Measuring the Muck:

Water quality, coastal flooding and sea level rise

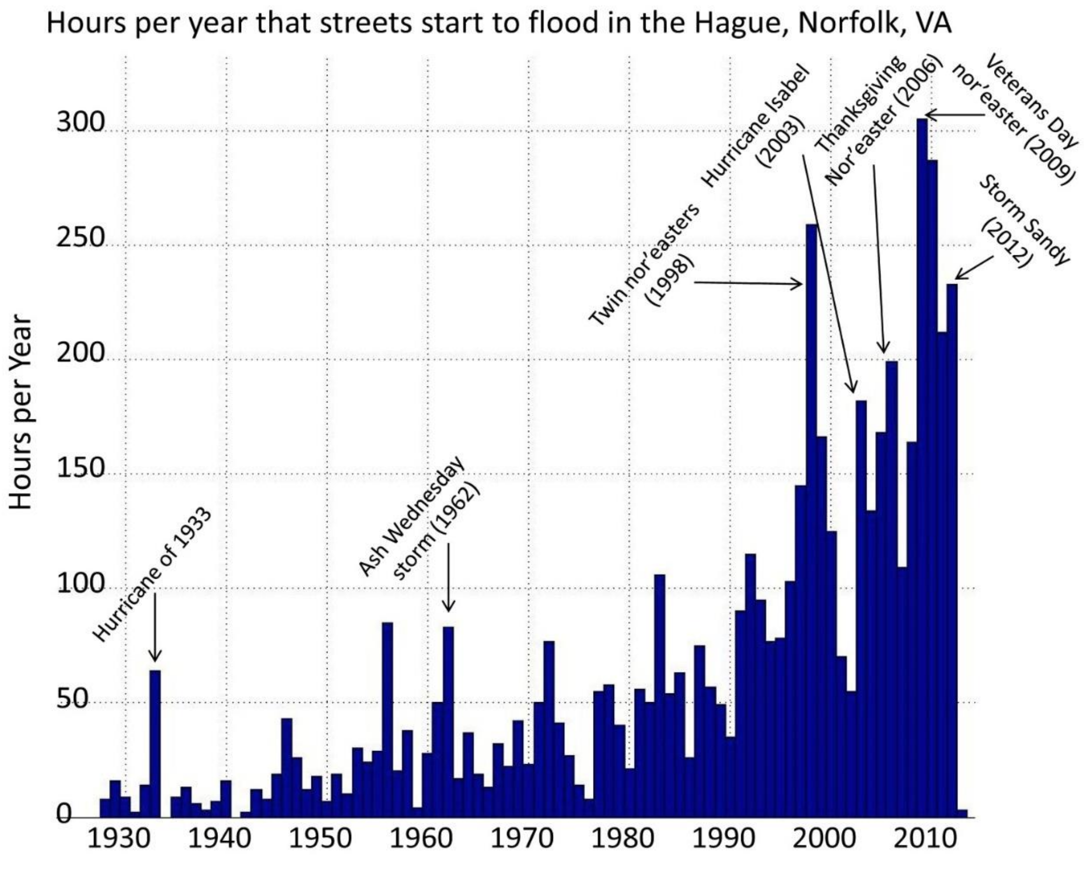
HRSD
Cleaning wastewater every day for a better Bay.

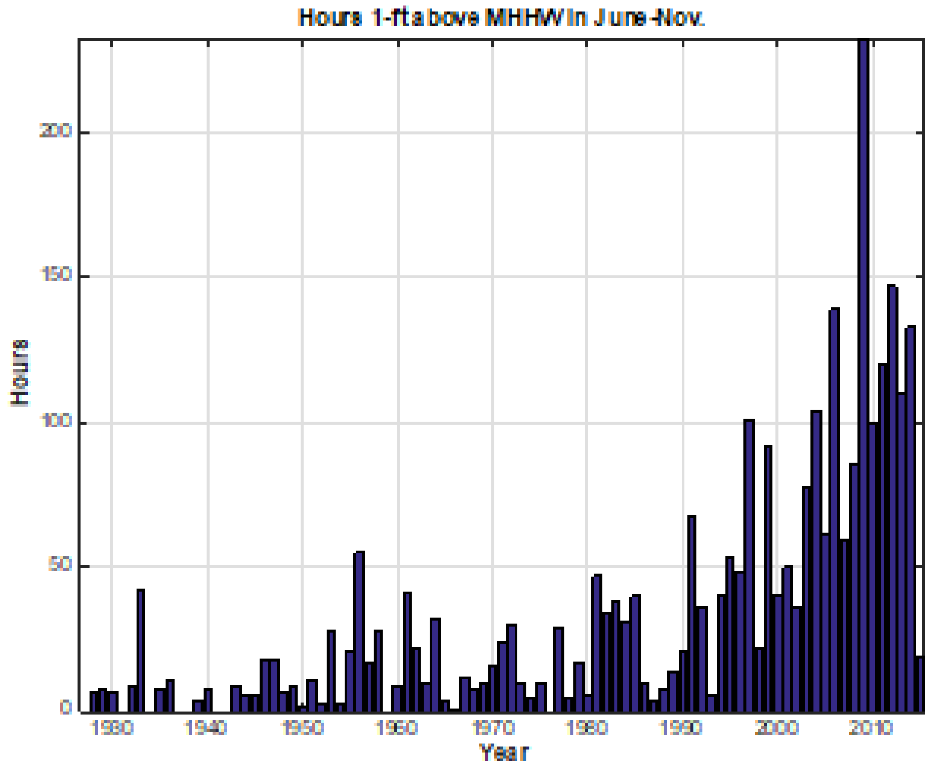
OLD DOMINION UNIVERSITY
1930

OCEAN, EARTH & ATMOSPHERIC SCIENCES

There are storms

But its not just storms!

