Lumber River Basin
Flood Risk Management Study
Technical Report

Charleston District
South Atlantic Division

Main Report
January 2022

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Executive Summary

The Lumber River Basin Flood Risk Management Study Technical Report documents the plan formulation study conducted by the U.S. Army Corps of Engineers (USACE), Charleston District. The Non-Federal Sponsor for this study effort is the State of North Carolina Department of Environmental Quality (NCDEQ).

The study is an interim response to the Senate Committee on Public Works Resolution adopted October 15, 1968; House Committee on Public Works Resolution adopted December 11, 1969 and was included in the 2019 Additional Supplemental Appropriations for Disaster Relief (Public Law 116-20).

Lumber River basin has a history of riverine flooding which occurs from rainfall during storm and hurricane events. Problems include damage to residential and non-residential structures, impacts to industry, commerce, transportation, and the natural environment, as well as damages to public infrastructure.

The purpose of the study is to identify, formulate and evaluate cost effective, environmentally acceptable and technically feasible alternatives to reduce flood damages and impacts within the Basin. To this end, an initial array of management measures was brainstormed to address the planning objectives. These measures included structural and non-structural measures and consideration of natural and nature based solutions throughout the basin. Measures were then screened based on effectiveness, cost and environmental acceptability. Screening level analysis relied on professional judgement and qualitative assessments of the screening criteria. Based on this screening, none of the identified measures were retained for additional consideration and no plan was identified for USACE implementation. Therefore, the No Action Alternative is the Recommended Plan.

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1. Introduction

The USACE Charleston District has conducted a feasibility study for the Lumber River basin in North and South Carolina for the purpose of flood risk management (FRM).

Feasibility studies are funded by specific appropriations and are conducted through a single phase. The feasibility study phase consists of a study to investigate and determine the extent of Federal interest in plans to reduce flood risk. The study phase includes an assessment of flood risk, analysis of a range of alternatives formulated to reduce flood risk and identification of a recommended plan for implementation. The purpose of the Technical Report is to describe the findings of the feasibility study and a recommended plan, if Federal interest is determined to exist.

1.1. Study Authorization

This Lumber River Basin FRM study is an interim response to the Senate Committee on Public Works Resolution adopted October 15, 1968; House Committee on Public Works Resolution adopted December 11, 1969:

> *"Resolved by the Committee on the Public Works of the United States Senate [House of Representatives], that the Board of Engineers for Rivers and Harbors [Act approved in June 13, 1902], is hereby requested to review the report of the Chief of Engineers on the Yadkin-Pee Dee River and its Tributaries, North Carolina and South Carolina,…with a view to determining the advisability of modifying the recommendations contained therein, with particular reference to providing flood protection on the Lumber River and its Tributaries…"*

The study was included in the 2019 Additional Supplemental Appropriations for Disaster Relief (Public Law 116-20):

> *For an additional amount for ''Flood Control and Coastal Emergencies'', as authorized by Section 5 of the Act of August 18, 1941(33 U.S.C. 701n), for necessary expenses to prepare for flood, hurricane and other natural disasters and support emergency operations, repairs, and other activities in response to such disasters, as authorized by law, $1,000,000,000, to remain available until expended…*

The USACE Wilmington District brokered the study to the Charleston District. The total authorized study cost is $3M and the authorized schedule is 36 months.

1.1.1. Additional Study Guidance

This study is being undertaken in accordance with:

- Implementation Guidance for Section 1005 of the Water Resources Reform and Development Act of 2014 (WRRDA 2014), Project Acceleration, issued 20 March 2018;
- ASA(CW) Memorandum for the Commanding General, U.S. Army Corps of Engineers: Comprehensive Documentation of Benefits in Feasibility Studies (03 April 2020);

- Memorandum for Commanding General, U.S. Army Corps of Engineers: Policy Guidance on Implementation of Supplemental Appropriations for Disaster Relief Act, 2019 (Public Law 116-20); and,
- SACW Policy Directive – Comprehensive Documentation of Benefits in Decision Document (5 January 2021).

1.2. Non-Federal Sponsor

The non-Federal sponsor for this study is the State of North Carolina Department of Environmental Quality (NCDEQ).

1.3. Purpose and Need

The purpose of the study is to identify, formulate and evaluate cost effective, environmentally acceptable, and technically feasible alternatives to reduce flood damages and impacts within the Basin. As described in subsequent sections of this report, Lumber River basin has a history of riverine flooding which occurs from rainfall during storm and hurricane events.

1.4. Study Area

The Lumber River basin is a sub-basin of the Pee Dee River Basin. The Basin exists primarily within the borders of North Carolina, with a small portion of the drainage area and stream length within South Carolina. The headwaters of the river are composed of the Drowning Creek drainage area in Montgomery, Moore, and Richmond Counties in the northeastern Sand Hills region. Drowning Creek becomes the Lumber River approximately 9 miles downstream of Moore and Richmond Counties and 3 miles into the Coastal Plain region, forming the border of Hoke and Scotland Counties. From there the river flows 115 miles downstream to the North Carolina – South Carolina border.

The Lumber River flows into the Little Pee Dee River 10 miles downstream from the border. The Little Pee Dee River meets the Great Pee Dee River, which flows into Winyah Bay and the Atlantic Ocean. The study area for this interim report has been limited to the entirety of the 8-digit Lumber River basin, Hydrologic Unit Code (HUC) 03040203, including all associated tributaries, which is 1,753 square miles (See **Figure 1.1**). Major tributaries are shown in **Table 1.1**.

Table 1.1 - Major Tributaries

Tributary	Contributing Area (Square Miles)
Naked Creek	39
Horse Creek	43
Aberdeen Creek	38
Drowning Creek	324
Gum Swamp	39
Back Swamp	35
Bear Swamp	26
Richland Swamp	47
Raft Swamp	170
Saddletree Swamp	21
File Mile Branch	36
Little Marsh Swamp	53
Galberry Swamp	87
Big Marsh Swamp	65
Tenmile Swamp	62
Crawley Swamp	43
Big Swamp	445
Lumber River	1,370

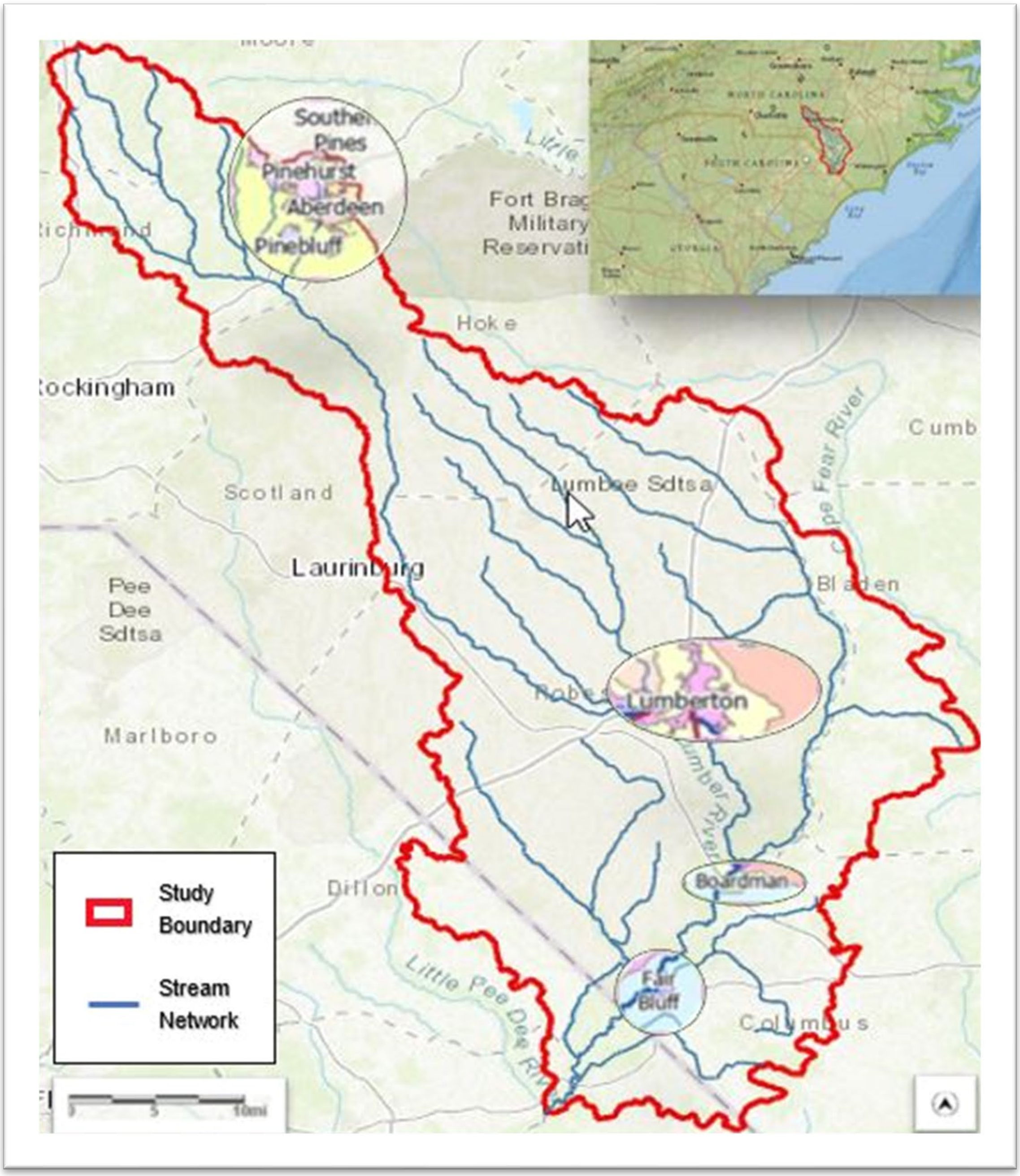

Figure 1.1 - Study location.

Major population centers in the Lumber River basin include the village of Pinehurst, the towns of Aberdeen, Boardman, Fair Bluff, Fairmont, Maxton, Pembroke, Pinebluff, Red Springs and Southern Pines, as well as the cities of Lumberton and Raeford, discussed in more detail in subsequent sections.

1.5. Study Scope and Federal Interest

Consistent with the study authority, the scope of this study is to assess alternatives which could reduce flood risk and increase resiliency within the Lumber River basin. The communities most severely impacted by flooding include Lumberton, Fair Bluff, and Boardman, North Carolina and Nichols, South Carolina.

1.6. Study History and Background

In response to flooding caused by Hurricanes Matthew and Florence in 2016 and 2018, respectively, USACE received funding through the 2019 Additional Supplemental Appropriations for Disaster Relief (H.R. 2157) for a feasibility study to assess and recommend actions which reduce flood risk and increase resiliency within the Lumber River basin. As previously stated, the NCDEQ is the non-Federal sponsor. The Feasibility Cost Sharing Agreement (FCSA) was signed on 8 April 2020.

An initial scoping charrette was held in May 2020 and included members of USACE, the non-Federal sponsor and other key stakeholders. The charrette resulted in the following objectives:

- Reduce damage to structures (residential and non-residential) and public infrastructure (critical infrastructure) throughout the river basin over the period of analysis;
- Reduce economic damages to industries (e.g. agriculture) and commerce throughout the study area over the period of analysis;
- Reduce life and safety risk associated with inundation of structures (residential, non-residential and critical facilities) and public infrastructure throughout the river basin over the period of analysis; and
- Reduce life and safety risk associated with inundation of and damage to transportation infrastructure throughout the river basin over the period of analysis.

1.6.1. Prior Reports and Existing Water Resource Projects

A variety of projects and activities are ongoing or have been completed in the Basin. While they are not part of this study, the scope and status of these efforts have been tracked for consideration in the planning process, conceptual design development and impact analysis. **Table 1.2** below summarizes the related projects and studies which have been identified and the applicability to the planning process.

Table 1.2 - Prior Projects and Studies

Project/Study Name	Responsible Organization	Status	Applicability to Planning Process
Lumber River Basin Flood Analysis and Mitigation Strategies Study	North Carolina Department of Transportation	Complete – 1 May 2018	Provides detail on Basin, considers FRM measures
Hurricane Matthew Resilient Redevelopment Plans for all counties within the study area	Rebuild North Carolina		Provides detail on Basin, considers FRM measures

1.7. History of Flooding

Widespread and severe flooding has been recorded within central and eastern North Carolina, including the Lumber River basin as far back as 1928, with another historically significant flood occurring in September 1945. Both events occurred as a result of hurricanes. The most notable hurricanes to impact the study area in recent history include Hurricanes Floyd, Matthew and Florence which occurred in 1999, 2016 and 2018, respectively.

Hurricane Floyd resulted in approximately 5 to 10 inches of rainfall across parts of the Basin. This rainfall only served to exacerbate flooding from Hurricane Dennis, which occurred approximately 2 weeks prior. The wet soil conditions increased runoff from Hurricane Floyd and resulted in higher flood elevations than would have occurred had the hurricane been a standalone event.

Hurricane Matthew occurred during September 2016 and produced extreme depths of flooding across a wide portion of the Basin, with some areas experiencing as much as 16 inches of rainfall. At the time, soils in the basin were already saturated from above average rainfall, resulting in runoff over and above what would have otherwise occurred.

There were 28 fatalities reported across North Carolina related to Hurricane Matthew. Statewide, the North Carolina Floodplain Mapping Program (NCFMP) reported approximately 99,000 structures affected by flooding associated with the hurricane. Emergency Management estimates approximately $1.5B in damages statewide. This does not include damages to agriculture or roads. In terms of transportation impacts, there were over 600 road closures, including portions of Interstates 40 and 95, both which intersect the Lumber River basin.

Economic damages attributable to Hurricane Matthew along the Lumber River Mainstem are shown below in **Table 1.3**.

Table 1.3 - Hurricane Matthew Economic Damages

Structural Damages		
Location	Structures Impacted	Damages
Lumberton	2,367	$251,574,000
Robeson County	1,412	$15,153,000
Boardman	55	$634,000
Fair Bluff	340	$11,109,000
Columbus Co.	66	$907,000
Total	4,240	$279,459,000

Hurricane Florence occurred in September 2018, causing widespread flooding resulting in damage to residential and commercial buildings and over 2,200 primary and secondary roadways (including Interstates 40 and 95), some of which remained impassable for days after the storm ended. The hurricane resulted in over $24B in damages, most of which was realized in North and South Carolina. As with previous storms, the flooding associated with the hurricane was compounded by already wet conditions due to previous rainfall. Civilians, local government employees and the National Guard worked to sandbag a section of the Lumberton Levee which sustained damage during Hurricane Matthew.

2. Existing and Future Without Project Condition

The existing condition are those at the time the study is conducted. The existing condition is determined by developing an inventory of critical resources relevant to the problems and opportunities under consideration. The Future Without Project (FWOP) condition is the condition expected in the future absent Federal action and is determined by forecasting the existing condition into the future. The FWOP condition provides the basis from which alternative plans are formulated and impacts are assessed.

Specific to this study, the most significant change between the Existing and FWOP conditions are the issues associated with the Lumberton Levee (discussed below in **Section 2.1**). Addressing the issues associated with the levee will result in a significant decrease in flood damages and directly contributes to the finding of no Federal interest and recommendation of No Action.

All of the existing and FWOP assumptions are discussed in detail in the following sections.

2.1. Issues Associated with the Lumberton Levee

The Lumber River and the Jacob Swamp Watershed in Robeson County both have a long history of flooding issues. In the 1960s the Jacob Swamp Watershed Improvement Plan was developed by the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), to mitigate flooding issues and allow for safer development of the land for commercial, agricultural, and residential uses. These improvements included widening and deepening of drainage channels, construction of a levee system along the Lumber River that included an earthen berm connected to I-95 north to Alamac Road (SR 2289), and operation and maintenance plans to maintain the channels and levee system. Design of the levee was completed in 1974 and construction was completed by about 1977.

The plan for works of improvement for the Jacob Swamp Watershed was authorized under authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Sat. 666). According to the work plan agreement, Robeson County Drainage District Number 1 is responsible for the operation and maintenance of the channel improvement measures; the City of Lumberton is responsible for the operation and maintenance of the levee embankment.

The leveed area is sizeable at approximately 11.4 square miles and is highly developed (**Figure 2.1**). Development in the leveed area includes a mix of residential, commercial, agricultural, industrial, and rural undeveloped areas. In addition, the leveed area includes a solar farm, several churches, a school, and industrial warehouse facilities. Critical infrastructure includes a police station, airport and water treatment plant.

According to the FWOP structure inventory (the development of which is described in **Section 2.7.3,**), within the leveed area there is a total population of approximately 5,647 (day) and 4,944 (night). The total number of structures in the leveed area is estimated to be 1,808, which includes residential, public, industrial, agricultural, and commercial structures valued at $750,213,331. While only 17% of these structures are non-residential, they make up approximately 69% of the structure value within the leveed area. The mean household income in Lumberton is $47,282, which is significantly less than the national average ($77,866) and the state of North Carolina average ($67,367). Census data indicates that the population of Lumberton increased from 20,795 in 2000 to 21,542 in 2010 and fell to 21,499 in 2016.

Table 2.1 – FWOP Structures by Type within Lumberton Levee Area

Damage Category	Structures Impacted	Damages	Content Value
Commercial	211	$238,044,325	$243,243,703
Industrial	33	$236,358,410	$352,339,988
Public/Government	57	$46,925,758	$51,931,236
Residential	1507	$228,884,837	$182,600,747
Total	1808	$750,213,330	$830,115,674

The existing levee is not certified by the Federal Emergency Management Agency (FEMA). Recent flooding has been attributed to the following four deficiencies:

- Conveyance through the opening at VFW Road I-95 underpass and interstate culverts;
- Overtopping of portions of Interstate 95 non-project segment;
- Insufficient conveyance in the interior drainage canals; and
- Backwater from the Lumber River entering though a bridge over Jacob Branch on Alamac Road (SR 2289) non-project segment.

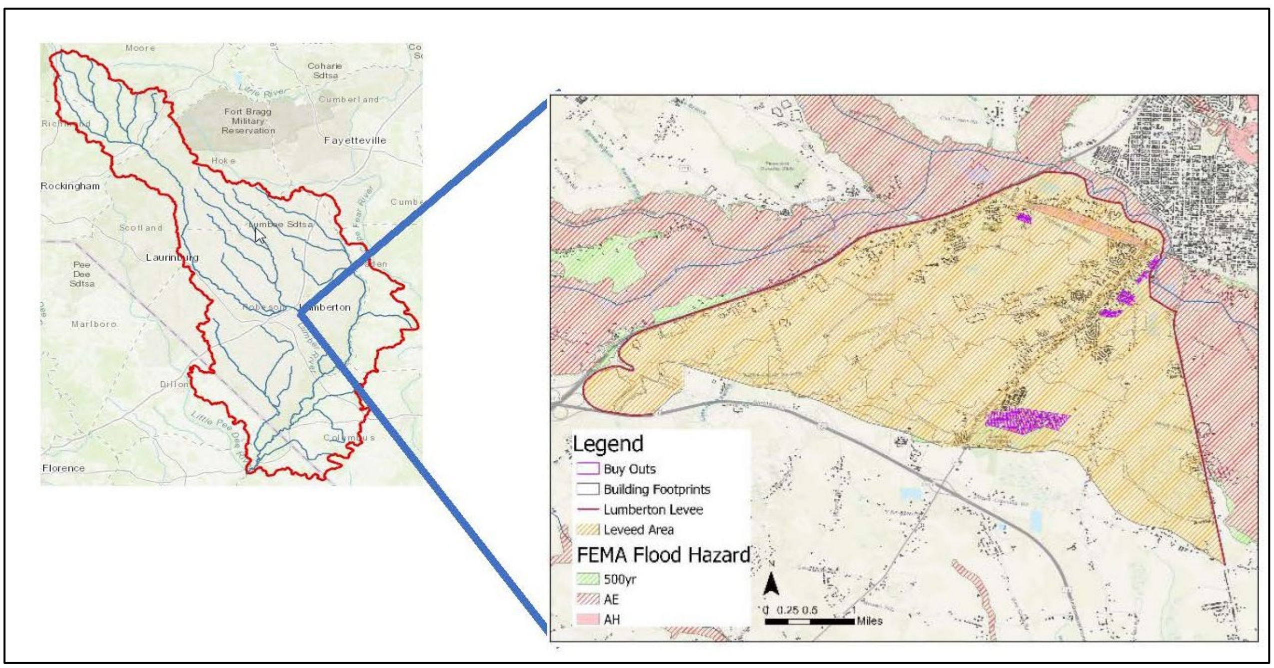

Figure 2.1 – Leveed area, Lumberon, NC.

Unless corrected, these deficiencies will likely result in some flood risk, although it is unlikely to be significant enough to warrant Federal action. At the time this study was initiated it was unclear whether the City of Lumberton had plans to address all four levee deficiencies and ensure it could operate as intended. The City has since received an Economic Development Administration (EDA) grant to be combined with North Carolina Department of Transportation (NCDOT) funding for a local floodgate project where I-95 spans over the Lumber River. The NCDOT is planning a large-scale I-95 project to address the flooding issues on the interstate, with construction expected to begin in late 2022. The City is planning to move forward with complex coordination with NCDOT and the Railroad, so the floodgate project is integrated with the larger I-95 project being undertaken by the NCDOT. This combined effort should reduce the risk of flood damages within the leveed area of Lumberton as well as on Interstate 95 near Lumberton.

