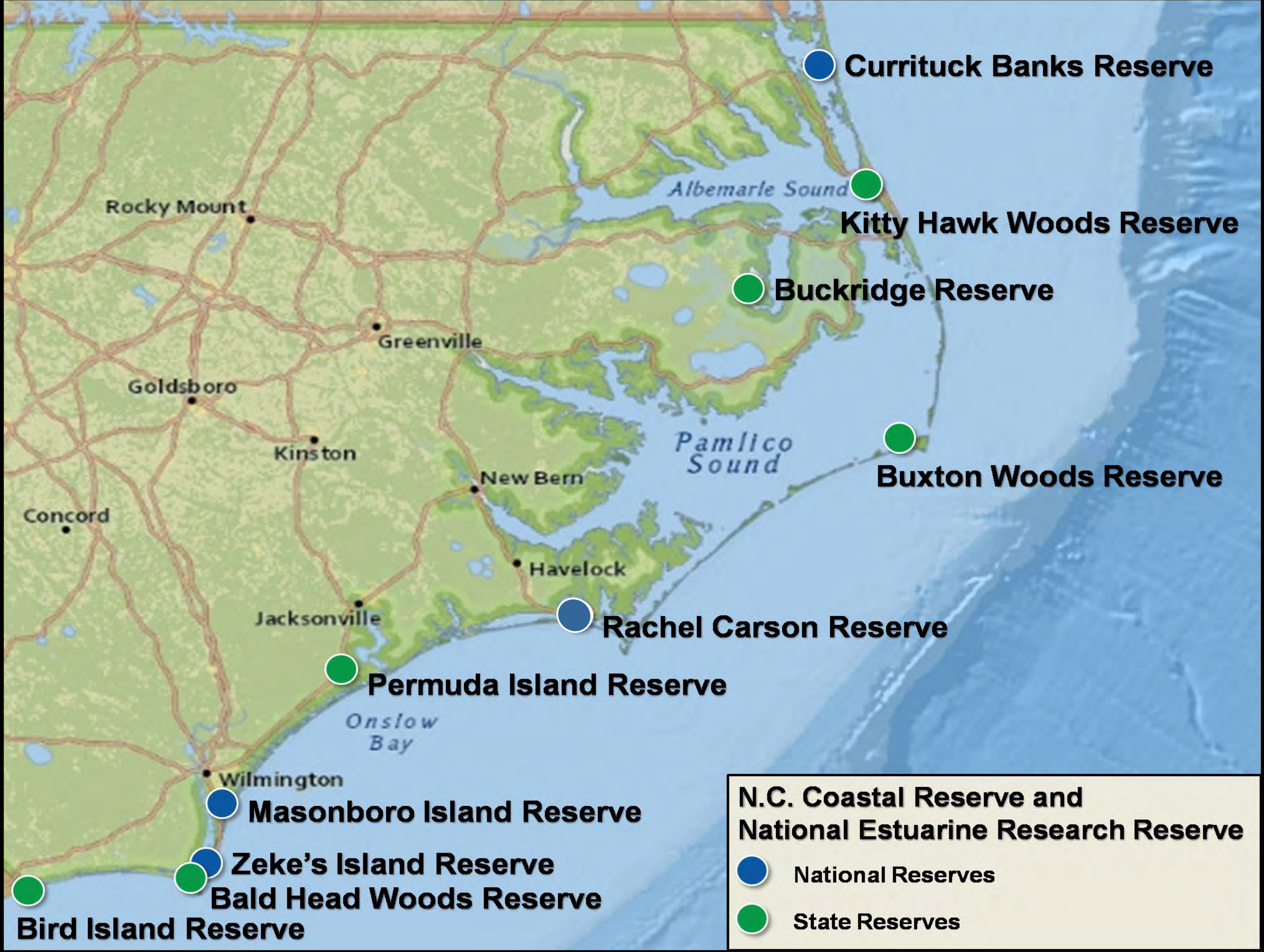
Rachel Noble
University of North Carolina

Whitney Jenkins
North Carolina NERR

NORTH CAROLINA
COASTAL RESERVE &
NATIONAL ESTUARINE
RESEARCH RESERVE

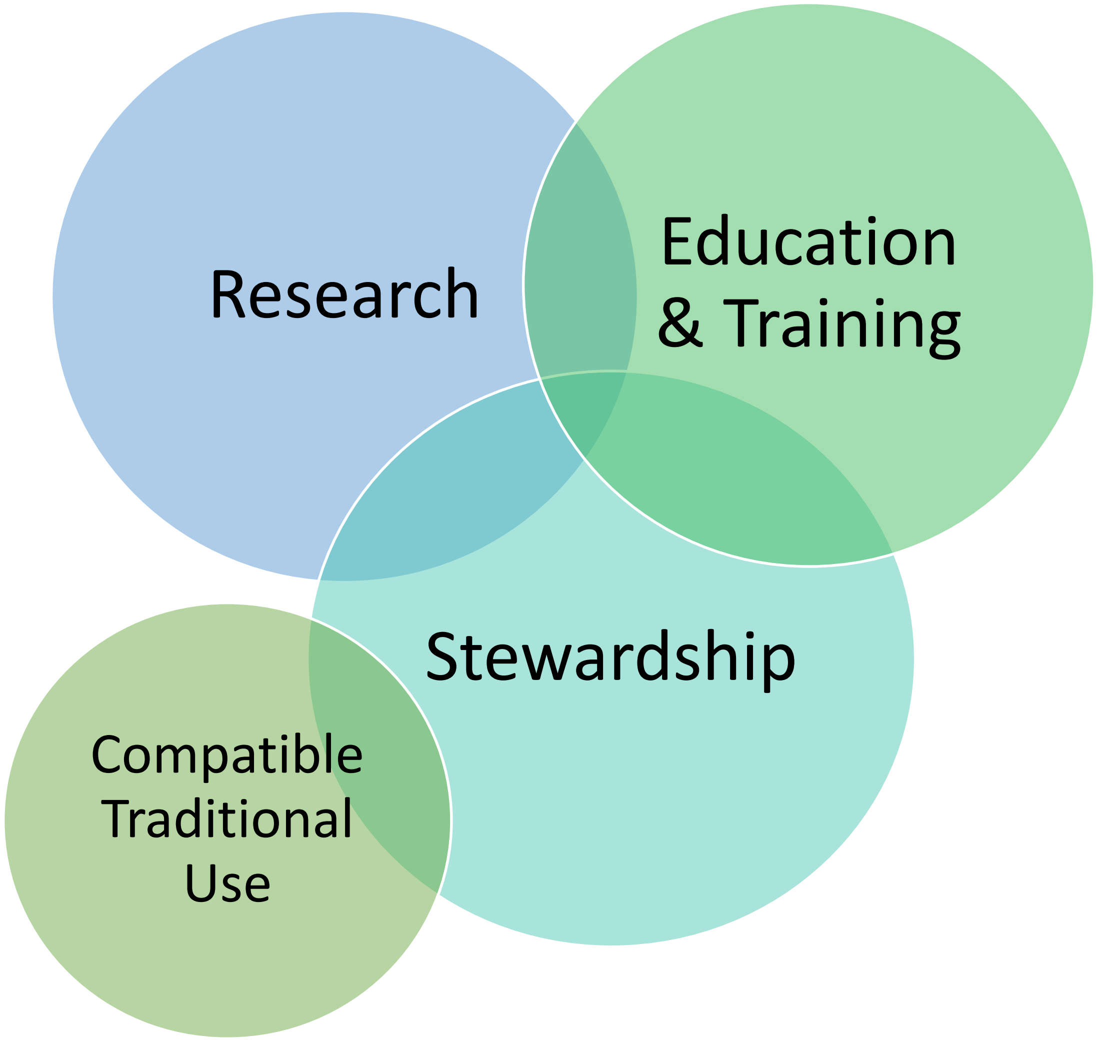
North Carolina Coastal Reserve

North Carolina
National Estuarine Research Reserve

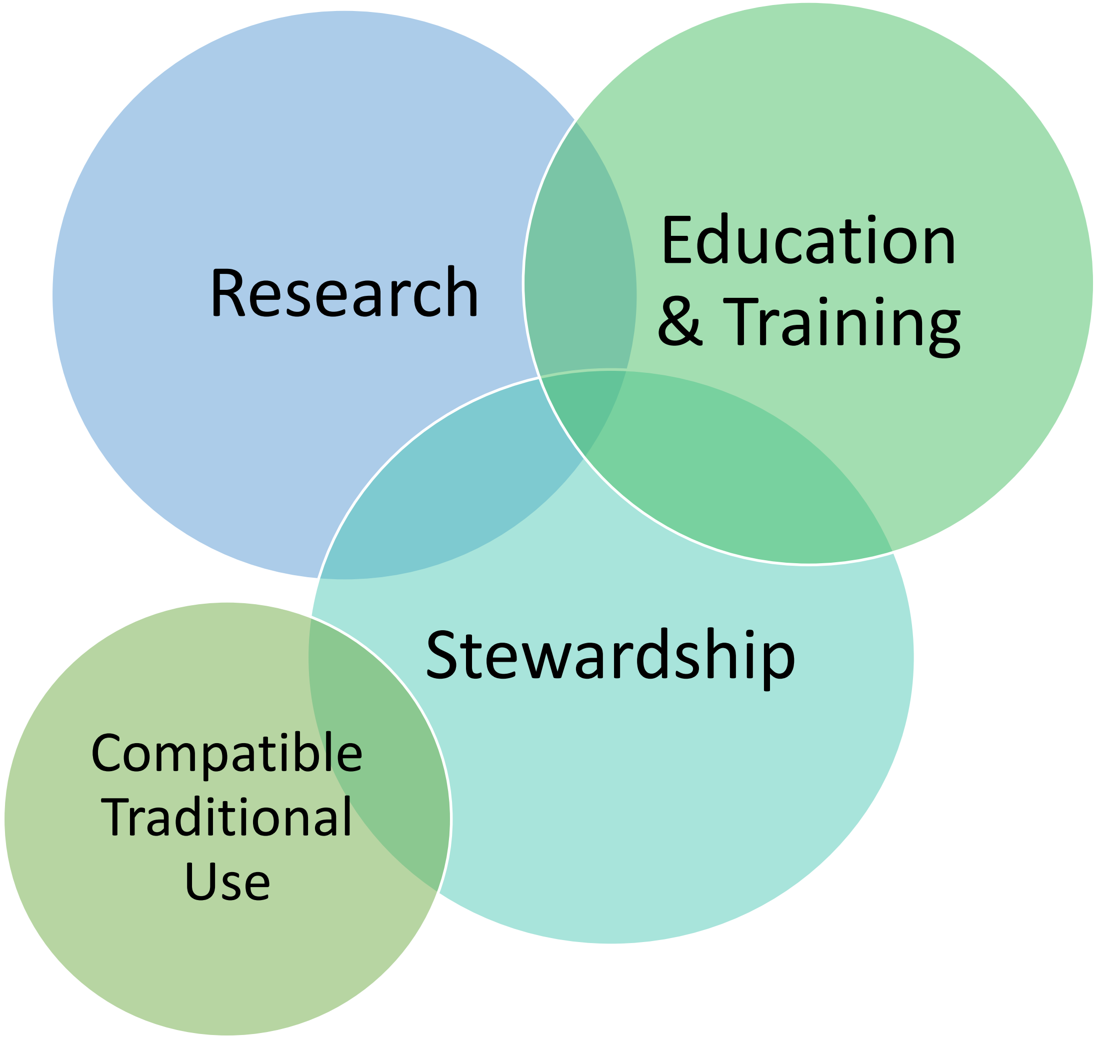

Currituck Banks Reserve
Albemarle Sound
Kitty Hawk Woods Reserve
Rocky Mount
Buckridge Reserve
Greenville
Goldsboro
Pamlico Sound
Buxton Woods Reserve
Kinston
New Bern
Concord
Havelock
Jacksonville
Rachel Carson Reserve
Permuda Island Reserve
Onslow Bay
Wilmington
Masonboro Island Reserve
Zeke's Island Reserve
Bald Head Woods Reserve
Bird Island Reserve
N.C. Coastal Reserve and
National Estuarine Research Reserve
National Reserves
State Reserves

Mission

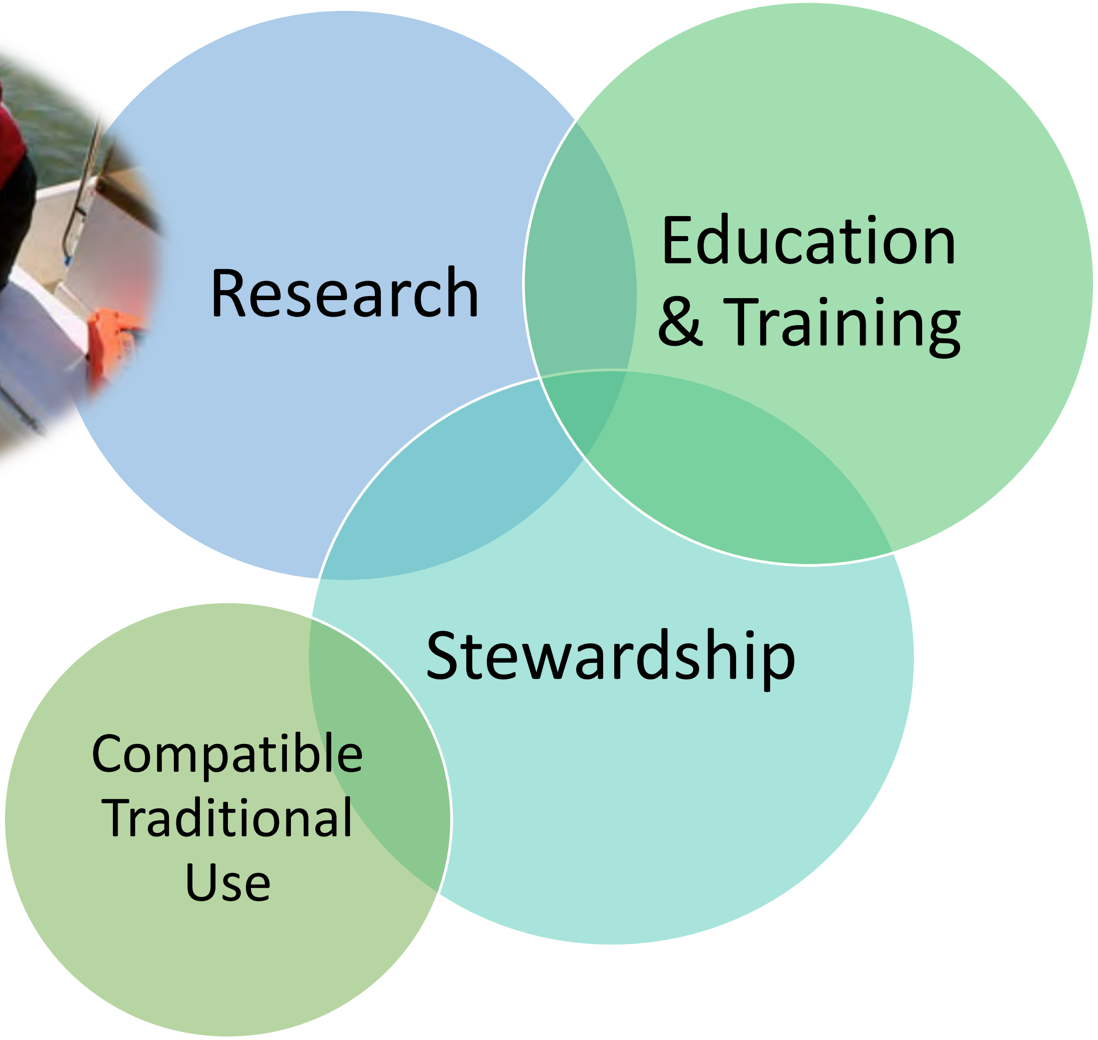
To practice and promote stewardship of coasts and estuaries through innovative research, education, and training using a place-based system of protected areas.



