NORTH CAROLINA
Department of Transportation

Hydraulic Tools Overview

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina

OUR MISSION

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina

Hydraulic Tool Categories

- Flood Warning/ Planning Tools
- Hydraulics Data
- Stormwater
- Hydraulic Calculators

Flood Warning/ Planning Tools

FIMAN-T: Flood Inundation Mapping Alert Network for Transportation

- Gauge-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

BridgeWatch

- Bridgewatch is a real-time bridge flooding warning system that relies on stream gauges and weather radar to indicate when bridges and culverts are near flooding, actively flooding, or weather conditions are favorable for flooding

RIT: Roadway Inundation Tool

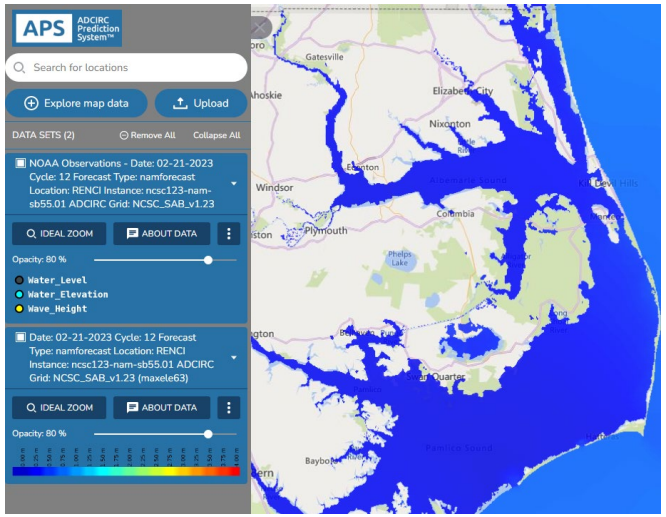
- Planning tool with estimated roadway inundation based on static flood recurrence intervals from FEMA studies

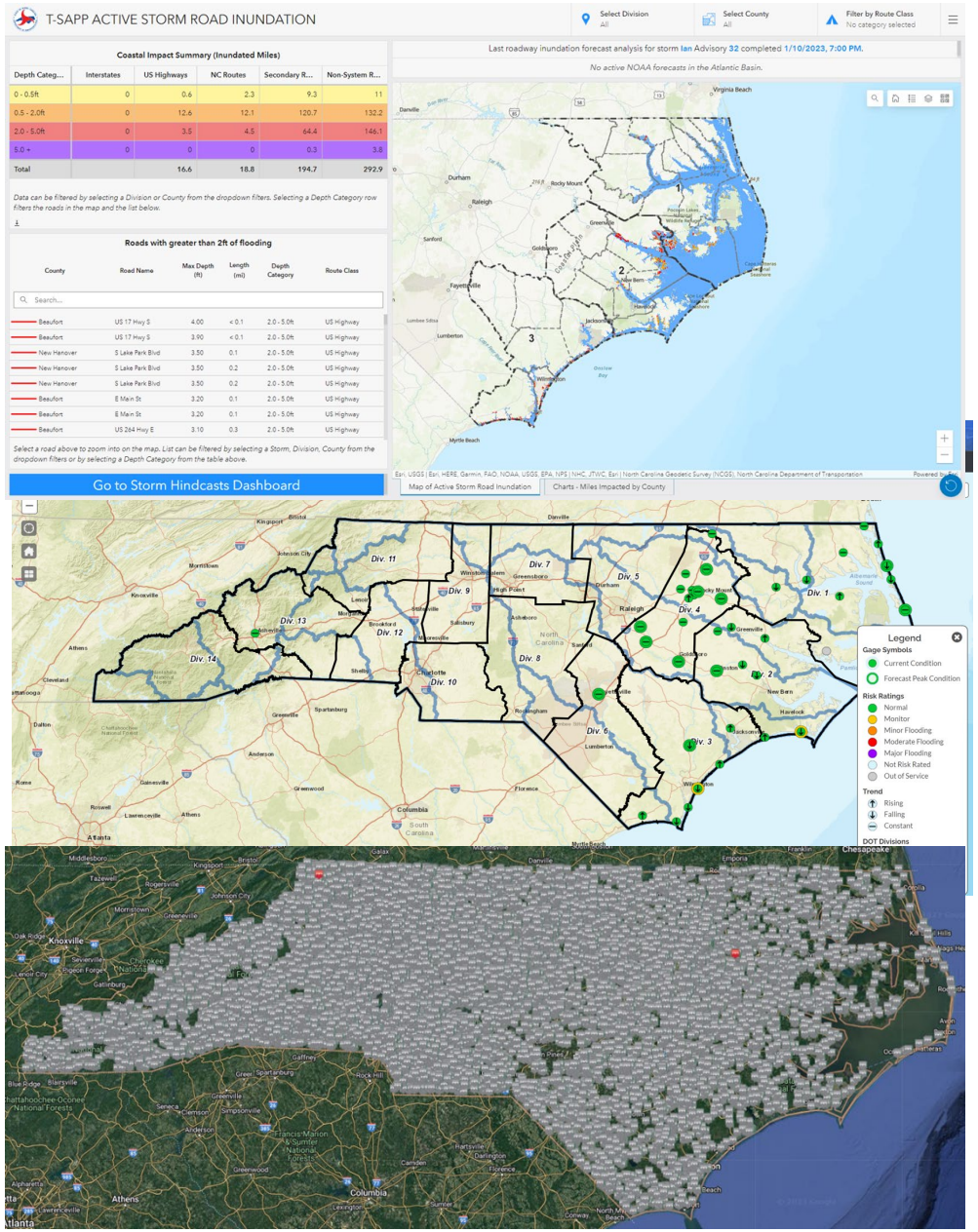
CRIS: Coastal Roadway Inundation System

- Planning tool for coastal road inundation based on intervals of static, level pool flooding along the NC coast

Flood Warning Tools-Storm Prep

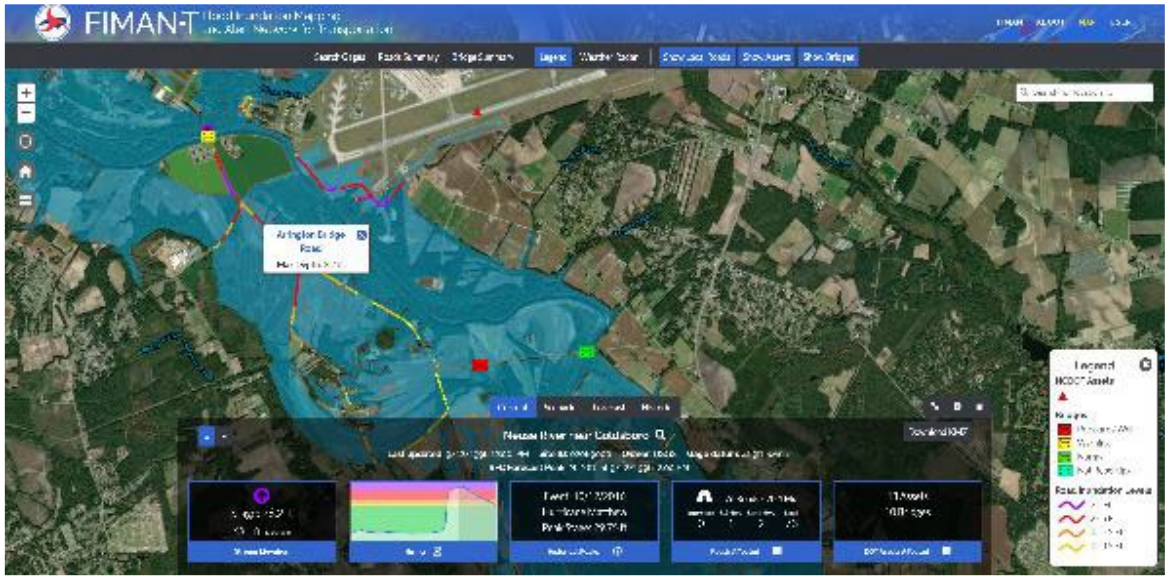
- FIMAN-T
- T-SAPP (Transportation Surge Analysis Predictive Program)
- BridgeWatch

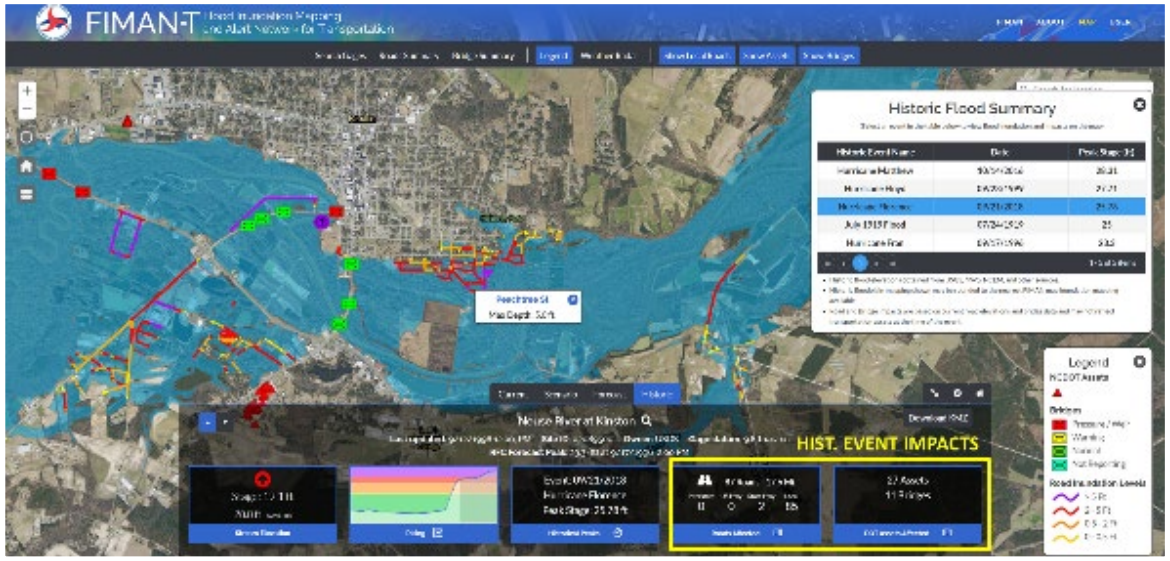




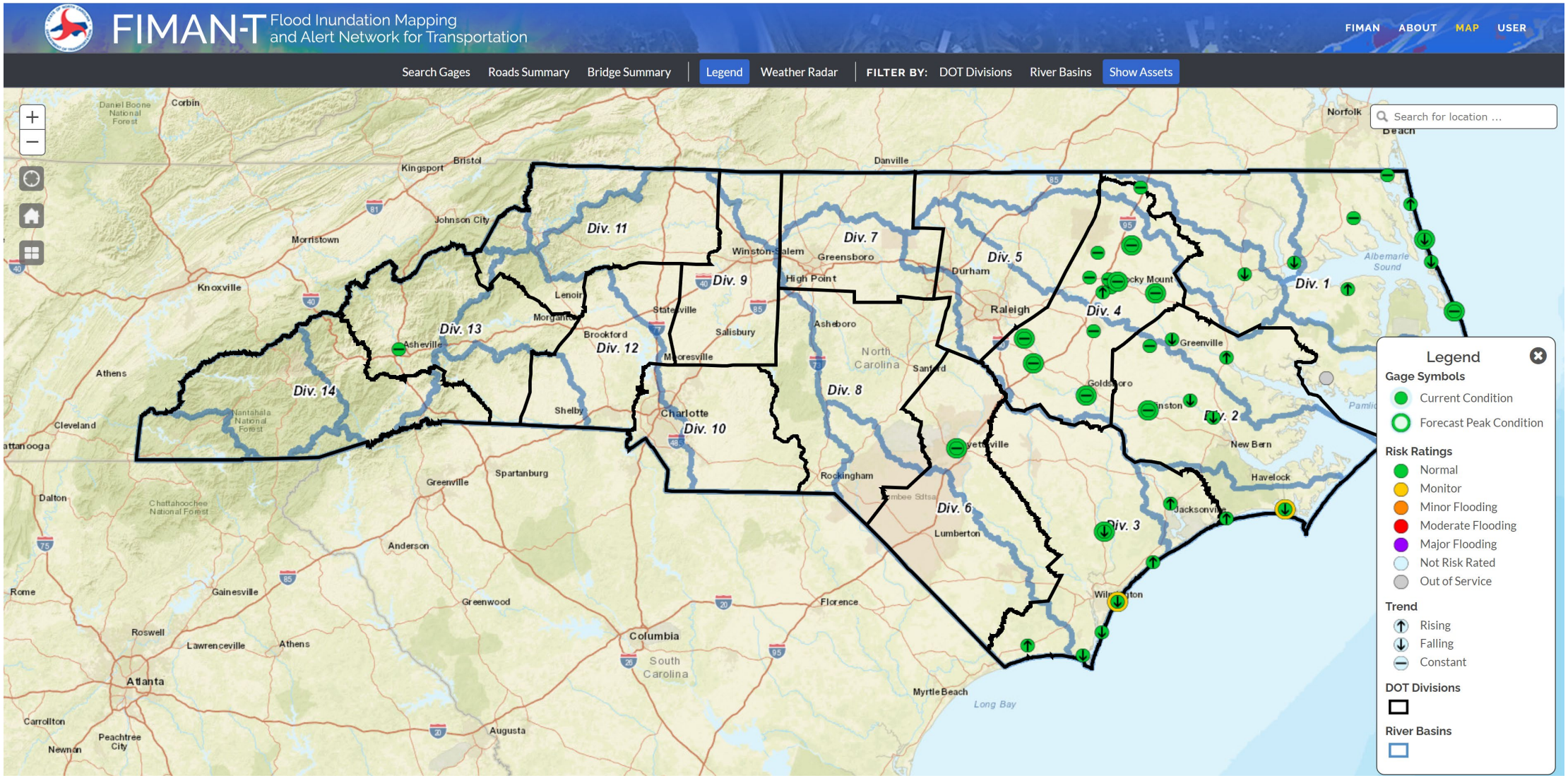
FIMAN-T

- Leverages North Carolina's 15-year investment in flood warning gauges and geospatial data.
- Provides real time and forecasted roadway inundation depths for high-risk locations.
- Visualized current and forecasted road flooding both upstream and downstream of gauged sites (Riverine and Coastal)
- Visualize NCDOT asset impacts.
- Provides bridge hydraulic performance (freeboard and overtopping) for over 100 bridges.
- Advanced reporting tools.
- Export tools to Google Earth.

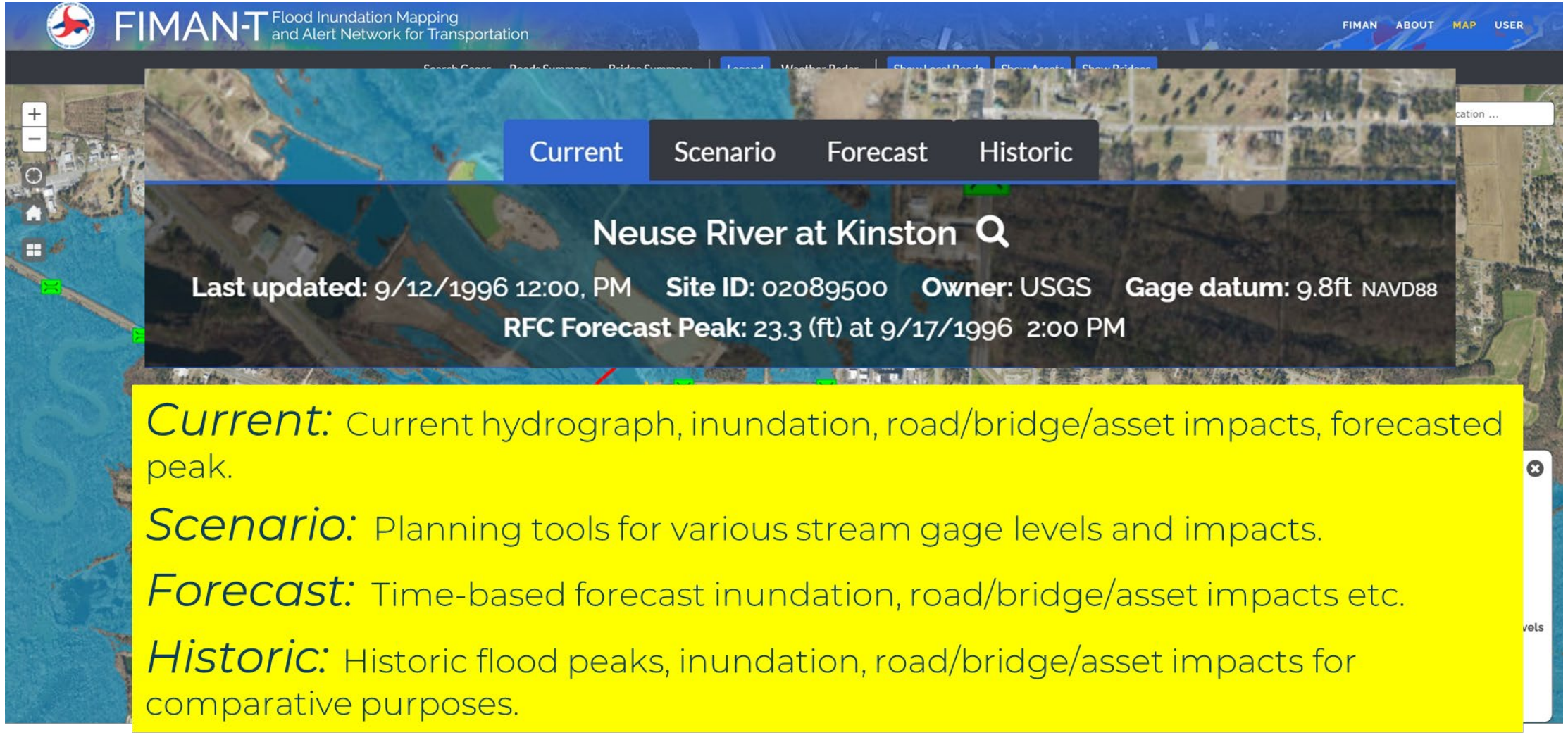




FIMAN-T: Home Screen



FIMAN-T Display “Tabs”



