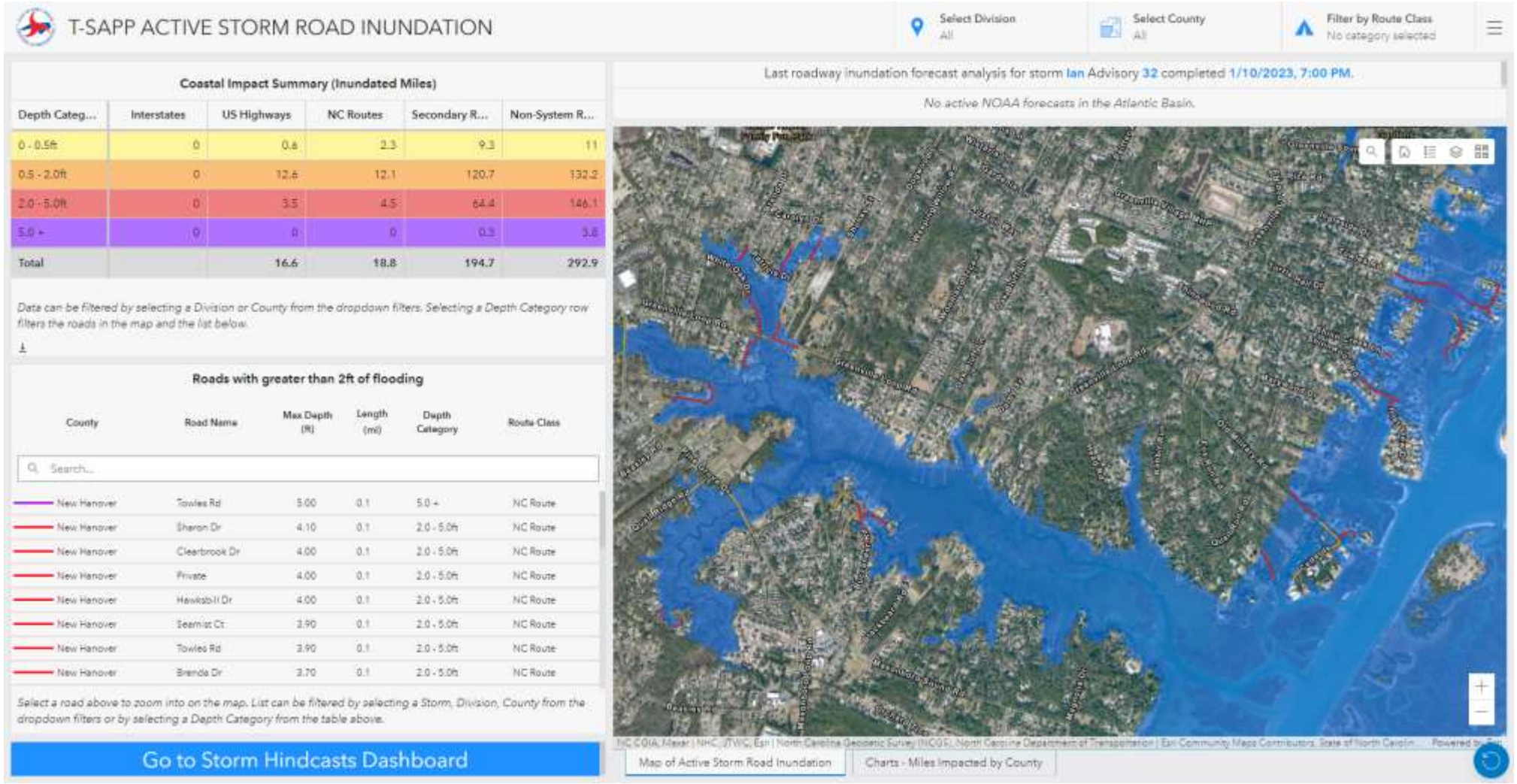


T-SAPP

Transportation Surge Analysis Prediction Program

Predictive Statewide Coastal Inundation Mapping for Road Networks

Coastal GeoTools Conference 2023
Charleston, SC – February 9, 2023

Kurt Golembesky, PE, CFM
NCDOT Hydraulics

Matthew Dudley, PE, CFM
ESP Associates, Inc.

Presentation Outline

- Background
- NCDOT Flood Warning Tools Overview
- T-SAPP Goals
- Data and Processing
- Application Overview
- Next Steps

Image Credit: US Coast Guard

Background

- North Carolina Susceptible to Hurricanes
  - 413 known cyclones that have affected NC
  - 16 have made landfall in NC over last 27 years
  - Hurricane Florence - $266M damage to roads
- North Carolina FIMAN
  - Successful gage-based statewide flood warning system developed by NCEM
  - Near real-time awareness of flood impacts to structures in limited area around gage location
  - Scenario planning tool available but forecasts limited to where River Forecast Centers provide information (predominantly large riverine systems)

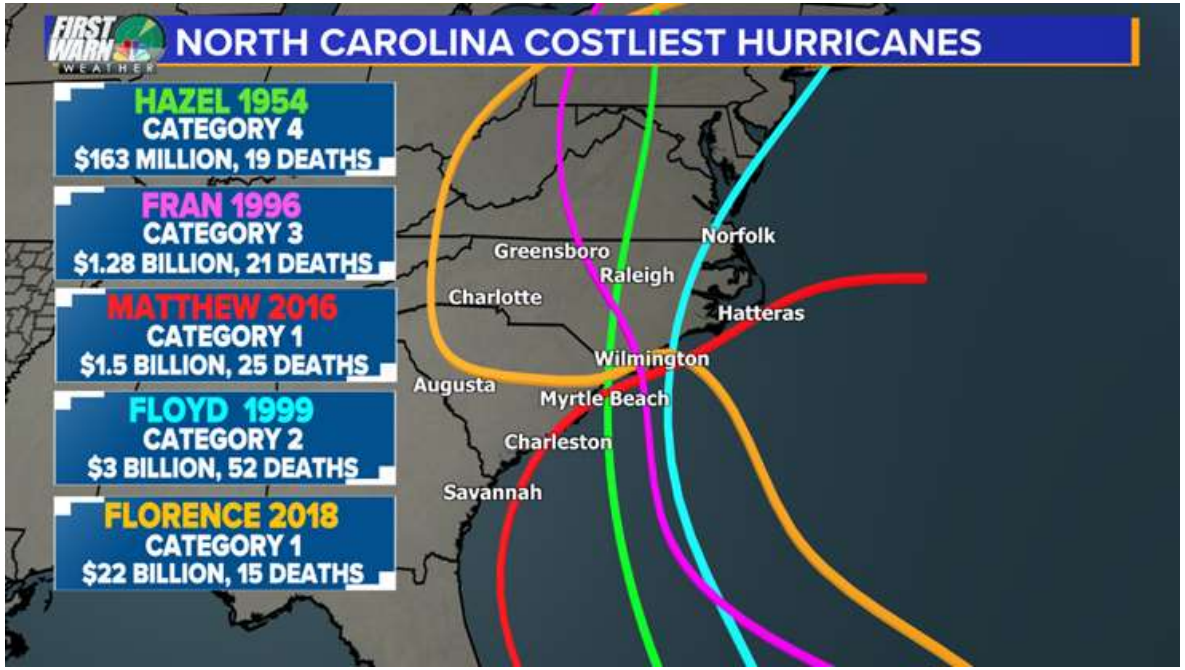
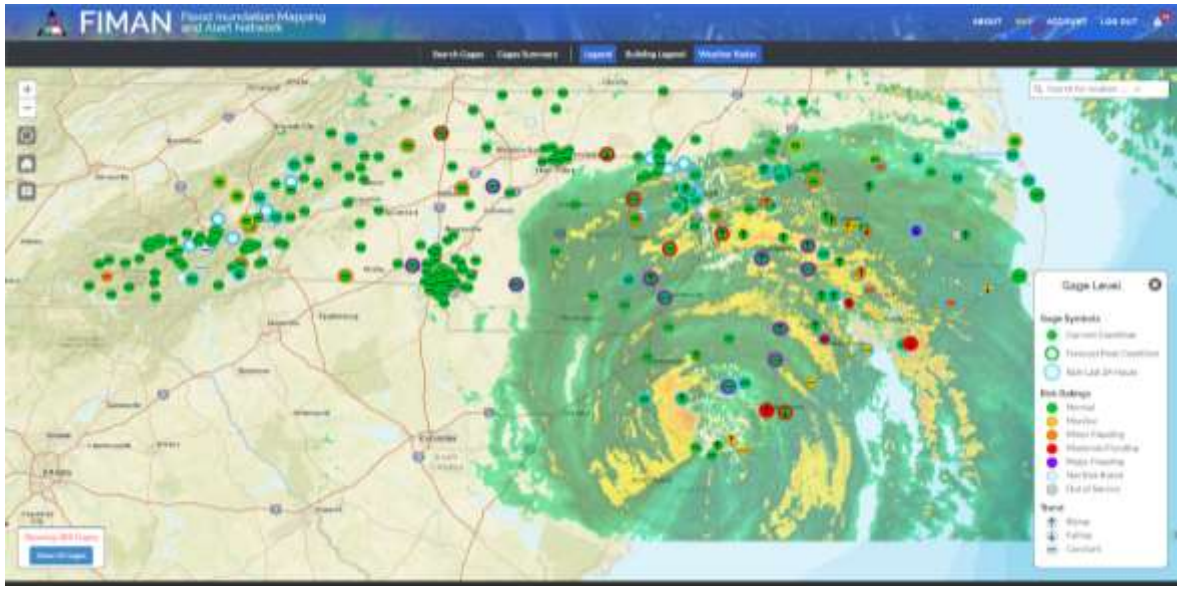