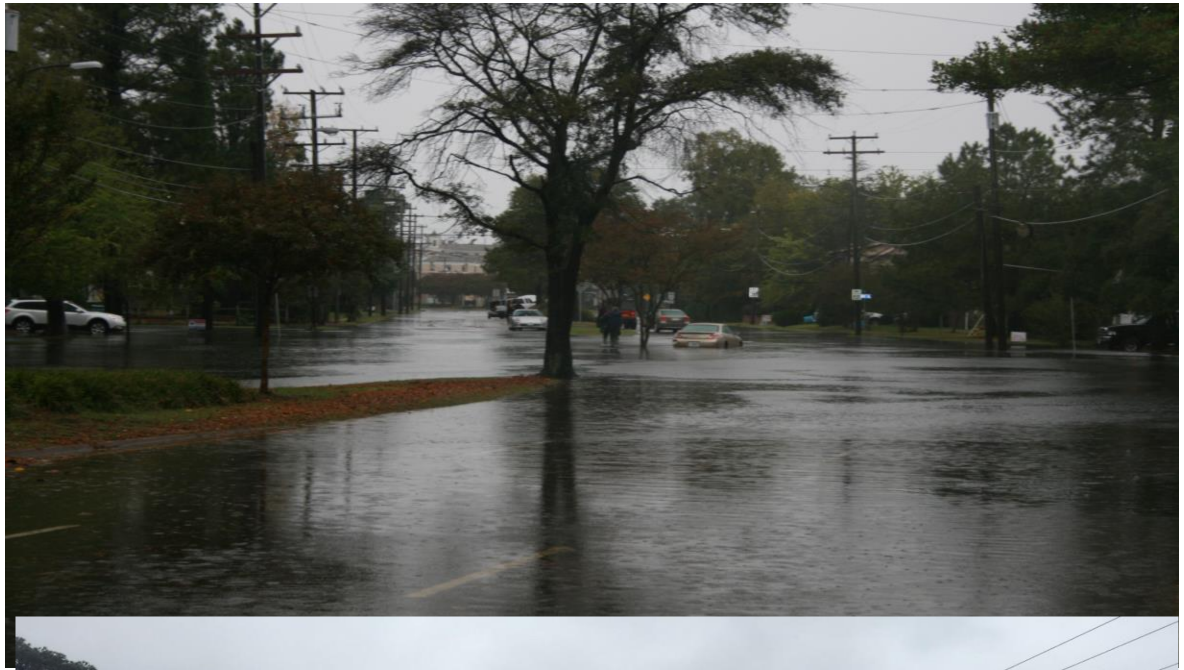




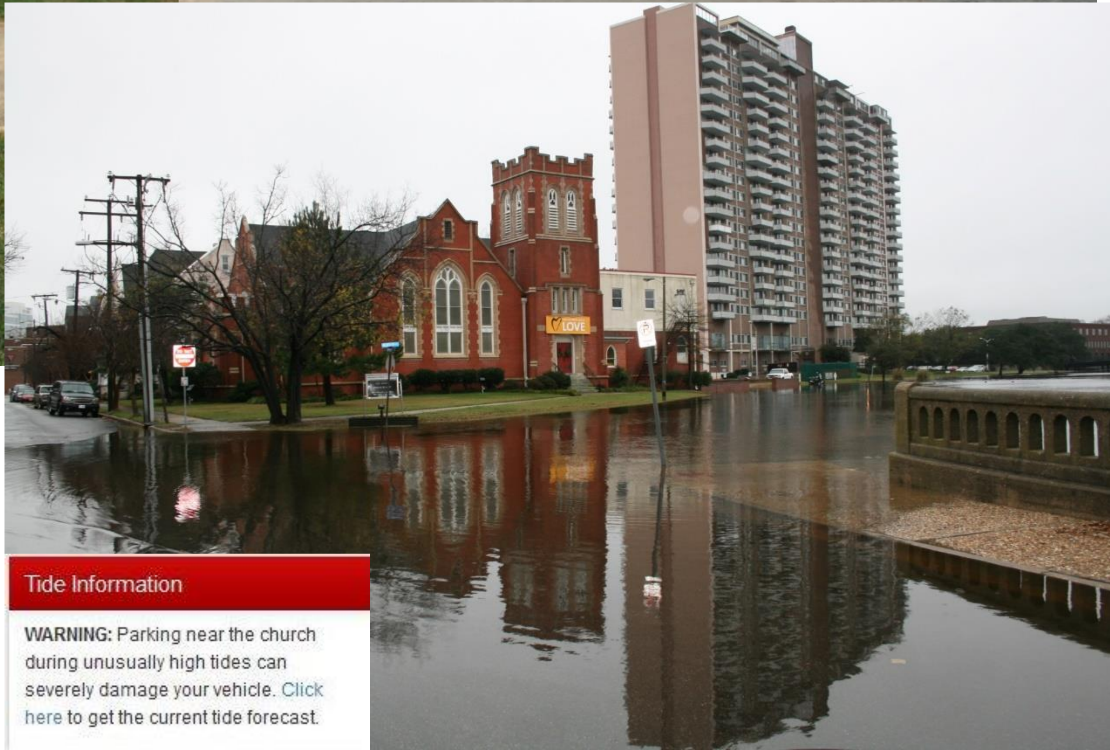
Hours spent 1-ft above mean higher high water (MHHW) during June-Nov. as measured at the Sewell's Point tide gauge in Norfolk, VA.

We expect it when there is a storm, right?

When it floods, it is inconvenient and hard to get around!



On land, we're adapting….



Vegetation is responding

Algal mats in yards

Terrestrial vegetation threatened by saltwater intrusion

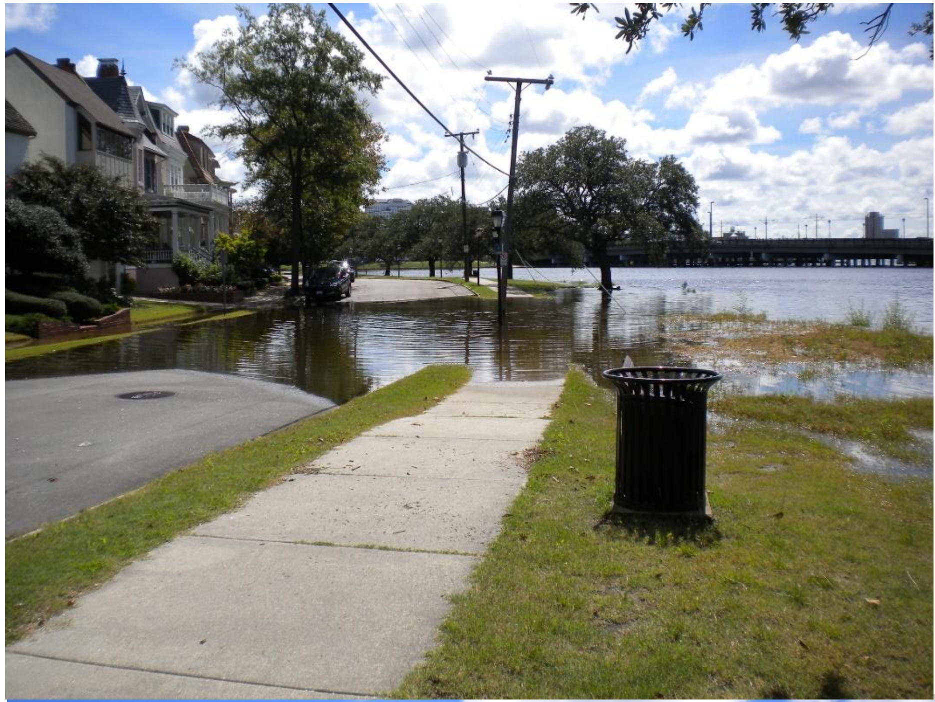
We are trying to protect our infrastructure

Flooded buildings and roads

FEMA raising houses

And, we are flooding even when the skies are blue!

