FINAL REPORT – HYDROLOGIC AND HYDRAULIC STUDY

TOWN OF SUMMERTON, SC | SC OFFICE OF RESILIENCE

MAY 2023

SEAMONWHITESIDE

McCORMICK TAYLOR

Final Report – Hydrologic and Hydraulic Study

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Town of Summerton Hydrologic and Hydraulic Study

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Executive Summary

A comprehensive hydrologic and hydraulic study was completed for the Town of Summerton to investigate the existing drainage system, identify drainage system deficiencies, and develop solutions to address systemic flooding. Meetings with town officials and residents helped shape the scope of this investigation and highlight areas of concern that were at an increased risk of flooding. The existing drainage network was then surveyed to identify all visually apparent drainage infrastructure within areas of concern. Most notably, it was discovered during these field investigations that most of the town north of Larry King Jr Highway/Main St drains to a central trunk line that routes stormwater to an outfall south of Evergreen Cemetery (see **Figure i** and **Appendix A**).

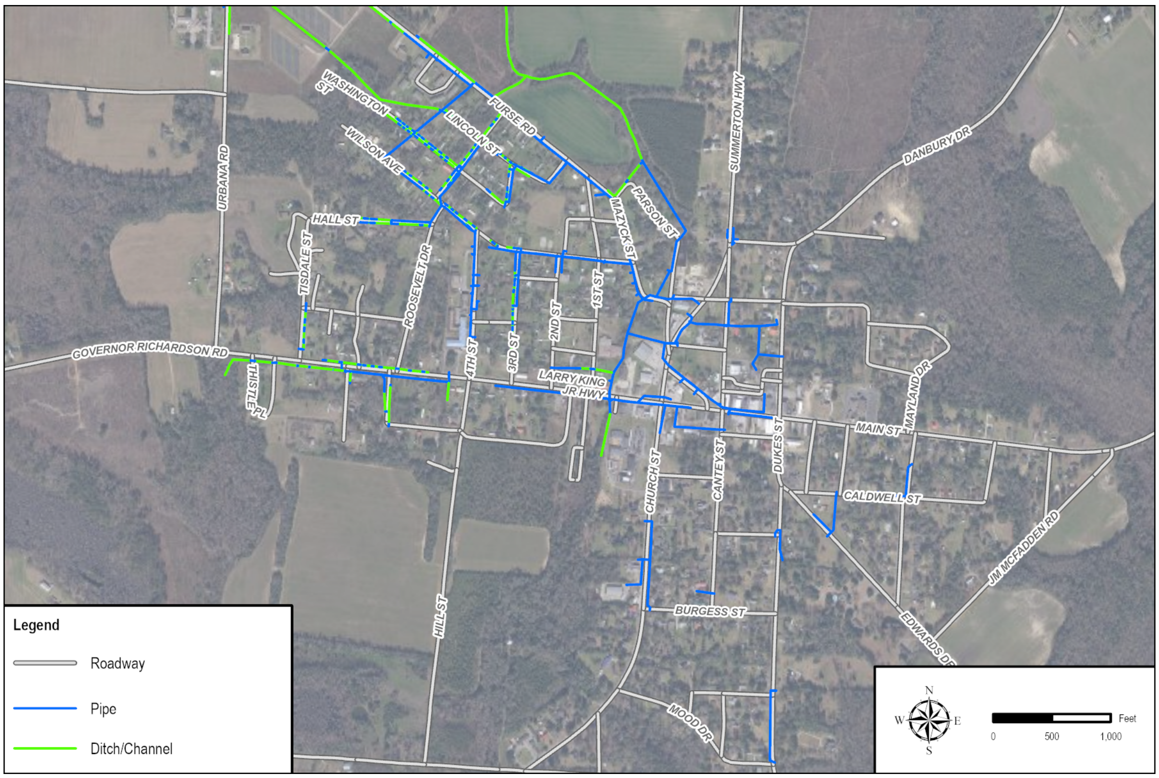
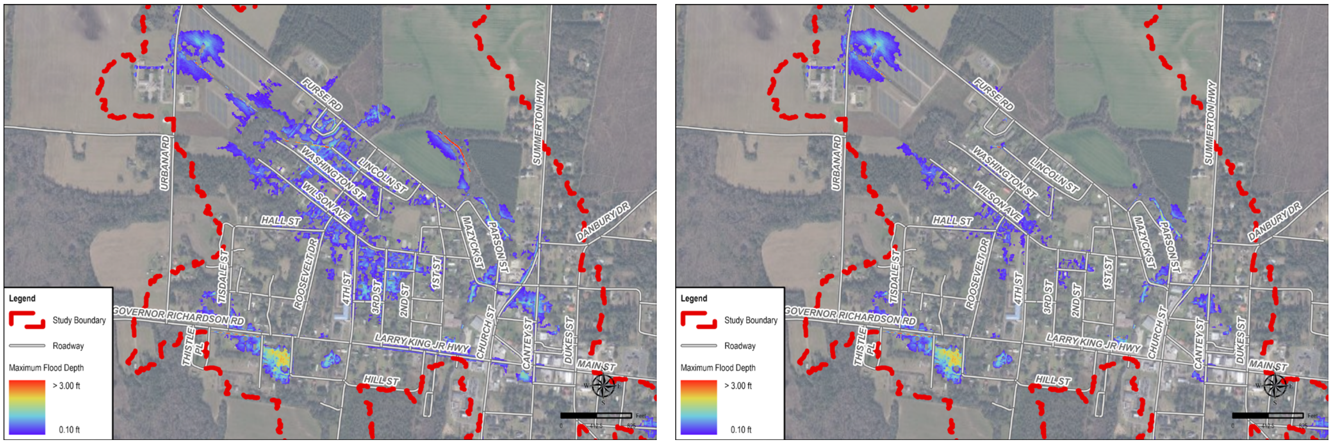


Figure i – Extents of drainage infrastructure survey and/or evaluated by field investigations.

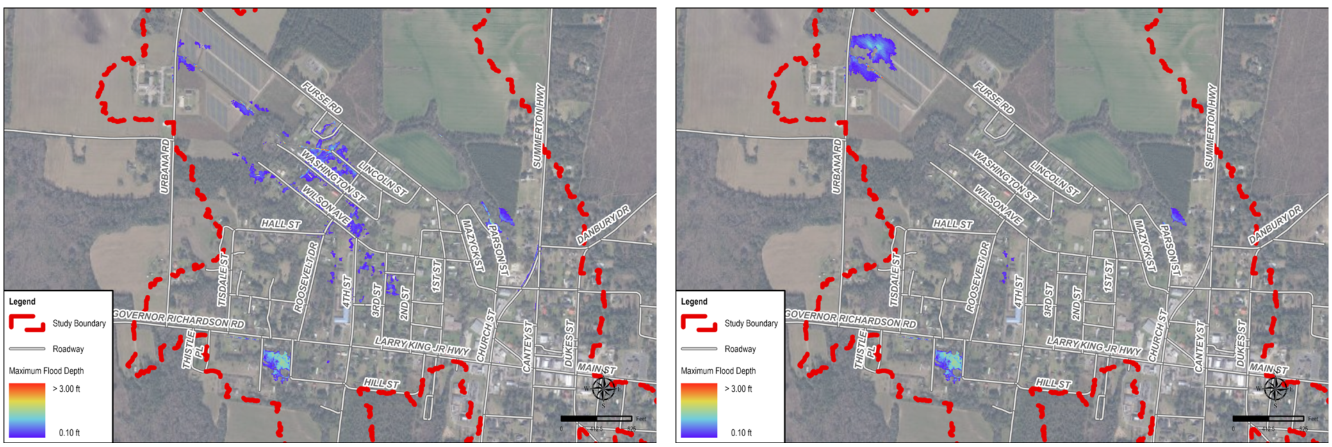
Following completion of this inventory of existing drainage infrastructure, a comprehensive hydrologic assessment was completed to delineate watersheds and determine critical hydrologic parameters (i.e., soil characteristics, land use/land cover classifications, etc.) used to determine the volume and rate of runoff routed to the existing drainage system during rainfall events. Using the results of the existing drainage infrastructure inventory and hydrologic assessment, a combined 1D/2D hydrologic and hydraulic model was developed. This combined 1D/2D model allowed for investigations to not only consider flow within the drainage network (1D) but also the depth, extent, and duration of flooding (2D) that occurred.

Several rainfall scenarios were investigated to identify drainage system deficiencies. Specifically, the existing drainage system's response to high-intensity (NRCS/SCS Type-II) and realistic-intensity (SC Long) rainfall events for the 2-, 10-, 25-, and 100-year design rainfall depths were investigated. Results from this analysis confirmed most residents' concerns (in addition to several more identified as part of this analysis) with the exceptions of those related to maintenance deficiencies within the system (i.e., clogged inlets, etc.).

Alternatives that would alleviate flooding were investigated. The alternatives analysis consisted of an iterative process in which existing drainage infrastructure in the model was improved to investigate how those improvements could mitigate flooding. These improvements



(a) Existing (left) and Proposed (right) NRCS/SCS Type-II



(b) Existing (left) and Proposed (right) SC Long

Figure ii – Comparison of existing (left) and proposed (right) flood results for an intense 10-year (NRCS/SCS Type-II) rainfall event (a) and an average 10-year (SC Long) rainfall event.

generally consisted of upgrading existing drainage infrastructure (upsizing pipes to a larger diameter or adding additional barrels), installation of new drainage infrastructure (new inlets or closed piping systems), installation of detention facilities, and re-routing watersheds that exacerbate flooding within their existing drainage systems.

The criteria used to determine if the proposed improvements appropriately mitigated flooding was based on the ability to substantially mitigate flooding during the 2- and 10-year NRCS/SCS Type-II rainfall events. Secondary design criteria was based on an improvement's ability to mitigate flooding during the 2- and 10-year SC Long rainfall events. Final improvements underwent a proposed conditions flood analysis to investigate the proposed drainage system's response to all the same rainfall events as the existing conditions flood analysis to allow for simple comparison of any proposed improvements' effectiveness across a wide range of scenarios. An example of this can be found in **Figure ii** which compares the existing and proposed flood results for the 10-year high-intensity (NRCS/SCS Type-II) rainfall event and the 10-year realistic-intensity (SC Long) rainfall event.

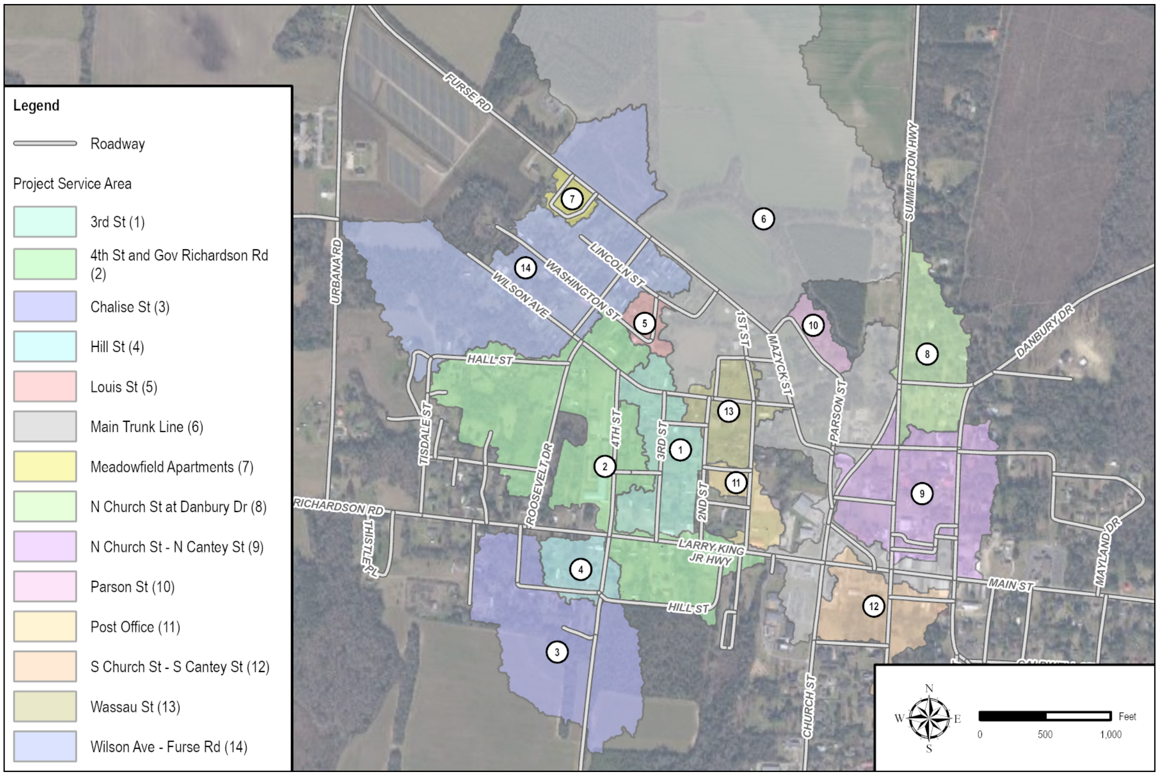


Figure iii – Project service areas.

The results from the proposed conditions flood analysis were then investigated to determine which improvements needed to be implemented concurrently as individual infrastructure improvement projects and to determine project prioritization and scheduling. Overall, proposed improvements were divided into 15 infrastructure improvement projects (see **Figure iii**). Implementation cost of each project (including engineering, construction administration, and permitting) was estimated and a benefit-cost analysis (using FEMA methodology) was performed to determine the cost effectiveness of each project (benefits vs cost). Using a ranked scoring metric (which weighted each project's benefit-cost ratio, impacted buildings, and flood reduction), results from a series of "what-if" analyses, and engineering judgement, a final list of recommended projects was determined including their final priority/ranking (see **Table i**). All recommended projects are located within Low-to-Moderate Income populations which should provide substantial flood relief for those communities.

Ahead of any project implementation or construction it is recommended that the town engage in two tasks. The first task is to engage the South Carolina Department of Transportation (SCDOT) to pursue maintenance (cleaning inlets and pipes) along SCDOT maintained roads, especially in areas of concern identified during this study, to provide some immediate flood relief to residents. The second task would be to deploy hydrologic monitoring equipment at key locations within the town's drainage system. Specifically, this monitoring equipment would need to measure (at a high resolution) water depth and rainfall for as long as possible to capture the hydrologic response of the existing drainage infrastructure to high intensity or infrequent rainfall events.

Table i – Summary of recommended priority projects including their estimated project cost, benefit-cost ratio, and final ranking/priority. Projects in bold represent high-priority projects that should be pursued first.

