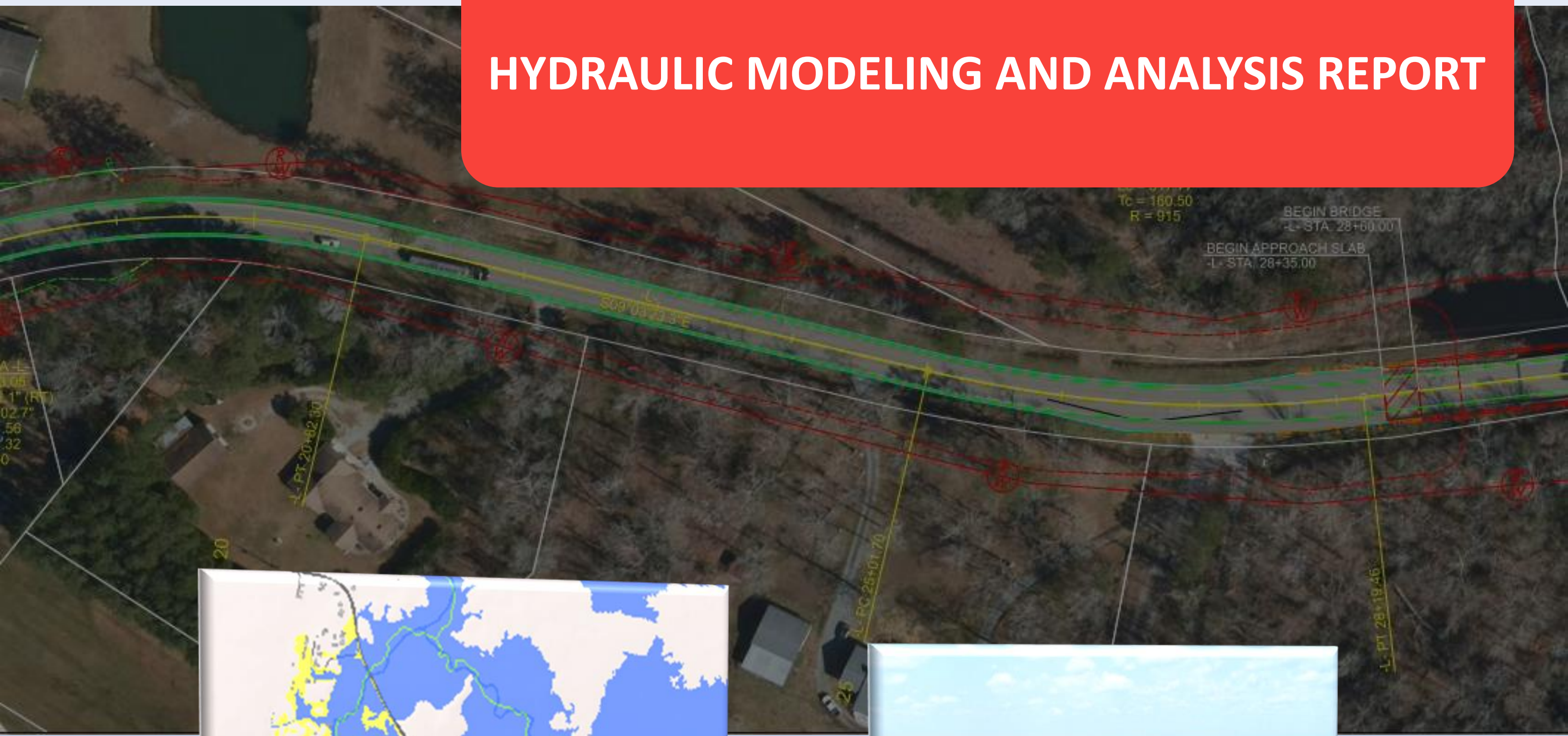
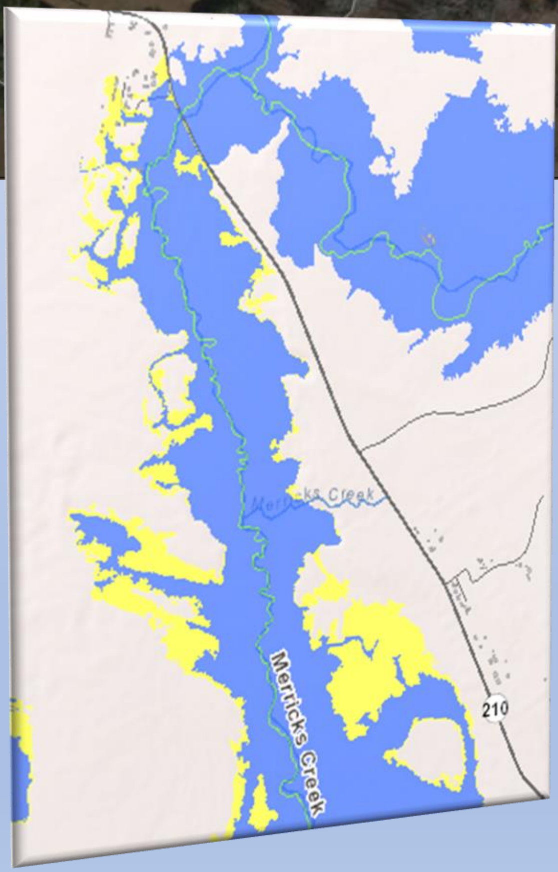
PENDER COUNTY

NORTH CAROLINA HIGHWAY 210 RESILIENCY ANALYSIS

HYDRAULIC MODELING AND ANALYSIS REPORT





PREPARED BY WSP

NOVEMBER 14, 2023

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1 PROJECT OVERVIEW

WSP has been tasked with assisting Pender County in assessing flood resiliency of Highway 210, spanning from the intersection of Highway 210 and I-40 east to the intersection of US 17 and Highway 210. This segment of Highway 210 is designated as the evacuation route for coastal areas from US 17 to Interstate I-40 in Rocky Point, NC. This route serves as the primary evacuation corridor for the eastern portion of the County where a significant portion of the County's population resides.

The primary objectives of this study are to identify barriers to resiliency, develop alternatives to improve roadway resiliency, and create design plans and cost estimates in alignment with NCDOT's Roadway Feasibility Studies.

An existing conditions hydraulic model was developed to assess the impacts for the 10, 25, 50, 100, 500-year recurrence intervals as well as Hurricane Florence along the Highway 210 corridor. This analysis encompassed the Northeast Cape Fear Watershed, Merricks Creek and Harrison Creek watersheds, and several unnamed small drainage basins (see Figure 1).

On March 28th, 2023, WSP delivered a presentation to staff members of NCDOT and Pender County, showcasing the results of the existing conditions modeling. During the presentation, four locations of concern were identified from the existing conditions model: Merricks Creek, Harrisons Creek, culverts located 1.6 miles north of Harrisons Creek, and a culvert located 0.8 miles north of Harrisons Creek. These locations experienced considerable flooding in the model simulation, which could impede evacuation traffic and inhibit the access of emergency responders.

Along with the specific areas of concern, the intent of the meeting was to discuss and define the goals for resilience for the corridor. Resilience is defined as the capacity of a system to recover quickly from an event. For the purposes of this study, resilience will be defined as the ability of Highway 210 to remain open or recover quickly from flooding events. The presentation and discussion led to the decision to establish the 100-year recurrence interval as the resiliency target for the Highway 210 corridor. Typically, major arterials in North Carolina, which Highway 210 is classified as, are designed to convey 50-year recurrence interval events with flooding or overtopping. NCDOT's Hydraulic Guidelines (NCDOT, 2022) state that,

"it would be considered reasonable and prudent that higher hydraulic performance standards for the Strategic Transportation Corridor network, major arterials, evacuation routes, and other important roadways should be carefully considered during planning and design to include, among other things, risk to commerce, accessibility, and evacuation due to road closure caused by inundation, including non-stationarity in future climate models."

Because Highway 210 is a state-identified evacuation route, the decision was made to increase the design frequency from the 50-year to the 100-year recurrence interval storm event. It was also discussed that the extent of improvements necessary to target the 500-year recurrence interval event or a theoretical hurricane event would be exceedingly impactful and cost-prohibitive. Subsequently, the proposed conditions model was developed to assess multiple design alternatives aimed at enhancing flood resiliency at the identified locations of concern. The model also evaluated the design impacts on the upstream and downstream areas.

This report details the methodology used for both the existing and proposed conditions hydraulic models and presents the recommended resilience measures for the Highway 210 corridor in Pender County for the 100-year recurrence interval.

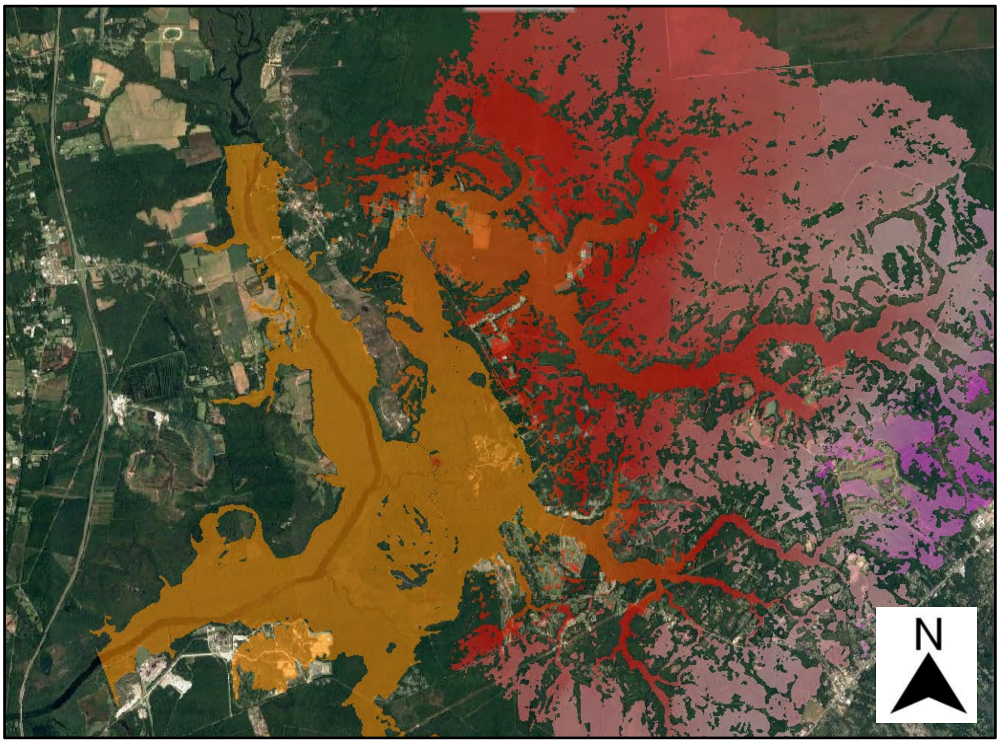

Figure 1: Inundation area developed through 2D model for Highway 210 corridor.

2 EXISTING CONDITIONS MODEL

The existing conditions model is developed using two-dimensional (2D) modeling in HEC-RAS version 6.3.1. HEC-RAS is simulation software created by the US Army Corps of Engineers, specifically designed for modeling the hydraulics of water flow through natural river and channels (U.S. Army Corps of Engineers).

One-dimensional (1D) modeling of riverine systems is limited to one-directional flow and lacks the capability to model large and complex watershed systems with multiple inflow and outflow locations. 2D modeling is the preferred modeling method for wide floodplain areas where flow is expected to spread across large areas.

2.1 HYDROLOGY

Simulations were conducted for the standard 24-hour design storm frequency for recurrence intervals of 10, 25, 50, 100, and 500-year events, as well as the impact of Hurricane Florence. These simulations covered the watershed area that drains into the Highway 210 study corridor. The study area encompasses Merricks Creek, Harrisons Creek, Northeast Cape Fear River, Island Creek, and several unnamed small tributary drainage basins.

2.1.1 NORTHEAST CAPE FEAR RIVER

Hydrologic inputs for the Northeast Cape Fear River (NECF) are modeled using 1D hydrology. Due to the extensive area covered by the Northeast Cape Fear River drainage basin, utilizing the rain-on-grid method would demand substantial computational power and simulation run time, which would present complexities in computational resources and execution runtime for this study.

The existing conditions model utilizes steady flow data from FEMA's Effective model for the Northeast Cape Fear. The 25-year streamflow is determined through StreamStats, a web application provided by the US Geological Survey that offers GIS and analytical tools for water resources purposes. The hydrologic steady flow data uses in the model are listed in Table 1.

Table 1: Northeast Cape Fear Hydrology

STORM EVENT	FLOW (CFS)	SOURCE
10-year	16,100	Effective Model
25-year	19,700	StreamStats
50-year	30,500	Effective Model
100-year	37,900	Effective Model
500-year	59,7000	Effective Model

2.1.2 ISLAND CREEK

Island Creek is located south of the Highway 210 corridor and has been incorporated into the model to consider any potential minimal impacts on water surface elevations that could propagate upstream to Highway 210. Hydrologic inputs for the Island Creek watershed are modeled as 1D hydrology.

The existing conditions model makes use of steady flow data from the current Effective model for Island Creek. The 25-year flow is determined through StreamStats. Table 2 presents the steady flow data utilized in the model.

Table 2: Island Creek Hydrology

STORM EVENT	FLOW (CFS)	SOURCE
10-year	657	Effective Model
25-year	865	StreamStats
50-year	1,257	Effective Model
100-year	1,589	Effective Model
500-year	2,574	Effective Model

2.1.3 ATLANTIC OCEAN

The backwater effects from the Atlantic Ocean are of considerable significance, with their impacts extending to the Highway 210 corridor. The backwater elevations from the Atlantic Ocean have been integrated into the existing conditions model as downstream boundary conditions, utilizing a stage hydrograph.

The determination of backwater elevations was based on data from the Pender County Effective Flood Insurance Study (FIS) Report, specifically the coastal stillwater elevations. The FIS report, with an effective date of June 2, 2021(Appendix 2), provides these coastal Stillwater elevations. It is worth noting that coastal Stillwater elevations are not provided for the 25-year storm event, and are determined through linear interpolation of the provided stillwater elevations in the FIS.

Table 3: Atlantic Ocean Costal Stillwater Elevations

STORM EVENT	STILLWATER ELEVATIONS (FT)	SOURCE
10-year	4.9	Flood Insurance Study Report
25-year	5.8	Linear Interpolation
50-year	6.6	Flood Insurance Study Report
100-year	7.3	Flood Insurance Study Report
500-year	8.7	Flood Insurance Study Report

Note: Coastal Stillwater elevations are in NAVD88

2.1.4 PRECIPITATION

The watershed encompassing Harrisons Creek and Merricks Creek include several unnamed tributaries that flow into the Highway 210 study corridor. To account for cumulative flow impacts within the drainage area, a rain-on-grid (precipitation) approach is utilized for the hydrologic inputs.

Precipitation data sourced from NOAA Atlas 14 has been used for the 10-year, 25-year, 50-year, 100-year, and 500-year recurrence intervals. Atlas 14 is a precipitation frequency data server developed by the National Oceanic and Atmospheric Administration (NOAA) that provides precipitation frequency estimates for the United States (see Appendix 3).

The precipitation data is input as a 24-hour storm hydrograph. Areal reduction of 85% is used for this area based on guidance provided in the USDA technical report, TR-60 (USDA, 2005). The incorporation of the areal reduction factor into the precipitation hydrograph is necessary because rainfall intensity across large catchments is not constant throughout the entire catchment during the duration of a storm. Table 4 presents the NOAA Atlas 14 precipitation values for the 24-hour storm intensity for the Merricks Creek and Harrisons Creek watershed. Precipitation data for Hurricane Florence is based on NOAA's National Hurricane Center Tropical Cyclone Report published September 25, 2019 (National Hurricane Center, 2019).

Table 4: NOAA Atlas 14 Precipitation

STORM EVENT	PRECIPITATION (INCHES)
10-year	7.04
25-year	8.83
50-year	10.4
100-year	12.2
500-year	17.5
Florence	35.0

2.1.5 HURRICANE FLORENCE

Documented USGS gage data near the study area's limits were not available for Hurricane Florence. However, documented high watermarks were available for Hurricane Florence. To simulate the water surface elevations during Hurricane Florence, inflows for the Northeast Cape Fear were interpolated until the model produced water surface elevations similar to those indicated by the high watermarks.

For the rain-on-grid watershed, recorded precipitation data from NOAA was employed, amounting to approximately 35 inches of rainfall. In the model, this rainfall was simulated with a conservative 2-day rainfall duration.

2.2 HYDRAULICS

2.2.1 BUILDING THE BASE MODEL

2D FLOW AREA

The 2D flow area has been established by incorporating watersheds for the Northeast Cape Fear River and Harrisons/Merricks Creek.

Given the extensive size of the Northeast Cape Fear, utilizing a rain-on-grid method would require significant processing power and run time. Instead, 1D hydrology from the Effective model is used for the NECF and the 2D flow area is limited to the vicinity just upstream of the Highway 210 crossing of the Northeast Cape Fear River

The watershed area for Merricks and Harrisons Creeks is determined up to their confluence with the Northeast Cape Fear River. Two methods were used to determine the watershed area: StreamStats and the “watershed” tool in ArcMap. These two methods yielded very similar results, with minor variations observed at the outer edges of the watershed. To maintain a conservative approach, the boundaries of the watershed extents from both methods were merged into one.