Stormwater Impacts?



Stormwater Impacts?



Stormwater Impacts?

Research

Education & Training

Stewardship

Compatible Traditional Use

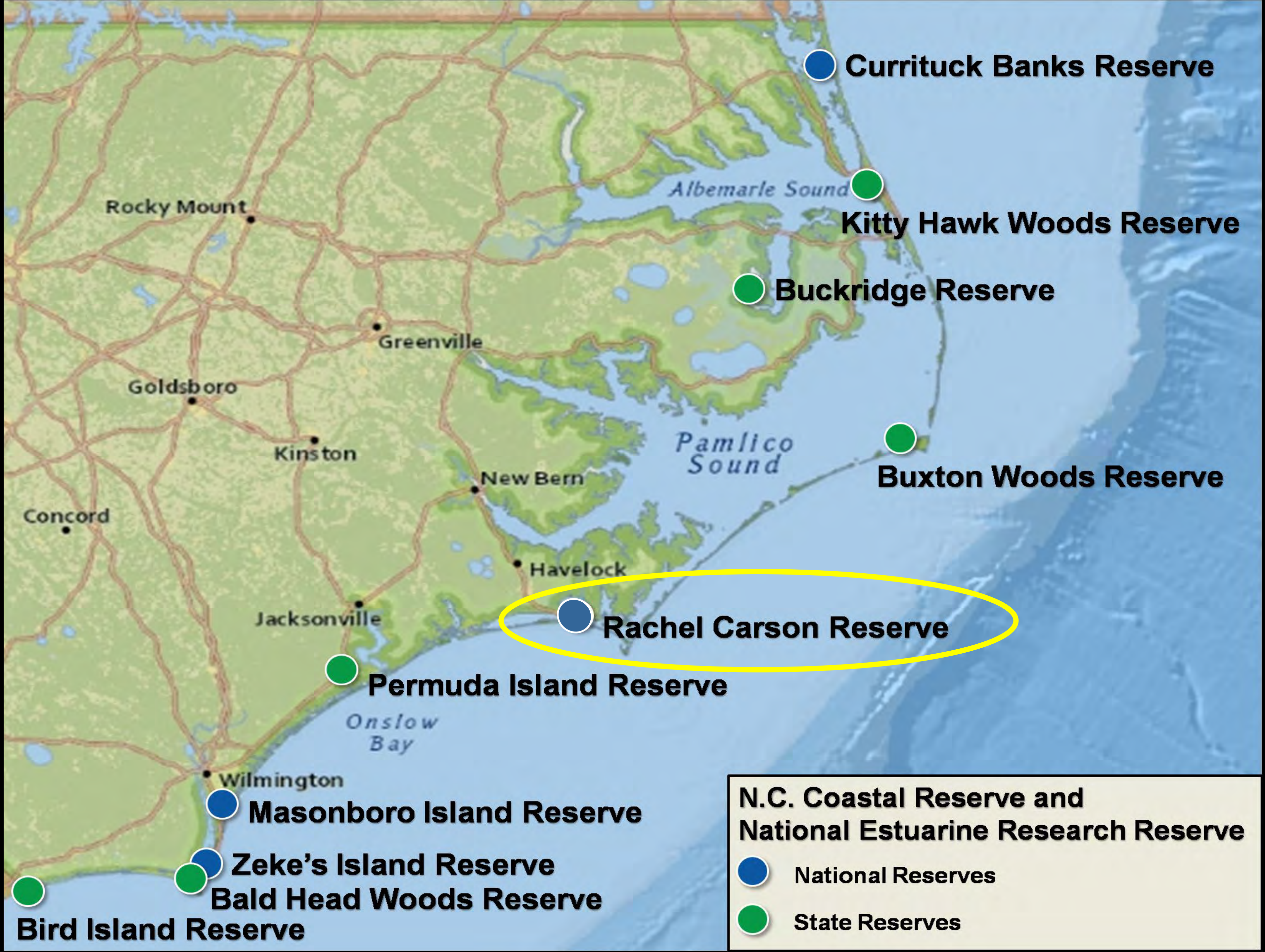
Stormwater Impacts?

Research

Education & Training

Stewardship

Compatible Traditional Use


Currituck Banks Reserve
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N.C. Coastal Reserve and
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National Reserves
State Reserves


Town of Beaufort
Taylor's Creek
Cape Lookout National Seashore
Rachel Carson Reserve
N

Collaborative Research to Manage Stormwater Impacts on Coastal Reserves

Rachel T. Noble and Whitney Jenkins

On behalf of the NERRS Science Collaborative Team

Collaborative Science for Estuaries Series

30 November 2021

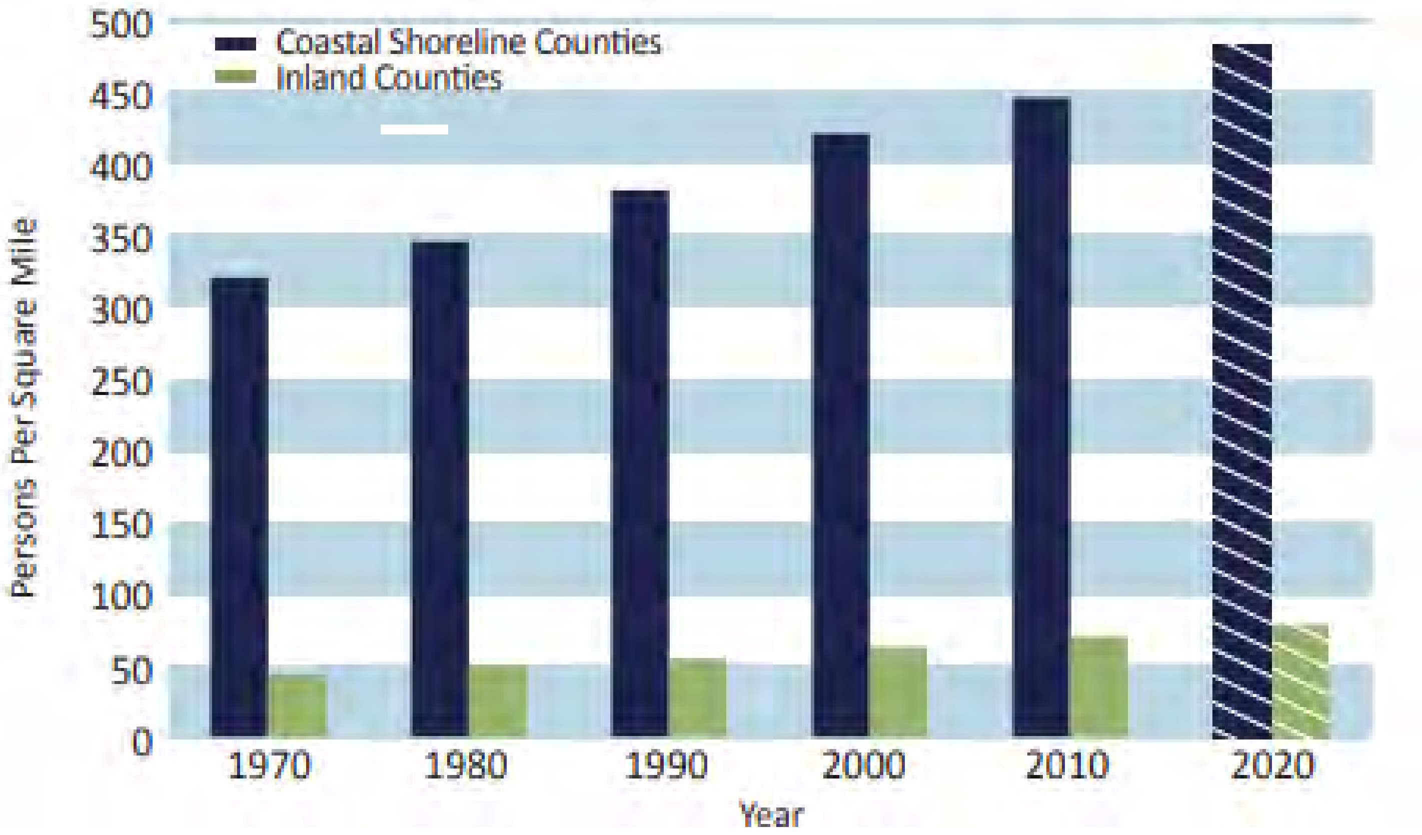
Outline

- The need for a collaborative approach
- Stormwater/wastewater research outcomes
- Innovation
- Community learning
- Collaboration
- Final thoughts

Collaborative Approach

- Municipalities in NC are faced with multiple stressors and needs
- Coastal reserves are intertwined with their local governments, managers, and visitors
- Stormwater and wastewater lend themselves necessarily to collaborative science, research, engineering, management, education, outreach, learning from the past….
- Coastal infrastructure is feeling an unprecedented squeeze

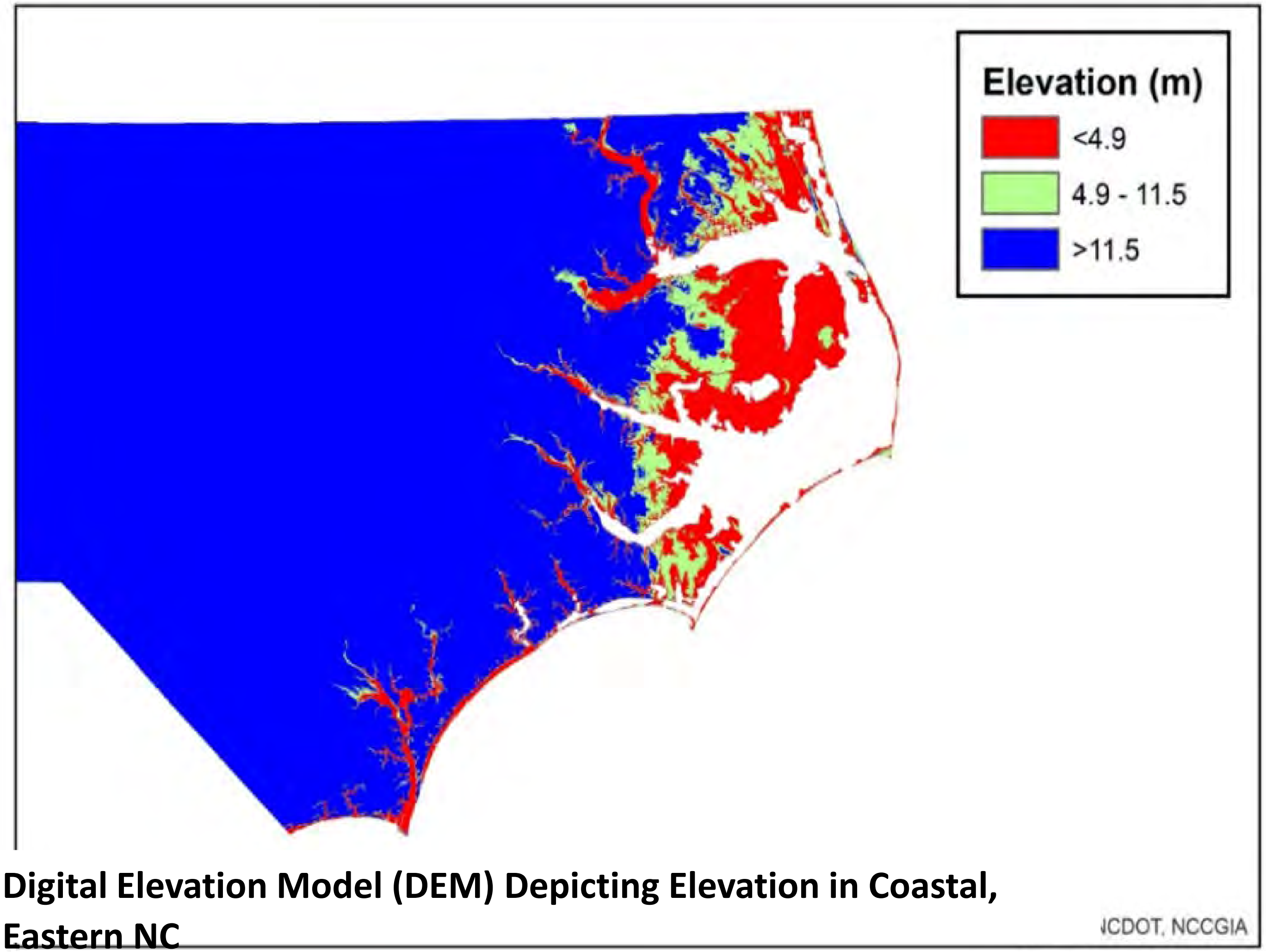
Scope of the Problem



(NOAA, 2013)

- Urbanization in coastal watersheds (Freeman et al., 2019)
- Aging infrastructure with increasing demand (ASCE, 2017)
- More frequent and intense storm events (Knutson et al., 2020)