Image Credit: WCNC Charlotte



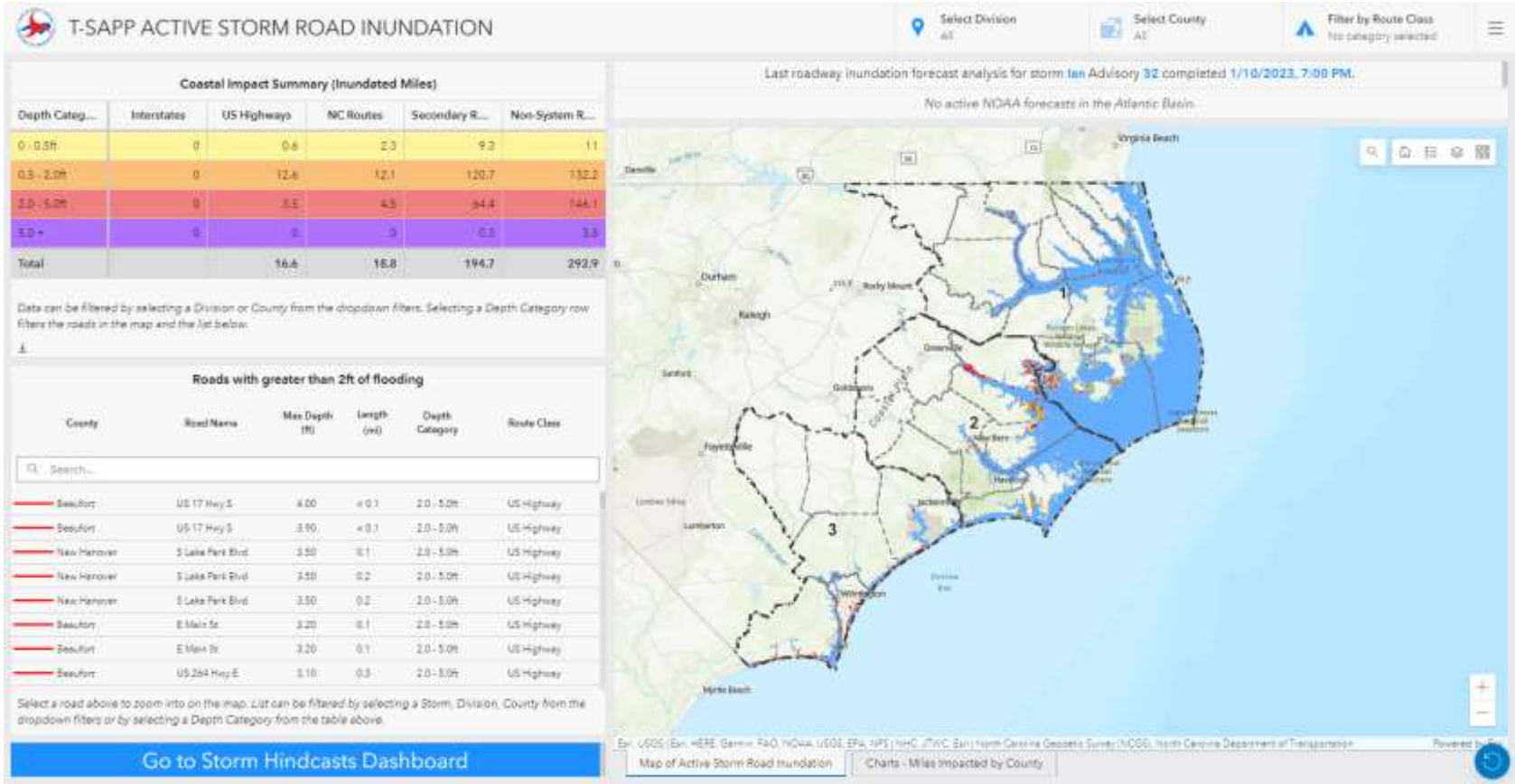
NCDOT Flood Warning Tools

NCDOT Flood Warning Tools

- RIT: Roadway Inundation Tool
  - Planning tool with estimated roadway inundation based on static flood recurrence intervals from FEMA studies
- CRIS: Coastal Roadway Inundation System
  - Planning tool for coastal road inundation based on intervals of static, level pool flooding along the NC coast
- FIMAN-T: Flood Inundation Mapping Alert Network for Transportation
  - Gage-based tool providing near real time awareness of flood impacts to roads and bridges within limited areas around riverine and coastal gages
- T-SAPP: Transportation Surge Analysis Prediction Program
  - Predictive tool based on ADCIRC modeling provided by UNC-RENCI Center capable or providing advance awareness of potential coastal roadway flood impacts for entire NC coast specific to individual storms

T-SAPP Goals

- Provide advance awareness of potential coastal roadway impacts for improved planning
- Seamless coverage of entire NC coastline
- Inundation mapping and inundated road products of sufficient detail to identify street level impacts
- Ability to compare impacts from past storms
- Reporting tools to summarize impacts for Sr. leadership



UNC RENCI Center

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Contact RENCI

919-445-9640
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100 Europa Drive Suite 540
Chapel Hill, North Carolina 27517

Forecasting Coastal Impacts from Tropical Cyclones along the US East and Gulf Coasts using the ADCIRC Prediction System

Overview

Over the past two decades ADCIRC (http://adcirc.org) has become one of, if not the most widely used community modeling platform for storm surge / coastal flooding predictions across academia, governmental agencies and the private sector. The ADCIRC Prediction System (APS) manages ADCIRC on HPC resources for real-time computation of coastal hazards. This project is expanding the existing APS to incorporate new forcing mechanisms and models (NOAA's new WaveWatch3, COAMPS-Tropical Cyclone forcing, and XBeach) and new features such as coastal erosion and sediment transport and damage assessment tools.

Project Team

- Rich Luettich (lead)
- Brian Blanton

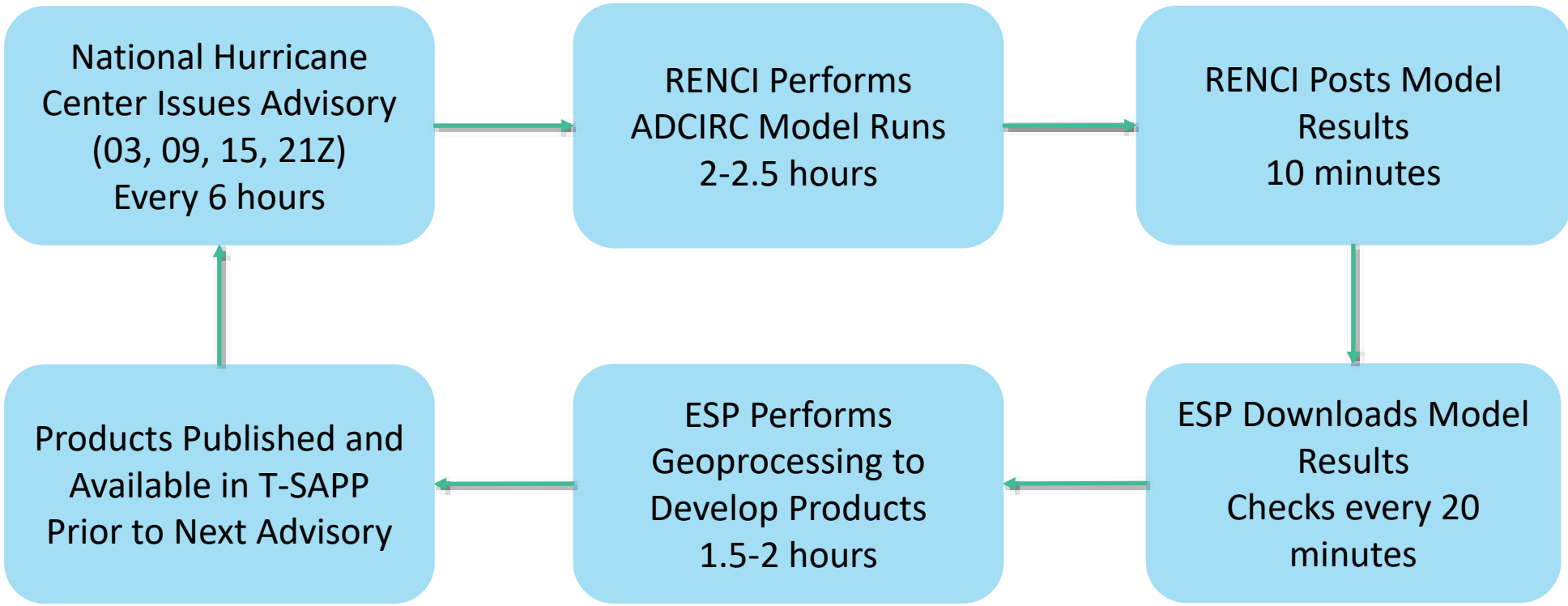
Partners

- University of Georgia
- The Water Institute of the Gulf
- Oregon State University
- North Carolina State University
- University of Rhode Island
- Seahorse Coastal Consulting

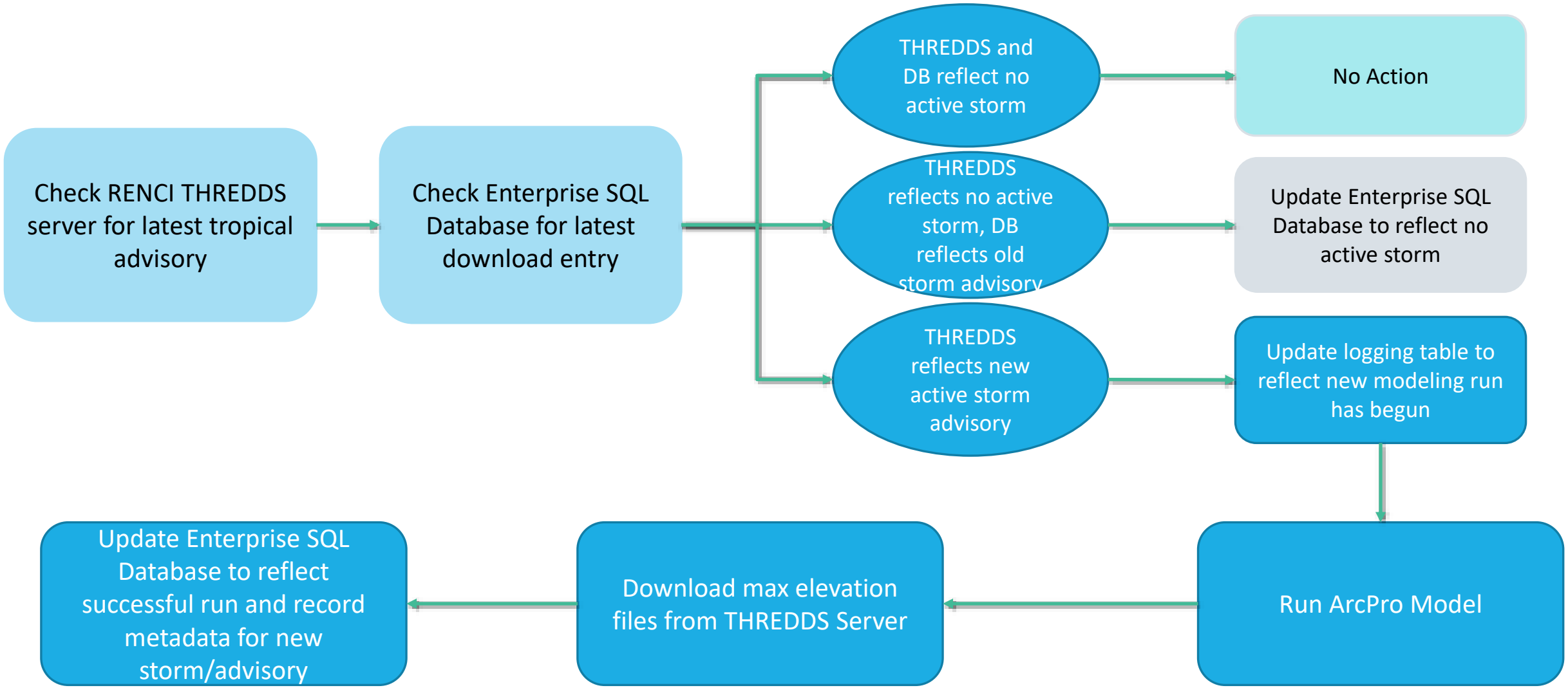
Funding

- National Ocean Partnership Program (NOPP) and the Office of Naval Research (ONR)