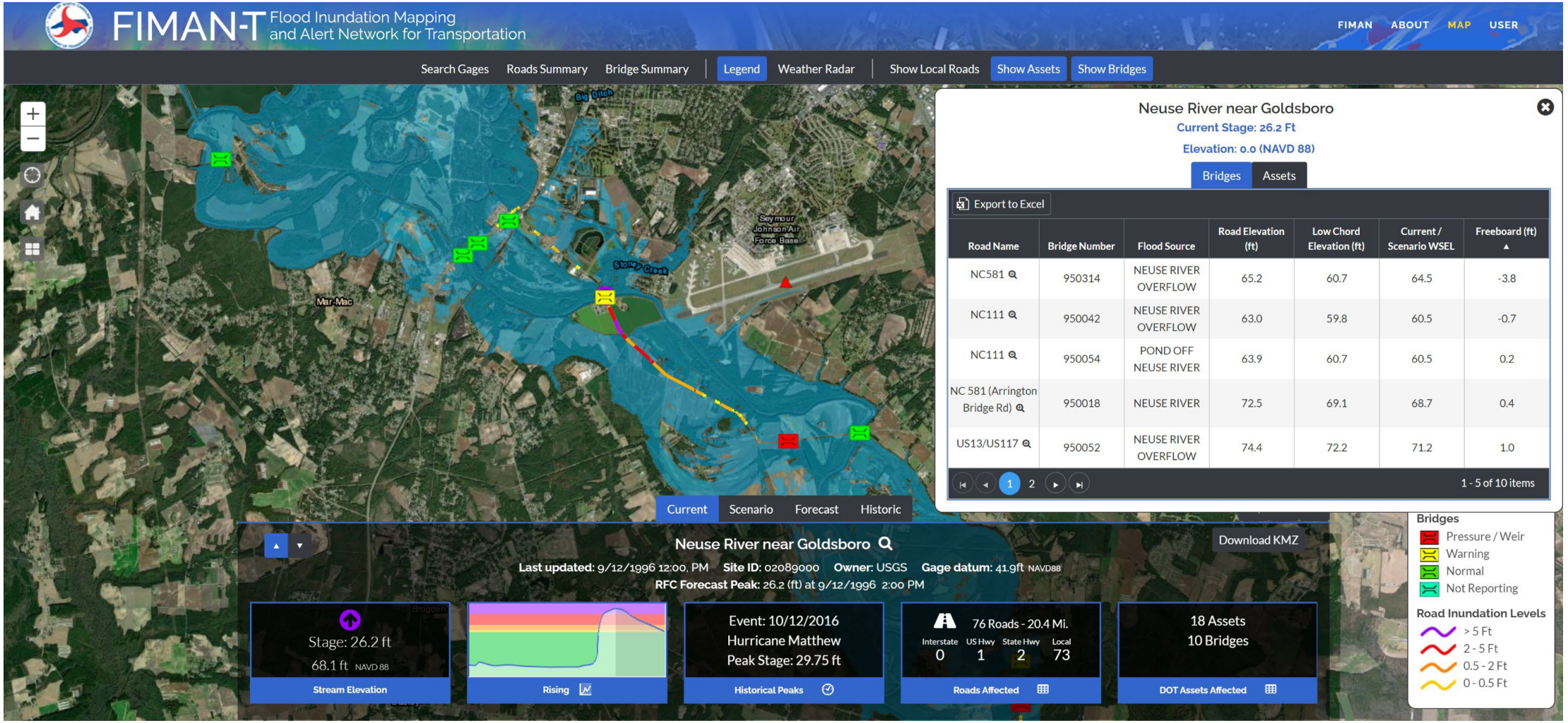
Current: Current hydrograph, inundation, road/bridge/asset impacts, forecasted peak.

Scenario: Planning tools for various stream gage levels and impacts.

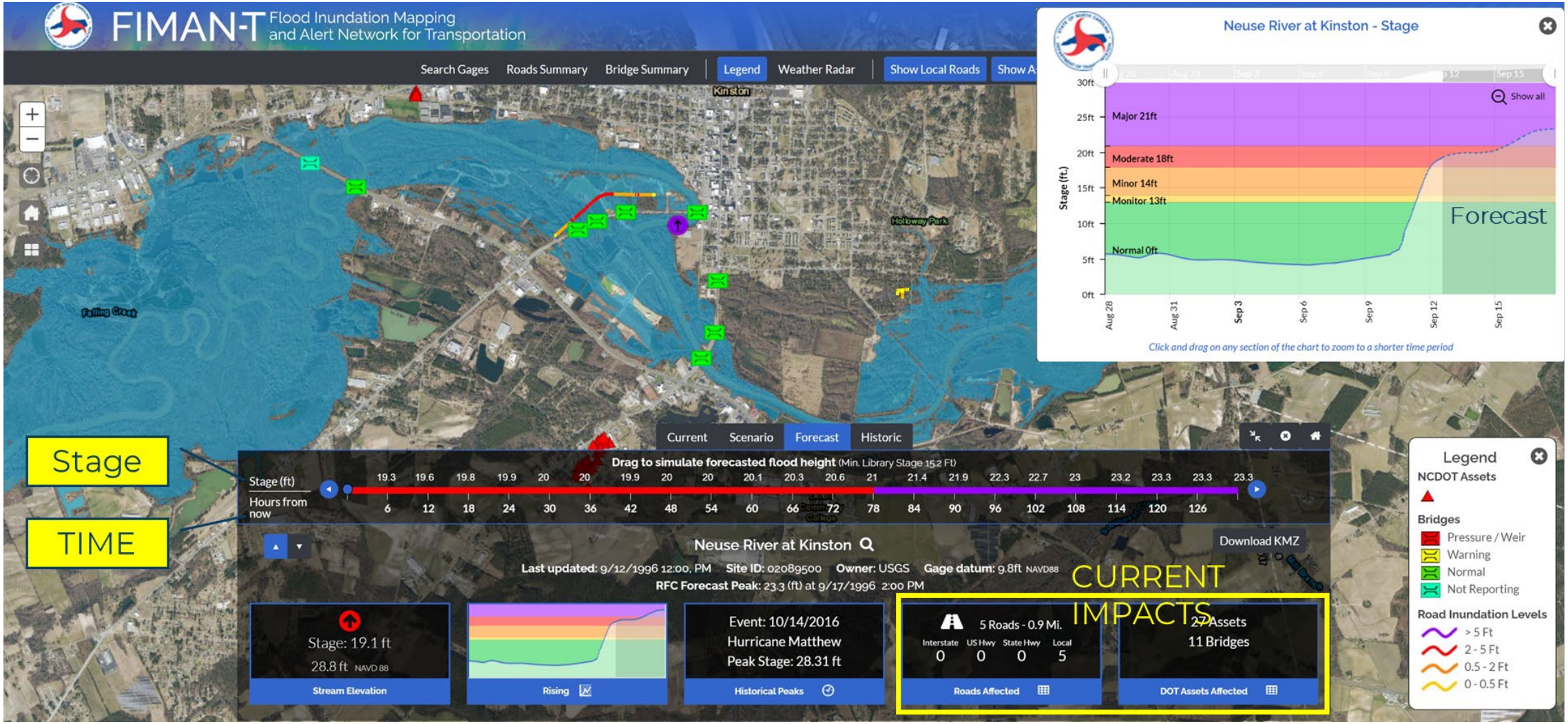
Forecast: Time-based forecast inundation, road/bridge/asset impacts etc.

Historic: Historic flood peaks, inundation, road/bridge/asset impacts for comparative purposes.

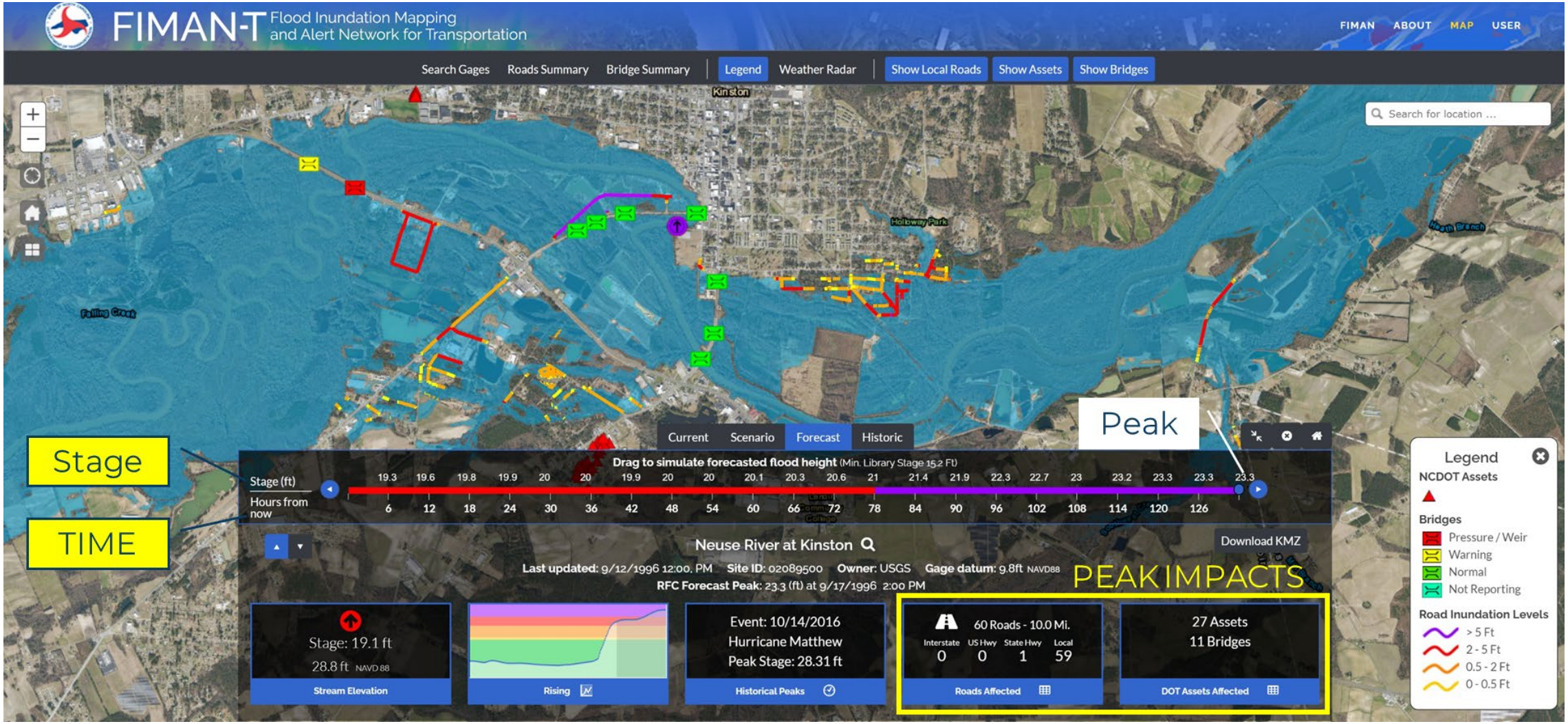
FIMAN-T: Current Conditions: Bridge Hydraulic Performance



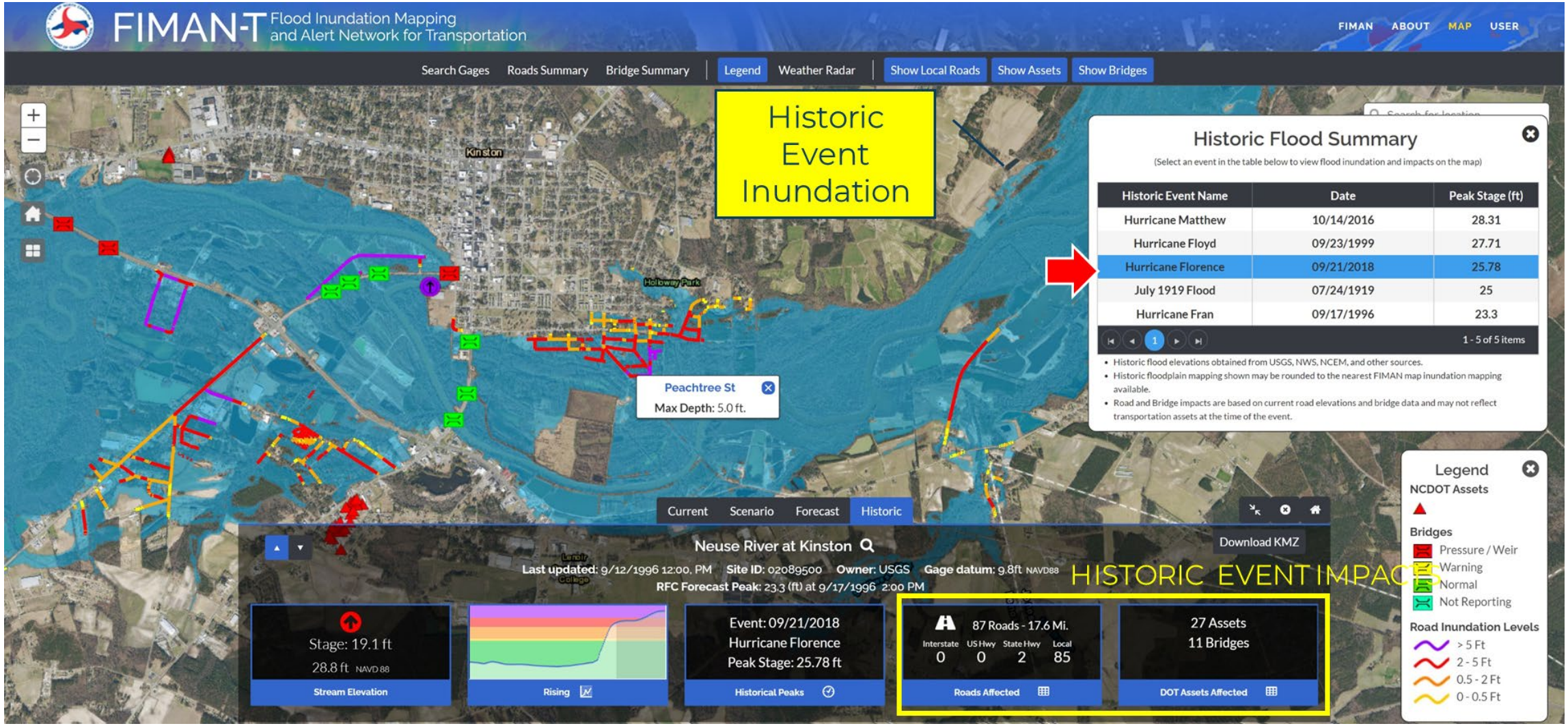
FIMAN-T: Forecast Tab



FIMAN-T: Forecast Tab



FIMAN-T: Historic Tab / Event Viewer

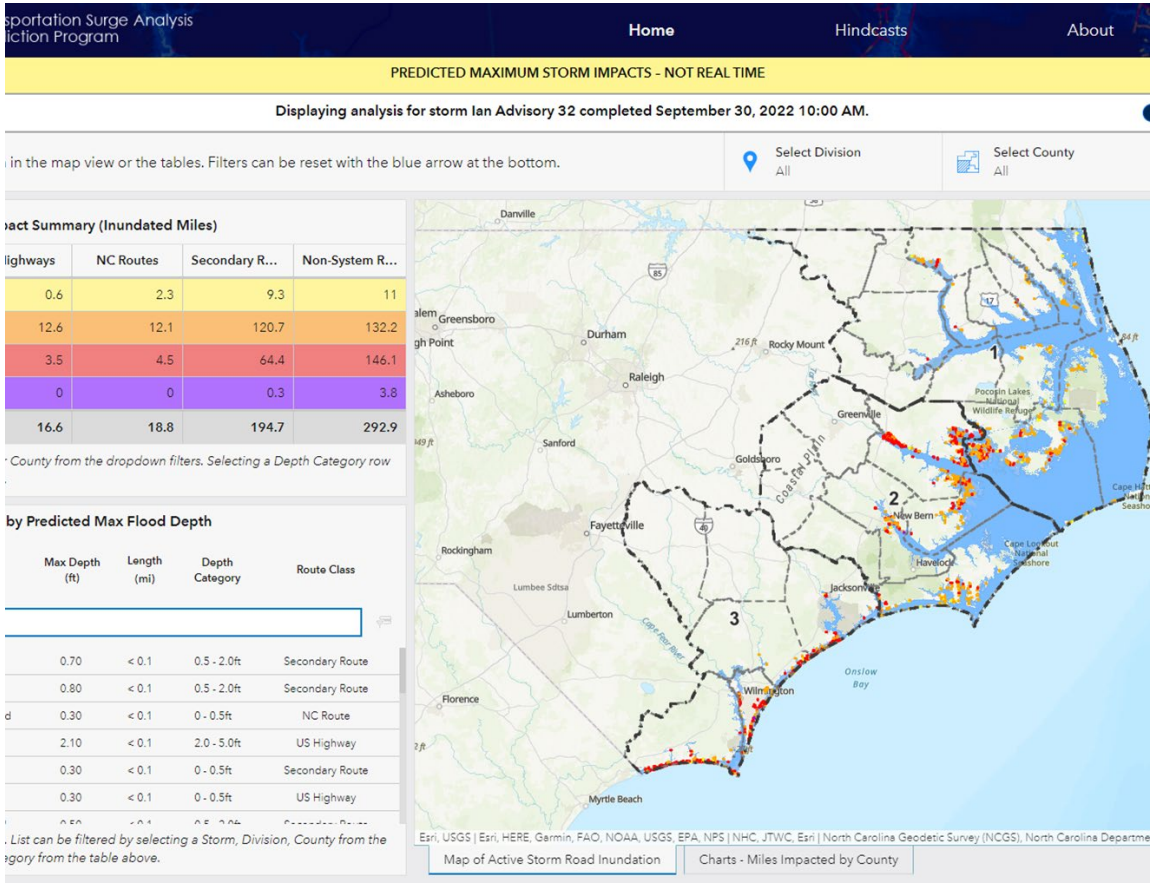


FIMAN-T: Validation

T-SAPP: Transportation Surge Analysis Prediction Program

What is T-SAPP?