2.2. Climate and Climate Change

According to the Köppen climate classification, eastern North Carolina is classified as a humid subtropical climate. In the study region, the summers can be hot and muggy, and the winters can be cold, cloudy, and short. The area typically experiences its coldest month in January with an average high of 55 °F and average low of 35 °F. The warmest month occurs in July with an average high of 91 °F and low of 72 °F. The average annual temperature is approximately 64 °F **Table 2.2**). The average annual rainfall ranges from 45.7 inches to 49.0 inches with the highest rainfall totals occurring during June, July, and August. During these months, the study area receives between 4.7 and 6.0 inches of rain per month. **Figure 2.2** shows the average rainfall for the study area for the period 1980 to 2010.

In general, most long-term climate stations in eastern North Carolina have recorded an approximate one-half degree (F) increase in average temperatures over the past ten years. The increase is indicated for all months of the year except the month of November where temperatures have slightly decreased over the past decade. It is expected that the changing climate in North Carolina will lead to a decrease in crop yields, an increase in damage to livestock, and an increase in the number of unpleasantly hot days and risk of heat related illness (USEPA 2021).

In the future, climate change is expected to result in increasing air temperatures and changes to the temporal variability of precipitation. This could contribute to more frequent storm events, and increased surface water flows, leading to degradation of aquatic ecosystems.

In summary, flooding in the project area is due to extensive rainfall throughout the year, multi-day rainstorms leading to saturated soils, warmer Atlantic Ocean is contributing to the increased rainfall and an increase in intensity and frequency of hurricanes.

The projected changes and impacts to Lumber River Watershed include an increase of rainstorms and extreme rainfall events resulting in flooding that puts people and infrastructure at risk. Stronger hurricanes coupled with extreme precipitation will destroy or damage public and private buildings and property. Increased inland flooding caused by extreme precipitation events will further increase economic and agricultural losses after an event. Vulnerable populations are most at risk of flooding and may have difficulty evacuating when necessary. Please refer to **Appendix A** for the Climate Change Analysis.

Table 2.2 - Monthly and Annual Average Temperatures for the Lumber River Basin from 1991 to 2020[1]

Annual	**Average Temperature**	**Average High**	**Average Low**
	63.5	**74.1**	**52.9**
Monthly	Average Temperature	Average High	Average Low
January	44.9	54.6	35.3
February	48.0	58.6	37.4
March	54.5	65.8	43.1
April	62.7	74.7	50.7
May	71.0	82.5	59.5
June	78.8	88.8	68.7
July	81.6	91.0	72.3
August	80.0	89.1	70.9
September	74.5	84.2	64.8
October	64.2	75.9	52.2
November	54.1	65.9	42.4
December	47.5	57.5	37.5

[1] https://www.weather.gov/ilm/1991-2020ClimateNormals

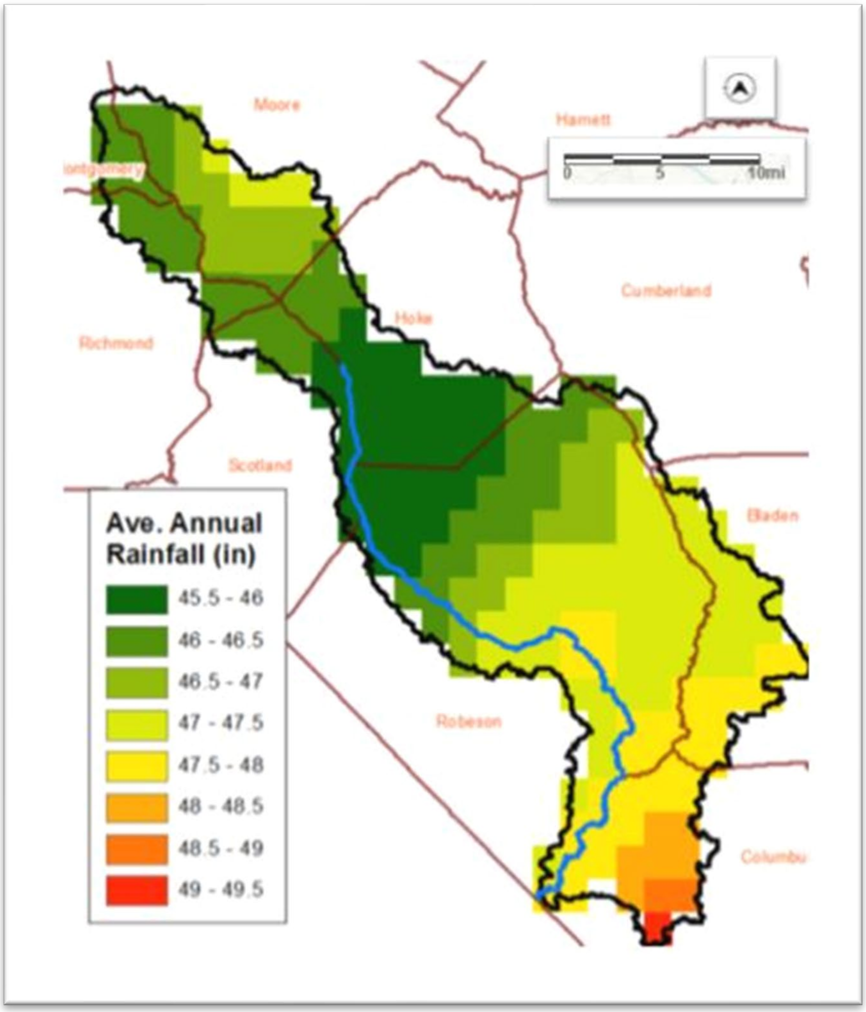

Figure 2.2 - Average annual rainfall for the period 1980 to 2010.

2.3. Topography, Geology and Soils

The Lumber River basin is made up of sediments dating to the Cretaceous Period with stratigraphic units of the Black Creek and Middendorf formations. Elevations in the study area range from approximately 735 feet at the headwaters in Montgomery County to approximately 55 feet at the state border with South Carolina. The topography in the basin varies from rolling hills at the high elevations to broad swampy flats at low elevations.

The basin is located within the Coastal Plain province of the Atlantic Plains physiographic region and the Southeastern Plains Level III eco-region, including the Sandhills in the upper portion of the basin, the Atlantic Southern Loam Plains in the middle and lower portions of the basin, and the Southeastern Floodplains and Low Terraces delineated along the main stem of the Lumber River. The Sandhills is characterized by coarse, unconsolidated sandy soils which support hearty vegetation adapted to dry, nutrient-poor conditions. Typical species include longleaf pine, turkey oak and wiregrass. The Atlantic Southern Loam Plains is a major agricultural zone due to its flat terrain and well-drained, fine textured soils. Most of the natural vegetation in this region has been converted to cropland. The Southeastern Floodplains and Low Terraces are composed of alluvium and terrace deposits of sand, clay, and gravel that support oak-dominated bottomland hardwood forests, and swamp forests with bald cypress and water tupelo.

2.4. Land Use

This section describes the existing land use of the Lumber River basin, taking into consideration both natural and human modified activities. Natural land use classifications include wildlife areas, forests, and other open or undeveloped areas. Human-modified land use classifications include residential, community, commercial, industrial, utilities, agricultural, recreational, and other developed uses. Land use is regulated by management plans, policies, and regulations determining the type and extent of land use allowable areas, and protection specifically designated for environmentally sensitive areas.

The majority of the study area is rural, as shown in **Figure 2.3** below. The rural areas are dominated by cultivated crops, with some areas of evergreen forest. Lumberton, Pinehurst, and Southern Pines have the highest populations in the basin and are the most developed. Wetlands are more dominant along the waterways, particularly in the lower elevations.

Due to the rural characteristics of the study area, significant changes in land use are not expected in the foreseeable future. Developed areas in the Lumber River sub-basin increased an average of 9% between 2001 and 2016. Wetlands/water features and agricultural lands currently occupy approximately two-thirds of the study area, and a review of historic aerials and topographic maps indicates similar trends dating back to the 1950s. **Table 2.3** provides information on land cover trends from 2001 to 2016.

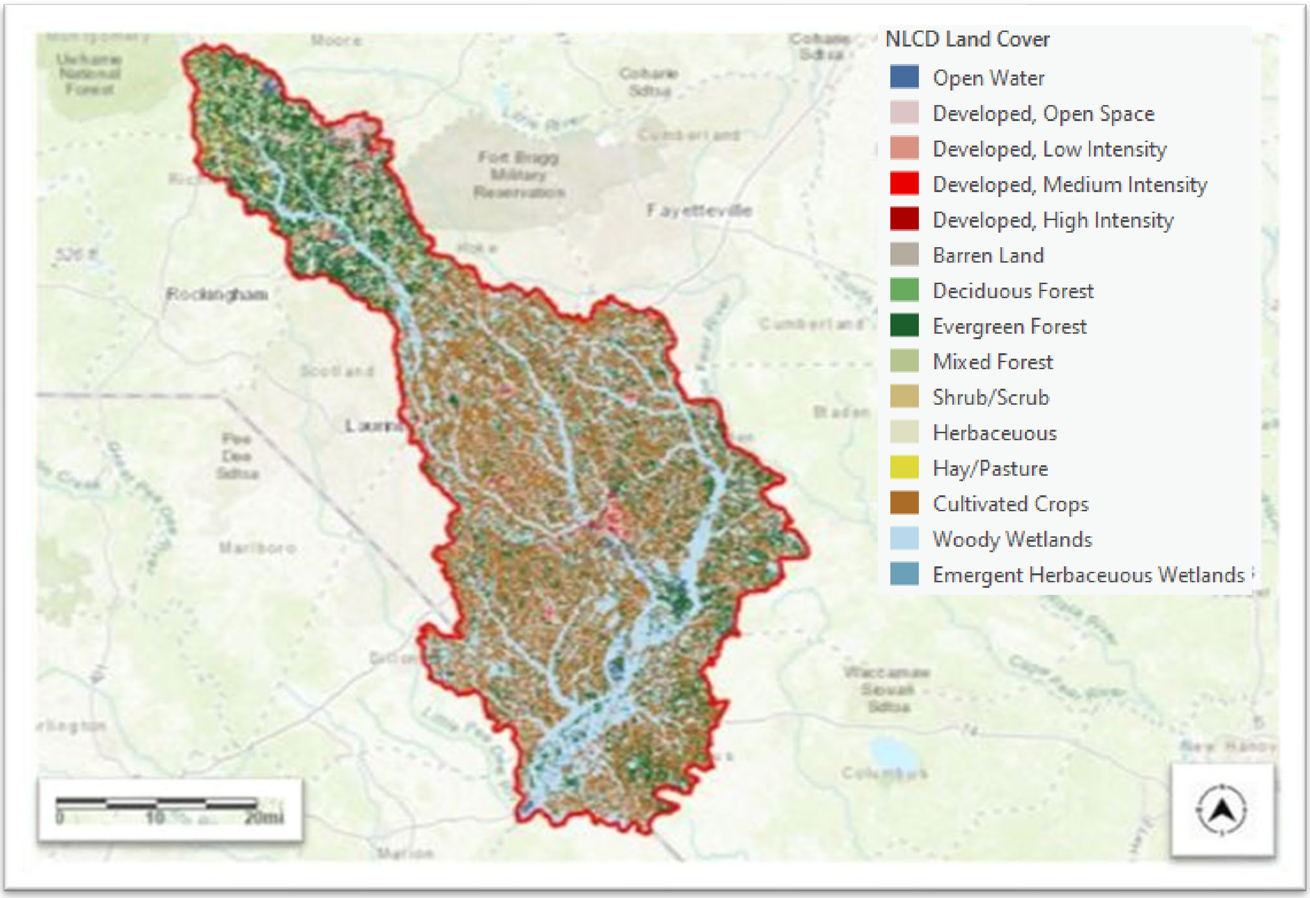

Figure 2.3 - Lumber River Basin land use.[2]

Table 2.3 - Land Cover Trends in the Lumber River Basin[3]

Land Cover	2001	2006	2011	2016
Developed	7.8%	8.1%	8.3%	8.5%
Forest	20.3%	19.6%	18.5%	21.4%
Water/Wetlands	29.2%	29.2%	29.3%	30.7%
Crops/Pasture	29.4%	29.2%	29.1%	32.7%
Grassland/Scrub	13.3%	13.9%	14.8%	7.1%
Total	100%	100%	100%	100%

[2] NLCD 2016
[3] Rebuild.NC.gov

2.5. Water Resources

Water resources include both surface water and groundwater resources; associated water quality; and floodplains. Surface water includes all lakes, ponds, rivers, streams, impoundments, and wetlands, while groundwater is typically found in areas known as aquifers. Water quality describes the chemical and physical composition of water as affected by natural conditions and human activities.

2.5.1. Hydrology and Hydraulics

The major HUC-10 contributing to the drainage within the study area include: Lumber River (1850 sq mi contributing area), Upper (130 sq mile) and Lower (193 sq mil) Drowning Creek (323 sq mi), Raft Swamp (170 sq mi) and Upper, Middle and Lower Big Swamp (445 sq mi). The confluence of Raft Swamp and Lumber River is upstream of Lumberton and the confluence of Big Swamp and Lumber River is directly upstream of Boardman. The town of Nichols, located in northeastern South Carolina, is just upstream of the confluence of the Little Pee Dee and Lumber Rivers. Elevations range from 735 ft at Montgomery County to 55 ft at the border with South Carolina.

The two storm events that caused significant damages in the Lumber River watershed were Hurricane Matthew in 2016 and Hurricane Florence in 2018. Both storms were extreme events that created flow rates and water surface elevations well above the 100-year flood elevations shown on the Flood Insurance Rate Maps (FIRMs). The FEMA Flood Insurance Study (FIS) calculates the 100-year flow rate at the mouth of the Lumber River to be approximately 23,900 cubic feet per second (cfs), producing water surface elevations ranging from 52.0 feet to 54.0 feet from the downstream end to the upstream end of Nichols. The Hurricane Matthew and Hurricane Florence events produced approximately 41,000 and 64,700 cfs, respectively, at the USGS Galivants Ferry river gaging station, which is double any flow seen at this station since 1940 and created water surface elevations at the downstream end of approximately 56.5 feet. These numbers begin to show the extreme nature of these two hurricanes and to explain why the watershed saw unprecedented flooding twice in the past five years.

The United States Geological Survey (USGS) currently maintains 6 calibrated stream gages in the Lumber River basin. The locations of the USGS stream gage are as follows; Drowning Creek in Hoffman, Lumber River at Maxton, Lumber River at Lumberton, Lumber River at Boardman, Big Swamp at Tarheel, NC and Lumber River at Nichols, SC. **Figure 2.4** shows the USGS gage from Nichols, South Carolina, the furthest most downstream location of the Lumber River Watershed. The Nichols gage was initiated after the Hurricane Matthew Storm event in 2016 and experienced a maximum gage height of 27.36 ft during Hurricane Florence in September of 2018. Peak stages during Hurricane Matthew (2016) by gauge were: Lumberton (21.87 ft), Maxton (15.49 ft), Boardman (14.41 ft) and Tarheel (18.72 ft).

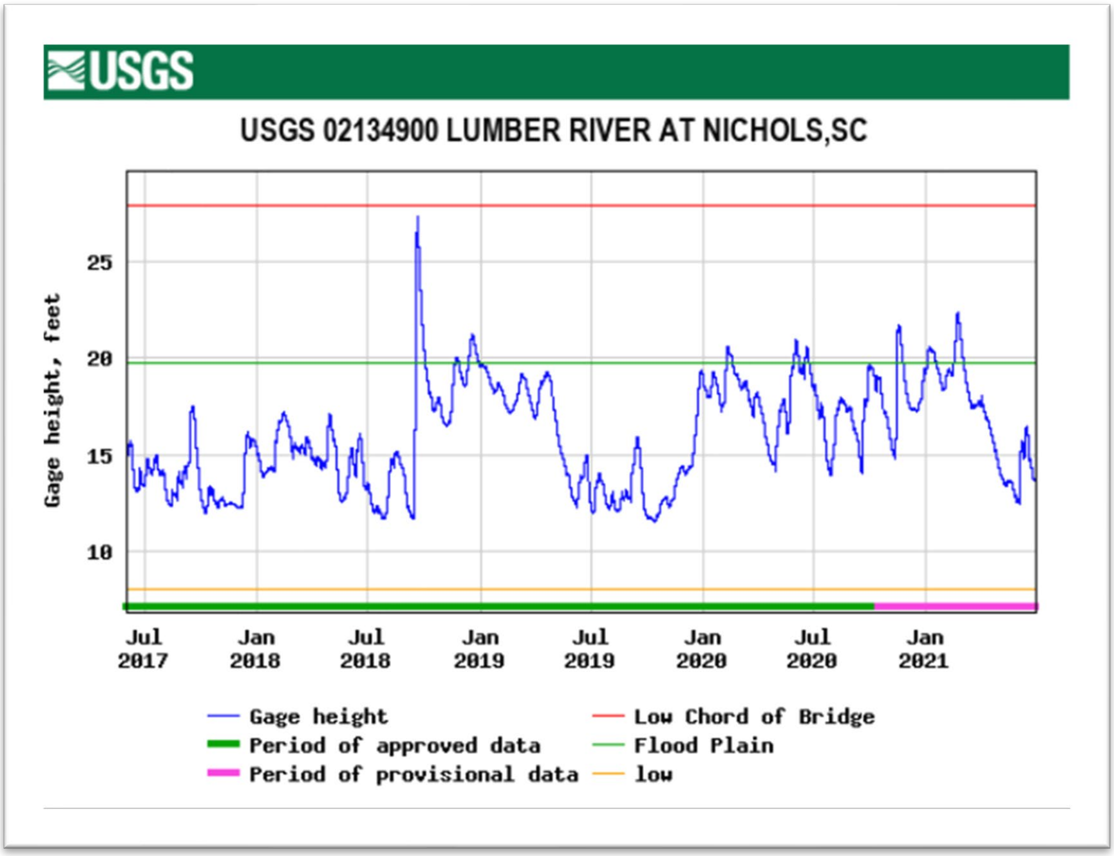

Figure 2.4 - USGS gage 02134900 gage height of Lumber River at Nichols, SC.

The North Carolina Emergency Management Division (NCEMD) provided the PDT with Hydrologic calculations using HEC-HMS and hydraulic models using HEC-RAS using LIDAR data from 2001 for the North Carolina portion of the watershed. Sub-basins within the Lumber River basin were delineated using a 50-foot hydrocorrected grid developed from the LiDAR data collected between January and March 2001 by NCEMD. Basins were delineated with average size of 10 square miles. This is a large basin size for a hydrologic analysis but was deemed appropriate for this project level analysis. Hydraulic calculations of the South Carolina portion were conducted in-house using HEC-RAS 5.0.7. Hydrologic models employed simulated storms at the 10% ,4%, 2%, 1%, 0.2%, and 0.1% Annual Exceedance Probability (AEP), or the probability of a flood event occurring in any year. Hurricane Matthew was chosen as the calibration storm for the HEC-HMS model. The model was calibrated in an attempt to replicate the peak discharges, total flood volumes, and flood peak timing. Calibration was achieved by adjusting the computed basin curve numbers, lag times, and the channel routing parameters.

Curve numbers are used to describe the amount of rainfall that makes it to the stream as opposed to being intercepted by vegetation, absorbed into the soil, or otherwise prevented from contributing to riverine flooding. The SCS Curve Number method was used to compute direct runoff depths and losses. Inputs for this method are land use and hydrologic soil group. Land use data was established based on the 2011 National Land Cover Database (NLCD) developed by the Multi-Resolution Land Characteristics Consortium. Soil type information was acquired from the NRCS. These values are based on antecedent moisture condition II (AMC II), which implies an average moisture condition for the soil.

The SCS Unit Hydrograph was used for the hydrologic model. The default peaking factor of 484 was maintained. The lag time for a basin can be thought of as how long it takes from the peak of the rain event until the peak of the flooding event. Channel routing of the discharges was performed using the Muskingum-Cunge method. Muskingum-Cunge reach routing plays a significant role in calibrating hydrograph volumes (as well as peak timing). The curve number and reach routing adjustments were made based on reported volumes at gages during the calibration storm. Channel and overbank roughness parameters as well as 8-point cross sections were developed based on cross sections in the effective HEC-RAS models.

Gridded rainfall data from the Hurricane Matthew event was acquired from the NCEMD Resilient Redevelopment effort and used as input for the hydrologic model. A 24-hour duration storm was selected for the model. The temporal distribution was based on NOAA Atlas 14 Volume 2 2nd quartile storm. This distribution was selected based on a comparison of the rainfall data from the Hurricane Matthew event to rainfall data collected at National Weather Service reporting sites for the event in Raleigh and Lumberton. Frequency rainfall depths were developed from gridded rainfall data acquired from Atlas 14. The gridded data was used to determine rainfall depths for each of the studied frequencies including the 10-, 4-, 2-, 1-, 0.2-, and 0.1-percent AEP events. The rainfall depths were applied on a basin-by-basin basis.