Overall Workflow

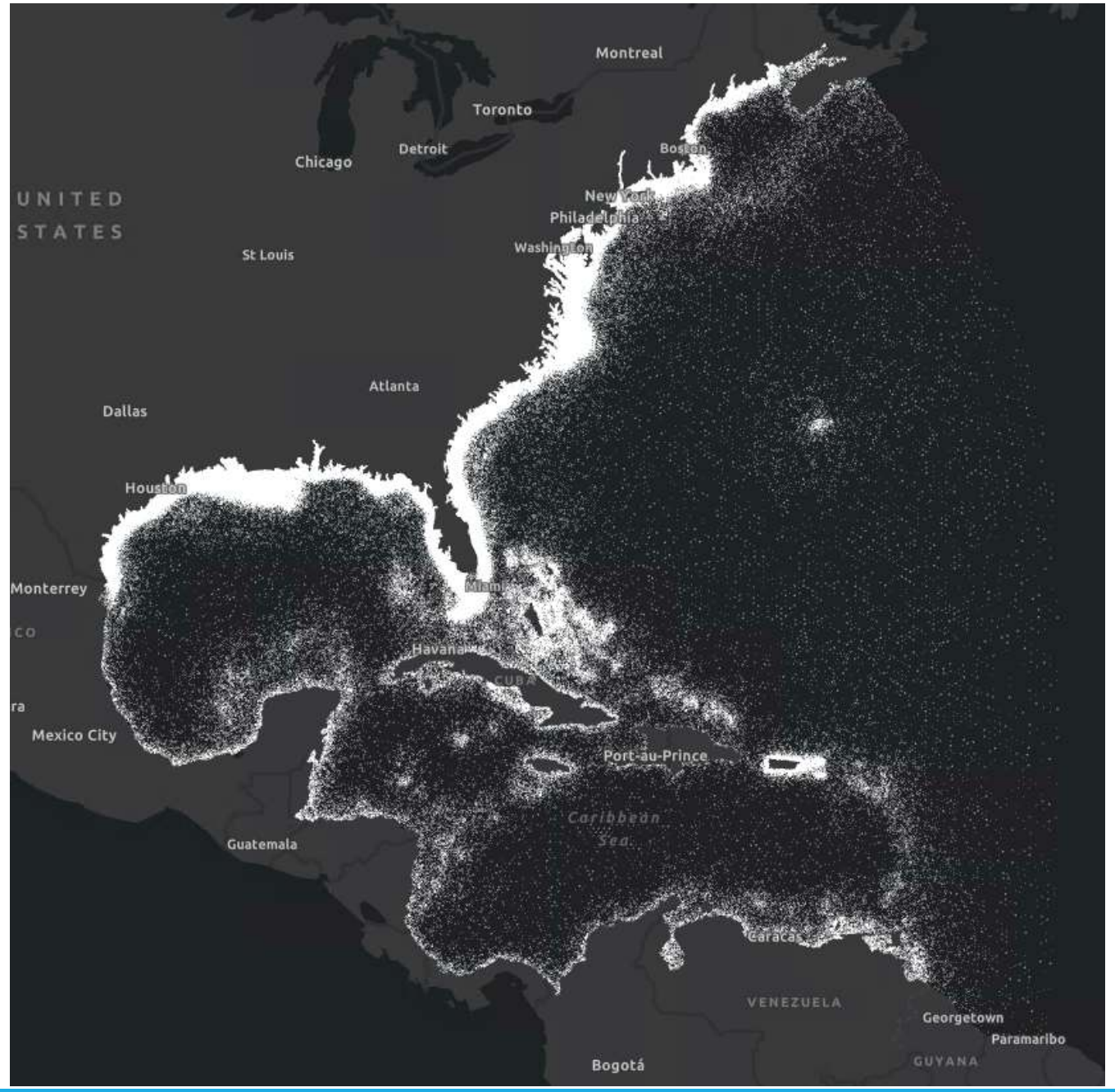


Automation Flow



RENCI Data

- Data downloaded from RENCI covers the entire eastern coast of the US, as well as coastlines bordering the Gulf of Mexico and the Caribbean Sea
- Data is maximum for each point for duration of model prediction (no time series)

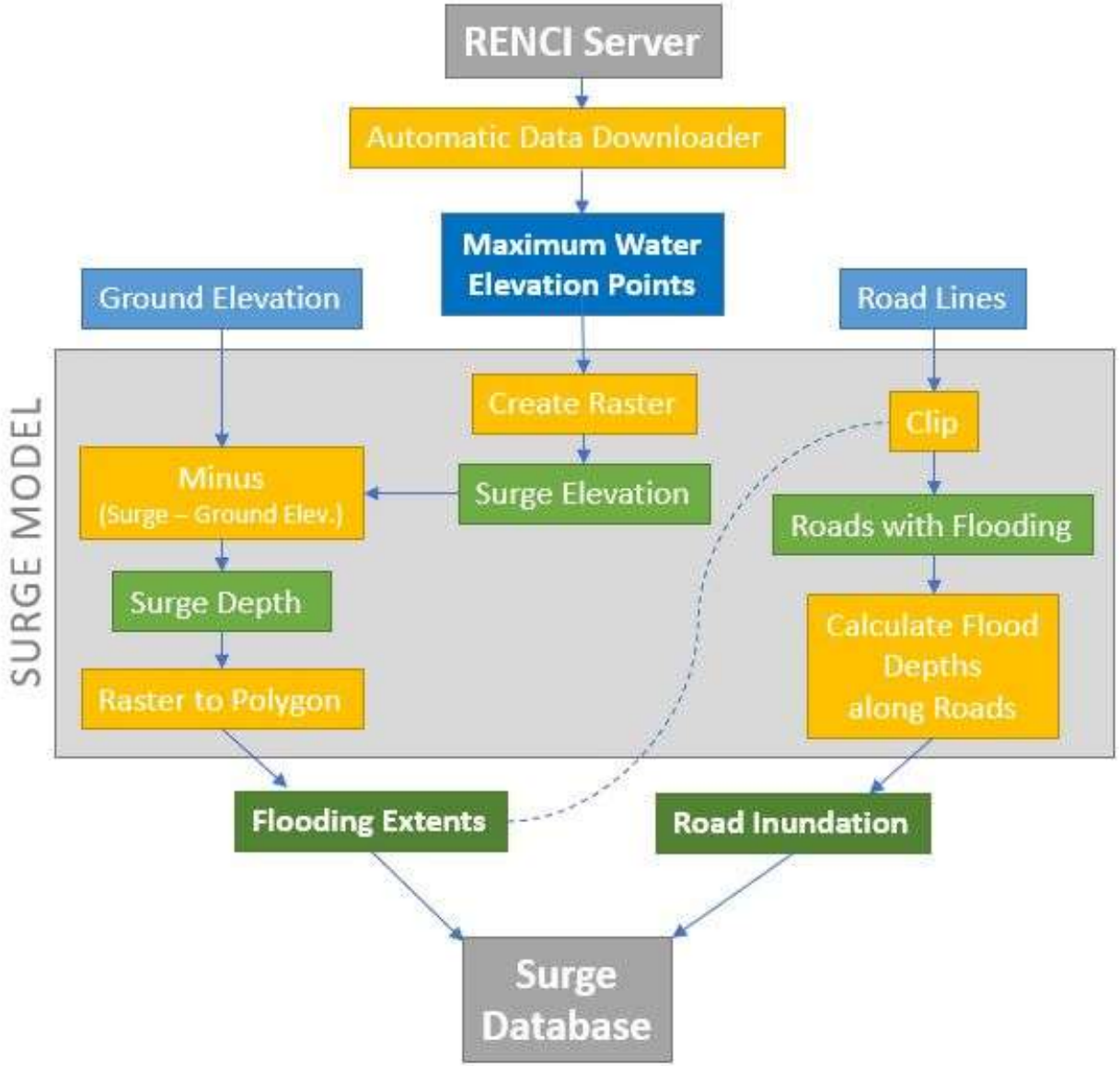


RENCI Data

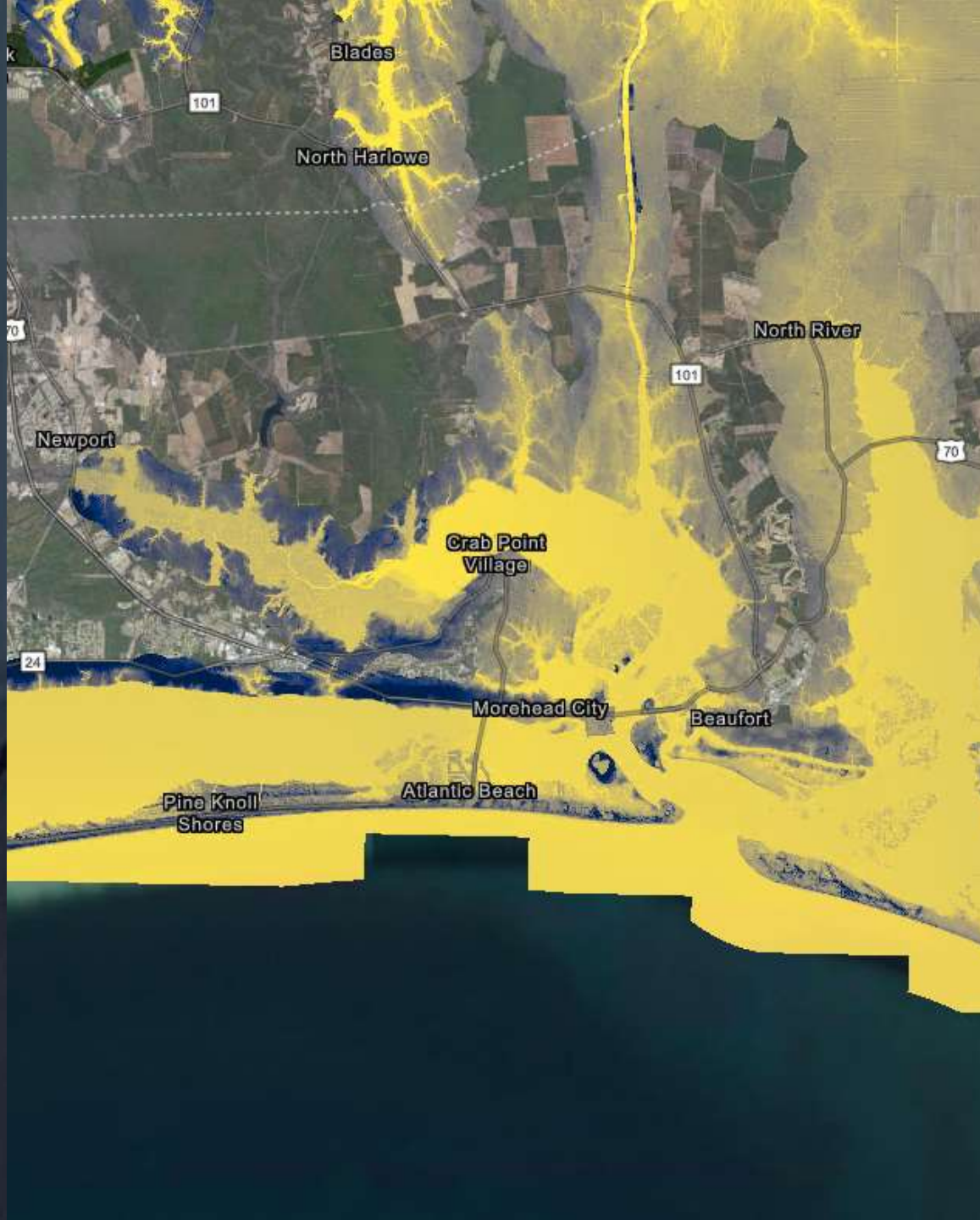
- RENCI data points are clipped to the coastal boundary of NC, resulting in 58,350 points of water surface elevation data
- Data clipped up rivers based on expected coastal flood surge extent from known storm extents and FEMA FIRMs