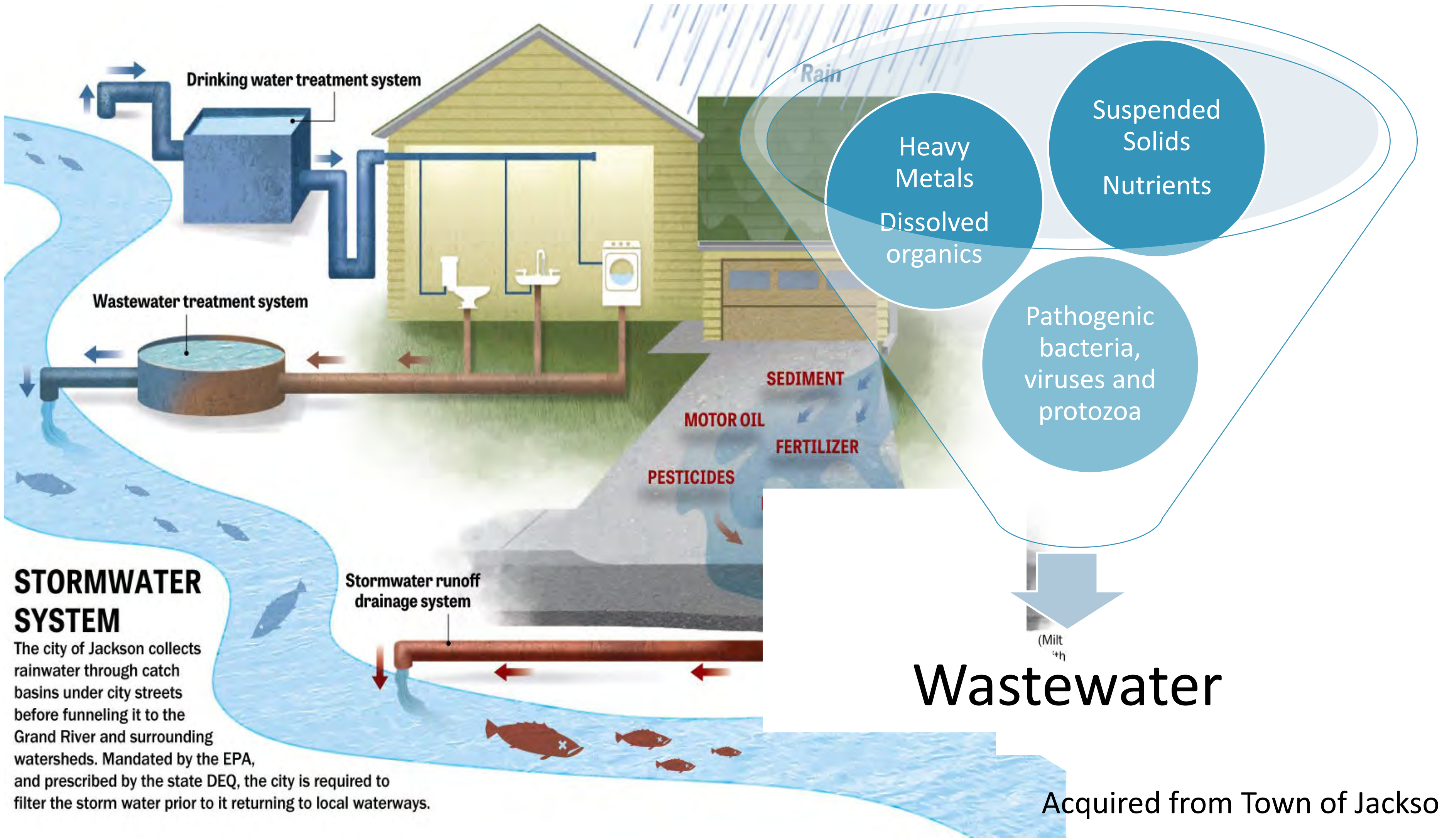
NC Coastal Plain



Digital Elevation Model (DEM) Depicting Elevation in Coastal, Eastern NC

- NC 3rd largest low-lying region in the US (Poulter et al., 2009)
- Sea level up 0.28 meters higher than in 1950 (SeaLevelRise.org, 2020)
- Coastal region expected to grow 26% within decade (NC Office of State Budget and Management, 2015)

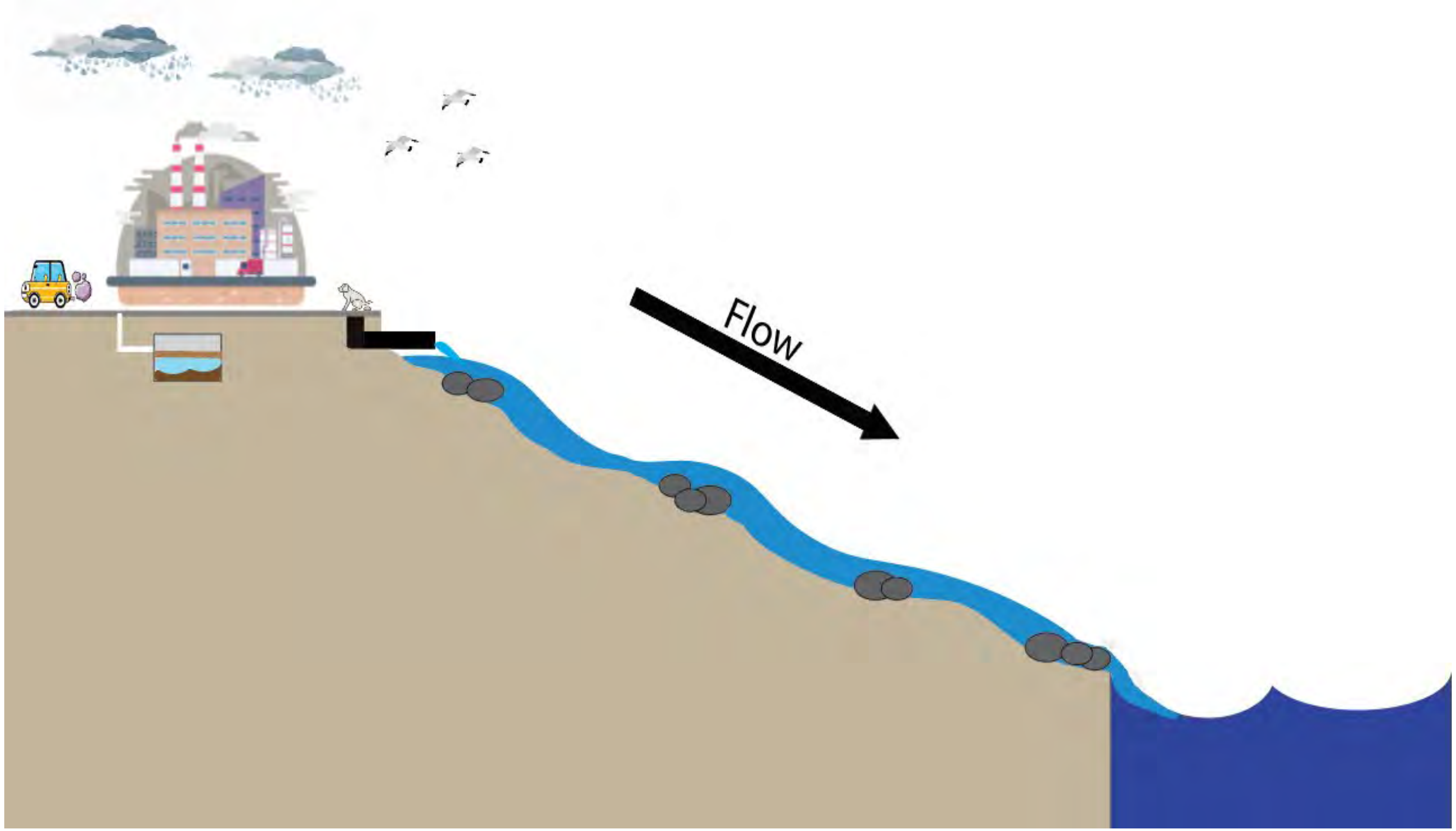
Wastewater vs. Stormwater



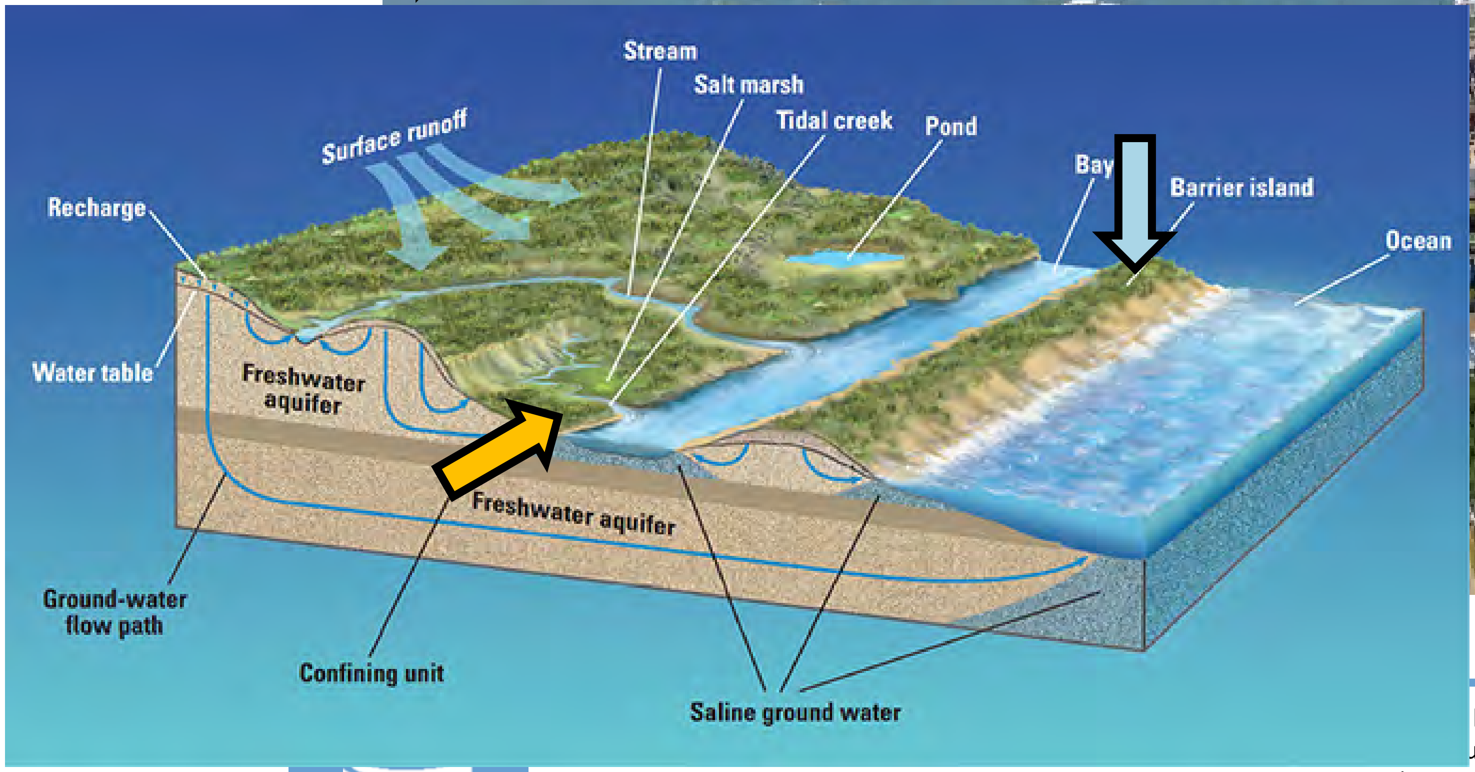
Acquired from Town of Jackson, MI website

Public Health & Economic Significance

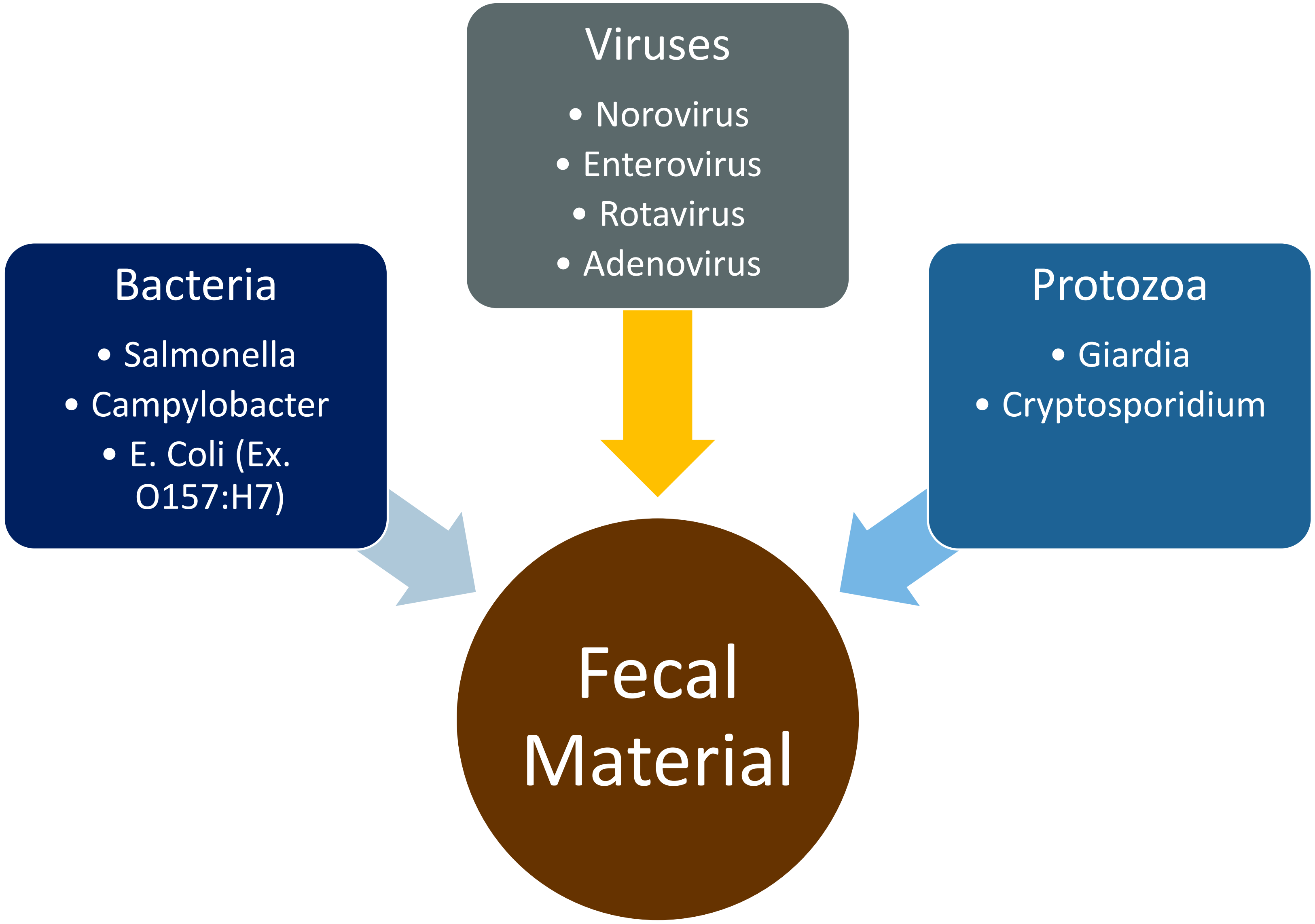
- Exposure linked with adverse health effects
  - Increased incidence of gastrointestinal illness (Arnold et al., 2017)
- Estimated annual economic burden of $2.9 billion (DeFlorio-Barker et al., 2018)
- USEPA Regulatory Framework