At high tide



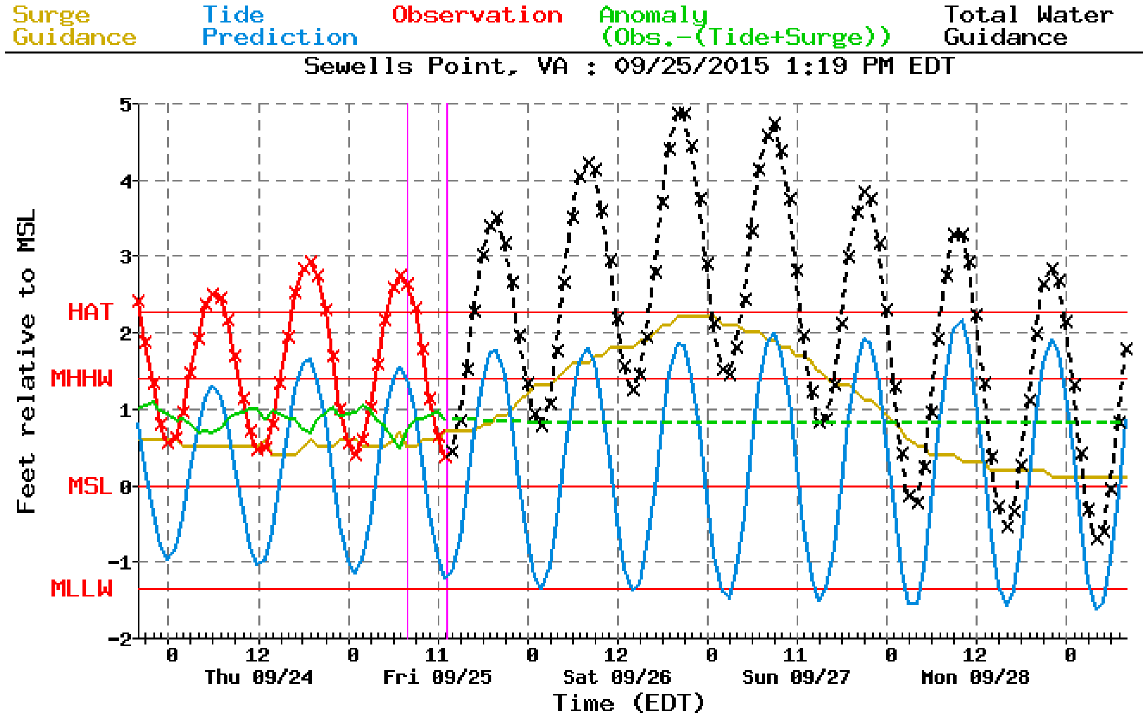
Winds can exacerbate (or reduce) tidal flooding

Tide prediction – dynamic theory of tides for a location

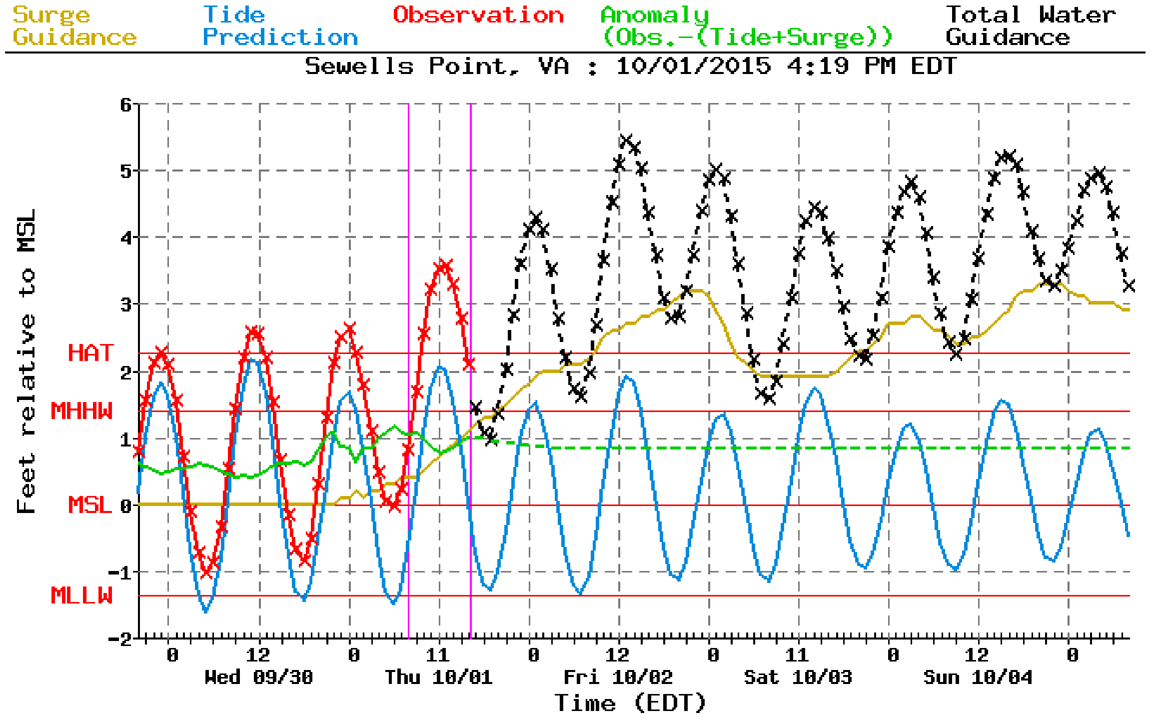
Observation – what was measured

Total water guidance – includes weather

A perigean spring tide (spring tide when moon is at perigee)
with strong northeasterly winds
Going into spring tide
No rain



Extratropical frontal storm (Nor'easter)
moving into neap tide
LOTS of rain



Most efforts to adapt or mitigate for sea level rise have focused on the landward side of the picture.

Flooded buildings and roads

FEMA raising houses

Let’s think about the water side now

The water rises and falls with the tide.

What is going into the estuary when the tide returns?

Whatever was on the paved surfaces
Oil and hydrocarbons

Litter

Trash

Everything!

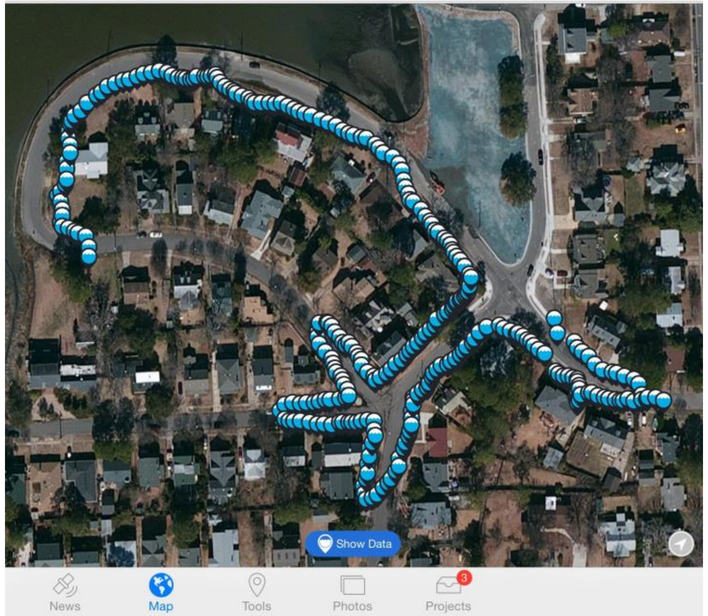
How can we quantify N inputs during coastal flooding?