Figure 2 provides an overview of the limits of the 2D flow areas, hydrologic inflows, stream locations, and Highway 210. The eastern area represents the Merricks Creek and Harrisons Creek watershed, while the western area covers the Northeast Cape Fear and Island Creek. Precipitation inflow occurs through the right watershed, while 1D hydrology and ocean backwater inflows are routed through the left watershed. The boundary between these two 2D areas facilitates flow interchange based on terrain and hydraulic considerations at specific locations. The configuration of the 2D areas is further elaborated on in the following section.

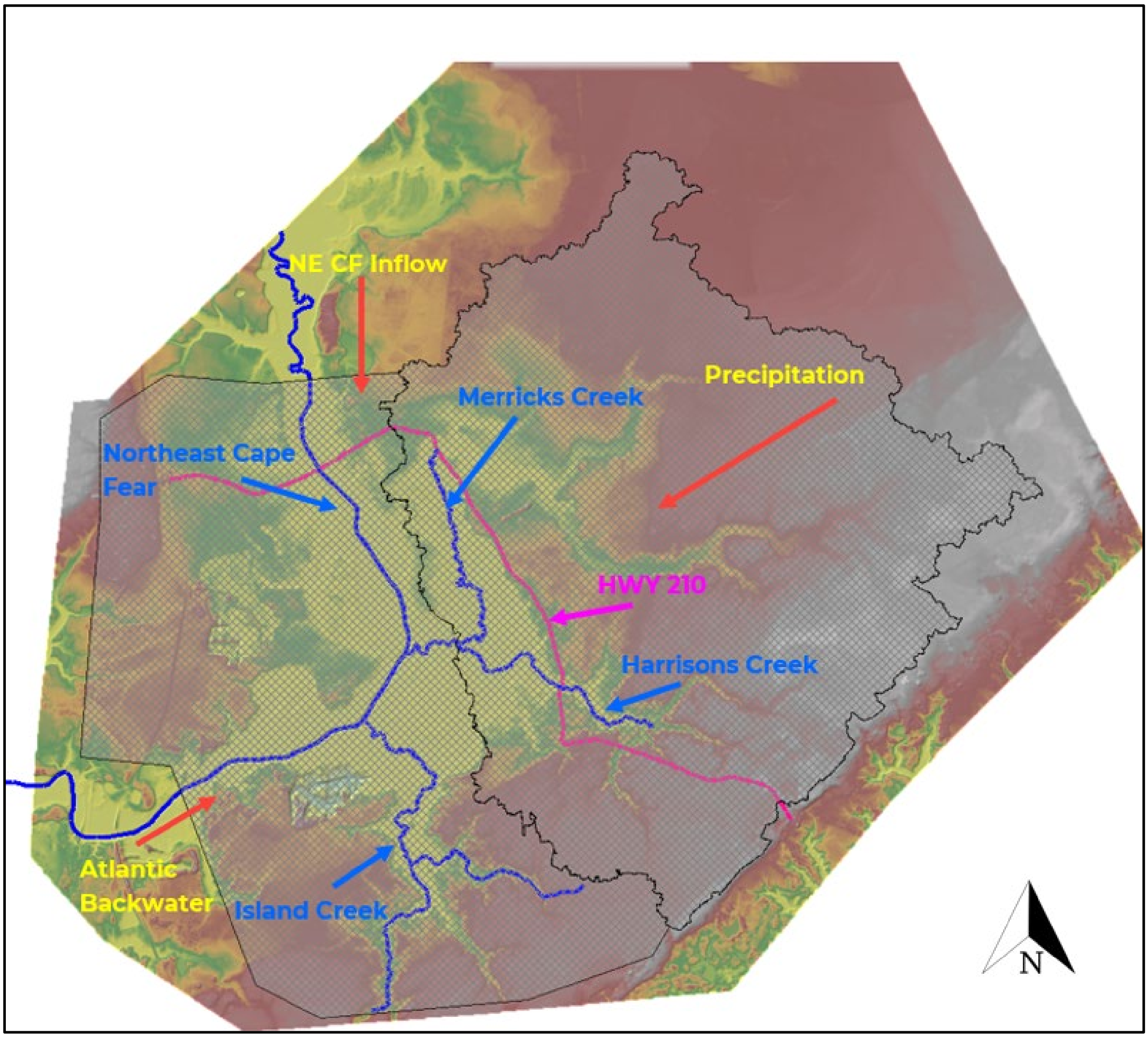

Figure 2: Summary of watersheds, hydrologic inflows, critical streams, and Highway 210 in the 2D area.

SA/2D CONNECTIONS

The confluence area where the Northeast Cape Fear (NECF) meets Merricks/Harrisons Creek is characterized by low-lying marshland. In this region, it is anticipated that flow from the NECF will cross into the rain-on-grid watershed, and conversely, flow from the rain-on-grid watershed will enter the NECF. To accommodate this flow exchange between the two watersheds, SA/2D connections in the form of weirs have been incorporated along the entire shared boundary between these two watersheds.

The SA/2D connection is a specific layer within HEC-RAS used for establishing connections between storage areas and 2D flow areas (U.S. Army Corps of Engineers). This approach ensures that flow does not accumulate excessively in either of the 2D areas, allowing it to progress downstream as the simulation unfolds.

TERRAIN:

LiDAR, or Light Detection and Ranging, is a remote sensing method utilized to measure variable distances to the Earth's surface (National Oceanic and Atmospheric Administration). Notably, LiDAR data does not capture bathymetric information below the water surface. This limitation poses challenges for accurately representing the total flow area in large and deep rivers.

Considering the Northeast Cape Fear (NECF) is a notably wide and deep river, the inclusion of additional storage area is essential to obtain reasonable results in constructing the existing conditions model. To account for the storage area of the NECF, the channel bottom has been incorporated into the terrain. The available Effective model data is limited to the Highway 210 crossing over the NECF, requiring assumptions about the channel's slope and width.

Assumptions were made that the NECF maintains a relatively flat slope and a consistent width throughout the model's extent. The channel bottom elevation is approximated based on the Effective model data.

Additionally, a terrain scan was conducted to identify culverts, which were then integrated into the terrain. Existing buildings within the area were elevated within the terrain model to account for potential obstructions to the flow.

LANDCOVER:

Land cover data is incorporated into the model from the National Landcover Dataset (NLCD) 2019 dataset (MRLC). Land cover data documents the type of surface that covers the project area. Such surfaces include forest, wetlands, impervious surface, open water, asphalt, or bare ground.

SOILS:

Soils layer is incorporated into the model from the USGS Soil Survey Geographic Database (SSURGO) data set (USDA). Soil layer data documents the type of soil that covers the project area. Varying soil types can impact precipitation infiltration rates into the ground.

INFILTRATION:

Infiltration into the soil is determined by creating an infiltration layer from the landcover and soils. This function can be completed within HEC-RAS.

BREAKLINES:

NCDOT road lines are imported into the model as breaklines. Breaklines are adjusted as necessary based on the latest aerial imagery. A breakline is a line in a digital elevation model that represents a distinct interruption in the slope of a surface, such as a ridge, road, or stream.

BRIDGE STRUCTURES:

Three bridge structures are incorporated into the 2D model from data available in the Effective models. The structures are bridge crossings at the Northeast Cape Fear, Merricks Creek, and Harrisons Creek.

2.2.2 RUNNING THE MODEL

The HEC-RAS model is run in two plans for each storm event. The model is computed in this manor to account for the different boundary conditions.

Plan 1: The first plan is run to only include the flow for the NECF and Island Creek. This plan considers the “base flow”. The plan is run to get the model stabilized and a steady state. Plan is titled “Existing Conditions_100yr_Base”. A restart file is created at the end of the simulation.

Plan 2: The second plan is run to include the precipitation and Atlantic backwater. The “base flow” plan is used as a restart file before the precipitation and Atlantic backwater start. Plan is titled “Existing Conditions_100yr+100yr Base”

Each plan is run for a simulated window of three days to ensure the peak of the storm has passed through the 2D flow area.

2.2.3 VALIDATING MODEL OUTPUTS

Recorded highwater marks from Hurricane Florence and Effective model water surface elevations are used to validate the model. Channel depth and downstream normal depth are adjusted until the 100-yr flood elevations are similar to the Effective and highwater elevations. The validation ensures the hydraulic system within the 2D area is similar to recorded and current Effective data.

2.3 RESULTS

2.3.1 NORTHEAST CAPE FEAR

A summary of the results from each storm event for the Northeast Cape Fear is provided in Table 5. The maximum overtopping depth is an approximate value derived from the HEC-RAS Depth raster and represents the water depth over the roadway along the roadway centerline within our elevation data. The duration of overtopping is also an approximate value calculated from the HEC-RAS water surface elevation raster. The duration of overtopping is determined from the timestamp when the road becomes significantly inundated to the timestamp when the road is clear again and allows for traffic to pass.

The Northeast Cape Fear River approach roads overtop in the 500-year and Hurricane Florence storm events.

Table 5: Northeast Cape Fear Results

STORM EVENT	STREAM FLOW (CFS)	ROAD OVERTOPPING	MAX OVERTOPPING DEPTH (FT)***	DURATION OF OVERTOPPING
10-yr	16,100	No	0.0	NA
25-yr	19,700*	No	0.0	NA
50-yr	30,500	No	0.0	NA
100-yr	37,900	No	0.0	NA
500-yr	59,700	Yes	5.1	+
Hurricane Florence	74,000**	Yes	7.9	+

*Determined from StreamStats.

**Approximated to simulate reported high-water marks.

*** The water depth over the roadway along the roadway centerline within our elevation data

+ 1D hydrology was used on the NE Cape Fear River, so duration is not an output.

2.3.2 MERRICKS CREEK

A summary of the results from each storm event for Merricks Creek is presented in Table 6. The maximum overtopping depth is an approximate value measured from HEC-RAS Depth raster and represents the water depth over the roadway along the roadway centerline within our elevation data. Duration of overtopping is an approximated value measured from HEC-RAS water surface elevation raster. The duration of overtopping is determined from the timestamp when the approach road experiences significant inundation to the timestamp when the road has cleared again to allow for traffic to pass.

The Merricks Creek bridge or approach roads overtop in the 25-year, 50-year, 100-year, 500-year, and Hurricane Florence storm events.

Table 6: Merricks Creek Results

STORM EVENT	STREAM FLOW (CFS)	ROAD OVERTOPPING	MAX OVERTOPPING DEPTH (FT)*	DURATION OF OVERTOPPING
10-yr	5.98	No	0.0	NA
25-yr	7.50	Yes	3.2	~14 hours
50-yr	8.84	Yes	3.9	~19 hours
100-yr	10.37	Yes	4.8	~24 hours
500-yr	14.87	Yes	6.9	~2 days
Hurricane Florence	25.0	Yes	8.9	>3 days

* The water depth over the roadway along the roadway centerline within our elevation data

2.3.3 HARRISONS CREEK

A summary of the results from each storm event for Harrisons Creek is presented in Table 7. Maximum overtopping depth is an approximated value measured from HEC-RAS Depth raster and represents the water depth over the roadway along the roadway centerline within our elevation data. Duration of overtopping is an approximated value measured from HEC-RAS water surface elevation raster. The duration of overtopping is determined from the timestamp when the approach road experiences significant inundation to the timestamp when the road has cleared again to allow for traffic to pass.

The Harrisons Creek bridge or approach roads overtop in the 50-year, 100-year, 500-year, and Hurricane Florence storm events.

Table 7: Harrisons Creek Results

STORM EVENT	STREAM FLOW (CFS)	ROAD OVERTOPPING	MAX OVERTOPPING DEPTH (FT)*	DURATION OF OVERTOPPING
10-yr	5.98	No	0.0	NA
25-yr	7.50	No	0.0	NA
50-yr	8.84	Yes	1.0	~9 hours
100-yr	10.37	Yes	1.5	~15 hours
500-yr	14.87	Yes	2.9	~26 hours
Hurricane Florence	25.0	Yes	5.1	>3 days

* The water depth over the roadway along the roadway centerline within our elevation data

2.3.4 ADDITIONAL LOCATIONS OF FLOODING

In addition to the three critical stream crossings in the Highway 210 corridor, additional locations along Highway 210 were observed to have overtopping, at varying recurrence intervals, which may have potential to block the evacuation route. For example, Location 3 was only observed to overtop during a storm equivalent to Hurricane Florence, whereas Location 1 was observed to overtop during a storm event equivalent to the 100-year, 500-year, and Hurricane Florence. A summary of the results from each storm event for additional locations of flooding is presented in Table 8. Locations are identified in Figure 3.

Table 8: Additional Locations of Flooding

LOCATION	OVERTOPPING RECURRENCE INTERVAL*	MAX DEPTH (FT)
1	100-yr	~ 0.5-1.5
	500-yr	~ 1.5-1.7
	Florence	**~ 1.8-2.1**
2	100-yr	~0.5-1.3
	500-yr	1.0
	Florence	**1.2**
3	**Florence**	**~0.3-0.5**

4	500-yr	1.0
	Florence	**2.0**
5	500-yr	1.1
	Florence	**1.3**

*Only storm recurrence intervals where roadway overtopping occurs are listed within Table 8.

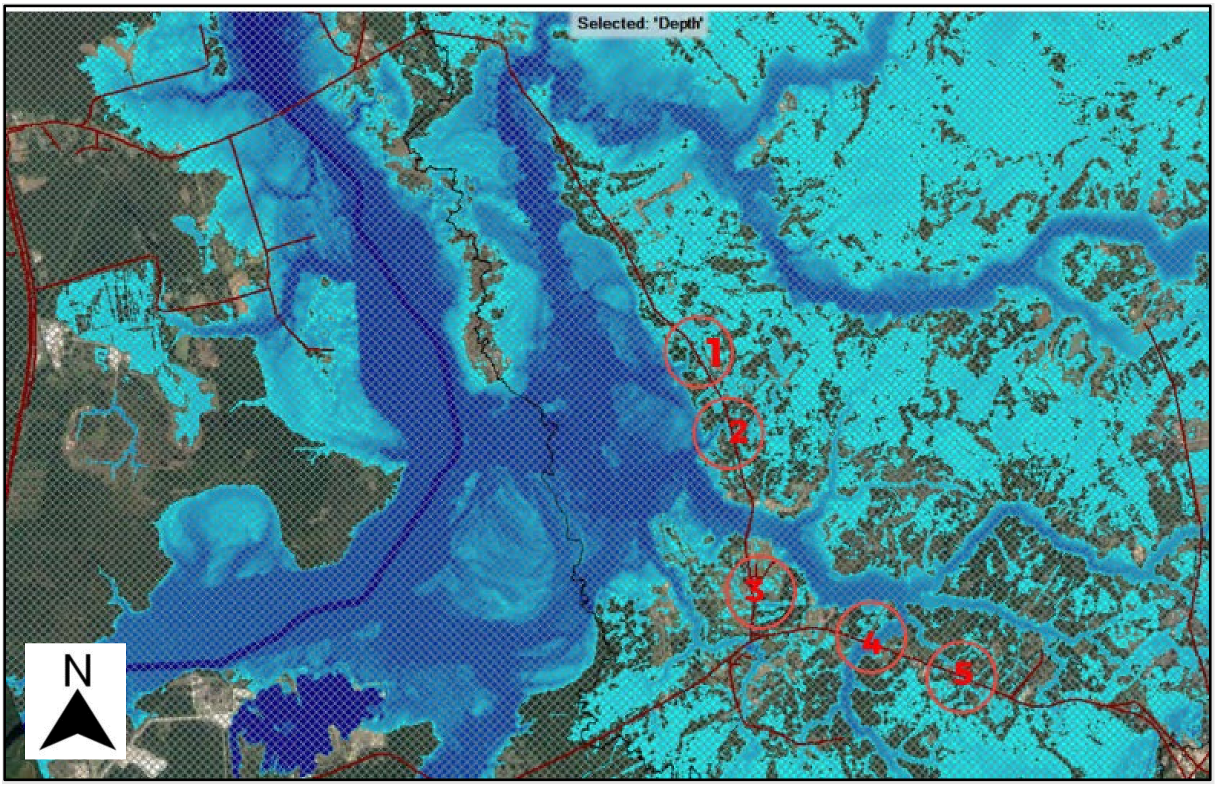

Figure 3: Additional Locations of Overtopping

3 PROPOSED CONDITIONS MODEL

Following the meeting held on March 28th, 2023, involving NCDOT, Pender County, and WSP, the decision was made to designate the 100-year recurrence interval as the resiliency target for the Highway 210 Corridor.

Along with the specific areas of concern, the intent of the meeting was to discuss and define the goals for resilience for the corridor. Resilience is defined as the capacity of a system to recover quickly from an event. For the purposes of this study, resilience will be defined as the ability of Highway 210 to remain open or recover quickly from flooding events. The presentation and discussion led to the decision to establish the 100-year recurrence interval as the resiliency target for the Highway 210 corridor. Typically, major arterials in North Carolina, which Highway 210 is classified as, are designed to convey 50-year recurrence interval events with flooding or overtopping. NCDOT's Hydraulic Guidelines (NCDOT, 2022) state that,

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Because Highway 210 is a state-identified evacuation route, the decision was made to increase the design frequency from the 50-year to the 100-year recurrence interval storm event. It was also discussed that the extent of improvements necessary to target the 500-year recurrence interval event or a theoretical hurricane event would be exceedingly impactful and cost-prohibitive.