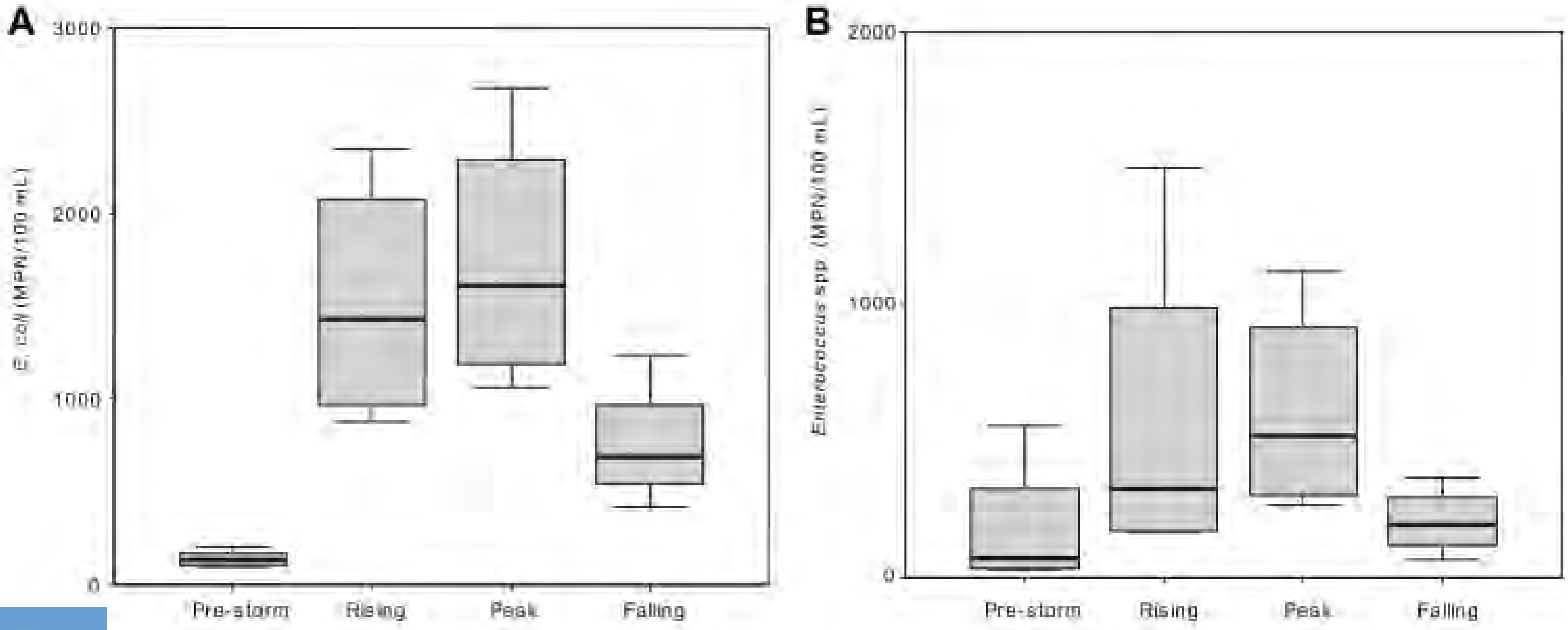
(Adapted from Palmer et al., 2014)



http://www.theshellcottage.com/images/bncn.jpg
urce: http://cdn.foresternetwork.com/wp-content/uploads/we1606_40_687.jpg


Viruses
• Norovirus
• Enterovirus
• Rotavirus
• Adenovirus
Bacteria
• Salmonella
• Campylobacter
• E. Coli (Ex. O157:H7)
Protozoa
• Giardia
• Cryptosporidium
Fecal Material

Stormwater Contamination: Concentration and Loading



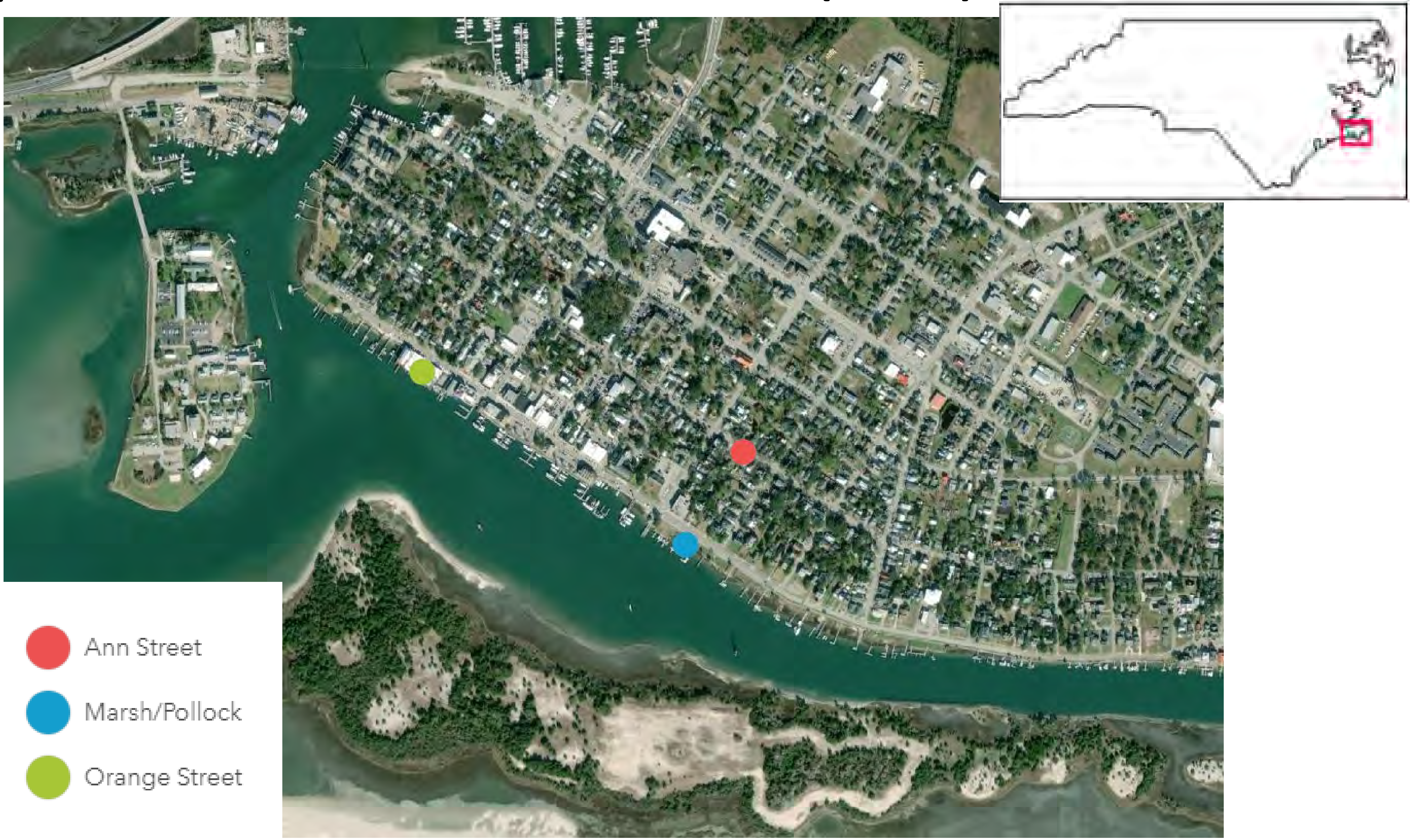
Integrating Culture and Molecular Quantification of Microbial Contaminants into a Predictive Modeling Framework in a Low-Lying, Tidally-Influenced Coastal Watershed

M Price, AD Blackwood, RT Noble, 2021

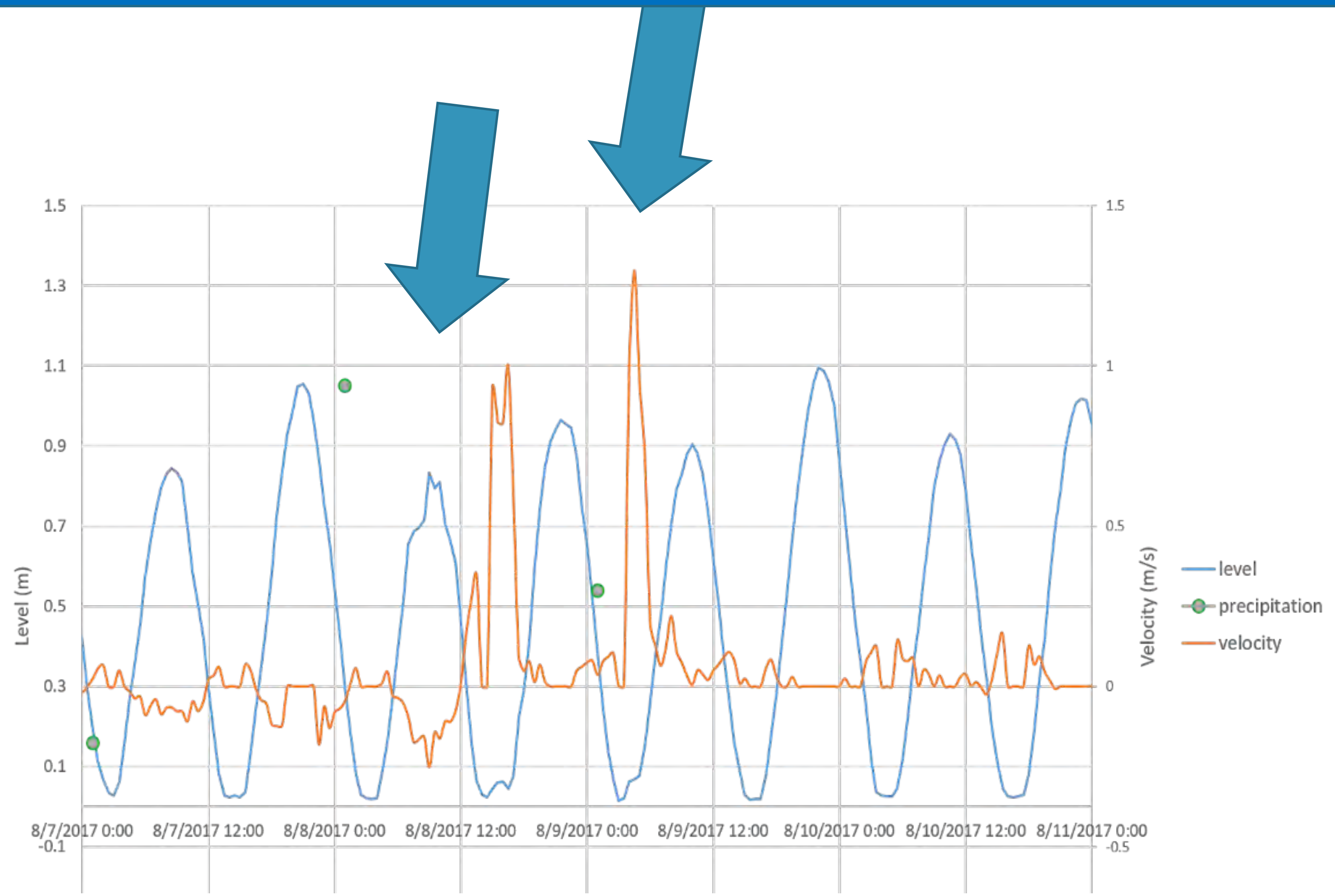
Previous Research

- Stormwater dynamics in coastal NC vary (Hart et al., 2020)
  - Hydrological and meteorological factors vary on a local scale (Ex. regional weather patterns)
- Low-lying coastal terrain with minimal topographic slope (NOAA, 2020)
- Semi-diurnal tides with moderate range (King Tides, 2020)
- Predictive models have been generated that are valuable tools for managing recreational and shellfish harvesting water quality (e.g. Gonzalez et al. 2014)
- Proximity to Rachel Carson Reserve (RCR)
  - Within NC Coastal and National Estuarine Research Reserve Systems (NC NERRS)