Converting RENCI data

- Data is downloaded from RENCI as a NetCDF
- The NetCDF data for maximum water surface elevation is converted into points with stored values
- Points are converted into rasters using IDW
- A coastal DEM that includes bridge and roadway elevations is subtracted from the RENCI water surface elevation raster to create a raster of flood depth

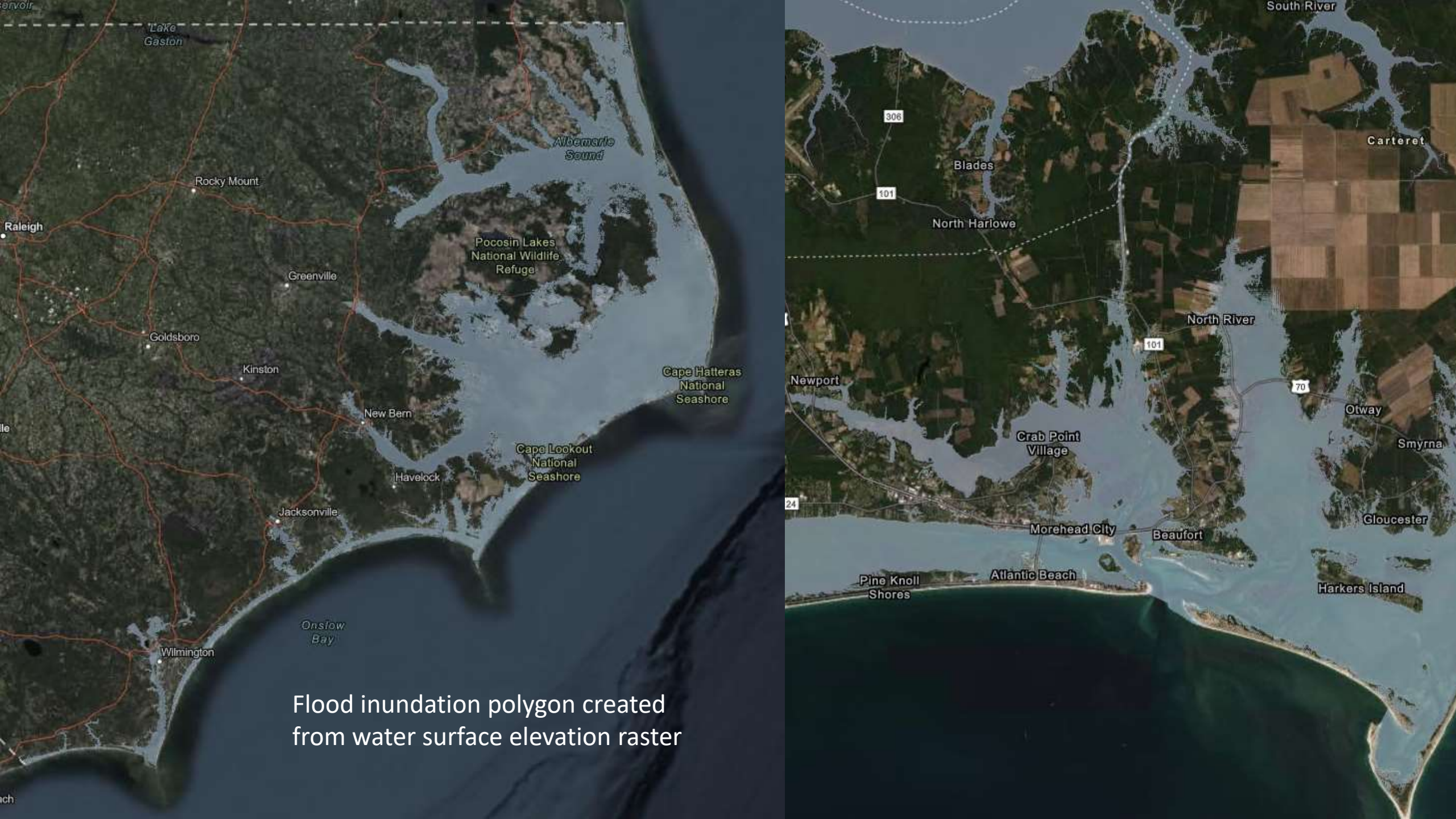


Raster created from RENCI points



Service Creation – Flood Inundation

- The flood depth raster is reclassified as an integer raster, then converted to a polygon
- Small pockets of flooding (< 5000 sqft) are deleted from the polygon
- Open water areas are merged with the flood polygon
- Smoothing/simplification to reduce vertices
- The polygon is then split by geographic boundaries for NCDOT divisions (1-3)
- Inundation polygon is published to GIS Services/GIS Server, overwriting previous advisory

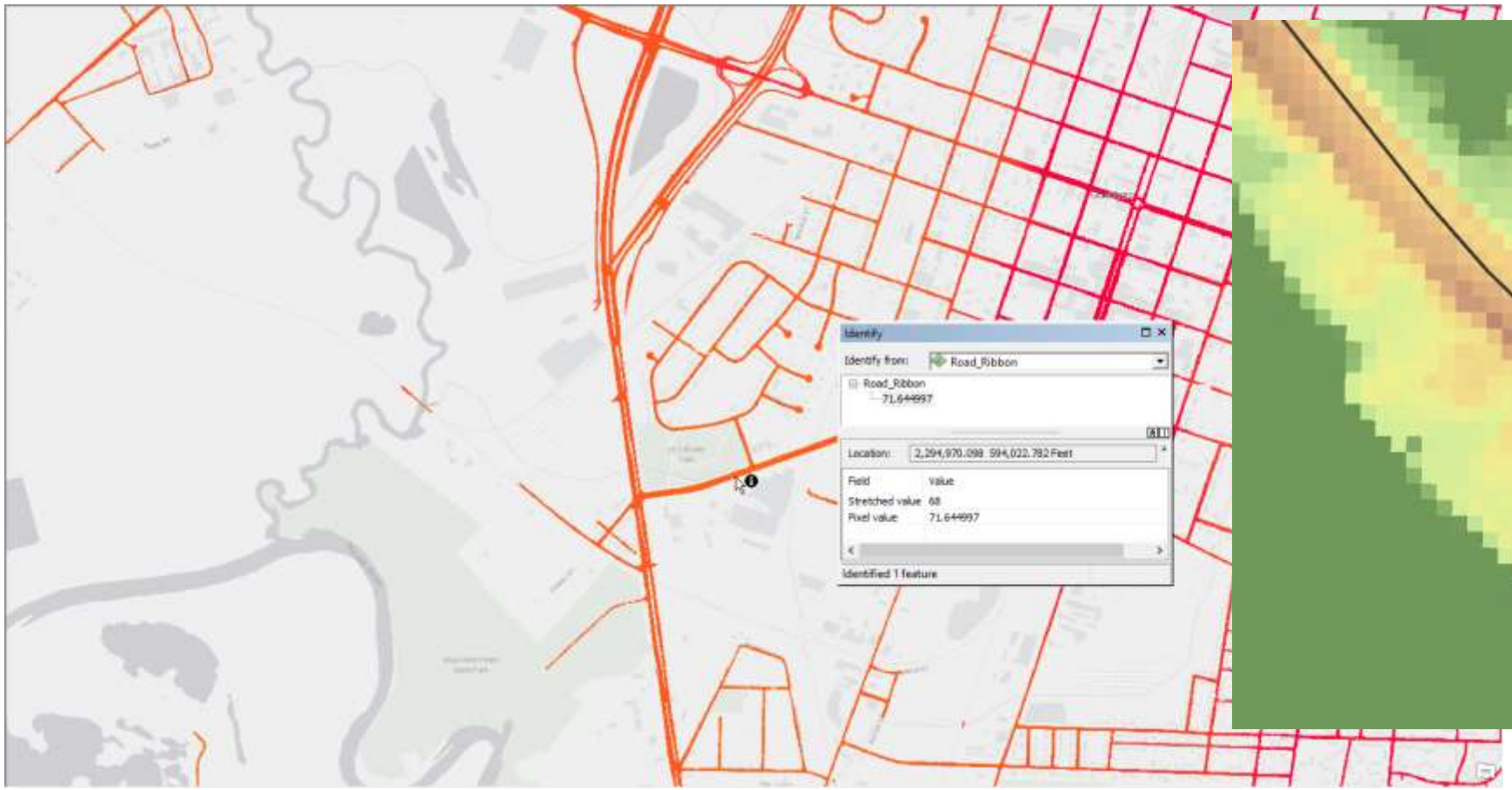


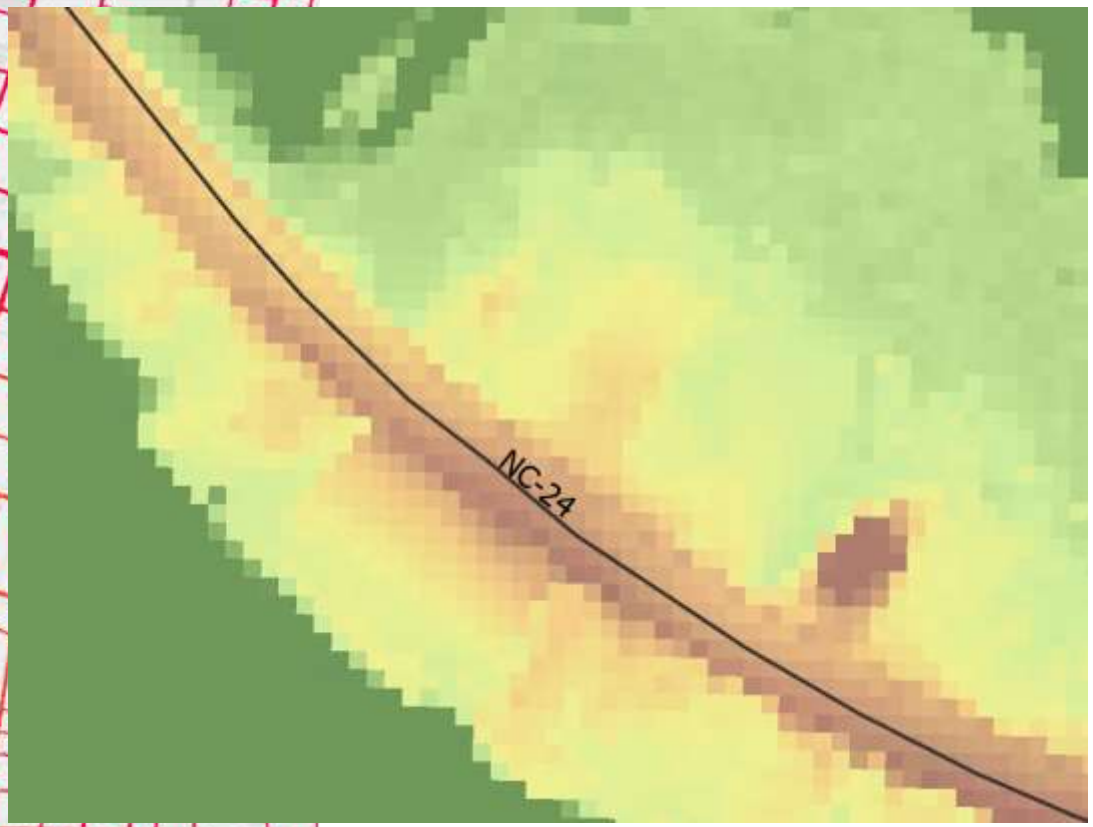
Flood inundation polygon created from water surface elevation raster