2.5.1.1. Hydraulic Modeling

A hydraulic model is used to calculate the water surface for a particular storm event and are a critical tool to show the hydrologic response of a watershed and evaluate potential system improvements. The hydraulic model for this study was updated with project discharges from the calibrated HEC-HMS model for each of the 6 frequency events discussed above and for the Hurricane Matthew discharges. Minor revisions to the channel and overbank roughness coefficients were made in order to calibrate the hydraulic model using the Matthew discharges and observed high water marks collected following the flood. For this study the project water surface elevations for the interior of the levee at Lumberton are based on water surface elevations from the models provided by NCEM that were calibrated to observed high water marks of Hurricane Matthew along the main stem using the discharges from the calibrated rainfall-runoff model. The model was calibrated in an attempt to replicate the peak discharges, total flood volumes, and flood peak timing. Calibration was achieved by making adjustments to the computed basin curve numbers, lag times, and the channel routing parameters

A 2-dimensional hydraulic model was created for the Town of Nichols to determine at-risk structures during storm events of varying magnitudes. These models enabled assessment of different flood risk mitigation options including relocating structures, creation of an off-line storage area, widening bridge openings over the Lumber River, building a levee, and raising buildings.

A HEC-RAS 2-dimensional model was created using LiDAR data from Marion, Horry, and Dillon Counties to determine the flow path of the water. 2D models are able to evaluate overland flow using grid cells at designated levels of detail. With HEC-RAS, the grid cells can vary in size to show more or less detail throughout the model and break-lines are used to define cell edges at high or low points along the ground surface that represent roadways and/or ditches. The HEC-RAS model 2D grid cells near Nichols are shown in **Figure 2.5**. The smaller grid cell sizes provide more detail in areas of interest: near structures within the town and along the banks of the rivers. Areas with minimal elevation change, no development, and consistent land use were represented with larger grid cell sizes. This creates a model that provides the correct amount of detail in the areas of interest but with manageable run times to effectively evaluate the causes of flooding and potential solutions.

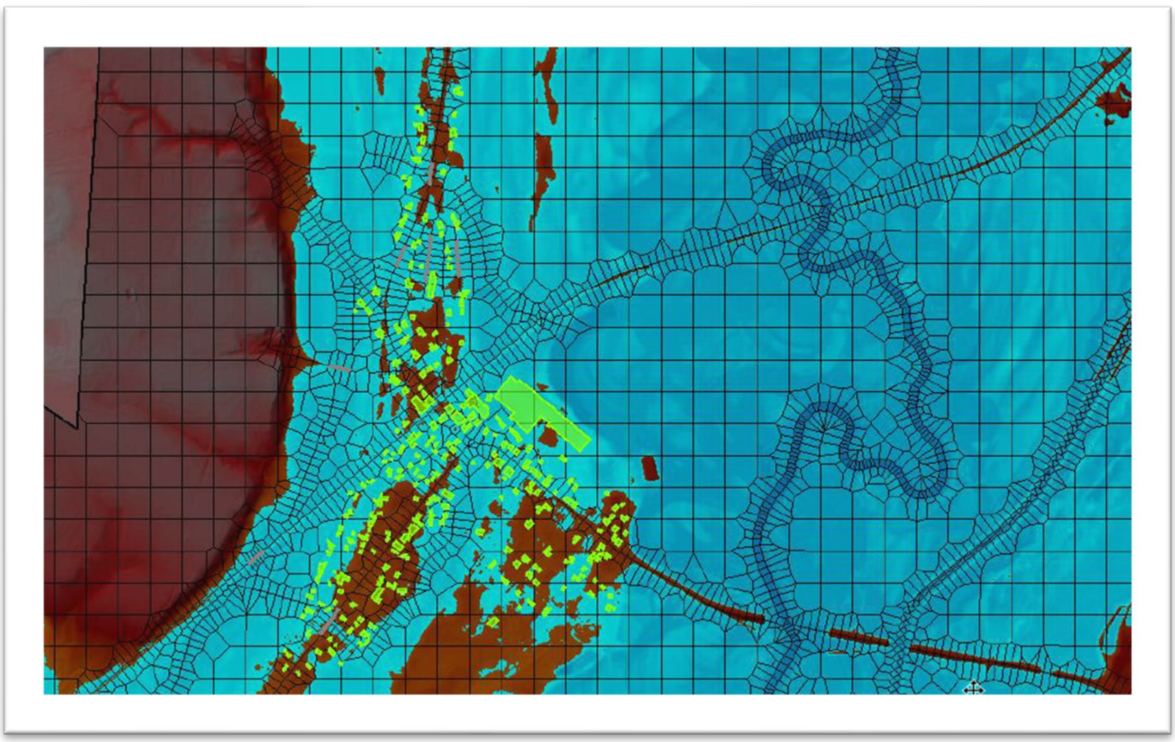

Figure 2.5 - Grid structure of the Hydraulic Model using HEC-RAS in the downstream region of the Lumber River Watershed.

Figure 2.6 shows the map of the extents of the 1% AEP for the Lumber River Watershed from the modeling effort described above. The smaller tributaries throughout the watershed were modeled using 1-D HEC-RAS. The model results were then used to evaluate structures within the watershed to determine the number that would be impacted during each storm event. That evaluation is discussed in **Section 2.7.4** below.

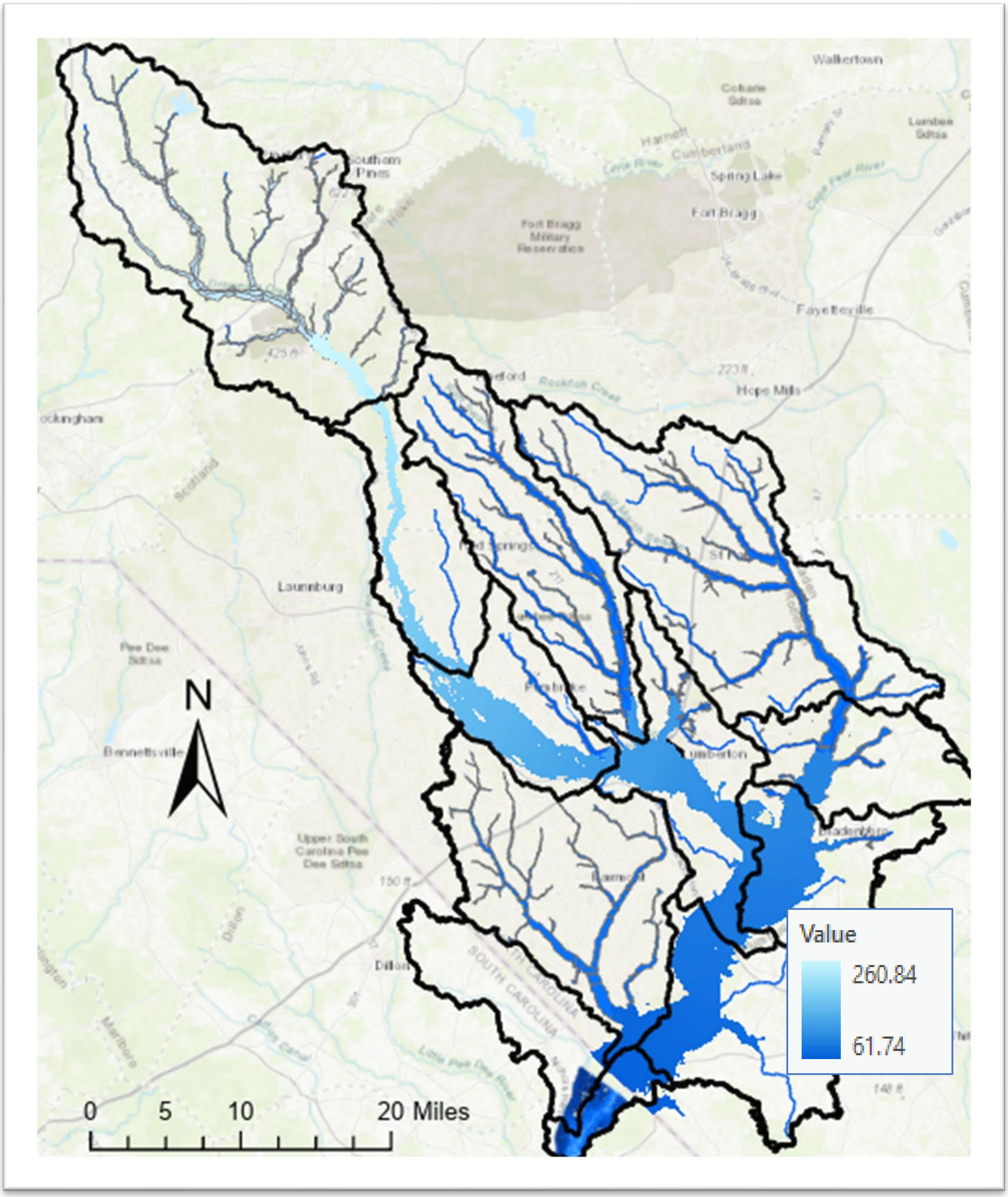

Figure 2.6 - Lumber River Watershed 1% AEP HEC-RAS model.

2.5.1.2. Hydrology & Hydraulics Future Without Project Conditions

As urban land development continues to replace agricultural uses, storm water will continue to increase, which means that there will be an elevated future flood risk. Given the slow increase in urban development, this increase will occur over a longer timeframe in the Lumber River basin than in more rapidly growing regions. However, the Lumber River region will see increased runoff flows and higher erosive channel velocities which will result in continued bank failures, incising, and scouring over time. This will result in an increase in flooding in existing flooded regions such as Fair Bluff, Lumberton, and Boardman. There are more frequent and intense extreme storm events, which will only exacerbate the flooding issues within this region eventually. In addition, the risk of loss of life and property will continue to rise at a commensurate pace. Plans are underway for the installation of the floodgate at the underpass within the City of Lumberton, which will prevent devastating flooding at this more urbanized location. In addition to the floodgate, the NCDOT plans to raise I-95 in both the north and south direction. This will also mitigate some of the flooding issues in Lumberton area.

2.5.1.3. Uncertainties

Uncertainties include any additional sediment within the channel due to continued bank failure or sedimentation which may result in more sediment to remove from the channel or a change in the floodplain bench elevation. New land uses within the basin (i.e. increase in imperviousness) may result in higher storm flows, or structures within the floodplain.

2.5.2. Surface Water

The headwaters of the Lumber River, which begins at the confluence of Drowning Creek and Buffalo Creek in the Sand Hills ecoregion, originate from Drowning Creek and all of its tributaries (Naked Creek, Deep Creek, Quewhiffle Creek, Jackson Creek, Aberdeen Creek, and Mountain Creek). Major tributaries to the Lumber River in the southern portion of the study area include Gum Swamp, Back Swamp, Bear Swamp, Raft Swamp, Big Swamp, and Porter Swamp. These tributaries are often referred to as blackwater streams due to the tannin stained waters.

Several stream segments in the upper portions of the study area, including portions of the Drowning Creek and Naked Creek watersheds, have been classified as Outstanding Resource Waters (ORW) or High Quality Waters (HQW). HQW are those waters rated as excellent due to biological and physical/chemical characteristics and typically include natural or low development water supply waters (WSW). ORW are a subset of HQW that denotes unique or special waters with excellent water quality and state or national ecological or recreational significance. **Table 2.4** lists ORW, HQW, and WSW waters for the study area.

Approximately 81 miles of the Lumber River has been designated as part of the National Wild and Scenic Rivers System under Section 2(a)(ii) of the National Wild and Scenic Rivers Act. Of these 81 miles, 60 are classified as scenic and 21 and are classified as recreational. The Lumber River is also part of the North Carolina Natural and Scenic River System, which was passed to "preserve, protect and maintain selected free-flowing rivers and adjacent land for their outstanding natural, scenic, educational, geological, recreational, historic, fish and wildlife, scientific and cultural values."

Table 2.4 - List of Outstanding Resource, High Quality, and Water Supply Waters

Waterway	Stream Miles	% Stream Miles HQW or ORW	% Stream Miles WSW
Naked Creek	91	100	0
Mill Branch	61	82	1
Gum Swamp	125	6	0
Back Swamp	69	7	45
Bear Swamp	94	14	57
Lower Raft Swamp	35	13	87
Porter Swamp	338	0	0
Little Raft Swamp	265	0	9
Lumber River	113	86	7

2.5.3. Groundwater

The Lumber River is fed by the Black Creek aquifer. The aquifer is composed of fine to very fine sands and is present at elevations of 318 feet to -1483 feet in the coastal plain of North Carolina, averaging approximately 160 feet in thickness. The Black Creek aquifer is considered a principal aquifer because it covers a large area of the state and because it is a significant source of groundwater for potable water supply, agriculture, and industrial use. Wells generally produce 200 to 400 gallons per minute. See **Figure 2.7** below for average water levels for the Black Creek aquifer in North Carolina.

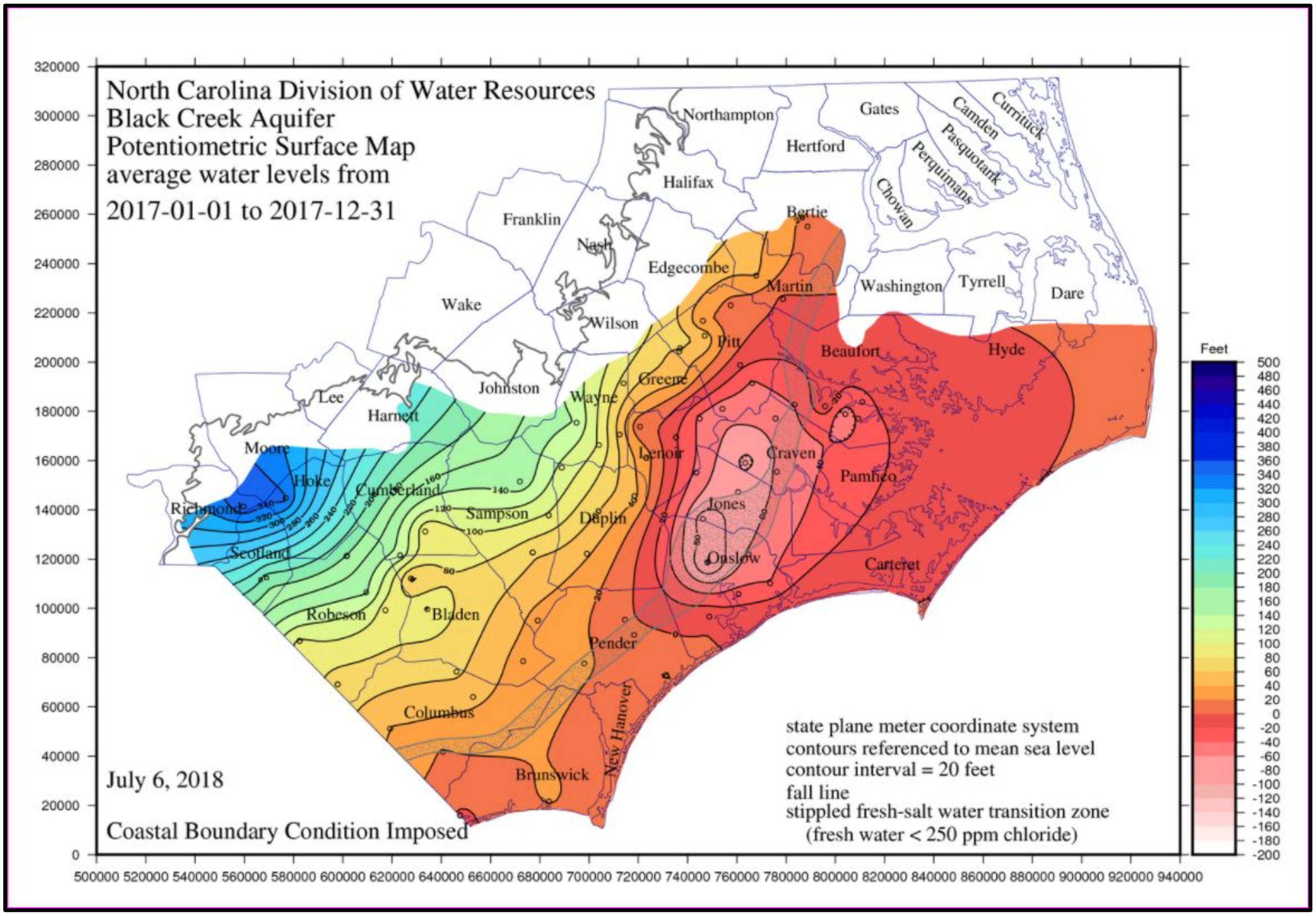

Figure 2.7 - Black Creek Aquifer Average Water Levels for 2017[4].

4 https://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/AquiferCharacteristics/potmaps/bc/bc2017.png

2.5.4. Wetlands

The term, “wetlands,” is defined in 33 CFR 328.3(c)(16) as areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. These areas are known to support both aquatic and terrestrial species. According to the USFWS National Wetlands Inventory, approximately 25% of the Lumber River basin is classified as “wetlands”. The eleven wetland types found in the study area and their acreages are shown in **Table 2.5** below.

Table 2.5 – National Wetland Inventory Wetland Types and Acreages

System	Subsystem	Acreage
Lacustrine		
	Littoral	1,287.2
	Limnetic	61.6
Palustrine		
	Aquatic Bed	282.4
	Emergent	8,089.0
	Forested	239,530.5
	Shrub Scrub	24,860.5
	Unconsolidated Bottom	4,518.5
	Unconsolidated Shore	39.6
Riverine		
	Lower Perennial	2,355.5
	Intermittent	2,023.8
	Unknown Perennial	1,904.5
Total		284,953.4

2.5.5. Water Quality

The North Carolina Division of Water Resources (NCDWR) is the agency in North Carolina responsible for enforcing water quality standards. NCDWR conducts surface water quality assessments and publishes a list of impaired waters every two years. The 2018 NC 303(d) list was approved in June 2019. The draft 2020 NC 303(d) list was released for public comment on 1 Feb 2021. The NC 2018 303(d) list identifies seven water bodies in the Lumber River subbasin (03040203) as impaired. These impairments are also documented in the draft 2020 303(d).

Table 2.6 - List of 2018 North Carolina Impaired Waters

Waterbody	Classification	Location	Reason for Listing	Parameter
Big Swamp	C/ Sw	From NC 211 to Lumber River	Criteria Exceedance	pH (4.3 su, AL, Sw)
Little Raft Swamp	C/ Sw	From SR1776 to Raft Swamp	Severe Criteria Exceedance	Benthos (Nar, AL, FW)
Long Branch	C /Sw	From Source to Little Swamp	>10% and >90 conf Criteria Exceedance	Mercury (0.012 µg/l, FC, FW)
Mill Branch	C	From Source to Lumber River	Fair Criteria Exceedance	Benthos (Nar, AL, FW)
Naked Creek	WS-II/ORW	From Source to Drowning Creek	>10% and >90 conf Criteria Exceedance	pH (6 su, AL, FW)
Porter Branch	C/ Sw	From Source to Dunn	Severe Criteria Exceedance	Benthos (Nar, AL, FW)
Porter Branch	C/ Sw	From Dunn to Lumber River	Severe Criteria Exceedance	Benthos (Nar, AL, FW)

2.6. Threatened and Endangered Species

The Lumber River basin supports numerous Federally-listed threatened and endangered species under the Endangered Species Act (ESA) of 1973, and the Marine Mammal Protection Act (MMPA) of 1972. Species lists were obtained from the USFWS Field Office in Raleigh, North Carolina, and the National Marine Fisheries Service (NMFS) Southeast Regional Office in St. Petersburg, FL. These lists were combined to develop the following composite list for the counties in North Carolina that are located within the boundaries of the Lumber River basin (**Table 2.7**). The table includes the Federally-listed species that may be present in the study area based upon their geographic range. According to information provided by USFWS, the six Federally-listed species known to be present in the study area include the northern long-ear bat, red cockaded woodpecker, wood stork, American chaffseed, Michaux's sumac, and rough-leaf loosestrife.

Table 2.7 - Federally Listed Threatened and Endangered Species by County

Taxonomic Group	Scientific Name	Common Name	Federal Status	Location by County
Bird	*Haliaeetus leucocephalus*	Bald Eager	BGPA	Bladen, Columbus, Montgomery
Bird	*Picoides borealis*	Red Cockaded Woodpecker	E	Bladen, Columbus, Cumberland, Hoke, Moore, Montegomery, Rhicmond, Robeson, Scotland
Freshwater Bivalve	*Fusconia masoni*	Atlantic Pigtoe	PT	Bladen, Cumberland, Montegomery, More
Freshwater Fish	*Acipenser oxyrinchus*	Atlantic Sturgeon	E	Bladen, Columbus, Richmond
Freshwater Fish	*Notropis mekistocholas*	Cape Fear Shiner	E	Cumberland, Hoke Moore
Freshwater Fish	*Acipenser brevirostrum*	Shortnose Sturgeon	E	Bladen, Columbus, Richmond
Freshwater Fish	*Menidia extensa*	Waccamaw Silverside	T	Columbus
Insect	*Neonympha mitchellii francisci*	Saint Francis satyr butterfly	E	Hoke
Mammal	*Myotis septentrionalis*	Northern Long-Ear Bat	T	Bladen, Columbus
Mammal	*Mycteria americana*	Wood Stork	T	Bladen, Columbus, Robeson
Reptile	*Alligator mississippiensis*	American Alligator	T(S/A)	Bladen, Columbus, Cumberland, Hoke, Robseon, Scotland
Vascular Plant	*Schwalbea americana*	American Chaffseed	E	Bladen, Cumberland, Hoke, Moore, Scotland
Vascular Plant	*Oxypolis canbyi*	Canbys Dropwort	E	Scotland
Vascular Plant	*Thalictrum cooleyi*	Cooley's Meadowrue	E	Columbus
Vascular Plant	*Rhus michauxii*	Michaux's Sumac	E	Cumberland, Hoke, Montgomery, Moore, Richmond, Robseon, Scotland
Vascular Plant	*Lindera melissifolia*	Pondberry	E	Blanden, Cumberland
Vascular Plant	*Lysimachia asperulifolia*	Rough-leaf Loosetrife	E	Bladen, Columbus, Cumberland, Hoke, Richmond, Scotland
Vascular Plant	*Helianthus schweinitzii*	Schweinitz Sunflower	E	Montgomery, Richmond
Vascular Plant	*Echinacea laevigata*	Smooth Coneflower	E	Montgomery

2.7. Flood Damages

There are 2,918 structures within the current FEMA 1% AEP floodplain. The Lumberton Levee protected area contains 914 of these structures, leaving 2,004 structures, mostly residential, in the study area outside the leveed area. These structures are spread throughout the basin. **Table 2.8** shows the distribution of structures within the 1% AEP, as well as the population at risk (PAR) for both day and nighttime populations.