Project	Estimated Project Cost	Benefit-Cost Ratio	Final Ranking
Wilson Ave – Furse Rd	**$9,107,000**	**2.96**	**1**
4th St and Gov Richardson Rd	**$8,631,000**	**1.1**	**2**
3rd St	**$2,470,000**	**7.05**	**3**
Main Trunk Line	**$12,868,000**	**0.85**	**4**
Meadowfield Apartments	**$759,000**	**11.67**	**5**
Wassau St	**$1,625,000**	**3.63**	**6**
Parson St	**$294,000**	**4.47**	**7**
N Church St – N Cantey St	$2,349,000	0.77	8
Louis St	$952,000	0.33	9
N Church St at Danbury Dr	$634,000	0.13	10
Post Office	$318,000	0.14	11
Hill St	$484,000	0.09	12
S Church St – S Cantey St	$811,000	0.01	13
Chalise St	$1,022,000	0	14

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1.0 Introduction, Background, and Overview of Project

The purpose of this comprehensive hydrologic and hydraulic study completed for the Town of Summerton was to investigate the existing drainage system, identify drainage system deficiencies, and develop solutions to address systemic flooding. The following report outlines data collected, methodology for assessing drainage system capacities and addressing systemic flooding, and a final list of recommended projects.

1.1 Study Area

The Town of Summerton is located in Clarendon County, South Carolina approximately 5 miles northeast of Lake Marion. The incorporated town covers a land area of approximately 1.4 square miles with a 2020 population of 814 according to the United States Census Bureau. Most of the town is zoned for residential use with a central commercial district as well as commercial and industrial land uses near Interstate 95 in the southern spur of town.

1.1.1 Demographics

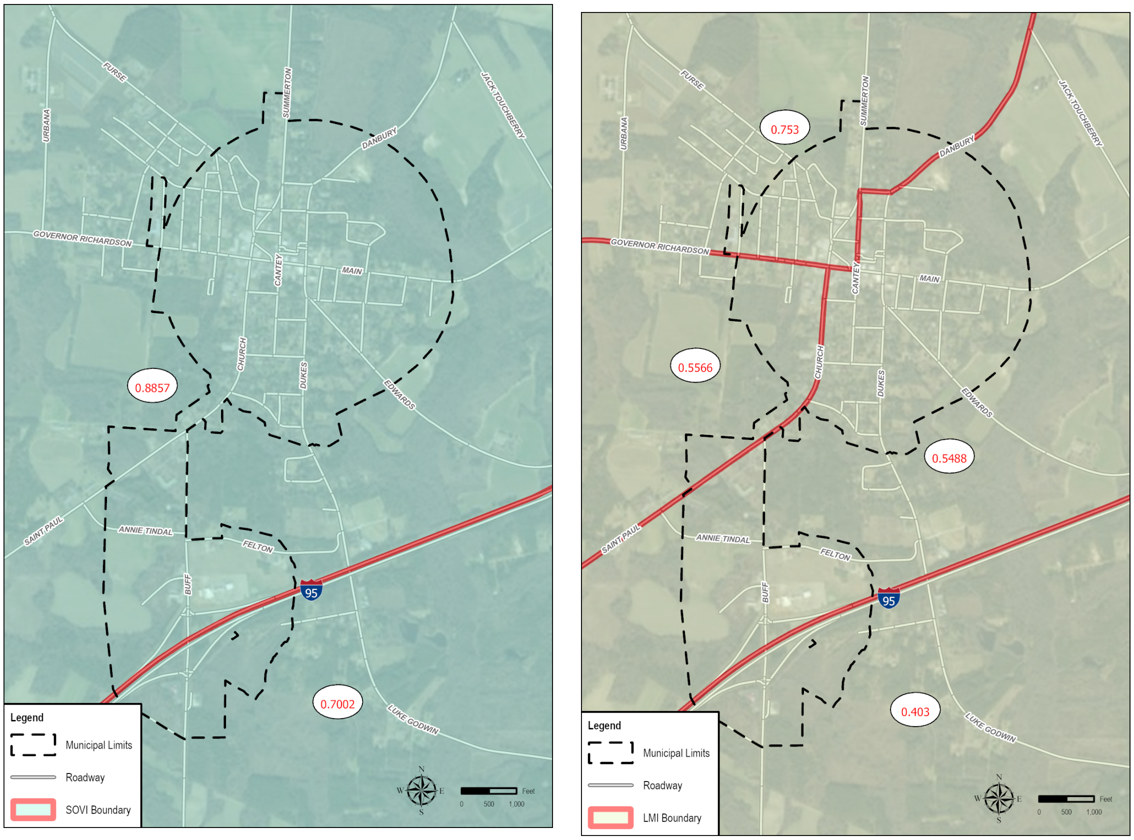
Demographic data was obtained from the United States Census Bureau for 2020. A summary of this data is shown in **Table 1**.

Table 1 – Demographic data for the Town of Summerton.

Parameter	Town of Summerton	South Carolina
Total population	814	5,118,425
Median age	50.7	39.7
Above age 65	31.90%	17.70%
Veteran	5.00%	9.10%
Disabled persons	14.50%	14.50%
Under age 18	11.80%	21.80%
Black or African American	53.07%	25.02%
Hispanic or Latino	2.09%	6.89%
White	42.51%	63.37%
Two or more races	1.35%	5.83%
Other races	2.46%	3.54%
Median household income	$24,183	$54,864
Poverty rate	27.90%	14.70%
Bachelor’s degree or higher	35.50%	29.00%
Employment rate	35.50%	56.20%
Median gross rent	$258	$918
Homeownership rate	56.10%	70.10%
Total housing units	427	2,344,963
Housing value less than $50k	36.30%	10.70%
Housing value $50k-$99.999k	15.50%	15.40%
Housing value $100k-$149.999k	15.90%	16.00%
Housing value $150k-$199.999k	19.60%	16.60%
Housing value $200k-$299.999k	4.10%	19.20%
Housing value $300k-499.999k	6.90%	14.40%
Average family size	2.53	3.13

1.1.2 Social Vulnerability and Low-to-Moderate Income

The Town of Summerton has high a social vulnerability index (SoVI) with the exception of the extreme southern edge according to the 2018 SVI index published by the United States Center for Disease Control and Prevention. SoVI values range from 0 to 1 with values closer to 1 representing areas with the highest vulnerability. **Figure 1a** presents SoVI indices for the town with a dominant value of 0.8857. This indicates that most of the town is at an increased risk of vulnerability to impacts from natural hazards including flood-related events. The percentage of Low-to-Moderate Income (LMI) households are documented by the United States Department of Housing and Urban Development (HUD). LMI values for the Town of Summerton are presented in **Figure 1b**. Based on these LMI statistics, the majority of the town is well above the 50% threshold required to receive priority from community development block grant funding (e.g., SCOR CDBG-MIT program).



(a) (b)

Figure 1 – Social vulnerability index (a) and percentage of low-to-moderate Income (b) households in Summerton.

1.2 Hydrologic Background

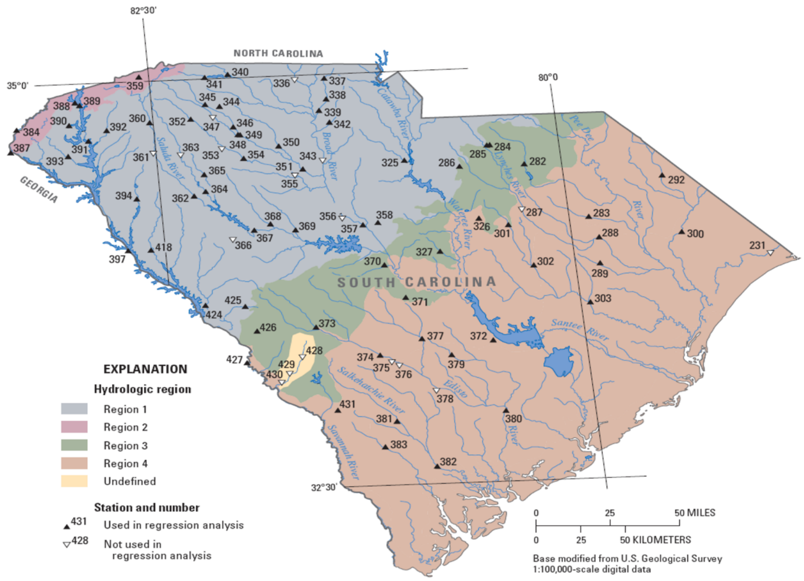
In this section, the hydrologic setting of the Town of Summerton is presented and discussed. The data include the hydrographic regions, major watersheds, local drainage patterns, and stream gauge and rainfall data.

1.2.1 Hydrographic Region

Located within the South Carolina Hydrologic Region 4, the Town of Summerton is within the Southeastern Plains ecoregion (see **Figure 2**). These zones dictate the parameters used in regional regression equations for hydrological calculations relating rainfall to runoff.

1.2.2 Major Watersheds

Figure 3 presents major watersheds of South Carolina. The Town of Summerton lies within the Santee River Basin. Upstream, the combined Broad and Saluda River Basins along with the Catawba River Basin drain into the Santee River and the Santee River basin northwest of Lake Marion. The Santee River continues seaward where it discharges into the Atlantic Ocean.



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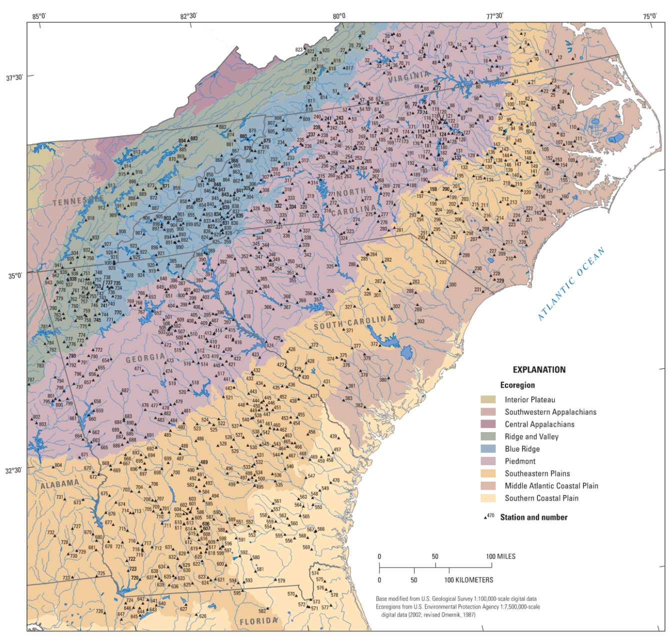


(b)

Figure 2 – Hydrologic regions of South Carolina (a) and ecoregions of the southeastern United States (b) (Source: USGS).

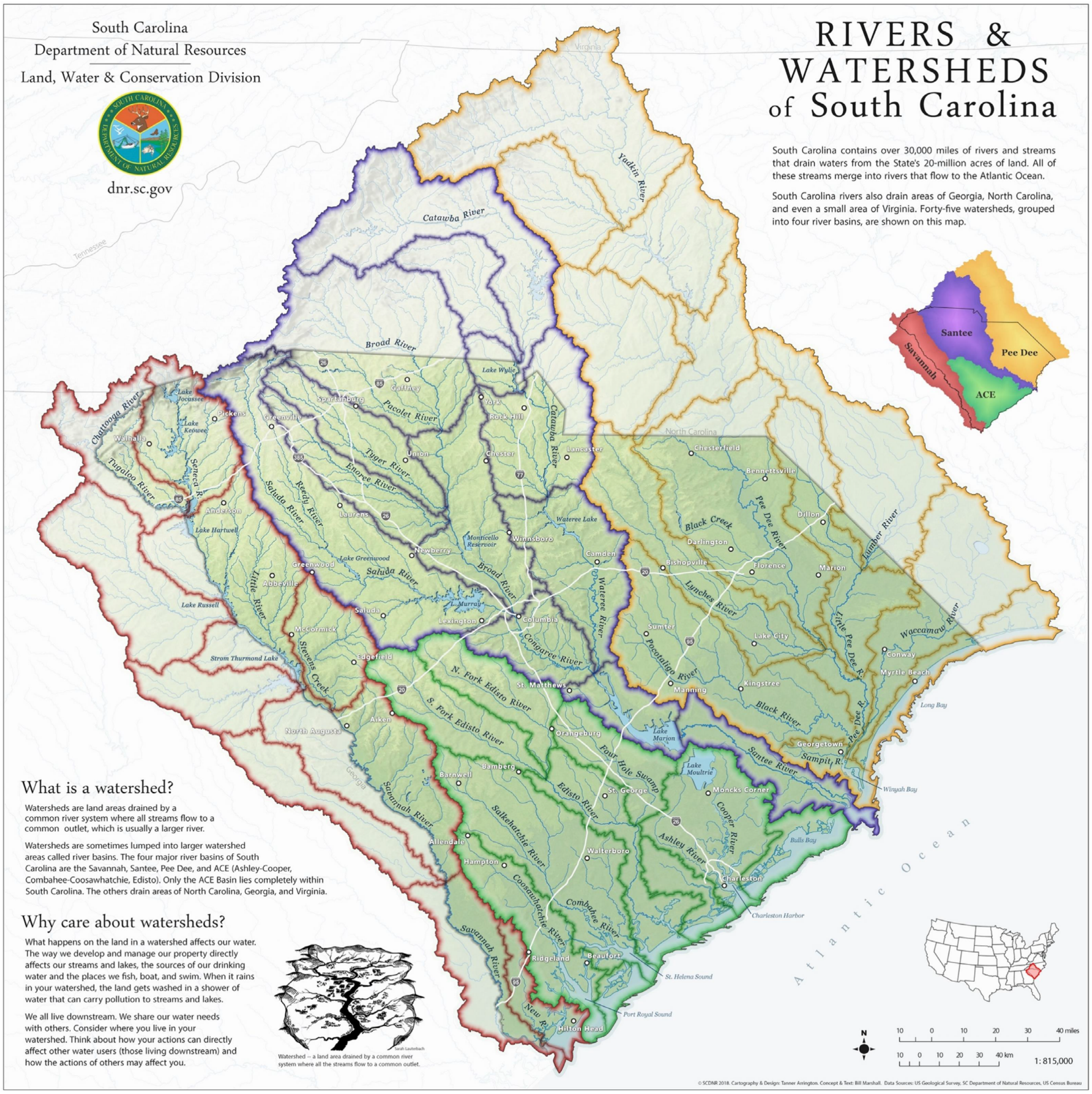


Figure 3 – Major watersheds of South Carolina (Source: SCDNR).