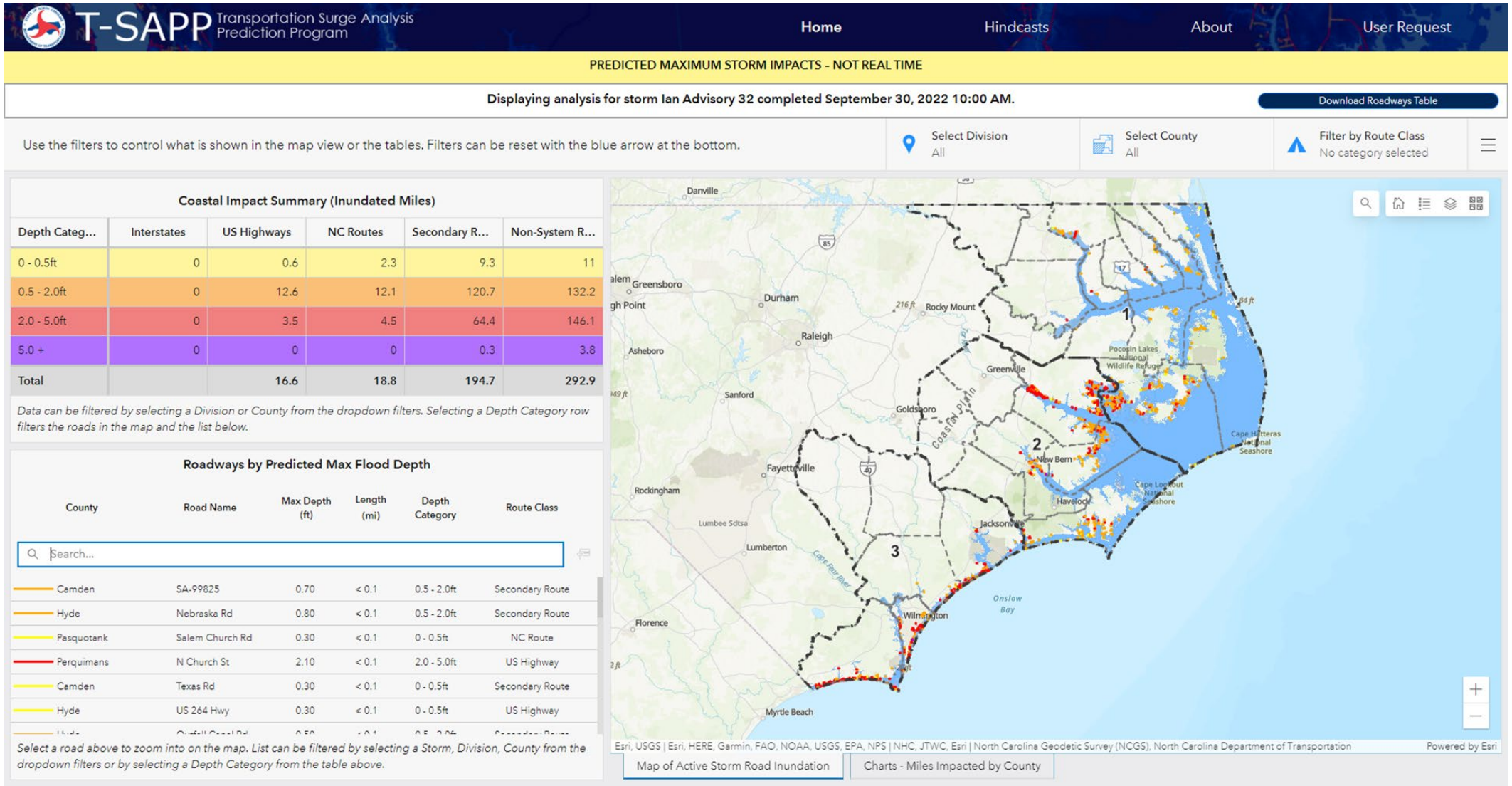
- Storm Surge forecast values (Statewide) are downloaded from APS THREDDS Server Every 6 hours during events.
- Geoprocessing tools to process, develop inundation mapping, inundation depths, roadway depths, bridge overtopping, etc.
- Interactive web mapping application
- Comparison to past storm events (Fran, Floyd, Matthew, Florence, Dorian, Isaias, Ian)



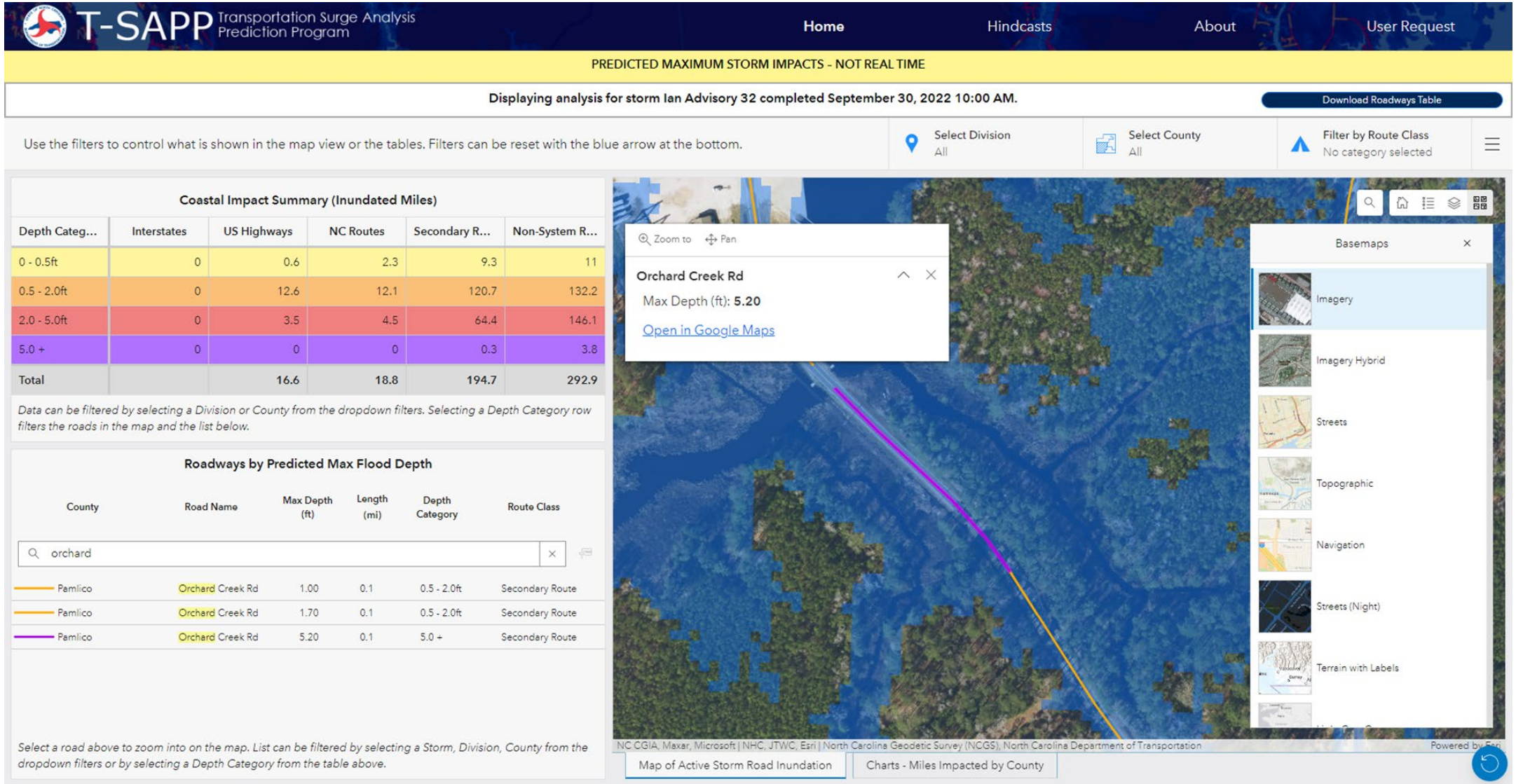
T-SAPP: Current Metrics

Item	Metric
Active Sites	N/A (Entire Coastline)
Monitored Roadway Miles	*10,990 miles*
Coastal Bridges Monitored	199
Historic Flood Events Included	7 Fran (1996), Floyd (1999), Matthew (2016), Florence (2018), Dorian (2019), Isaias (2020), Ian (20222)
Historic Impacted Roadway Miles Mapped	6,637 miles
Historic Flood Inundation Area Mapped (7 events)	46,459 sq. miles

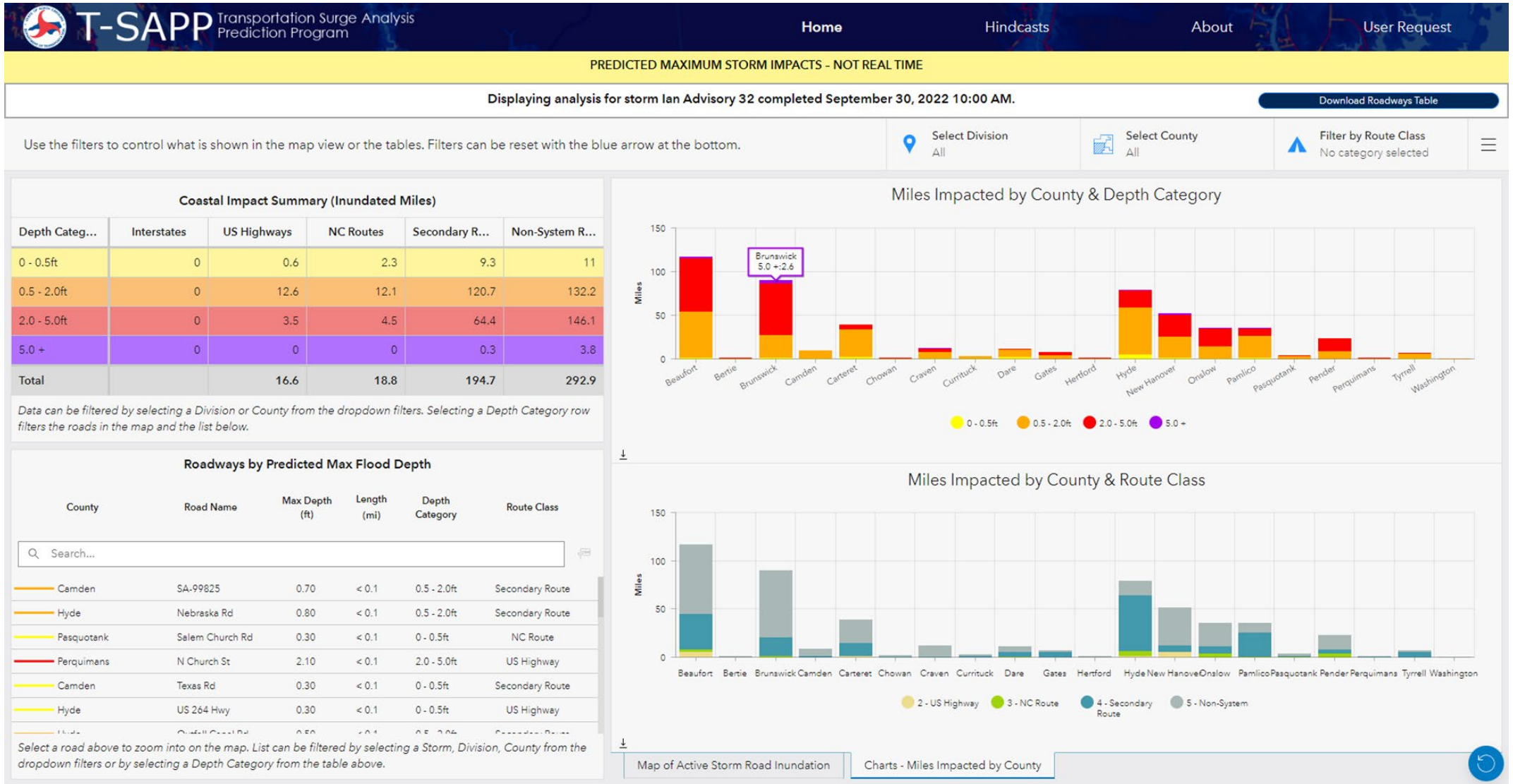
T-SAPP: Home Screen



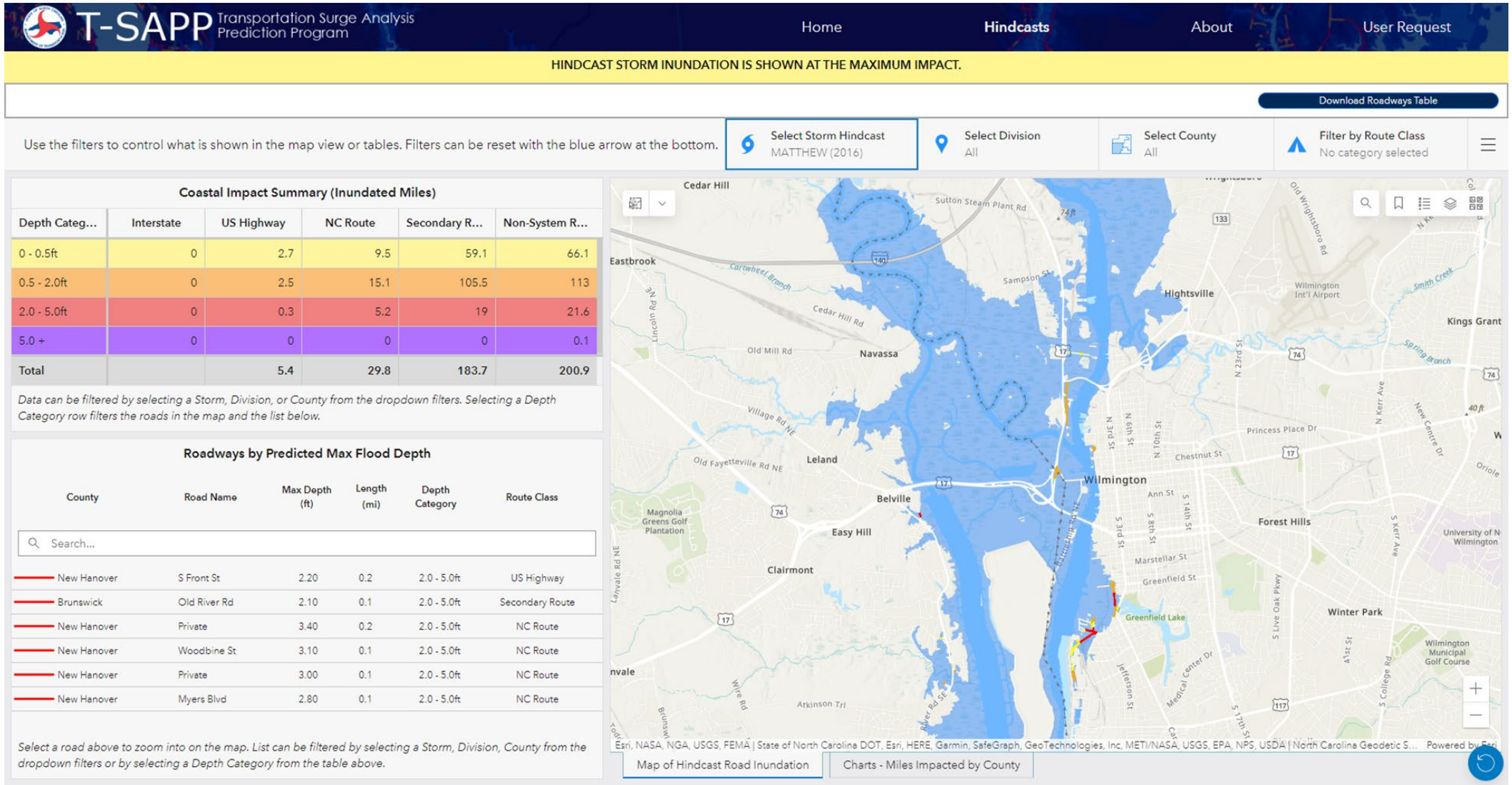
T_SAPP: Event Viewer



T-SAPP: Dashboard



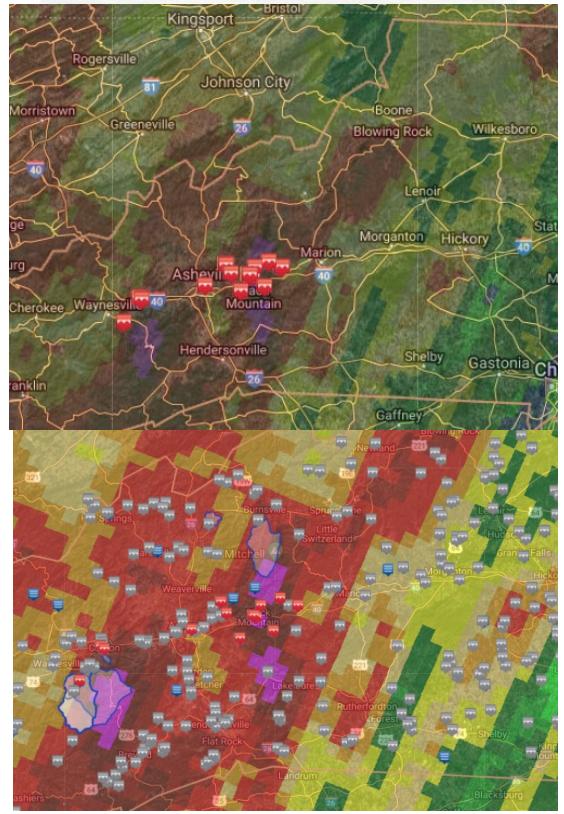
T-SAPP: Historic Event Viewer



NCDOT BridgeWatch

What is BridgeWatch?

- Real-time monitoring for structures over water.
- Alerted immediately when levels exceed set threshold
- Alerts help identify flooded roadways and scour critical structures impacted by heavy rainfall



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Bridge Watch: How it works

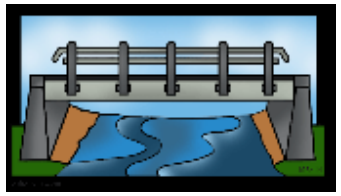
Environmental Monitoring

Stream Gauges

Weather Radar

NWS Alerts

Monitoring Location



Bridges

Culverts

Counties

Ferry Ramps

Landslides

Levels/Thresholds Monitored

Water Elevation > Bridge Deck

Inches of Rainfall > 50yr Storm Over Watershed

Storm Surge 10% Chance of Exceeding Bridge Low Chord

Alert

Texts

Emails

GIS Map

Web Application

Excel Report

Measured Response

Post-Storm Inspection

Road Closure

Bridge Watch: Flood Warning and Asset Management

BridgeWatch

Public Safety Through Real-time Structure Monitoring

Overview: BridgeWatch is an online asset-management service that collects and process data from stream gauges, weather radar, National Weather service, and National Hurricane Center and compares these external datasets to user defined limits. The program sends alert notifications via email or cell phone when user defined thresholds are exceeded.

Statistics: Monitoring locations represent NCDOT assets at which parameters are compared to external data sources. Currently, BridgeWatch monitors over 15,000 bridges, approaches, and culverts. Additionally, 25 ferry ramps, 14 levee and flap gate locations near Princeville, and 21 Western Division landslide locations are monitored.

Critical Conditions: The severity and indication of real-world conditions at a monitoring location depends on the alert type and level. There are three alert categories: gauge, rainfall, or storm surge. Color coding of alert levels, that follows the National Weather Service flood risk colors, indicates alert priority. Gauge alerts, based on real-time water levels, are considered the most reliable and highest priority during a storm event. Alert notifications sent via SMS text or email include key details such as severity, type, location of asset, and values exceeded.