Table 2.8 – Structures and Population within the FEMA 1% AEP Floodplain

Location	Number of Structures	PAR Day	PAR Night
Drowning Creek	30	32	55
Upper Lumber River	551	1,275	2,129
Raft Swamp	86	717	242
Big Swamp	340	967	731
Lower Lumber River	45	62	102
Ashpole Swamp	29	49	81
Aberdeen	50	371	38
Pinehurst	29	31	44
Boardman	7	6	12
Lumberton	407	4,823	866
Fair Bluff	69	146	96
Fairmont	18	26	46
Middle Lumber River	343	641	1,144
Lumberton Levee	914	2,250	2,282
TOTAL	**2,918**	**11,396**	**7,868**

2.7.1. Existing Condition Structure Inventory and Hydraulics

A structure inventory for the Lumber River basin was developed from the USACE National Structure Inventory (NSI) developed in 2019. This statistical inventory is developed using building footprints, parcel data, FEMA Hazards US (HAZUS) data, and census data among other sources. The inventory was calibrated using aerial imagery and available flood inundation data. Structure and content values in the NSI represent depreciated replacement values are were indexed from 2018 to 2020 price levels using the Engineering News Record Construction Cost Index (ENR CCI). Population estimates per structure are based primarily on the 2010 Census data, indexed using 2017 county growth estimates. Population per structure is estimated in the NSI for both daytime (2pm) and nighttime (2am) values to account for differences between residential and working populations. Structure content values in the NSI are based on standard ratios specific to each occupancy type; content values are typically higher than the structure values in non-residential structures and lower than the structure values in residential structures.

Hydraulic inundation data was obtained from the Lumber River basin Flood Analysis and Mitigation Strategies Study conducted by the State of North Carolina. USGS 1/9th Arc-Second terrain was subtracted from the water surface elevation grids to create depth grids along the major rivers included in the mitigation study. This resulted in depth grids for the 0.1% AEP (1000 year), 0.2% AEP (500 year), 1% AEP (100 year), 2% AEP (50 year), 4% AEP (25 year), and the 10% AEP (10 year) flood events based on the NC Mitigation Study modeling.

The NC Mitigation Study modeling was generally along the mainstem of the Lumber River and did not include some of the smaller tributaries and upstream areas. To analyze flood damages in the upper reaches of the watershed and tributaries, a depth grid was created based on the FEMA 1% AEP water surface elevations. Cross sections with water surface elevations were obtained from the North Carolina FRIS web portal. ArcGIS was used to interpolate a water surface elevation raster from the cross sections, and the terrain grid was subtracted from the water surface elevation grid to create a depth grid for the FEMA 1% AEP.

2.7.2. Existing Condition Flood Damages

The structure inventory and depth grids were used in USACE's LifeSim software to compute estimated flood damages to structures and contents from the range of flood events. The LifeSim inputs are primarily the structure inventory and the maximum inundation depth grids of each event. Structure and content depth-damage curves based on USACE economic guidance are pre-loaded into the software. LifeSim uses Monte-Carlo method sampling on uncertainty parameters to determine mean results; 500 iterations were run for each event. **Table 2.9** below presents the existing flood damages displayed by flood event.

Table 2.9 – Existing Condition Flood Damages by Event (2020 price level)

Hydraulic Scenario	Structures Inundated	Mean Structure Damages	Mean Content Damages	Mean Total Damages
0.1% AEP (1000yr)	3,928	$231,865,638	$408,597,592	$640,463,230
0.2% AEP (500yr)	3,620	$168,423,266	$290,854,928	$459,278,195
1% AEP (100yr)	2,677	$68,506,402	$107,810,678	$176,317,080
2% AEP (50yr)	2,211	$40,883,990	$60,469,345	$101,353,335
4% AEP (25yr)	1,716	$22,125,801	$30,210,119	$52,335,920
10% AEP (10yr)	895	$7,953,684	$8,411,700	$16,365,384
FEMA 1% AEP (100yr)	2,626	$46,802,506	$76,520,530	$123,323,036

Average annual damages for the existing condition NC Mitigation Study flood events, displayed in **Table 2.10**, were computed using the average interval method (these do not include the FEMA 1% AEP).

Table 2.10 – Existing Condition Average Annual Damages (2020 price level)

Hydraulic Scenario	C-Probability Interval[5]	D-Total Damages[6]	E-Interval Average Damages[7]	F-Interval Damage Calculation[8]	G-Summary Expected Annual Damages[9]
10% AEP (10yr)		$16,365,384			
Interval	0.0600		$34,350,652	$2,061,039	$2,061,039
4% AEP (25yr)		$52,335,920			
Interval	0.0200		$76,844,628	$1,536,893	$3,597,932
2% AEP (50yr)		$101,353,335			
Interval	0.0100		$138,835,208	$1,388,352	$4,986,284
1% AEP (100yr)		$176,317,080			
Interval	0.0080		$317,797,638	$2,542,381	$7,528,665
0.2% AEP (500yr)		$459,278,195			
Interval	0.0010		$549,870,713	$549,871	$8,078,536
0.1% AEP (1000yr)		$640,463,230			

The expected annual average damages of $8,078,536 can be further broken out by location within the basin to understand where there are concentrated areas prone to flood risk (**Table 2.11**).

Table 2.11 – Existing Condition Average Annual Damages by Area (2020 price level)

Location	Expected Annual Damages	Percent of Total
Drowning Creek	$1,305	0.0%
Upper Lumber River	$213,766	2.6%
Raft Swamp	$975	0.0%
Big Swamp	$132,678	1.6%
Lower Lumber River	$26,459	0.3%
Ashpole Swamp	$0	0.0%
Boardman	$13,088	0.2%
Lumberton	$212,990	2.6%
Fair Bluff	$110,841	1.4%
Fairmont	$0	0.0%
Middle Lumber River	$383,384	4.7%
Lumberton Levee	$6,983,050	86.4%
TOTAL	**$8,078,536**	**100%**

[5] Column C = Interval probability computed as difference of probabilities between two events
[6] Column D = Total damages by event
[7] Column E = Average damages for the interval. Ex: (10yr damages + 25yr damages)/2 = average damages for the interval of 0.1 and 0.04 (0.06 probability)
[8] Column F = Probability interval (column C) * Interval Average Damages (column E)
[9] Column G = Cumulative sum of column F (Note: last item is the average annual damages)

In the existing conditions, over 86% of the average annual damages occur within the protected area of the Lumberton levee system because it does not protect up to the 1% AEP level.

2.7.3. Future Without Project Condition Structure Inventory and Hydraulics

There are two key assumptions that change the structure inventory and hydraulics in the FWOP. The first is the non-structural acquisition program in progress at the state level in several areas of the Lumber River basin. While this program is voluntary and the participation rate will likely not be 100%, the decision was made not to use those structures as part of justifying a project since they are already in a flood damage mitigation program. Buyout parcels were obtained from the State and those structures were removed from the structure inventory.

The second major assumption is that the known deficiencies in the Lumberton Levee system will be addressed and the levee will be able to provide flood protection up to the 1% AEP event. The FWOP inundation grids were modified in GIS to remove the inundation depths in the interior of the levee for the 1% AEP (1/100), 2% AEP (1/50), 4% AEP (1/25), and 10% AEP (1/10) events. Since 86% of the expected annual average damages on the existing condition were within the levee protected area, this assumption results in a significant reduction.

2.7.4. Future Without Project Condition Flood Damages

The structure inventory and depth grids were used in USACE's LifeSim software to compute estimated flood damages to structures and contents from the range of flood events. LifeSim uses Monte-Carlo method sampling on uncertainty parameters to determine mean results; 500 iterations were run for each event. **Table 2.12** below shows the damages for each event, as well as the flood depth range which represents the 15th and 85th percentiles of all structure flood depths above ground for each event; this means that 70% of the structures flooded in the event experience flood depths within that range.

Table 2.12 – FWOP Flood Damages by Event (2020 price level)

Hydraulic Scenario	Depth Ranges (feet)	Structures Inundated	Mean Structure Damages	Mean Content Damages	Mean Total Damages
0.1% AEP (1000yr)	1.8 - 6.6	3,702	$223,627,457	$403,626,626	$627,254,082
0.2% AEP (500yr)	1.2 - 5.4	3,399	$162,433,876	$287,104,005	$449,537,881
1% AEP (100yr)	0.4 - 2.8	836	$10,624,527	$11,649,567	$22,274,093
2% AEP (50yr)	0.4 - 2.5	544	$5,569,673	$5,444,209	$11,013,882
4% AEP (25yr)	0.3 - 2.2	373	$3,295,683	$2,591,980	$5,887,663
10% AEP (10yr)	0.3 - 2.2	221	$1,831,303	$1,214,540	$3,045,843
FEMA 1% AEP (100yr)	0.5 - 3.0	1,865	$34,918,399	$56,386,225	$91,304,623

Average annual damages for the existing condition NC Mitigation Study flood events were computed using the interval average method.

Table 2.13 – FWOP Average Annual Damages

Hydraulic Scenario	C-Probability Interval[10]	D-Total Damages[11]	E-Interval Average Damages[12]	F-Interval Damage Calculation [13]	G-Summary Expected Annual Damages [14]
10% AEP (10yr)		$3,045,843			
Interval	0.0600		$4,466,753	$268,005	$268,005
4% AEP (25yr)		$5,887,663			
Interval	0.0200		$8,450,773	$169,015	$437,021
2% AEP (50yr)		$11,013,882			
Interval	0.0100		$16,643,988	$166,440	$603,461
1% AEP (100yr)		$22,274,093			
Interval	0.0080		$235,905,987	$1,887,248	$2,490,708
0.2% AEP (500yr)		$449,537,881			
Interval	0.0010		$538,395,982	$538,396	$3,029,104
0.1% AEP (1000yr)		$627,254,082			

The expected annual average damages of $3,029,104 can be further broken out by location within the basin to understand where there are concentrated areas prone to flood risk.

Table 2.14 – FWOP Average Annual Damages by Area (2020 price level)

Location	Expected Annual Damages	Percent of Total
Drowning Creek	$1,305	0.0%
Upper Lumber River	$214,727	7.1%
Raft Swamp	$979	0.0%
Big Swamp	$133,682	4.4%
Lower Lumber River	$26,527	0.9%
Ashpole Swamp	$0	0.0%
Boardman	$13,055	0.4%
Lumberton	$210,741	7.0%
Fair Bluff	$75,199	2.5%
Fairmont	$0	0.0%
Middle Lumber River	$385,504	12.7%
Lumberton Levee	$1,967,384	64.9%
TOTAL	**$3,029,104**	**100%**

[10] Column C = Interval probability computed as difference of probabilities between two events
[11] Column D = Total damages by event
[12] Column E = Average damages for the interval. Ex: (10yr damages + 25yr damages)/2 = average damages for the interval of 0.1 and 0.04 (0.06 probability)
[13] Column F = Probability interval (column C) * Interval Average Damages (column E)
[14] Column G = Cumulative sum of column F (Note: last item is the average annual damages)

In the FWOP, approximately 65% of the average annual damages occur within the protected area of the Lumberton levee system; these damages are only occurring at the 0.1% AEP (1/1000) and the 0.2% AEP (1/500) due to the levee being overtopped as it exceeds its protection level. The remainder of the river basin has average annual damages of just over $1 million. The heat map below provides a visual of where the average annual damages occur throughout the basin (Figure 2.8).

Figure 2.8 – FWOP Average Annual Damages.

2.8. Socioeconomics

Socioeconomics is defined as the basic attributes and resources associated with the human environment, particularly population, demographics, and economic development. Demographics entail population characteristics and include (but are not limited to) data pertaining to race, income, housing, poverty status, and educational attainment. Economic development or activity typically includes employment, wages, business patterns, an area's industrial base, and its economic growth. **Table 2.16** provides the total population, the race and ethnicity composition, the age structure, education, and income levels for the towns included in the Lumber River basin.

Table 2.15 provides population trends for the period 2000 to 2019. The towns with the largest population growth during this period are Aberdeen, Pinebluff, Pinehurst, and Raeford. Fair Bluff, Maxton, and Red Springs populations declined during this period while Lumberton showed a slight increase in population.

Table 2.15 - Population Trends 2000 - 2019[15]

Municipality	Population (2000)	Population (2010)	Population (2016)	Population (2019)	Percent Change (2000 - 2019)
Aberdeen	3,400	6,350	7,502	7,595	123
Boardman	202	157	157	275	36
Fair Bluff	1,181	951	905	545	-54
Lumberton	20,795	21,542	21,499	20,928	0.6
Maxton	2,551	2,426	2,434	2,549	-0.07
Pembroke	2,399	2,973	3,009	3,002	25
Pinebluff	1,109	1,337	1,464	1,664	50
Pinehurst	9,706	13,124	15,945	16,050	65
Raeford	3,386	4,611	4,998	4,926	45
Red Springs	3,493	3,428	3,419	3,378	-3.2
Southern Pines	10,918	12,334	13,782	14,022	28
State of North Carolina	7,748,000	9,459,000	10,150,000	10,490,000	35

[15] United States Census Bureau

Table 2.16 - Population, Demographic and Economic Data for Lumber River Basin Communities[16]

Population Metric	Aberdeen	Boardman	Fair Bluff	Lumberton	Maxton	Pembroke	Pinebluff	Pinehurst	Raeford	Red Springs	Southern Pines	North Carolina
	Population											
Total Population	7,595	275	545	20,928	2,549	3,002	1,664	16,050	4,926	3,378	14,022	10,490,000
Median Age	34.9	36	55.9	34.4	39	23.1	40.2	61.2	38.7	39.2	44.5	38.9
	Race and Ethnicity											
White	70.1%	56.0%	32.3%	38.8%	17.4%	17.6%	84.4%	90.2%	34.2%	24.6%	74.9%	62.7%
Non-White	29.9%	44.0%	66.7%	61.2%	82.6%	82.4%	15.6%	9.8%	65.8%	75.4%	25.1%	37.3%
	Education											
High School Diploma	91.6%	56.8%	73.3%	79.5%	80.8%	80%	94.1%	97.6%	83.6%	80.1%	92.5%	87.4%
Bachelor's Degree or Higher	35%	9%	18%	20%	8%	29%	20%	59%	18%	21%	51%	31.3%
	Household Income											
Median Household Income	$53,757	$37,083	$21,042	$35,399	$25,083	$22,321	$51,220	$80,128	$33,326	$24,329	$58,453	$53,855
Median Home Value	$171,900	$52,500	$61,900	$111,500	$81,200	$90,800	$158,300	$297,100	$101,300	$71,600	$295,900	$180,000
Persons in Poverty	9.7%	24.9%	21.2%	33.5%	41.4%	45.7%	6.35%	2.7%	29.3%	43%	14.2%	15.4%

[16] United States Census Bureau, 2019

2.9. Life Safety

The LifeSim software was used to perform a screening level analysis of potential life safety risk for the various hydraulic events. Since the hydraulic modeling was not unsteady flow with modeling arrival times, an arrival grid was created with a uniform arrival time of 1 hour across the entire basin. The LifeSim model was set up with unknown parameters similar to what the Modeling, Mapping, and Consequences (MMC) production center uses for dam and levee breach modeling. Warning time was set at a uniform distribution of -24 to 0 hours prior to the arrival of water to estimate potential life loss across a range of uncertain flood events.

Table 2.17 – Existing Condition Life Safety Risk by Event

Hydraulic Scenario	Population at Risk		Day Life Loss			Night Life Loss		
	Day	Night	5^{th}	Median	95th	5^{th}	Median	95th
0.1% AEP (1000yr)	11,595	11,612	1	21	86	1	24	59
0.2% AEP (500yr)	10,182	10,269	0	4	18	0	4	19
1% AEP (100yr)	7,022	7,084	0	0	0	0	0	1
2% AEP (50yr)	5,757	5,787	0	0	0	0	0	0
4% AEP (25yr)	3,990	4,029	0	0	0	0	0	0
10% AEP (10yr)	1,694	1,752	0	0	0	0	0	0
FEMA 1% AEP (100yr)	8,866	8,689	0	0	1	0	0	1

Both the 0.1% AEP (1/1000) and the 0.2% AEP (1/500) events have the potential for life loss, however, nearly all of the estimated life loss for those events occur within the Lumberton Levee protected area which would be overtopped prior to the peak of those events. Detailed modeling of breach and non-breach overtopping was not performed; a detailed levee model would likely change these results. An Emergency Action Plan with warning trigger elevations prior to overtopping could also reduce the life safety risk in the leveed area.

Changes in life safety risk between the existing condition and FWOP are minimal since most life safety risk only occurs at the higher two events. PAR is reduced due to the future acquisitions, and PAR at levels below the 1% AEP (1/100) events are significantly reduced due to the protection of Lumberton Levee.

Table 2.18 – FWOP Life Safety Risk by Event

Hydraulic Scenario	Population at Risk		Day Life Loss			Night Life Loss		
	Day	Night	5^{th}	Median	95th	5^{th}	Median	95th
0.1% AEP (1000yr)	11,217	11,207	1	20	85	2	23	58
0.2% AEP (500yr)	9,814	9,874	0	4	16	0	4	14
1% AEP (100yr)	2,100	2,162	0	0	0	0	0	0
2% AEP (50yr)	1,281	1,318	0	0	0	0	0	0
4% AEP (25yr)	751	786	0	0	0	0	0	0
10% AEP (10yr)	425	451	0	0	0	0	0	0
FEMA 1% AEP (100yr)	6,947	6,768	0	0	1	0	0	1

2.10. Critical Infrastructure

Critical infrastructure includes assets such as schools, medical facilities, emergency services, utilities, and transportation infrastructure. The table below shows critical infrastructure within the FEMA 1% AEP floodplain within the basin.

Table 2.19 - Critical Infrastructure Breakdown

Critical Infrastructure Category	Number	Location Notes
Wastewater Treatment Plants	5	Boardman, Bladenboro, Parkton, Saint Paul's, Pembroke
Schools	2	Riverside Christian Academy, W. H. Knuckles Elementary (in Lumberton Levee)
Broadcast Communications	2	WFVL Radio Station (in Lumberton Levee)
Electric Power Generation	1	Active Energy (wood pellet)
Electric Substations	5	Scattered locations
Emergency Medical Services (EMS)	2	Fair Bluff, Lumberton Levee
Fire Stations	1	Lumberton Levee
Fire Stations w/ EMS	1	Lumberton Levee
Law Enforcement	3	1 in Fair Bluff, 2 in Lumberton Levee
Airports	1	Lumberton Regional Airport is not in the floodplain, but access would be limited
Railroad	1	CSX-Wilmington
TOTAL	**24**	

Nearly half of the critical infrastructure within the FEMA 1% AEP floodplain is also within the protected area of Lumberton Levee; if levee deficiencies are addressed in the future then impacts to critical infrastructure at that flood level would be significantly reduced.

2.11. Transportation Infrastructure

During Hurricane Matthew in 2016, over 2500 roads across the state of North Carolina were closed due to flooding. In 2018, Hurricane Florence stalled over eastern North Carolina resulting in over 1600 road closures from flooding (**Figure 2.9**). In the study area, Robeson and Columbus counties were the primary counties with major road closures including Interstate 95, U.S. 74, U.S 76, U.S 301, U.S. 501, and state highways 71, 72, 83, 130, 211, 904, and 905. Portions of I-95 in Robeson and Cumberland counties were closed for 9 days, with travelers being re-routed as far west as Charlotte. As a result of damages to roads and bridges associated with severe weather events, North Carolina Department of Transportation (NCDOT) is exploring resiliency strategies through a variety of assessments and initiatives including a feasibility study for the I-40 and I-95 corridors, and a flood risk vulnerability assessment of the Strategic Transportation Corridor, 25 critical transportation corridors throughout North Carolina (**Figure 2.10**). Design plans include raising bridges and roadways along the I-95 corridor extending from Lumberton to Dunn to increase resilience to future flood events and to prevent road closures. Another project intended to address flooding in Lumberton involves the installation of two floodgates at the abutments of the I-95 bridge near VFW road to prevent floodwaters from the Lumber River inundating roads and structures in the municipality. The city has secured funding for the project through Federal and State grants. Under the FWOP scenario, these initiatives and projects would be implemented and should improve the resiliency of roads and bridges in the study area.

2.12. Recreation

The Lumber River basin is one of the most highly utilized recreation corridors in the state of North Carolina. Outdoor recreational opportunities within the area include festivals, boating, hunting and fishing, camping, hiking, swimming, biking and artifact hunting. Anglers use the stream to fish for common game fish such as black crappie, largemouth bass, catfish and redbreast sunfish.