1.2.3 Local Topography and Drainage Directions

The Town of Summerton receives stormwater from the northwest which passes through the center of the town before entering Tributary 8 (of Tawcaw Creek) which connects to Tawcaw Creek to the southeast (**Figure 4**). The northeastern and southeastern portions of the town drain directly to Tawcaw Creek which eventually discharges into Lake Marion. The central portion of the town, and many of the main highways (e.g., US- 301/Main Street and US-15/Church Street), drain via storm inlets and underground pipes. Residential and more rural parts of the town drain via open ditches. The southwestern town spur along Buff Boulevard drains independently to the southwest via open ditches before combining with I-95 drainage infrastructure.

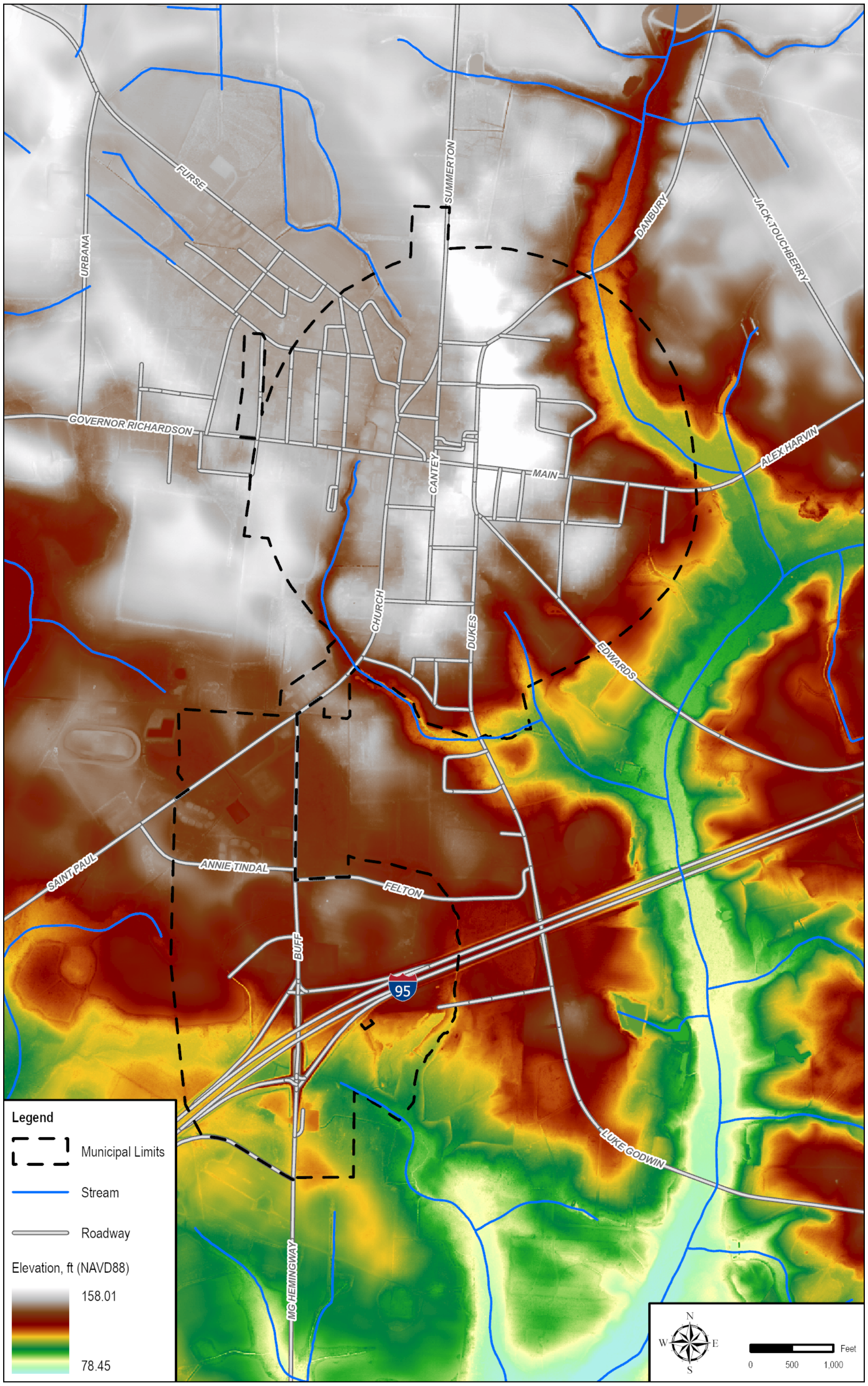


Figure 4 – Local topography and streams near the Town of Summerton.

1.2.4 Stream Gauging Stations

The United States Geological Society (USGS) and National Oceanic and Atmospheric Administration (NOAA) maintain stream gauges throughout the United States. **Figure 5** presents nearby stream gauges. None of the gauges are on streams passing through or near the town. As a result, data from nearby stream gauges were not used for this study.

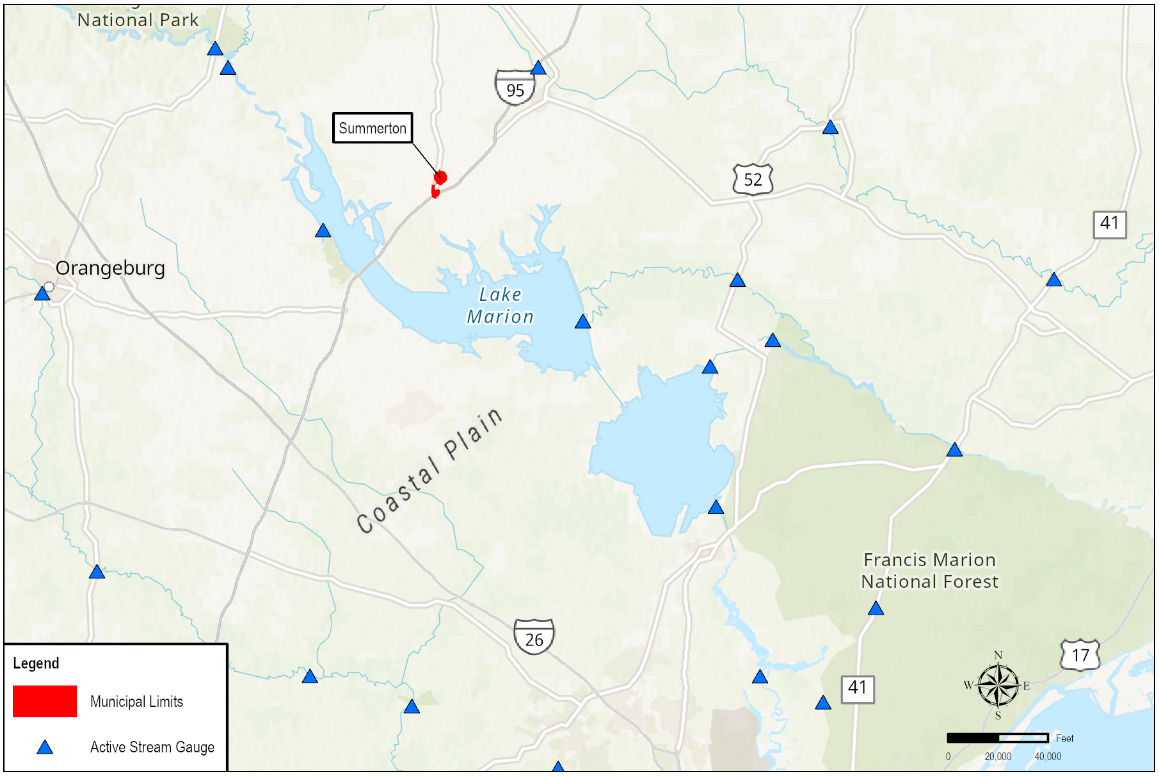


Figure 5 – Active USGS and NOAA stream gauges near the Town of Summerton.

1.2.5 FEMA Designated Flood Zones

The Federal Emergency Management Administration (FEMA) maintains maps of flood zones relating to the 100-year (1% annual chance) floodplain, floodway, and other designations. Some areas have established floodways which represent areas of significant danger to flooding during the 100-year event. **Figure 6** presents effective FEMA mapping for the 100-year floodplain and floodway near the Town of Summerton.

1.2.6 Water Quality

The South Carolina Department of Health and Environmental Control (SCDHEC) maintains water quality monitoring stations as part of their stormwater regulatory compliance. Depending on the impairments of a given water body, regulatory standards may apply to proposed drainage improvements. **Figure 7** presents locations of water quality monitoring stations near the Town of Summerton. Note that the closest downstream station is ST-018. This monitoring station indicates that dissolved oxygen is an impairment of Tawcaw Creek.

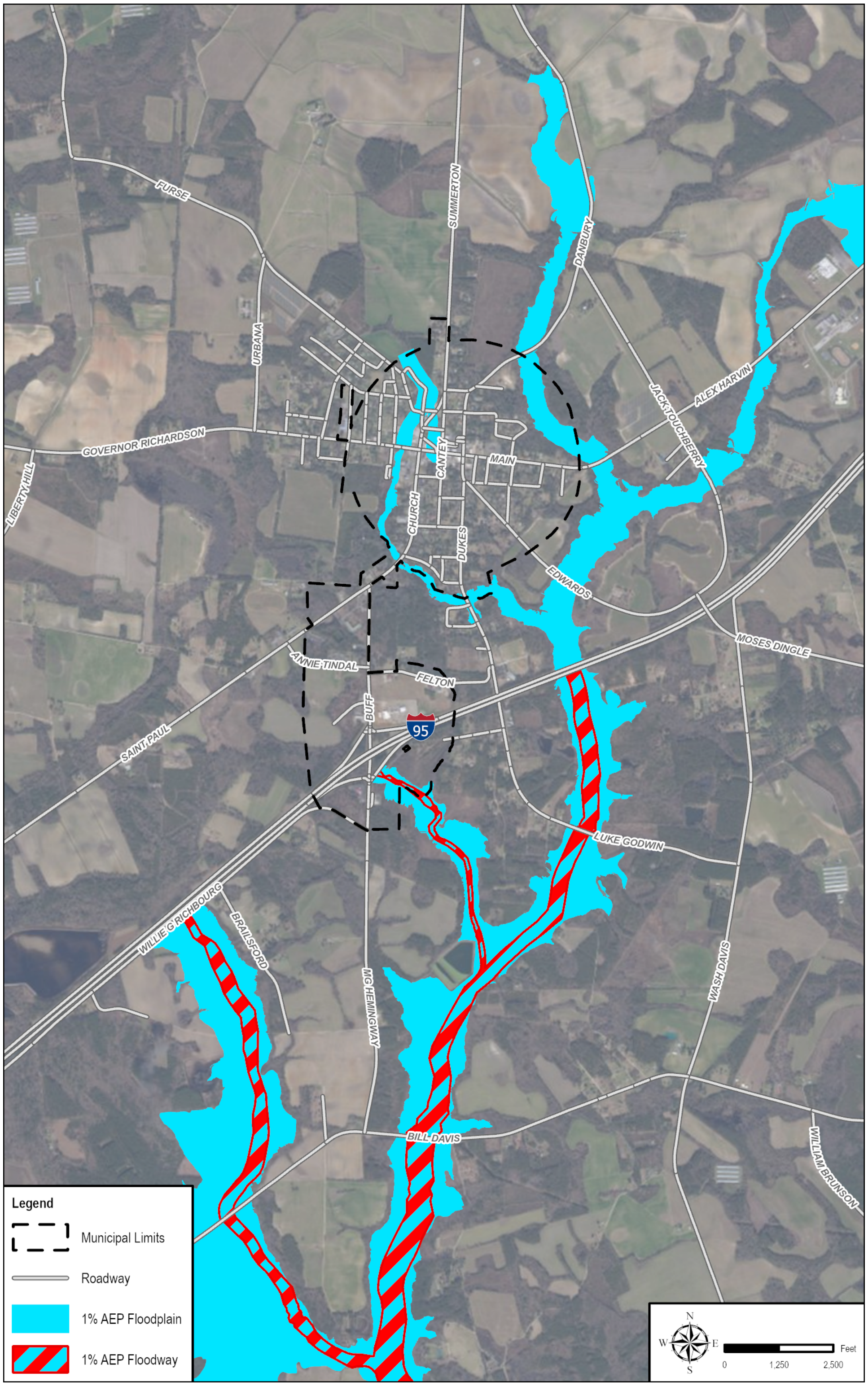


Figure 6 – FEMA flood hazard zones near the Town of Summerton.

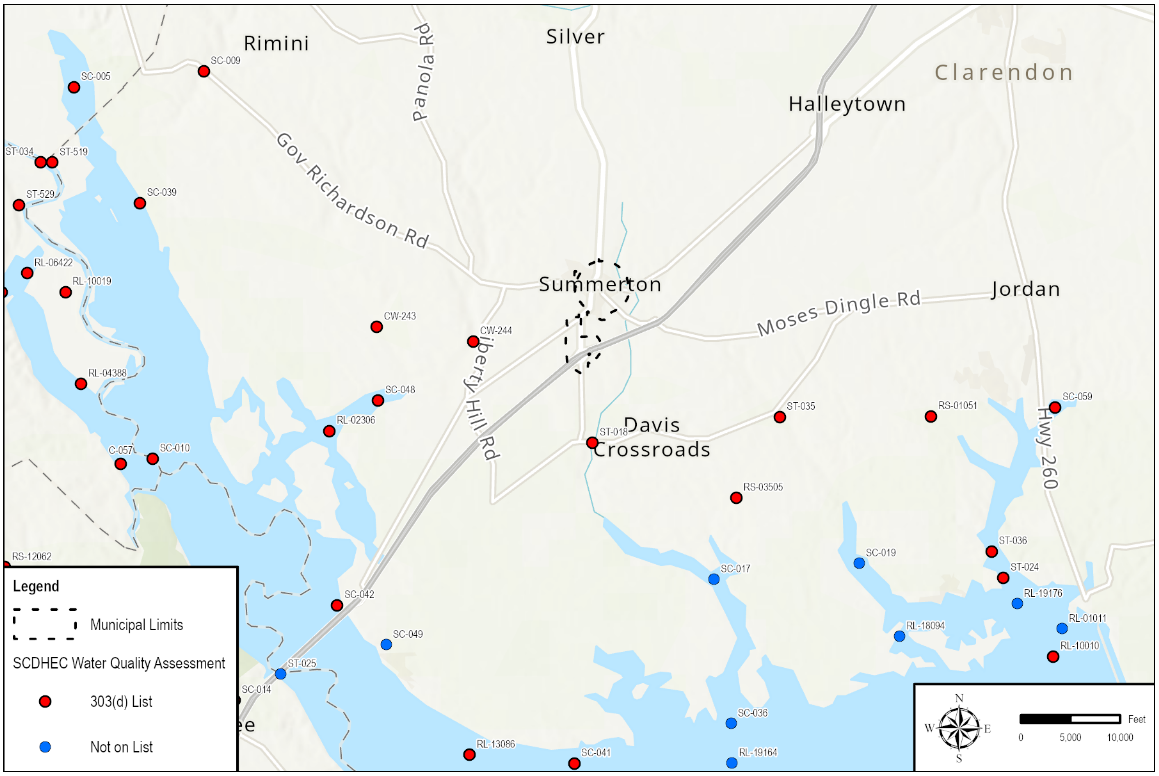


Figure 7 – Water quality monitoring stations maintained by SCDHEC near Summerton.