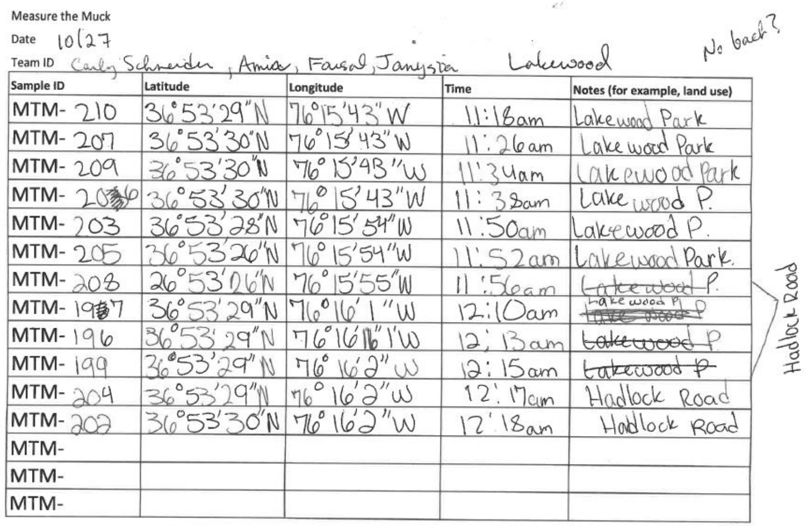
- Need it to flood
- Need to sample as floodwaters recede
- Need to sample multiple sites at the same time
- This will take an army!

We measured the nutrient load associated with a single flooding event. How could we do it?

KING TIDE

NOV. 5, 2017 | LET'S TRACK HOW FAR IT REACHES





Measure the Muck

Date 10/27

Team ID Carly Schneider, Amiar, Faisal, Janystia Lakewood

No back?

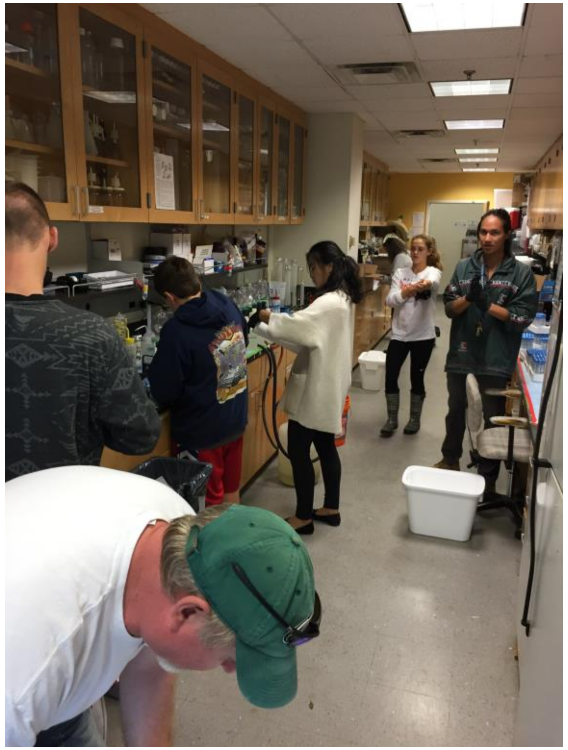
Sample ID	Latitude	Longitude	Time	Notes (for example, land use)
MTM- 210	36°53'29"N	76°15'43"W	11:18am	Lakewood Park
MTM- 207	36°53'30"N	76°15'43"W	11:26am	Lake wood Park
MTM- 209	36°53'30"N	76°15'43"W	11:34am	Lakewood Park
MTM- 206	36°53'30"N	76°15'43"W	11:38am	Lake wood P.
MTM- 203	36°53'28"N	76°15'54"W	11:50am	Lakewood P.
MTM- 205	36°53'26"N	76°15'54"W	11:52am	Lakewood Park.
MTM- 208	26°53'26"N	76°15'55"W	11:56am	~~Lakewood~~ P.
MTM- 197	36°53'29"N	76°16'1"W	12:10am	Lake wood P ~~Lake wood~~ P
MTM- 196	36°53'29"N	76°16'1"W	12:13am	~~Lakewood~~ P
MTM- 199	36°53'29"N	76°16'2"W	12:15am	~~Lakewood P~~
MTM- 204	36°53'29"N	76°16'2"W	12:17am	Hadlock Road
MTM- 202	36°53'30"N	76°16'2"W	12:18am	Hadlock Road
MTM-				
MTM-				
MTM-				

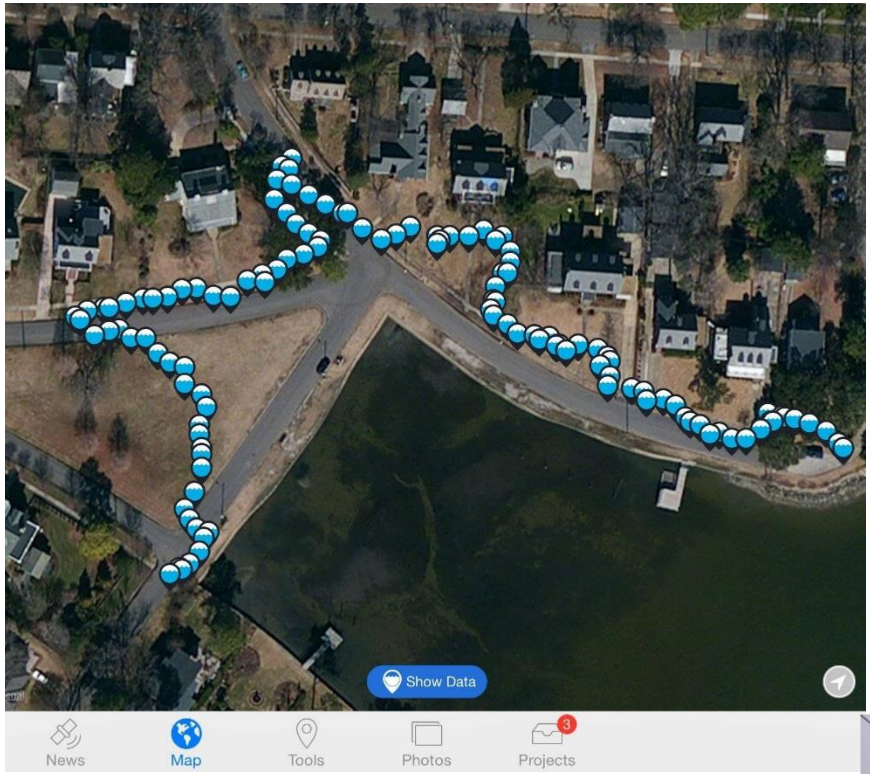
Hadlock Road

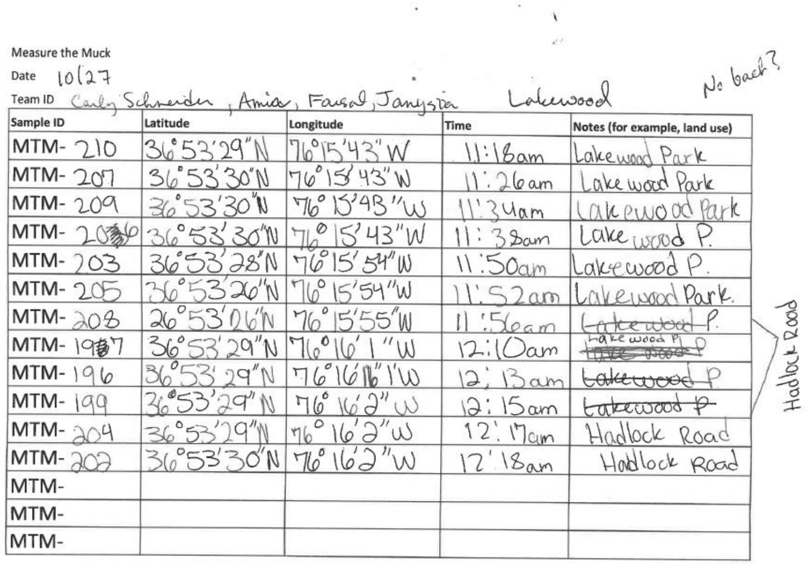
- Tapped into the Citizen Science project “Capture the King”
- Use sea level rise application to track samples
- Engaged students of all ages to “Measure the Muck”
- Trained them to collect water samples while mapping