The proposed conditions model has been developed to assess the impacts of alternative bridge designs on the 100-year water surface elevations.

3.1 HYDROLOGY

Hydrologic inputs are unchanged from the existing conditions model.

3.2 HYDRAULICS

Hydraulic inputs are modified for the proposed conditions model to better represent the proposed conditions. Details of modifications are provided in section 3.2.1.

3.2.1 MODEL MODIFICATIONS

TERRAIN

In response to the 100-year floodplain analysis, modifications have been incorporated into the model terrain data to ensure that the approach roads for Merricks and Harrisons Creek are situated above the 100-year water surface elevations.

The target freeboard elevation for both locations has been established at 2 feet. Freeboard represents the minimum clearance between the approach water-surface elevation and the low steel of the bridge. The modified terrain, referred to as "Terrain_PC_Raised Road," is integrated into the proposed conditions model.

To accommodate various bridge opening scenarios, modifications were made to the terrain because the raised terrain of the preliminary bridge approach roads did not account for varying openings. These modifications allow for increase in conveyance of flow through the varying bridge alternatives. An example of the raised approach roads with terrain modification is displayed in Figure 4 for Merricks Creek.

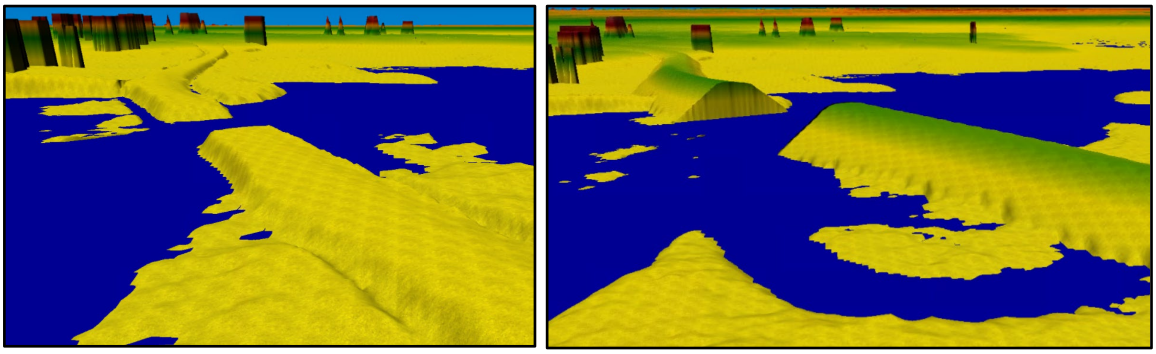

Figure 4: Terrain modification for Merricks Creek. Existing on the left and proposed on the right.

STRUCTURES

Merricks and Harrisons Creek bridges are modified to increase the top of road elevation and low chord elevation to achieve, at a minimum, 2-ft freeboard from the 100-year water surface elevations. Additionally, the bridge openings have been widened, with a series of five alternatives considered to analyze their impact on the upstream and downstream floodplains. Each alternative is analyzed with an increased bridge opening. Bridge openings are increased with each alternative to increase conveyance of flow and select an option which does not cause an increase to water surface elevation at upstream or downstream structures. A summary of these five bridge alternatives is provided in Table 9. No piers or abutments are included as part of this analysis.

Table 9 : Bridge Alternatives for Merricks Creek and Harrisons Creek.

MERRICKS CREEK	EXISTING STRUCTURE	ALT-1	ALT-2	ALT-3	ALT-4	ALT-5
Top of Road Elevation (ft)	8.9	20.0	20.0	20.0	20.0	20.0
Bridge Low Chord Elevation (ft)	6.4	14.0	14.0	14.0	14.0	14.0
Freeboard (ft)	OVERTOPPING	2.24	2.33	2.42	2.43	2.53
Bridge Opening (ft)	112.0	255.0	305.0	355.0	405.0	605.0
HARRISONS CREEK	EXISTING STRUCTURE	ALT-1	ALT-2	ALT-3	ALT-4	ALT-5
Top of Road Elevation (ft)	8.6	18.9	18.9	18.9	18.9	18.9
Bridge Low Chord Elevation (ft)	4.1	12.4	12.4	12.4	12.4	12.4
Freeboard (ft)	OVERTOPPING	2.36	2.69	2.80	2.79	2.93
Bridge Opening (ft)	112	265.0	325.0	365.0	375.0	615.0

Two culvert locations were identified as potential locations of concern based on the results of the existing conditions presented in section 2.3.4. The two locations are hereby referred to as Location 1 and Location 2 (see Figure 3).

Proposed conditions model includes the existing culverts and introduces additional culverts for two alternative scenarios. Additional culverts are introduced to increase the flow conveyance and to analyze the impacts to the overtopping elevation. Culvert Location 1 introduced additional 30-in culverts for a series of two alternatives. Due to the shallow ditches, installing a larger culvert would require increasing the top of road elevation, so instead the quantity of already existing culverts are increased.

Culvert Location 2 introduced an additional 3-ft or 8-ft culvert for a series of two alternatives. The existing culvert at Location 2 is 8-ft wide, and introducing a larger culvert may require increasing the top of road elevations. Thus, the 8-ft culvert size was selected as the largest culvert size. Invert data for these culverts could not be located, thus a conservative assumption from the terrain is made for invert elevations.

Table 10: Culvert Alternatives for Location 1 and Location 2

CULVERT LOCATION 1	EXISTING STRUCTURE	ALT-1	ALT-2
Top of Road Elevation (ft)	19.72	19.72	19.72

Culvert Type	Concrete	Concrete	Concrete
Culvert size	24" and 30 "	24" and 2 x 30”	24" and 4 x 30”
Culvert quantity	2	3	5
CULVERT LOCATION 2	EXISTING STRUCTURE	ALT-1	ALT-2
Top of Road Elevation (ft)	15.81	15.81	15.81
Culvert Type	Corrugated metal	Corrugated metal	Corrugated metal
Culvert size	8'	8' and 3'	8' and 8'
Culvert quantity	1	2	2

BREAKLINES AND 2D MESH

Breaklines in the model, which are incorporated to represent road crossings, are further optimized for better model outputs. Additionally, computation cells within the 2D mesh are improved to increase the density of cells near structures. Increased density of computation cells are beneficial for more detailed outputs.

3.2.2 RUNNING THE MODEL

The HEC-RAS model is run in two plans for each alternative. The model is computed in this manor to account for the different boundary conditions.

- Plan 1: The first plan is run to only include the flow for the NECF and Island Creek. This would be considered the “base flow”. The plan is run to get the model stabilized and a steady state. Plan is titled “*Proposed Conditions_100yr_Base_Test1*”. A restart file is created at the end of the simulation.
- Plan 2: The second plan is run to include the precipitation and Atlantic backwater. The “base flow” plan is used as a restart file before the precipitation and Atlantic backwater start. Plan is titled “*Proposed Conditions_100yr+100yr Base_Test1*”

A “CalculatedLayer” is created to compare the change in maximum water surface elevations between the existing and proposed conditions for each design alternative. This method of analysis is useful in locating areas, upstream or downstream, that may be impacted by a rise in water surface elevation caused by the proposed design. Results from these layers are further described in Section 3.

3.3 RESULTS

3.3.1 MERRICKS CREEK

A summary of the results from each design alternative for Merricks Creek is presented in Table 11.

The headwater elevation for each alternative is determined as the maximum headwater elevation through the bridge opening reported in HEC-RAS. Freeboard is calculated as the vertical distance between the headwater elevation and the bridge's low chord elevation. It's important to note that all alternatives meet the basic requirements for freeboard and avoid overtopping.

The bridge opening is progressively widened with each alternative, leading to consequences for both the upstream and downstream floodplain. Narrower openings result in increased proposed water surface elevations upstream of the structure, while wider openings lead to higher proposed water surface elevations downstream of the structure.

In the vicinity downstream of the bridge, there are several residential homes, whereas upstream of the bridge, the area consists mostly of uninhabited farms and wooded areas. There are approximately 10-15 structures that are at risk of increased flooding. Structures are displayed in Figure 5 and Figure 6. It's noteworthy that the increase in water surface elevations for each alternative remains less than 1.0 foot.

Alternative 1 is selected as the optimal design because it has the least impact on residential structures downstream of the bridge. Only one home, located approximately 1.25 miles upstream of Highway 210 over Merricks Creek, experiences a rise of approximately 0.08 feet under the proposed conditions, as shown in Figure 5.

Table 11: Merricks Creek Design Alternative Results

	ALT-1	ALT-2	ALT-3	ALT-4	ALT-5
Top of Road Elevation (ft)	**20.0**	20.0	20.0	20.0	20.0
Bridge Low Chord Elevation (ft)	**14.0**	14.0	14.0	14.0	14.0
Headwater Elevation (ft)	**11.76**	11.67	11.58	11.57	11.47
Freeboard (ft)	**2.24**	2.33	2.42	2.43	2.53
Bridge Opening (ft)	**255.0**	305.0	355.0	405.0	605.0
Structures Impacted by Rise	**Impacted upstream**	Impacted upstream and downstream	Impacted upstream and downstream	Impacted upstream and downstream	Impacted upstream and downstream

Note: All elevations are in NAVD88

Figure 5 displays the dataset associated with Alternative 1, the narrowest bridge opening. Figure 6 displays the dataset associated with Alternative 5, the widest bridge opening. Structures in the vicinity are highlighted in yellow. Areas where there is an increase in the proposed conditions floodplain are represented in red, areas with a decrease in the proposed conditions floodplain are shown in green, and no change in the proposed conditions floodplain is indicated in white/gray.

Figure 5: Floodplain impacts of Alternative 1 at Merricks Creek.

Figure 6: Floodplain impacts of Alternative 5 at Merricks Creek

3.3.2 HARRISONS CREEK

A summary of the results from each design alternative for Harrisons Creek is presented in Table 12.

The headwater elevation for each alternative is determined as the maximum headwater elevation through the bridge opening reported in HEC-RAS. Freeboard is calculated as the vertical distance between the headwater elevation and the bridge's low chord elevation. It's important to note that all alternatives meet the basic requirements for freeboard and avoid overtopping.

The bridge opening is progressively widened with each alternative, leading to consequences for both the upstream and downstream floodplain. Narrower openings increase the proposed water surface elevations upstream of the structure. Wider openings increase the proposed water surface elevations downstream of the structure.

At this location, directly upstream of the bridge is a residential community. Downstream of the bridge is mostly uninhabited wooded areas. All increases for each alternative are less than 1.0ft.

Alternative 5 is selected as the optimal design due to the least impact to the residential community upstream of the bridge.

Table 12: Harrisons Creek Design Alternative Results

	ALT-1	ALT-2	ALT-3	ALT-4	**ALT-5**
Top of Road Elevation (ft)	18.9	18.9	18.9	18.9	**18.9**
Bridge Low Chord Elevation (ft)	12.4	12.4	12.4	12.4	**12.4**
Headwater Elevation (ft)	10.04	9.71	9.6	9.61	**9.47**
Freeboard (ft)	2.36	2.69	2.80	2.79	**2.93**
Bridge Opening (ft)	265.0	325.0	365.0	375.0	**615.0**
Structures Impacted by Rise	Impacted upstream	Impacted upstream	Impacted upstream	Impacted upstream	**Not impacted**

Note: All elevations are in NAVD88

Figure 7 displays the dataset associated with Alternative 5, structure with the widest opening. Figure 8 displays the dataset associated with Alternative 1, structure with the narrowest opening. Structures in the vicinity are highlighted in yellow. Areas where there is an increase in the proposed conditions floodplain are represented in red, areas with a decrease in the proposed conditions floodplain are shown in green, and no change in the proposed conditions floodplain is indicated in white/gray.