1.2.7 Wetlands

Wetland data is maintained by the United States Fish and Wildlife Service (USFWS) through the national wetlands inventory (NWI). Wetland impacts should be avoided in drainage improvement activities since wetlands are regulated by the United States Army Corps of Engineers (USACE) and any construction activities within these delineated areas may require lengthy and potentially costly permitting processes. However, it is important to note that wetland impacts cannot always be avoided. A map of wetlands near the Town of Summerton is presented in **Figure 8**.

1.3 Historic Flooding Events in Summerton

South Carolina was severely impacted by three major hurricanes and storm events over the span of 4 years. These include flooding associated with Hurricane Joaquin in 2015, Hurricane Matthew in 2016, and Hurricane Florence in 2018.

Figure 9 shows hurricane and tropical storm paths throughout South Carolina and near the Town of Summerton from 2010 through 2020. As will be shown in this section, although Hurricane Florence (2018) had the most direct impact on the town geographically, the flooding associated with Hurricane Joaquin (2015) was the most devastating to residents. **Figure 10** reiterates the compounded impacts of repetitive major storms. Results presented in **Figure 10** show that the Town of Summerton was struck by storms with a 1% annual chance ("100 year") twice and a 0.1% annual chance ("1000 year") once between 2015 and 2018.

As an initial comparison, **Figure 11** shows a side-by-side comparison of each historic event in terms of rainfall totals and average recurrence interval (ARI). The 2015 floods had the largest impact on Clarendon County and the Town of Summerton; however, when compounded with deficient and aged drainage infrastructure, even lower-intensity storm events could affect quality of life and safety of residents.

Figure 8 – Wetland classifications and mapping near the Town of Summerton as published by USFWS.

1.3.1 Hurricane Joaquin (2015)

In late September into early October 2015, Hurricane Joaquin lingered in the Atlantic Ocean and released extreme volumes of rainfall across the southeastern United States. **Figure 11** shows the interpolated rainfall totals between October 1 and October 5 of that year. As seen in the figure, Clarendon County received anywhere between approximately 17 and 23.5 inches of rainfall with uplands areas receiving equally devastating rainfall. This storm event resulted in 19 storm-related fatalities in South Carolina with the largest impact on small, low-lying communities.

The Sumter Item periodical reported that Summerton received "up to 4 feet of rain" and more than 100 Summerton residents were rescued on October 4, 2015, as the floodwaters rose. Town officials reported to the project team that swift water and other boat rescues were conducted during the event. The Sumter Item article can be viewed at: https://www.theitem.com/stories/more-than-100-people-rescued-from-homes-in-summerton,255520.

1.3.2 Hurricane Matthew (2016)

In October 2016, Hurricane Matthew traveled along the east coast of the United States from Florida northward. It made a brief landfall near Charleston as a category 1 hurricane before moving back offshore south of Myrtle Beach. Although much of the state was not hit directly, heavy rains and strong wind gusts associated with the storm caused four deaths in South Carolina. The Town of Summerton experienced both factors as reported in a WIS News article stating that the strong wind gusts caused trees to fall, damaging homes and causing loss of power for residents. Additionally, floodwater inundated roads and properties. The WIS News article can be accessed here: https://www.wistv.com/story/33356764/worst-since-hugo-summerton-residents-say-after-matthew-damages-town/.

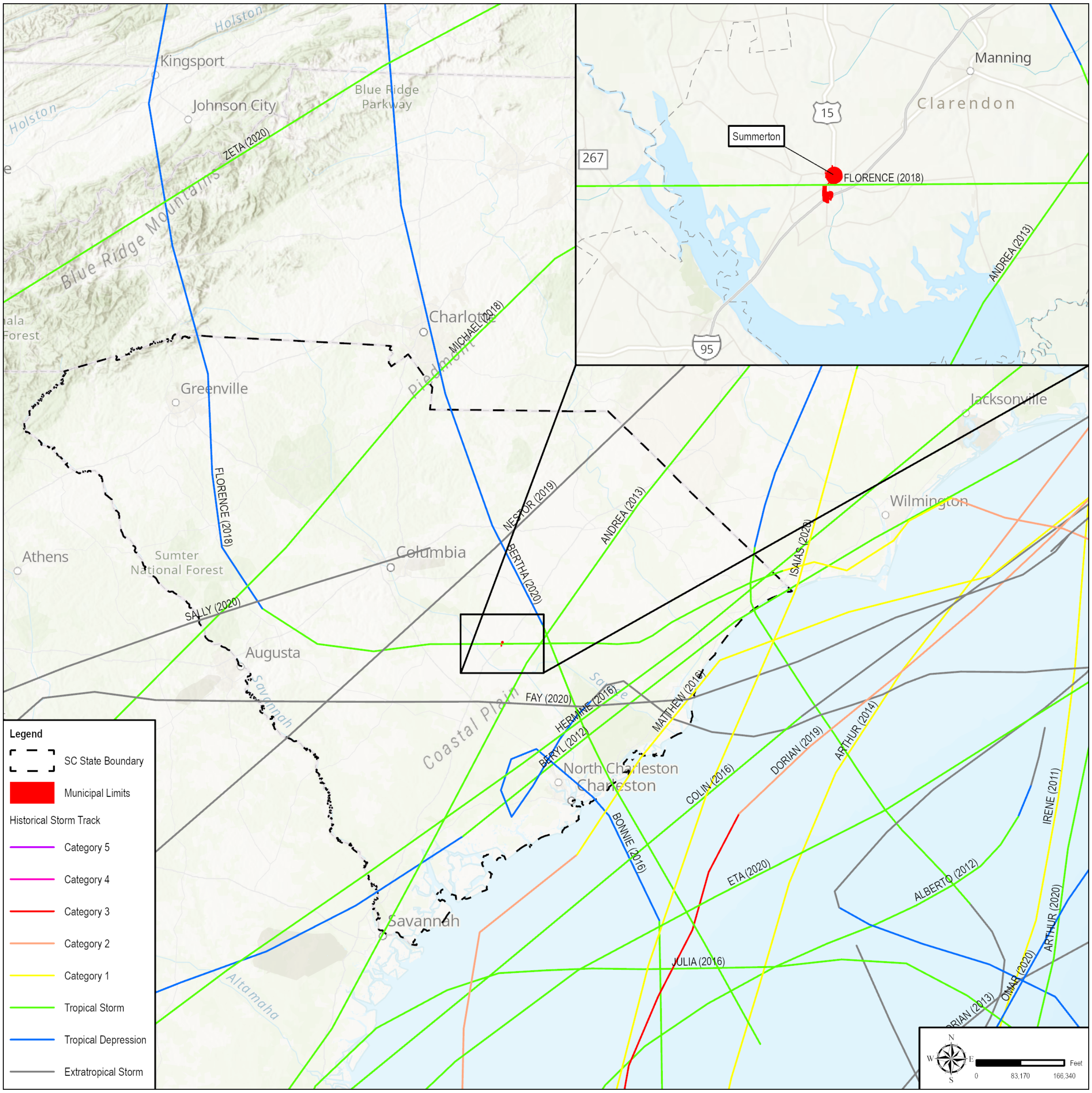


Figure 9 – Historic hurricane paths from 2010-2020 near South Carolina and the Town of Summerton.

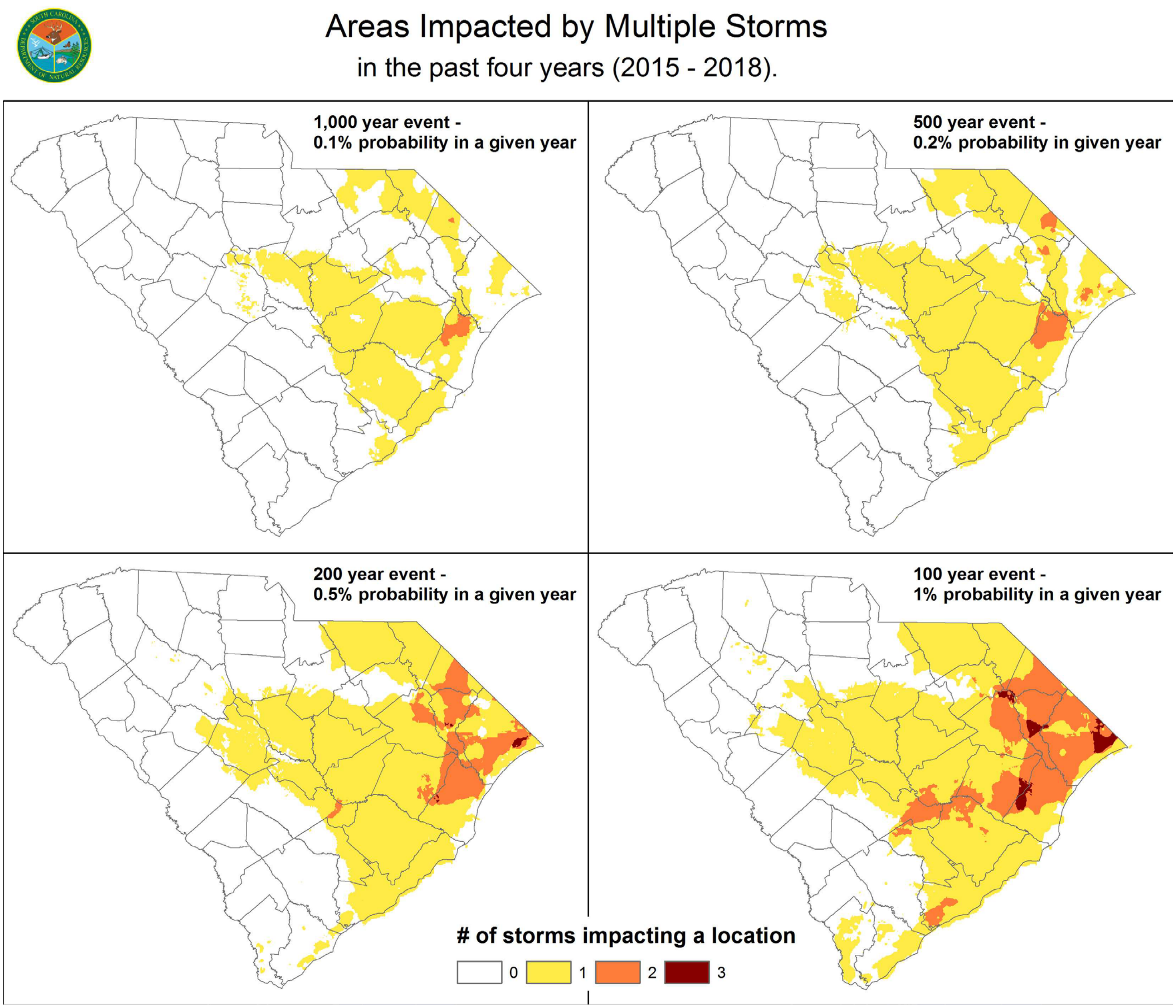


Figure 10 – South Carolina areas impacted by multiple storms from 2015 through 2018 (Source: SCDNR).

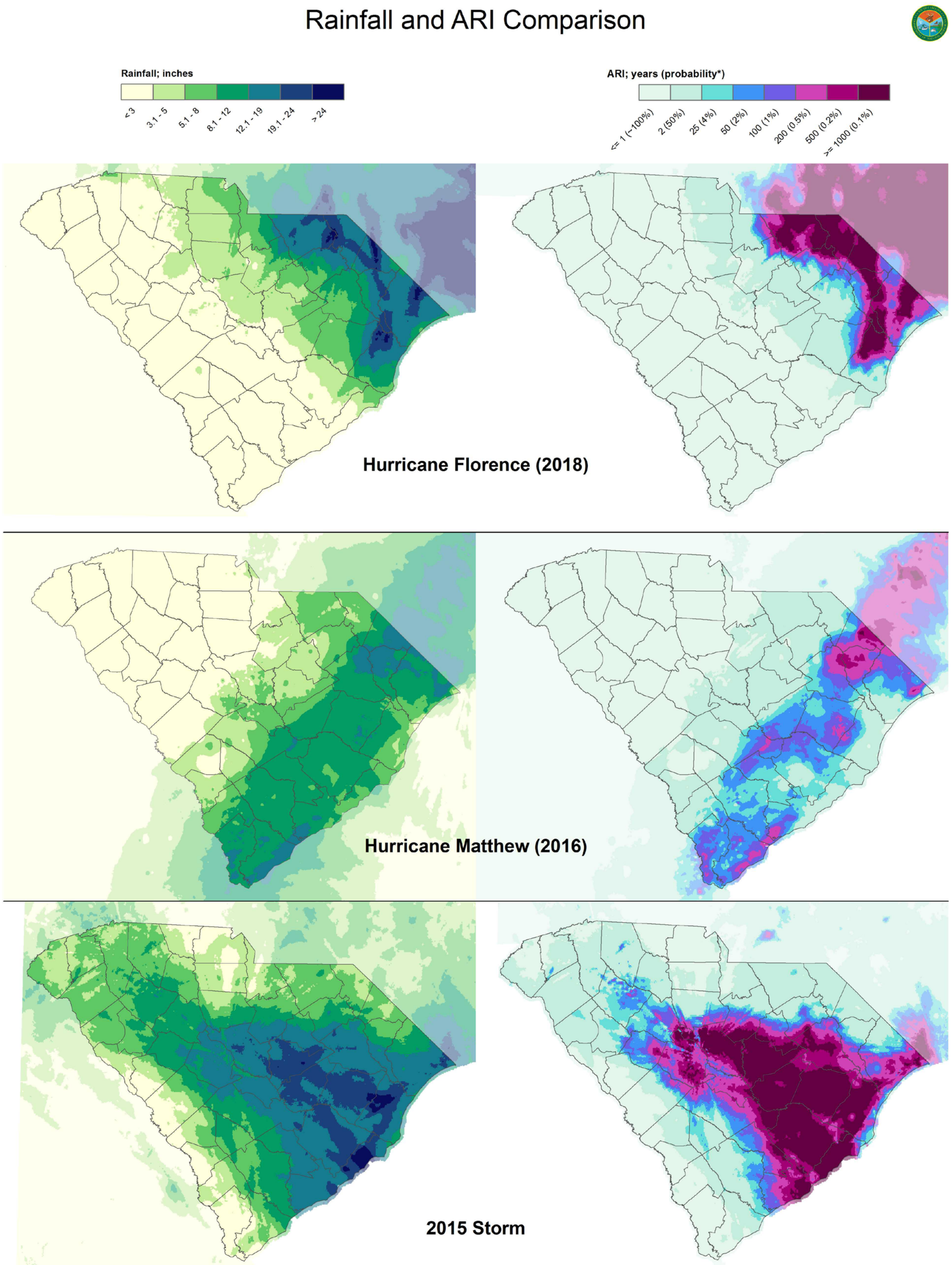


Figure 11 – Rainfall and ARI comparisons of Hurricane Florence, Hurricane Matthew and the 2015 flooding (Source: SCDNR).