Input Data – Roadways

Roadway polylines are corrected to align with the coastal DEM

Road lines are dissolved by route name and class and split into 50-ft segments for inundated roads processing





Inundated Roadways Calculation

- Roadways are clipped to the polygon flood inundation
- Zonal statistics are calculated for each 50-ft roadway segment, extracting values from the flood depth raster
- The maximum value from each segment is then used to assign a pre-defined depth category to the segment
- Roadway segments are dissolved based on roadway category, resulting in longer continuous segments that share depth category, route name, route class, division, and county
- Length attributes are calculated for each segment
- Roadways are published to GIS Services/GIS Server, overwriting previous advisory

Roadways Summary Table Generation

- The attribute tables from inundated roadways are used to generate summary tables
- Pivot is used to summarize inundated roadways length, categorized by depth category
- Fields retained in pivot include roadway division, county, class, and maximum depth
- Final summarization is completed to calculate total lengths affected within each county and division, aggregated by depth category
- Summary table is published to GIS Services/GIS Server, overwriting previous advisory

T-SAPP ACTIVE STORM ROAD INUNDATION

Select Division: All | Select County: All | Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Cat...	Interstates	US Highways	NC Routes	Secondary ...	Non-Syste...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
5.0 +	0	0	0	0.3	3.8
Total		**16.6**	**18.8**	**194.7**	**292.9**

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

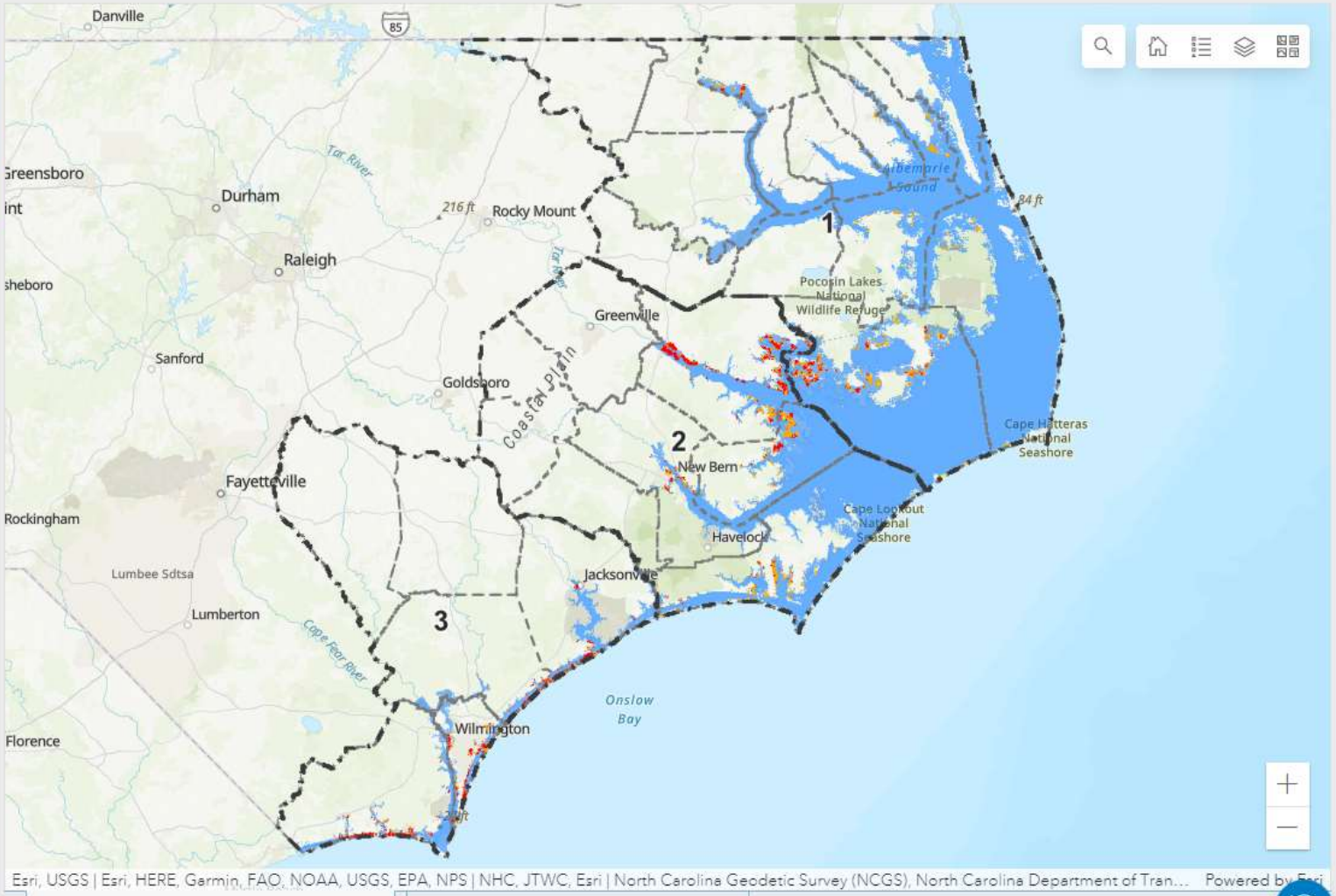
County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Search...					
Beaufort	US 17 Hwy S	4.00	< 0.1	2.0 - 5.0ft	US Highway
Beaufort	US 17 Hwy S	3.90	< 0.1	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.1	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.2	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.2	2.0 - 5.0ft	US Highway

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Storm Hindcasts Dashboard

Last roadway inundation forecast analysis for storm **Ian** Advisory **32** completed **1/10/2023, 7:00 PM.**

No active NOAA forecasts in the Atlantic Basin.



Map of Active Storm Road Inundation | Charts - Miles Impacted by County

T-SAPP ACTIVE STORM ROAD INUNDATION

Select Division: All | Select County: All | Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Cat...	Interstates	US Highways	NC Routes	Secondary ...	Non-Syste...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
Total		**16.6**	**18.8**	**194.7**	**292.9**

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Craven	Neuse Ave	3.20	0.1	2.0 - 5.0ft	NC Route
Craven	Trappers Trl	3.00	0.1	2.0 - 5.0ft	NC Route
Craven	Harbor Dr	2.70	0.1	2.0 - 5.0ft	NC Route
Craven	Oaks Rd	2.60	< 0.1	2.0 - 5.0ft	NC Route
Craven	National Ave	2.50	0.1	2.0 - 5.0ft	NC Route
Craven	Oaks Rd	2.30	0.1	2.0 - 5.0ft	NC Route

Search...

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Storm Hindcasts Dashboard

Last roadway inundation forecast analysis for storm **Ian** Advisory **32** completed **1/10/2023, 7:00 PM.**

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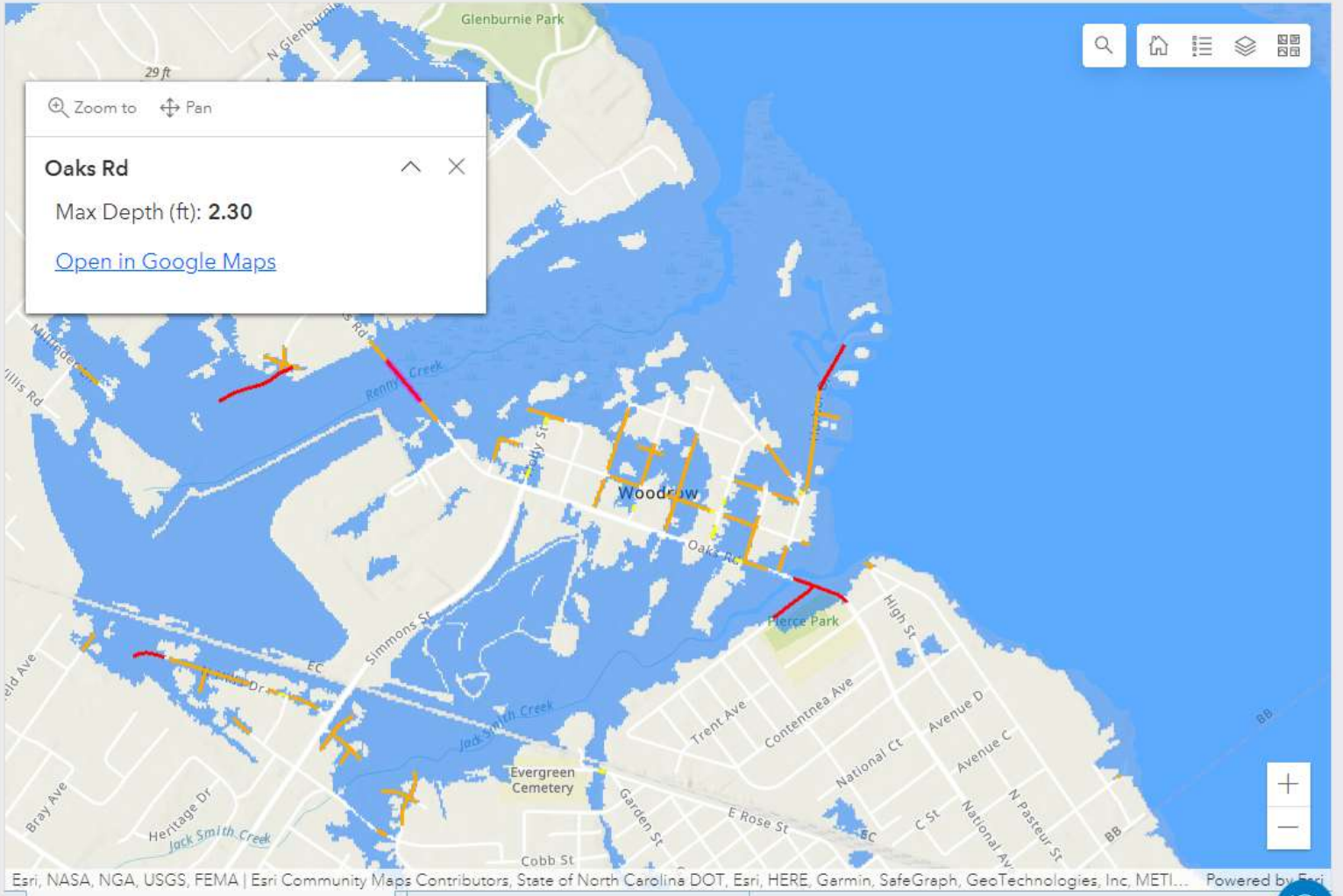