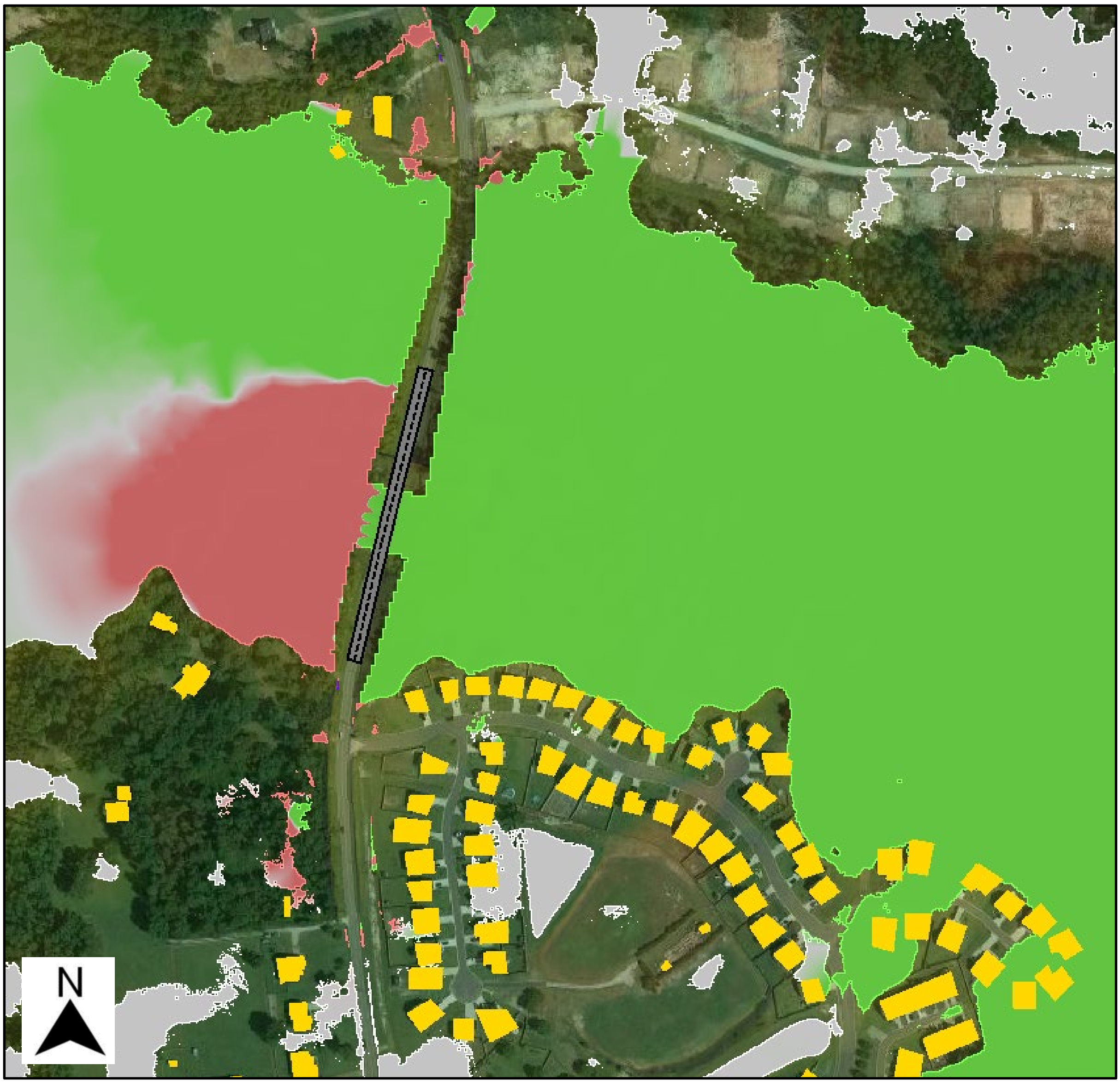

Figure 7: Floodplain impacts of Alternative 5 at Harrisons Creek

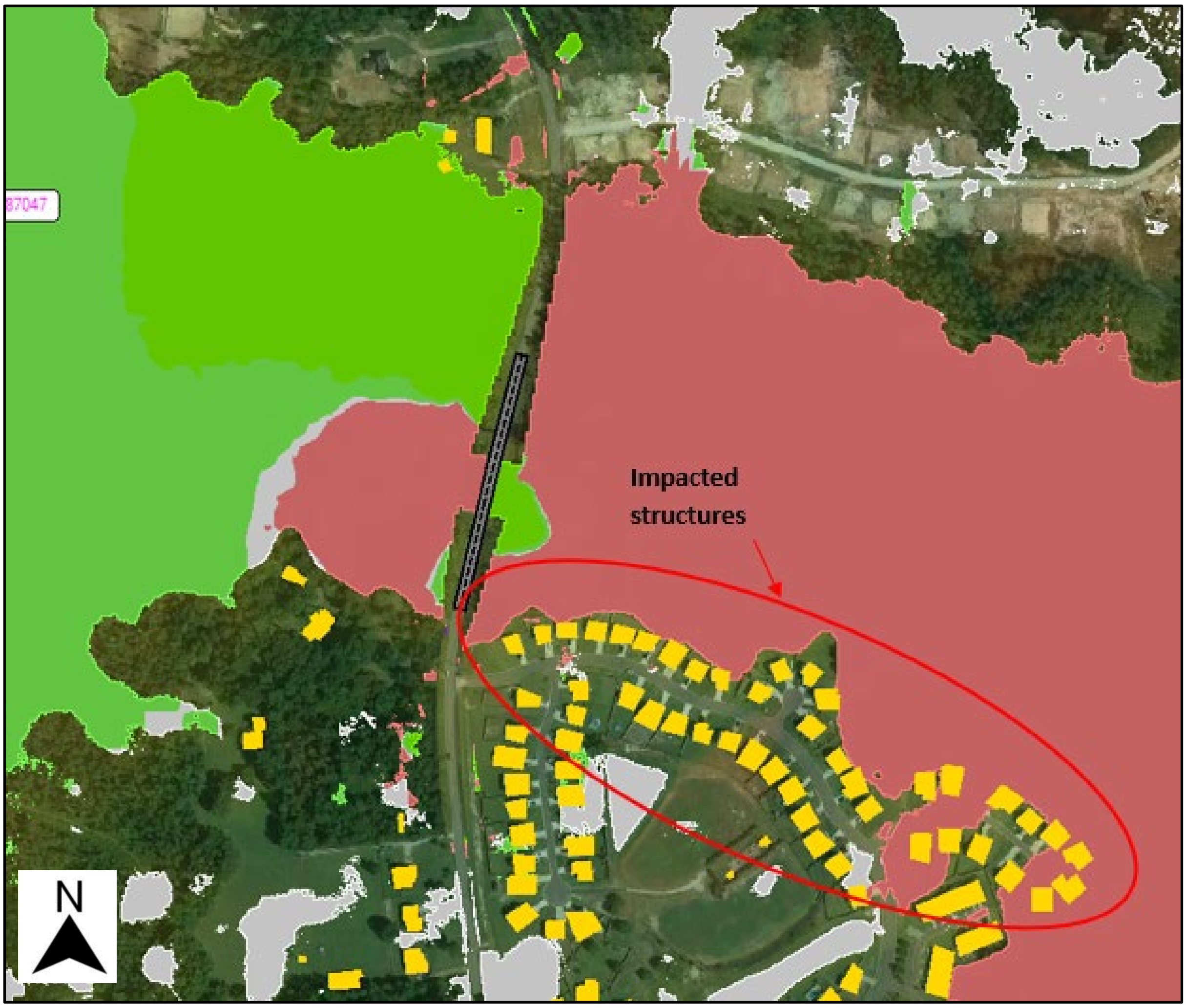

Figure 8: Floodplain impacts of Alternative 1 at Harrisons Creek

3.3.3 CULVERT LOCATIONS

A summary of the results from each culvert design alterative for Location 1 and Location 2 are presented in Table 13.

At Culvert Location 1, there is limited vertical space available for installing large culverts. The addition of extra culverts yields minimal improvements in overtopping due to the road's curved and downward-sloping nature. To address the inundation issue effectively, raising the road's elevation would be necessary.

Meanwhile, at Culvert Location 2, overtopping concerns can be resolved by introducing an additional 8-foot culvert.

Upon further examination of these two locations, it was determined that the existing conditions overtopping depth is not significantly problematic, and the overtopping duration lasts only a few hours. Location 1, under existing conditions, experiences maximum overtopping depth of 1.5 feet and the duration is approximately 5 hours. Location 2, under existing conditions, experiences maximum overtopping depth of 1.3 feet and the duration is approximately 4 hours. Discussions with NCDOT have led to the conclusion that these locations may not pose significant concerns. Instead, alternative measures such as road hardening are recommended to mitigate the risk of road washouts.

Table 13 : Culvert Locations Design Alternative Results

CULVERT LOCATION 1	ALT-1	ALT-2
Top of Road Elevation (ft)	19.72	19.72
Culvert Type	Concrete	Concrete
Culvert size	24" and 2 x 30”	24" and 4 x 30”
Culvert quantity	3	5
Road Overtopping	Yes	Yes
CULVERT LOCATION 2	ALT-1	ALT-2
Top of Road Elevation (ft)	15.81	15.81
Culvert Type	Corrugated metal	Corrugated metal
Culvert size	8' and 3'	8' and 8'
Culvert quantity	2	2
Road Overtopping	Yes	No

4 RESILIENCY RECOMMENDATIONS

4.1 BRIDGE DESIGN

Based on the comprehensive analysis presented in this report, we have arrived at the following recommendations for bridge designs for Merricks and Harrisons Creek. These recommendations also include preliminary scour calculations, details of which can be found in Appendix 6.

The selection of these specific alternatives for each location is based upon the minimal impact on nearby residential structures while at the same time keeping Highway 210 open as an evacuation route. Consideration was given to the preservation of the surrounding residential areas, and these alternatives were found to align best with the overarching goal of minimizing disruptions to the communities situated near by the structures.

Table 14: Bridge Resiliency Recommendations

	MERRICKS	HARRISONS
Top of Road Elevation (ft)	20	18.9
Bridge Low Chord Elevation (ft)	14	12.4
Bridge Opening (ft)	255	615
Contraction Scour (ft)	8.2	3.7
Pier Scour (ft)	6.59	4.24

4.2 CULVERT LOCATIONS

As indicated in Section 3, two culvert locations along the Highway 210 alignment experience overtopping during major events. Overtopping at these locations is limited to a duration of 4 to 5 hours and a depth of 18 inches or less. In consultation with NCDOT, it is recommended that the roadway embankment at these locations be “hardened”. At these locations, the recommendation is for hardening using Class II riprap along the fill slope. Details of road hardening can be found in Appendix 4.

“Hardening” or rock plating along embankment slopes provides mitigation for erosion risks presented through high flows from major events. Oftentimes when culverts experience high flows, swirling, turbulent waters at the ends of the culvert can cause scour and erosion. As erosion and scour continue to occur over time, the potential for "piping” or water flowing along the outside of the culvert can lead to roadway failure and washout. Due to the short duration of flooding impacts, the cost for raising the road profile and installation of additional conveyance culverts was deemed infeasible. Instead, the recommendation at the culvert locations is to provide for mitigation of the major risks of culvert washout instead of excessive reconstruction for short-duration impacts.

4.3 COST ESTIMATES

WSP has developed project cost estimates in line with NCDOT's functional cost estimate process. In total, the project construction cost is estimated at $12,249,606 while right of way (ROW) costs are estimated at $700,000. Detailed cost estimates can be found in Appendix 5.

5 GIS DASHBOARD

The Pender County NC-210 Dashboard serves to visually communicate areas of interest, costs, and plans derived from WSP's report in an interactive website. To access the dashboard, users must have at minimum a basic ArcGIS Online account with "Viewer" privileges. The dashboard is shared to a user group with invite-only access for contents to remain private to only the client and WSP employees involved in this effort.

The dashboard is separated into three tabs that navigate to the Home page, Cost, and Plan Sheets. Within the Home page, users can view the proposed structures' locations and swipe to view the existing and proposed floodplains for the Merrick's Creek and Harrison's Creek sites along NC-210 in a 3D map viewer. A Parcel and Buildings layer sourced from NC OneMap are also included to view relevant features within the study area. A side panel for these maps with additional context and a series of short videos simulating the existing and proposed flood conditions are also visible alongside the maps.

The Cost tab provides a snapshot of the predicted cost for this project, separated into several categories of labor and materials, along with an overall estimate for the project's scope.

Finally, the plan sheets can be found in a PDF format in its corresponding tab.

While this report serves to provide a detailed analysis of the Highway 210 resiliency study, the GIS dashboard should be used to gain "at-a-glance" insights outside of a traditional, text-based format.

REFERENCES

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(National Oceanic and Atmospheric Administration. n.d.). Lidar: Creating a Detailed Map of the Coastline. NOAA's National Ocean Service. https://oceanservice.noaa.gov/facts/lidar.html

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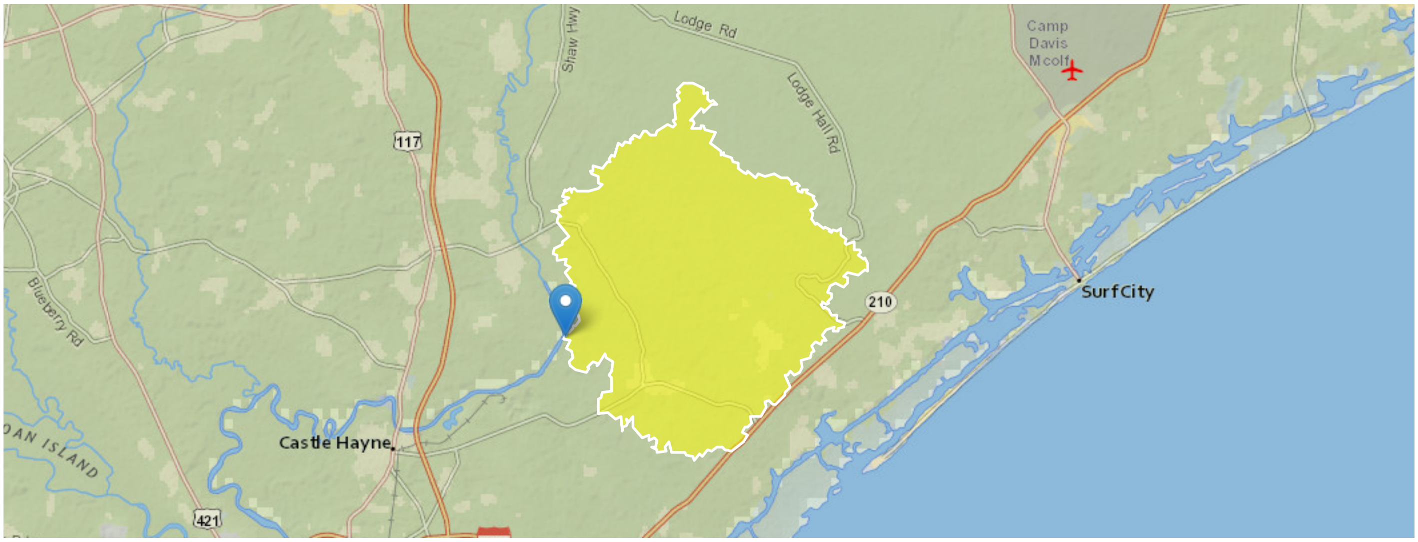
(USDA, U.S. Department of Agriculture, Natural Resources Conservation Service. n.d.). Soil Survey Geographic Database (SSURGO). https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo

APPENDIX 1 : STREAMSTATS

Merricks and Harrisons Creek Watershed

StreamStats Report

Region ID: NC
Workspace ID: NC20230104191228443000
Clicked Point (Latitude, Longitude): 34.40294, -77.81151
Time: 2023-01-04 14:13:02 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	58.4	square miles
I24H50Y	Maximum 24-hour precipitation that occurs on average once in 50 years	10.4	inches
LC06IMP	Percentage of impervious area determined from NLCD 2006 impervious dataset	0.51	percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley	0	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge	0	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills	0	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains	100	percent
PCTREG5	Percentage of drainage area located in Region 5 - Lower Tifton Uplands	0	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Southeast US over 1 sqmi 2009 5158]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	58.4	square miles	1	9000
PCTREG1	Percent Area in Region 1	0	percent	0	100
PCTREG2	Percent Area in Region 2	0	percent	0	100
PCTREG3	Percent Area in Region 3	0	percent	0	100
PCTREG4	Percent Area in Region 4	100	percent	0	100
PCTREG5	Percent Area in Region 5	0	percent	0	100

Peak-Flow Statistics Flow Report [Peak Southeast US over 1 sqmi 2009 5158]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
50-percent AEP flood	844	ft^3/s	486	1460	34.5
20-percent AEP flood	1580	ft^3/s	917	2720	34
10-percent AEP flood	2140	ft^3/s	1220	3750	35.1
4-percent AEP flood	2890	ft^3/s	1590	5240	37.5
2-percent AEP flood	3550	ft^3/s	1900	6650	39.6
1-percent AEP flood	4260	ft^3/s	2200	8250	41.9
0.5-percent AEP flood	4900	ft^3/s	2440	9820	44.3
0.2-percent AEP flood	5890	ft^3/s	2800	12400	47.7

Peak-Flow Statistics Citations

Weaver, J.C., Feaster, T.D., and Gotvald, A.J.,2009, Magnitude and frequency of rural floods in the Southeastern United States, through 2006—Volume 2, North Carolina: U.S. Geological Survey Scientific Investigations Report 2009–5158, 111 p. (http://pubs.usgs.gov/sir/2009/5158/)

Application Version: 4.11.1
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Merricks Creek Watershed

StreamStats Report

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Workspace ID: NC20230317004358389000
Clicked Point (Latitude, Longitude): 34.44634, -77.80352
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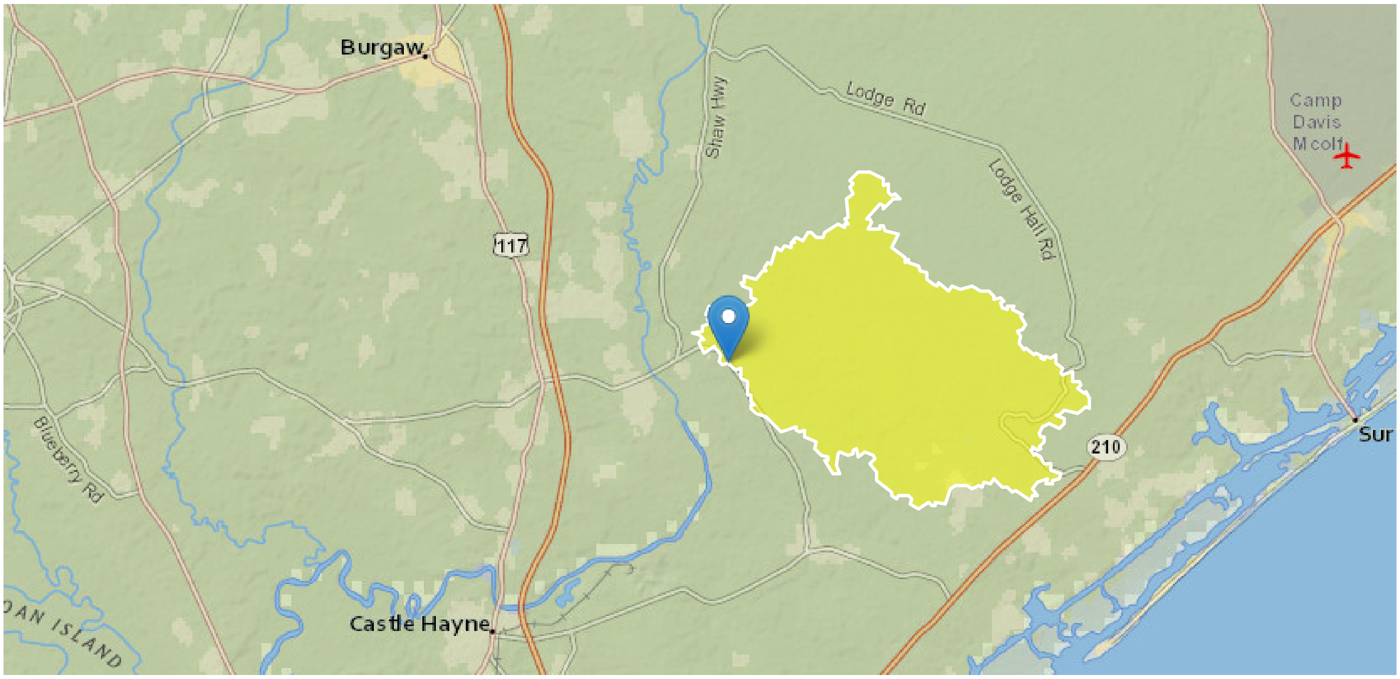


Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	35.9	square miles
I24H50Y	Maximum 24-hour precipitation that occurs on average once in 50 years	10.3	inches
LC06IMP	Percentage of impervious area determined from NLCD 2006 impervious dataset	0.19	percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley	0	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge	0	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills	0	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains	100	percent
PCTREG5	Percentage of drainage area located in Region 5 - Lower Tifton Uplands	0	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Southeast US over 1 sqmi 2009 5158]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	35.9	square miles	1	9000
PCTREG1	Percent Area in Region 1	0	percent	0	100
PCTREG2	Percent Area in Region 2	0	percent	0	100
PCTREG3	Percent Area in Region 3	0	percent	0	100
PCTREG4	Percent Area in Region 4	100	percent	0	100
PCTREG5	Percent Area in Region 5	0	percent	0	100

Peak-Flow Statistics Flow Report [Peak Southeast US over 1 sqmi 2009 5158]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
50-percent AEP flood	616	ft^3/s	355	1070	34.5
20-percent AEP flood	1160	ft^3/s	673	2000	34
10-percent AEP flood	1580	ft^3/s	902	2770	35.1
4-percent AEP flood	2150	ft^3/s	1190	3900	37.5
2-percent AEP flood	2650	ft^3/s	1420	4960	39.6
1-percent AEP flood	3190	ft^3/s	1650	6180	41.9
0.5-percent AEP flood	3680	ft^3/s	1830	7380	44.3
0.2-percent AEP flood	4430	ft^3/s	2100	9330	47.7