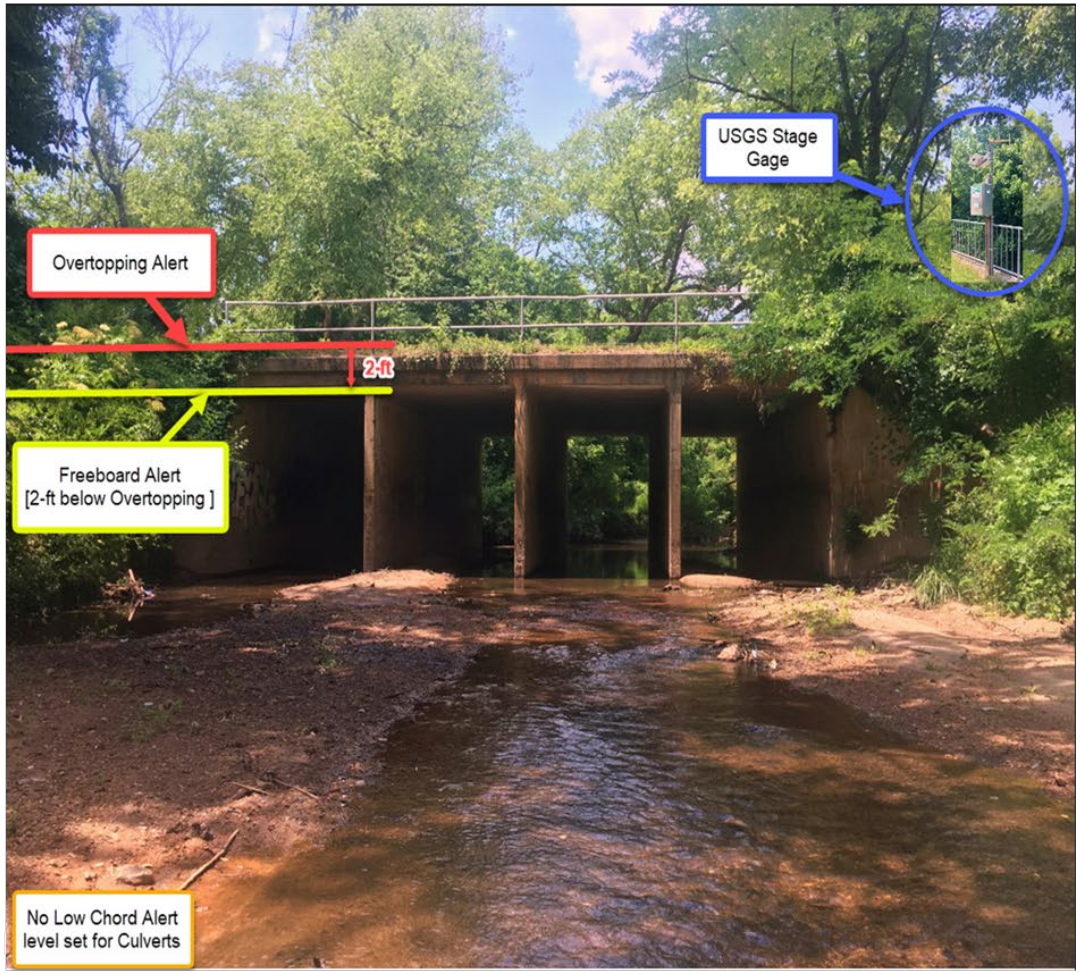
Example of flap gate structure in BridgeWatch with thresholds linked to upstream USGS gage (left), the text alert format for the flap gate (upper right) and field verification of alert (lower right).

Alert Types

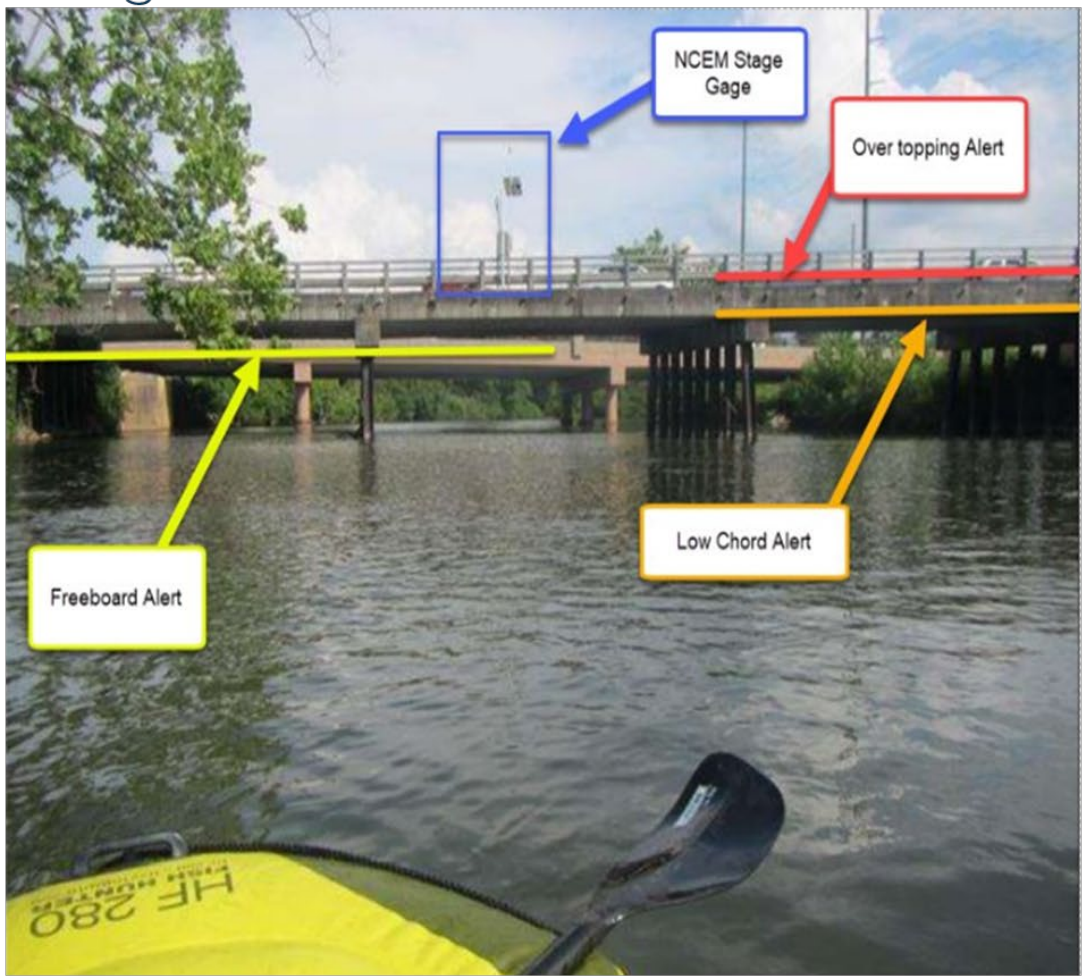
- ***Gauge Alert, Overtopping, (Warning-Magenta):*** Issued when on-site water surface elevation gauge indicates water is overtopping the bridge, bridge approach, or the roadway over a culvert.
- ***Gauge Alert, Low Chord, (Warning-Red):*** The low chord is typically the lowest structure member (beam) above the stream or river. Officials are notified when flood waters reach this level. Low chord alerts are not issued for culverts.
- ***Gauge Alert, Freeboard, (Watch-Orange):*** Officials are notified when stream levels rise close to a critical level at a structure, which indicates that flooding is approaching the bridge structure or road overtopping for culverts. Generally these alerts are triggered when stream levels are within 2-ft of low chord for bridges or within 2-ft of overtopping roadway for culverts. Some coastal bridges use 1-ft below low chord.
- ***Rainfall Alert, NEXRAD or QPF, (Watch-Yellow):*** The system actively monitors NEXRAD for over 15,000 of structure drainage areas statewide. Officials are notified if rainfalls (actual or forecasted) trigger predetermined rainfall intensity thresholds.
- ***Storm Surge Alerts:*** National Hurricane Center advisories are monitored and forecasted storm surge levels are compared to bridge elevations. Custom alerts are available for when forecasted storm surge may impact bridges.