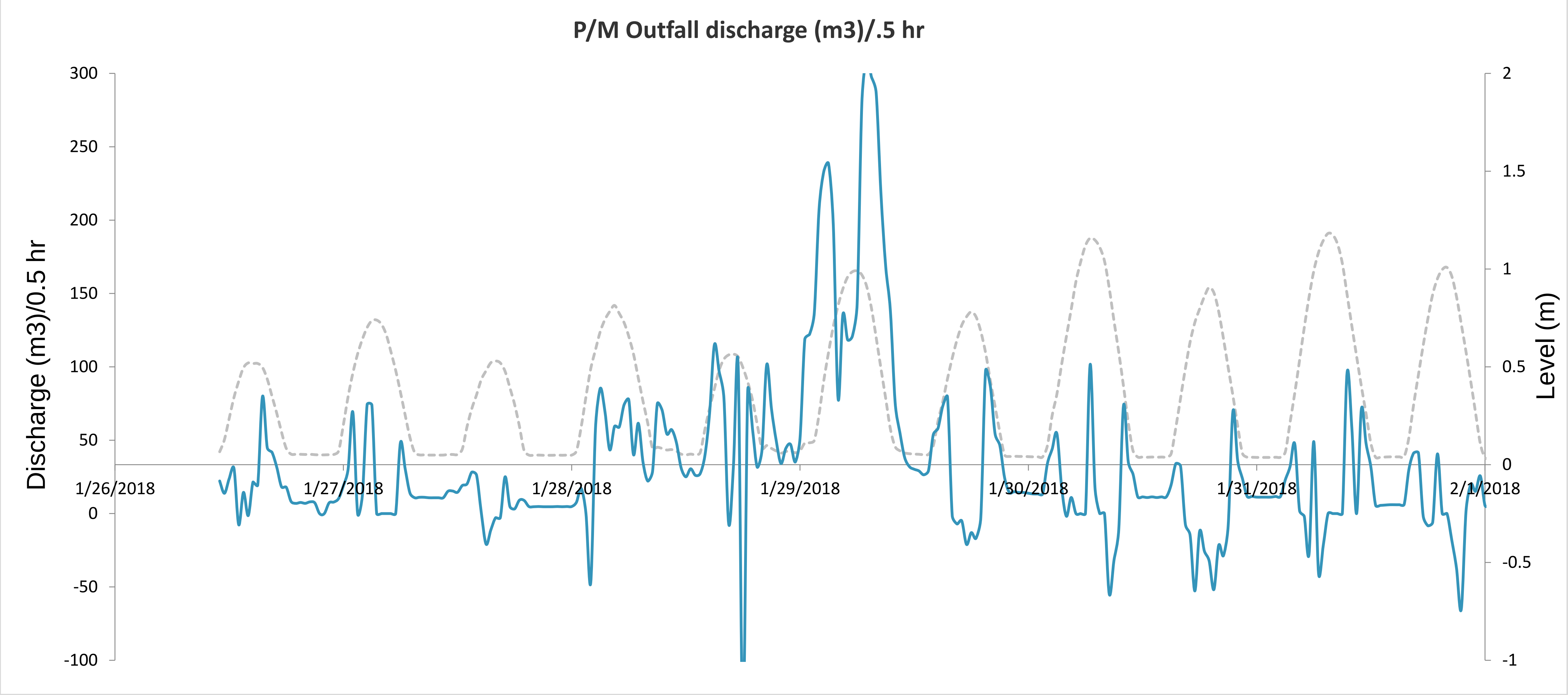
Study Site: Town of Beaufort (ToB), NC



In a Perfect World

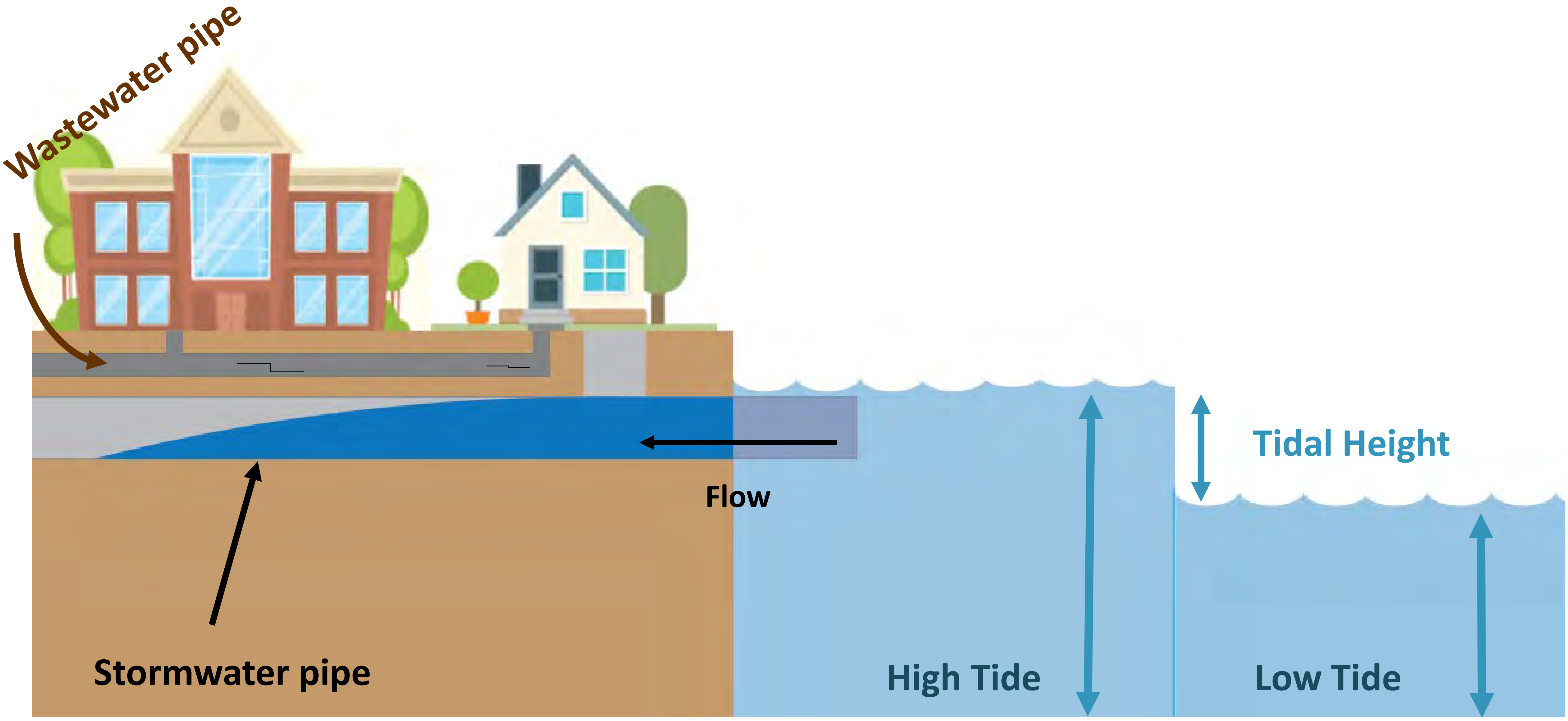


In Reality



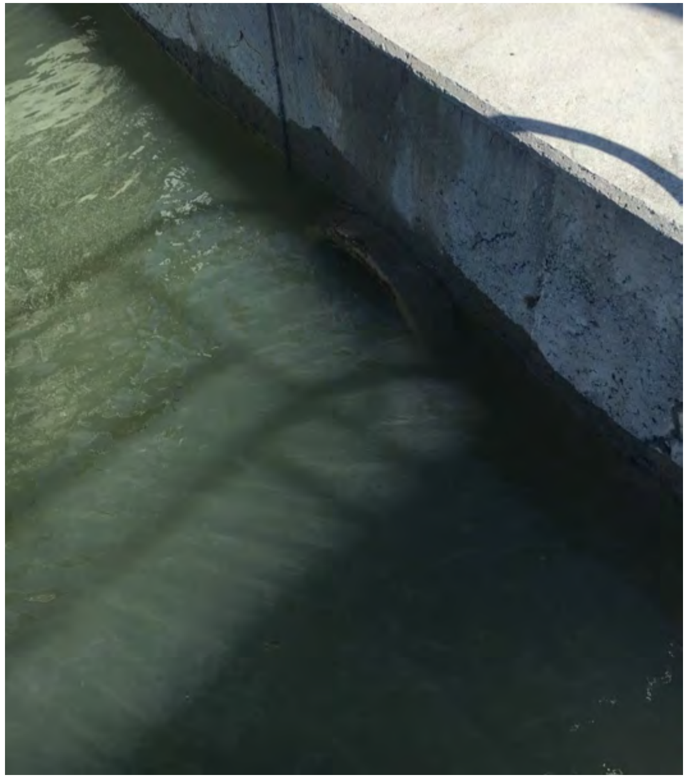
P/M Outfall discharge (m3)/.5 hr
Discharge (m3)/0.5 hr
Level (m)
300
250
200
150
100
50
0
-50
-100
2
1.5
1
0.5
0
-0.5
-1
1/26/2018
1/27/2018
1/28/2018
1/29/2018
1/30/2018
1/31/2018
2/1/2018

Schematic of NC Coastal Towns



Methods

- Samples were collected during both storm (>0.25 in) and ambient conditions from July 2017 to June 2018.
- Classified into tidal categories by distance of sample collection from nearest high tide.
    - Inundated (<2 h), Transition (2-4 h) and Receding (>4 h)

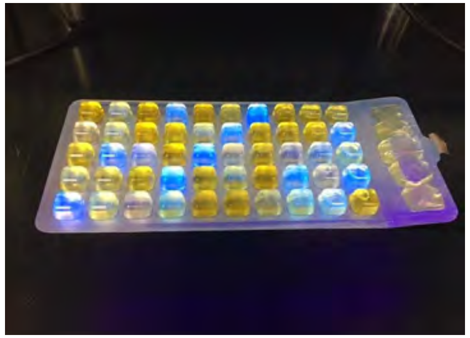


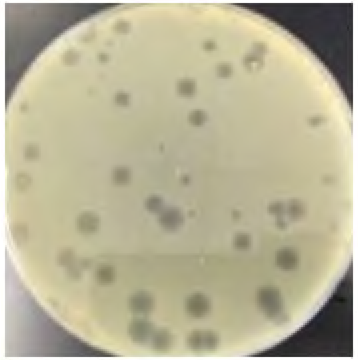
Indicator

Method

Fecal Indicator Bacteria (FIB)

- Enterococcus
- E. Coli
- Fecal Indicator Virus (FIV)
  - Male-specific
  - Somatic