Tidal flooding water characterization

More than 200 water samples were collected during each King Tide event to measure dissolved nitrogen



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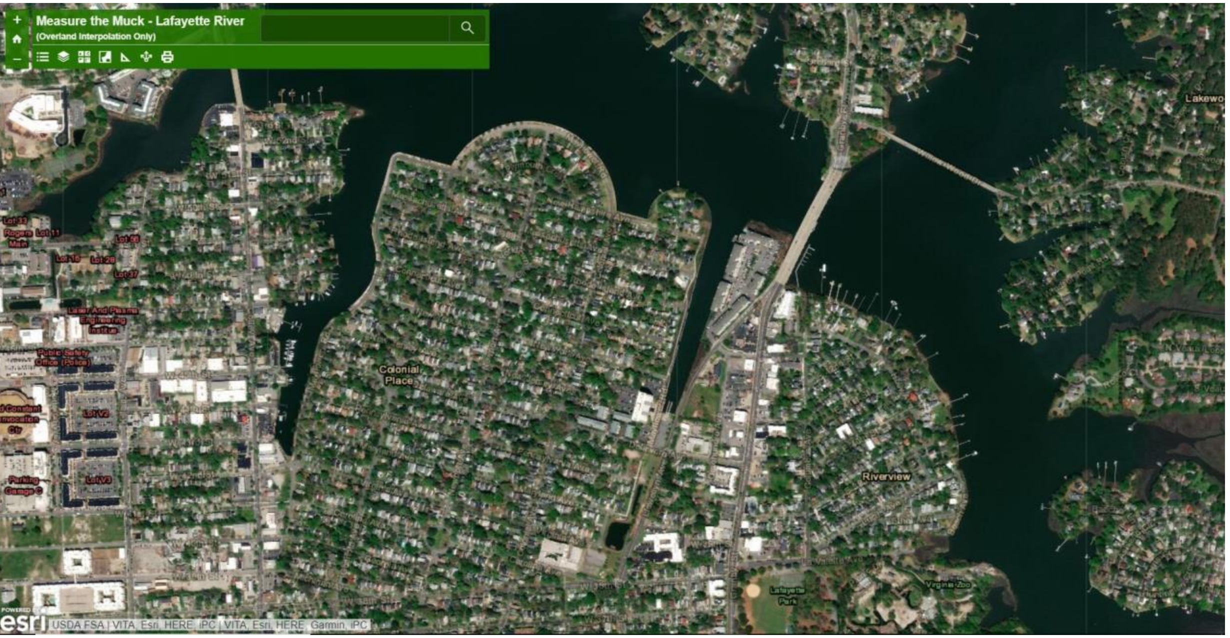
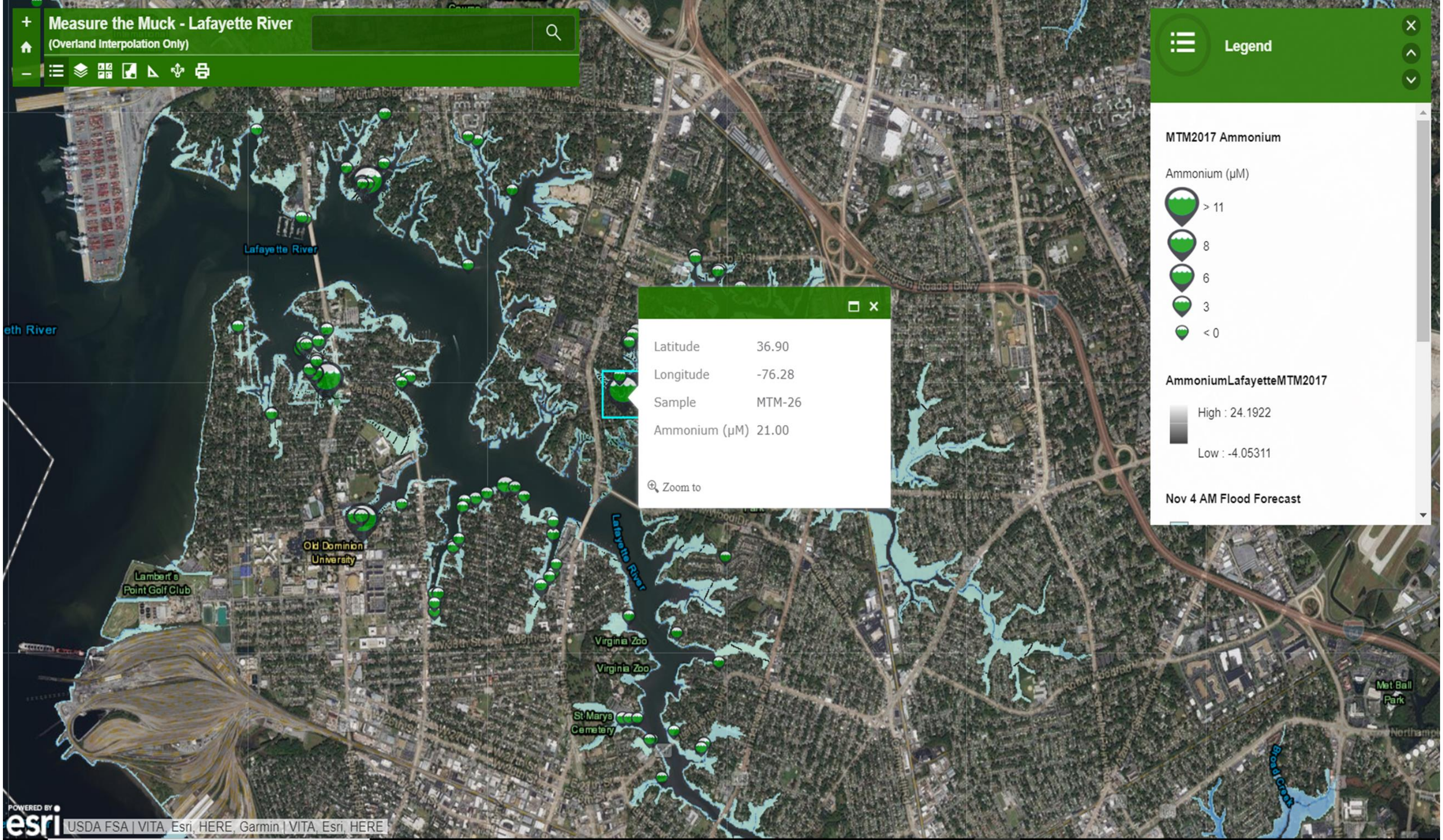
MTM-				
MTM-				
MTM-				