Peak-Flow Statistics Citations

Weaver, J.C., Feaster, T.D., and Gotvald, A.J.,2009, Magnitude and frequency of rural floods in the Southeastern United States, through 2006—Volume 2, North Carolina: U.S. Geological Survey Scientific Investigations Report 2009–5158, 111 p. (http://pubs.usgs.gov/sir/2009/5158/)

Urban Peak-Flow Statistics

Urban Peak-Flow Statistics Parameters [Region 4 CoastalPlain Urban 2014 5030]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	35.9	square miles	0.1	53.5
LC06IMP	Percent Impervious NLCD2006	0.19	percent	0.02	34.8
I24H50Y	24 Hour 50 Year Precipitation	10.3	inches	6.51	10.9

Urban Peak-Flow Statistics Flow Report [Region 4 CoastalPlain Urban 2014 5030]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
Urban 50-percent AEP flood	745	ft^3/s	333	1660	40.8
Urban 20-Percent AEP flood	1510	ft^3/s	722	3160	36.9
Urban 10-percent AEP flood	2170	ft^3/s	1050	4490	36.7
Urban 4-percent AEP flood	3170	ft^3/s	1480	6800	38.2
Urban 2-percent AEP flood	4040	ft^3/s	1820	8990	40.2
Urban 1-percent AEP flood	5000	ft^3/s	2150	11600	42.7
Urban 0.5-percent AEP flood	6110	ft^3/s	2490	15000	45.4
Urban 0.2-percent AEP flood	7710	ft^3/s	2900	20500	49.9

Urban Peak-Flow Statistics Citations

Feaster, T.D., Gotvald, A.J., and Weaver, J.C.,2014, Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina, 2011 (ver. 1.1, March 2014): U.S. Geological Survey Scientific Investigations Report 2014–5030, 104 p. (http://pubs.usgs.gov/sir/2014/5030/)

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [Crippen Bue Region 2]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	35.9	square miles	0.1	3000

Maximum Probable Flood Statistics Flow Report [Crippen Bue Region 2]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	51400	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

Bankfull Statistics

Bankfull Statistics Parameters [Atlantic Plain D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	35.9	square miles	0.30888	1086.8715

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	35.9	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Atlantic Plain D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	37.7	ft
Bieger_D_channel_depth	3.4	ft
Bieger_D_channel_cross_sectional_area	122	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	43.7	ft
Bieger_USA_channel_depth	2.58	ft
Bieger_USA_channel_cross_sectional_area	118	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	37.7	ft
Bieger_D_channel_depth	3.4	ft
Bieger_D_channel_cross_sectional_area	122	ft^2
Bieger_USA_channel_width	43.7	ft
Bieger_USA_channel_depth	2.58	ft
Bieger_USA_channel_cross_sectional_area	118	ft^2

Bankfull Statistics Citations

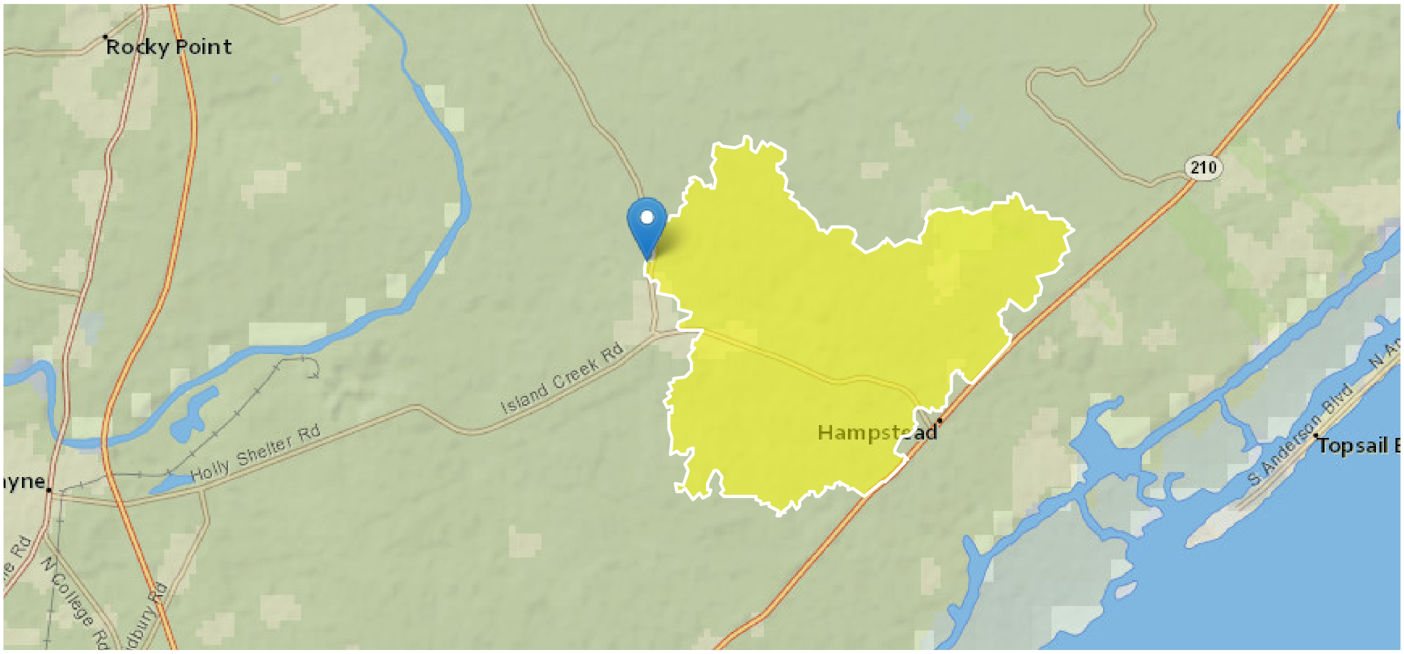
Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515? utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campaign=PDFCove

Application Version: 4.13.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Harrisons Creek Watershed

StreamStats Report

Region ID: NC
Workspace ID: NC20230317004101117000
Clicked Point (Latitude, Longitude): 34.39565, -77.77286
Time: 2023-03-16 20:41:21 -0400



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	13.3	square miles
I24H50Y	Maximum 24-hour precipitation that occurs on average once in 50 years	10.6	inches
LC06IMP	Percentage of impervious area determined from NLCD 2006 impervious dataset	1.36	percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley	0	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge	0	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills	0	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains	100	percent
PCTREG5	Percentage of drainage area located in Region 5 - Lower Tifton Uplands	0	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Southeast US over 1 sqmi 2009 5158]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.3	square miles	1	9000
PCTREG1	Percent Area in Region 1	0	percent	0	100
PCTREG2	Percent Area in Region 2	0	percent	0	100
PCTREG3	Percent Area in Region 3	0	percent	0	100
PCTREG4	Percent Area in Region 4	100	percent	0	100
PCTREG5	Percent Area in Region 5	0	percent	0	100

Peak-Flow Statistics Flow Report [Peak Southeast US over 1 sqmi 2009 5158]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	ASEp
50-percent AEP flood	323	ft^3/s	186	561	34.5
20-percent AEP flood	623	ft^3/s	361	1070	34
10-percent AEP flood	858	ft^3/s	489	1500	35.1
4-percent AEP flood	1180	ft^3/s	650	2140	37.5
2-percent AEP flood	1460	ft^3/s	779	2740	39.6
1-percent AEP flood	1770	ft^3/s	913	3430	41.9
0.5-percent AEP flood	2050	ft^3/s	1020	4120	44.3
0.2-percent AEP flood	2480	ft^3/s	1180	5230	47.7

Peak-Flow Statistics Citations

Weaver, J.C., Feaster, T.D., and Gotvald, A.J.,2009, Magnitude and frequency of rural floods in the Southeastern United States, through 2006—Volume 2, North Carolina: U.S. Geological Survey Scientific Investigations Report 2009–5158, 111 p. (http://pubs.usgs.gov/sir/2009/5158/)

Urban Peak-Flow Statistics

Urban Peak-Flow Statistics Parameters [Region 4 CoastalPlain Urban 2014 5030]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.3	square miles	0.1	53.5
LC06IMP	Percent Impervious NLCD2006	1.36	percent	0.02	34.8
I24H50Y	24 Hour 50 Year Precipitation	10.6	inches	6.51	10.9

Urban Peak-Flow Statistics Flow Report [Region 4 CoastalPlain Urban 2014 5030]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
Urban 50-percent AEP flood	450	ft^3/s	201	1010	40.8
Urban 20-Percent AEP flood	903	ft^3/s	430	1900	36.9
Urban 10-percent AEP flood	1280	ft^3/s	617	2660	36.7
Urban 4-percent AEP flood	1860	ft^3/s	863	4010	38.2
Urban 2-percent AEP flood	2350	ft^3/s	1050	5260	40.2
Urban 1-percent AEP flood	2900	ft^3/s	1240	6790	42.7
Urban 0.5-percent AEP flood	3510	ft^3/s	1420	8690	45.4
Urban 0.2-percent AEP flood	4390	ft^3/s	1640	11700	49.9

Urban Peak-Flow Statistics Citations

Feaster, T.D., Gotvald, A.J., and Weaver, J.C.,2014, Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina, 2011 (ver. 1.1, March 2014): U.S. Geological Survey Scientific Investigations Report 2014–5030, 104 p. (http://pubs.usgs.gov/sir/2014/5030/)

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [Crippen Bue Region 2]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.3	square miles	0.1	3000

Maximum Probable Flood Statistics Flow Report [Crippen Bue Region 2]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	29700	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

Bankfull Statistics

Bankfull Statistics Parameters [Atlantic Plain D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.3	square miles	0.30888	1086.8715

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.3	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Atlantic Plain D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	26.3	ft
Bieger_D_channel_depth	2.47	ft
Bieger_D_channel_cross_sectional_area	62.1	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	30.8	ft
Bieger_USA_channel_depth	2.09	ft
Bieger_USA_channel_cross_sectional_area	69.1	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	26.3	ft
Bieger_D_channel_depth	2.47	ft
Bieger_D_channel_cross_sectional_area	62.1	ft^2
Bieger_USA_channel_width	30.8	ft
Bieger_USA_channel_depth	2.09	ft
Bieger_USA_channel_cross_sectional_area	69.1	ft^2

Bankfull Statistics Citations

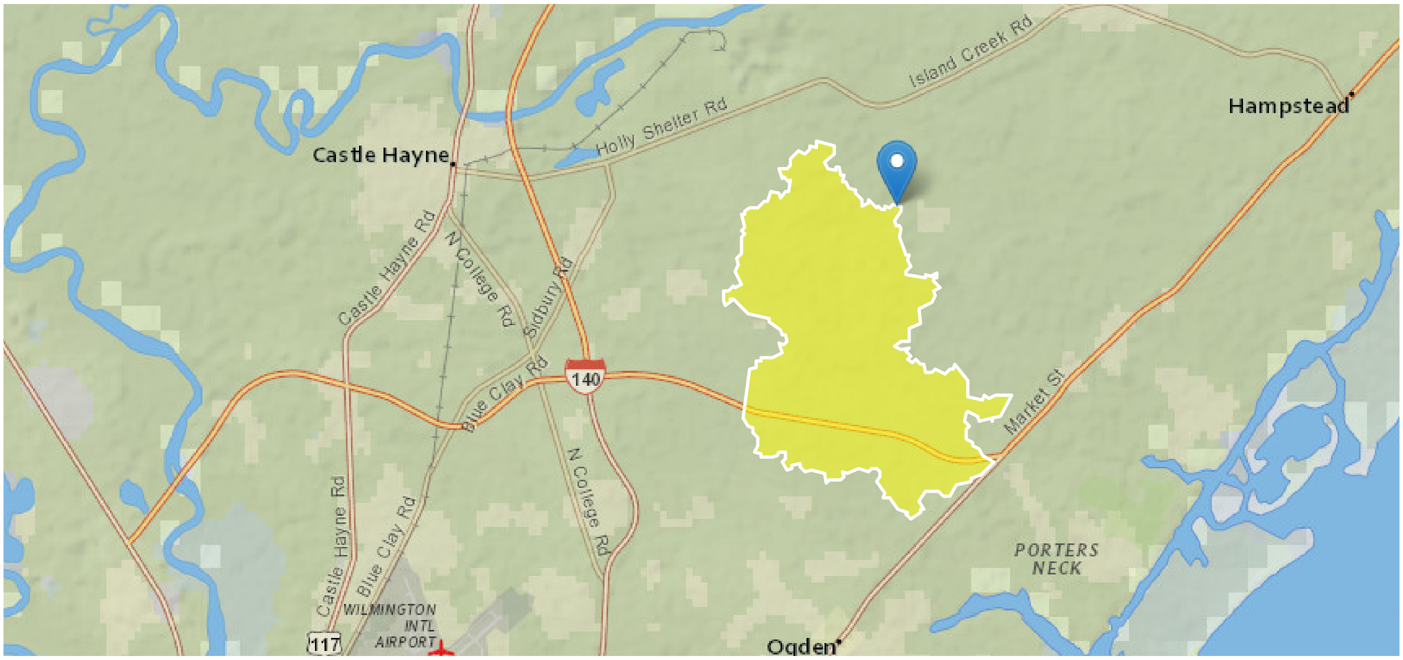
Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campaign=PDFCoverPag

Application Version: 4.13.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Island Creek Watershed

StreamStats Report

Region ID: NC
Workspace ID: NC20230315205453378000
Clicked Point (Latitude, Longitude): 34.34813, -77.80653
Time: 2023-03-15 16:55:14 -0400



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	7.99	square miles
I24H50Y	Maximum 24-hour precipitation that occurs on average once in 50 years	10.7	inches
LC06IMP	Percentage of impervious area determined from NLCD 2006 impervious dataset	0.9	percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley	0	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge	0	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills	0	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains	100	percent
PCTREG5	Percentage of drainage area located in Region 5 - Lower Tifton Uplands	0	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Southeast US over 1 sqmi 2009 5158]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	7.99	square miles	1	9000
PCTREG1	Percent Area in Region 1	0	percent	0	100
PCTREG2	Percent Area in Region 2	0	percent	0	100
PCTREG3	Percent Area in Region 3	0	percent	0	100
PCTREG4	Percent Area in Region 4	100	percent	0	100
PCTREG5	Percent Area in Region 5	0	percent	0	100

Peak-Flow Statistics Flow Report [Peak Southeast US over 1 sqmi 2009 5158]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
50-percent AEP flood	232	ft^3/s	133	403	34.5
20-percent AEP flood	453	ft^3/s	263	782	34
10-percent AEP flood	626	ft^3/s	357	1100	35.1
4-percent AEP flood	865	ft^3/s	476	1570	37.5
2-percent AEP flood	1080	ft^3/s	576	2030	39.6
1-percent AEP flood	1310	ft^3/s	675	2540	41.9
0.5-percent AEP flood	1520	ft^3/s	756	3060	44.3
0.2-percent AEP flood	1850	ft^3/s	877	3900	47.7

Peak-Flow Statistics Citations

Weaver, J.C., Feaster, T.D., and Gotvald, A.J.,2009, Magnitude and frequency of rural floods in the Southeastern United States, through 2006—Volume 2, North Carolina: U.S. Geological Survey Scientific Investigations Report 2009–5158, 111 p. (http://pubs.usgs.gov/sir/2009/5158/)

Application Version: 4.13.0

StreamStats Services Version: 1.2.22

NSS Services Version: 2.2.1

APPENDIX 2: FLOOD INSURANCE REPORT

A summary of the drainage area-peak discharge relationships for the flooding sources studied by detailed methods is shown in Table 13, Summary of Discharges.