1.3.3 Hurricane Florence (2018)

Hurricane Florence was a category 1 hurricane when it made landfall near Wilmington, North Carolina in September 2018. As it tracked westward through South Carolina, it was downgraded to a tropical storm and passed directly through the Town of Summerton. Due to its weakened state and its directional path, Hurricane Florence was far less devastating to the South Carolina Midlands including the Town of Summerton when compared to the storms of 2015 and 2016. **Figure 11** shows rainfall totals during the storm event, and in which the town received approximately 2.3 inches of rain between September 14 and September 18 of that year.

1.4 Town Water and Sewer Utilities

Local water and sewer utility pipes, structures, and facilities may affect the placement and cost of proposed drainage infrastructure. These data were requested and obtained from the town for use in improvement investigations and cost estimating. **Figure 12** presents approximate locations of water and sewer lines as documented by the town's water and sewer department.

1.5 Roadway System

Most of the drainage infrastructure and other public utilities (e.g., water and sewer) within the town are located within public rights-of-way along public roadways. **Figure 13** presents the approximately location and extents of roadways currently available at the time of the study. As shown, the South Carolina Department of Transportation (SCDOT) owns most roadways located within the Town of Summerton and adjacent areas. As a result, analysis of drainage systems located within SCDOT right-of-way should be conducted in accordance with their standards. Most importantly, SCDOT should be considered a major stakeholder in the implementation of any projects recommended herein.

1.6 Previous and Planned Projects and Studies

Previous studies that may have an impact on the present study and proposed improvements include previous hydrologic and hydraulic studies and maintenance projects maintained by the South Carolina Department of Transportation (SCDOT).

Two previous hydrologic and hydraulic related studies were conducted by FEMA. This includes the flood insurance study (FIS) Report and the flood risk report (FRR). The FIS is often used in tandem with flood insurance rate maps (FIRMs) and other FEMA products and include details of the methods used to establish flood zones. The FEMA FIS covers the entirety of Clarendon County with an effective date of August 2013.

The FEMA FRR is slightly newer than the FEMA FIS but was developed prior to the 2015 flooding with a publication date of June 30, 2015. **Figure 14** presents the flood risk map (FRM) developed as a part of the FRR. It is important to note there are three at-risk essential facilities in the Town of Summerton including the town hall, the police department building, and a power facility. Each of these facilities is subject to the 1% annual chance (100-year) flooding according to FEMA. Additionally, there are streamflow constrictions farther downstream on Tawcaw Creek and one non-levee embankment.

The SCDOT did not report any ongoing projects within the Town of Summerton at the time of this study. However, the SCDOT has ongoing improvement projects near the town as presented in **Figure 15**. These include two resurfacing projects and one bridge replacement over Tawcaw creek.

2.0 Understanding Drainage Concerns

To understand current and past drainage concerns the team conducted site visits to the Town of Summerton, held a workshop with town officials, and hosted a town hall style public meeting with residents. Additionally, a field survey of all visually apparent drainage infrastructure within identified areas of concern was conducted.

2.1 Public Engagement

Public outreach was an important component of this study wherein feedback and information regarding drainage concerns were discussed with residents. A project website was created and included an introduction to the project, real-time project updates, a link to a survey regarding drainage issues in town, and contact information. In addition to virtual public input via web reporting, a traditional in-person workshop with town officials and an in-person public meeting with town residents were completed.

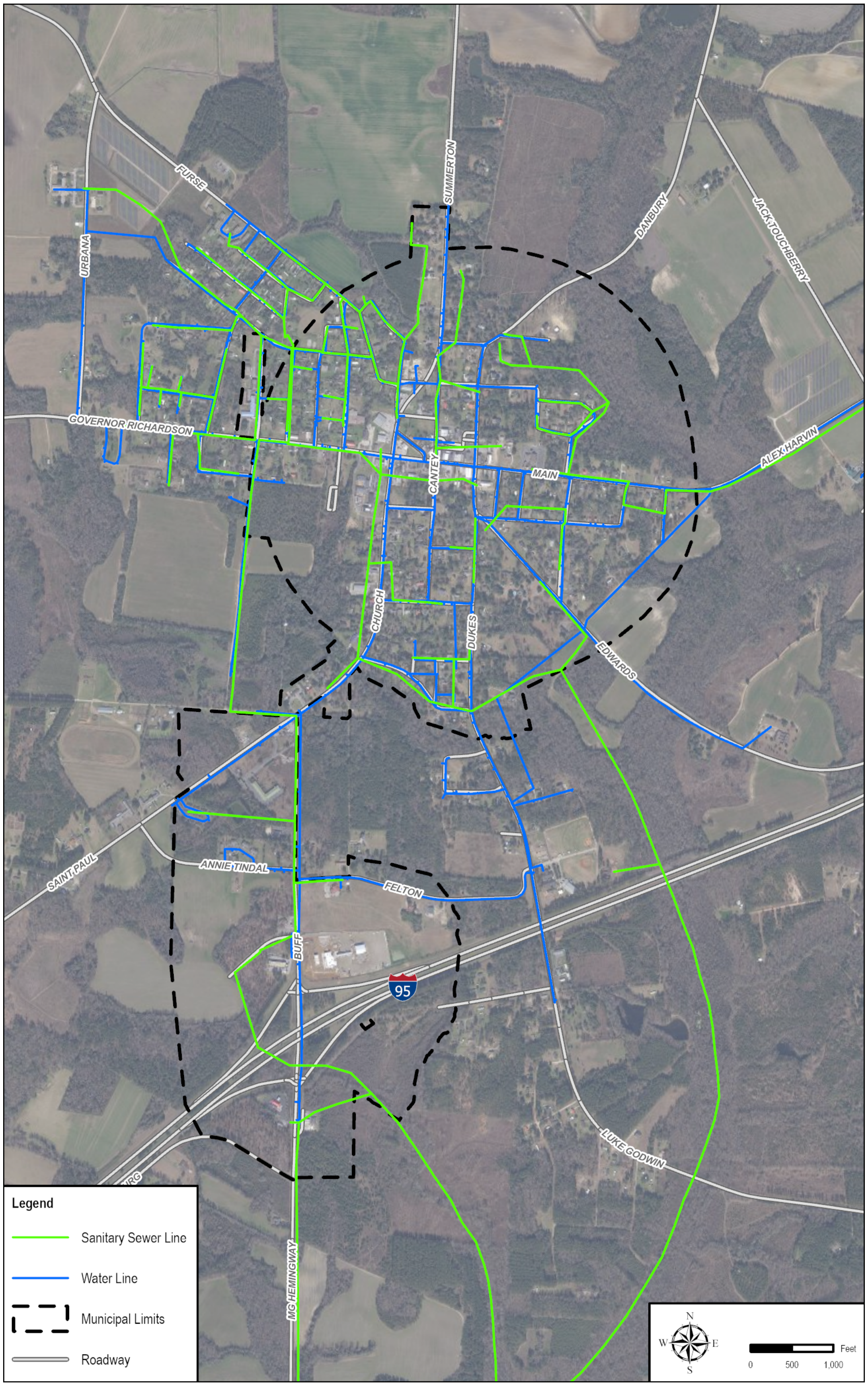


Figure 12 – Approximate locations of local water and sewer lines within the Town of Summerton.

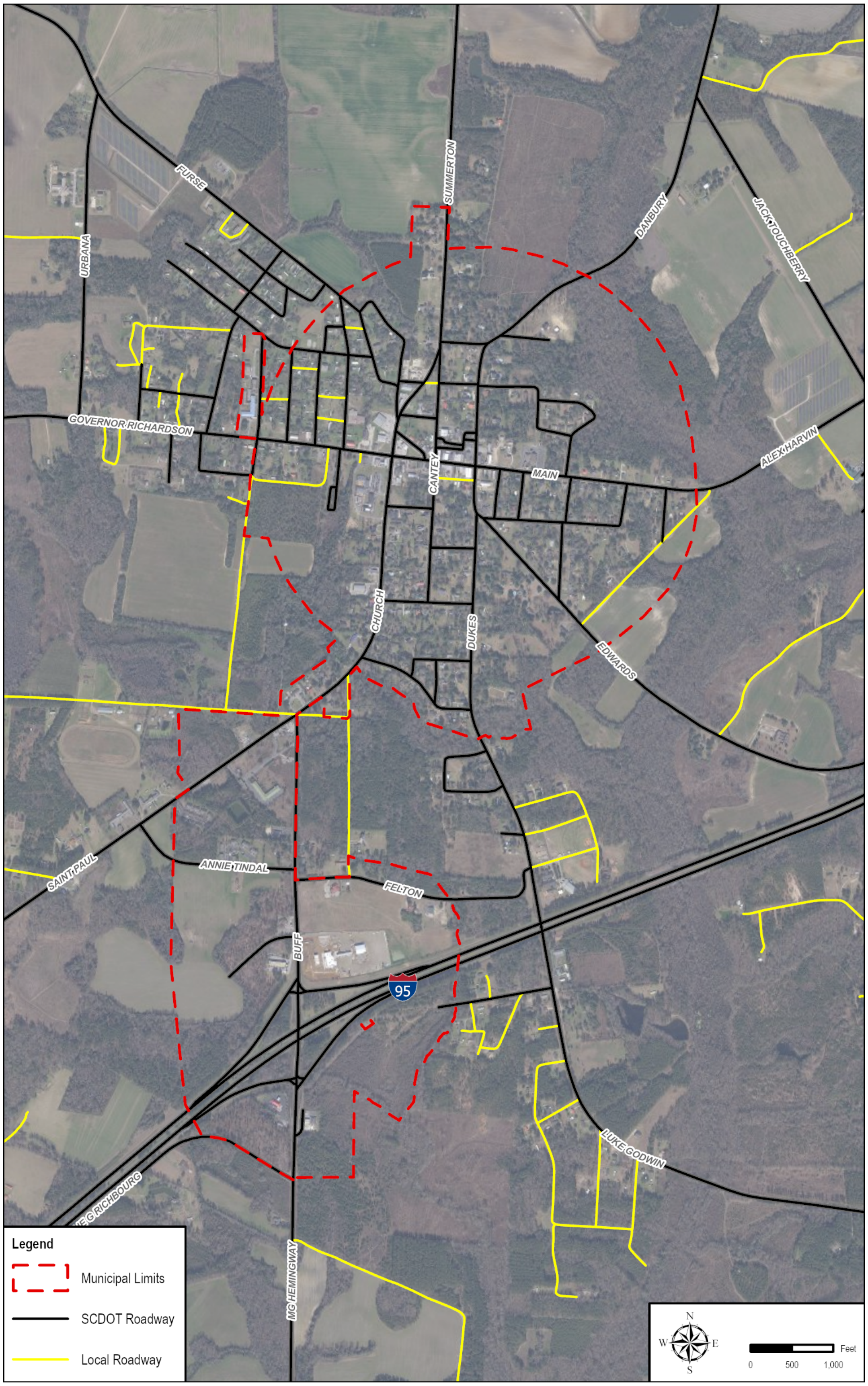


Figure 13 – Approximate location of currently mapped roads by ownership for the Town of Summerton.

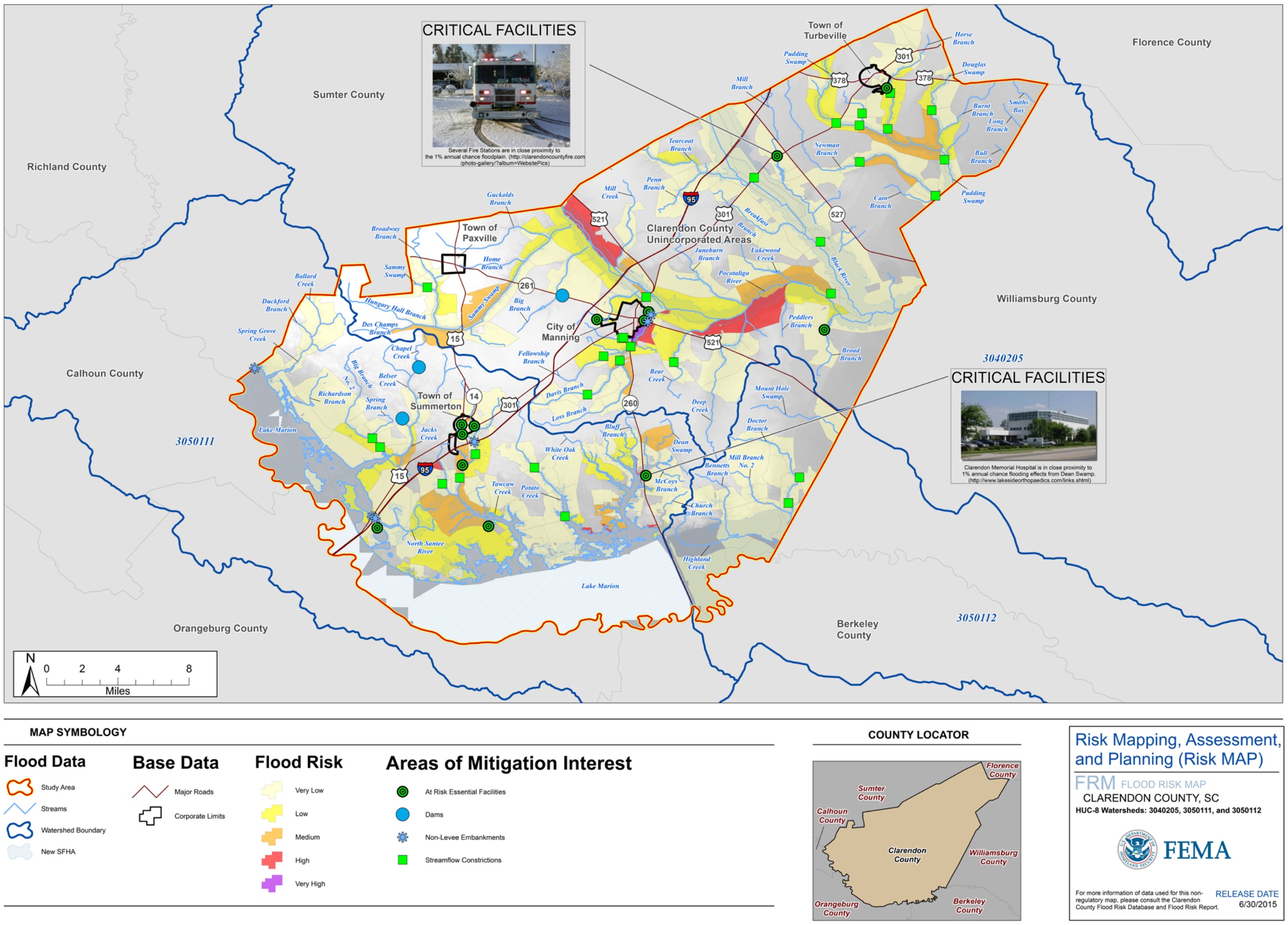


Figure 14 – Flood risk map (FRM) for Clarendon County. Image obtained from FEMA.