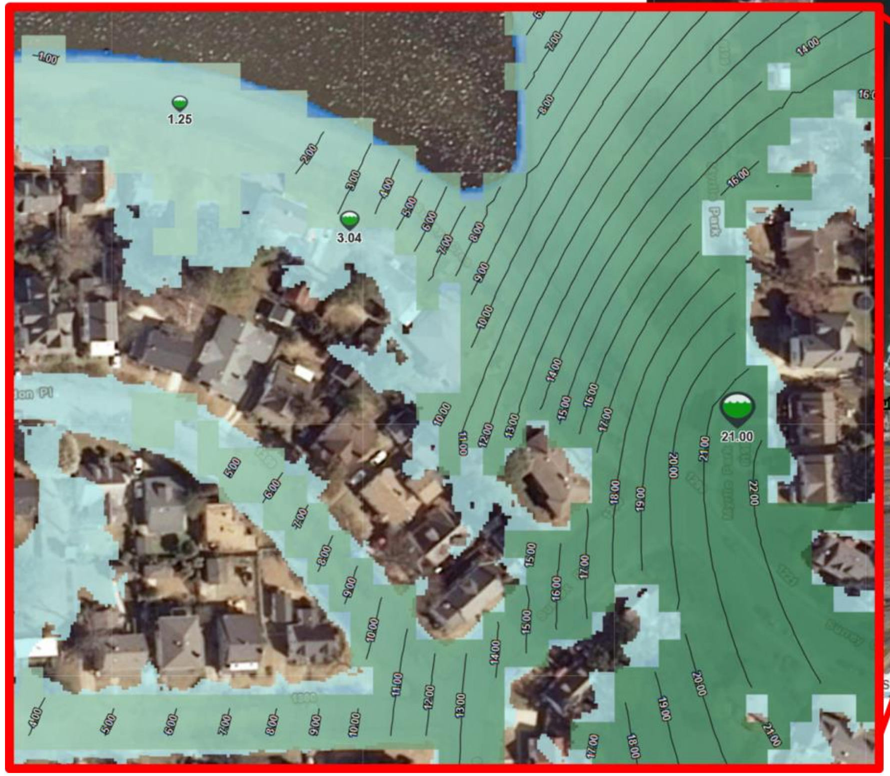
Hadlock Road

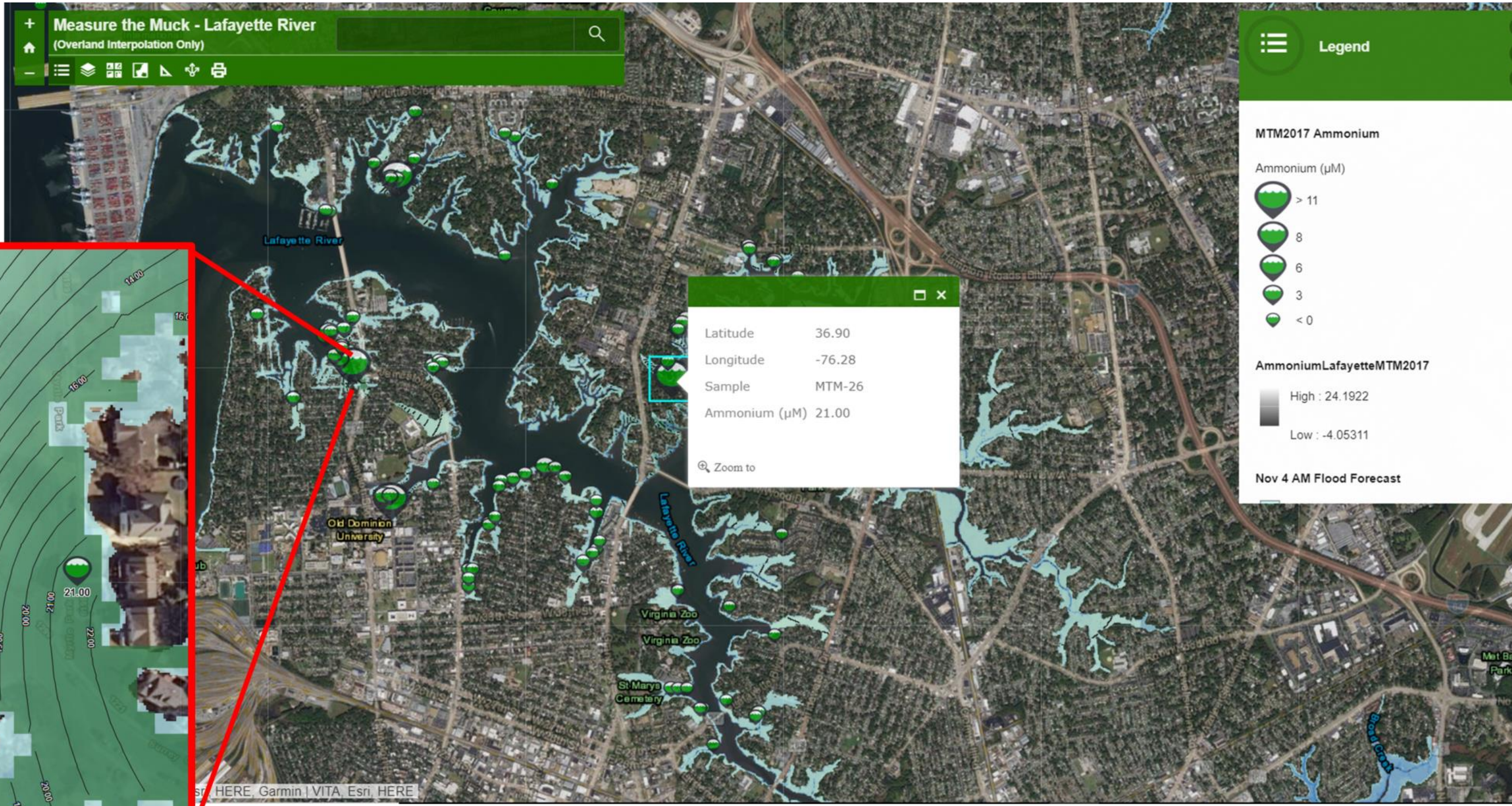

rmouth St 700
South Mowbray Arch 300
UNITARIAN CHURCH OF NORFOLK
10 30 AM
COME SEE US AT
OUR NEW LOCATION
909 S MILITARY HWY

Using all of the data collected during the King Tide mapping (which was >>> than our small sampling subset), inundation depths were calculated by Derek Loftis at VIMS and corrected using Lidar data. This allowed us to know the volume of the flood waters