Map of Active Storm Road Inundation | Charts - Miles Impacted by County

T-SAPP ACTIVE STORM ROAD INUNDATION

Select Division: All | Select County: All | Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Cat...	Interstates	US Highways	NC Routes	Secondary ...	Non-Syste...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
Total		**16.6**	**18.8**	**194.7**	**292.9**

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Pamlico	Orchard Creek Rd	5.20	0.1	5.0 +	Secondary Route

Search: Orchard

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Storm Hindcasts Dashboard

Last roadway inundation forecast analysis for storm **Ian** Advisory **32** completed **1/10/2023, 7:00 PM.**

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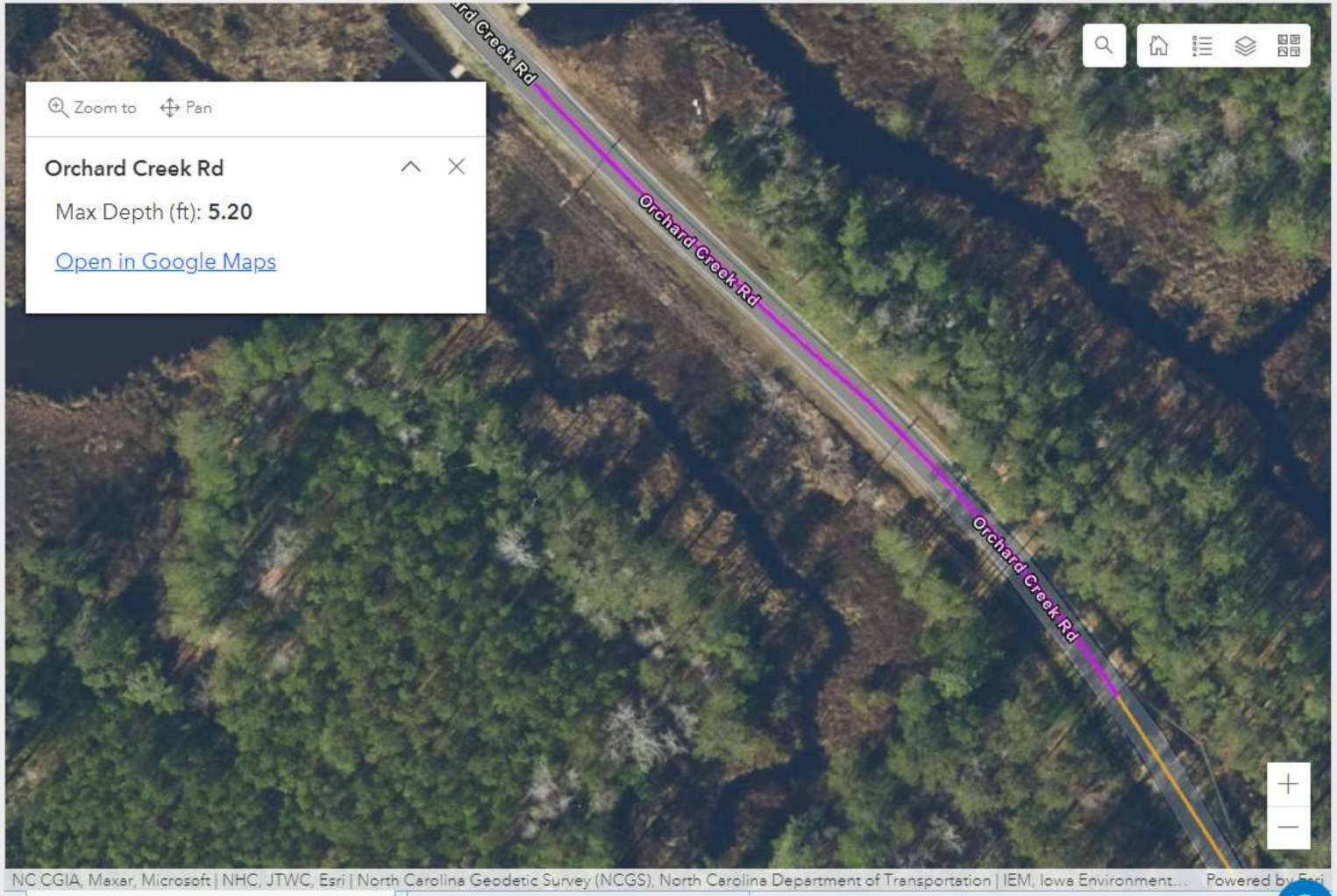


Map of Active Storm Road Inundation | Charts - Miles Impacted by County

T-SAPP ACTIVE STORM ROAD INUNDATION

Select Division: All | Select County: All | Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Cat...	Interstates	US Highways	NC Routes	Secondary ...	Non-Syste...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
Total		**16.6**	**18.8**	**194.7**	**292.9**

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Beaufort	US 17 Hwy S	4.00	< 0.1	2.0 - 5.0ft	US Highway
Beaufort	US 17 Hwy S	3.90	< 0.1	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.1	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.2	2.0 - 5.0ft	US Highway
New Hanover	S Lake Park Blvd	3.50	0.2	2.0 - 5.0ft	US Highway

Search...

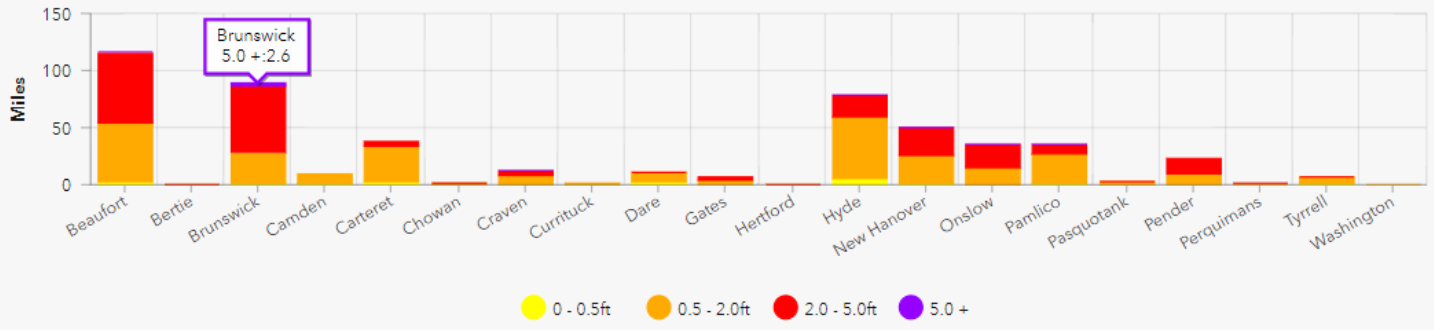
Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Storm Hindcasts Dashboard

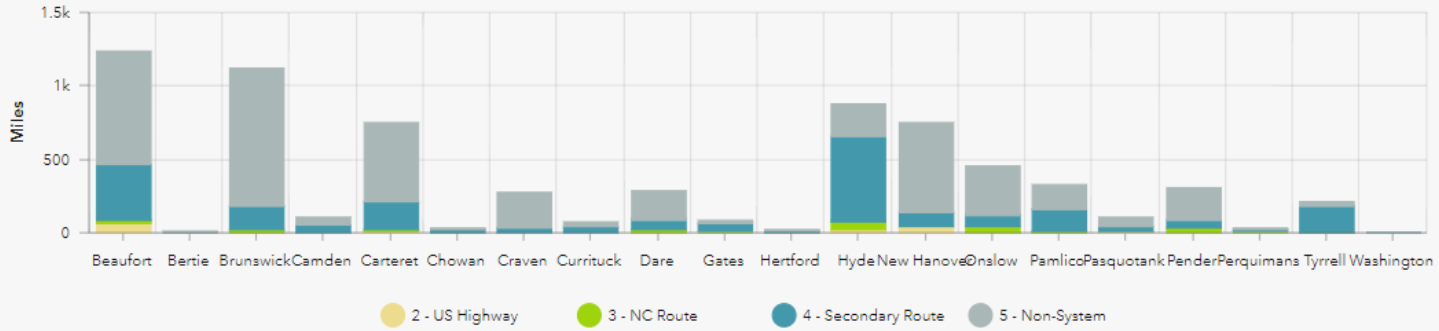
Last roadway inundation forecast analysis for storm **Ian** Advisory **32** completed **1/10/2023, 7:00 PM**.

No active NOAA forecasts in the Atlantic Basin.

Miles Impacted by County & Depth Category



Miles Impacted by County & Route Class



Map of Active Storm Road Inundation | Charts - Miles Impacted by County

T-SAPP ACTIVE STORM ROAD INUNDATION

Select Division: 1 | Select County: All | Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Cat...	Interstates	US Highways	NC Routes	Secondary ...	Non-Syste...
0 - 0.5ft	0	0.2	2	5.3	4
0.5 - 2.0ft	0	2.4	3.9	56.4	24.5
2.0 - 5.0ft	0	0.3	0.2	18.5	4.2
Total		**2.9**	**6.2**	**80.2**	**32.8**

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Search...					
Hyde	US 264 Hwy	2.80	0.2	2.0 - 5.0ft	US Highway
Hyde	Oyster Creek Rd	2.70	0.1	2.0 - 5.0ft	NC Route
Hyde	NC-12	2.10	0.1	2.0 - 5.0ft	NC Route
Hyde	Newlands Rd	4.50	0.8	2.0 - 5.0ft	Secondary Route
Hyde	Sladesville Credle Rd	4.30	0.2	2.0 - 5.0ft	Secondary Route

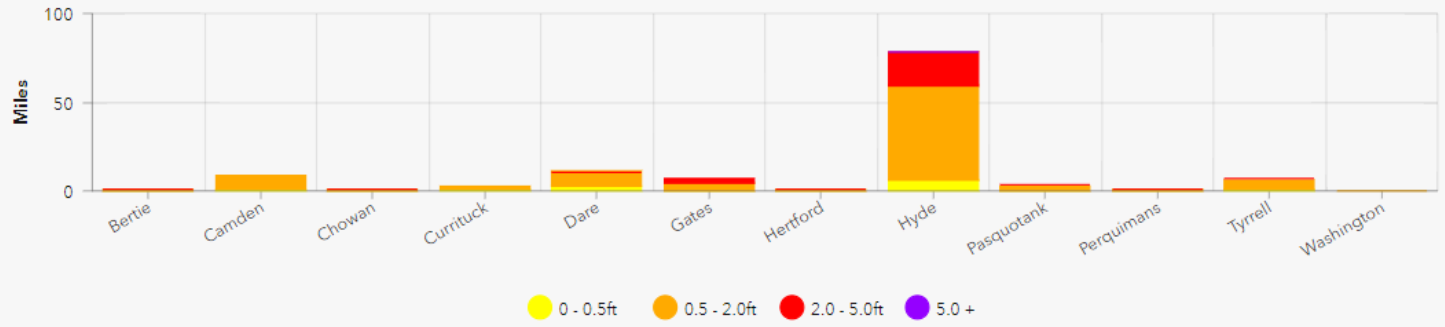
Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Storm Hindcasts Dashboard