2.1.1 Workshop with Town Officials

A workshop with town officials was held on July 25, 2022 at the town hall. Attendees included the mayor, city council members, the town administrator, and SCOR personnel. The project team introduced the project and presented findings from field investigations. Town officials helped the team identify additional areas of known flooding or drainage concern. Additionally, town personnel aided in obtaining contact information for local utilities and additional data included in this report. A compiled map of the areas of concern is presented in **Section 2.1.3**.

2.1.2 Public Meeting

A public meeting was held on August 22, 2022 at the Clarendon Community Resources Center located in Summerton. A mailer was distributed to addresses in the town and posted at the town hall inviting individuals to attend the public meeting. The purpose of the meeting was to introduce the study and allow the public to provide input on drainage concerns within the town including specific areas of concern. Attendees included the public, local business owners, town officials including the mayor and council members, community leaders, state representatives, and SCOR representatives. The attendees identified areas of concern, described issues at each location, and discussed possible causes for drainage concern. Additionally, the attendees were invited to complete brief surveys to articulate areas of concern.

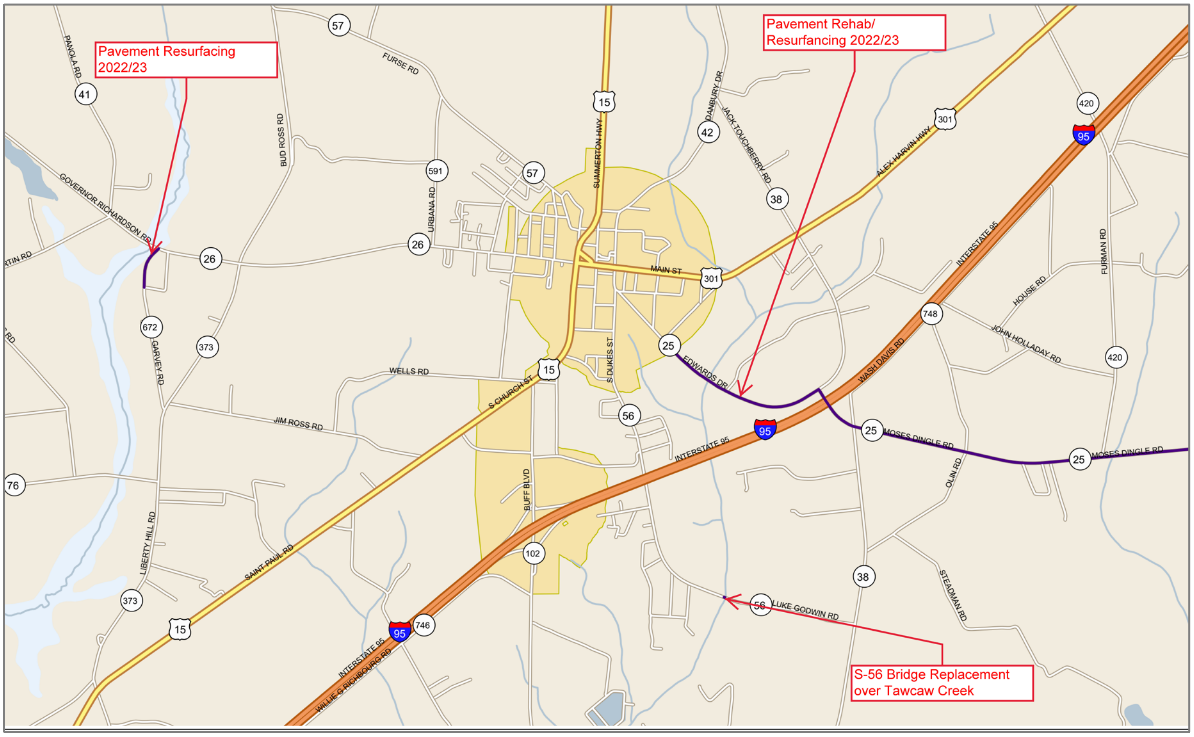


Figure 15 – On-going and planned SCDOT projects near Summerton. Courtesy of SCDOT.

2.1.3 Areas of Concern

Areas of flooding and drainage concern were compiled and are visually presented in **Figure 16**. **Table 2** lists the areas of concern and the description of flooding at each location.Several areas of concern were identified in the northwest residential areas of Summerton. This area is generally characterized by flat terrain, networks of open ditches and roadway culverts, and has been reported to be affected by frequent flooding during relatively small storm events. This area was the epicenter of swift water rescues during the historic flooding in 2015.

Flooding was also reported in the commercial and business districts around Main Street and Church Street. This area is characterized primarily by curbed roads and underground drainage infrastructure. Much of this infrastructure is clogged with debris and sediment. The southern spur of the town has relatively independent drainage infrastructure from the rest of the town. These areas were reported as either areas of frequent flooding or areas that were only impacted during Hurricanes Joaquin (2015) and Matthew (2016).

2.2 Field Survey

Field survey was completed using a two-step process. First, a survey was completed for visually apparent drainage infrastructure located within defined areas of concern of concern. Next, survey data was augmented/supplemented based on drainage infrastructure connectivity to complete a reasonable hydraulic analysis of the system. Survey efforts were completed using survey-grade global positioning system (GPS) units. Data collected during field survey efforts included drainage structure elevations (e.g., inverts and rims), ditch cross sections, size (e.g., pipe diameter), and material (e.g., concrete). Photo documentation of infrastructure conditions was also collected during field investigations. It is important to note that all elevation data was collected based on the North American Vertical Datum of 1988 (NAVD88).

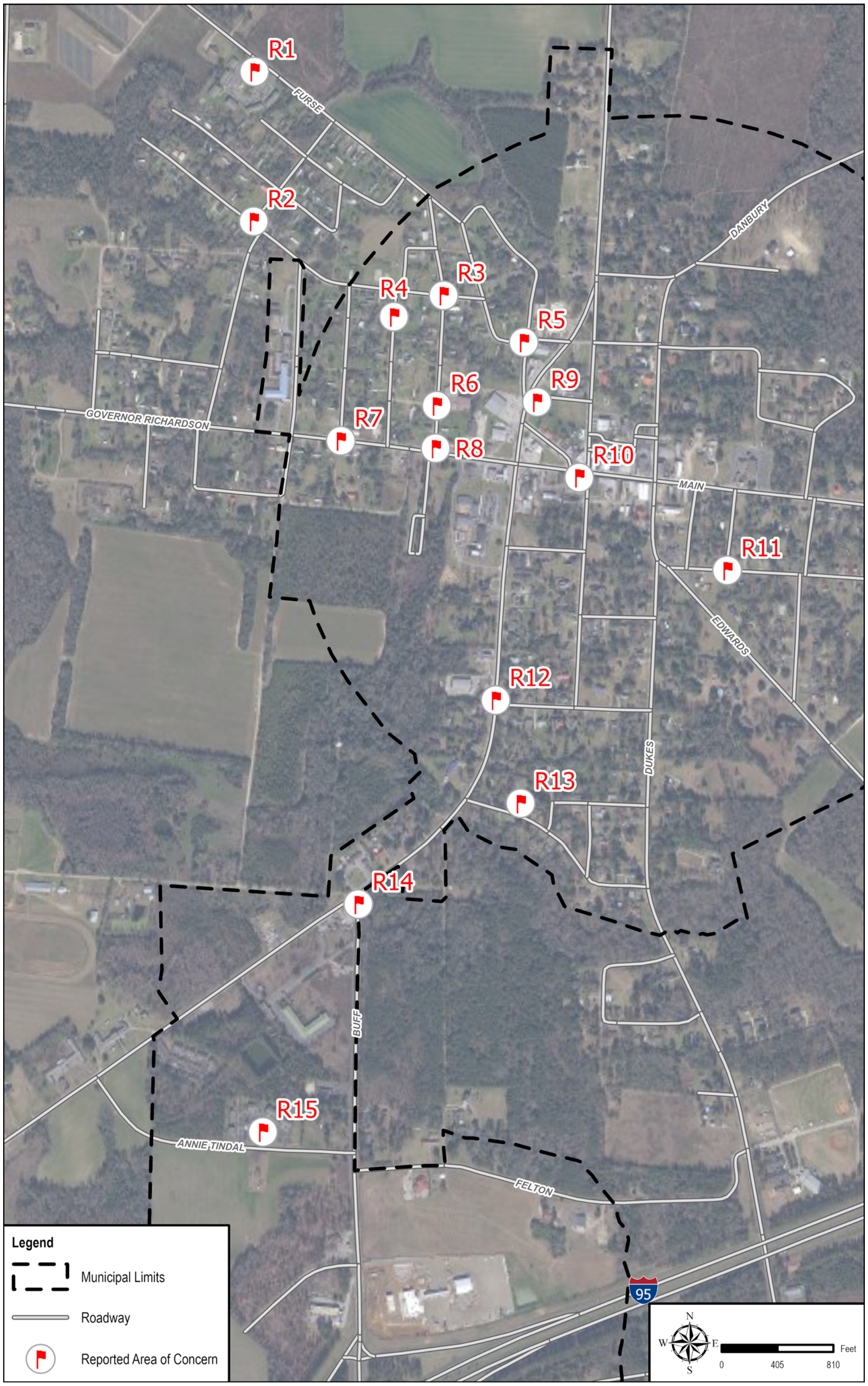


Figure 16 – Aerial map showing the areas of drainage or flooding concern.

Table 2 – Locations and descriptions of the areas of drainage or flooding concern.

Index	Nearest Intersection	Description
R1	Mayzek Street at Meadowfield Drive	Meadowfield Apartments experiences flooding and was mentioned multiple times within public survey responses. The parking lot was reported to flood frequently. Site of displaced individuals following 2015 flooding.
R2	Wassau Street at Roosevelt Drive	Several unmaintained culverts and ditches (i.e., filled with silt and debris) along Roosevelt Drive leading toward the intersection with Wassau Street. This is paralleled for Washington Street and Lincoln Street toward Roosevelt Drive.
R3	Wassau Street at 1st Street	The intersection floods during long duration storm events. Inlets at the intersection are clogged and nearby ditches are in poor condition.
R4	2nd Street at Grant Marti Street	Apartment parking lot and yards flood. Heavily affected by 2015 floods (i.e., Hurricane Joaquin).
R5	Mazyck Street at Parson Street	The stretch of Parson Street above the intersection was stressed by residents that it is one of the worst flooding areas in town. The intersection floods, and flooding extends to neighboring lawns. Ditches and inlets near the intersection appear to seem ineffective. Residents indicated that old drainage pathways behind the residents on Parson Street were blocked by landowners. The industrial building on Parson Street appears to exacerbate flooding at the intersection.
R6	Tripp Street at 1st Street	The intersection appears to flood due to clogged inlets and ineffective ditches. The culvert intended to carry stormwater across 1st Street between Tripp Street and Larry King Highway is clogged and was thought to be undersized by residents.
R7	3rd Street at Larry King Highway	Ditches along 3rd Street end prior to the Larry King Highway intersection and have no known outfall. Residents report stormwater in homes on 3rd Street during heavy rains. The church at the intersection has accumulated sediment indicating ponding of stormwater. Flooding was reported to continue down Hill Street (across from 3rd St).
R8	1st Street at Larry King Highway	The ditch on 1st Street above intersection terminates in a junction box that is likely clogged. The trailer adjacent to the church at the intersection is reportedly sinking due to saturated soil. During strong storms, water ponds in yards along 1st Street. The 2015 flooding (i.e., Hurricane Joaquin) caused damage inside the church.
R9	South Church Street at Ridgeway Street	Ponding water near inlets during strong storm events. The drainage inlets at this intersection and farther north on South Church Street near the gas station are clogged with debris and sediment. Residents also report flooding near the gas station. The intersection had water waist deep during the 2015 floods (i.e., Hurricane Joaquin). Homes along Ridgeway Street were flooded during the event. Two homes were demolished due to the damage.
R10	Main Street at Cantey Street	The intersection floods regularly along with the grassed area behind the police station. Residents reported flooding in the grassed area reaches over 1 foot regularly. Cantey Street has only two inlets which are both clogged with sediment and debris. There is no other drainage infrastructure along Cantey Street which collects stormwater from a long distance away. Main Street near the intersection is relatively steep also with unmaintained infrastructure.
R11	Caldwell Street at Broadway Street	During heavy rains the gutters flood above the curb. Stormwater inlets along Caldwell St above the intersection are clogged. Stormwater regularly bypasses inlets.
R12	South Church Street at Burgess Street	The roadway floods during heavy rain events. The drains along Burgees Street approaching the intersection require maintenance and have accumulated debris. Lack of curbs at the intersection allow stormwater to runoff toward businesses.
R13	South Church Street at Mood Street	The ditch conveying stormwater parallel with Mood Street before crossing South Church Street through a culvert floods during heavy rain. The area experienced severe flooding during the 2015 floods (i.e., Hurricane Joaquin).
R14	South Church Street at Buff Boulevard	The intersection experienced flooding during the 2015 floods (i.e., Hurricane Joaquin). Homes were spared due to local topography. Drainage ditches along Buff Boulevard are overgrown with vegetation.
R15	Annie Tindal Road and Buff Boulevard	Residents of Clarendon Court Apartments experience stormwater in lawns and damaging properties during storm events.