In addition to numerous local and municipal parks, the Basin is the home of the Lumber River State Park, which covers approximately 10,000 acres of land and 115 miles of waterway. The State Park has boat launches, primitive camp sites, hiking trails and picnic areas.

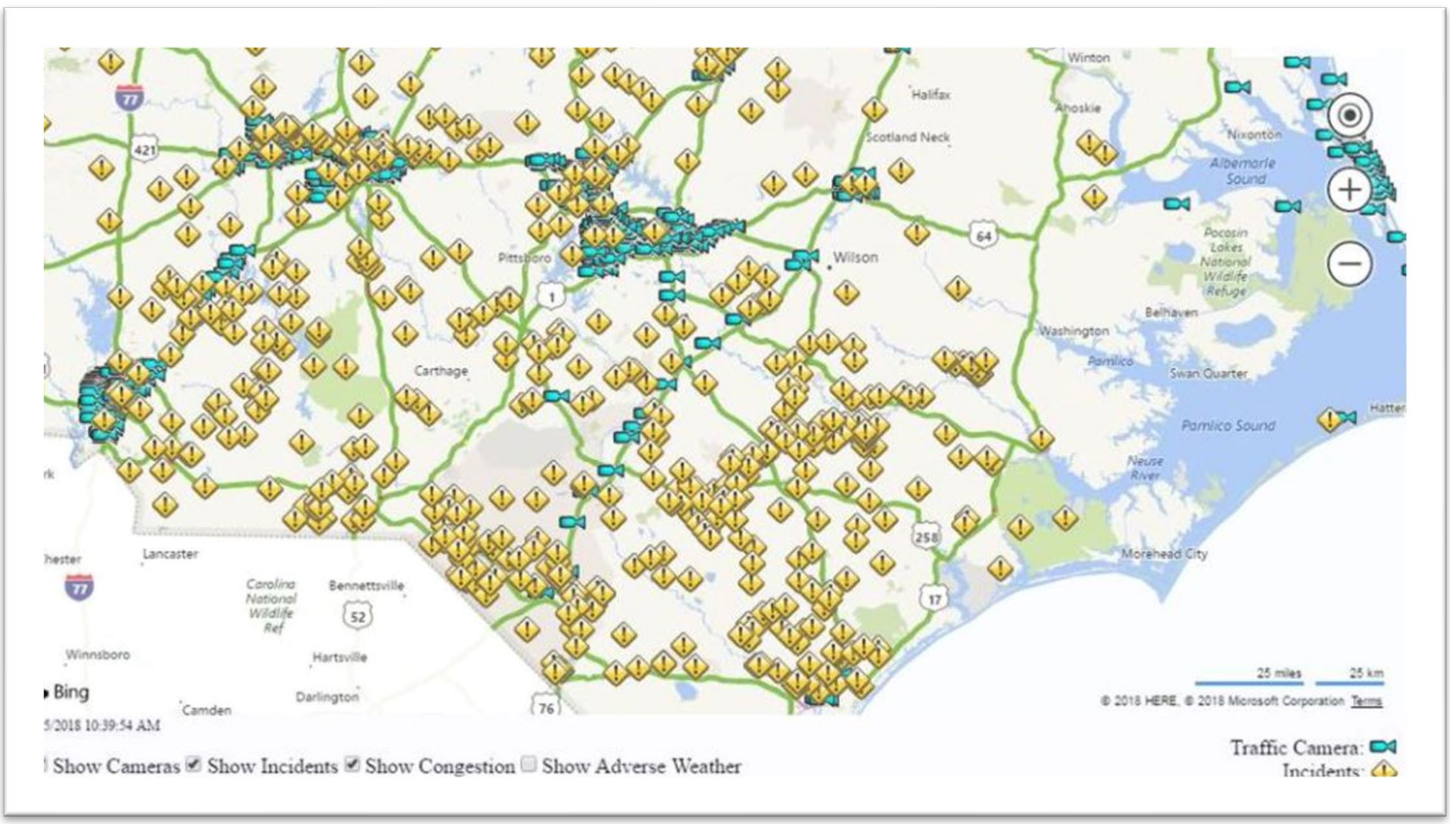

Figure 2.9 - Road Closures in Southeastern NC During Hurricane Florence[17]

[17] NCDOT Traffic Information System

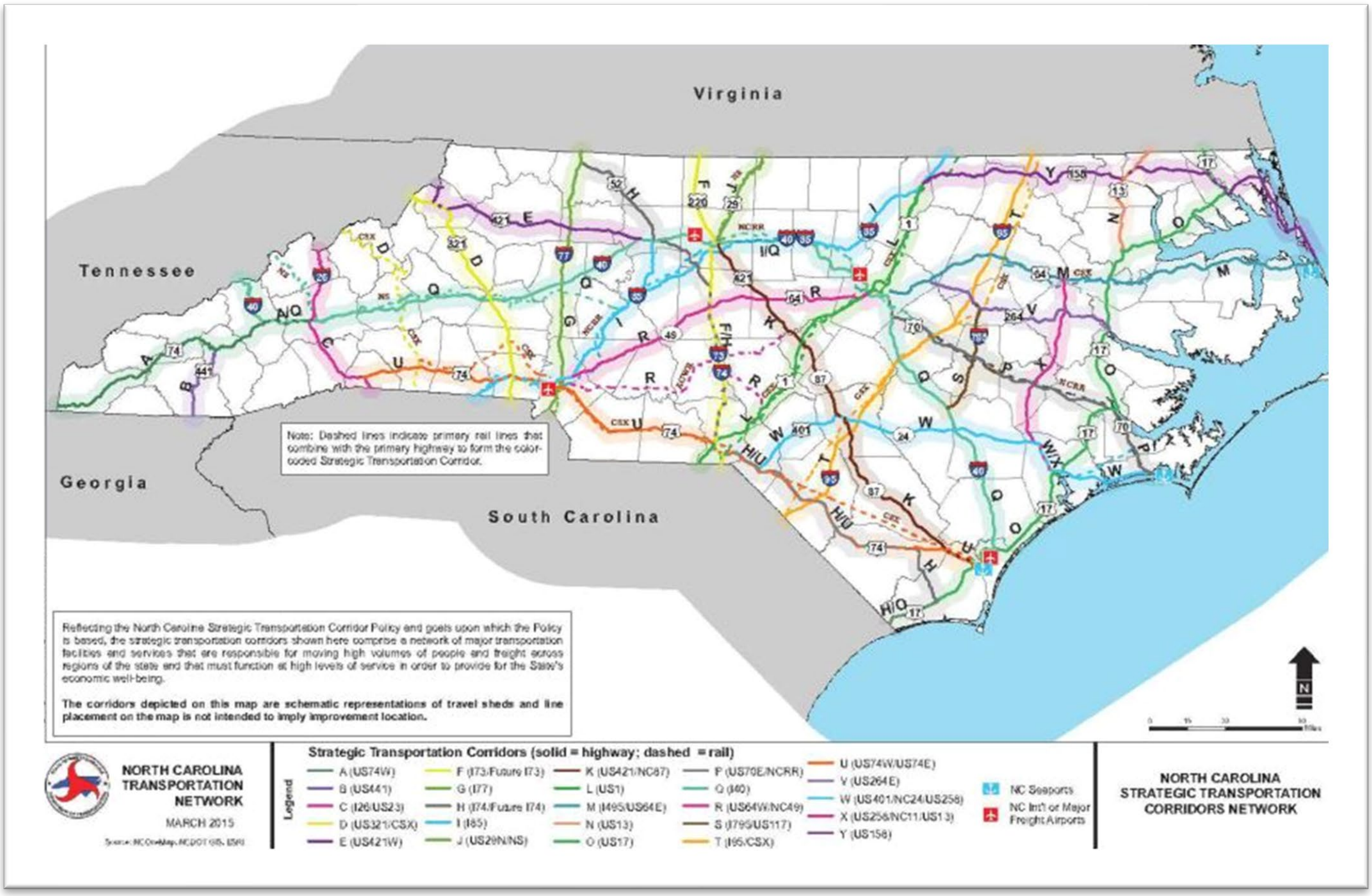

Figure 2.10 - NCDOT Strategic Transportation Corridor[18]

[18] NCDOT 2021 Resilient Strategy Report

3. Plan Formulation

The guidance for conducting civil works planning studies, Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, requires the systematic formulation of alternative plans that contribute to the Federal objective. ER 1105-2-100 also defines a six-step planning process that provides a systematic approach to problem solving and a rational framework for sound decision-making. The iterative planning process is designed not only to stimulate creative thought and generate innovative solutions but also to accommodate dynamic problems and opportunities. The steps include: (1) identifying problems and opportunities; (2) inventorying and forecasting conditions; (3) formulating alternative plans; (4) evaluating alternative plans; (5) comparing alternative plans; and (6) selecting a plan.

This chapter presents the results of the plan formulation process.

3.1. Problems, Opportunities, Objectives and Constraints

This section defines the problems which exist due to flooding issues within the Lumber River basin. It is focused on defining the overall problem and opportunity statements, followed by a discussion of objectives and constraints for the study.

An initial scoping charrette was held on 14 May 2020 and included members of the USACE Project Delivery Team (PDT) and representatives from the non-Federal sponsor and other key stakeholders including the North Carolina Department of Transportation (NCDOT), the North Carolina Department of Public Safety (NCDPS), and the North Carolina Department of Environment and Natural Resources (NCDENR). The problems, opportunities, objectives and constraints developed during the charrette are:

3.1.1. <u>Problems and Opportunities</u>

Economic damage resulting from riverine flood inundation.

- Problems
  - Damage to residential and non-residential structures throughout the study basin
  - Impacts to industry (e.g. agriculture) and commerce throughout the basin
  - Damage to public infrastructure (e.g. roads, bridges, wastewater treatment plants)
  - Traffic delays associated with inundation of and damage to transportation infrastructure
  - Cost to remediate degraded environmental resources impacted by inundation

- Opportunities
  - Reduce flood damage to residential and non-residential structures and public infrastructure throughout the study basin
  - Reduce flood related impacts to industry and commerce throughout the basin
  - Reduce traffic delays associated with inundation and damage to transportation infrastructure

Risks to life safety associated with riverine flood inundation.

- Problems
  - Isolation of communities as a result of inundated roadways
  - Loss of life due to inundated occupied vehicles on roadways
  - Potential inundation of critical infrastructure
  - Elevated life safety risk to vulnerable populations (e.g. elderly and residents without vehicles) located within the floodplain

- Opportunities
  - Improve ingress/egress issues to isolated communities during flood events
  - Reduce life safety issues associated with inundated occupied vehicles on roadways
  - Reduce the likelihood of inundation of critical infrastructure
  - Address life safety risk to vulnerable populations (e.g. elderly and residents without vehicles) located within the floodplain

3.1.2. Planning Objectives

- Objective 1: Reduce the risk of flood damages to structures (residential and other) and public infrastructure (critical and other) throughout the study basin over the period of analysis[19].

- Objective 2: Reduce the risk of economic damage to industries (e.g. agriculture) and commerce throughout the study basin over the period of analysis.

- Objective 3: Reduce life safety risk associated with inundation of structures (residential, non-residential and public infrastructure (critical facilities) throughout the basin over the period of analysis.

- Objective 4: Reduce life safety risk associated with inundation of and damage to transportation infrastructure throughout the basin over the period of analysis.

[19] The period of analysis for this study is 50 years, spanning from 2022 to 2072.

3.1.3. Constraints

The following are also constraints to be considered during the development of the study:

- Plans should avoid transferring flood risk to other areas;
- Plans should not reduce performance of existing flood risk projects in the study area;
- Plans should not induce development in the floodplain;
- Avoid adverse impacts to numerous endangered species; and
- Avoid impacts to cultural/historic/archeological resource values, particularly that portion of the Lumber River basin designated as part of the National Wild and Scenic Rivers System.

3.1.4. Assumptions

As described in detail in **Section 2.1**, the existing Lumberton Levee is not currently certified. During study development the City confirmed there is an active plan in place to address the most critical deficiencies in the system. While the remaining deficiencies will likely result in some flood risk, it is unlikely to be significant enough to warrant Federal action.

There is currently a voluntary FEMA buy-out program, administered by the State of North Carolina, underway in the Basin. This includes approximately 470 parcels (it should be noted this includes some parcels without structures). For the purposes of this study these parcels have been included in the existing condition but excluded from the FWOP.

The State of North Carolina provided the H&H modeling from the 2018 Lumber River Basin Flood Analysis and Mitigation Strategies Study. For the purposes of this study, this modeling was considered sufficient for screening level decision making.

3.2. Alternative Formulation

The following section summarizes the formulation and development of alternative plans to meet the study objectives of reducing the risk of economic damages and life safety risk associated with flooding in the Lumber River basin.

The first step in the formulation of alternative plans is brainstorming measures. Measures are actions that can be taken to address one or more of the study objectives and may be stand-alone or combined with other measures to form complete alternatives. Measures are generally broken into two categories:

- structural measures which address the study objectives by altering the way water moves through the Basin; and
- nonstructural measures which remove the at-risk structures and individuals from the inundation area.

Alternative formulation focused primarily on the damage centers identified above, along with several plans to reduce flooding holistically across the Basin.

3.3. Management Measures

The following sections describe the measures which were considered, basic assumptions about their design and the rationale for the initial screening decision.

A management measure (measure) is a feature or an activity that can be implemented at a specific geographic site to address one or more planning objectives. Measures are the building blocks of alternative plans and are categorized as structural and nonstructural. Structural measures are those which modify the flow of water, such as a dam or levee. Nonstructural measures seek to remove individuals and structures from the path of damage, as well as increasing flood education and utilization of Flood Warning Systems (FWS).

An alternative plan is a set of one or more measures functioning together to address one or more objectives. Typically, an array of alternative plans is identified at the beginning of the planning process and screened and refined in subsequent iterations throughout study development.

Specific to Lumber River Basin, none of the identified measures passed the initial screening, therefore alternative plans were not formulated for this study. Screening level analysis, which relied on qualitative assessments of the screening criteria described below was used to make these determinations.

Specific screening criteria included effectiveness, cost and environmental impacts. The definition of these screening criteria, as used within the parameters of this study are described below:

- Effectiveness: the degree to which the measure meets the study objectives. This considers a qualitative assessment of the measure's ability to reduce the risk of flood damage and life safety risk. Measures were rated low, medium or high based on the magnitude of the reduction in risk of flood damages or life safety risk.
- Cost: the range of construction cost for each measure. These costs were estimated based on similar measures considered or implemented as part of other comparable construction projects. Costs are listed in ranges as follows: $0-$10M (considered low cost) ; $10M-$25M (considered medium/moderate cost) and above $25M (high cost).
- Environmental impacts: the extent to which each measure has the potential to impact or affect statutorily projected or regulated resources. Measures were rated low, medium or high based on the magnitude of the likely impact on the human and natural environment.

The remainder of this section is organized by damage center, along with a discussion of Basin-wide measures considered.

3.3.1. Basin-Wide Measures

The following measures were considered to holistically reduce flood damages and life safety risk across the Basin.

3.3.1.1. Upstream Retention

Any upstream retention structure would likely need to be sited in the Drowning Creek or Raft Swamp areas for maximum effectiveness. Given the coastal plains topography of the area, there is no sufficient "pinch point" for a single structure. The mitigation study completed by the NCDOT showed that this type of measure would likely require 4-5 separate retention structures in the areas of Drowning Creek, Raft Creek, and Big Swamp. These would likely be dry dams, ranging in height from 25 – 35 feet, which would only hold water during a rain event. Of the structures considered in the NCDOT study, only one was economically justified. The Raft Swamp 1, Dam Scenario 2, had a benefit to cost ratio (BCR) of 1.14 over a 50-year planning horizon (NCDOT 2018). However, the BCR calculation assumed that there would be no levee in the City of Lumberton, and so counted the benefits of damages reduced in Lumberton that the levee would provide. Further, the cost calculation did not include an analysis of environmental impacts and required mitigation. Given that this portion of the Lumber River is designated as Wild and Scenic, environmental impact mitigation could be extensive. Finally, the analysis shown in the NCDOT report indicated that water surface elevations would only be reduced by 0.2-0.4 inches for the region below where the river enters the Big Swamp floodplain, making the measure only effective for the City of Lumberton. Given both the inflated benefits that are no longer available due to the City's progress on completing the levee in Lumberton, and the increased cost associated with required mitigation, it is not likely the BCR would equal or surpass 1 for this measure.

While this measure would likely be effective if the levee in Lumberton is not completed as planned, it is a high cost alternative that would not be economically justified. The initial cost of $55 million is an annual cost of nearly $2 million dollars (at the FY21 discount rate of 2.5%), and the average annual damages in Lumberton outside of the leveed area are $211k in the FWOP. At that cost level, the upstream retention would have to provide complete flood protection well beyond the level of the 0.2% AEP (1/500) for the whole basin to be economically justified. For these reasons this measure has been screened from further consideration.

3.3.1.2. Modification/Removal of Existing Structures

This measure considered the raising or removal of existing small dams situated on tributaries to the Lumber River mainstem. These dams were analyzed to determine if they had capacity to retain larger pools during high water events, or if they could be removed (channel naturalization) to allow floodwaters to dissipate more naturally over specific areas of the floodplain. It should be noted that none of the existing detention structures in the Lumber River area are designed for FRM. Most existing structures are used for irrigation, water supply and recreation.

This measure was given a medium rating for effectiveness because the existing structures have very small drainage areas compared to the total drainage area of the basin and a moderate rating for cost. Existing structures are in headwater areas, none are on the mainstem or the lower parts of any major tributaries. The lower part of the basin where several damage centers such as Lumberton, Boardman, Fair Bluff and Nichols, SC are located would receive no benefit from this measure. Too many tributaries enter the system below these existing dams, bringing damaging flood waters to the lower basin. Given the low estimated annual damages that could be reduced in the basin, this measure would not be economically justified and would likely result in significant environmental impacts. For these reasons this measure has been screened from additional consideration.

3.3.1.3. Basin Wide Nonstructural Plan

This measure consists of the development of a nonstructural plan comprised of a combination of buyouts, elevation and wet floodproofing for the entire Basin. At the time of brainstorming this measure appeared to be effective, as the flood depths across the Basin are not high and the required number of buyouts were not high. However, as the study progressed it was found that many of the structures eligible for buyout were either already considered under an existing FEMA buyout plan, were not suitable for floodproofing or elevation, and or were uninhabited. Each of these conditions eliminates a structure from eligibility for a USACE-funded nonstructural plan.

The potential for non-structural remediation by elevation, floodproofing, or acquisition was evaluated by computing the average annual damages at the individual structure level. The summary mean results for each flood event were exported from LifeSim and combined in GIS. Average annual damages per structure were computed using the interval method based on the probability intervals between each event.

Consultation with subject matter experts from the USACE non-structural committee were held to determine a screening level cost estimate per structure for non-structural mitigation. Costs on similar recent projects averaged out to around $200,000 per structure. As a screening metric, a more conservative cost threshold of $170,000 was annualized using the current FY21 discount rate of 2.5%. Annualized over a 50-year study period at that rate, a $170,000 initial cost equates to an average annual cost of $5,993 which was rounded to $6,000 for the screening analysis. Using the FWOP structure inventory and hydraulics, structures with greater than $6,000 in average annual damages were isolated using GIS for the purpose of identifying any clusters of structures that could potentially have a positive net benefit for nonstructural mitigation.

A first iteration of this screening resulted in approximately 12 structures with more than $6,000 in average annual damages. The structure inventory data on these structures was manually checked and calibrated as needed for both accurate placement and reasonable values and attributes using aerial imagery, street view pictures, and real estate valuations. The LifeSim modeling was rerun and the average annual damages per structure were recomputed in GIS for a second screening iteration. The result was approximately 9 structures that would have a potential positive net benefit. Several of these were along Beulah Church Road southeast of Lumberton.