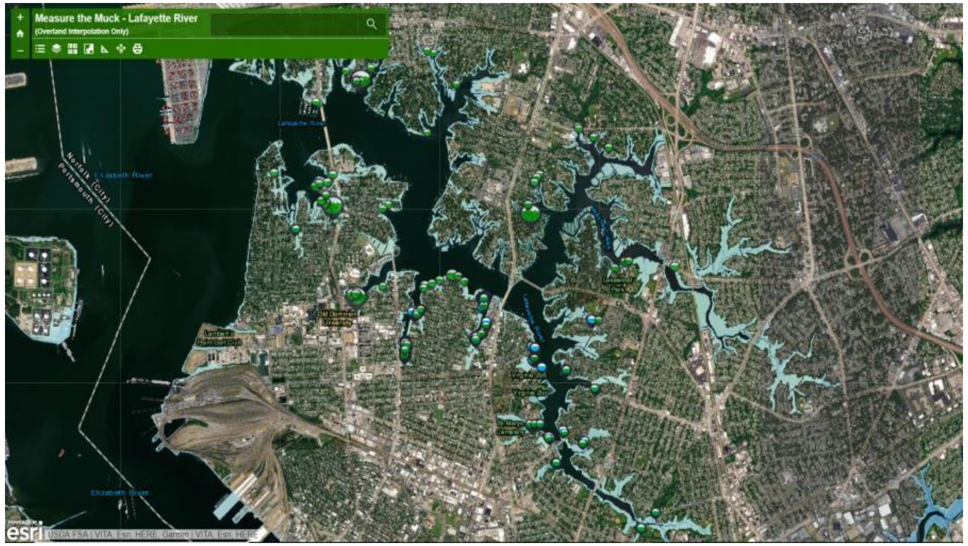


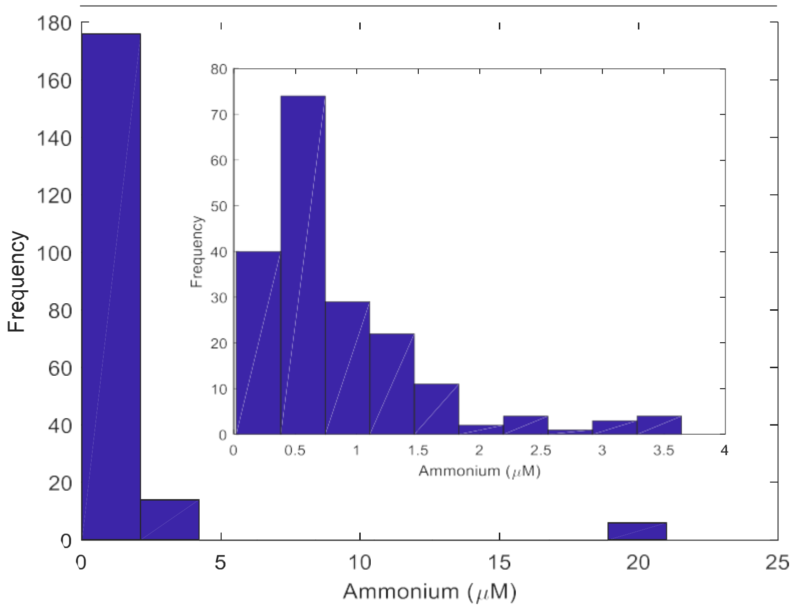

Measure the Muck - Lafayette River
(Overland Interpolation Only)
Legend
MTM2017 Ammonium
Ammonium (μM)
> 11
8
6
3
< 0
AmmoniumLafayetteMTM2017
High : 24.1922
Low : -4.05311
Nov 4 AM Flood Forecast
Latitude 36.90
Longitude -76.28
Sample MTM-26
Ammonium (μM) 21.00
Zoom to
Lafayette River
eth River
Old Dominion University
Lambert's Point Golf Club
Virginia Zoo
Virginia Zoo
St Marys Cemetery
Lafayette River
Met Ball Park
POWERED BY esri
USDA FSA | VITA, Esri, HERE, Garmin | VITA, Esri, HERE





From all of this, we can start to make calculations – we can interpolate if data density is great enough





Or look at data distribution and use a median concentration

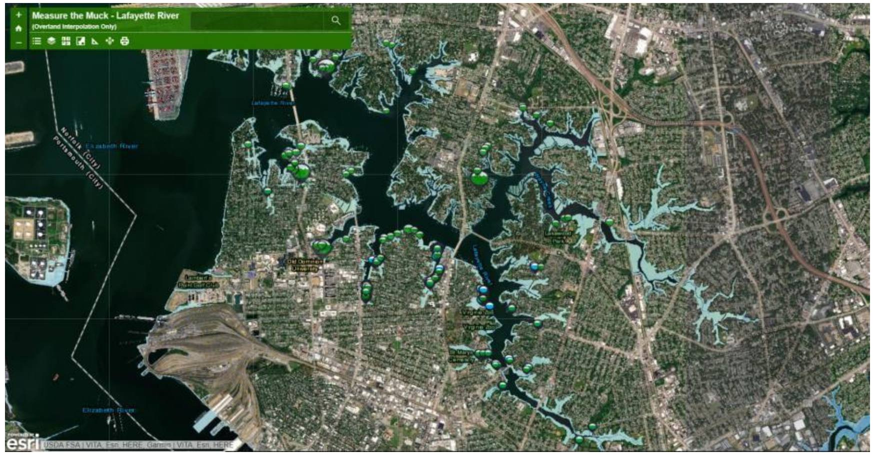
[N] in flooding water = volume of water on the streets $\times$ ($[NH_4^+]_{\text{flood water}}$ – $[NH_4^+]_{\text{river}}$)

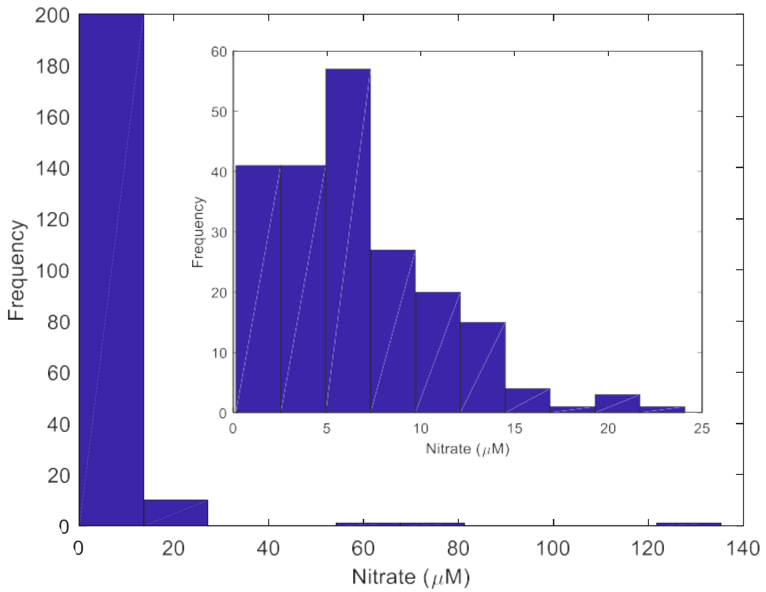
40,000,000,000 L $\times$ (0.70 µM NH_4^+ - 0.55 µM NH_4^+)

39,394,402 m^3 ≈ **40,000,000,000 L** of flooding water during the King tide event in the Lafayette River based on mapping results.