3.0 Modeling Methodology

A hydrologic and hydraulic model of the town's drainage infrastructure was constructed to quantify existing flood vulnerabilities and drainage system deficiencies. First, a comprehensive hydrologic assessment was performed to delineate watershed boundaries and hydrologic properties required to estimate rainfall-runoff processes. Then, the results of the existing drainage infrastructure inventory and hydrologic assessment were used to create a combined 1D/2D hydrologic and hydraulic model. A combined 1D/2D hydrologic and hydraulic model quantifies not only drainage system deficiencies (1D) but also the extent, depth, and duration (2D) of flooding. Analysis of flood conditions observed in the existing conditions model (across a range of scenarios) informed the alternatives analysis and supported development of proposed improvements.

3.1 Assumptions and Limitations

Models are a representation of an existing system and are therefore limited in their ability to completely recreate observed conditions. However, by understanding the assumptions made and limitations encountered during a model's creation, the results can lead to more pragmatic solutions. For example, thorough investigation of all visually apparent drainage infrastructure was performed across the study area. However, several instances of inaccessible or missing drainage infrastructure were encountered. When this occurred, the physical properties (e.g., condition, capacity, flow direction, etc.) of the drainage infrastructure were assumed using surrounding drainage infrastructure and engineering judgement. Each of the subsequent sections outline limitations or assumptions associated with their respective analyses.

3.2 Hydrologic Analysis

A comprehensive hydrologic analysis was performed to delineate watershed boundaries within the study area to determine drainage paths where runoff will flow and accumulate (e.g., inlets and ditches/channels). Watershed boundaries were delineated using Clarendon County 2008 LiDAR topographic data and results from the field survey (or inventory of existing drainage infrastructure) and site investigations. Once watersheds were delineated, hydrologic parameters required to estimate runoff rates and volumes (e.g., curve numbers, soil classification, etc.) were determined. The methodology for estimating these hydrologic parameters is discussed in subsequent sections.

3.2.1 Soil Analysis

Understanding soil conditions (e.g., texture/classification, hydrologic soil group, etc.) is critical for estimating rainfall-runoff processes. Soil conditions within the study area were analyzed using the Unites States Department of Agriculture (USDA) Soil Survey Geographic (SSURGO) database. According to this database, there are 12 unique soil types found within the study area (see **Figure 17**). The soil parameters discussed herein are limited by the data collection methods used to develop regional characteristics and therefore may not be representative of site-specific conditions. Two key soil parameters, hydrologic soil group classification and hydraulic conductivity, were evaluated using this database.

Hydrologic soil group classifications are a qualitative measurement of a soil's infiltration capacity. These classifications assign soils into one of four single classes (A, B, C, or D) or one of three dual classes (A/D, B/D, and C/D). Generally, these classifications are evaluated on a scale from A to D, with A soils exhibiting high infiltration capacities (i.e., low runoff potential) and D soils exhibiting low infiltration capacities (i.e., high runoff potential). Analysis of the SSURGO database concluded that hydrologic soil groups found within the study area included A, B, C, D, A/D, and B/D hydrologic soil groups. In instances where dual hydrologic soil groups were encountered, soil drainage classes were used to determine the appropriate classification following USDA guidance. Soils classified as moderately drained to excessively drained were assigned to the hydrologic soil group with the higher infiltration capacity (e.g., A/D would be assigned as A), while soils classified less than moderately drained were assigned to the hydrologic soil group with the lower infiltration capacity.

Also contained within the SSURGO database are estimates of hydraulic conductivity, or a quantitative measurement of the rate at which soil can transmit water. These estimates were used in the creation of the stormwater model's 2D overland flow elements to represent field conditions and the study area's response to flooding.

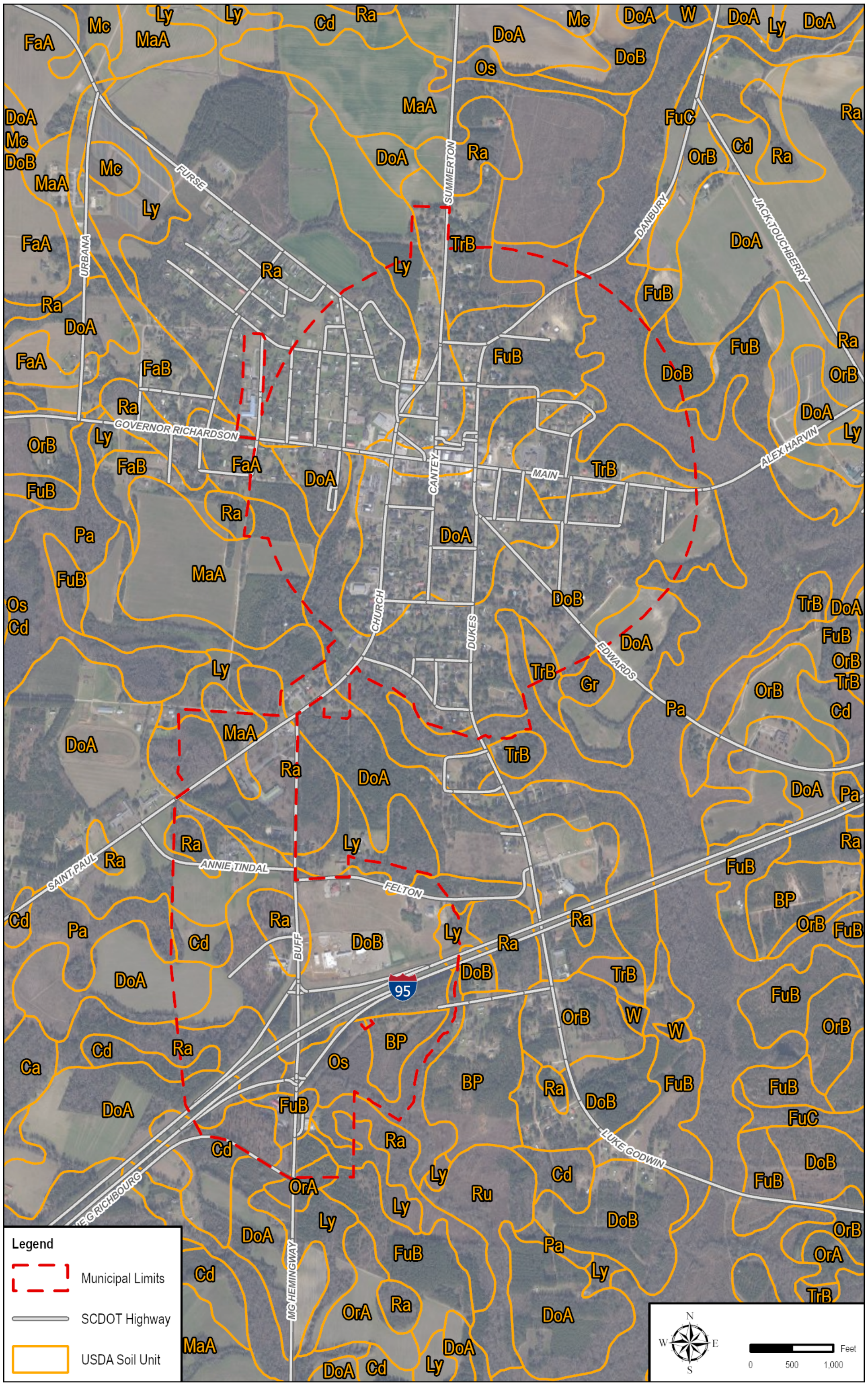


Figure 17 – Soil classifications near the Town of Summerton according to USDA.

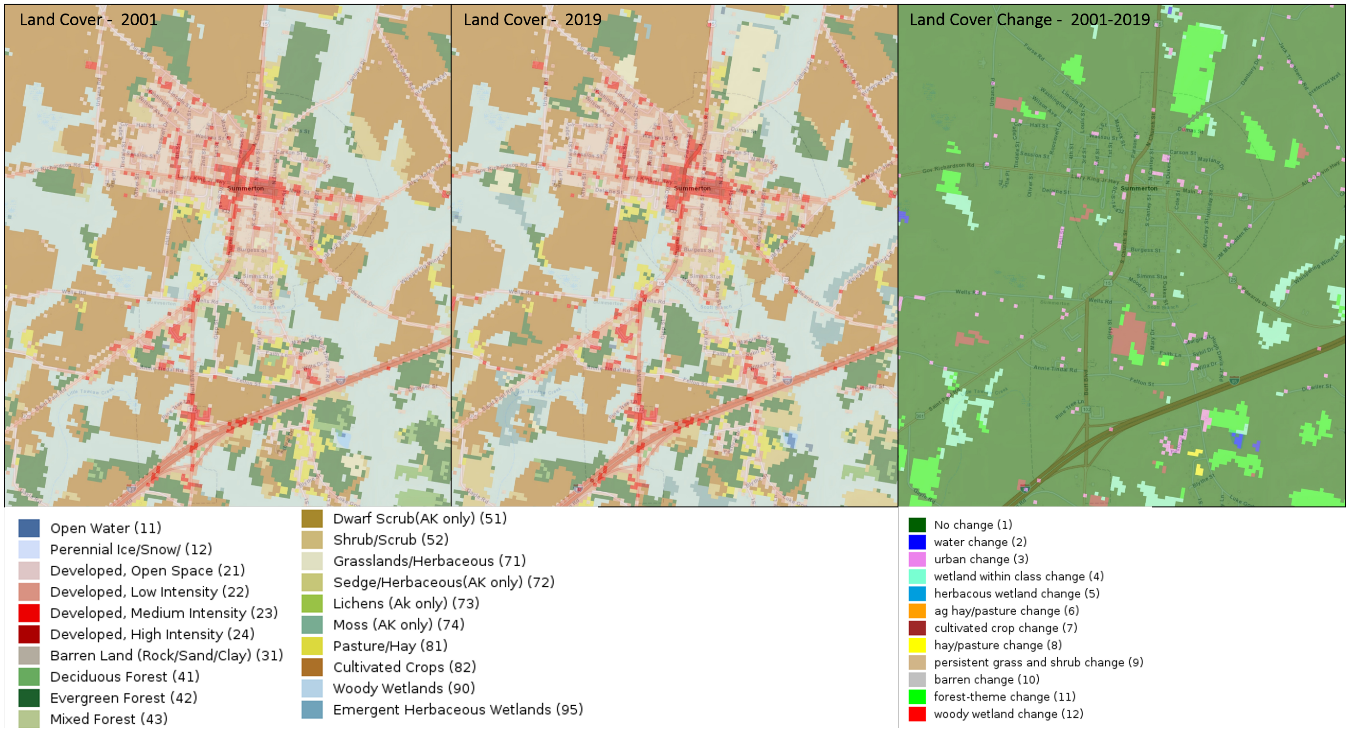


Figure 18 – Land cover NLCD mapped by USGS near Summerton in 2001 and 2019 (left), as well as the change between those years (right).

3.2.2 Land Use/Land Cover Classifications

While soil conditions generally describe underlying hydrologic processes, land cover and land use classifications describe the impact that surface cover has on a watershed's potential to generate surface runoff. These qualitative classifications can range from urban scenarios with high runoff potential (i.e., developed, high intensity) to more natural ecosystems (i.e., wetlands). Land use and land cover classifications were assigned to each watershed based on the Natural Resources Conservation Service's (NRCS) methodology using the 2019 national land cover dataset (NLCD) published by USGS. The 2019 NLCD resolution for this region is approximately 100 feet (30 meters). **Figure 18** shows the land use/cover classification for the town.

3.2.2.1 Future Conditions Land Use/Land Cover Classifications

To investigate if significant changes in land use and cover will occur in the future (which will impact runoff potential), past (2001) and present (2019) land cover datasets were compared to assess and analyze trends in land development (i.e., expansion of residential neighborhoods, new industrial zones, etc.). Results from the analysis (**Figure 18**) show there have been relatively few changes in land cover between 2001 and 2019. Therefore, no changes in land use and cover were considered when evaluating drainage infrastructure under future scenarios.

3.2.3 Estimating Runoff

Runoff generated by each watershed were estimated using the NRCS methodology. This methodology was originally developed by researchers to estimate runoff volumes for agricultural watersheds but has since been adapted for use in urban areas. To estimate runoff volume for a watershed using this method, three hydrologic parameters must be known: hydrologic soil group classification, land use and land cover classification, and watershed surface area. The first two hydrologic parameters are used to determine a parameter called the curve number (CN), a variable which describes a watershed's ability to produce runoff during a rainfall event. CNs generally range from 0 to 100 wherein a watershed with a CN of 100 will produce runoff volumes equal to rainfall (no infiltration) and a watershed with a CN of 0 will

Table 3 – Curve number values based on land cover/use and hydrologic soil group classifications encountered within the study area.

Land Cover/Use Classification	Hydrologic Soil Group Classification			
	A	B	C	D
Cultivated Crops	62	74	82	86
Deciduous Forest	30	30	41	48
Developed, High Intensity	88	92	93	94
Developed, Medium Intensity	84	89	93	94
Developed, Low Intensity	81	88	90	93
Developed, Open Space	52	68	78	84
Emergent Herbaceous Wetlands	80	80	80	80
Evergreen Forest	30	55	70	77
Hay/Pasture	40	61	73	79
Herbaceous	63	63	75	85
Mixed Forest	36	60	73	79
Shrub/Scrub	42	42	55	62
Woody Wetlands	86	86	86	86

produce no runoff. **Table 3** summarizes CN values (based on the input data) used in this study. In instances where multiple land cover or soil conditions were encountered in a watershed, CNs were developed and assigned using an area-weighted (or composited) approach.

Once a CN has been assigned to a watershed, runoff volume can be estimated by multiplying the watershed surface area by the runoff depth. Runoff depth is determined using the following methodology:

$$Q = \begin{cases} 0 & \text{for } I \leq 0.2S \\ \dfrac{(I - 0.2S)^2}{I + 0.8S} & \text{for } I > 0.2S \end{cases} \quad (1)$$

where Q is runoff depth, I is rainfall depth, and S is the maximum potential difference between rainfall and runoff (fraction of rainfall which infiltrates, is stored within small depressional features of the watershed, or is intercepted by vegetation) defined as:

$$S = \left(\frac{1000}{\text{CN}}\right) - 10. \quad (2)$$

3.2.4 Rainfall Data

3.2.4.1 Current Conditions Rainfall

Rainfall data were obtained from the NOAA precipitation frequency data server; specifically, the estimates for the Town of Summerton (33.6082°, -80.3504°). Precipitation depths analyzed in this study (**Table 4**) included the 50 percent (2-year return period), 10 percent (10-year return period), 4 percent (25-year return period), and 1 percent (100-year return period) annual exceedance probability rainfall events. These precipitation depths were then combined with the dimensionless Type-II NRCS/SCS rainfall distribution to generate cumulative design rainfall event distributions.