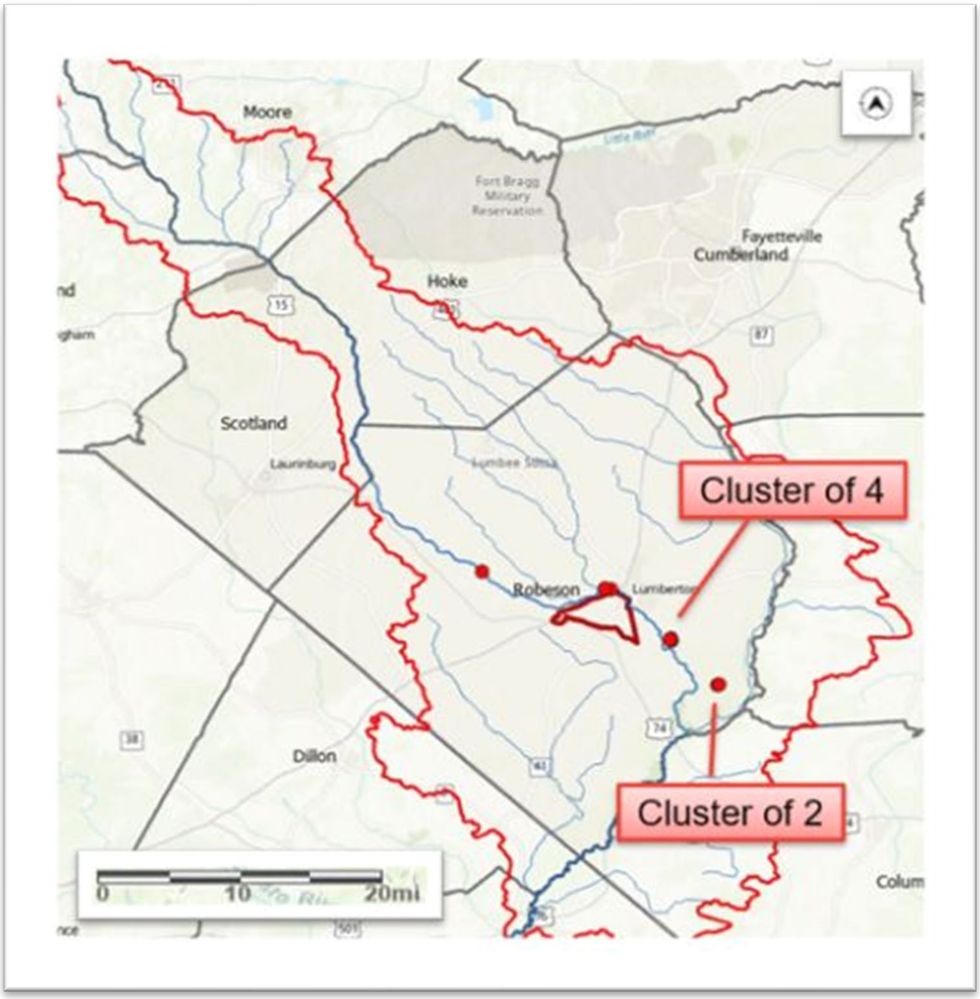

Figure 4.1 – Structures with Potential Positive Nonstructural Net Benefit

The structures with potential positive net benefits are flooded in most cases by the estimated 10% AEP (1/10) flood event, which is why they have relatively high average annual damages, however, flood depths in these areas remain relatively low at higher events. Even at the 0.1% AEP (1/1000) event, flood depths on these structures are in the range of 3-5 feet above ground.

Given the low number of potential structures with positive net benefits, nonstructural mitigation measures were rated low for effectiveness. Cost and environmental impacts did not affect the screening decision for this measure. Despite the potential for a positive net benefit, the low number of homes do not reasonably rise to the level of Federal investment as a stand-alone measure. Based upon this analysis, non-structural measures were screened from additional consideration at the damage center level as a stand-alone measure. If another measure, or set of measures, are found to have a positive net benefit, this measure could be added to those to create a larger alternative plan.

3.3.1.4. Wetland/Floodplain Restoration

This measure would consist of wetland and floodplain restoration in various appropriate locations throughout the Basin. Wetland soils have the capacity to hold greater amounts of water than other soil types, thus providing flood storage after a storm event and minimizing the risk of flood damages. Floodplains also provide water storage and reduce stream flow velocities during storm events by allowing excess water to spread out across the floodplain. Additional benefits provided by wetland and floodplain restoration include water quality improvements, increased fish and wildlife habitat, and groundwater recharge. Restoration measures would likely be implemented in rural areas located above the identified damage centers.

Ultimately, this measure was rated low for effectiveness. The existing wetlands within the basin are in a near pristine state, leaving little room for enhancement. Further, 25-30% of the basin currently consists of wetlands, leaving mainly lands actively under cultivation to be converted. There would likely not be enough improvement in the condition of the existing wetlands or floodplains to significantly reduce flood damages or life safety risk. Wetland restoration projects typically require larger project sites to ensure ecological integrity and sustainability. Therefore, buying and converting the acreage of cropland necessary for restoration success in a region with an agricultural economic base would be costly and impractical, while providing minimal risk reduction. It was determined that the implementation cost combined with loss to the economic base would be greater than the benefits that could be achieved with this measure. This measure has been screened from additional consideration.

3.3.1.5. Clearing/Snagging/Debris Removal

This measure would entail restoring the historic flows of the Basin, primarily by removing debris and other obstructions within the waterway. Debris removal would need to be done in a manner which would not significantly impact aquatic or riparian resources. This measure would potentially require recurring maintenance to maintain restored flows, and therefore long-term environmental impacts could be difficult to calculate or mitigate.

While this could likely be a low-cost measure in the short term, it would require an ongoing investment to continuously clear debris as it amasses, particularly after flood events. This long-term commitment by local city/county/state entities would be costly and if debris is allowed to collect for too long, the effective flood mitigation gained would be undone. For these reasons, the team determined that clearing/snagging/debris removal would not be effective over the long term. Given the low effectiveness rating, this measure has been screened from additional consideration.

3.3.1.6. Flood Warning Systems

A FWS is used to provide information on rainfall, stream levels and other hydrometerological data, allowing public warnings of potential flood danger to the public. Most FWSs are based on a system of rain and stream gages which report the data that makes it possible to develop this information. The largest benefit associated with a FWS is the increased warning time for flood watches and warnings for areas which may be at risk due to high water events. It also allows for predictions on flood crest times and flooding severity.

This measure was screened from additional consideration in this study due to low effectiveness at meeting the study objectives. A FWS reduced life safety risk but does little to reduce economic damages. As discussed below, there is minimal life safety risk to be further reduced at high frequency events. Additionally, there would be little economic benefit given that the Basin is not prone to flash flooding, so most flooding is preceded by flood warnings via the National Weather Service (NWS) and programs. These events would likely be driven by hurricanes and major storm systems with significant flood warning time.

3.3.1.7. Basin Wide Measures Summary

A solution that may holistically reduce flood damages and life safety risk across the basin was not found (Table 4.1).

Table 4.1 - Basin Wide Measures Screening

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Structural Measures				
Upstream Retention	High	$25M-$50M	High	Screened
Modification/Removal of Existing Structures	Medium	$10M-$25M	High	Screened
Nonstructural Measures				
Basin Wide nonstructural plan	Low	$25M-$50M	Low	Screened
Wetland/floodplain restoration	Low	$10M-$25M	High**	Screened
Clearing/snagging/debris removal	Low	$1M-$10M*	Medium	Screened

*Recurring maintenance costs due to future storm events is unknown.

** Wetland and floodplain restoration would provide a high level of beneficial environmental impacts such as an increase in food and habitat for aquatic and terrestrial species, including threatened and endangered species.

3.3.2. Fair Bluff Measures

The following measures are those which were considered for the town of Fair Bluff, North Carolina. Fair Bluff has approximately 69 structures scattered across the FEMA 1% AEP floodplain.

3.3.2.1. Levees/Floodwalls

This measure considers the use of levees and/or floodwalls to reduce flood damages and life safety risk in the Fair Bluff area. The levee/floodwall would be approximately 1,300 feet long and would likely consist of a sheetpile wall set back from the river's edge enough for lateral wall support. A removable closure with a simple operating system would be needed at the existing bridge. The rough cost of floodwall construction could be between $650,000 to over $2,000,000 for 1300 linear feet - depending on factors such as construction materials and methods, location, the need for a cofferdam, real estate costs such as easements and utility relocation, and acquisition and demolition costs. The FWOP average annual damages for Fair Bluff, which takes into consideration the risk resolved by the FEMA buyouts, as well as reduction in the number of inhabited structures in the town after abandonment is $75,199 (see Table 2.14).

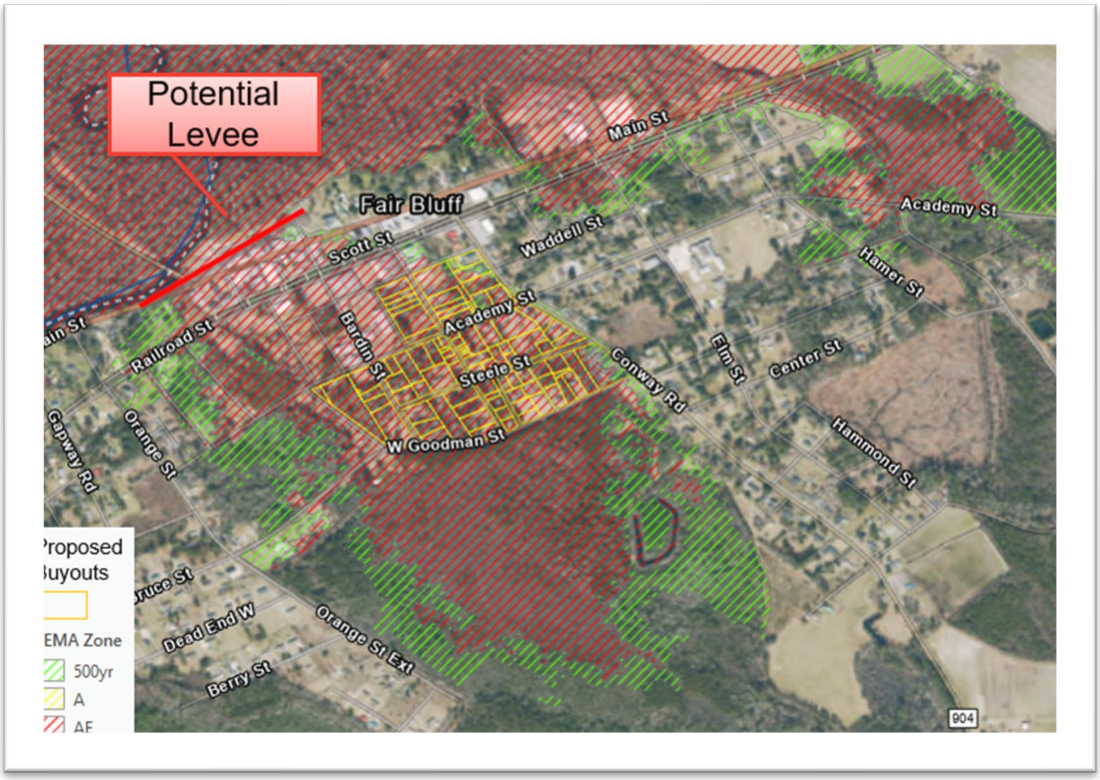

Figure 4.2 – Fair Bluff Levee/Floodwall Measure

While this measure would be highly effective, it would also be a costly measure that would not be economically justified for USACE investment. For this reason, this measure has been screened from additional consideration.

3.3.2.2. Temporary Barrier on the Roads (Deployable Levee)

This measure considers a temporary barrier or deployable levee which could be implemented during high water events. Deployable levee systems take many forms from water filled geo tube, to metal barriers that can be slotted into permanently mounted stations as needed. Depending on the system, deployable levees cost between $500 and $3000 per linear foot. These systems require some level of pre installation as well as an Operations and Maintenance (O&M) commitment on behalf of the local community. A space to store the temporary barrier would need to be secured. The local community would need to ensure the appropriate personnel were available to monitor the flood conditions, decide to deploy the barrier, place the barrier, monitor the performance of the barrier during the flood event, and remove, repair and store the system again after the event. This is a significant outlay of resources for a small community. While 1,300 LF of deployable flood protection could cost as little as $650,000 in initial outlay, plus the cost of storage, repairs, deployment and clean up, in a community as small as Fair Bluff, having the trained personnel present and reliably available to maintain and deploy these systems becomes a risk. Given the high reliance on a very few members of a diminishing community, this type of measure quickly loses economic justification for USACE investment. Without local support and commitment to take responsibility for implementation and operation of such a measure, the measure has been screened from further consideration for USACE action. However, a deployable system could be considered for purchase locally or through state or federal grants if the town or county or other organization chooses to commit to the operation and maintenance of the system.

3.3.2.3. Fair Bluff Measures Summary

Table 4.2 - Fair Bluff Measures Screening

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Structural Measures				
Levees/Floodwalls	High	\$5M-\$15M	Medium	Screened
Temporary Barrier on the Roads (Deployable Levee)	Medium	\$650k-\$5M	Low	Screened

3.3.3. Boardman Measures

The following measures are those which were considered for the town of Boardman, North Carolina. Boardman has approximately 7 structures within the FEMA 1% AEP floodplain.

3.3.3.1. Boardman Structural Measures

At the time of measures brainstorming, a list of typical structural measures was compiled for Boardman. These measures included channel modification, levees/floodwalls, upstream detention, a diversion channel and barrier removal. As these measures were further discussed it became apparent that this community was more suited for nonstructural measures on the basis of its size. The community has a population of approximately 275 people, with 7 structures at risk in the floodplain. Most of the homes and structures damaged in the last several flood events have been abandoned or elevated, reducing the economic and life safety benefits so low that measures that could be implemented by USACE would not be economically justified. Therefore, no structural measures were developed or considered for the town of Boardman.

3.3.3.2. Road Elevation

This measure would consist of the elevation of existing roads. Road elevation would primarily address the study objective of reducing life safety risk. As discussed in **Section 3.3.3**, no life safety risk is identified in Boardman, therefore no relevant justification exists for Federal expenditure on this measure. Further, this measure would require the demolition of multiple structures in a small community.

3.3.3.3. Road Berms

This measure is similar to the temporary barrier/deployable levee measure considered above for Fair Bluff. It would consist of a temporary barrier or deployable levee which could be implemented along the road during a highwater event. As with Fair Bluff, this would require an O&M commitment on behalf of the local community with the same resource obligations. Again, this is a significant outlay of resources for a small community with only 7 structures at risk with annual damages estimated at $13,055. Over the long term, the team felt the high cost of O&M made this measure unjustified for USACE investment.

3.3.3.4. Boardman Measures Summary

Table 4.3 - Boardman Measures Screening

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Nonstructural Measures				
Road elevation	Low	$25M-$50M	Medium	Screened
Road berms	Medium	$650k-$5M	Low	Screened

3.3.4. <u>Lumberton Measures</u>

The following measures are those which were considered for the town of Lumberton, North Carolina. Lumberton has approximately 407 structures within the FEMA 1% AEP floodplain, with an additional 914 structures within the area protected by the Lumberton Levee (which is also part of the FEMA 1% floodplain).

3.3.4.1. Lumberton Structural Measures

As described above in **Section 2.1**, at the time this study was initiated it was unclear whether the City had plans to address all four levee deficiencies and ensure it could operate as intended. Structural and nonstructural measures were developed for Lumberton in the event the levee deficiencies would not be addressed. These measures included channel modification, levee improvements (i.e. fix the levee), upstream detention, and a diversion channel. Once the City confirmed an active plan to address the levee deficiencies /VFW railroad closure, it was determined that the measures or combination of measures could not effectively reduce the risk for the remaining at-risk structures. Therefore, there is no economic justification to continue development of these measures.

3.3.4.2. Road Elevation

This measure would consist of raising a portion of Interstate 95 (to include the non-project segment of the levee) near Lumberton and would primarily address the study objective of reducing life safety risk. The section of Interstate 95 which floods during significant highwater events impacts transportation of goods, ingress/egress of emergency personnel during emergencies, and could increase life safety risk in the area. This action falls within the authority of the North Carolina Department of Transportation (NCDOT), who is currently developing a plan to address flooding for this segment of the Interstate. This measure has been screened from additional USACE consideration.

Nonstructural measures for the City of Lumberton were discussed in detail in **Section 3.3.1.3** above and screened from further USACE consideration.

3.3.4.3. Lumberton Measures Summary

Table 4.4 - Lumberton Measures Screened

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Nonstructural Measures				
Road Elevation	Low	$25M-$50M	Medium	Screened

3.3.5. Fairmont Measures

The following measures are those which were considered for the town of Fairmont, North Carolina. Fairmont has approximately 18 structures throughout the FEMA 1% AEP floodplain.

3.3.5.1. Fairmont Structural Measures

Measures brainstorming for Fairmont was similar to that of Boardman, discussed above. As with Boardman, most of the homes and structures that have been damaged during recent flood events have been either abandoned or elevated. This reduces the potential economic and life safety benefits of measures considered by USACE to the point where they can no longer be justified.

Nonstructural measures were discussed in detail in **Section 3.3.1.3** above and screened from further USACE consideration.

3.3.6. Pinehurst Measures

The following measures are those which were considered for the Village of Pinehurst, North Carolina. Pinehurst has approximately 29 structures across the FEMA 1% AEP floodplain.

3.3.6.1. Modification of Existing Structures

This measure is a smaller scope in comparison with the measure discussed above in **Section 3.3.1.2.** It considers the modification of existing small dams. Again, these dams were analyzed to determine if they had capacity to retain larger pools during high water events, or if they could be removed (channel naturalization) to allow floodwaters to dissipate over specific areas in the floodplain. The analysis showed that there is no additional capacity available, nor is there room to add additional capacity given the surrounding land use and development. Further, due to floodplain development, there is not sufficient room to allow floodwaters to flow in a more natural pattern within the floodplain.

This measure was again given a low rating for effectiveness and a moderate rating for cost. This measure would likely result in significant environmental and economic impacts making economic justification even less likely. For these reasons this measure has been screened from additional consideration.

Nonstructural measures were discussed in detail in **Section 3.3.1.3** above and screened from further USACE consideration.

3.3.6.2. Pinehurst Measures Summary

Table 4.5 - Pinehurst Measures Screening

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Structural Measures				
Modification of Existing Structures	Low	$10M-$25M	Medium	Screened

3.3.7. Aberdeen Measures

The following measures are those which were considered for the town of Aberdeen, North Carolina. Aberdeen has approximately 50 structures within the FEMA 1% AEP floodplain.

3.3.7.1. Modification of Existing Structures

Similar to the measures discussed above in **Section 3.3.1.2**, this measure considers the modification of existing dams to either add to capacity or removal for the purposes of channel naturalization. As with Pinehurst, the analysis showed that there is no additional capacity available, nor is there room to add additional capacity given the surrounding land use and development. Dam removal for the purposes of channel naturalization would not be effective in this area due development in and around the floodplain. This measure was ranked low in effectiveness, moderate in cost and medium in environmental impacts. It has been screened from additional consideration.

3.3.7.2. Temporary Barrier on Sand Hills Boulevard

This measure is similar to that discussed above in **Section 3.3.2.2** for Fair Bluff. It would consist of a temporary barrier or deployable levee which could be placed along Sand Hills Blvd during high water events. The barrier would need to be approximately 1,600 ft long to protect against the 1% AEP flood, and would reduce flood risk to approximately 60% of the structures at risk within Aberdeen. As with Fair Bluff and Boardman, this would require an O&M commitment on behalf of the local community with the same resource obligations. Again, this is a significant outlay of resources for a small community. Over the long term, the team felt the high cost of O&M along with the residual risk for those structures not helped by this measure made this measure unjustified for USACE investment. This measure has been screened from further consideration for USACE action, however, it could be considered locally if the community want to commit to the O&M necessary.

3.3.7.3. Levee on Sand Hills Boulevard

This measure would consist of a levee along Sand Hills Boulevard. Given space confinements, this measure would require significant real estate acquisition, structure demolition and road modification. Again, this measure would likely leave nearly half the structures in the floorplan still at risk. Construction and land acquisition costs would be too high for an economically justified project. For these reasons, this measure has not been screened for additional consideration.

Nonstructural measures were discussed in detail in **Section 3.3.1.3** above and screened from further USACE consideration.

3.3.7.4. Aberdeen Measures Summary

Table 4.6 - Aberdeen Measures Screening

Measure	Effectiveness	Cost	Environmental Impacts	Screening Decision
Structural Measures				
Modification of Existing Structures	Low	$10M-$25M	Medium	Screened
Temporary Barrier on Sand Hills Blvd.	Low	$10M-$25M	Low	Screened
Levee on Sand Hills Blvd.	Medium	$10M-$25M	Medium	Screened

3.4. Comprehensive Documentation of Benefits

A USACE Policy Directive dated 5 January 2021 issued policy direction on the comprehensive assessment and documentation of benefits in the development of USACE water resources studies. The purpose of the directive is to ensure that the decision-making framework comprehensively considers the total benefits of project alternatives, including equal consideration of economic, environmental and social categories. This is done by documenting the benefits of project implementation across the four accounts detailed in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G)* (need reference): National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ) and Other Social Effects (OSE).

3.4.1. National Economic Development

As previously discussed, this study has not identified an economically justified plan, so there is no NED plan for the study.

3.4.2. Regional Economic Development

As there has been no plan identified for implementation, there are no benefits to the regional economy associated with the construction of a project.

3.4.3. Environmental Quality

While the Lumber River basin is not pristine in terms of environmental quality, it is also not degraded enough to warrant environmental restoration actions. Much of the Lumber River

Mainstem is designated as Wild and Scenic, a designation that is granted to certain waters of the U.S. to preserve rivers with outstanding natural, cultural, and recreational values. The designation of a Wild and Scenic River within the Basin speaks to the general health of the environment. Therefore, no measures to address flood risk that would also enhance environmental quality were identified.

3.4.4. Other Social Effects

Other social considerations include factors such as urban, rural and community impacts; life, health, and safety factors; displacement and long-term productivity. A general threshold for consideration of benefits to minority populations is whether or not 50% of the community at risk is non-white or whether 45% or more of the total population are low-income. Within the Lumber River basin, 3 population centers are more than 50% minority; however, of these three, only Lumberton has damages. The damages in Lumberton will be addressed once the Levee modifications are complete. With regard to the low-income threshold, there are no damage centers within the Basin which meet the 45% criteria. For example, in areas such as Pembroke, Red Springs, and Maxton – all of which meet the criteria overall - no damages are identified within the 100 year FEMA floodplain. There are no measures that could be implemented that would provide a reduction in flood risk while positively affecting those populations considered by this account.

3.5. Plan Selection

Based on the evaluation detailed above, no plan was identified for USACE implementation; therefore, the No Action Alternative is the Recommended Plan. **Section 4.2** details recommended actions which could be implemented by local entities to address the study problems independent of USACE investment in a solution.