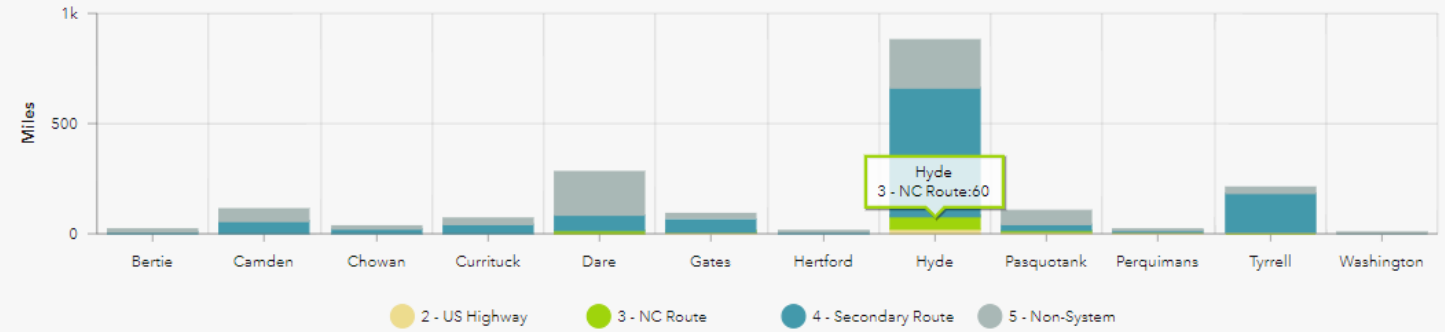
Last roadway inundation forecast analysis for storm **Ian** Advisory **32** completed **1/10/2023, 7:00 PM**.

No active NOAA forecasts in the Atlantic Basin.

Miles Impacted by County & Depth Category



Miles Impacted by County & Route Class



Map of Active Storm Road Inundation | Charts - Miles Impacted by County

T-SAPP HINDCAST ROAD INUNDATION

Select Storm Hindcast: DORIAN (2019)
Select Division: All
Select County: All
Filter by Route Class: No category selected

- DORIAN (2019)
- FLORENCE (2018)
- FLOYD (1999)
- FRAN (1996)
- IAN (2022)
- ISAIAS (2020)

Coastal Impact Summary (Inundated Miles)

Depth Ca...	Interstate	US Highw...	NC Route	Secondar...	Non-S
0 - 0.5ft	0	8	15.9	79.4	
0.5 - 2.0ft	0	11.3	35.3	210.1	
2.0 - 5.0ft	0	0.7	16.4	128.5	
5.0 +	0	0.1	1.8	2.5	
Total		**20.1**	**69.4**	**420.6**	

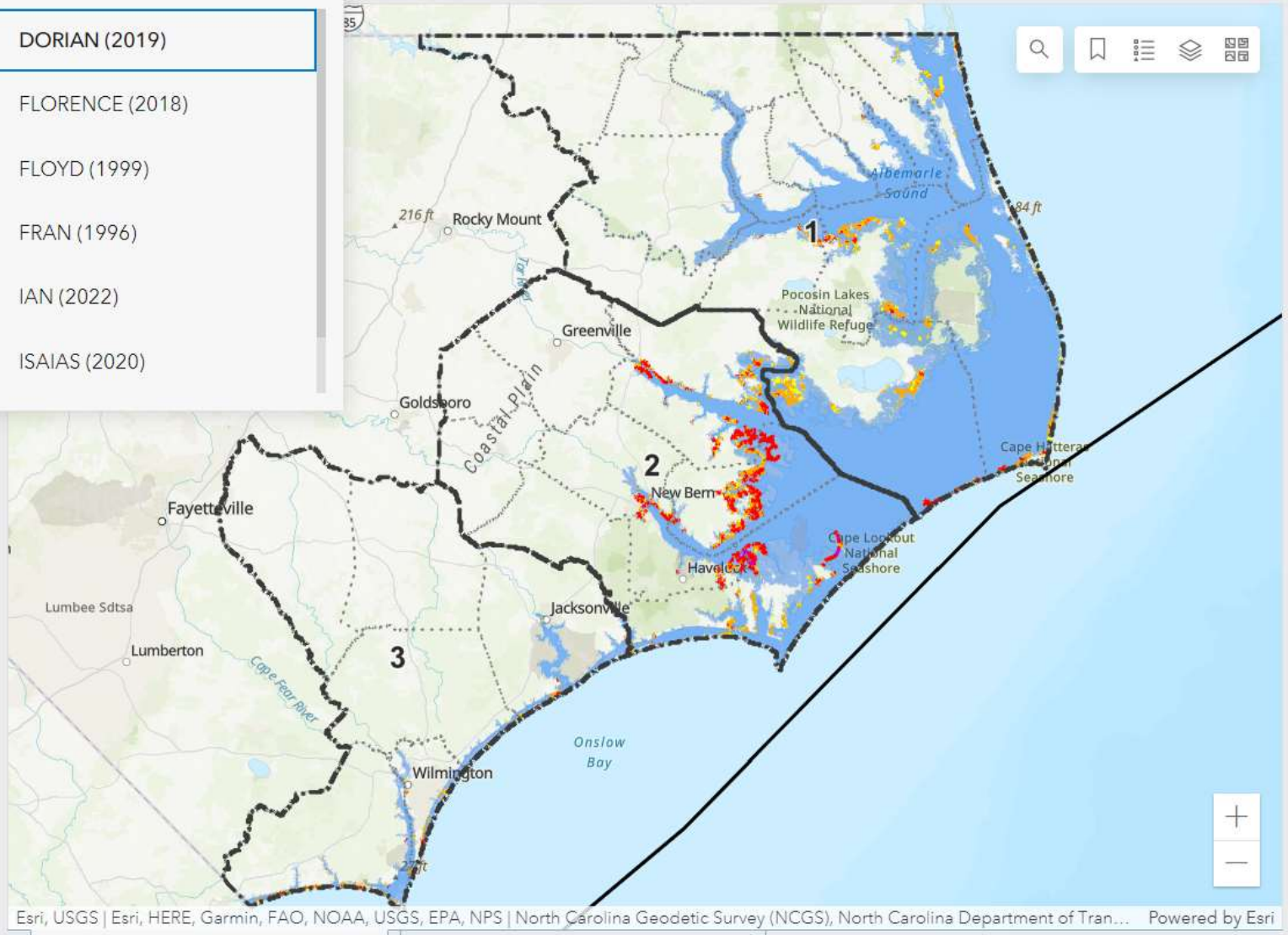
Data can be filtered by selecting a Storm, Division, or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Search...					
Pasquotank	E Elizabeth St	5.60	0.1	5.0 +	US Highway
Beaufort	E Main St	3.00	0.2	2.0 - 5.0ft	US Highway

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Active Advisory Dashboard



Map of Hindcast Road Inundation | Charts - Miles Impacted by County

T-SAPP HINDCAST ROAD INUNDATION

Select Storm Hindcast: FRAN (1996)

Select Division: All

Select County: All

Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Ca...	Interstate	US Highw...	NC Route	Secondar...	Non-Syst...
0 - 0.5ft	0	2.7	2.9	9.4	23.8
0.5 - 2.0ft	0	5.8	8.2	31.4	100.5
2.0 - 5.0ft	0	10.9	13.5	54.4	174.2
5.0 +	0	4	5	26.5	120.9
Total		**23.5**	**29.6**	**121.7**	**419.4**

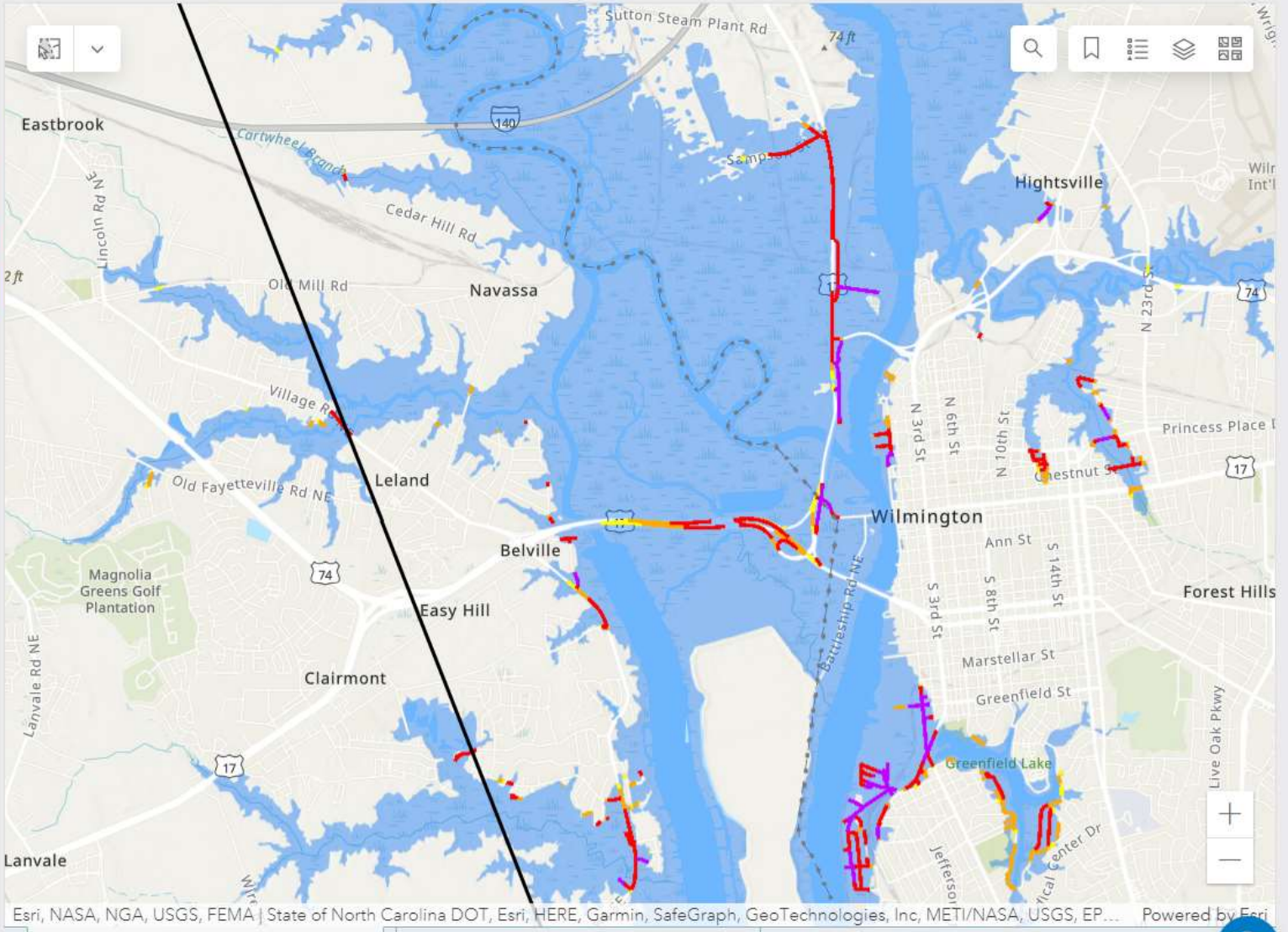
Data can be filtered by selecting a Storm, Division, or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Search...					
New Hanover	S Front St	7.60	0.4	5.0 +	US Highway
Brunswick	Hwy 133/US 421	6.70	0.2	5.0 +	US Highway