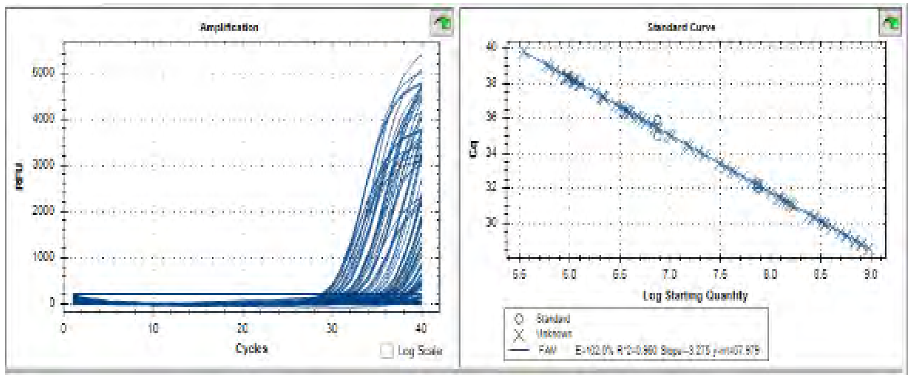


Culture-Based

- IDEXX Colilert-18®
- IDEXX Enterolert®
- EPA Method 1642

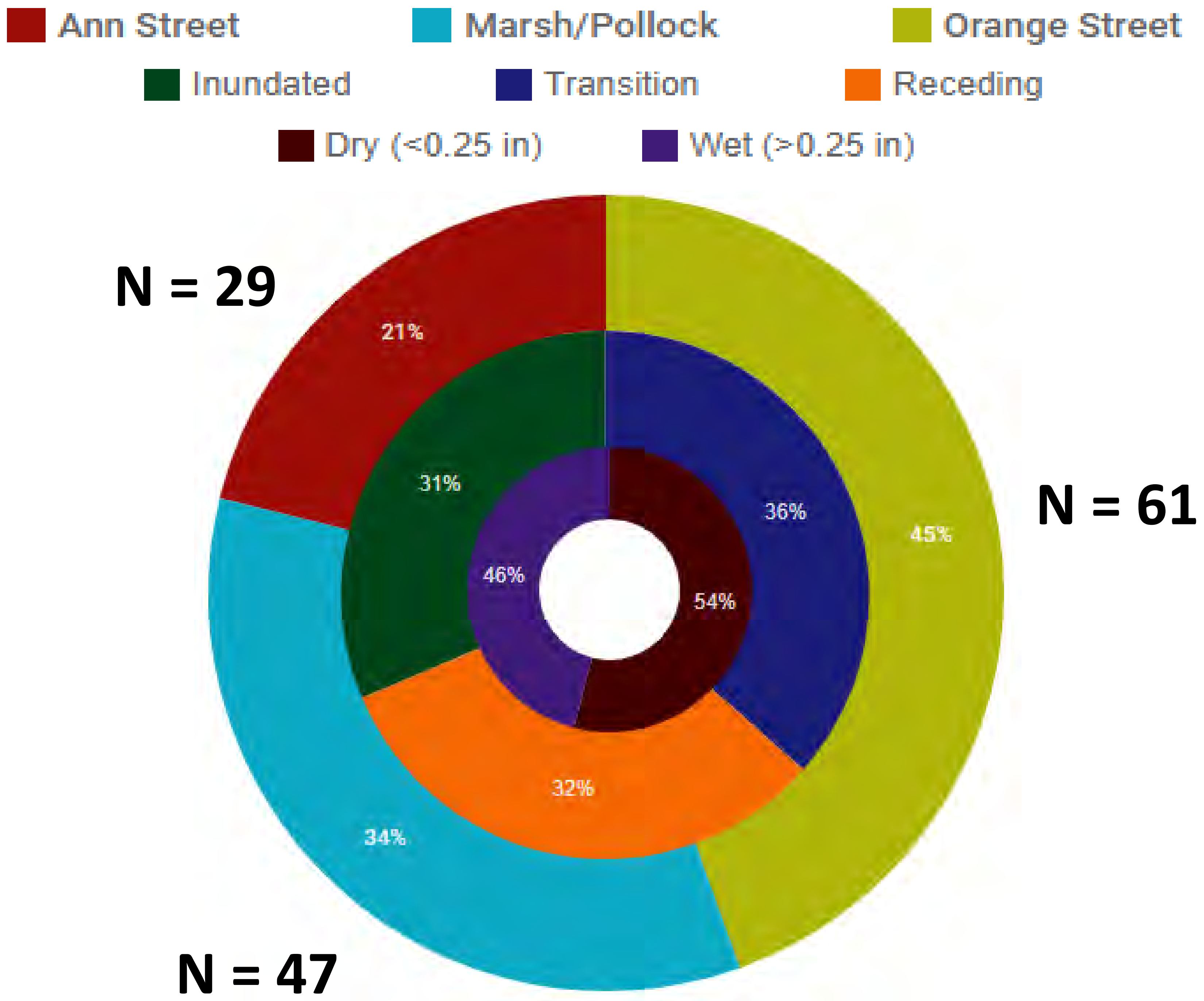
Microbial Source Tracking Markers

- HF183



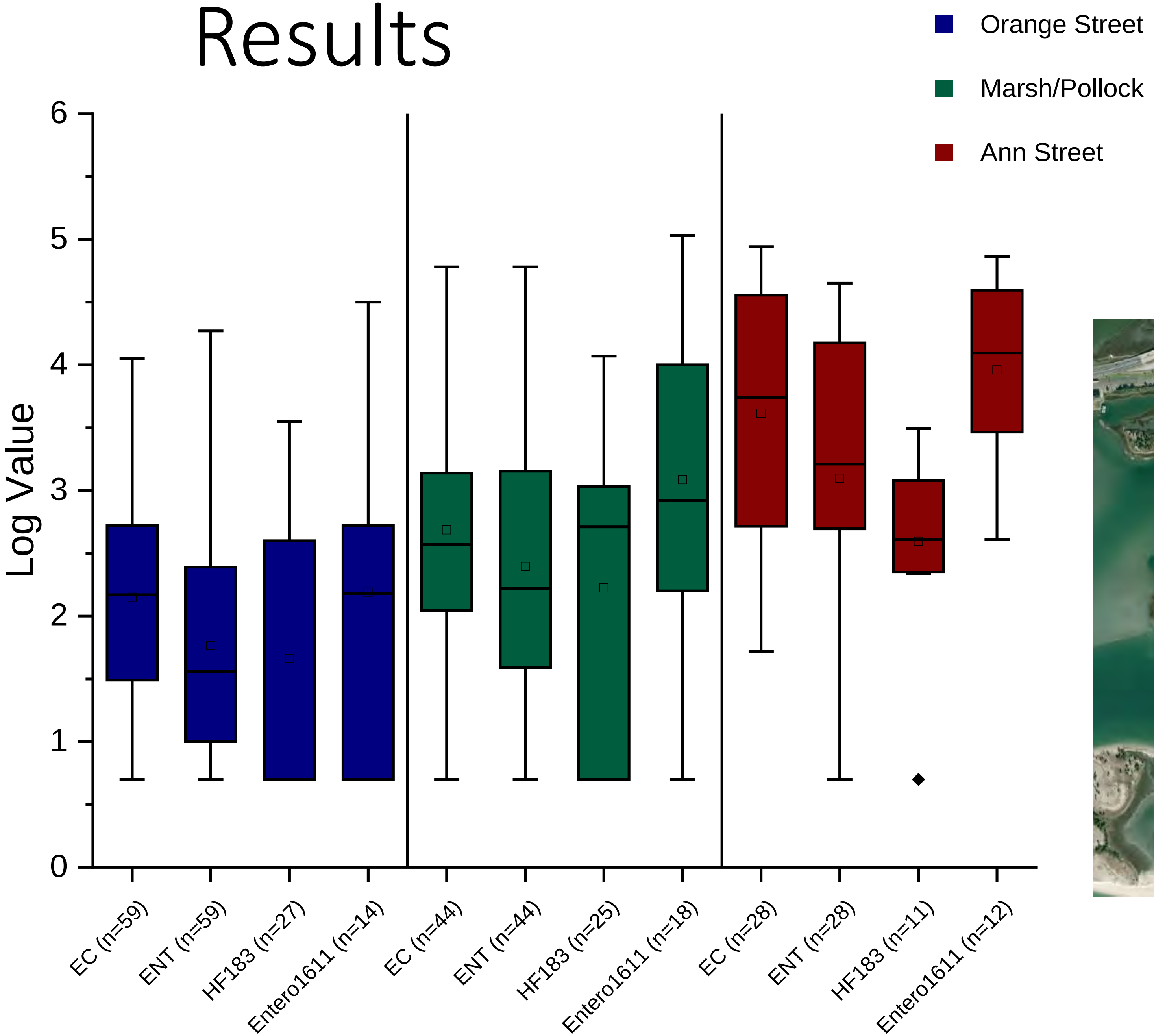
Molecular-Based

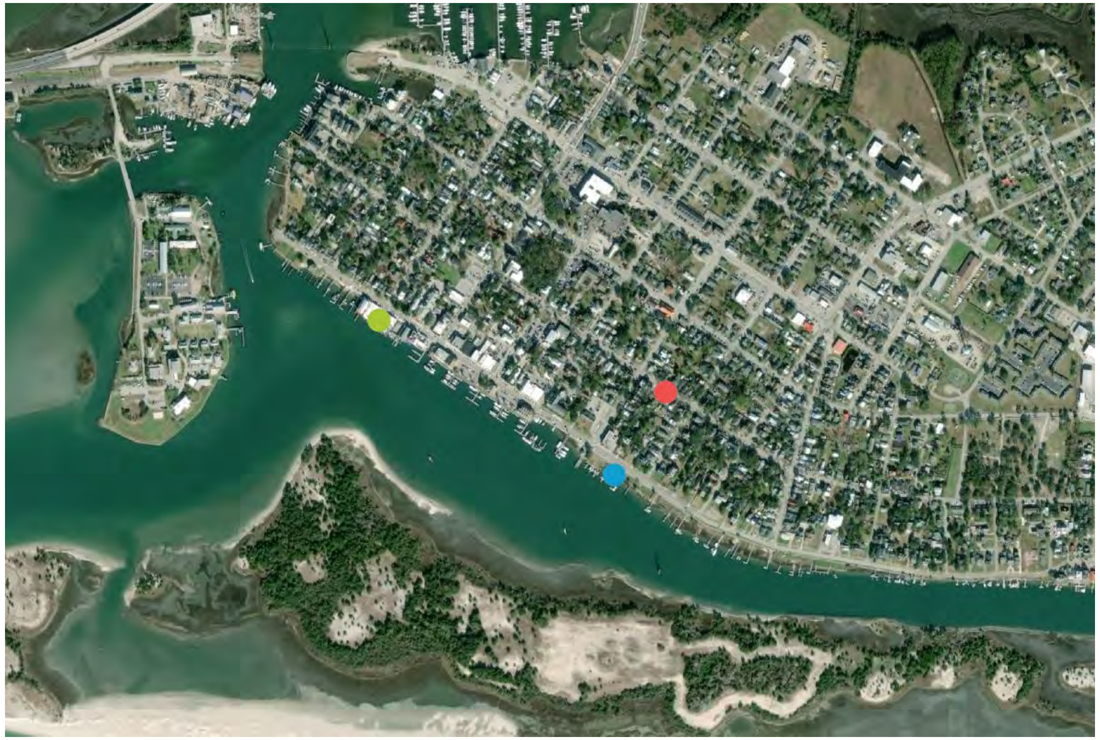
- Quantitative Polymerase Chain Reaction (qPCR)



Ann Street
Marsh/Pollock
Orange Street
Inundated
Transition
Receding
Dry (<0.25 in)
Wet (>0.25 in)
N = 29
N = 61
N = 47
21%
45%
34%
31%
36%
32%
46%
54%

Results

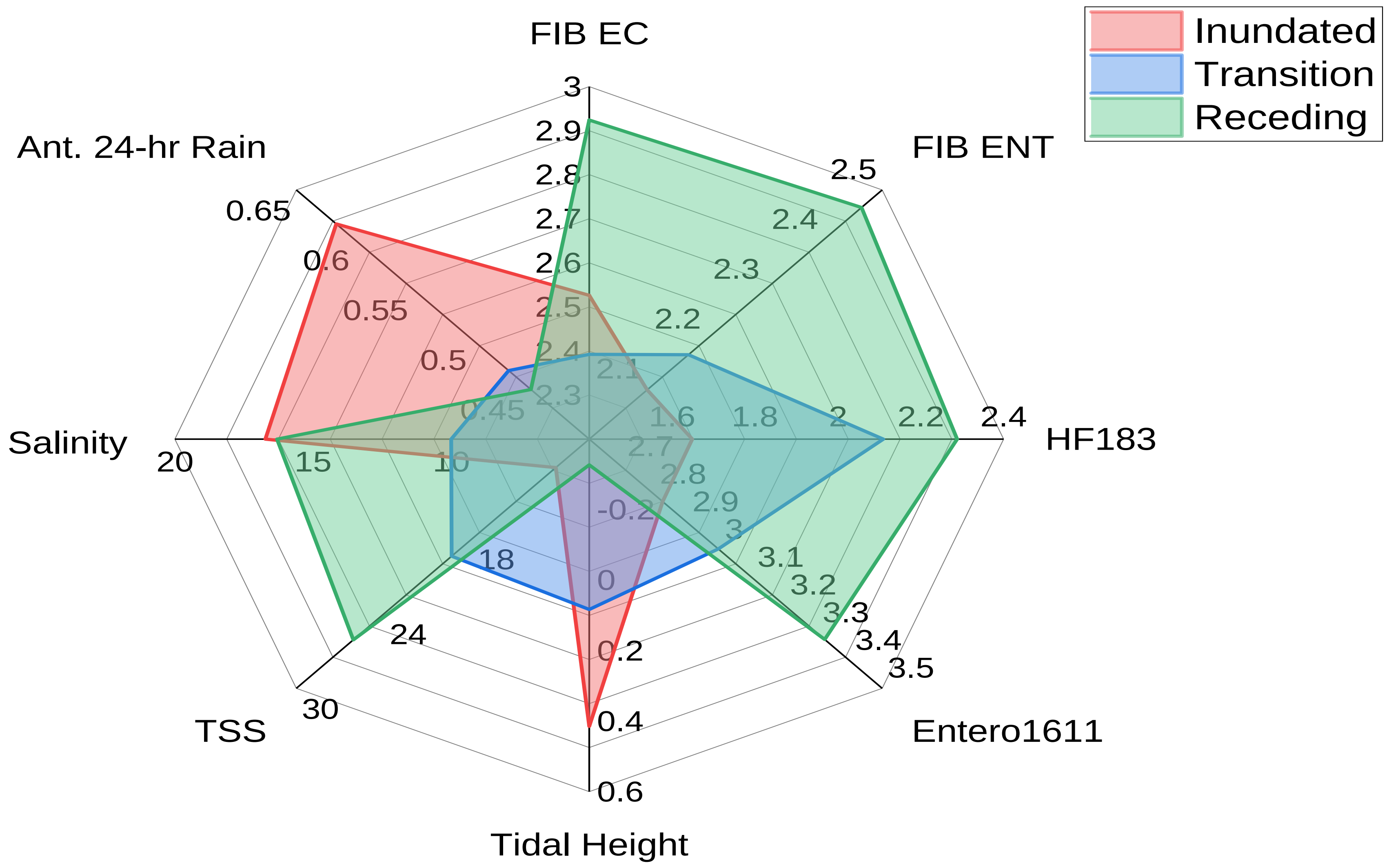

Orange Street
Marsh/Pollock
Ann Street
Log Value
0
1
2
3
4
5
6
EC (n=59)
ENT (n=59)
HF183 (n=27)
Entero1611 (n=14)
EC (n=44)
ENT (n=44)
HF183 (n=25)
Entero1611 (n=18)
EC (n=28)
ENT (n=28)
HF183 (n=11)
Entero1611 (n=12)

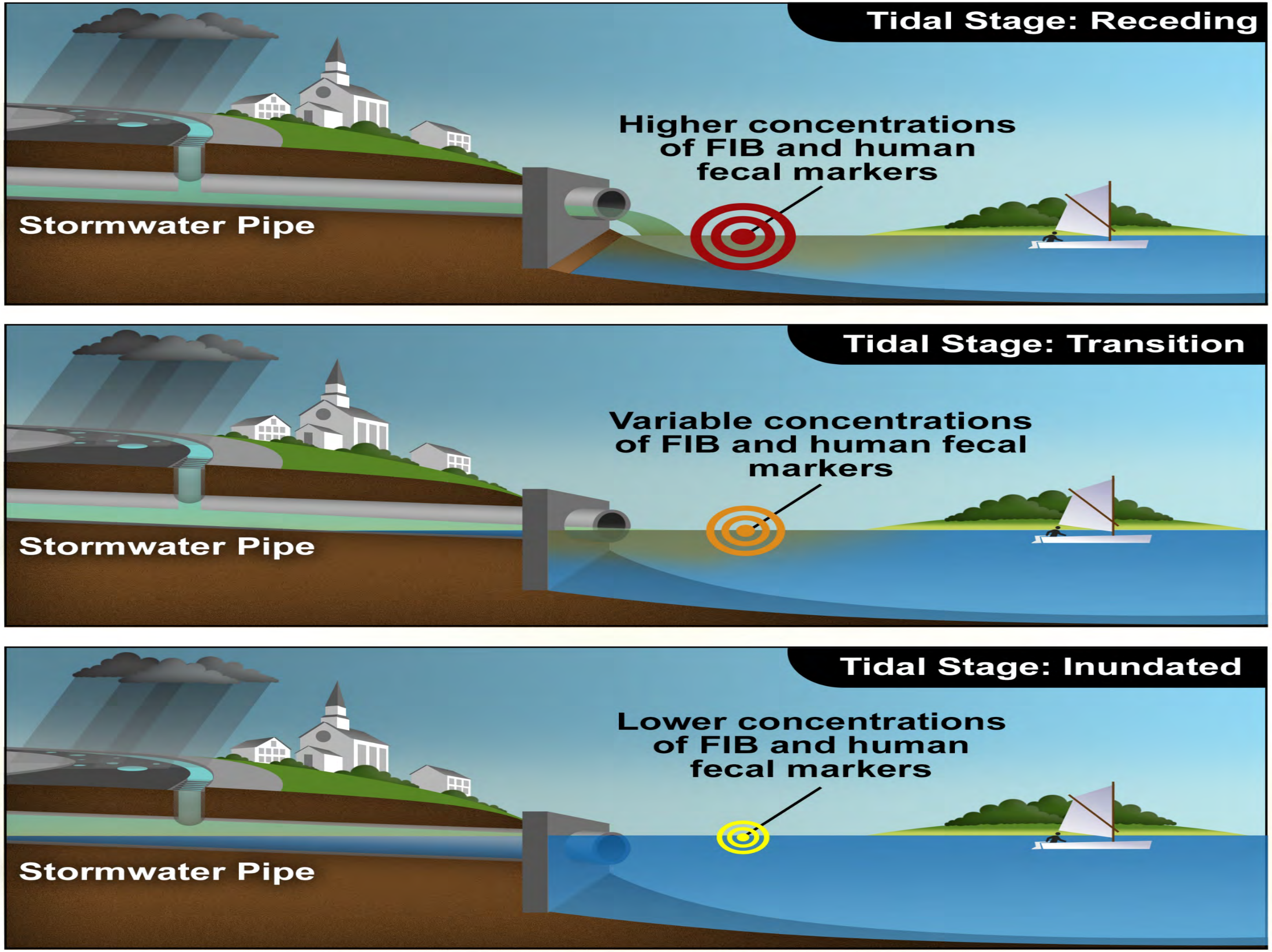


	FIB						qMST	
	EC		ENT		ENT-qPCR		HF183	
	Mean (min-max) N	Above standard	Mean (min-max) N	Above standard	Mean (min-max)	Above standard N	Mean (min-max)	Above standard N
Site	Log MPN/100 mL	EC %[a]	Log MPN/100 mL	ENT %[b]	Log copies/100 mL	ENT-qPCR%[d]	Log copies/100 mL	HF183 %[c]
OS	2.15 (0.7 – 4.05) 59	32.2	1.76 (0.7 – 4.27) 59	27.1	2.19 (0.7 – 4.5) 14	14.3	1.66 (0.7 – 3.55) 27	14.8
M/P	2.69 (0.7 – 4.78) 44	54.5	2.39 (0.7 – 4.78) 44	61.4	3.08 (0.7 – 5.03) 18	38.9	2.22 (0.7 – 4.07) 25	32.0
AS	3.62 (1.72 – 5.64) 29	75.9	3.10 (0.7 – 4.65) 29	79.3	3.96 (2.61 – 4.86) 12	83.3	2.59 (0.7 – 3.49) 11	27.3

[a] US EPA 2012 FIB recommended threshold; [b] NC DEQ ENT threshold; [c] Haugland et al., 2010; [d] US EPA 2012 molecular marker recommended threshold

Results of Tidal Inundation Model

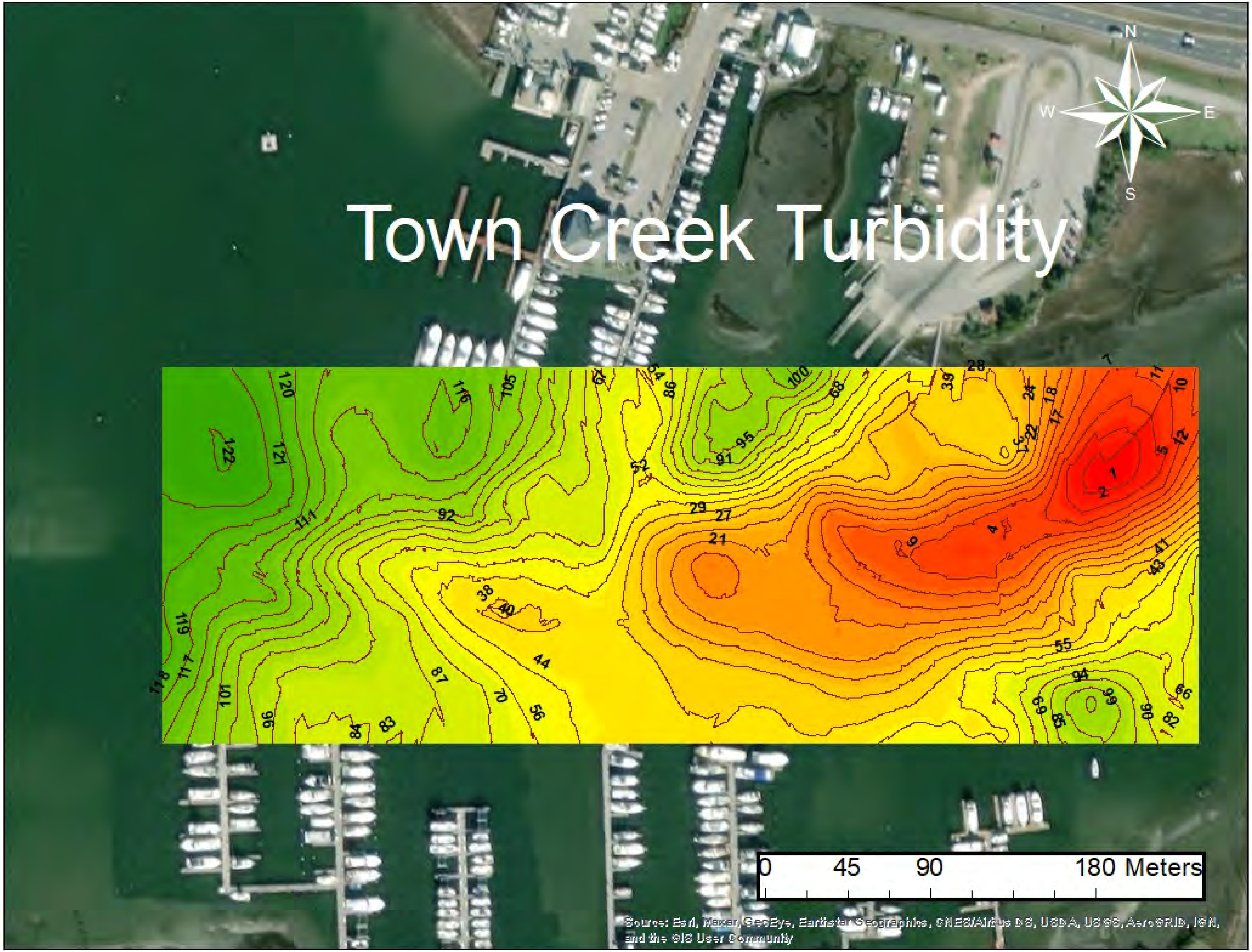



Tidal Stage: Receding
Higher concentrations of FIB and human fecal markers
Stormwater Pipe
Tidal Stage: Transition
Variable concentrations of FIB and human fecal markers
Stormwater Pipe
Tidal Stage: Inundated
Lower concentrations of FIB and human fecal markers
Stormwater Pipe