4. Recommendations

4.1. Federal plan

There is no recommendation for USACE action.

While there was no Federal interest found for implementation of an FRM project by USACE, there are three USACE authorities which may benefit the non-Federal sponsor and stakeholders within the Lumber River basin. These include the Section 729 Watershed Assessment authority, Planning Assistance to States and Floodplain Management Services. While these authorities do not typically result in bricks and mortar projects, they do offer a range of planning services as described in the following sections. These programs differ from more traditional USACE feasibility studies in that they do not result in identification of a project in which USACE would cost share in implementation. Rather, they offer an opportunity to tap into USACE's vast engineering expertise to help identify and or model water resources problems in a community and recommend example solutions the community could implement without USACE involvement.

4.1.1. Section 729 Watershed Assessment

Section 729 of the Water Resources Development Act of 1986, as amended authorizes USACE to assess the water resources needs of river basins and watersheds of the U.S. including needs related to: ecosystem protection and restoration, navigation and ports, FRM, watershed protection, water supply and drought preparedness.

Specifically, watershed planning goes beyond project planning for a specific USACE project towards more comprehensive and strategic evaluation and analyses which include diverse political, geographic, physical, institutional, technical and stakeholder considerations. Watershed planning addresses identified water resource needs from any source, regardless of agency responsibilities or authorities, and provides a shared vision of a desired end state.

While rarely resulting in a bricks and mortar project, watershed study recommendations typically take the form of suggested strategies, policies (new or revisions to existing policies), programs for local or state agencies and multi-agency partnerships, or federal and non-Federal projects. These recommendations are documented in the form of a watershed management plan, watershed assessment, river basin assessment, comprehensive plan or watershed study which forms a strategic roadmap to assist with prioritizing needs and investments.

Additional information on Section 729 Watershed Studies may be found in **Appendix B**.

4.1.2. Planning Assistance to States

Section 22 of the WRDA 1974, as amended, provides authority for USACE to help states, local governments, Tribal Nations, and other non-Federal entities prepare comprehensive plans for the development, utilization, and conservation of water and related land. The program can encompass many types of studies dealing with water-resources issues, including flood damage reduction studies and floodplain management studies. Individual states determine needed planning assistance. Every year, each State and Tribal Nation can request studies from USACE under the program, and USACE then accommodates as many studies as possible within the funding allotment. Typical studies are only at the planning level of detail; they do not include detailed designs for project construction. The studies generally involve the analysis of existing data for planning purposes, using standard engineering techniques, although some data collection often is necessary. Information on how to request planning assistance activities is included as **Appendix B**.

4.1.3. Floodplain Management Services

This program's authority stems from Section 206 of the 1960 Flood Control Act (PL 86-645), as amended. Its objective is to foster public understanding of the options for dealing with flood hazards and to promote prudent use and management of the Nation's floodplains.

The floodplain management program provides a full range of technical services and planning guidance needed to support effective floodplain management:

- General Technical Services — The program develops or interprets site-specific data on obstructions to flood flows, flood formation, and timing; flood depths or stages; flood-water velocities; and the extent, duration, and frequency of flooding. It also provides information on natural and cultural floodplain resources of note, and flood loss potentials before and after the use of floodplain management measures.

- General Planning Guidance — The program provides assistance and guidance in the form of "Special Studies" on all aspects of floodplain management planning, including the possible impacts of off-floodplain land use changes on the physical, socio-economic, and environmental conditions of the floodplain.

- Guides, Pamphlets, and Supporting Studies — The program enables studies to be conducted to improve methods and procedures for mitigating flood damages. The program also allows for preparation of guides and pamphlets on flood-proofing techniques, floodplain regulations, floodplain occupancy, natural floodplain resources, and other related aspects of flood plain management.

On request, program services are provided to State, regional, and local governments, Tribal Nations, and other non-Federal public agencies without charge. Program services are also offered to non–water resources Federal agencies and to the private sector on a 100% cost recovery basis. For more information, please see **Appendix B** of this report.

4.2. Recommendations for Local Action

In addition to the federal programs described above, and those the State of North Carolina is already participating in with FEMA and HUD, local communities and stakeholders can take small actions at the local level that could help to reduce risk from flooding. The following list is not exhaustive, but gives some ideas for further actions that can be taken on the local level.

4.2.1. Flood Mitigation Activities

Investigation and evaluation of a wide range of potential mitigation activities that may be applicable for the Lumber River Watershed identified the following seven global categories of mitigation measures that can be taken:

- Preventive measures,
- Property protection,
- Structural projects,
- Natural resource protection,
- Flood warning systems,
- Emergency Service, and
- Public education and awareness

Each category offers specific advantages and risks to the community. Creating multiple layers of defense by employing tactics from each of the categories helps ensure a higher and redundant level of protection.

4.2.1.1. Preventative Measures

Preventive measures aim to prevent the exacerbation of existing flooding problems. This is primarily achieved through the protection and control of flood-prone areas and floodplains by preventing development or impacts to these areas. Some examples include future flood mapping, more protective regulatory standard Floodplain regulations, drainage system and bridge maintenance, and town planning.

4.2.1.2. Property Protection

As the Lumber River experienced during the 2016 and 2018 flood events, flood waters move through the low areas and into higher areas with no regard to structures or features in its way. By identifying, preserving, and protecting these areas and allowing them to serve their natural function, this provides the floodwaters with somewhere to go without adversely impacting structures. This includes wetland protection and floodplain protection as well as individual floodproofing

4.2.1.3. Structural Projects

There are a variety of potential structural projects that may reduce the risk of flooding, such as impoundments or reservoirs, diversions, channel modifications, installation of temporary levees (Muscle Wall) and drainage improvements. As well deployable and permanent flood walls that could be built to help reduce the risk of flooding. These options did not meet the criteria for USACE investment of federal dollars. However, local community, county and state governments, stakeholders and individuals are not required to calculate benefits or costs using the same methodology as USACE and may not require the same cost to benefit ratio as USACE, making some of these options more viable at the local level than they are for USACE to implement.

4.2.1.4. Natural Resource Protection

Natural resource protection and in particular wetland and floodplain restoration measures can be implemented locally, and even to minimize damages to a single property. Wetland soils have the capacity to hold greater amounts of water than other soil types, thus providing flood storage after a storm event and minimizing the risk of flood damages. Floodplains also provide water storage and reduce stream flow velocities during storm events by allowing excess water to spread out across the floodplain. Additional benefits provided by wetland and floodplain restoration include water quality improvements, increased fish and wildlife habitat, and groundwater recharge. Small restoration measures could be implemented in rural areas to effect a positive change in flood risk to individual properties. Natural Resource Protection measures should be developed in conjunction with appropriate state and Federal resource agencies.

4.2.1.5. Flood Warning Systems

A Flood Warning System is used to provide information on rainfall, stream levels and other hydro-meteorological data, allowing public warnings of potential flood danger to the public. Most Flood Warning Systems are based on a system of rain and stream gages which report the data that makes it possible to develop this information. The largest benefit associated with such a system is the increased warning time for flood watches and warnings for areas which may be at risk due to high water events. It also allows for predictions on flood crest times and flooding severity. A flood Warning System is highly localized and often managed by local emergency management personnel, and does not generally rise to the level of federal investment. Systems can be simple or complex as best fits the community and can be developed to best fit the community's needs through local or county emergency management planning.

4.2.1.6. Emergency Services

In general, emergency services are more relevant to flood disaster response than pre-disaster protection but are equally important to protecting residents. However, certain emergency services such as early warning systems can help property owners better prepare for an impending flood and can help save lives. Some examples include early warning, real-time modeling, and flood response planning.

4.2.1.7. Public Education

Educating the public on its risk of flooding, measures to protect property, and the importance of flood risk awareness provides another line of defense against flood damages and enhances recovery efforts.

4.3. Study Termination

With the selection of the No Action Plan, the USACE feasibility study has been terminated. This Technical Report describing the measures considered to reach this conclusion has undergone District Quality Control and Agency Technical Review as required by ER 1165-2-217, "Civil Works Review Policy". The final report will be provided to the Charleston and Wilmington Districts and to the South Atlantic Division and made available to the non-federal sponsor, the North Carolina Department of Environmental Quality.

Lumber River Basin
Flood Risk Management Study

Charleston District
South Atlantic Division

Appendix A – Climate Change
September 2021

1. Introduction - Inland Climate Factors for the Lumber River Watershed

The Lumber River is a 133-mile-long river, located in south-central North Carolina in the flat Coastal Plain. The river extends downstream from the Scotland County-Hoke County border to the North Carolina-South Carolina border. Big Marsh swamp, Little Raft Swamp, and Raft Swamp are tributaries that contribute to the Lumber River Watershed. The Lumber River flows into Nichols, South Carolina where it ends at the confluence with the Little Pee Dee River. Inland communities across the state are at risk from flooding due to extreme precipitation throughout the entire year.

Flooding in the project area primarily results from:

- Extensive rainfall throughout the year;
- Multi-day rainstorms leading to saturated soils;
- Warm Atlantic Ocean and getting warmer contributing to the increased rainfall; and
- Increase in intensity and frequency of Hurricanes.

These climate factors are the primary cause of floods that damage infrastructure in the project area and the focus of this climate hazard analysis.

2. Current Conditions

Large rainfall events can occur at any time of the year and cause flooding in the project area. Most recently, in November2020, a record average annual maximum 1-day precipitation totals was set at Lumberton, North Carolina at the municipal Airport. An average annual maximum 1-day record rainfall of 2.76in was set at Lumberton (NOAA and NWS, weather.gov ‘Lumberton, NC’). This breaks the previous record of 2.07 in set in 2009, which is a 33% increase. This is the average annual maximum 1-day precipitation total for each epoch-scenario. The intensity of the 1-day event is a particularly good metric for estimating changes in flash and urban flooding exposure. Larger numbers indicate increased exposure.

Not only is the rainfall throughout the entire year a great concern, the multiday storms exacerbate the flooding issues within this region. The five-day maximum precipitation total for the Lumber River Watershed is 4.45 in (Gade et al. 2020 “Indicator Values for the Lumber River Watershed”). Unlike 1-day precipitation, the five-day maximum precipitation measure can consider the effect of saturated soils on exacerbating flood risk by increasing the share of precipitation that runs off once the soil is saturated. Larger numbers indicate increased exposure. The saturated soils from the multiday storms only worsen the flooding in this area, because the rainfall cannot be absorbed into the soil, thus causing a larger and faster runoff.

The warmer Atlantic Ocean leads to an increase in moisture in the environment, thus more rainfall events. Climate change is likely causing parts of the water cycle to speed up as warming global temperatures increase the rate of evaporation worldwide. With more evaporation, there is more

water in the air so storms can produce more intense rainfall events in some areas. This can cause flooding – a risk to the environment and human health.
Hurricanes are another source of flood risk in the project area. Communities along the Lumber River have experienced major flooding events over the past 25 years, with Hurricanes Fran (1996), Floyd (1999), Matthew (2016) and Florence (2018) all ranking among the most destructive storms in state history (Kunkle et al 2020). The damage from these storms was due primarily to flooding that resulted from the widespread heavy rains that accompanied the storms. Hurricane frequency for this watershed is 2.71% per year (Gade et al. 2020,"Indicator Values for the Lumber River Watershed"), which is the mean annual probability of being impacted by a hurricane, defined as being within 200 km buffer around the hurricane track.

Flooding puts people and infrastructure at risk. Energy infrastructure located along inland watersheds is vulnerable to flooding during heavy precipitation events. Heavy precipitation from more intense and frequent storms can cause significant damage to public and private structures such as homes, roads, utility services, etc. Vulnerable populations are most at risk of flooding and may have difficulty evacuating when necessary. Flooding posts a threat to archaeological and historic sites on floodplains across all three physiographic regions and within every river basin in the state. Increased or more frequent flooding may inundate and potentially destroy more cultural resources.

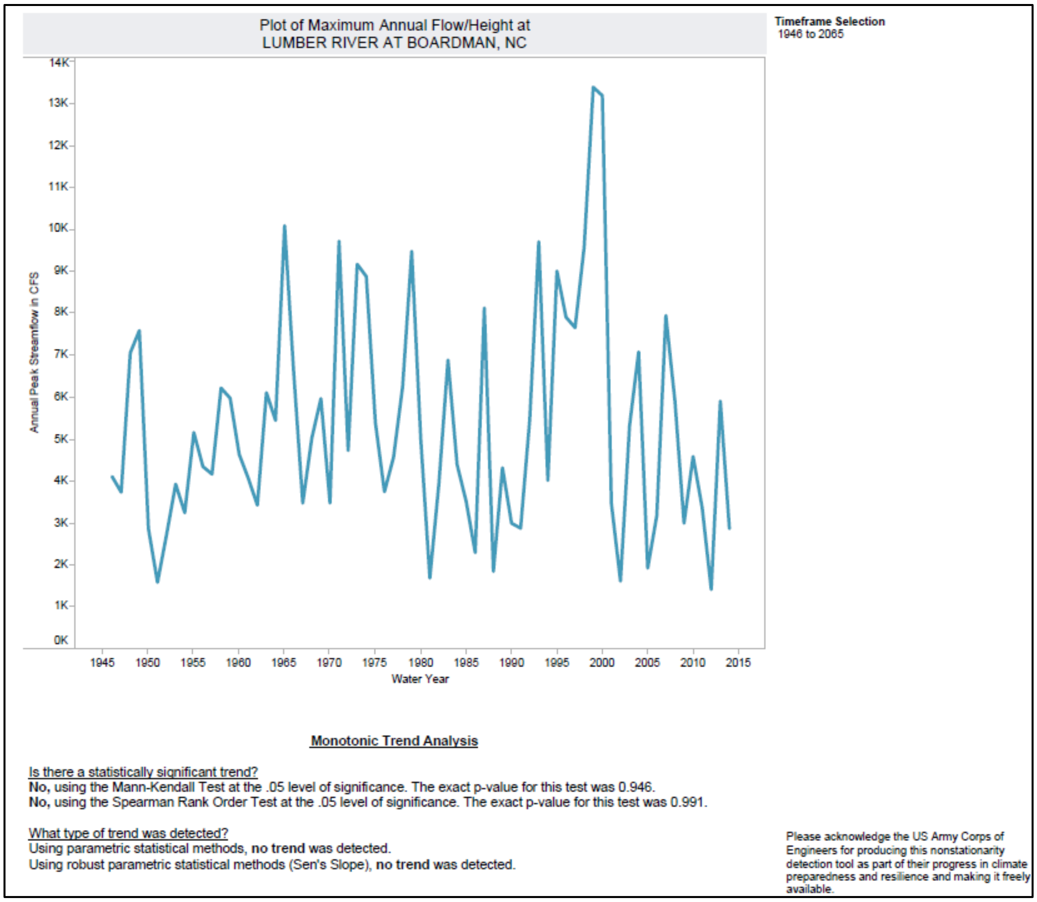

Figure 2.1 - Trend Analysis of Boardman, NC along the Lumber River for the timeframe 1946-2065 using the Nonstationary Tool USACE (Gade et al. 2020.).

Figure 1 shows the trend analysis for Lumber River at Boardman, NC for the years 1946 to 2065. This location was chosen because it provided the appropriate historical data range and is located downstream of the confluence of Big Marsh Swamp and the Lumber River, at one of the final USGS gages along the Lumber River. As indicated by the Nonstationary Detection Tool developed by USACE there is no significant Trend in this location.

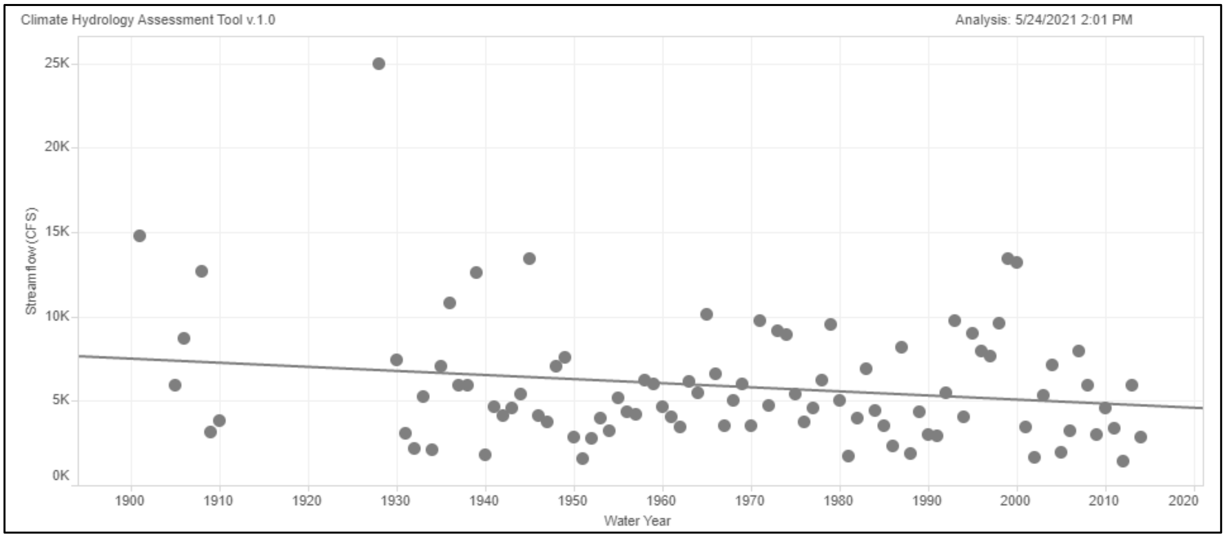

Figure 2.2 - Annual Peak Instantaneous Streamflow, LUMBER AT BOARDMAN, NC (Gade et al., 2020 Climate Hydrology Assessment Tool).

The annual peak instantaneous streamflow plot made available through the Climate Hydrology Assessment Tool (CHAT) shows that there is a slight downward trend of streamflow vs. water year is shown in Figure 2.

3. Future Conditions

The intensity of the strongest rainfall is likely to increase with warming of the oceans and atmosphere, leading to greater damage to people, communities, our economy and natural resources from more intense hurricanes and accompanying flooding and precipitation. Sea surface temperature increased during the 20th century and continues to rise, enhancing precipitation in the project area. More frequent flooding will impact inland habitats, fisheries, and the protective services that natural areas provide to local communities.

The intense rainfall events are expected to increase in magnitude and frequency as well as the multi day rainfall events, which exacerbate the flooding issues in this region.

From 1901 through 2020, global sea surface temperature rose at an average rate of 0.14°F per decade (see Figure 3). Sea surface temperatures are projected to increase in the future, and these warmer temperatures are expected to contribute to increasing precipitation intensity in the project area. In addition, many storms draw moisture from the nearby Atlantic Ocean, and warming sea surface temperatures are expected to increase the available moisture, enabling larger storms to form and increase the precipitation in the project area.

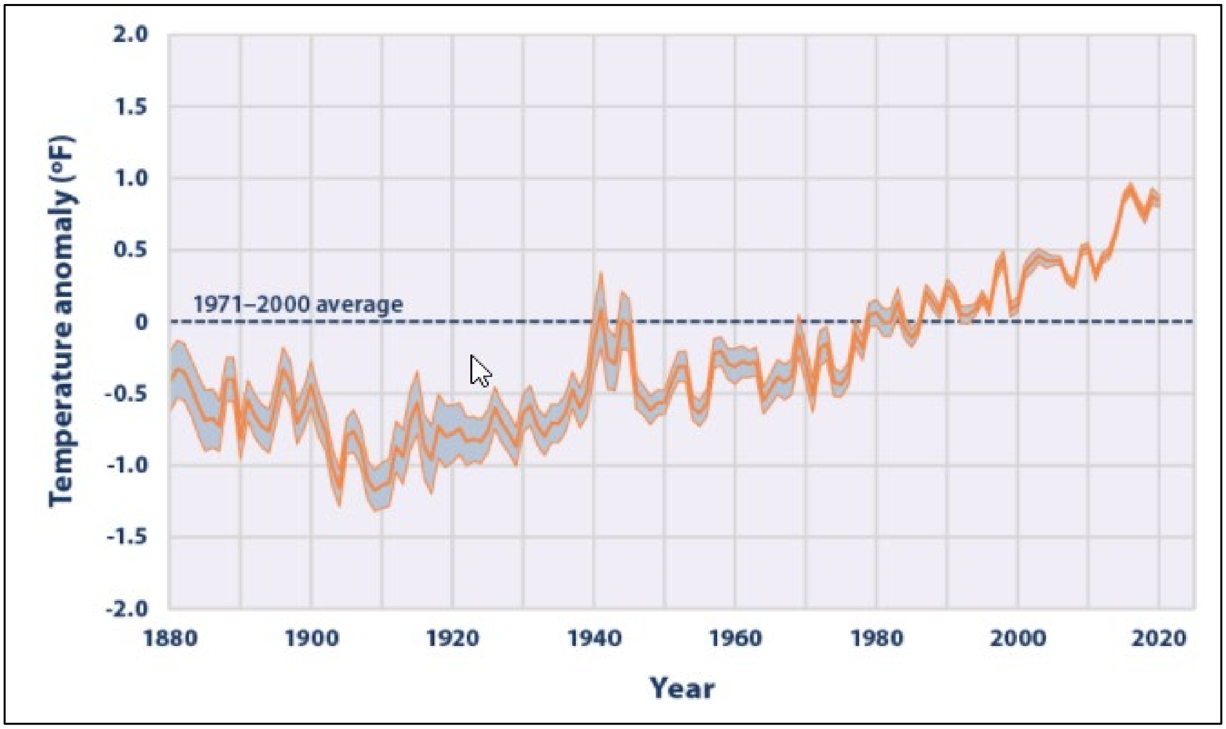

Figure 3.1 - Average Global Sea Surface Temperature Change, 1881-2020. (NOAA, 2021).