In river NH4+ is the median of post-bloom in river surface concentrations from August and Sept

≈ 185 lbs N





[N] in flooding water = volume of water on the streets x ($[NO_3^-]_{flood\ water}$ – $[NO_3^-]_{river}$)

40,000,000,000 L x ($5.9\ \mu M\ NO_3^-$ - $4.6\ \mu M\ NO_3^-$)

39,394,402 m^3 ≈ **40,000,000,000 L** of flooding water during the King tide event in the Lafayette River based on mapping results.

In river NO3- is the median of post-bloom in river surface concentrations from August and Sept

≈ 1,602 lbs of Nitrate
≈ 1786 lbs of N total

Table 9-1. Chesapeake Bay TMDL total nitrogen (TN) annual allocations[a] (pounds per year) by Chesapeake Bay segment[b] to attain Chesapeake Bay WQS

Segment ID	Jurisdiction	CB 303(d) Segment	TN WLA (lbs/yr)	TN Land Based LA (lbs/yr)	TN AtDep[c] LA (lbs/yr)	TN TMDL (lbs/yr)	TN 2009 Existing (lbs/yr)
YRKMH	VA	Middle York River	15,026	333,648	164,516	513,189	428,617
EBEMH	VA	Eastern Branch Elizabeth River	162,243	9,662	14,810	186,716	263,580
LAFMH	VA	Lafayette River	70,367	1,941	7,274	79,582	71,296
LYNPH	VA	Lynnhaven River	409,349	25,873	5,728	440,951	1,850,029
NORTF	PA	Northeast River	1,324	33,132		34,456	55,984
NORTF	MD	Northeast River	55,341	177,361		232,702	253,404
NORTF		Northeast River	56,665	210,493	31,564	298,723	309,388
ELKOH	PA	Elk River	39,372	210,104		249,476	385,703
ELKOH	DE	Elk River	2,193	8,312		10,506	12,615
ELKOH	MD	Elk River	92,717	277,145		369,863	470,335
ELKOH		Elk River	134,283	495,562	83,506	713,351	868,653
C&DOH_DE	DE	C&D Canal, DE	5,787	14,830		20,617	29,732
C&DOH_DE	MD	C&D Canal, DE	1	105		106	193
C&DOH_DE		C&D Canal, DE	5,788	14,935	18,818	39,540	29,925
C&DOH_MD	DE	C&D Canal, MD	15,427	38,028		53,455	72,814
C&DOH_MD	MD	C&D Canal, MD	10,954	37,855		48,808	59,686

This amount equals the TN-TMDL permitted for land-based load allocation in a year!

- Conservative nutrient concentrations;
- Not considering organic or particulate components;
- It is the calculation for a single event

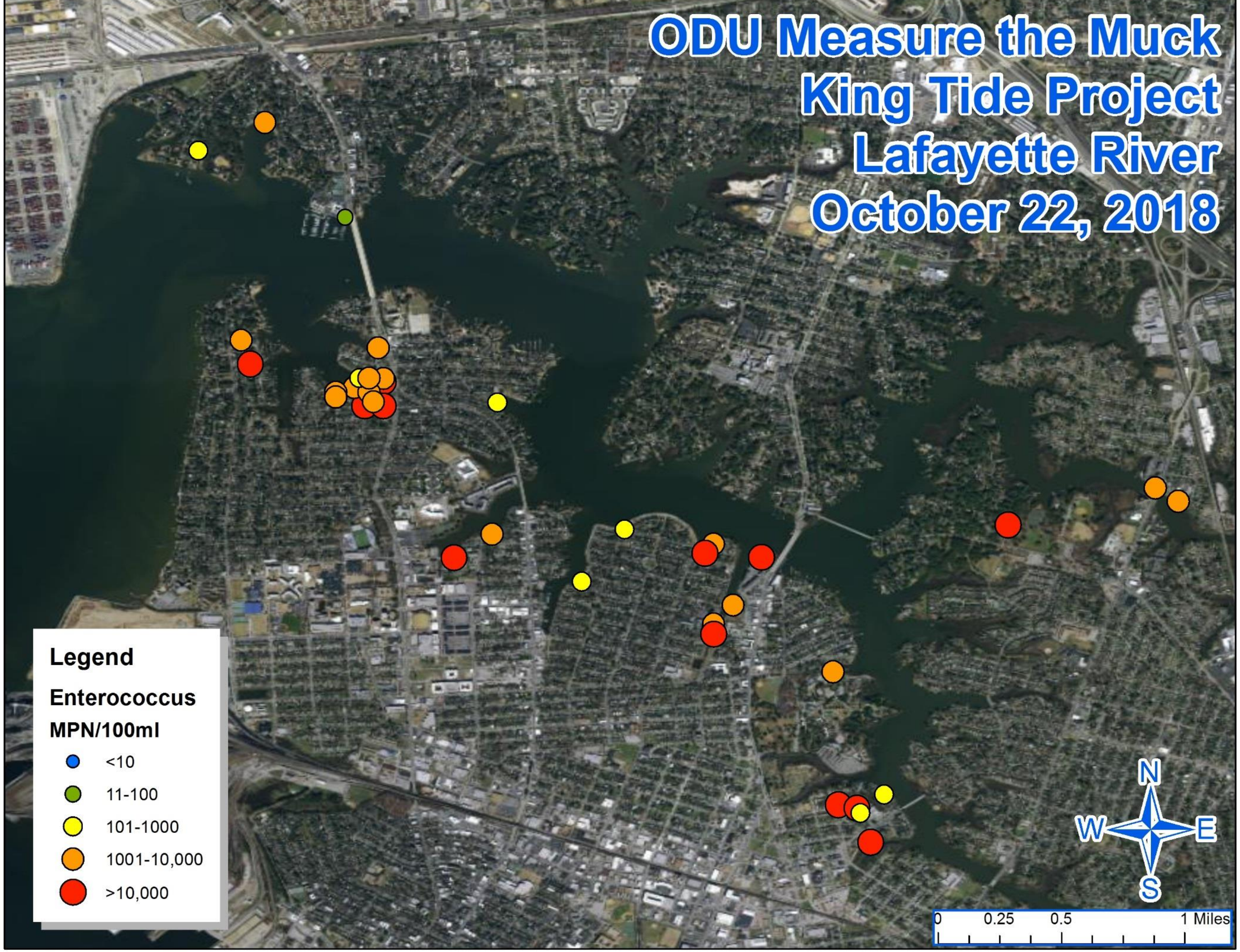
a. MOS is implicit for nitrogen (see Section 6.2.4)
b. Each of the 92 segments is displayed as white rows while contributing portions of some of the 92 segments are displayed as gray rows.
c. AtDep means atmospheric deposition only for direct deposition to tidal waters.
Note: Any differences between this table and Table 8-5 are due to rounding.

WLA= waste load allocations

And a big ick for Enterococcus!

3 samples met swimmable standards (106 MPN)

7 were above 24,000 MPN



Now what? We've established sentinel sites to assess variability in loading during tidal flooding

- Seasonal variability
- Different landscape prehistory
- Different land uses

What’s next?

Climate change and flooding will jeopardize coastal restoration efforts. We need to adapt our efforts to reduce water quality impairments.