BridgeWatch: Stage Threshold Examples

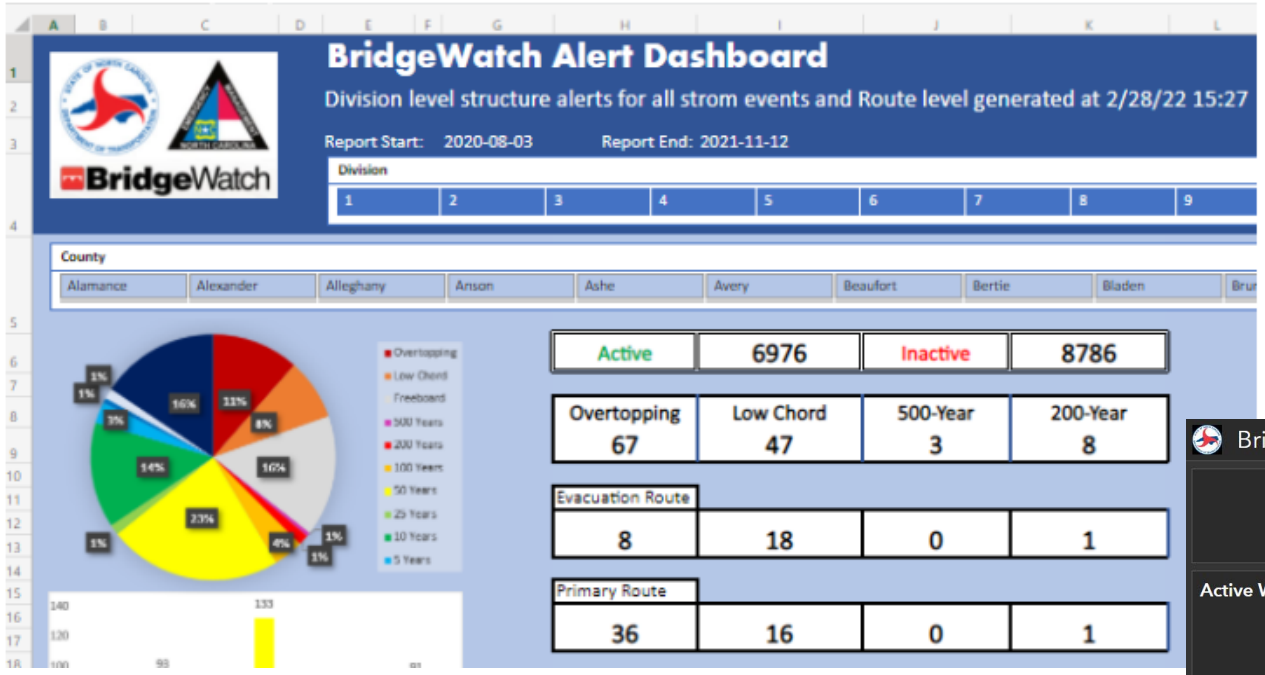
Culvert

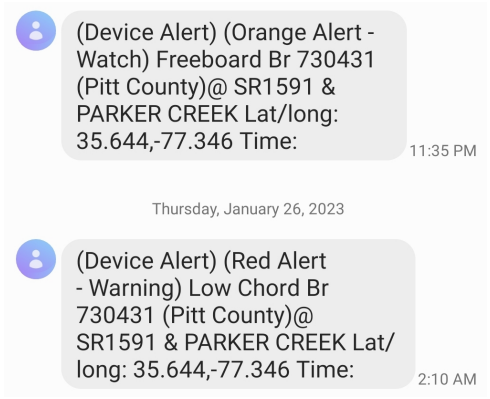


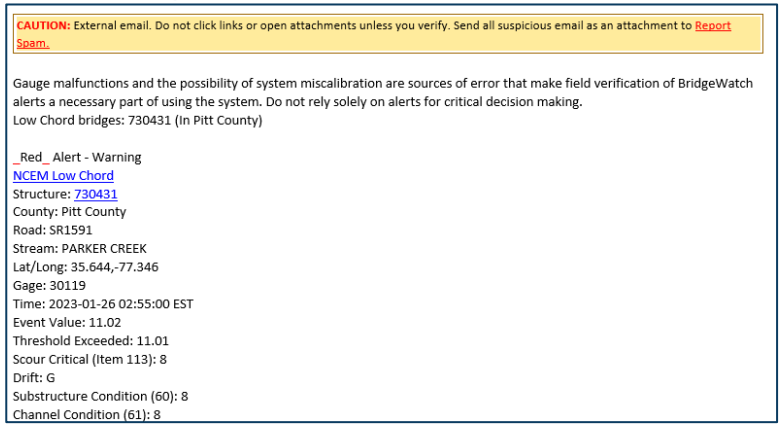
Bridge

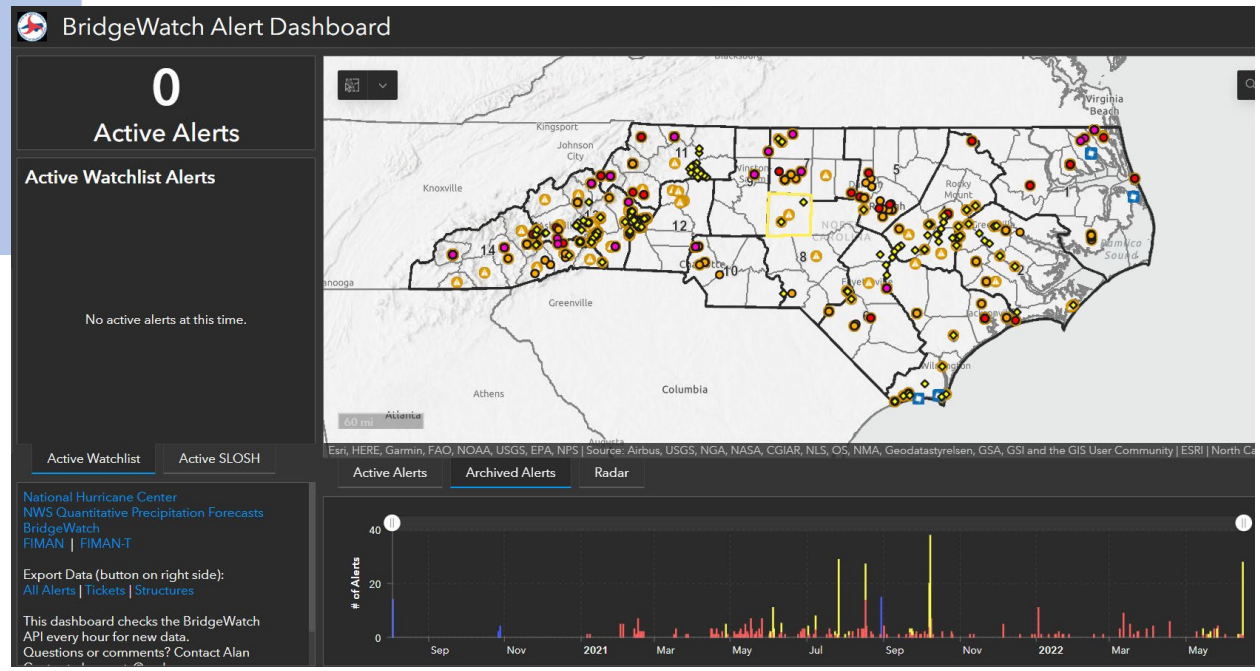


Bridge Watch: Flood Warning and Asset Management

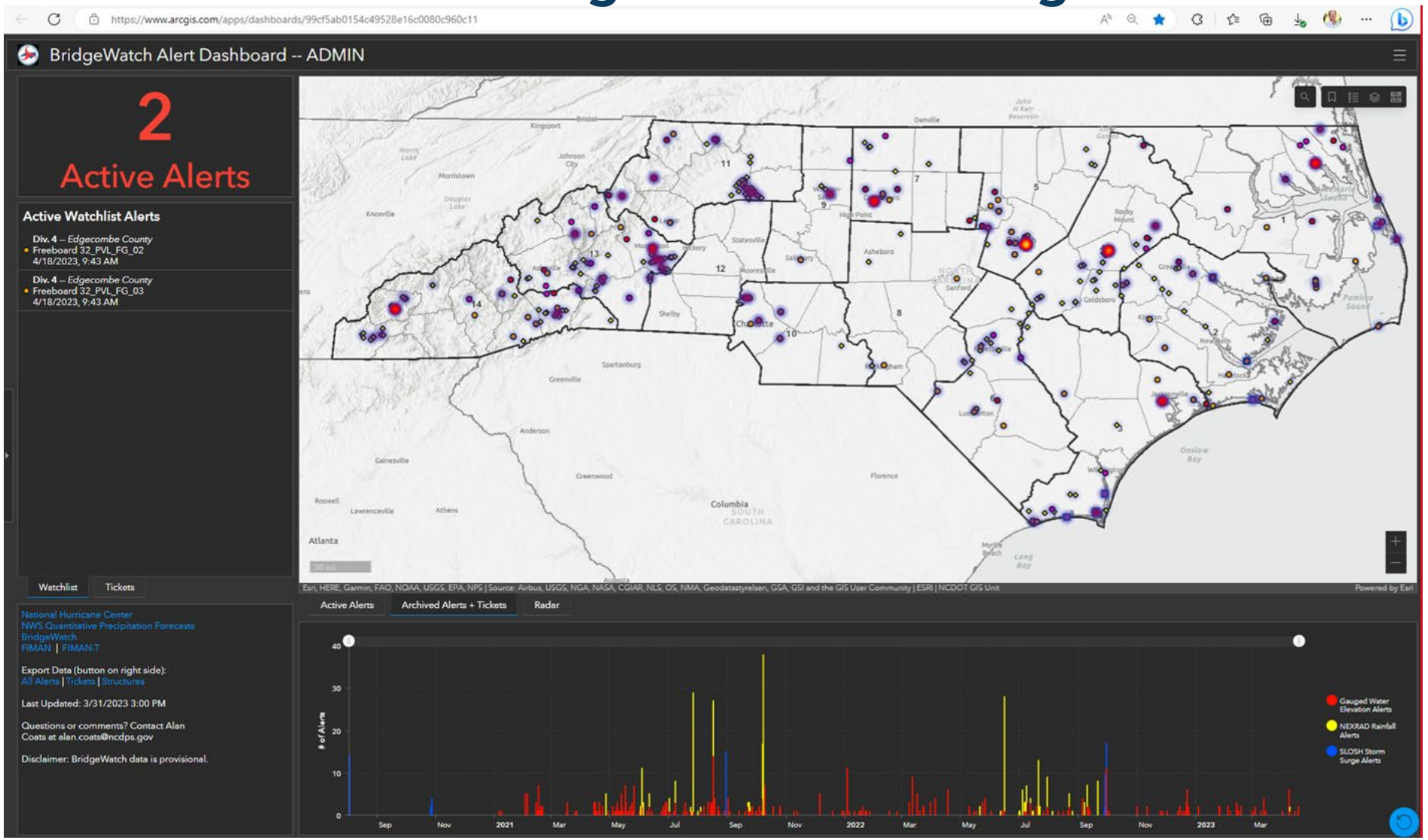








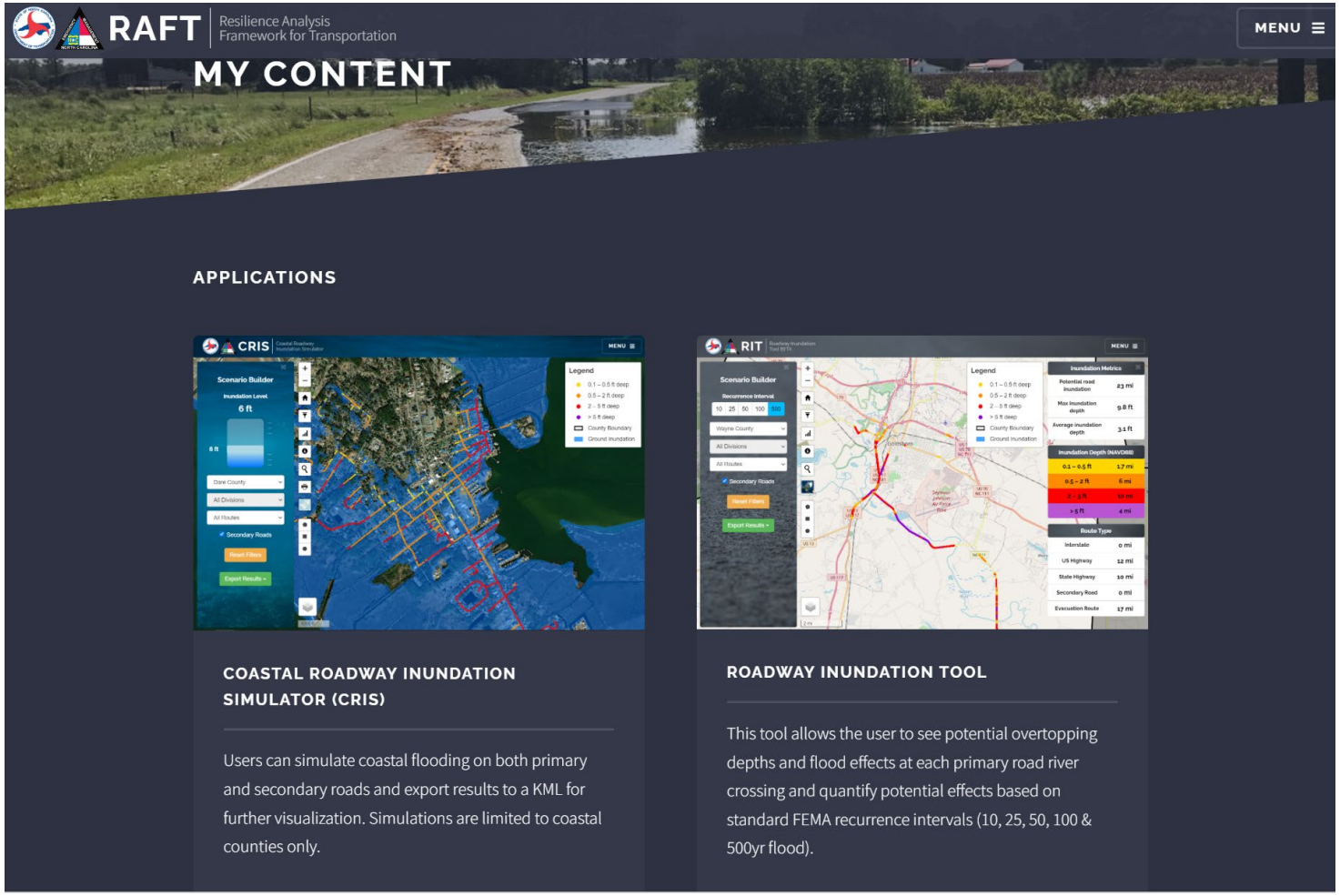
Bridge Watch: Flood Warning and Asset Management



Flood Planning Tools-Storm Prep

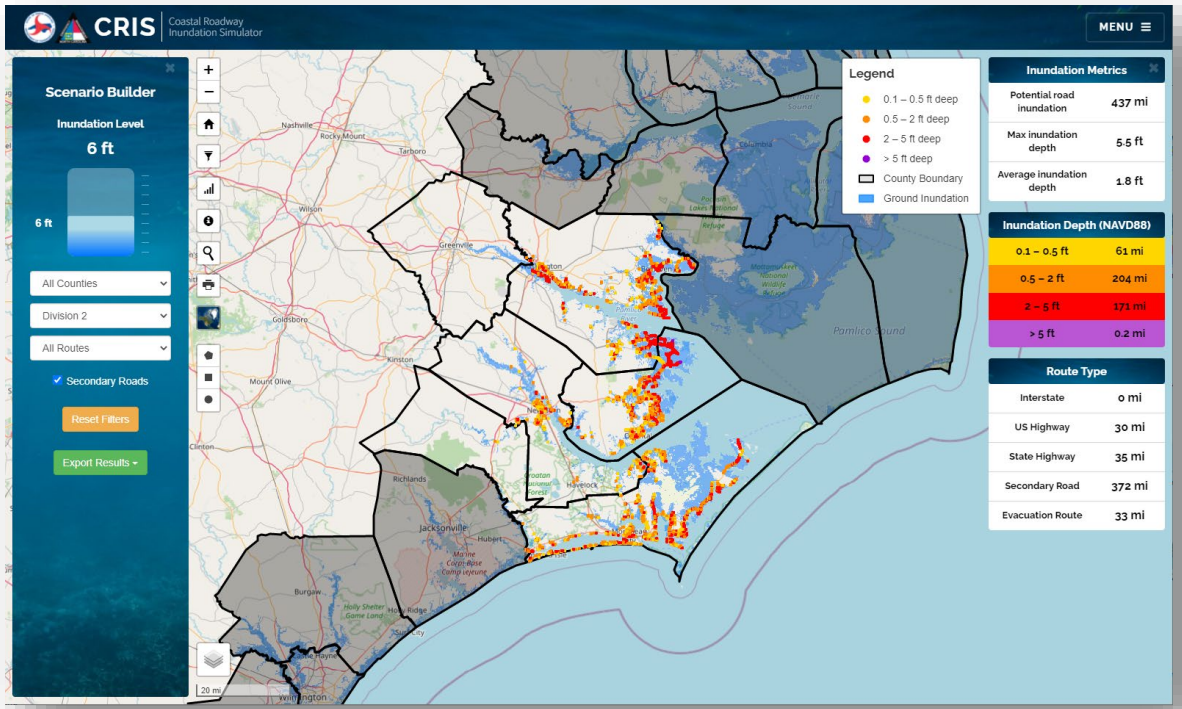
RAFT: Resilience Analysis Framework for Transportation

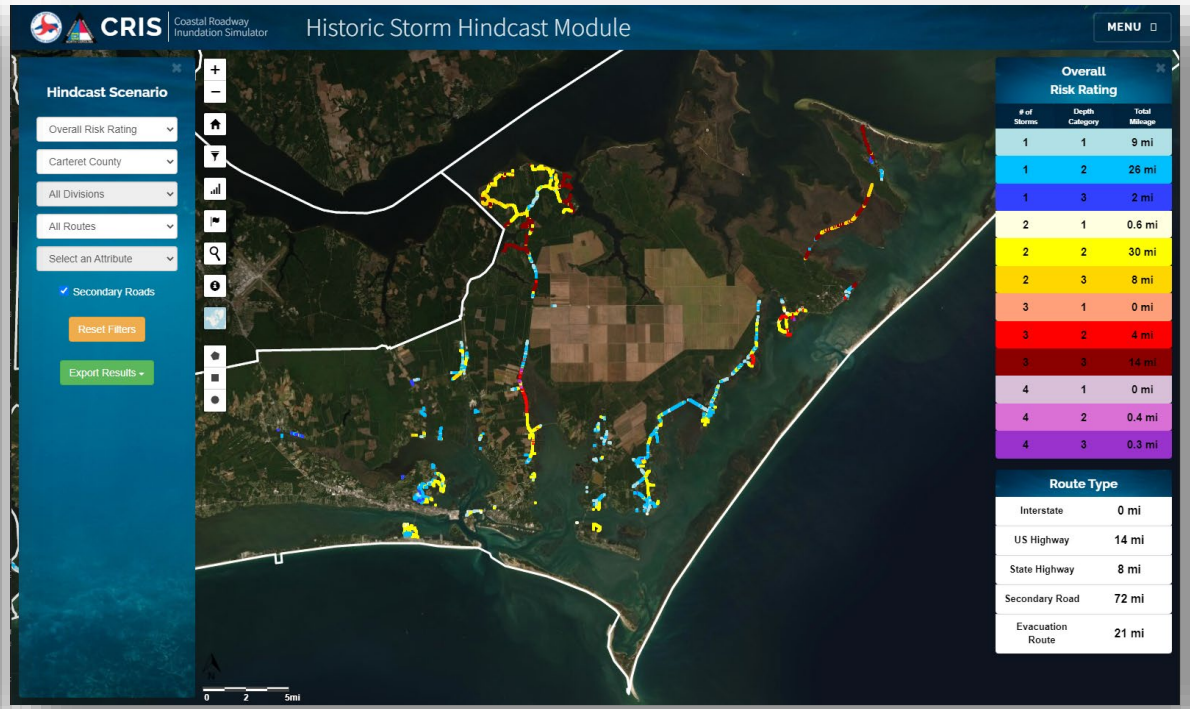
- CRIS: Coastal Roadway Inundation Simulator
- RIT: Roadway Inundation Tool



Coastal Roadway Inundation Simulator (CRIS)

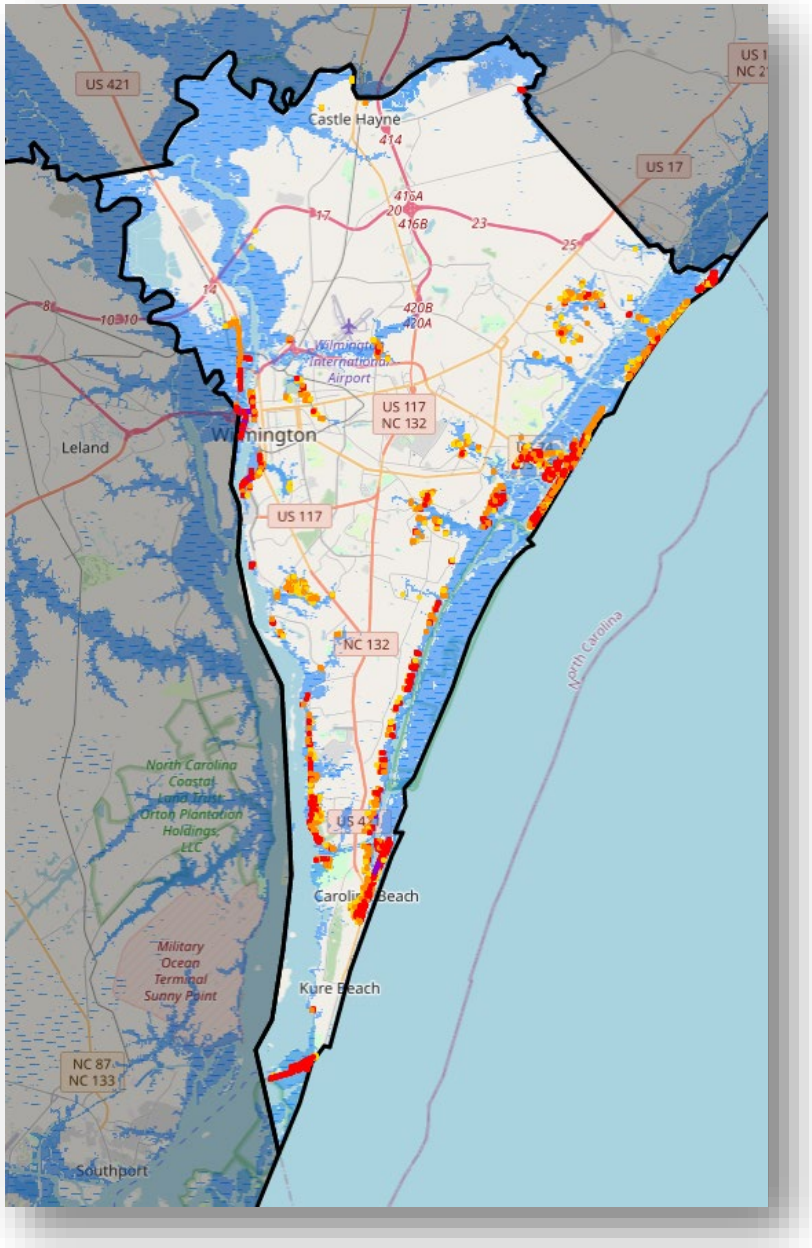
- Predicts impacts of roadway inundation for 23 coastal counties
- Inundation levels range from 1 to 17 feet
- Historic Storm Hindcast Module displays impacts from six past hurricanes





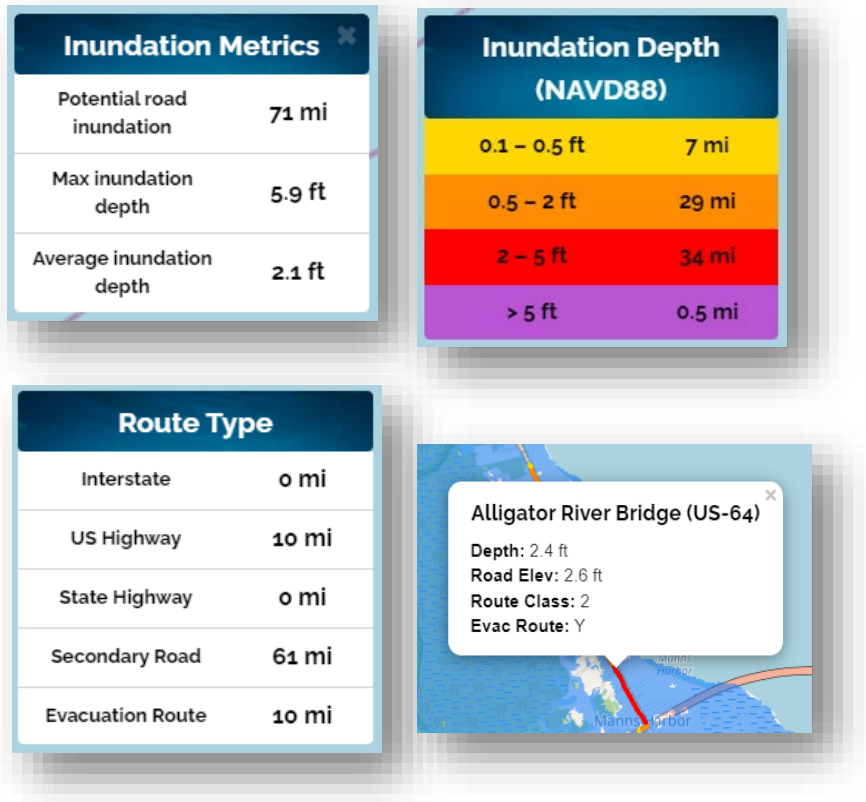
CRIS: Goals

- Quantify and simulate inundation impacts
- Plan for:
  - Emergency response
  - Evacuation
  - Road closure
  - Future resiliency
- Assist with maintenance of roadway infrastructure



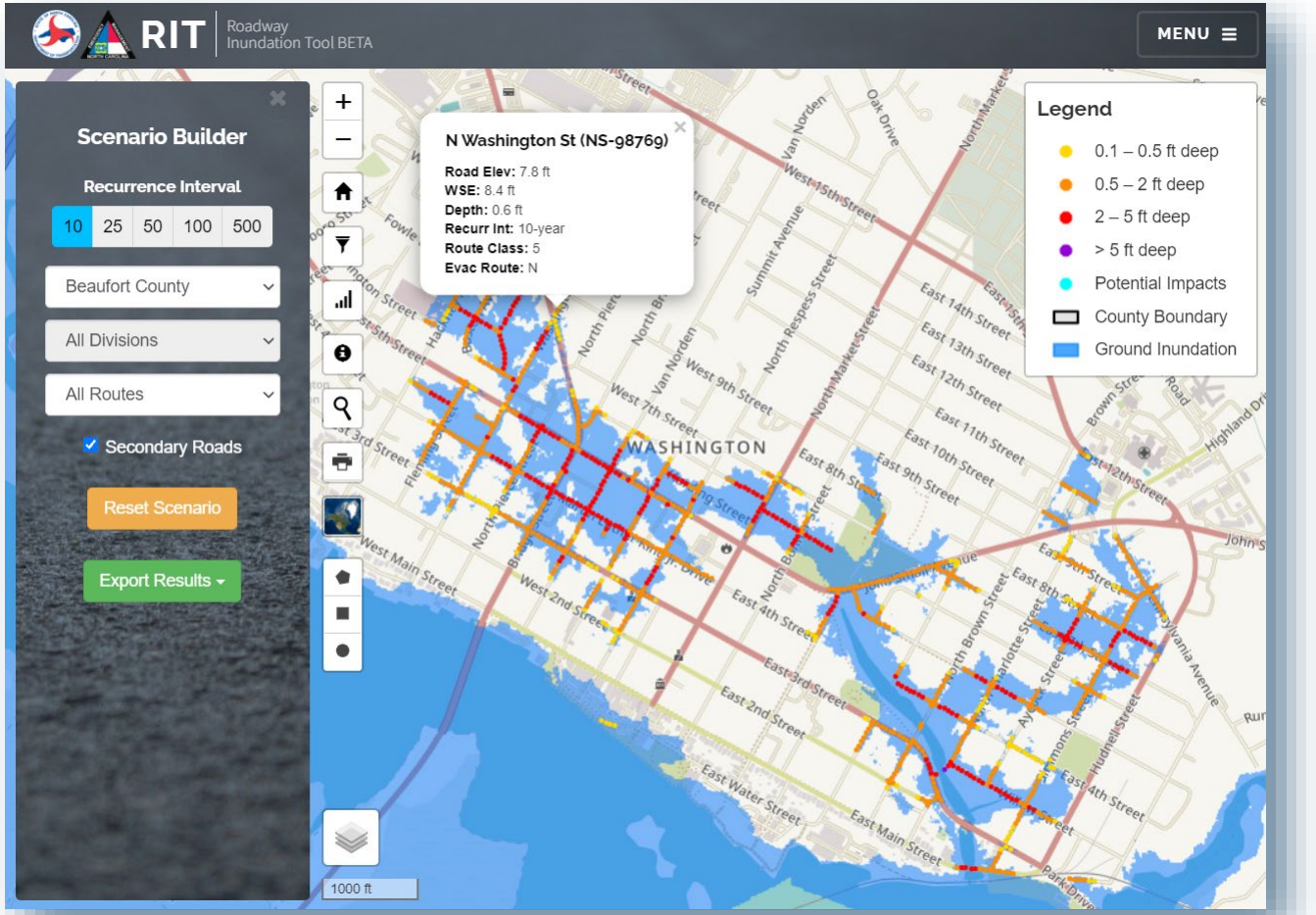
CRIS: Metrics and Process

- NC QL2 LiDAR (2014-2015) used to assign roadway centerline elevations (NAVD88 FT)
- LiDAR-based modeling used to produce inundation boundaries
- Points were generated every 50 feet along road centerlines
- At each point, roadway elevations were compared to the selected inundation profile to calculate inundation depth
- Mileage statistics determined by multiplying the number of impacted points by 50