An increase of the intensity hurricane rainfall is a major concern for this area in a warmer climate. Heavy precipitation accompanying hurricanes and other weather systems is likely to increase, thus increasing the potential for flooding in inland areas, such as this area. For the Lumber River Watershed, the average number of days of extreme precipitation days is expected to increase to an average of 4.94 days per year. This refers to the average annual number of days in which precipitation in the future is projected to exceed the amount that occurred 1% of the days in the historic period. This provides a measure of future increases in precipitation intensity that is relative to current conditions and can be used to assess how frequently heavy precipitation events may disrupt activities, and potentially overwhelm existing flood risk management infrastructure. Stronger hurricanes will destroy or damage public and private buildings and property. Increased inland flooding caused by extreme precipitation events will further increase economic and agricultural losses after a flooding event.

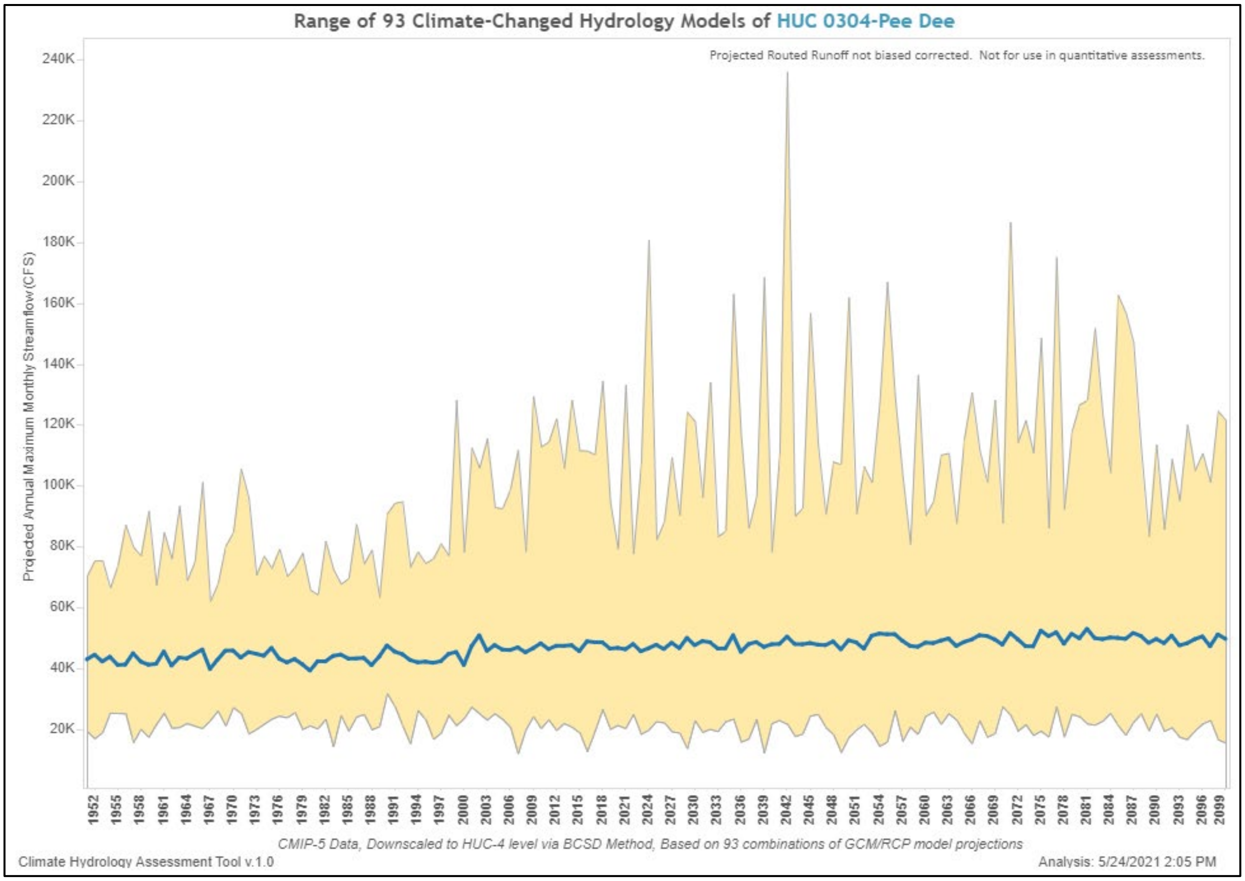

Figure 3.2 - Range of 93 Climate-Changed Hydrology Models of HUC 0304-Pee Dee (Gade et al.,2020 Climate Hydrology Assessment Tool).

Figure 4 shows the climate changed hydrology models for the HUC that the Lumber River watershed is within. As indicated in the plot, the projected annual maximum monthly streamflow has increasingly intense events, but the trendline continues at a slight upward trend.

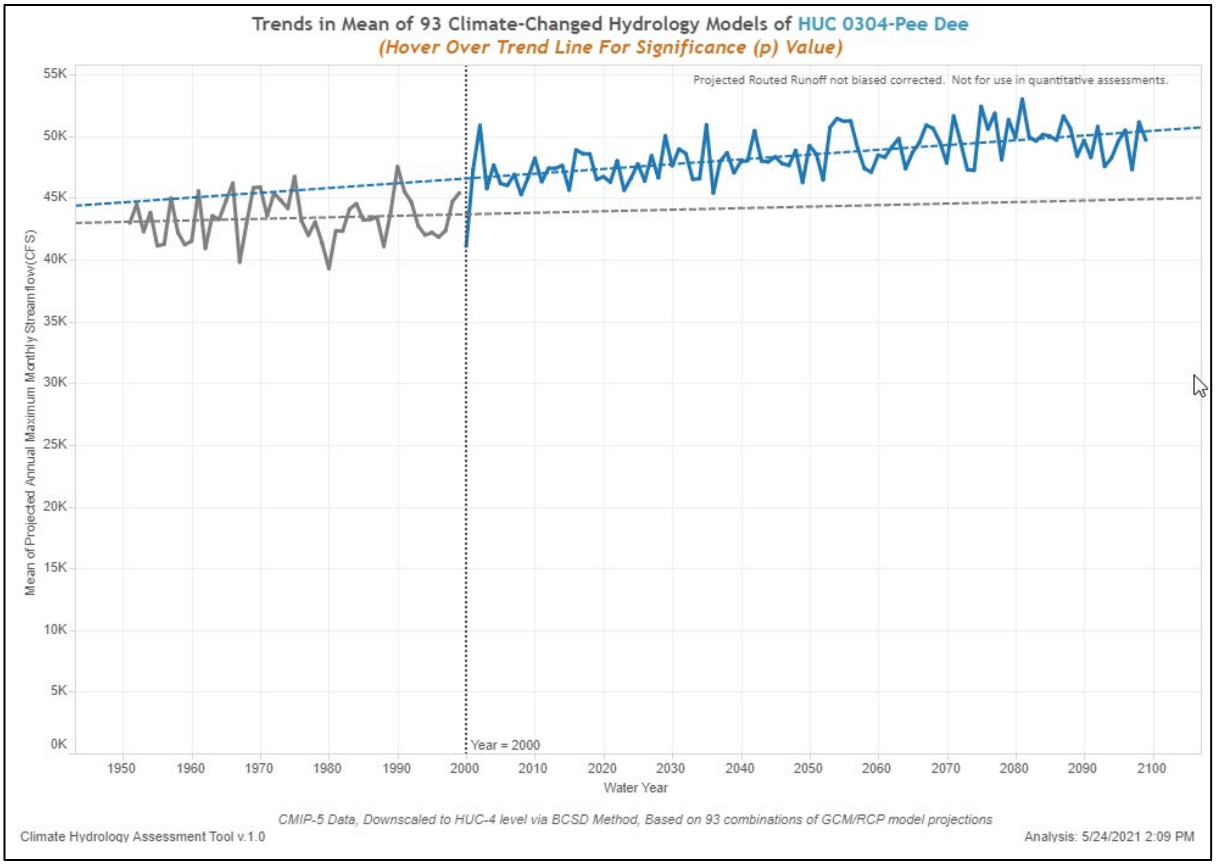

Figure 3.3 - Trends in Mean of 93 Climate-Changed Hydrology Models of HUC 0304- Pee Dee (Gade et al., 2020).

Similarly in figure 5, the mean of projected annual maximum monthly streamflow has an upward trend from 2000 to 2100. This shows the projected increase in streamflow for the Pee Dee HUC.

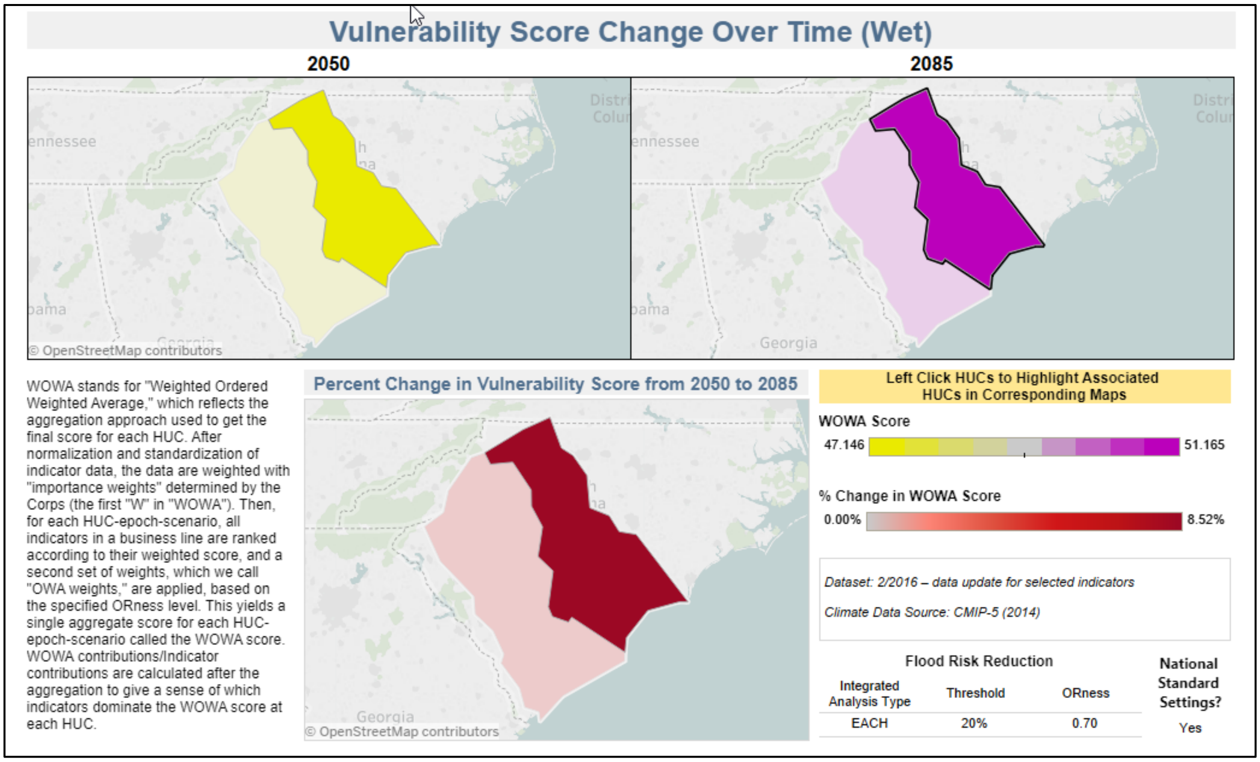

Figure 3.4: Vulnerability Score change over time for the Pee Dee watershed (Gade et al., 2020 Civil Works Vulnerability Assessment Tool).

Figure 6 shows a visualization of climate risk scores change over time for the Lumber River watershed region. The change in climate risk score changes over time from the year 2050 to 2085. The WOWA (Weighted Ordered Weighted Average) score indicate as 47.146 in 2050 and 51.165 in 2085, with a change in score of 8.52% (Gade et. al. 2020).

4. Summary

In summary, flooding in the project area is due to extensive rainfall throughout the year, multi-day rainstorms leading to saturated soils, warmer Atlantic Ocean is contributing to the increased rainfall and an increase in intensity and frequency of hurricanes.

The projected changes and impacts to Lumber River Watershed include an increase of rainstorms and extreme rainfall events causes flooding that puts people and infrastructure at risk. Stronger hurricanes coupled with extreme precipitation will destroy or damage public and private buildings and property. Increased inland flooding caused by extreme precipitation events will further increase economic and agricultural losses after an event. Vulnerable populations are most at risk of flooding and may have difficulty evacuating when necessary.

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Lumber River Basin
Flood Risk Management Study

Charleston District
South Atlantic Division

Appendix B – Information on Other USACE Programs
September 2021

SECTION 729
WATERSHED ASSESSMENTS

U.S. ARMY CORPS OF ENGINEERS **BUILDING STRONG®**

WHAT CAN THE CORPS DO?

Section 729 of the Water Resources Development Act of 1986, as amended, provides authority for the U.S. Army Corps of Engineers (USACE) to assess the water resources needs of entire river basins and watersheds of the United States, in consultation with appropriate federal, state and local agencies and stakeholders.

The objective of a Section 729 study is the development of a Watershed Management Plan (WMP) which identifies water resources problems and needs within a watershed and seeks to address those issues using a watershed approach. A watershed approach entails working collaboratively with all concerned stakeholders to help solve water resource problems in an integrated and sustainable manner. Water resource issues are analyzed on a large geographic scale and strategies and plans are developed with the goal of using water resources in a balanced way which reflects the needs and desires of a wide range of stakeholders. Typically, the WMP will culminate is a series of recommendations which will address the identified water resource issues via general, non-project specific plans and/or strategies.

THE PROCESS

After a state or local agency requests Federal assistance, the Corps will begin working to identify a non-Federal sponsor and obtain a Letter of Intent (LOI). The study is conducted in a single phase, which is cost shared 75/25 with the non-Federal sponsor, according to a Section 729 Assessment Agreement (also known as a Cost Share Agreement). Early in the study process stakeholder engagement takes place in order to identify problems, needs and opportunities within the watershed. With continued stakeholder involvement, active management strategies are formulated and evaluated. These strategies may include non-USACE, as well as USACE authorities and programs. Once the WMP has been developed, it is reviewed by stakeholders and applicable resource agencies, and once administrative review requirements are completed, is forwarded to USACE Headquarters for approval. This process may take between 18-24 months.

WHAT ARE THE LOCAL RESPONSIBILITIES?

Costs for Section 729 projects are shared between the Federal government and a non-Federal sponsor in accordance with the Water Resources Development Act of 1986, as amended. The non-Federal sponsor must contribute 25% of the total project cost. This contribution may take the form of cash, work in-kind or any combination thereof. The local sponsor (a state or local government) must have the legal and financial capability to fulfill the requirements of cost sharing and local cooperation.

HOW CAN A STUDY BE REQUESTED?

A Section 729 study may be initiated after receipt of a formal request from the prospective sponsoring agency. A sample letter is offered below. This letter is generally referred to as a Letter of Intent (LOI) and must be received by the Corps from a prospective non-Federal sponsor prior to initiating the study.

Planning Assistance to States

U.S. ARMY CORPS OF ENGINEERS **BUILDING STRONG®**

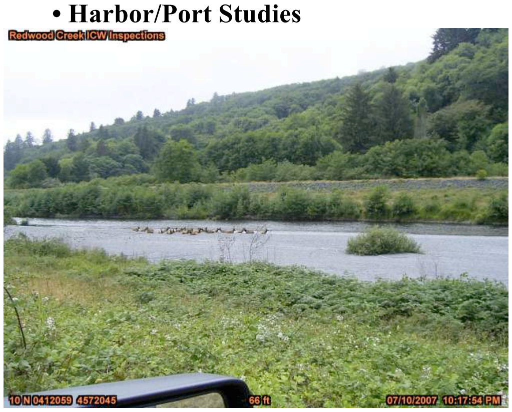
States, local governments and Native American Tribes often have needs in planning for water and related resources of a drainage basin or larger region of a state, for which the Corps of Engineers has expertise.

Authority and Scope. Section 22 of the Water Resources Development Act (WRDA) of 1974, as amended, provides authority for the Corps of Engineers to assist the States, local governments, Native American Tribes and other non-Federal entities, in the preparation of comprehensive plans for the development and conservation of water and related land resources.

Program Development. The needed planning assistance is determined by the individual States and Tribes. Typical studies are only undertaken at the planning level of detail; they do not include detailed design for project construction. The studies generally involve the analysis of existing data for planning purposes using standard engineering techniques although some data collection is often necessary. Most studies become the basis for State or Tribal and local planning decisions.

Typical Studies. The program can encompass many types of studies, dealing with water resources issues. Types of studies conducted in recent years under the program include the following:

- **Water Supply and Demand Studies**
- **Water Quality Studies**
- **Environmental Conservation/Restoration Studies**
- **Wetlands Evaluation Studies**
- **Dam Safety/Failure Studies**
- **Flood Risk Management Studies**
- **Flood Plain Management Studies**
- **Coastal Zone Management/Protection Studies**
- **Harbor/Port Studies**



Redwood Creek flow capacity study

Eau Galle River nutrient study for water quality

Funding. The Planning Assistance to States program is funded annually by Congress. Federal allotments for each State or Tribe from the nation-wide appropriation are limited to $2,000,000 annually, but typically are much less. Individual studies, of which there may be more than one per State or Tribe per year, are cost shared on a 50 percent Federal - 50 percent non-Federal basis (may include 100% work in kind).

How to Request Assistance. State, local government and Tribal officials who are interested in obtaining planning assistance under this Program can contact the appropriate USACE office for further details. Alternatively, interested parties can contact the appropriate State or Tribal Planning Assistance to States coordinator to request assistance. In either case, USACE will coordinate all requests for assistance with the State or Tribal Planning Assistance to States coordinator to ensure that studies are initiated on State or Tribal prioritized needs.

People that live and work in the flood plain need to know about the flood hazard and the actions that they can take to reduce property damage and to prevent the loss of life caused by flooding.

The Flood Plain Management Services (FPMS) Program was developed by the Corps of Engineers specifically to address this need.

Authority, Objective, and Scope. The program's authority stems from Section 206 of the 1960 Flood Control Act (PL 86-645), as amended. Its objective is to foster public understanding of the options for dealing with flood hazards and to promote prudent use and management of the Nation's flood plains.

Land use adjustments based on proper planning and the employment of techniques for controlling and reducing flood damages provide a rational way to balance the advantages and disadvantages of human settlement on flood plains. These adjustments are the key to sound flood plain management.

Types of Assistance. The FPMS Program provides the full range of technical services and planning guidance that is needed to support effective flood plain management.

a. General Technical Services. The program develops or interprets site-specific data on obstructions to flood flows, flood formation and timing; and the extent, duration, and frequency of flooding. It also provides information on natural and cultural flood plain resources of note, and flood loss potentials before and after the use of flood plain management measures.

b. General Planning Guidance. On a larger scale, the program provides assistance and guidance in the form of "Special Studies" on all aspects of flood plain management planning including the possible impacts of off-flood plain land use changes on the physical, socio-economic, and environmental conditions of the flood plain.

This can range from helping a community identify present or future flood plain areas and related problems, to a broad assessment of which of the various remedial measures may be effectively used.

Some of the most common types of Special Studies include:

- **Flood Plain Delineation/Flood Hazard Evaluation Studies**
- **Dam Break Analysis Studies**
- **Hurricane Evacuation Studies**
- **Flood Warning/Preparedness Studies**
- **Regulatory Floodway Studies**
- **Comprehensive Flood Plain Management Studies**
- **Flood Risk Management Studies**
- **Urbanization Impact Studies**
- **Stormwater Management Studies**
- **Flood Proofing Studies**
- **Inventory of Flood Prone Structures**
- **Evaluation of Levees for Potential FEMA Certification**

Example of a typical flood proofed structure

The program also provides guidance and assistance for meeting standards of the National Flood Insurance Program, flood risk communication and for conducting workshops and seminars on non-structural flood plain management measures, such as Flood Proofing.

c. Guides, Pamphlets, and Supporting Studies. Studies are conducted under the program to improve the methods and procedures for mitigating flood damages. Guides and pamphlets are also prepared on flood proofing techniques, flood plain regulations, flood plain occupancy, natural flood plain resources, and other related aspects of flood plain management.

The study findings and the guides and pamphlets are provided free-of-charge to Federal agencies, Indian Tribes, State, regional and local governments and private citizens for their use in addressing the flood hazard.

Charges for Assistance. Upon request, program services are provided to State, regional, and local governments, Indian Tribes, and other non-Federal public agencies without charge.

State, regional, local government, non Federal pubic agencies and Tribes can request activities/assistance under this program and provide voluntary funding. For most of these requests, payment is required before services are provided. Letter requests or signed agreements are used.

All requestors are encouraged to furnish available field survey data, maps, historical flood information and the like, to help reduce the cost of services.

Meeting with local governmental officials

How to Request Assistance. Agencies, governments, organizations, and individuals interested in flood-related information or assistance should contact the appropriate Corps office. Information that is readily available will be provided in response to a telephone request. A letter request is required for assistance that involves developing new data, making a map, or preparing a report.