Impact of Tide Study Conclusions

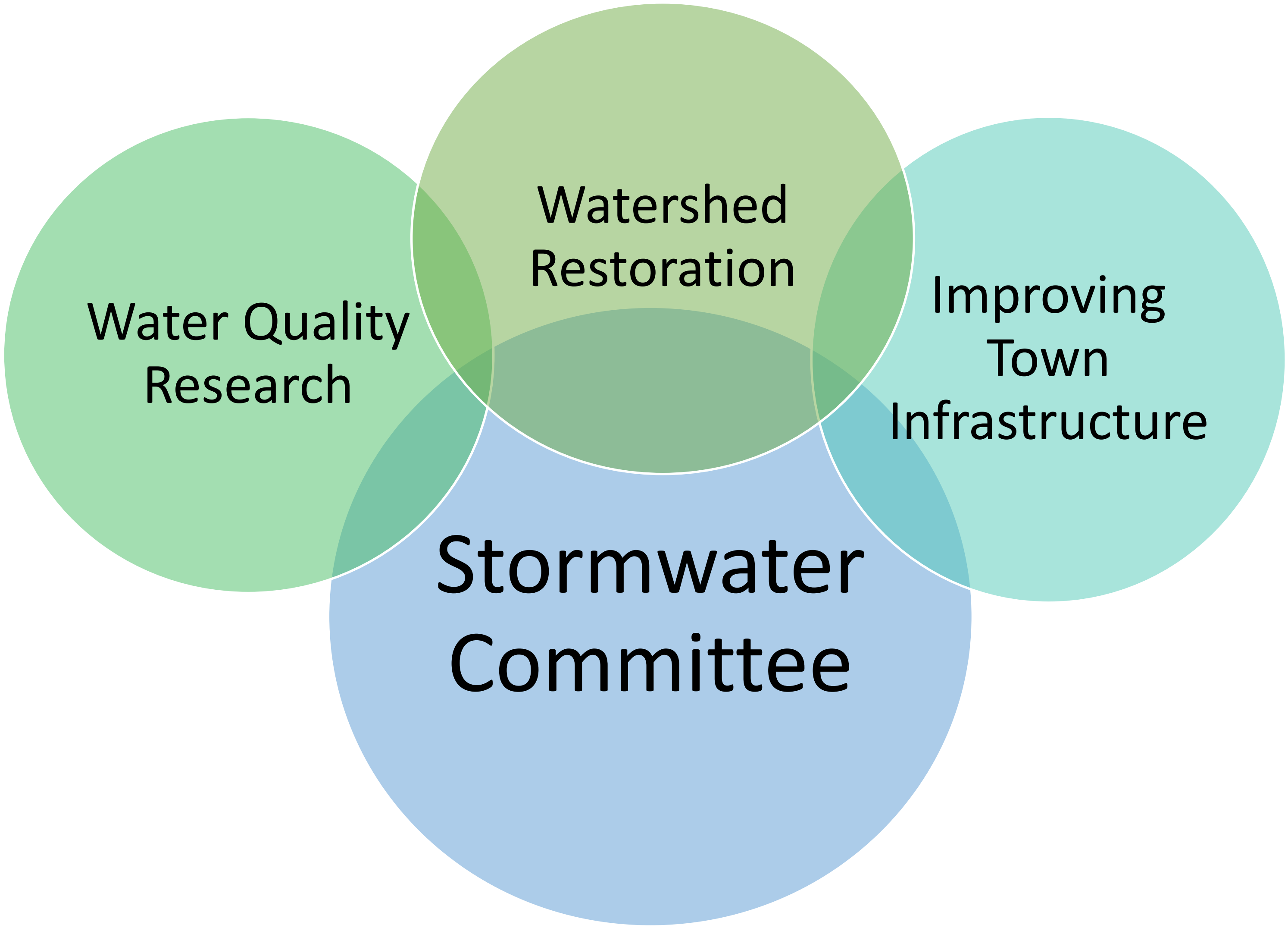
- Enterococci and HF183 concentrations significantly influenced by tidal stage
  - Consider monitoring programs that incorporate tide into monitoring and municipal engineering
  - Monitoring programs based solely on rainfall are problematic
- External factors drive stormwater delivery
  - Incorporate hydrologic flow and salinity measurements more extensively
- Application of predictive modeling possible
  - Inclusion of tidal parameters necessary
- King tides and sea level rise demand additional research on this topic

Collaborative, innovative research: Autonomous boat development by Duke Marine Robotics and Remote Sensing (MARRS) Lab


Town Creek Turbidity
N
W
E
S
0 45 90 180 Meters
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Town of Beaufort
Stormwater Advisory Committee


EXPRESS AGENCY


Watershed Restoration
Water Quality Research
Improving Town Infrastructure
Stormwater Committee

Watershed Restoration

Beaufort Watersheds Restoration Plan

2017

Davis Bay

Taylor Creek

Town Creek

Town of Beaufort North Carolina

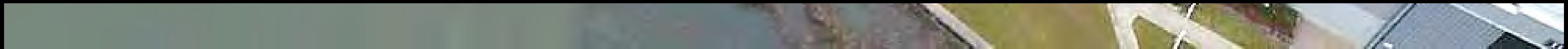
ecc

EasternCarolinaCouncil

North Carolina Coastal Federation

Working Together for a Healthy Coast

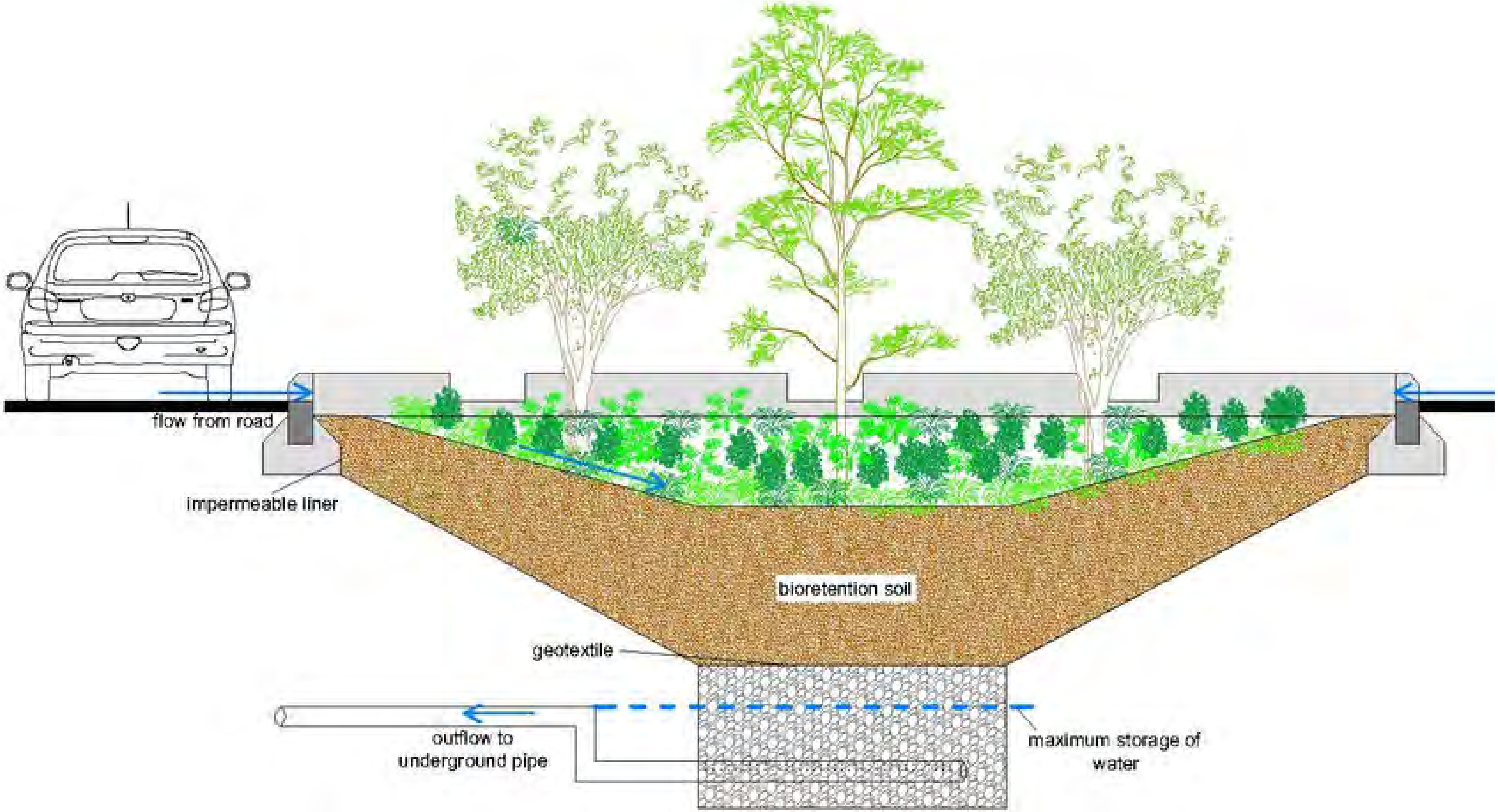
Improving Town Infrastructure – Pervious Pavers at Boat Ramp



Improving Town Infrastructure – Orange Street

Improving Town Infrastructure – Cedar Street

Improving Town Infrastructure – Cedar Street

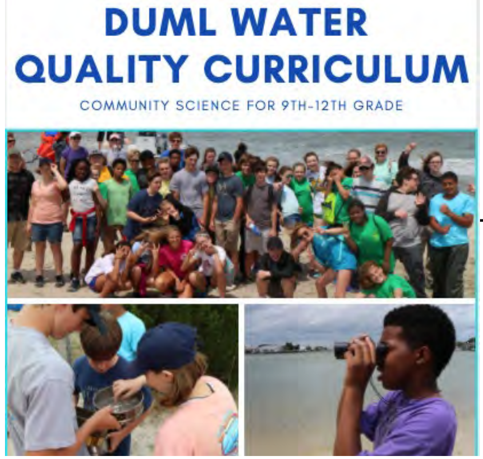


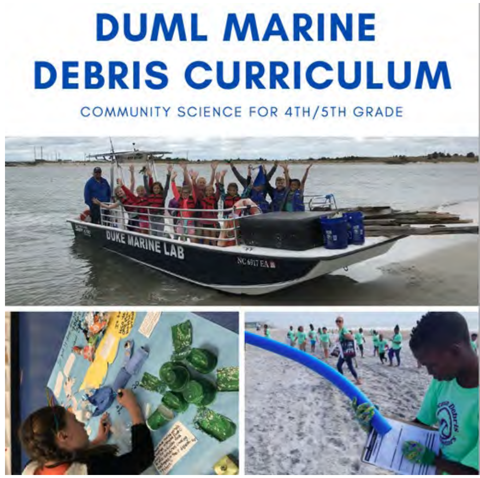
U.S. Department of Agriculture investing in Beaufort rural water and wastewater infrastructure

CITIZEN SCIENCE, PLASTIC POLLUTION & WATER QUALITY

Creating community through education programs

#ThinkOutsideTheSink





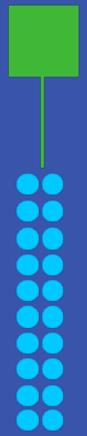
Drs. Liz Demattia, Rachel Noble, Kathryn Stevenson, and Lauren Gibson, Sage Riddick, Morgan Rudd, Jillian Wisse

UNC INSTITUTE OF MARINE SCIENCES

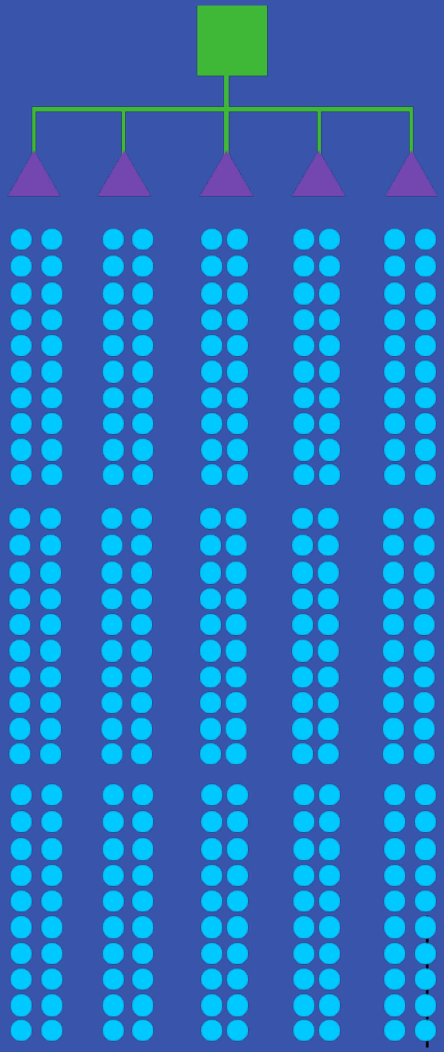
Duke NICHOLAS SCHOOL OF THE ENVIRONMENT DUKE UNIVERSITY MARINE LAB

NC STATE UNIVERSITY

Why work with Kids?



Reach = 20



Reach = 300

Intergenerational transfer!!