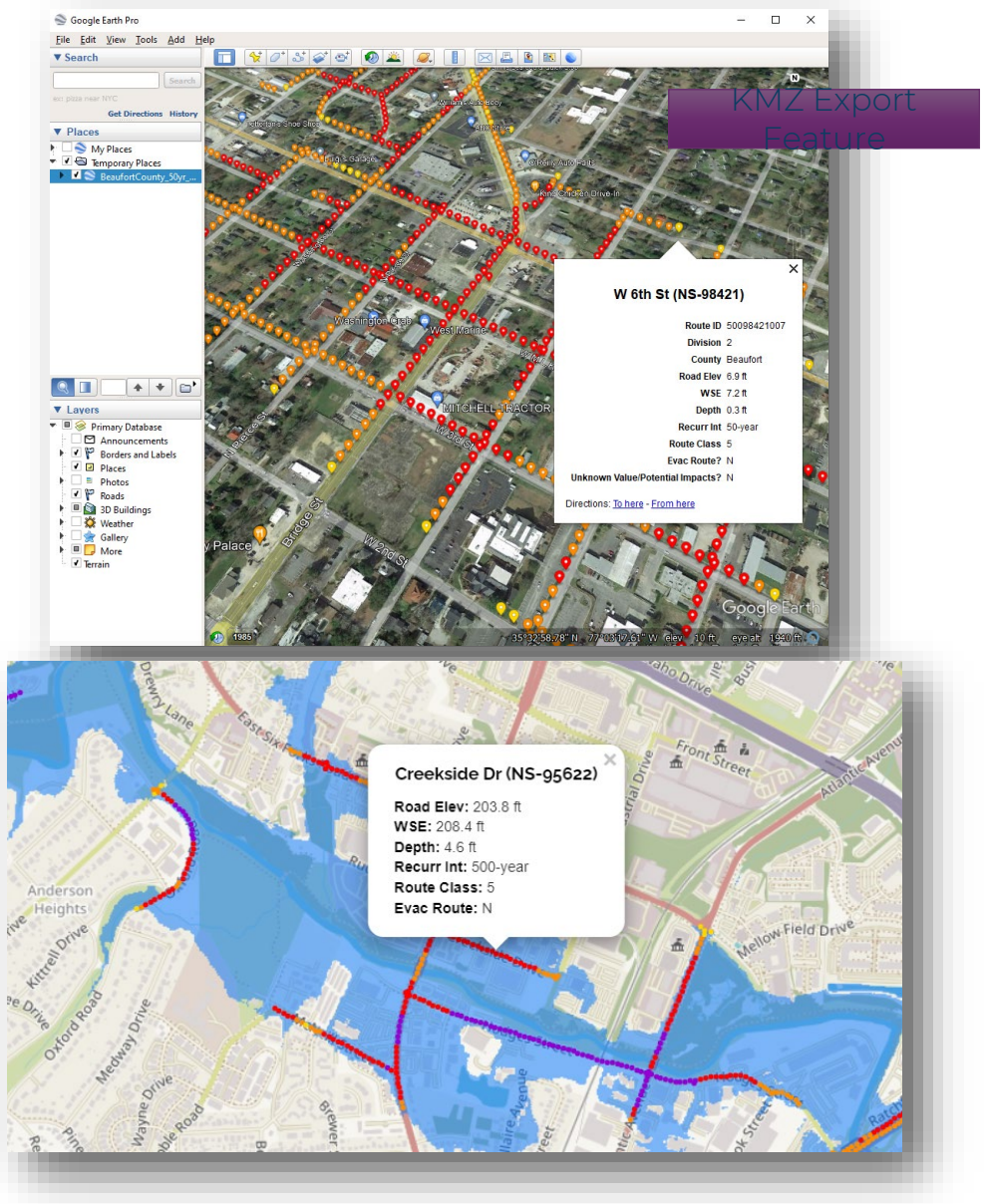
Roadway Inundation Tool (RIT)

- Based on multi-frequency riverine flood studies
  - 10-, 25-, 50-, 100- and 500-year recurrence intervals
- Statewide coverage
- Primary and secondary roads
- Originally an ArcGIS Online dashboard
- Built using open-source, scalable technologies



RIT: Goals

- Visualize and quantify road inundation
- Help NCDOT plan for:
  - Emergency response
  - Evacuation
  - Road closure
  - Climate change resiliency
- Provide quick, flexible access to data without reliance on GIS software
- Identify roads that may require higher maintenance or eventual replacement



Hydraulics Data

- Hydraulics Data Reservoir
  - This Repository is the final gathering place for records and documents utilized by the NCDOT as they relate to the Hydraulic aspects of design & maintenance.

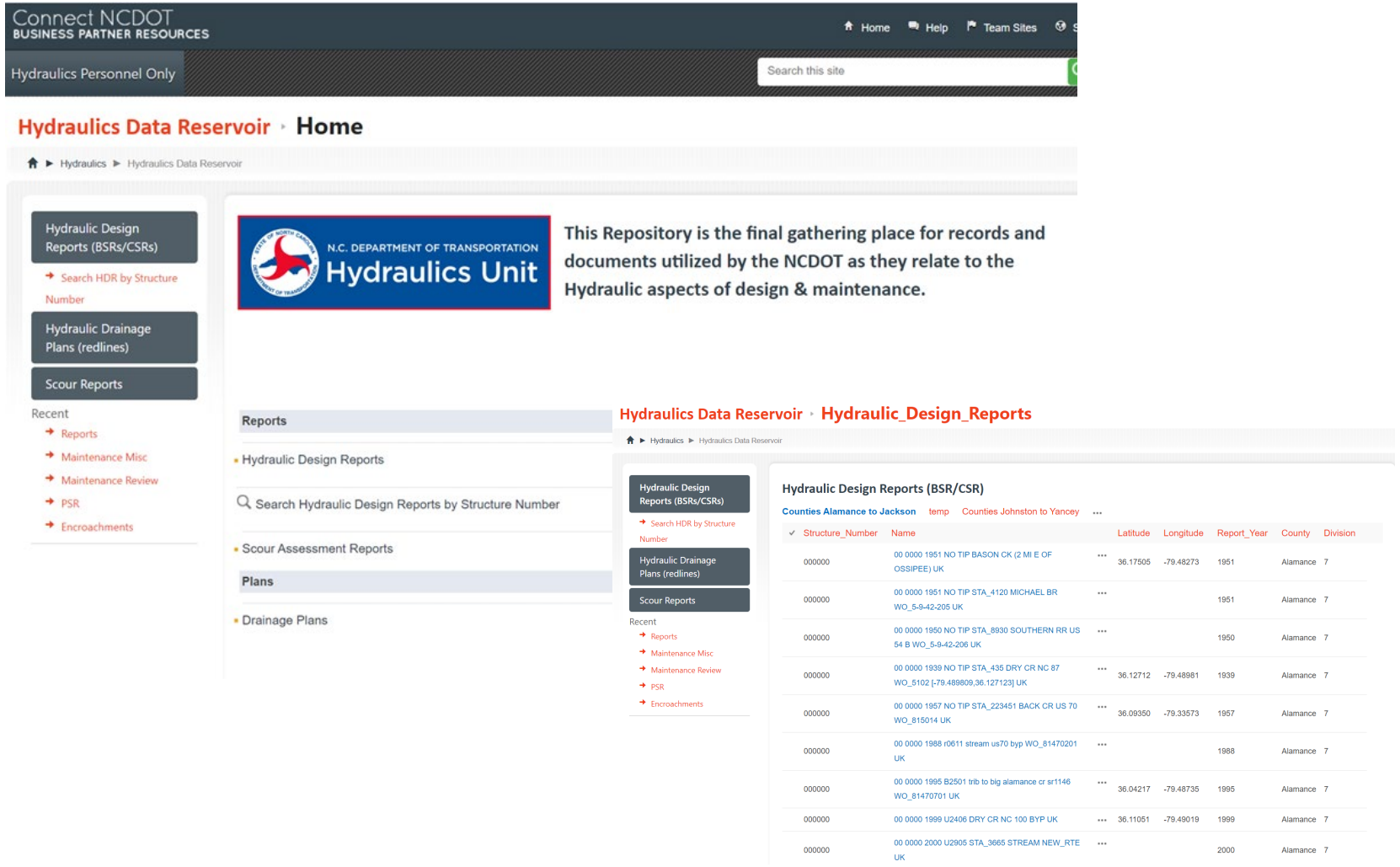
- Drainage Investigation Dataset
  - Available on ATLAS
  - The NCDOT Drainage Investigations dataset is a statewide point layer containing locations of Drainage Investigations for tracking and review.

- MPE – Multi- Sensor Precipitation Estimates (MPE) –
  - This simple mapping application enables you to visually see precipitation estimates over time for project sites.

Hydraulics Data Reservoir

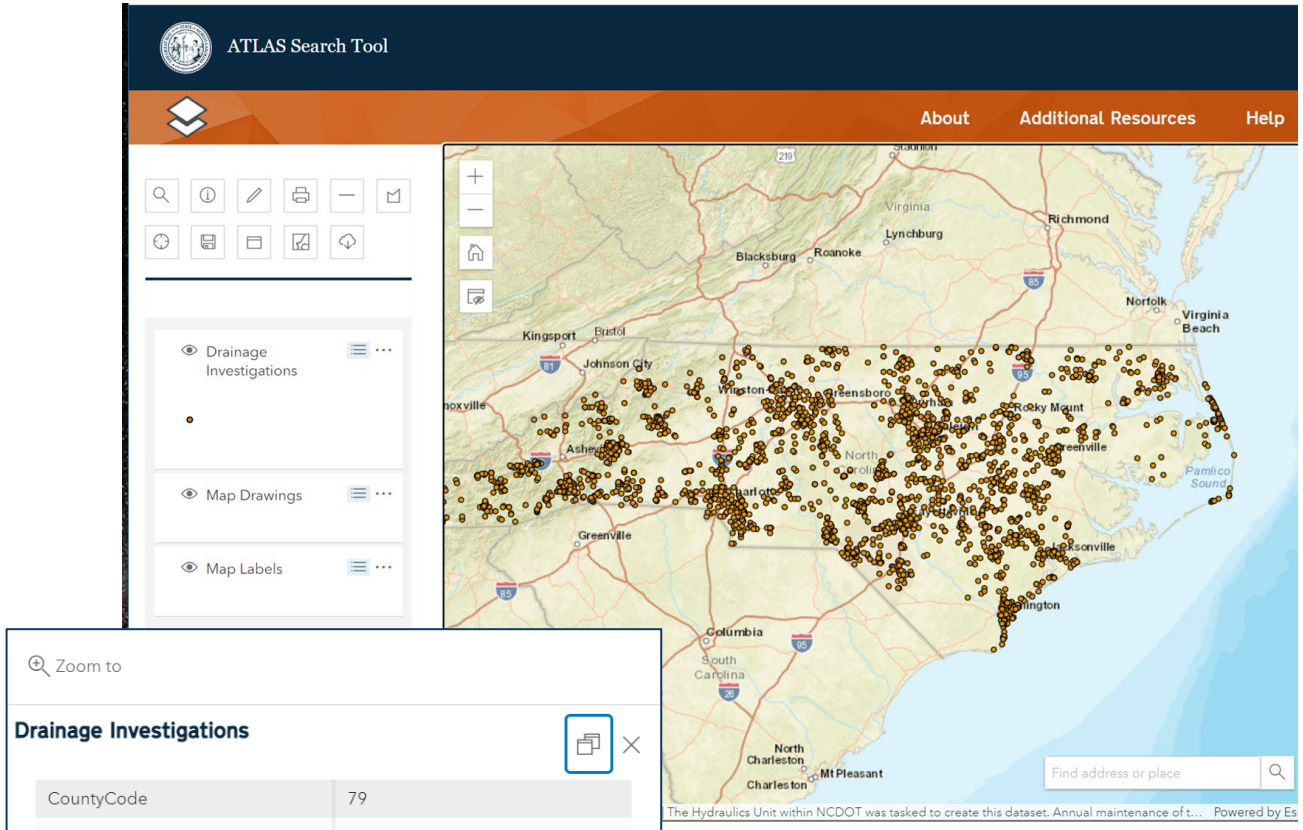
Available on Site

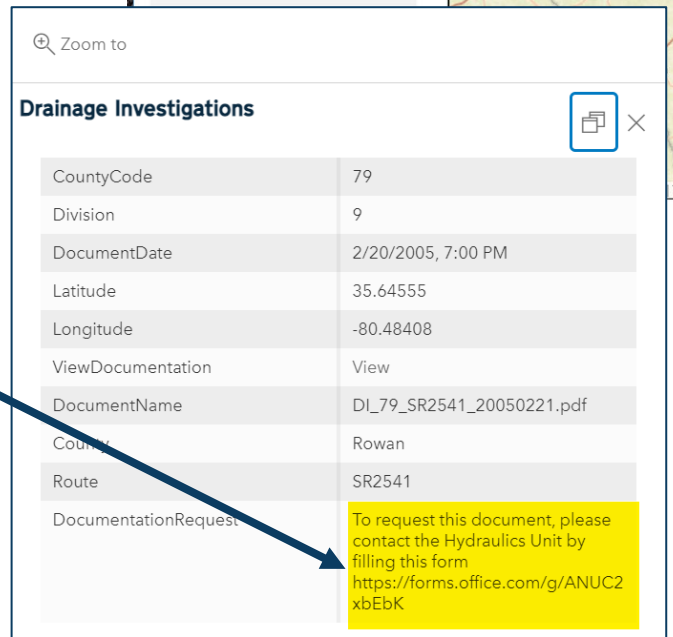
- Archived BSR/CSR
- Scour Assessments
- Archived Redline Drainage plans will be added soon.