Table 13 - Summary of Discharges

Flooding Source		Discharges (cfs)			
Location	Drainage Area (square miles)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Island Creek					
Approximately 0.46 mile downstream of Sidbury Road	5.81	657	1257	1589	2574
Approximately 0.9 miles upstream of Sidbury Road	3.14	450	870	1103	1799

Flooding Source	FIRM Panel Number(s)	Elevations (feet NAVD)			
		10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Topsail Sound / Atlantic Ocean	3720421200 3720420200	*	*	9.3	*
Topsail Sound	3720420200 3720420300 3720421300	4.4	7.7	9.1	11.8
Topsail Sound / Atlantic Ocean	3720421200 3720420200	4.3	7.7	9.0	11.8
Topsail Sound / Atlantic Ocean	3720420300 3720421200 3720421300	*	*	8.8	*
Topsail Sound / Atlantic Ocean	3720421200 3720421300	*	*	8.6	*
Topsail Sound / Atlantic Ocean	3720420300 3720421300	4.0	7.2	8.5	11.3
Topsail Sound / Atlantic Ocean	3720421300 3720422300	*	*	8.3	*
Topsail Sound	3720421300 3720422400	3.8	6.8	8.1	10.9
Topsail Sound / Atlantic Ocean	3720421300 3720422300	*	*	7.9	*
Topsail Sound / Atlantic Ocean	3720422300 3720422400 3720423400 3720423500 3720424500	*	*	7.7	*
Topsail Sound	3720422400 3720422500 3720423400 3720423500	3.4	6.4	7.6	11.0
Topsail Sound	3720421400 3720421500 3720422400 3720422500 3720423400 3720423500	3.4	6.2	7.5	11.0
Cape Fear River	3720229100	5.5	6.9	7.4	8.4
Northeast Cape Fear River	3720229100 3720320100 3720320200 3720320300 3720321200 3720321300 3720321400 3720322200 3720322300 3720323200 3720323300 3720324200 3720324300 3720325300 3720325400 3720325500 3720326200 3720326300 3720326400 3720326500 3720327300	4.9	6.6	7.3	8.7
Topsail Sound	3720422500 3720423400 3720423500	3.2	6.0	7.3	10.6
Topsail Sound	3720423500 3720423600 3720424500 3720424600	2.5	4.6	5.9	9.6

APPENDIX 3: PRECIPITATION

NOAA Atlas 14, Volume 2, Version 3
Location name: Rocky Point, North Carolina, USA*
Latitude: 34.4152°, Longitude: -77.8052°
Elevation: 16.31 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**0.511** (0.474-0.553)	**0.607** (0.563-0.657)	**0.710** (0.657-0.767)	**0.790** (0.729-0.853)	**0.892** (0.819-0.961)	**0.968** (0.885-1.04)	**1.05** (0.952-1.13)	**1.12** (1.02-1.21)	**1.23** (1.10-1.33)	**1.31** (1.16-1.42)
10-min	**0.816** (0.758-0.883)	**0.971** (0.901-1.05)	**1.14** (1.05-1.23)	**1.26** (1.17-1.36)	**1.42** (1.31-1.53)	**1.54** (1.41-1.66)	**1.66** (1.51-1.79)	**1.78** (1.61-1.93)	**1.94** (1.74-2.10)	**2.06** (1.83-2.24)
15-min	**1.02** (0.947-1.10)	**1.22** (1.13-1.32)	**1.44** (1.33-1.55)	**1.60** (1.48-1.73)	**1.80** (1.65-1.94)	**1.95** (1.79-2.11)	**2.10** (1.91-2.27)	**2.25** (2.03-2.43)	**2.44** (2.19-2.64)	**2.59** (2.30-2.81)
30-min	**1.40** (1.30-1.51)	**1.69** (1.57-1.83)	**2.04** (1.89-2.21)	**2.32** (2.14-2.50)	**2.67** (2.45-2.88)	**2.94** (2.69-3.17)	**3.22** (2.93-3.47)	**3.50** (3.16-3.78)	**3.89** (3.48-4.21)	**4.20** (3.72-4.55)
60-min	**1.74** (1.62-1.89)	**2.12** (1.96-2.29)	**2.62** (2.42-2.83)	**3.02** (2.78-3.26)	**3.55** (3.26-3.83)	**3.98** (3.64-4.30)	**4.43** (4.03-4.78)	**4.91** (4.44-5.30)	**5.58** (4.99-6.04)	**6.12** (5.43-6.64)
2-hr	**2.08** (1.91-2.28)	**2.54** (2.34-2.78)	**3.23** (2.97-3.53)	**3.80** (3.48-4.15)	**4.62** (4.21-5.04)	**5.32** (4.82-5.80)	**6.08** (5.48-6.63)	**6.91** (6.18-7.52)	**8.13** (7.19-8.87)	**9.18** (8.06-10.0)
3-hr	**2.23** (2.05-2.45)	**2.72** (2.50-2.99)	**3.48** (3.19-3.82)	**4.12** (3.76-4.52)	**5.08** (4.61-5.56)	**5.91** (5.33-6.47)	**6.83** (6.11-7.47)	**7.86** (6.97-8.58)	**9.41** (8.24-10.3)	**10.8** (9.32-11.8)
6-hr	**2.75** (2.52-3.04)	**3.35** (3.07-3.71)	**4.29** (3.92-4.74)	**5.10** (4.64-5.62)	**6.30** (5.70-6.93)	**7.35** (6.61-8.08)	**8.53** (7.60-9.36)	**9.85** (8.68-10.8)	**11.9** (10.3-13.0)	**13.6** (11.7-15.0)
12-hr	**3.23** (2.93-3.59)	**3.94** (3.57-4.38)	**5.07** (4.60-5.64)	**6.06** (5.46-6.73)	**7.54** (6.74-8.35)	**8.86** (7.87-9.78)	**10.3** (9.10-11.4)	**12.0** (10.5-13.3)	**14.6** (12.5-16.1)	**16.9** (14.3-18.6)
24-hr	**3.74** (3.41-4.16)	**4.54** (4.14-5.05)	**5.87** (5.35-6.52)	**7.04** (6.39-7.81)	**8.83** (7.93-9.79)	**10.4** (9.27-11.5)	**12.2** (10.8-13.6)	**14.3** (12.4-15.9)	**17.5** (14.8-19.5)	**20.3** (16.9-22.8)
2-day	**4.40** (4.02-4.87)	**5.32** (4.87-5.89)	**6.83** (6.23-7.55)	**8.14** (7.39-9.00)	**10.1** (9.12-11.2)	**11.9** (10.6-13.2)	**13.9** (12.2-15.4)	**16.1** (14.0-18.0)	**19.5** (16.6-21.9)	**22.6** (18.8-25.5)
3-day	**4.69** (4.29-5.18)	**5.66** (5.19-6.26)	**7.22** (6.59-7.98)	**8.56** (7.79-9.45)	**10.6** (9.54-11.7)	**12.3** (11.0-13.7)	**14.3** (12.6-15.9)	**16.5** (14.4-18.4)	**19.9** (17.0-22.3)	**22.8** (19.2-25.8)
4-day	**4.98** (4.56-5.50)	**6.00** (5.51-6.63)	**7.61** (6.96-8.40)	**8.98** (8.18-9.91)	**11.0** (9.95-12.2)	**12.8** (11.4-14.1)	**14.7** (13.1-16.3)	**16.9** (14.8-18.8)	**20.2** (17.4-22.6)	**23.1** (19.5-26.1)
7-day	**5.76** (5.32-6.30)	**6.94** (6.41-7.59)	**8.73** (8.04-9.54)	**10.2** (9.39-11.2)	**12.4** (11.3-13.5)	**14.3** (12.9-15.6)	**16.3** (14.6-17.8)	**18.5** (16.4-20.3)	**21.7** (18.9-24.0)	**24.4** (21.0-27.2)
10-day	**6.50** (6.02-7.07)	**7.79** (7.21-8.48)	**9.65** (8.91-10.5)	**11.2** (10.3-12.2)	**13.5** (12.3-14.7)	**15.4** (14.0-16.8)	**17.4** (15.7-19.0)	**19.6** (17.5-21.5)	**22.9** (20.1-25.3)	**25.6** (22.2-28.4)
20-day	**8.73** (8.14-9.40)	**10.4** (9.70-11.2)	**12.7** (11.8-13.7)	**14.6** (13.5-15.7)	**17.2** (15.9-18.6)	**19.4** (17.8-21.0)	**21.8** (19.8-23.6)	**24.2** (21.9-26.4)	**27.8** (24.7-30.4)	**30.7** (27.0-33.8)
30-day	**10.7** (10.1-11.5)	**12.7** (12.0-13.6)	**15.3** (14.4-16.4)	**17.4** (16.3-18.6)	**20.2** (18.9-21.6)	**22.5** (20.9-24.1)	**24.9** (23.0-26.8)	**27.4** (25.1-29.5)	**30.8** (27.8-33.4)	**33.5** (30.0-36.5)
45-day	**13.4** (12.6-14.3)	**15.8** (14.9-16.9)	**18.8** (17.7-20.0)	**21.2** (19.9-22.6)	**24.5** (22.9-26.2)	**27.2** (25.3-29.0)	**29.9** (27.7-32.0)	**32.7** (30.1-35.1)	**36.5** (33.2-39.4)	**39.5** (35.6-43.0)
60-day	**16.1** (15.2-17.1)	**19.0** (17.9-20.1)	**22.2** (21.0-23.6)	**24.8** (23.4-26.3)	**28.3** (26.6-30.0)	**31.0** (29.0-32.9)	**33.7** (31.4-35.9)	**36.4** (33.7-38.9)	**40.0** (36.8-43.0)	**42.8** (39.1-46.3)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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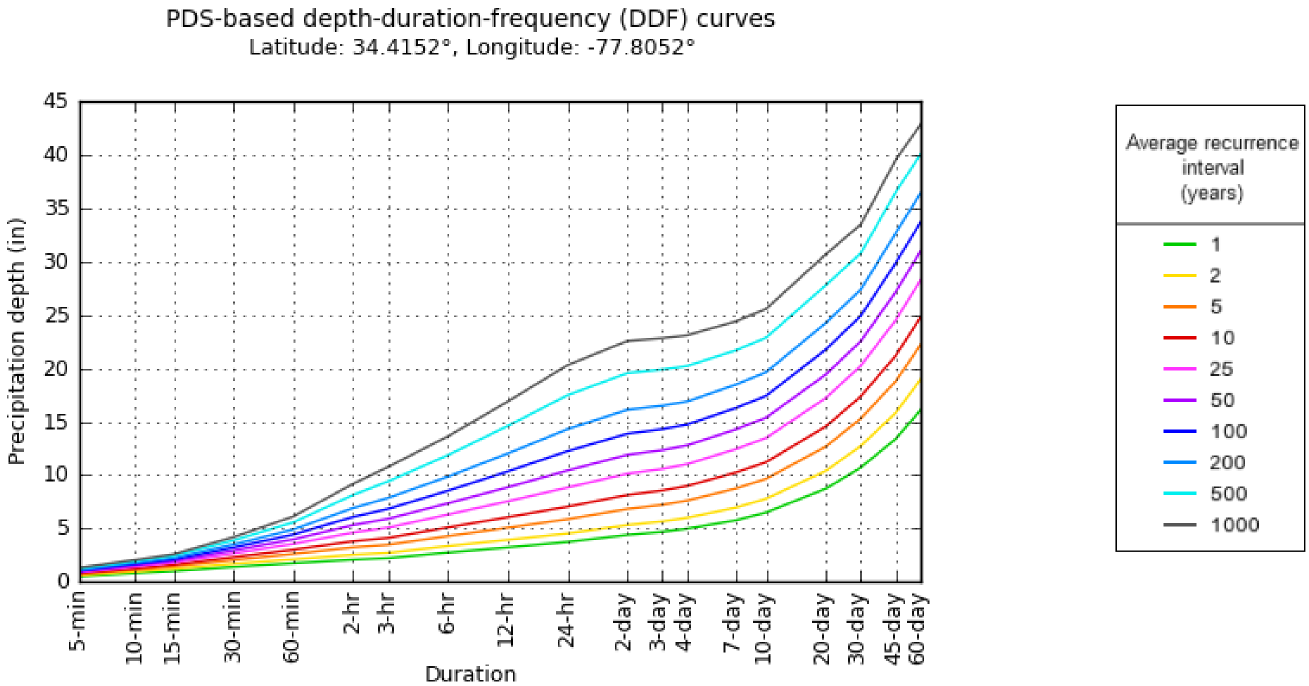
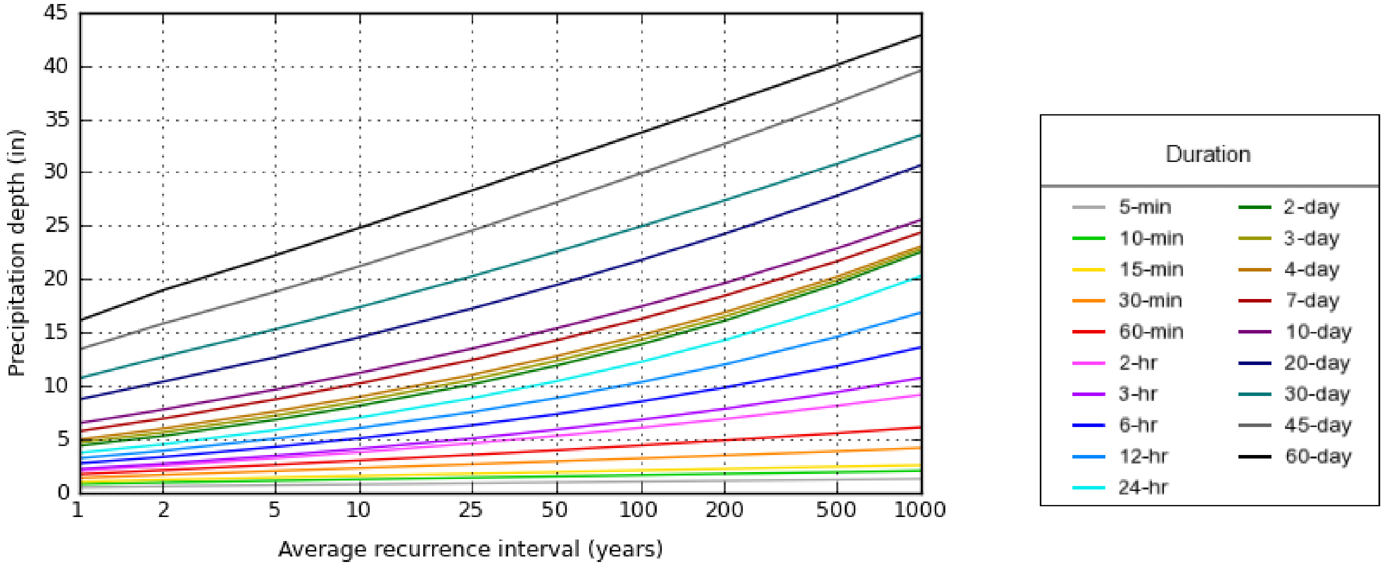
PF graphical





NOAA Atlas 14, Volume 2, Version 3 Created (GMT): Wed Feb 22 20:39:43 2023

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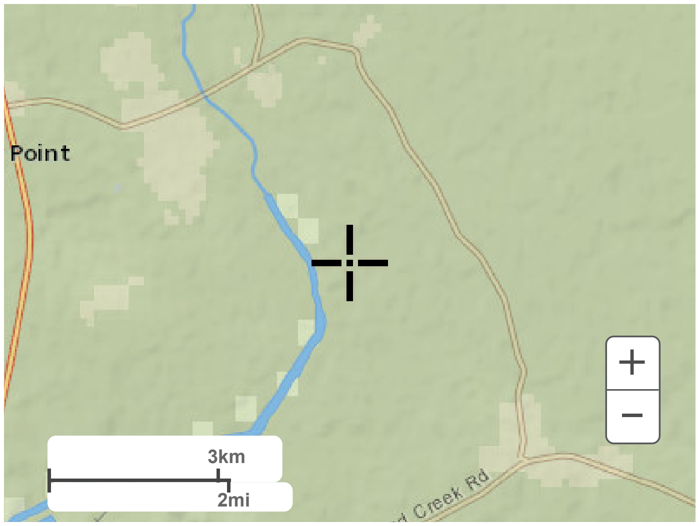
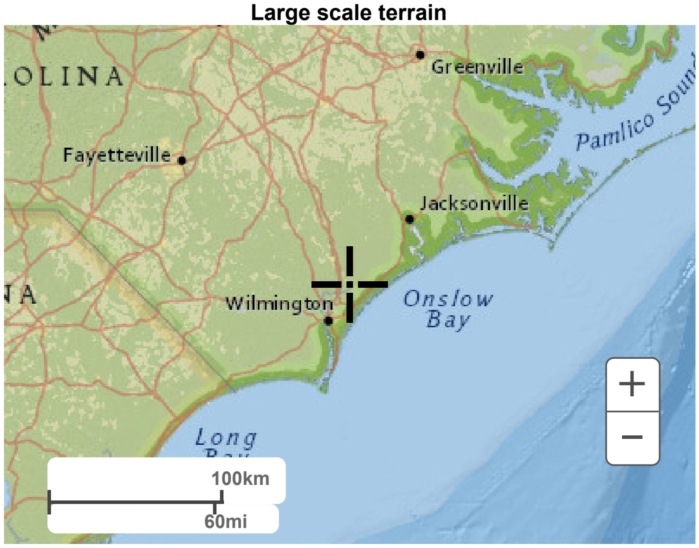
Maps & aerials