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Active Advisory Dashboard



Map of Hindcast Road Inundation | Charts - Miles Impacted by County

T-SAPP HINDCAST ROAD INUNDATION

Select Storm Hindcast: MATTHEW (2016)

Select Division: All

Select County: All

Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Ca...	Interstate	US Highw...	NC Route	Secondar...	Non-Syst...
0 - 0.5ft	0	2.7	9.5	59.1	66.1
0.5 - 2.0ft	0	2.5	15.1	105.5	113
2.0 - 5.0ft	0	0.3	5.2	19	21.6
5.0 +	0	0	0	0	0.1
Total		**5.4**	**29.8**	**183.7**	**200.9**

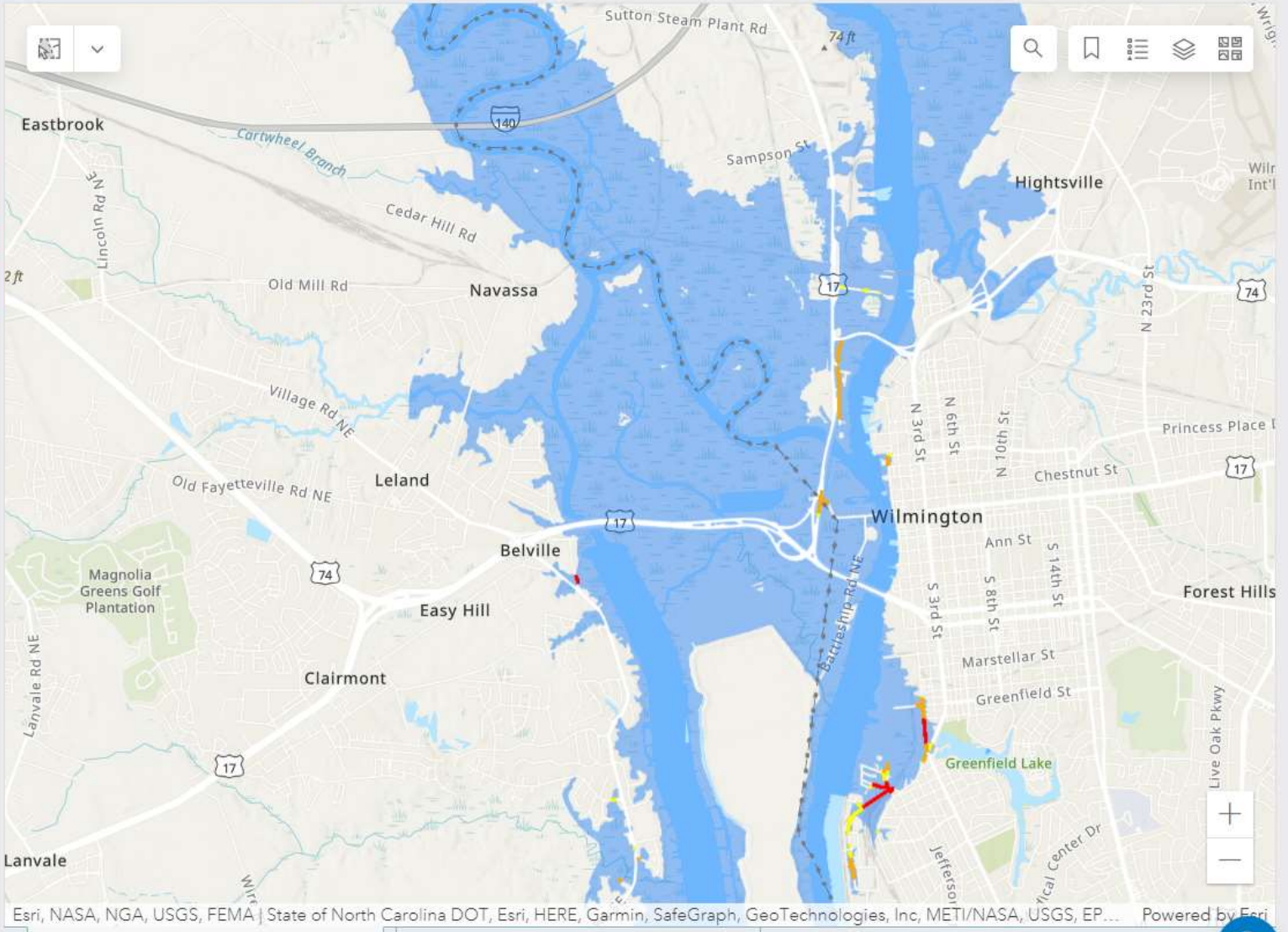
Data can be filtered by selecting a Storm, Division, or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roads with greater than 2ft of flooding

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Search...					
New Hanover	S Front St	2.20	0.2	2.0 - 5.0ft	US Highway
Brunswick	Old River Rd	2.10	0.1	2.0 - 5.0ft	Secondary Route

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Go to Active Advisory Dashboard



Map of Hindcast Road Inundation | Charts - Miles Impacted by County

T-SAPP: Planned Next Steps

Functionality / Reporting Enhancements

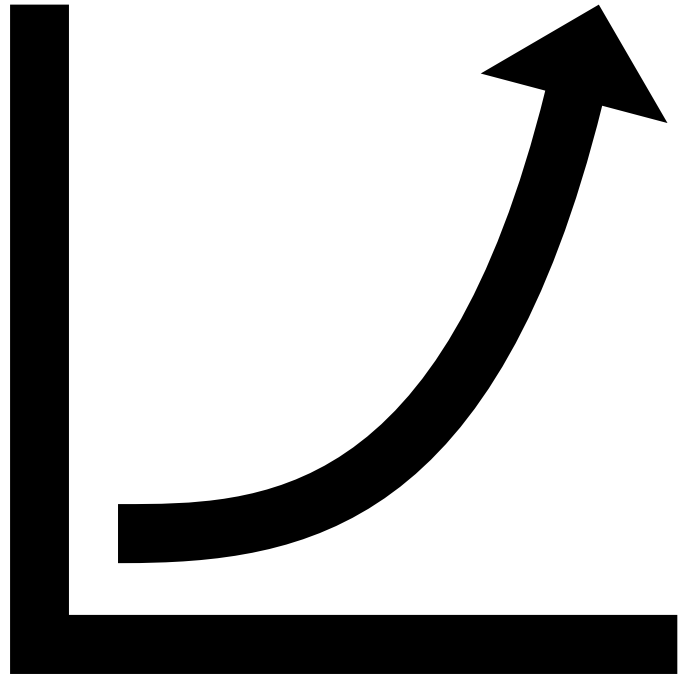
Bridge Monitoring Locations

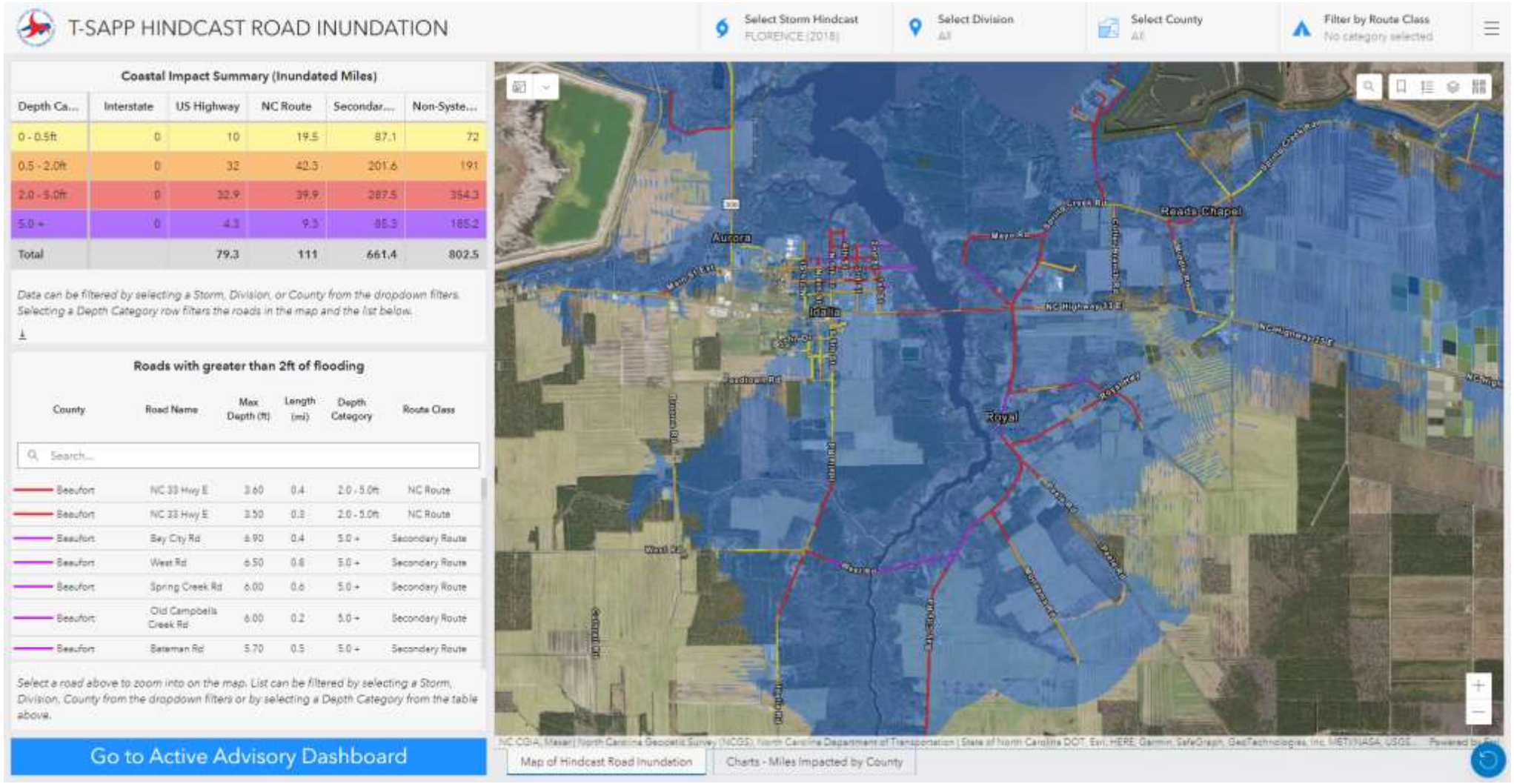
Archival of Previous Advisories

Hurricane Season 2023

Stakeholder Feedback

Process Improvement





QUESTIONS?

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