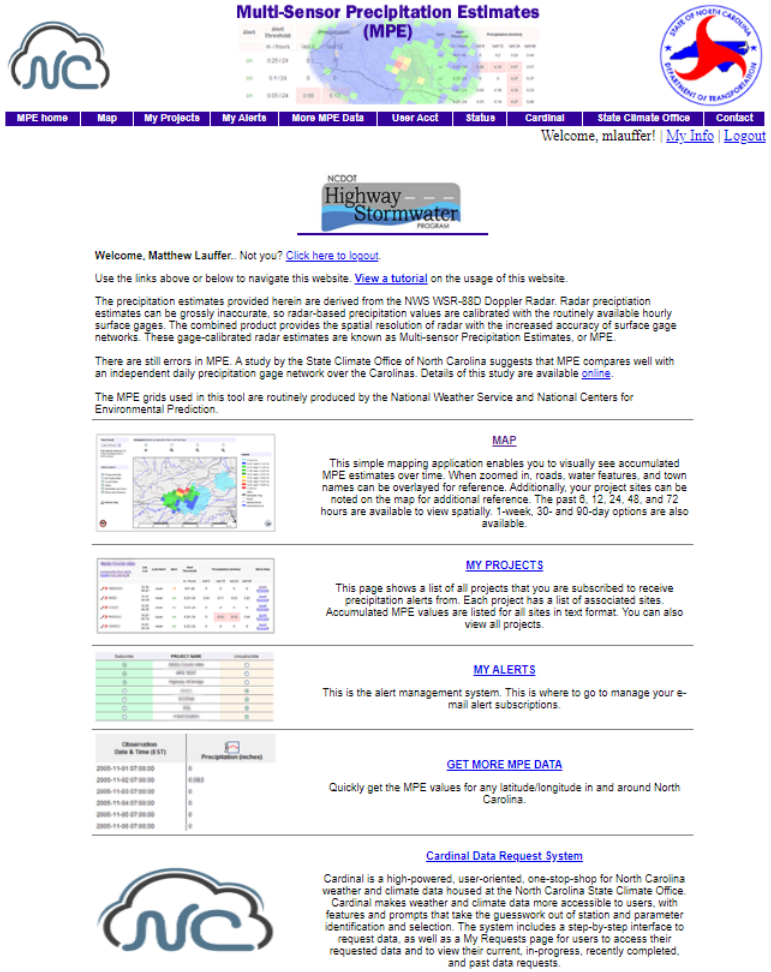
Drainage Investigation Dataset

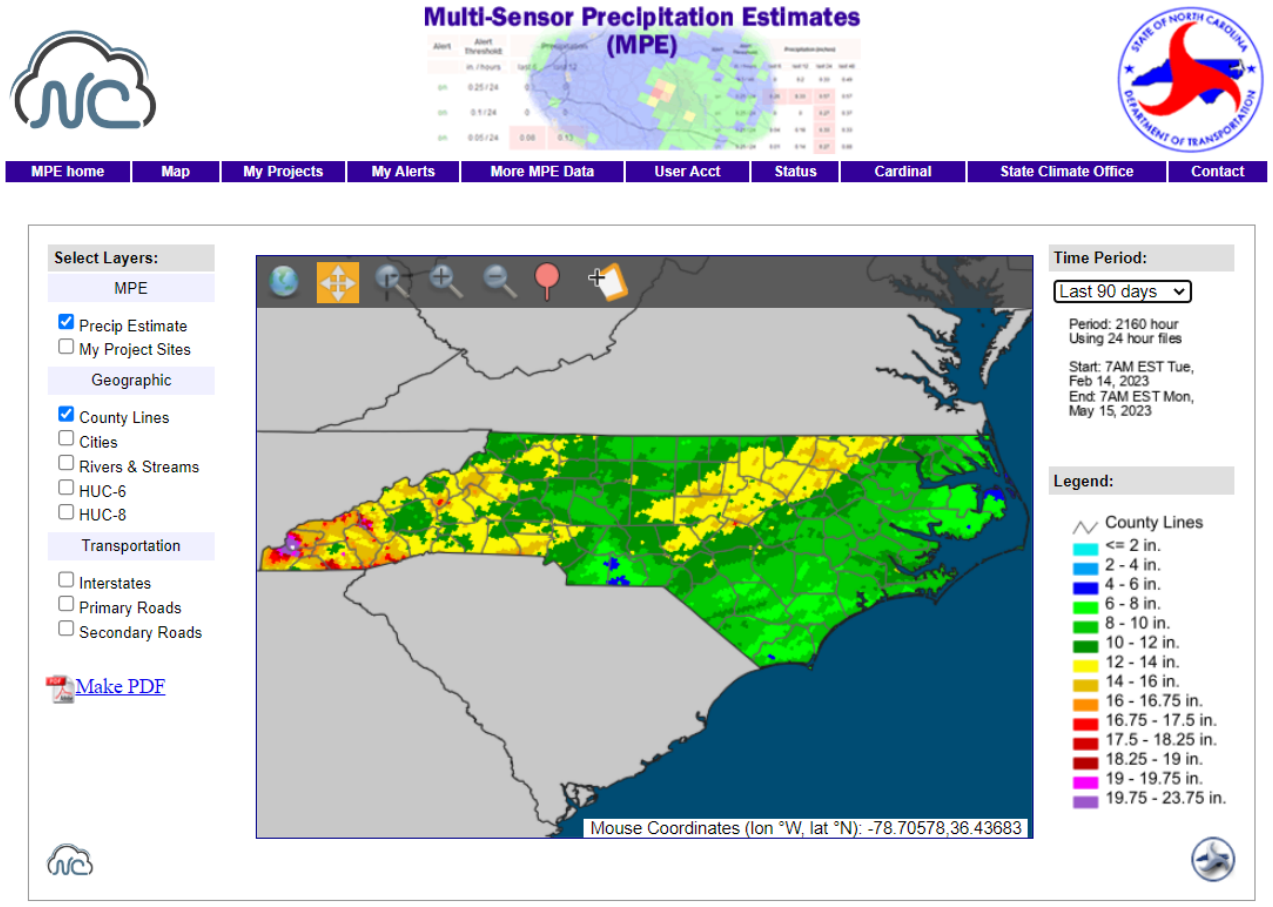
- A statewide point layer containing locations of Drainage Investigations for tracking and review.
- Locations contain information related to the location, division involved and related documents.
- Data is used to help facilitate understanding of past investigations and correlation between requests receive to help understand if they are potentially related to past incidents or a larger drainage problem.
- <u>While the layer itself is not restricted, the documents linked to this layer are restricted, and must be requested from the Hydraulics Unit using the provided form.</u>
- Use of this dataset for project scoping or screening is merely pre-decisional.





Multi-Sensor Precipitation Estimates

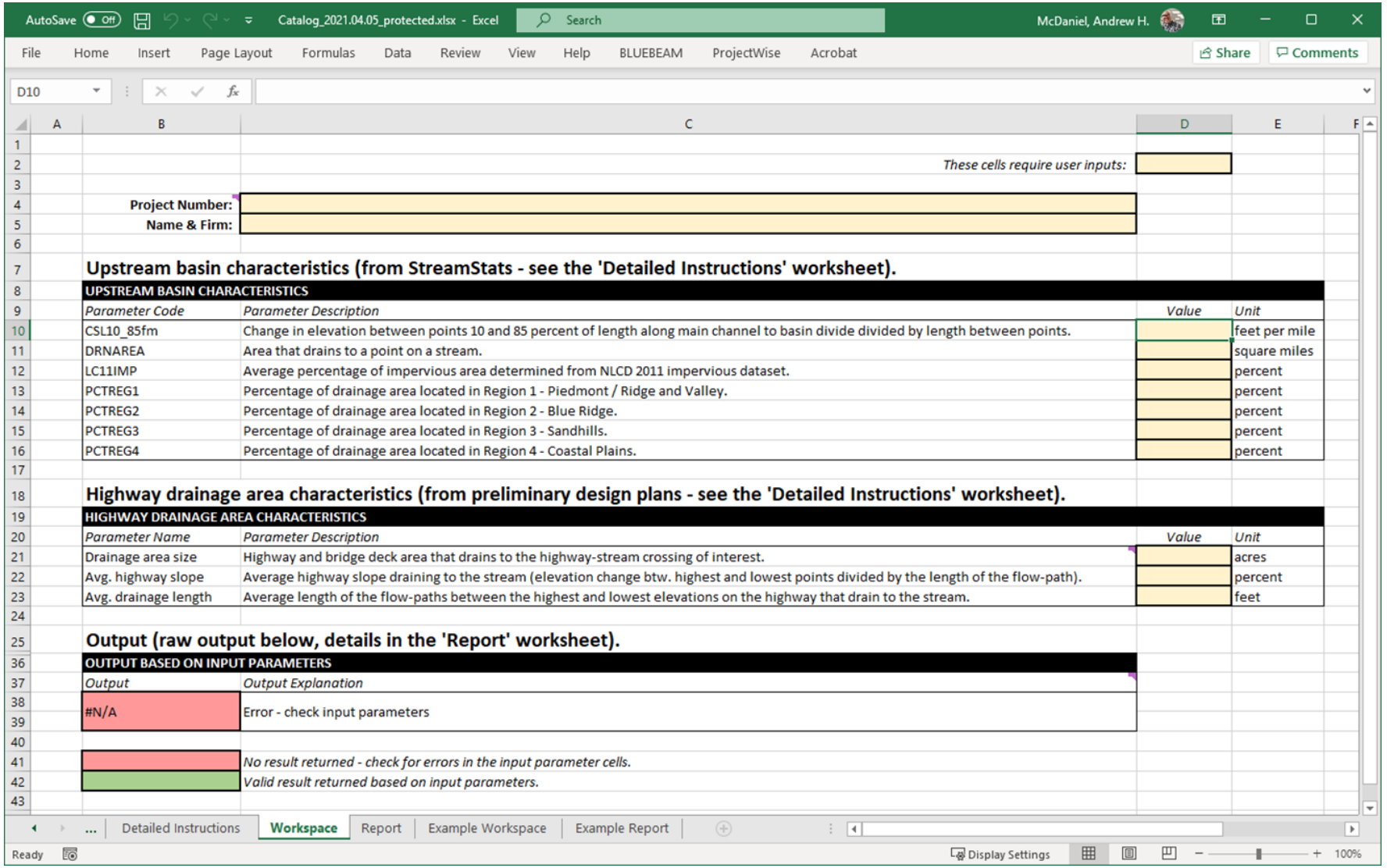




Stormwater

- NC-SELDM Catalog Tool
- BMP Decision Support Matrix
- Stormwater Control Measure Summary Sheets

NC-SELDM Catalog Tool



Catalog_2021.04.05_protected.xlsx - Excel

		These cells require user inputs:	
	Project Number:		
	Name & Firm:		

Upstream basin characteristics (from StreamStats - see the 'Detailed Instructions' worksheet).

UPSTREAM BASIN CHARACTERISTICS			
Parameter Code	*Parameter Description*	*Value*	*Unit*
CSL10_85fm	Change in elevation between points 10 and 85 percent of length along main channel to basin divide divided by length between points.		feet per mile
DRNAREA	Area that drains to a point on a stream.		square miles
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset.		percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley.		percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge.		percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills.		percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains.		percent

Highway drainage area characteristics (from preliminary design plans - see the 'Detailed Instructions' worksheet).

HIGHWAY DRAINAGE AREA CHARACTERISTICS			
Parameter Name	*Parameter Description*	*Value*	*Unit*
Drainage area size	Highway and bridge deck area that drains to the highway-stream crossing of interest.		acres
Avg. highway slope	Average highway slope draining to the stream (elevation change btw. highest and lowest points divided by the length of the flow-path).		percent
Avg. drainage length	Average length of the flow-paths between the highest and lowest elevations on the highway that drain to the stream.		feet

Output (raw output below, details in the 'Report' worksheet).

OUTPUT BASED ON INPUT PARAMETERS	
Output	*Output Explanation*
#N/A	Error - check input parameters
	No result returned - check for errors in the input parameter cells.
	Valid result returned based on input parameters.

Detailed Instructions | Workspace | Report | Example Workspace | Example Report

BMP Decision Support Matrix

BMP Selection Criteria	Bio-embank-ment[1a]	Biofiltration Conveyance[1a]		Bioretention[1a,2]		Bioswale[1a]		Dry Detention Basin[1a]	Filter Strip w/ Level Spreader[1a]	Filtration Basin[1a,2]		Green Roof[1a]	Infiltration Basin[1b]	Open Graded Friction Course[1a]	Permeable Pavement		Preformed Scour Hole[1a]	Rainwater Harvesting[1a,3]	Sand Filter[1a,4]	Soil Improve-ment[1a]	Storm-water Wetland[1a]	Swale[1a]		Tree Box[1a]	Wet Detention Basin[1a]
		w/o IWS	w/IWS	w/o IWS	w/IWS	w/o IWS	w/IWS			w/o IWS	w/IWS				Detention[1a]	Infiltrating[1b]						Dry	Wet		
Removal Efficiency for Parameters of Concern (POCs)[1]																									
Bacteria	Med	Med		High		Med		Low	Low	High		Low[12]	High	Low	Med	High	Low	Varies	Med	Low	High	Low		Med	High
Metals																									
Dissolved Metals	Low	Low		Med		Med		Low	Low	Med		Low	High	Low	Low	High	Low	Varies	Low	Low	Med	Low		Med	Low
Total Recoverable Metals	Low	Low		High		Med		Med	Med	High		Low	High	Low	Med	High	Med	Varies	Low	Low	High	Low		Med	Med
Nutrients																									
Dissolved Nitrogen[5]	Low	Low	Med	Med	High	Low	Med	Low	Low	Med	High	Low	High	Low	Low	High	Low	Varies	Low	Low	Med	Low	Low	Low	Low
Total Nitrogen[5]	Low	Low	Med	Med	High	Low	Med	Low	Low	Med	High	Med	High	Low	Low	High	Low	Varies	Low	Low	High	Low	Med	Med	Low
Dissolved Phosphorus	Med[11]	Med[11]		Med[11]		Med[11]		Low	Low	Med[11]		Low	High	Low	Low	High	Low	Varies	Med[11]	Low	Med	Low	Low	Med[11]	Low
Total Phosphorus	Med	Med		High		Med		Med	Low	High		Med	High	Low	Med	High	Low	Varies	Med	Low	High	Low	Med	Med	Med
Oil and Grease	High	High		High		High		Med	Med	High		N/A	High	Med	Med	High	Med	Varies	Med	Med	High	Med		High	Low
Organics	High	High		High		High		Med	Med	High		Med	High	Low	Low	High	Med	Varies	Med	Med	High	Med		High	Low
Temperature	Med	Med		High		Med		Low	Med	High		High	High	Low	High		Med	Low	Med	High	Low	Low		High	Low
Total Suspended Solids	High	High		High		High		Med	Med	High		High	High	Med	High		Med	High	High	Med	High	High		High	High
Trash	Med	High		High		High		High	High	High		N/A	High	Med	High		High	High	High	Med	High	Med		High	High
Water Quantity																									
Runoff Volume Reduction	Med	Low	Med	Med	High	Med	High	Med	Low	Med	High	Med	High	Low	Low	High	Low	Varies	Low	Med	Low	Low		Med	Low
Peak Flow Control	Low	Low		Med		Med		High	Med	Med		Med	High	Low	Med	High	Low	Varies	Med	Low	High	Low		Low	High
Siting Constraints and Other Implementation Considerations																									
Space Requirement	Low	Low		Med		Med		Med	Low	Med		Low	Med	Low	Low		Low	Low	Med	Low	High	Low		Low	High
Environmental Issues[6]																									
Contaminated Soils[7]	Use liner	Use liner		Use liner		Use liner		Use liner	Use liner	Use liner		Yes	No	Yes	Use liner	No	No	Yes	Use liner	No	Use liner	Use liner		Use liner	Use liner
Physical Site Limitations[6]																									
Karst Topography	Use liner	Use liner		Use liner		Use liner		Use liner	Yes	Use liner		Yes	No	Yes	Use liner	No	Yes	Yes	Use liner	Yes	Use liner	Yes		Use liner	Use liner
Shallow Bedrock[8]	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Shallow Water Table[9]	No	Yes		No		No		No	Yes	No		Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes
Steep Slopes (>5%)[10]	No	Yes		No		No		No	Yes	No		Yes	No	Yes	No		No	Yes	No	Yes	No	No		No	No
Cost Considerations																									
Construction Cost	$-$$	$$-$$$		$-$$		$-$$		$-$$	$-$$	$-$$		$$-$$$	$-$$	$$-$$$	$$-$$$		$	Varies	$-$$$	$-$$	$-$$	$		$-$$	$-$$
O&M Cost	$-$$	$$		$-$$		$-$$		$-$$	$	$		$-$$	$-$$	$$	$$-$$$		$	Varies	$-$$$	$	$-$$	$		$$-$$$	$-$$

[1] "High", "Med", "Low", or "N/A". [1a] EMC-based pollutant reduction. [1b] Load-based pollutant reduction.

[2] All NCDOT Bioretention and Filtration Basin facilities include underdrain; if no underdrain, see Infiltration Basin.

[3] Water quality and quantity performance varies based on size of system and use of captured water.

[4] For Sand Filter, an enclosed chamber type system (e.g., Austin/Delaware) is assumed.

[5] Note that nitrogen concentrations in roadway runoff are generally low; this reduces the removal efficiency of many BMPs.

[6] "Yes" indicates BMP is suitable for locations with a particular siting constraint. "No" indicates that the BMP is not suitable.

[7] When contaminated soils are present, consultation with the Geotech Unit and Hydraulics Unit is highly recommended.

[8] For suitable BMPs, it may be necessary to increase practice footprint and/or install an impermeable liner to achieve desired performance.

[9] For suitable BMPs, an impermeable liner may be required. Additional investigation and consultation with Geotech and Hydraulics Units recommended.

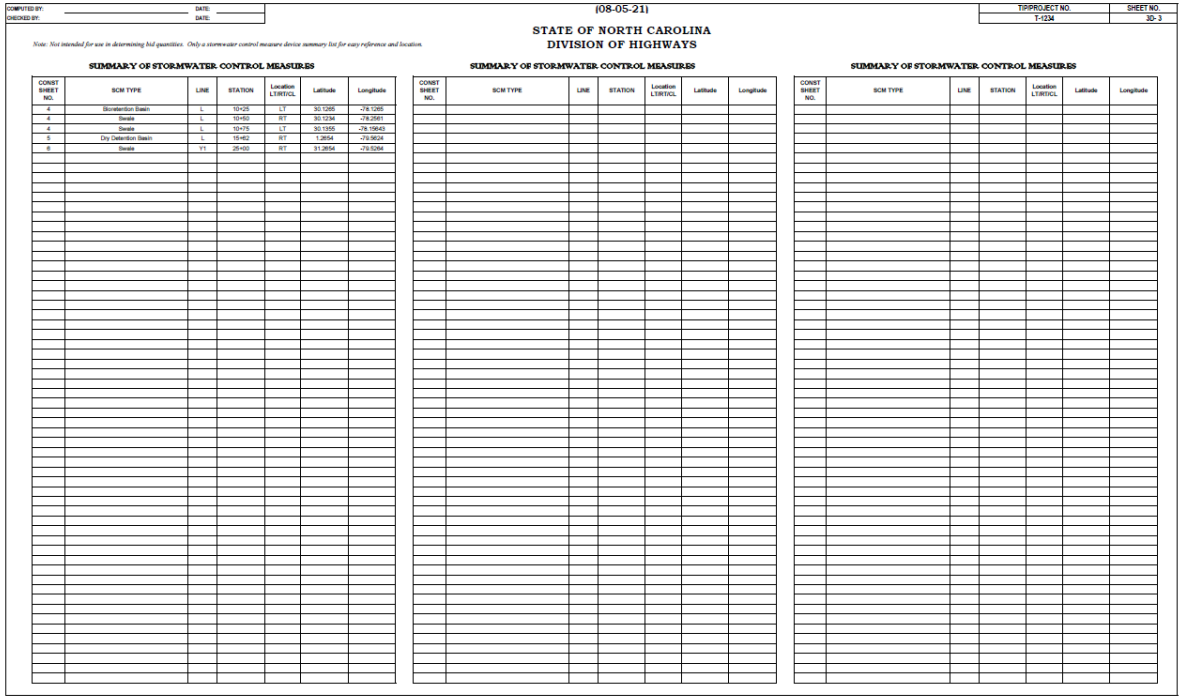
[10] For green roof, slope refers to roof pitch. Note that design modifications are required for roof pitch >8% (per NCDEQ).

[11] With media amended or enhanced to increase dissolved P removal.

[12] Green roofs are not typically a significant source of bacteria.

Stormwater Control Measure Summary Sheets

- To be a part of the 3D series (Drainage Summary) sheets in plan sets
- Auto-populated from entries in the stormwater management plan



COMPUTED BY: _____ DATE: _____
CHECKED BY: _____ DATE: _____

(08-05-21)

TIP/PROJECT NO. T-1234 | SHEET NO. 3D- 3

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS

Note: Not intended for use in determining bid quantities. Only a stormwater control measure device summary list for easy reference and location.

SUMMARY OF STORMWATER CONTROL MEASURES

CONST SHEET NO.	SCM TYPE	LINE	STATION	Location L/SRT/CL	Latitude	Longitude
4	Bioretention Basin	L	10+25	LT	30.1265	-78.1265
4	Swale	L	10+50	RT	30.1234	-78.2561
4	Swale	L	10+75	LT	30.1355	-78.15643
5	Dry Detention Basin	L	15+62	RT	1.2654	-79.9624
6	Swale	Y1	25+00	RT	31.2654	-79.5264

SUMMARY OF STORMWATER CONTROL MEASURES

CONST SHEET NO.	SCM TYPE	LINE	STATION	Location L/SRT/CL	Latitude	Longitude

SUMMARY OF STORMWATER CONTROL MEASURES

CONST SHEET NO.	SCM TYPE	LINE	STATION	Location L/SRT/CL	Latitude	Longitude

Completing 3D Series Hydraulic Summary Plan Sheets, Including Drainage Summary Sheets and Stormwater Control Measure Summary Sheets

August 5, 2021

Construction plan sheets include 3D Series drainage summary sheets. Traditionally these sheets have included the summary of pipe and drainage structure types. With the implementation of Project Delivery Network version 2.0 the 3D series sheets will now also include stormwater control measure summaries for projects where stormwater controls are included. Not all projects will include stormwater control measures, thus these sheets should be the last sheets within the 3D series.