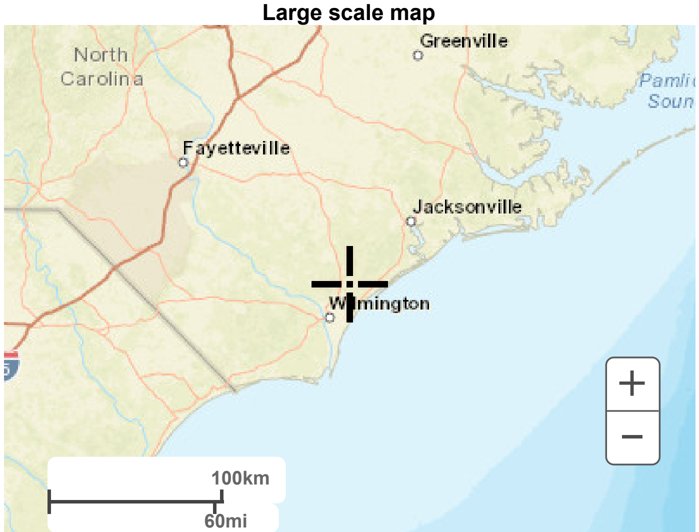
Small scale terrain



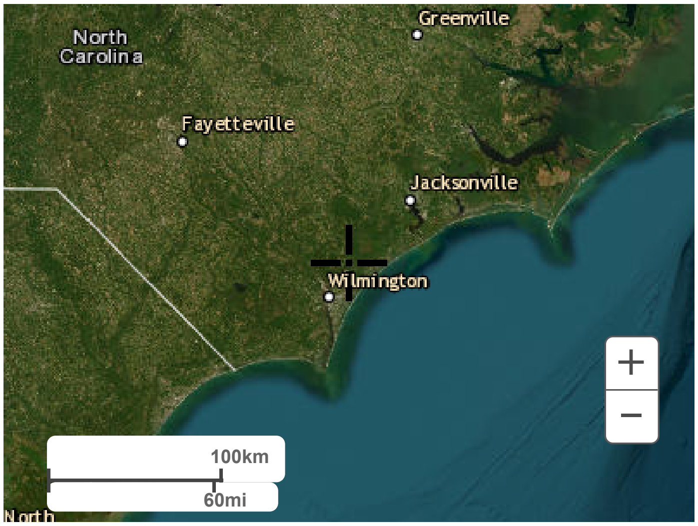
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

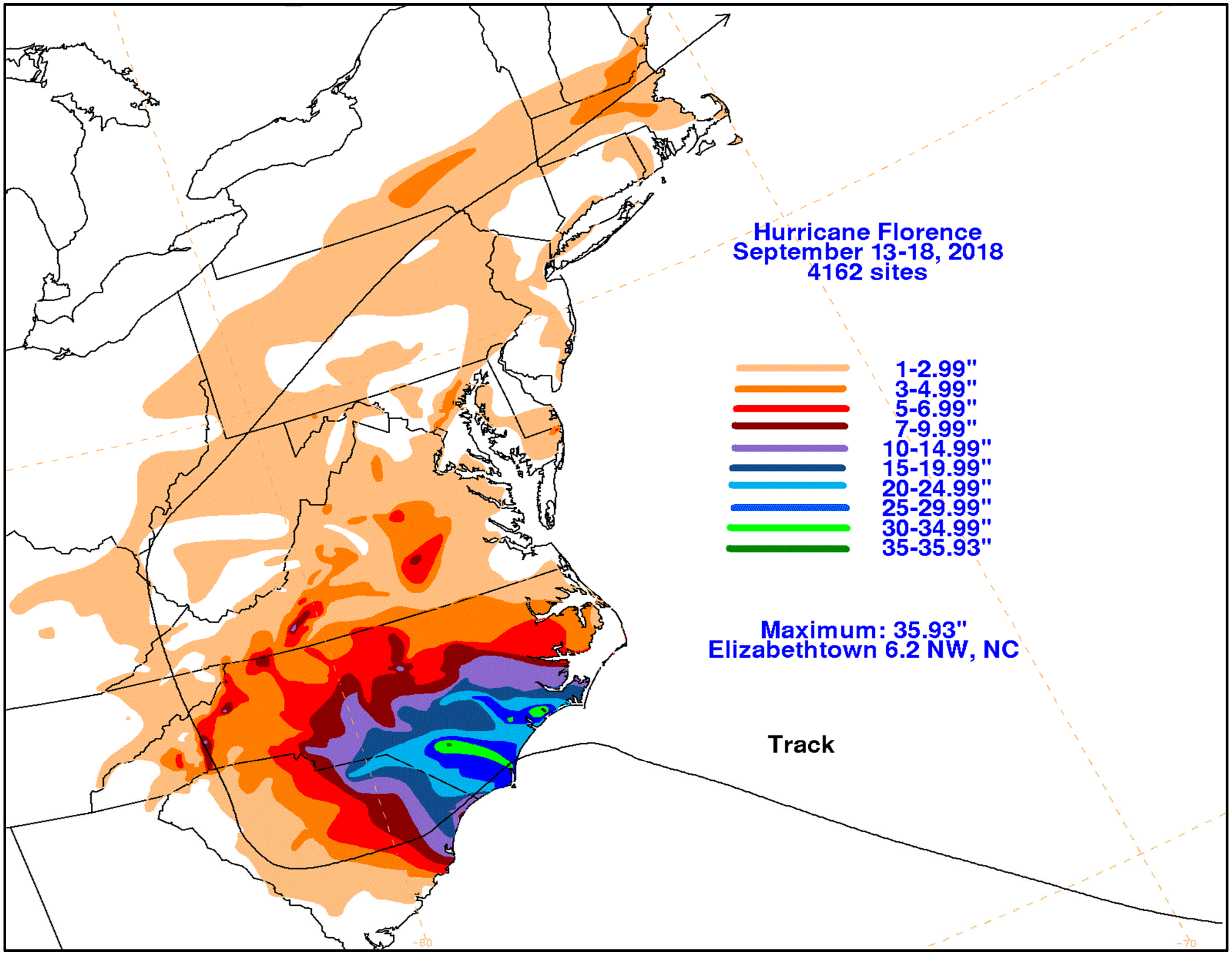


Figure 12. Hurricane Florence U.S. rainfall analysis (inches) during the period 13–18 September 2018, which includes extratropical phase. Graphic courtesy of the NOAA Weather Prediction Center.

APPENDIX 4: PLAN SHEETS

MERRICKS FUNC MC-1

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

ROADWAY DESIGN UNIT

PREPARED BY
wsp
4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253

SCALE IN FEET
1" = 50'

MERRICKS

FUNC	MC-2

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

INCOMPLETE PLANS

DO NOT USE FOR R/W ACQUISITION

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

ROADWAY DESIGN UNIT

PREPARED BY

wsp

4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253

SCALE IN FEET 1" = 50'

NAD 83/2011

HARRISONS

FUNC | HC-1

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

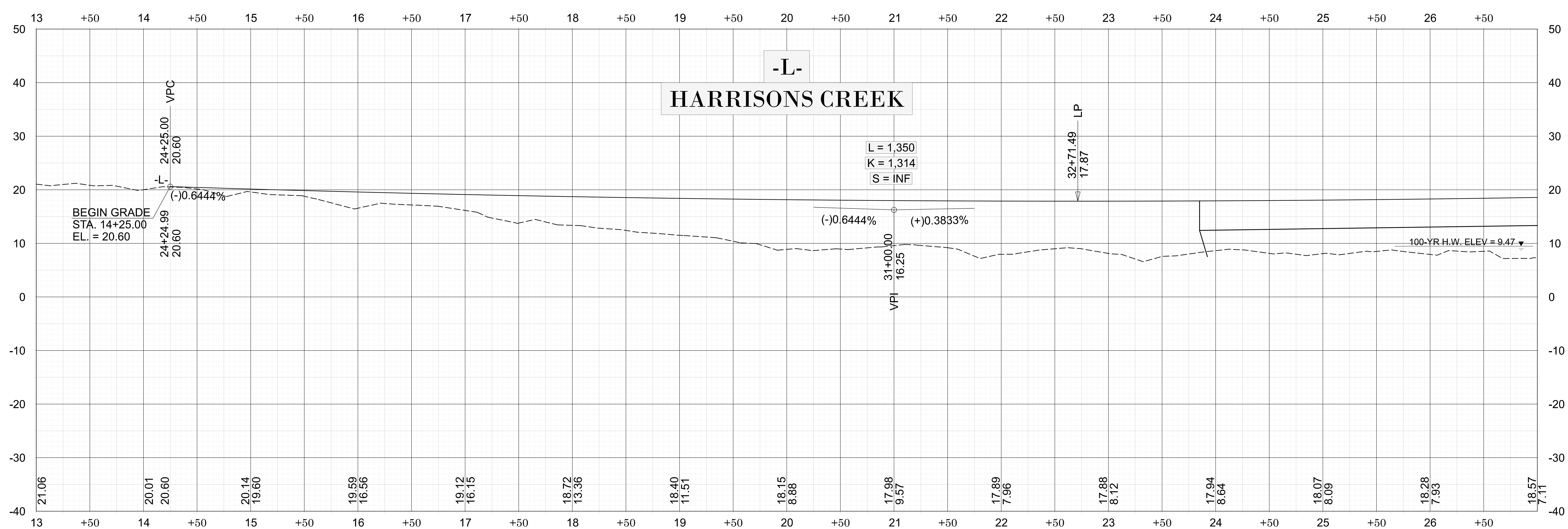
INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

ROADWAY DESIGN UNIT

PREPARED BY
wsp
4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253



HARRISONS

FUNC | HC-2

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

INCOMPLETE PLANS
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DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

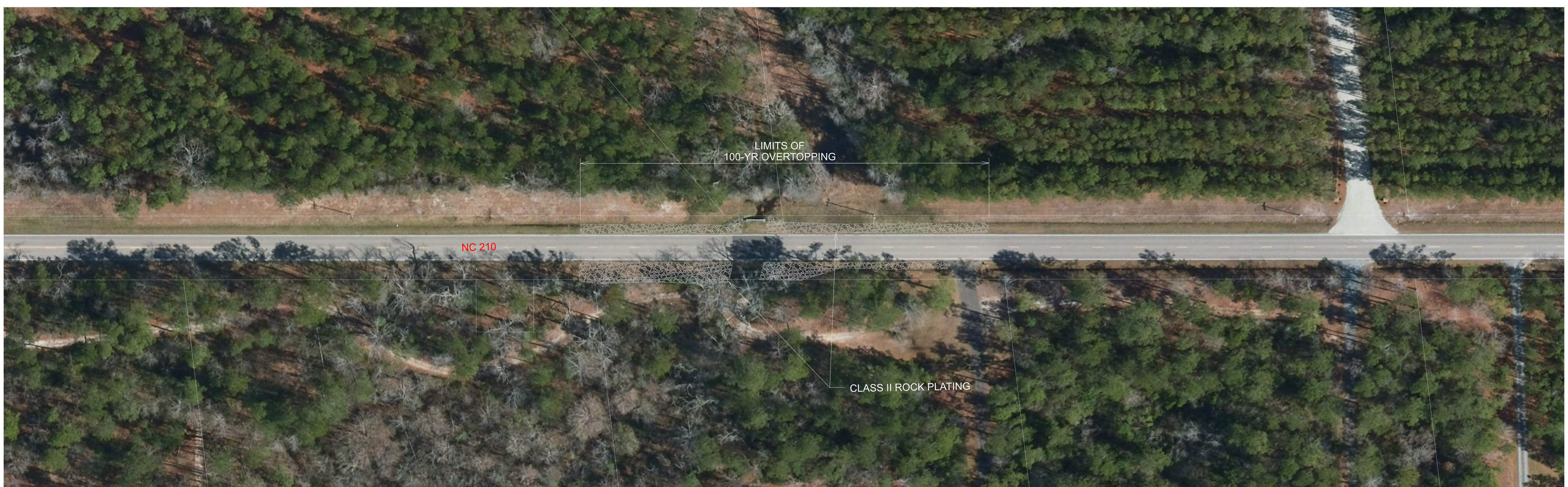
ROADWAY DESIGN UNIT

PREPARED BY

wsp

4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253

SCALE IN FEET
1" = 50'



OVERTOPPING FUNC | OT-1

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

ROADWAY DESIGN UNIT

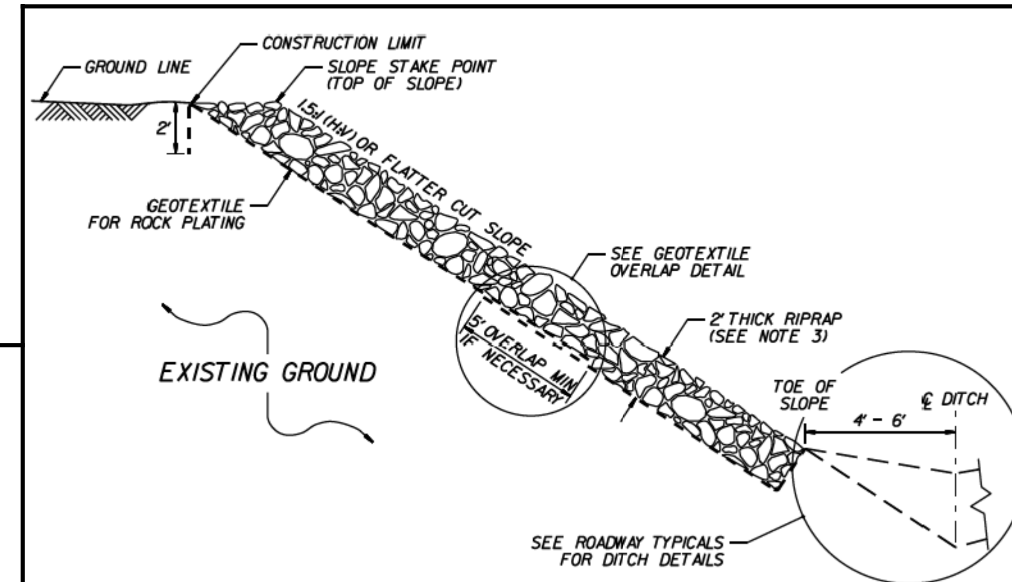
PREPARED BY
wsp

4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253

25' 0' 25' 50'
SCALE IN FEET
1" = 50'

NAD 83/2011

5/26/20



ROCK PLATING DETAIL - TYPICAL SECTION

OVERTOPPING

FUNC | OT-1

ROADWAY DESIGN ENGINEER

HYDRAULIC DESIGN ENGINEER

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

STATE OF NORTH CAROLINA

ROADWAY DESIGN UNIT

PREPARED BY
WSP
4021 STIRRUP CREEK DRIVE
DURHAM, NC 27703
NC ENG F-1253

25' 0' 25' 50'
SCALE IN FEET
1" = 50'

APPENDIX 5: COST ESTIMATES

North Carolina Department of Transportation
Preliminary Estimate

TIP No.		**Conceptual**	County: **Pender**
Route	NC 210 over Merricks Creek		
From			**CONSTR. COST**
Typical Section	2-lane undivided w/2' paved shoulders		**$4,563,260**
		Date	
Prepared By:	WSP USA	10/10/2023	
Requested By:			
Priced By:			

Line Item	Des	Sec No.	Description	Quantity	Unit	Price	Amount
			Mobilization	1	LS	$ 200,000.00	$ 200,000.00
			Construction Surveying	1	LS	$ 50,000.00	$ 50,000.00
			Clearing and Grubbing	2.3	Acre	$ 35,000.00	$ 80,500.00
			Supplemental Clearing and Grubbing	1	Acre	$ 10,000.00	$ 10,000.00
1 Br = 1 RBAF			Reinforced Bridge Approach Fills	1	Each	$ 45,000.00	$ 45,000.00
			Earthwork				
			Unclassified Excavation	1,500	CY	$ 6.00	$ 9,000.00
			Borrow Excavation	52,500	CY	$ 7.00	$ 367,500.00
			Drainage				
			Drainage Existing Location - 2-lane undivided w/2' paved shoulders	0.47	Miles	$ 300,000.00	$ 141,600.00
			Pavement (Asphalt)				
			Fine Grading	11,500	SY	$ 2.50	$ 28,750.00
			New Pavement	7,240	SY	$ 75.00	$ 543,000.00
			Subgrade Stabilization	7,730	SY	$ 11.00	$ 85,030.00
			Guardrail	550	LF	$ 27.00	$ 14,850.00
			Guardrail End Units - GREU Type TL-3	4	EA	$ 3,500.00	$ 14,000.00
			Guardrail Anchor Units - B-77	4	EA	$ 2,900.00	$ 11,600.00
			Removal of Existing Guardrail	550	LF	$ 2.50	$ 1,375.00
			Erosion Control	6.0	Acres	$ 40,000.00	$ 240,000.00
			Signing				
			L Line	0.47	Miles	$ 35,000.00	$ 16,520.00
			Traffic Control				
			L Line	0.47	Miles	$ 150,000.00	$ 70,800.00
			Thermo and Pavement Marking (2-lane undivided w/2' paved shoulders)	0.47	Miles	$ 35,000.00	$ 16,520.00
			STRUCTURES				
			Girder Type - Concrete				
			Off-Site Detour				
			Bridge - (255' x 40')	10,200.00	SF	$ 175.00	$ 1,785,000.00
			Removal of Existing Structure (110' x 28')	3,080	SF	$ 35.00	$ 107,800.00
			Bridge Approach Slabs (2 @ 40' x 25')	1,000	SF	$ 45.00	$ 45,000.00
			Utility Construction				
			Relocate Existing Water Line	500	LF	$ 100.00	$ 50,000.00
			Miscellaneous (10% Strs & Util)				$ 198,780.00
			Miscellaneous (40% Roadway)				$ 698,418.00

Lgth **0.472 Miles**

Contract Cost ………….............…..	$ 3,933,845.00
E. & C. 16% ………….............…..	$ 629,415.20
Construction Cost ………….............…..	**$ 4,563,260.20**

North Carolina Department of Transportation
Preliminary Estimate

TIP No.		**Conceptual**	County:	**Pender**
Route	NC 210 over Harrisons Creek			
From				**CONSTR. COST**
Typical Section	2-lane undivided w/2' paved shoulders			**$7,381,637**
		Date		
Prepared By:	WSP USA	10/10/2023		
Requested By:				
Priced By:				