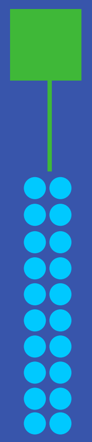
Teacher training programs

Youth Can Promote Marine Debris Concern and Policy Support Among Local Voters and Political Officials

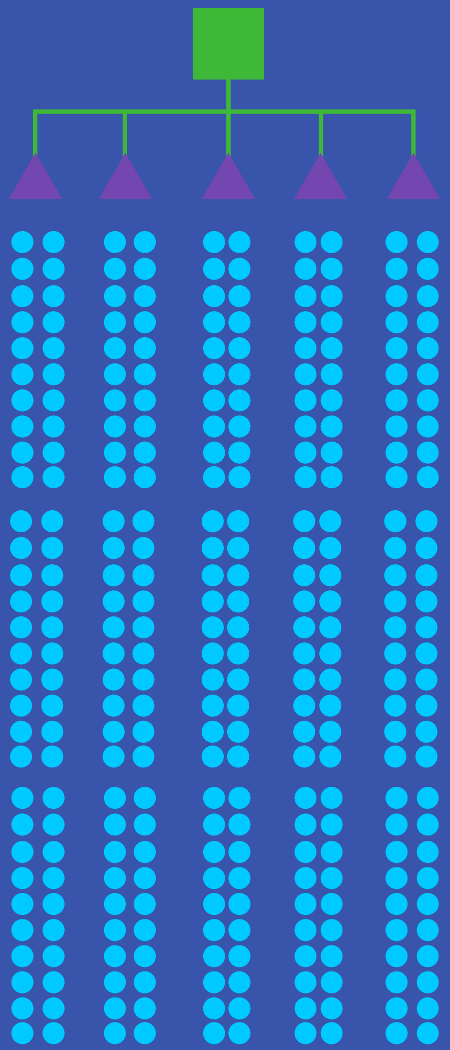
Jenna M. Hartley[1*], Kathryn T. Stevenson[1], M. Nils Peterson[2], Elizabeth A. DeMattia[3], Savannah Paliotti[4] and Thomas J. Fairbairn[4]

#ThinkOutsideTheSink

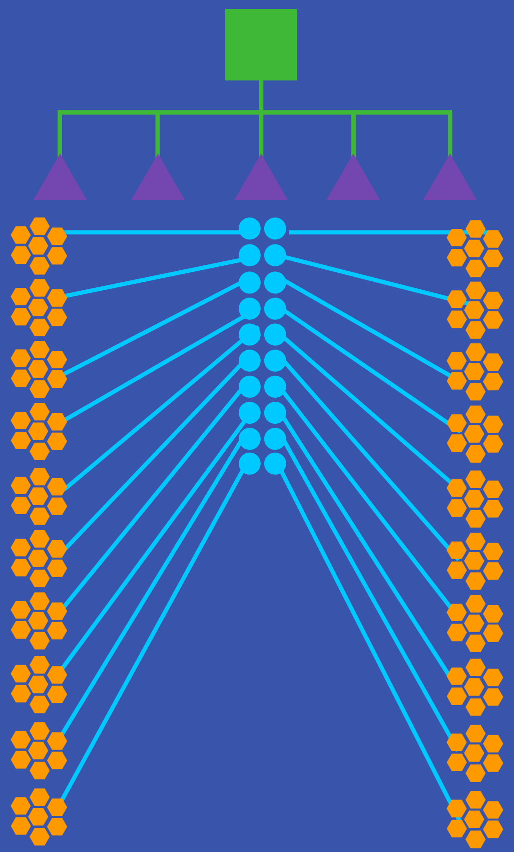
Citizen Science vs Community Science



Reach = 20



Reach = 300



Reach = 1050

#ThinkOutsideTheSink

Why Stormwater & Plastic Pollution?

- Local
- Visible to eye
- Connected to marine debris
- Affordable
- Data is missing
- Model system
- Action Oriented

#ThinkOutsideTheSink

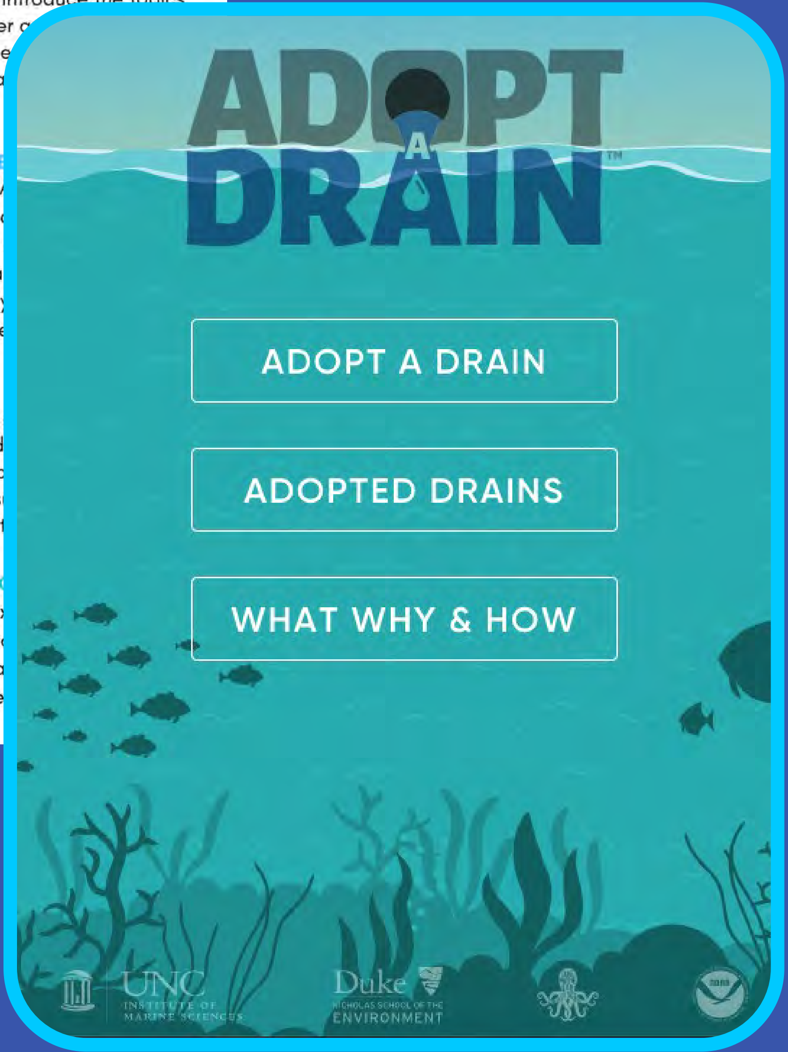

WORKBOOK ROADMAP

1 CLASSROOM PREPARATIONS
These background activities are used to introduce the topics of: how to ask questions in science, water q
stormwater. These activities set the stage
science field research (Adopt-A-Drain) a
research.

2 COMMUNITY SCIENCE FIELD RESE
This community science field research (A
designed to highlight how storm water c
water quality. By using microplastics as
can see how storm water transports wa
waterways. Students collect data, analy
then create ways to disseminate their re

3 CREATIVE ENGAGEMENT
These community engagement activities
the dissemination products from the stud
powerpoints, posters, lesson plans) can b
general public. By sharing their data/resu
develop a sense of civic engagement wit

4 OPTIONAL: INDEPENDENT RESEARC
These optional independent research ex
the Adopt-A-Drain research and let stud
hypotheses and test for the presence/a
pesticides/nutrients in local storm wate



- Exploration
- Graphing
- Developing Research Questions
- Extrapolation
- Differentiation
- Dissemination

#ThinkOutsideTheSink

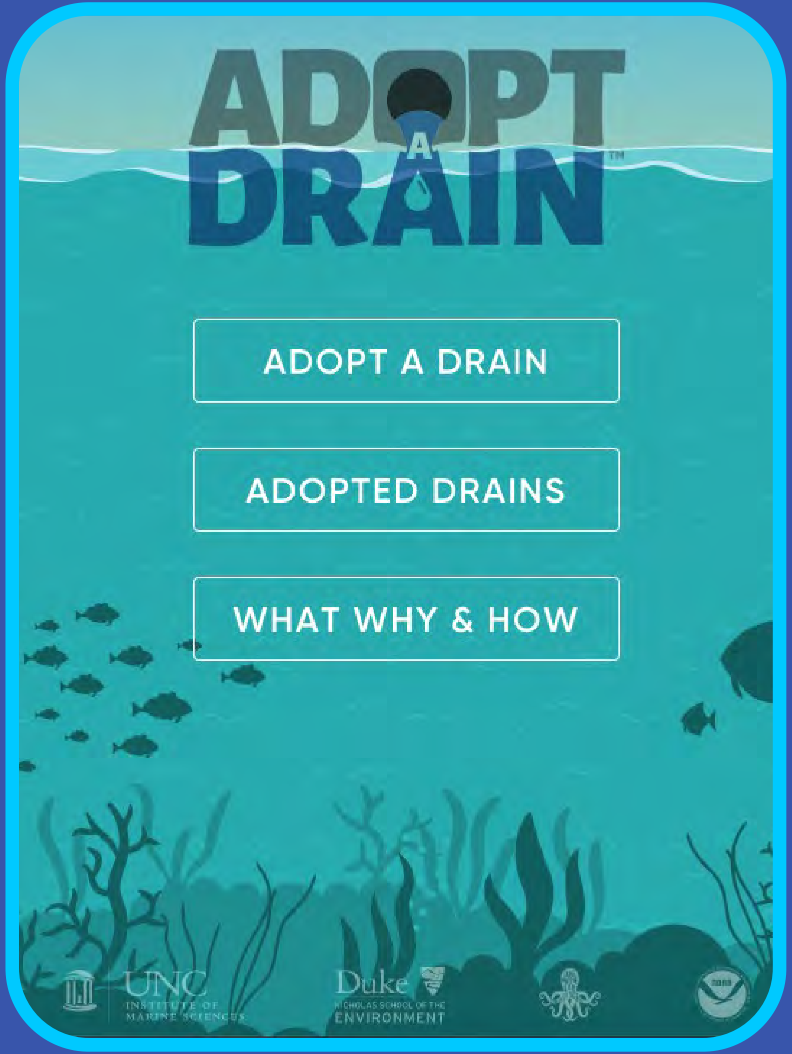
WORKBOOK ROADMAP

1. **CLASSROOM PREPARATIONS**
   These background activities are used to introduce the topics of: how to ask questions in science, water quality, and stormwater. These activities set the stage for the community science field research (Adopt-A-Drain) and for independent research.

2. **COMMUNITY SCIENCE FIELD RESEARCH**
   This community science field research (Adopt-A-Drain) is designed to highlight how storm water can affect local water quality. By using microplastics as a model, students can see how storm water transports waste into our waterways. Students collect data, analyze their results and then create ways to disseminate their results

3. **CREATIVE ENGAGEMENT**
   These community engagement activities are designed so that the dissemination products from the students (i.e., videos, powerpoints, posters, lesson plans) can be shared with the general public. By sharing their data/results, students develop a sense of civic engagement within their community.

4. **OPTIONAL: INDEPENDENT RESEARCH OPTIONS**
   These optional independent research extensions build on the Adopt-A-Drain research and let students create hypotheses and test for the presence/absence of pesticides/nutrients in local storm water.



#ThinkOutsideTheSink

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Conclusions and Future Work

- Wastewater/inflow/infiltration research underway with Town of Beaufort
- Continue to understand the role of flooding, precipitation and tidal inundation in stormwater runoff and wastewater discharge dynamics
- Development of improved technologies for measuring pathogens, rather than indicators
- Continue development of community learning engagement and teacher workshops

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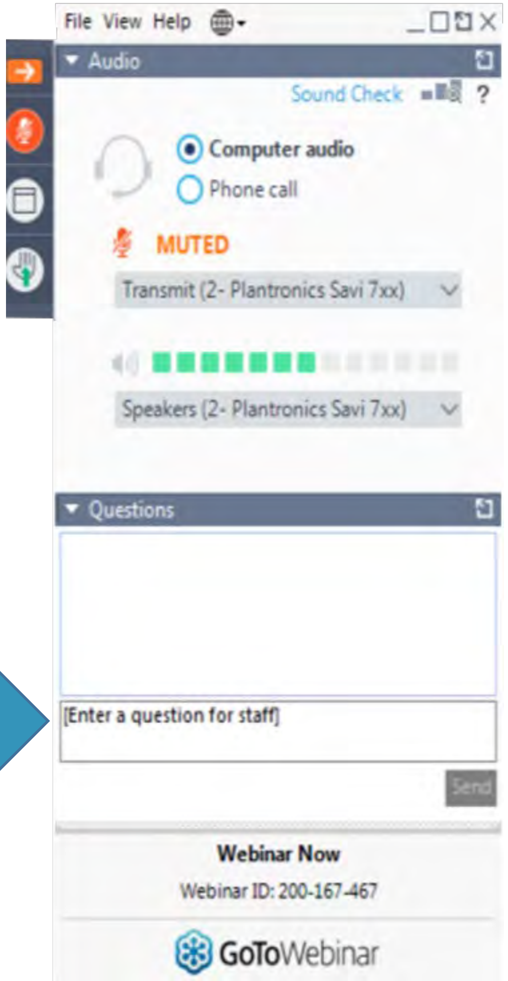
Q&A time

Have a question?

Use the "Questions" function to pose questions throughout the webinar.



Q&A

Q: Could you elaborate on the choice of *E.coli* monitoring and also if any ambient monitoring was conducted?

- **A**: *E. coli* is a fecal indicator bacterium used by many other coastal states. It's a single species, so conducting monitoring work provides us with fecal contamination from warm-blooded animals.

  Quite a bit of attention was devoted to monitoring during ambient conditions (see slide 33). The innermost circle shows wet and dry conditions.

Q: What is the elevation of the nearshore area?

- **A**: Basically zero! For the majority of the historic parts of Beaufort, it's probably between 18-42 inches.

Q: What are the heights of the tides? Did you include piezometric studies, and were you able to get retention times of water?

- **A**: 3.1 feet, generally, but this week, we'll experience a king tide event that will put us 14-18 inches our mean high tide. For example, for two months following Hurricane Florence, we were experiencing high tides from 4.5-4.8 feet just from excess water.

Q: Was sea level rise taken into account in any updates to the storm water system?

- **A**: At this point, it hasn't been updated, but they did replace a sewage pipe in the storm water conveyance system. No major sewage remediation has been done at this point, probably because attention is being paid to updating the wastewater infrastructure.

Q: Is it possible that the higher salinity of tidal water affected the lower count of fecal bacteria or was it simply dilution?

- **A**: Both, very good point. *Enterococcus* are grown at 6% salt (compared to the 3% salt of the ocean) so they don't care about salt, and would largely be expected to be diluted. *E. coli* response is probably such that they're dying or not being measured appropriately using lab methods because they aren't surviving as well as they would in fecal material.

Q: Is the public aware of water quality issues, and how do you weigh their concerns?

- **A**: Our mayor has made Beaufort being a clean water community a priority and has elevated that as a focus area. We're regularly talking to realtors, engineers, and marine contractors to do things like low-impact development and living shorelines to help protect water quality.

Q&A

Q: Have your findings generated any conversation about future increases in stormwater and tidal contamination impacts? Is the community beginning to talk about relocation needs to avoid the increase in flooding and exposure to water contamination?

- **A**: Great question. We're working on a collaborative NSF project bringing together city planners, microbial experts, physical oceanographers, and people that study storm surge. A major part of that is associated with understanding floodplain impacts from extreme events and identifying buyout solutions for the state. As you can expect, there are lot of entangled issues associated with buyout. It's a complex issue and a difficult conversation to have.

Q: How do you address concerns outside the jurisdiction of Beaufort (like problems caused upstream by farms, other?)

- **A**: We've been conducting research across the whole state and most towns are addressing the same concerns. One of the first things we did was try to establish a community of practice, and we held a workshop to involve coastal communities as stakeholders a week before we went into lockdown for COVID. It's been difficult to maintain momentum since then.

  Looking forward to working on coastal issues more and continuing conversations with the town.