Drainage Summary Sheets:

Drainage summary sheets should be filled out per guidance in the "Drainage Summary Sheet – Steps for Hydraulic Users" located on the Connect site here:
https://connect.ncdot.gov/resources/hydro/Geopak%20Applications%20Documents/Drainage%20Summary%20Sheet%20-%20Hydro%20Steps.pdf

Once the traditional drainage summary sheets have been filled out the user should add the stormwater control summary sheets starting with the next available consecutive page number.

Stormwater Control Measure Summary Sheets:

The Highway Stormwater Program (HSP) has amended the Stormwater Management Plan (SMP) template to automate the creation of the stormwater control measure summary sheet. Hydraulic design engineers are required to complete a Stormwater Management Plan (SMP) for all projects and should always use the latest SMP template version found on the Connect Site here:
https://connect.ncdot.gov/resources/hydro/Pages/HSPProductPages.aspx?PROD=SMP

Users should complete the SMP per the instruction included in that document. As a general summary, users should fill out the 'General Project Information' and 'Waterbody Information' tabs along with any applicable stormwater control measure tabs (Swales, Filter Strip, PSHs & Energy Dissipators, Level Spreader & HSB, Other Toolbox BMPs, Other Non-Toolbox BMPs). These tabs are illustrated in Figure 1.

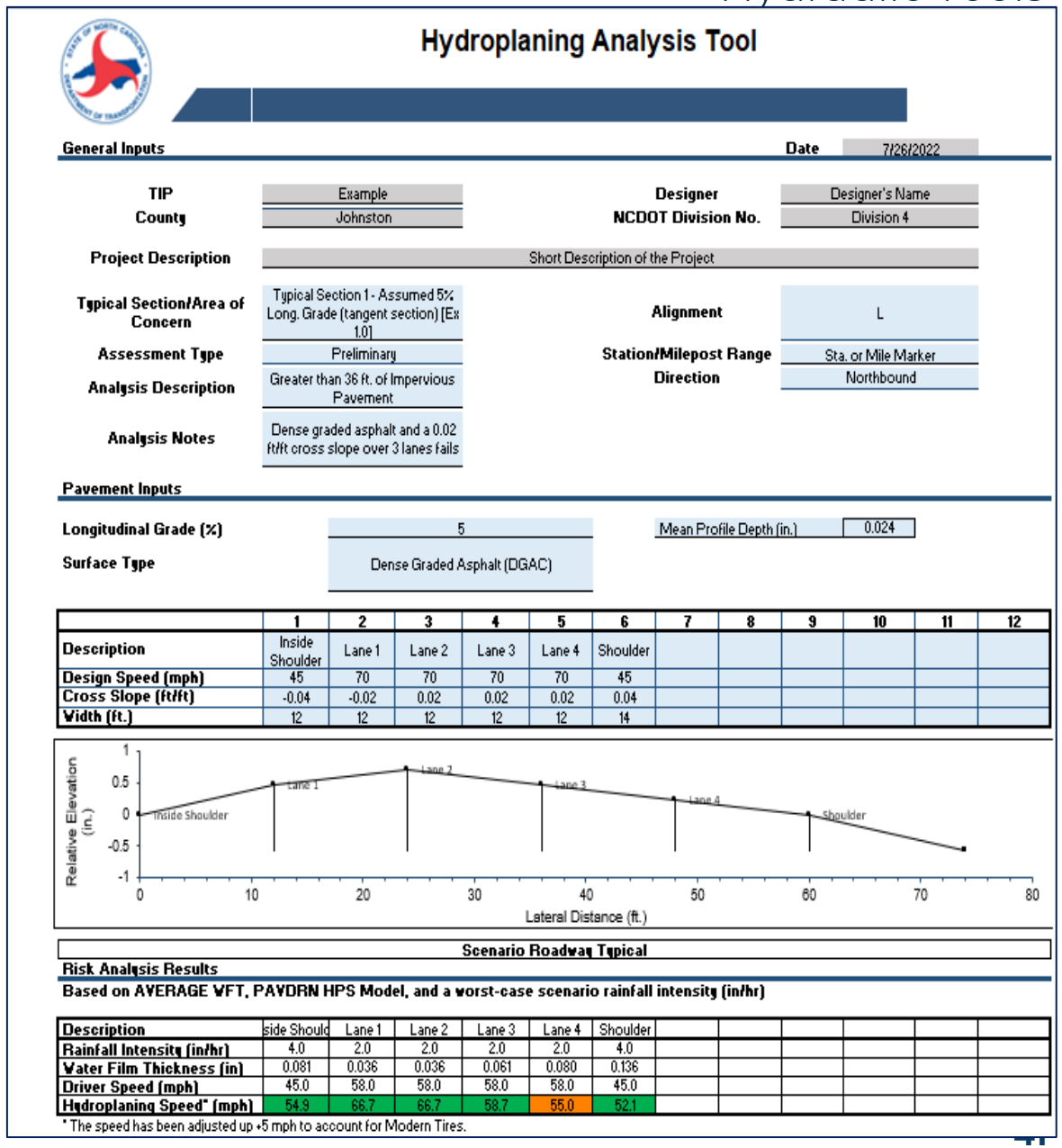
Hydraulic Calculators

- Hydroplaning Assessment Tool
  - This tool will assist in completing hydroplaning assessments, when required, on the projects
- Outlet Analysis
  - Coming Soon

NEW

Hydroplaning Assessment Tool

https://connect.ncdot.gov/resources/hydro/DrainageStudiesGuidelines/NCDOTHydroplaningAssessmentTool.xlsm



Hydroplaning Analysis Tool

General Inputs — **Date** 7/26/2022

TIP	Example	**Designer**	Designer's Name
County	Johnston	**NCDOT Division No.**	Division 4
Project Description	Short Description of the Project		
Typical Section/Area of Concern	Typical Section 1 - Assumed 5% Long. Grade (tangent section) [Ex 1.0]	**Alignment**	L
Assessment Type	Preliminary	**Station/Milepost Range**	Sta. or Mile Marker
Analysis Description	Greater than 36 ft. of Impervious Pavement	**Direction**	Northbound
Analysis Notes	Dense graded asphalt and a 0.02 ft/ft cross slope over 3 lanes fails		

Pavement Inputs

Longitudinal Grade (%)	5	Mean Profile Depth (in.)	0.024
Surface Type	Dense Graded Asphalt (DGAC)		

	1	2	3	4	5	6	7	8	9	10	11	12
Description	Inside Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Design Speed (mph)	45	70	70	70	70	45						
Cross Slope (ft/ft)	-0.04	-0.02	0.02	0.02	0.02	0.04						
Width (ft.)	12	12	12	12	12	14						

Scenario Roadway Typical

Risk Analysis Results

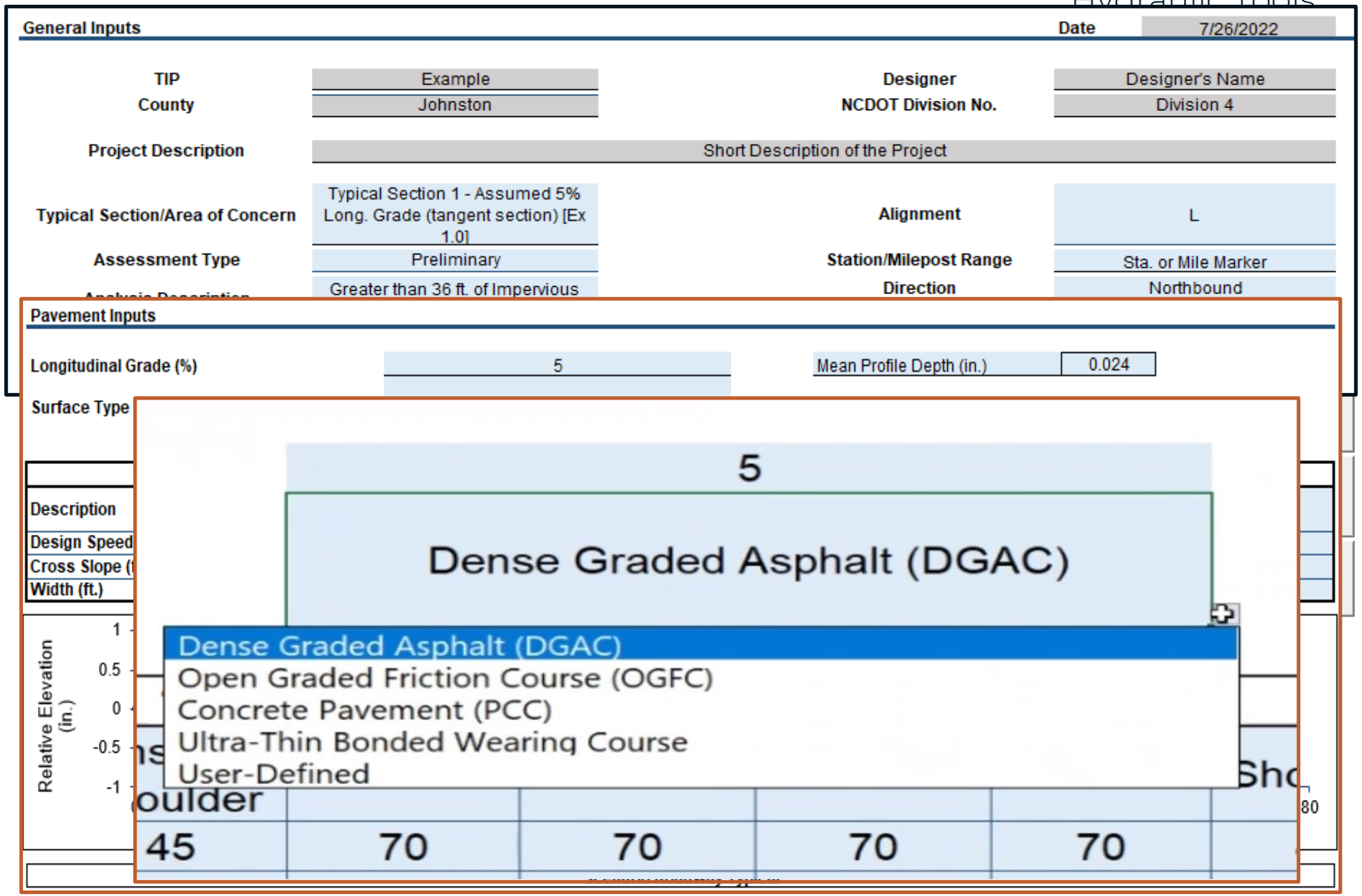
Based on AVERAGE WFT, PAVDRN HPS Model, and a worst-case scenario rainfall intensity (in/hr)

	side Should	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Rainfall Intensity (in/hr)	4.0	2.0	2.0	2.0	2.0	4.0						
Water Film Thickness (in)	0.081	0.036	0.036	0.061	0.080	0.136						
Driver Speed (mph)	45.0	58.0	58.0	58.0	58.0	45.0						
Hydroplaning Speed* (mph)	54.9	66.7	66.7	58.7	55.0	52.1						

* The speed has been adjusted up +5 mph to account for Modern Tires.

Inputs

- General
- Pavement
- Roadway



Scenario Results

Risk Analysis Results

Based on AVERAGE WFT, PAVDRN H

Description	sic
Rainfall Intensity (in/hr)	
Water Film Thickness (in)	
Driver Speed (mph)	
Hydroplaning Speed* (mph)	

* The speed has been adjusted up +5 m

Possible Hydroplane Conditions

High

High : *HPS is ≥ 4 mph Below the Pre*

Low: *HPS is ≥ 2 mph Below The Pr*
Mitigation methods needed and pro
driver responsibility.

None: *HPS is greater than Predicte*

Risk Analysis Results

(Based on AVERAGE WFT and PAVDRN HPS Models)

Predicted Water Film Thickness (in.)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	side Shoulde	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	-0.012	-0.014	-0.014	-0.009	-0.005	-0.004						
0.25	-0.002	-0.006	-0.006	0.002	0.009	0.010						
0.5	0.009	0.003	0.003	0.015	0.024	0.027						
1	0.025	0.016	0.016	0.034	0.047	0.051						
2	0.048	0.036	0.036	0.061	0.080	0.086						
3	0.066	0.051	0.051	0.082	0.106	0.113						
4	0.081	0.064	0.064	0.100	0.128	0.136						

Predicted Driver Speed (mph)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	side Shoulde	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	45.0	70.0	70.0	70.0	70.0	45.0						
0.25	45.0	70.0	70.0	70.0	70.0	45.0						
0.5	45.0	64.0	64.0	64.0	64.0	45.0						
1	45.0	62.0	62.0	62.0	62.0	45.0						
2	45.0	58.0	58.0	58.0	58.0	45.0						
3	45.0	45.0	45.0	45.0	45.0	45.0						
4	45.0	45.0	45.0	45.0	45.0	45.0						

Predicted Hydroplaning Speed (mph)

"These speeds are increased by 5MPH to account for Gunaratne research."

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	side Shoulde	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	999.0	999.0	999.0	999.0	999.0	999.0						
0.25	999.0	999.0	999.0	132.5	94.2	89.9						
0.5	93.9	122.5	122.5	82.1	73.1	71.3						
1	72.9	80.6	80.6	67.6	62.4	61.3						
2	62.3	66.7	66.7	58.7	55.0	54.2						
3	57.7	61.3	61.3	54.7	52.6	52.5						
4	54.9	58.1	58.1	52.8	52.2	52.1						

Superelevation Transitions

Typical Section/Area of Concern	Rollover Transition [Ex 3.0]			
Assessment Type	Final			
Analysis Description	Superelevation Transition			
Superelevation Transition	# of lanes	3	Factor	1.5

Fails with Dense Graded Asphalt

Risk Analysis Results

Based on AVERAGE WFT, PAVDRN HPS Model, and a worst-case scenario rainfall intensity (in/hr)

Max WFT Condition within the SE Rollover	
Rainfall Intensity (in/hr)	2.0
Water Film Thickness (in)	0.106
Driver Speed (mph)	58.0
Hydroplaning Speed* (mph)	52.6

* The speed has been adjusted up +5 mph to account for Modern Tires.

Pavem

Longitu

Surface

Descrip												
Design Speed (mph)	45	70	70	70	70	45						
Cross Slope (ft/ft)	-0.04	-0.02	0.02	0.02	0.02	0.04						
Width (ft.)	12	12	12	12	12	14						

Hydraulics Designer: Designer's Name
Reviewer:
Date: 7/26/2022
Project TIP #: Example

Final Hydroplaning Assessment

Area of Concern	Analysis Description	Alignment	Station	Direction	Lane	Design Speed (mph)	Rainfall Intensity (I, in/hr)	Long. Slope (%)	Cross Slope (ft/ft)	Pavement Width (ft)	Pavement Surface Material	Hydroplaning Average WFT (in)	PAVDRN Hydroplaning Speed (mph)	Predicted Driver Speed (mph)	Analysis Notes	User-Defined Pavement Notes
Typical Section 1 - Max. Long Grade (tangent section) [Ex 2.0]	Greater than 36 ft. of Impervious Pavement	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	3.3	0.02	36.0	DGAC	0.07	56.1	58.0	0.02 ft/ft cross slope on the exterior produces more potential for hydroplaning	
Typical Section 1 - Max. Long Grade (tangent section) [Ex 2.1]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	3.3	0.03	36.0	DGAC	0.07	57.6	58.0	No Hydroplaning potential w/ 0.03 ft/ft Exterior Lane cross slope	
Typical Section 1 - Max. Long Grade (tangent section) [Ex 2.2]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	3.3	0.03	36.0	PCC	0.06	60.1	58.0	Concrete Pavement (PCC) shows no potential for Hydroplaning	
Typical Section 1 - Max. Long Grade (tangent section) [Ex 2.3]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	3.3	0.03	36.0	UTBWC	0.05	60.9	58.0	Ultra-Thin Bonded Wearing Course Surface shows no potential for Hydroplaning	
Typical Section 1 - Max. Long Grade (tangent section) [Ex 2.4]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	3.3	0.03	36.0	OGFC	0.04	63.8	58.0	Open Graded Friction Course Surface shows no potential for Hydroplaning	
Rollover Transition [Ex 3.0]	Superelevation Transition	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	2.5	0.02	36.0	DGAC	0.11	52.6	58.0	Fails with Dense Graded Asphalt (DGAC)	
Rollover Transition [Ex 3.1]	Superelevation Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	2.5	0.02	36.0	PCC	0.09	54.6	58.0	Fails with Concrete Pavement (PCC)	
Rollover Transition [Ex 3.2]	Superelevation Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	2.5	0.02	36.0	UTBWC	0.09	55.5	58.0	Shows a high potential for hydroplaning conditions	
Rollover Transition [Ex 3.3]	Superelevation Mitigation	L	Sta. or Mile Marker	Northbound	Lane 4	70.0	2.0	2.5	0.02	36.0	OGFC	0.07	60.3	58.0	Open Graded Friction Course Surface Passes	
Initial Uniform Cross-slope After Rollover Transition [Ex 4.0]	Greater than 36 ft. of Impervious Pavement	L	Sta. or Mile Marker	Northbound	Lane 1	70.0	2.0	2.5	-0.02	24.0	DGAC	0.09	54.2	58.0	Fails when using Dense Graded Asphalt (DGAC)	
Initial Uniform Cross-slope After Rollover Transition [Ex 4.1]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 1	70.0	2.0	2.5	-0.02	24.0	PCC	0.07	56.1	58.0	Concrete Pavement (PCC) Shows more potential for hydroplaning conditions	
Initial Uniform Cross-slope After Rollover Transition [Ex 4.2]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 1	70.0	2.0	2.5	-0.02	24.0	UTBWC	0.07	56.7	58.0	Ultra-Thin Bonded Wearing Course Shows low potential for hydroplaning conditions	
Initial Uniform Cross-slope After Rollover Transition [Ex 4.3]	Mitigation	L	Sta. or Mile Marker	Northbound	Lane 1	70.0	2.0	2.5	-0.02	24.0	OGFC	0.06	60.8	58.0	Open Graded Friction Course Surface shows no potential for Hydroplaning	

Contact Us

Questions for the Hydraulics Unit

[Contact the Unit]

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