Line Item	Des	Sec No.	Description	Quantity	Unit	Price	Amount
			Mobilization	1	LS	$ 300,000.00	$ 300,000.00
			Construction Surveying	1	LS	$ 50,000.00	$ 50,000.00
			Clearing and Grubbing	2.0	Acre	$ 35,000.00	$ 70,000.00
			Supplemental Clearing and Grubbing	1	Acre	$ 10,000.00	$ 10,000.00
1 Br = 1 RBAF			Reinforced Bridge Approach Fills	1	Each	$ 45,000.00	$ 45,000.00
			Earthwork				
			Unclassified Excavation	2,000	CY	$ 6.00	$ 12,000.00
			Borrow Excavation	42,500	CY	$ 7.00	$ 297,500.00
			Drainage				
			Drainage Existing Location - 2-lane undivided w/2' paved shoulders	0.47	Miles	$ 300,000.00	$ 141,000.00
			Pavement (Asphalt)				
			Fine Grading	11,670	SY	$ 2.50	$ 29,175.00
			New Pavement	6,060	SY	$ 75.00	$ 454,500.00
			Subgrade Stabilization	6,480	SY	$ 11.00	$ 71,280.00
			Guardrail	550	LF	$ 27.00	$ 14,850.00
			Guardrail End Units - GREU Type TL-3	4	EA	$ 3,500.00	$ 14,000.00
			Guardrail Anchor Units - B-77	4	EA	$ 2,900.00	$ 11,600.00
			Removal of Existing Guardrail	550	LF	$ 2.50	$ 1,375.00
			Erosion Control	5.0	Acres	$ 40,000.00	$ 200,000.00
			Signing				
			L Line	0.47	Miles	$ 35,000.00	$ 16,450.00
			Traffic Control				
			L Line	0.47	Miles	$ 150,000.00	$ 70,500.00
			Thermo and Pavement Marking (2-lane undivided w/2' paved shoulders)	0.47	Miles	$ 35,000.00	$ 16,450.00
			STRUCTURES				
			Girder Type - Concrete				
			Off-Site Detour				
			Bridge - (615' x 40')	24,600.00	SF	$ 175.00	$ 4,305,000.00
			Removal of Existing Structure (110' x 28')	3,080	SF	$ 35.00	$ 107,800.00
			Bridge Approach Slabs (2 @ 40' x 25')	1,000	SF	$ 45.00	$ 45,000.00
			Utility Construction				
			Relocate Existing Water Line	800	LF	$ 100.00	$ 80,000.00
			Miscellaneous (10% Structuress & Util)				$ 453,780.00
			Miscellaneous (40% Roadway)				$ 610,272.00

Lgth	**0.467 Miles**	**Contract Cost** …………............….	$ 6,363,480.00
		E. & C. 16% …………............….	$ 1,018,156.80
		Construction Cost …………............….	**$ 7,381,636.80**

North Carolina Department of Transportation
Preliminary Estimate

TIP No.		**Conceptual**	County:	**Pender**
Route	NC 210 Flood Resiliency Improvements			
From	Rock plating at existing culvert crossings			**CONSTR. COST**
Typical Section	2-lane undivided w/2' paved shoulders			**$304,709**
		Date		
Prepared By:	WSP USA	11/1/2023		
Requested By:				
Priced By:				

Line Item	Des	Sec No.	Description	Quantity	Unit	Price	Amount
			STRUCTURES				
			Class II Rip Rap Rock Plating (Location 1)	1,620.00	Tons	$ 80.00	$ 129,600.00
			Class II Rip Rap Rock Plating (Location 2)	1,365.00	Tons	$ 80.00	$ 109,200.00
			Miscellaneous (10% Structuress & Util)				$ 23,880.00
Lgth	**0.183**					**Contract Cost** ……………........…….	$ 262,680.00
						E. & C. 16% ……………........…….	$ 42,028.80
						Construction Cost ……………........…….	**$ 304,708.80**

Merricks Creek ROW Estimate						
Owner ID	total area (GIS)	total value	cost per acre	ROW area (sf)	ROW area (ac)	cost
1	2.5	$174,845.00	$69,938.00	12914	0.30	$20,734.14
2	1	$25,000.00	$25,000.00	1368	0.03	$785.12
3	0.33	$33.00	$100.00	3084	0.07	$7.08
4	2.01	$198,056.00	$98,535.32	4495	0.10	$10,167.96
5	3.6	$162,476.00	$45,132.22	12578	0.29	$13,031.98
6	16.11	$44,201.00	$2,743.70	15623	0.36	$984.04
7	9.84	$46,520.00	$4,727.64	15505	0.36	$1,682.78
8	1832.2	$2,329,000.00	$1,271.15	80683	1.85	$2,354.46
					total	$49,747.57
					SAY	**$100,000.00**

Harrisons Creek ROW Estimate							
Owner ID	total area (GIS)	total value	cost per acre	ROW area (sf)	ROW area (ac)	cost	
9	1.45	$115,800.00	$79,862.07	6264	0.14	$11,484.30	
10	12.4	$457,666.00	$36,908.55	3458	0.08	$2,929.98	
11	7.3	$164,200.00	$22,493.15	30539	0.70	$15,769.47	
12	15.87	$328,843.00	$20,721.05	32805	0.75	$15,605.00	
13	2.55	$2,550.00	$1,000.00	13259	0.30	$304.38	
14	10.54	$297,237.00	$28,200.85	21994	0.50	$14,238.97	
15	0.25	$42,000.00	total take			$42,000.00	total take
16	0.25	$41,160.00	total take			$41,160.00	total take
17	1.18	$36,869.00	$31,244.92	2024	0.05	$1,451.78	
18	0.7	$31,829.00	$45,470.00	1848	0.04	$1,929.03	
19	0.37	$263,150.00	$711,216.22	1456	0.03	$23,772.52	
20	0.92	$34,139.00	$37,107.61	1905	0.04	$1,622.82	
21	0.92	$34,139.00	$37,107.61	2655	0.06	$2,261.72	
22	0.31	$208,949.00	$674,029.03	1070	0.02	$16,556.73	
23	0.31	$209,789.00	$676,738.71	1205	0.03	$18,720.62	
24	85.06	$412,400.00	$4,848.34	1613	0.04	$179.53	
25	0.32	$253,502.00	$792,193.75	1337	0.03	$24,315.04	
26	0.51	$233,481.00	$457,805.88	3627	0.08	$38,118.96	
27	0.29	$209,743.00	$723,251.72	1188	0.03	$19,725.05	
28	0.51	$207,027.00	$405,935.29	589	0.01	$5,488.89	
					total	$297,634.79	
					SAY	**$600,000.00**	

APPENDIX 6: SCOUR CALCULATIONS

SCOUR CALCULATION

LOCATION: HWY 210 over Merricks Creek

DETERMINE IF LIVE BED OR CLEAR WATER SCOUR, V>Vc	SEE NOTE	100-YEAR STORM	
AVERAGE DEPTH IN UPSTREAM MAIN CHANNEL (Y1), (FT)	1, 3	14.90	
D50 - BED MATERIAL, (FT)	2	0.000620	
$V_c=11.17\ (Y)^{1/6}\ (D_{50})^{1/3}$, HEC-18, EQ 6.1, PG 6.2, (FT/SEC)		1.50	
VELOCITY (FT/SEC)	1	1.51	
MODE OF TRANSPORT		LIVE BED	

NOTES:

1. TAKEN FROM HEC-RAS HYDRAULIC 2D MODEL. APPROX 300 ft upstream of bridge opening.

2. BASED ON D50 = 0.00062 FT (0.016 MM) FOR FINE SAND PER SECTION 14.1.6 OF GDOT DRAINAGE MANUAL

SCOUR CALCULATION

LOCATION: HWY 210 over Merricks Creek

CONTRACTION SCOUR **LIVE BED**	SEE NOTE	**100 YEAR STORM**	
Y1 - AVG. DEPTH IN UPSTREAM MAIN CHANNEL (FT)	1, 3	14.90	
W1 - TOP WIDTH OF UPSTREAM MAIN CHANNEL (FT)	5	55	
W2 - TOP WIDTH OF MAIN CHANNEL IN CONTRACTED SECTION, LESS PIERS (FT)	5	65	
Q1 - FLOW IN UPSTREAM CHANNEL (CFS)	1	1,324	
Q2 - FLOW IN CONTRACTED CHANNEL (CFS)	2	2,344	
Y0 = EXISTING DEPTH IN CONTRACTED SECTION BEFORE SCOUR	2	14.15	
S1 - SLOPE OF ENERGY GRADE LINE, UPSTREAM CHANNEL (FT/FT)	1	0.001700	
D50 - BED MATERIAL (FT)	3	0.000620	
ω - FALL VELOCITY (M/SEC). BASED ON D50, SEE FIGURE 6.8, PG 6.12 IN HEC-18		0.02	
ω - FALL VELOCITY (FT/SEC).		0.066	
V* - SHEAR VELOCITY, (FT/SEC). (g*Y1*S1)^0.5	4	0.90	
V*/ω		13.76	
k1 (FROM TABLE ON PAGE 6.10 IN HEC-18)		0.69	
(W1/W2)^k1		0.89	
(Q2/Q1)^6/7		1.63	
Y2 = Y1*(Q2/Q1)^6/7*(W1/W2)^k1 - (FT) HEC-18, EQ 6.2, PG 6.11		21.66	
Ys =Y2-Y0 = AVERAGE SCOUR DEPTH (FT)		7.5	

1. TAKEN FROM HEC-RAS HYDRAULIC 2D MODEL. APPROX 300 ft upstream of bridge opening

2. BASED ON D50 = 0.00062 FT (0.016 MM) FOR FINE SAND PER SECTION 14.1.6 OF GDOT DRAINAGE MANUAL

3. Main channel depth is incorporated into the terrain based on the effective model only at the structure opening. Based on the effective model XS 28061.9, the main channel invert is approximately 5-ft lower than the banks.
Upstream terrain does not incorporate the main channel inverts due to the rain on grid approach. Rain on grid assumes channel has normal flow prior to precipitation. Average depth US of channel is assumed by adding 5-ft to depth raster.

4. g = ACCELERATION OF GRAVITY (FT/S^2)

5. Measured using terrain and aerial imagery

SCOUR CALCULATION

LOCATION: HWY 210 over Merricks Creek

PIER SCOUR - 100 Year	SEE NOTE	100-yr
Y1 - DEPTH OF FLOW UPSTREAM OF PIER (FT)		**14.15**
K1 - CORRECTION FACTOR FOR PIER NOSE SHAPE SEE FIGURE 7.3 & TABLE 7.1, PG 7.4, HEC-18	1	1.00
K2 - CORRECTION FACTOR FOR ANGLE OF ATTACK SEE TABLE 7.2, PAGE 7.4, HEC-18	1	1.00
K3 - CORRECTION FACTOR FOR BED CONDITION SEE TABLE 7.3, PAGE 7.5, HEC-18		1.10
K4 - CORRECTION FACTOR FOR ARMORING BY BED MATERIAL SIZE, SEE PAGE 6.6, HEC-18, 4TH ED.		1.00
a - PIER WIDTH, (FT)		4.00
V1 - MEAN VELOCITY, UPSTREAM OF PIER (FT/SEC)		**4.03**
Fr1 - FROUDE NUMBER = V1/(g*Y1)^0.5		0.1888
Ys/Y1 = 2*K1*K2*K3*K4*(a/Y1)^0.65*Fr1^0.43 HEC-18, EQ 6.1, PG 6.2, 4TH ED.		0.47
(Ys) - CALCULATED SCOUR DEPTH (FT)		6.69
CORRECTION FOR MULTIPLE COLUMNS SEE HEC-18, PAGE 7.23		1.00
TOTAL PIER SCOUR (FT)		6.69

NOTES:
1. Assuming round nose piers
2. Contraction section is used to determine depth and velocity
3. Velocity determined from velocity raster in the contracted section

SCOUR CALCULATION

LOCATION: HWY 210 over Harrisons Creek

DETERMINE IF LIVE BED OR CLEAR WATER **SCOUR, V>Vc**	SEE NOTE	100-YEAR STORM	
AVERAGE DEPTH IN UPSTREAM MAIN CHANNEL (Y1), (FT)	1, 3	**9.25**	
D50 - BED MATERIAL, (FT)	2	0.000620	
$V_c=11.17\ (Y)^{1/6}\ (D_{50})^{1/3}$, HEC-18, EQ 6.1, PG 6.2, (FT/SEC)		1.38	
VELOCITY (FT/SEC)	1	**2.52**	
MODE OF TRANSPORT		LIVE BED	

NOTES:

1. TAKEN FROM HEC-RAS HYDRAULIC 2D MODEL.

2. BASED ON D50 = 0.00062 FT (0.016 MM) FOR FINE SAND PER SECTION 14.1.6 OF GDOT DRAINAGE MANUAL

SCOUR CALCULATION

LOCATION: HWY 210 over Harrisons Creek

CONTRACTION SCOUR **LIVE BED**	SEE NOTE	**100** **YEAR STORM**	
Y1 - AVG. DEPTH IN UPSTREAM MAIN CHANNEL (FT)	1, 3	**9.25**	
W1 - TOP WIDTH OF UPSTREAM MAIN CHANNEL (FT)	5	**25**	
W2 - TOP WIDTH OF MAIN CHANNEL IN CONTRACTED SECTION, LESS PIERS (FT)	5	**30**	
Q1 - FLOW IN UPSTREAM CHANNEL (CFS)	1	**699**	
Q2 - FLOW IN CONTRACTED CHANNEL (CFS)		**711**	
Y0 = EXISTING DEPTH IN CONTRACTED SECTION BEFORE SCOUR		**10.25**	
S1 - SLOPE OF ENERGY GRADE LINE, UPSTREAM CHANNEL (FT/FT)	1	0.001700	
D50 - BED MATERIAL (FT)	3	0.000620	
ω - FALL VELOCITY (M/SEC). BASED ON D50, SEE FIGURE 6.8, PG 6.11 IN HEC-18		0.02	
ω - FALL VELOCITY (FT/SEC).		0.066	
V* - SHEAR VELOCITY, (FT/SEC). (g*Y1*S1)^0.5	4	0.71	
V*/ω		10.84	
k1 (FROM TABLE ON PAGE 6.10 IN HEC-18)		0.69	
(W1/W2)^k1		0.88	
(Q2/Q1)^6/7		1.01	
Y2 = Y1*(Q2/Q1)^6/7*(W1/W2)^k1 - (FT) HEC-18, EQ 6.2, PG 6.11		8.28	
Ys =Y2-Y0 = AVERAGE SCOUR DEPTH (FT)		-2.0	

1. TAKEN FROM HEC-RAS HYDRAULIC 2D MODEL.

2. BASED ON D50 = 0.00062 FT (0.016 MM) FOR FINE SAND PER SECTION 14.1.6 OF GDOT DRAINAGE MANUAL

3. Main channel depth is incorporated into the terrain based on the effective model only at the structure opening. Based on the effective model XS 20727, the main channel invert is approximately 5-ft lower than the banks. Upstream terrain does not incorporate the main channel inverts due to the rain on grid approach. Rain on grid assumes channel has normal flow prior to precipitation. Average depth US of channel is assumed by adding 5-ft to depth raster.

4. g = ACCELERATION OF GRAVITY (FT/S^2)

5. Measured using terrain and aerial imagery

SCOUR CALCULATION

LOCATION: HWY 210 over Harrisons Creek

PIER SCOUR - 100 Year	SEE NOTE	100-yr
Y1 - DEPTH OF FLOW UPSTREAM OF PIER (FT)		**10.25**
K1 - CORRECTION FACTOR FOR PIER NOSE SHAPE SEE FIGURE 7.3 & TABLE 7.1, PG 7.4, HEC-18	1	1.00
K2 - CORRECTION FACTOR FOR ANGLE OF ATTACK SEE TABLE 7.2, PAGE 7.4, HEC-18	1	1.00
K3 - CORRECTION FACTOR FOR BED CONDITION SEE TABLE 7.3, PAGE 7.5, HEC-18		1.10
K4 - CORRECTION FACTOR FOR ARMORING BY BED MATERIAL SIZE, SEE PAGE 6.6, HEC-18, 4TH ED.		1.00
a - PIER WIDTH, (FT)		4.00
V1 - MEAN VELOCITY, UPSTREAM OF PIER (FT/SEC)		**1.64**
Fr1 - FROUDE NUMBER = V1/(g*Y1)^0.5		0.0903
Ys/Y1 = 2*K1*K2*K3*K4*(a/Y1)^0.65*Fr1^0.43 HEC-18, EQ 6.1, PG 6.2, 4TH ED.		0.42
(Ys) - CALCULATED SCOUR DEPTH (FT)		4.35
CORRECTION FOR MULTIPLE COLUMNS SEE HEC-18, PAGE 7.23		1.00
TOTAL PIER SCOUR (FT)		4.35

NOTES:
1. Assuming round nose piers
2. Contraction section is used to determine depth and velocity
3. Velocity determined from velocity raster in the contracted section