Lower intensity rainfall scenarios were also evaluated by combining the NOAA precipitation depth estimates with a rainfall distribution established by Powell et al. (2007) using similar techniques as Huff (1967) and the Texas Department of Transportation (Asquith et al., 2005). This SC Long rainfall event distribution used regional (South Carolina, North Carolina, and Georgia) NOAA rainfall data to develop a rainfall distribution more representative of an expected 24-hour rainfall event in South Carolina. This expands the hydrologic and hydraulic

Table 4 – Town of Summerton 24-hour design precipitation depths (NOAA, 2023).

Annual Exceedance Probability (Recurrence Interval)	Precipitation Depth (inches)	
	Current (90% Confidence Interval)	Future
50% (2-Year)	3.59 (3.31-3.94)	4.33
10% (10-Year)	5.48 (5.03-5.99)	6.59
4% (25-Year)	6.80 (6.19-7.42)	8.16
1% (100-Year)	9.24 (8.26-10.1)	11.11

study to analyze the impact of more realistic (less intense with equitable precipitation depth) rainfall events in addition to the high intensity Type-II rainfall events typical when evaluating drainage infrastructure capacity. A comparison of the Type-II NRCS/SCS and SC Long distributions for the 10 percent (10-year) event is presented in **Figure 19**.

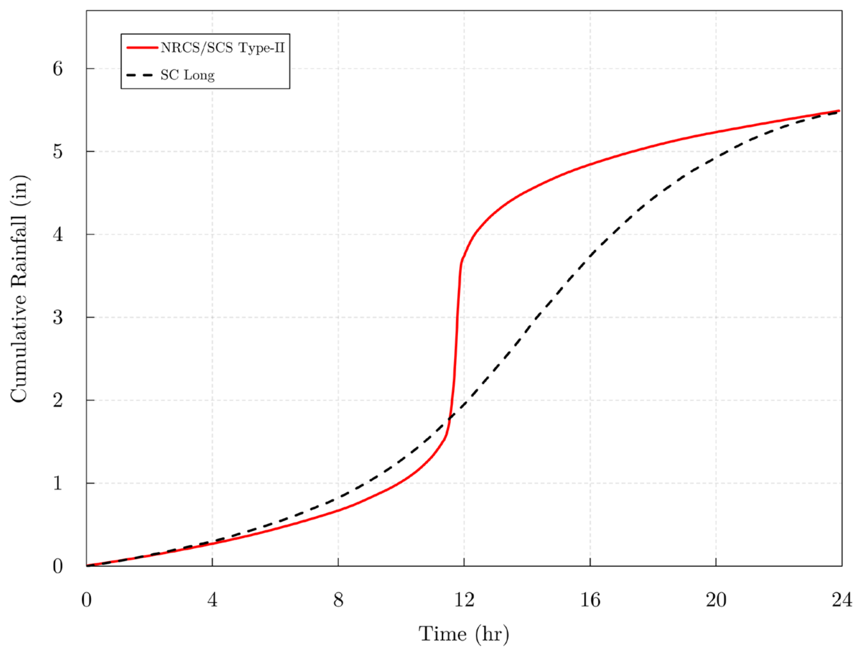


Figure 19 – Cumulative, 24-hour, rainfall for the 10 percent (10-year) design rainfall event for the NRCS/SCS Type-II and SC Long distributions.

3.2.4.2 Future Conditions Rainfall

With the cumulative impacts of climate change becoming a growing concern, it is imperative to understand and quantify these impacts when evaluating drainage system performance. As a result, future rainfall conditions were explored to understand if flood conditions experienced today will become exacerbated in the future. These changes were evaluated by increasing current condition rainfall depths by 10 percent (from the upper limit of the 90 percent confidence interval) to provide conservative estimates for future rainfall events (see **Table 4**). This 10 percent increase is based on SCOR's Draft Climate Chapter in which researchers estimated an average increase of 5 to 10 percent in precipitation state-wide. These future rainfall depths were combined with both the dimensionless Type-II NRCS/SCS and SC Long rainfall distributions for this analysis.

3.3 Hydraulic Analysis

Using the results from the field survey and hydrologic analysis, a combined 1D/2D hydrologic and hydraulic model was developed to analyze the existing drainage system. This model not only quantified drainage system deficiencies (1D), but the extent, depth, and duration (2D) of flooding. This model was developed using PCSWMM (PCSWMM; Computational Hydraulics International; version 7.5.3406), a comprehensive and complex modeling software for stormwater, wastewater, and water distribution applications. PCSWMM is considered a link-node model wherein inlets and junctions are represented as 1D nodes, pipes and channels are represented as 1D links, and overland flow is represented as a series of 2D nodes and links in the model domain. This study used the diffusive wave equations to estimate hydraulic routing.

3.3.1 Model Development

Based on data availability, results of the hydrologic analysis, and public engagement, the model developed for this study and any subsequent analysis and results were limited to the areas outlined in **Figure 20**.

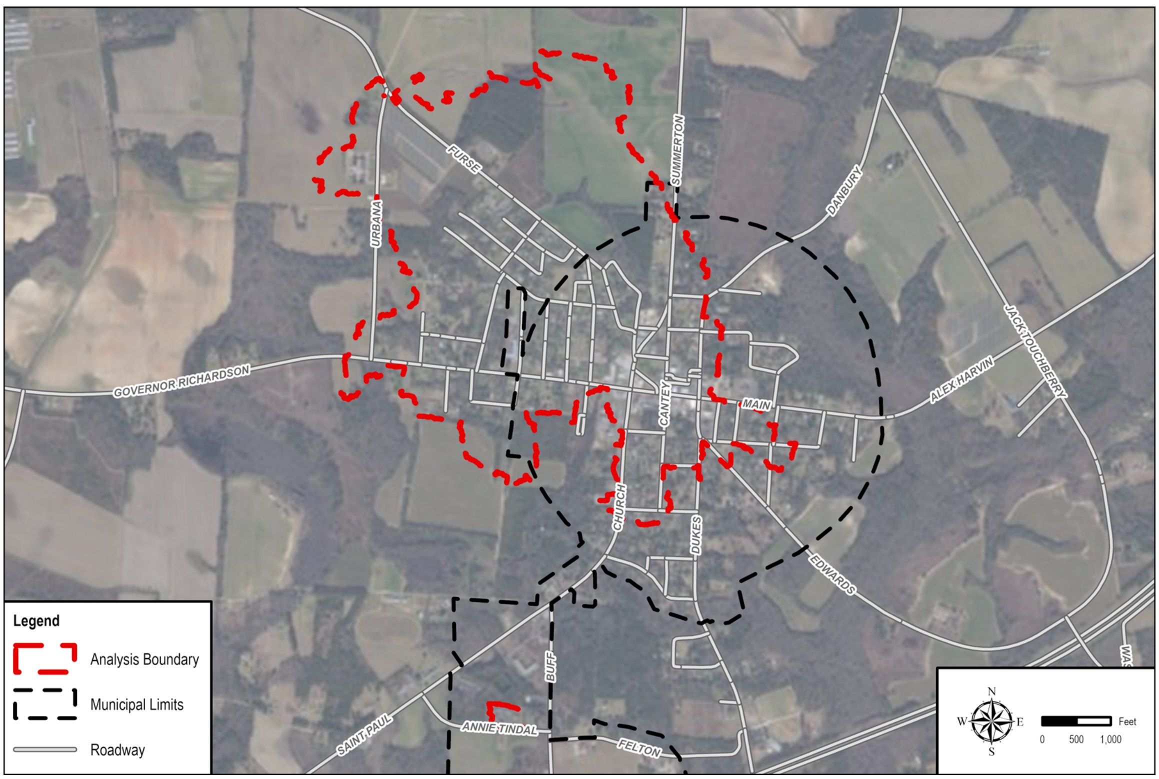


Figure 20 – Developed model and subsequent analysis was limited to the area within the analysis boundary.

3.3.1.1 Development of 1D Domain

Results from field survey (inventory of existing infrastructure) and site investigations were used to develop the 1D domain of the hydrologic and hydraulic model. Inlets, junctions, pipes, channels, and outfalls represented physical components of the drainage system. Physical attributes for these components such as invert and rim elevations, geometry attributes (e.g., size, cross-sections, etc.), material (e.g., concrete, PVC, etc.), and physical location were assumed directly from the field survey. If access was limited, or if a drainage system component was not visually apparent, engineering judgement was used to assume any missing attributes.

Watersheds were then assigned to route runoff into their receiving drainage system components (i.e., inlet, channel, catch basin, etc.) based on topographic data and flow paths. Once within the drainage network, stormwater was routed through the connected pipes and channels until it reached the outfall (i.e., the discharge point for the drainage system). Flow through these pipes and channels was determined using the diffusive wave equations which describe the relationship between flow and the physical attributes of the pipe/channel. The last variable incorporated into the model was Manning's roughness coefficient, *n*, which was assigned based on the material of a pipe/channel. **Table 5** summarizes the materials of pipes/channels encountered during this study along with the assigned Manning's roughness coefficient.

Table 5 – Summary of pipe/channel materials encountered during this study and the assigned Manning's roughness coefficient (modified from Huffman et al., 2013).

Type/Description of Pipe/Channel	Manning's Roughness Coefficient
Channel	0.060 - 0.080
Reinforced Concrete Pipe	0.014
Corrugated HDPE (≥ 12")	0.020
Other	0.014

3.3.1.2 Development of 2D Domain

Development of the model's 2D domain allowed this analysis to extend beyond pipe capacity or level-of-service classifications to include flood extent, depth, and duration results by enabling the model to replicate overland flow processes. The 2D domain was developed using topographic data and building footprints using an overland flow mesh, or set of discrete cells representative of a small area of land, through which water can flow and accumulate. This mesh was developed using a 10-foot resolution near (within 50-feet) roadways and a 50-foot resolution everywhere else in the study area. While flood results using this mesh will not delineate every small pocket of flooding (i.e., small depression in landscape, improperly graded road preventing stormwater from reaching an inlet, etc.), it is useful for identifying areas of significant flooding potential that likely need to be prioritized when developing solutions. Roughness coefficients (based on land cover classification) and hydraulic conductivity rates (based on SSURGO data; see **Section 3.2.1**) were assigned to the 2D elements of each cell within the mesh to simulate the study area's response to flooding more accurately. Finally, the 1D domain was connected to the 2D domain to allow the drainage system to surcharge and spill out (though openings in the drainage network such as inlets, channels/ditches, or open pipes) onto adjacent roadways and properties.

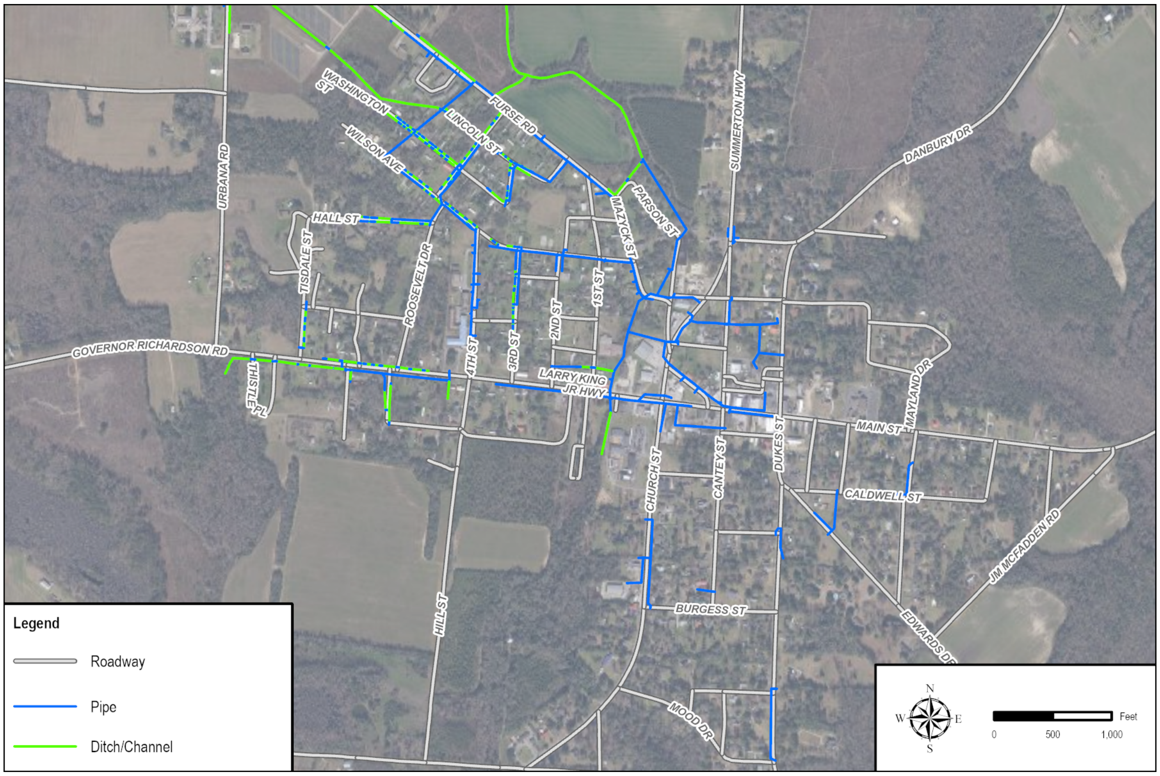
4.0 Existing Conditions Analysis and Results

An existing conditions combined 1D/2D hydrologic and hydraulic model was developed (see **Section 3.0** for details) to investigate the study area's response to diverse rainfall conditions. Using these results, areas with significant flooding issues were identified which laid the groundwork for the alternatives analysis and project recommendations.

4.1 Summary of Existing Drainage Infrastructure

Over 40,000 linear feet of drainage infrastructure was assessed during the field survey and site investigations (see **Figure 21a**). Generally, it was observed that the town's drainage infrastructure was comprised of inlets, closed piping networks, and alternating ditch/culvert systems to convey stormwater underneath driveways. Most notably, it was discovered that nearly all the town north of Larry King Highway (including approximately 115 acres of agricultural land) drains to a centralized trunk line that conveys stormwater south to an outfall which forms a tributary of Tawcaw Creek (south of Evergreen Cemetery). A detailed summary of all drainage infrastructure inventoried as part of this study can be found in **Appendix A**.

Several maintenance concerns were identified during field survey and site investigations. Common maintenance concerns included deteriorating or damaged drainage infrastructure, silted or clogged inlets, and inaccessible junctions within the closed pipe network (see **Figure 21b** through **Figure 21d**). Overall, much of the closed pipe network was observed to be clear of debris that would noticeably impede flow and performance. However, several inlets and driveway culvert systems were observed to be substantially clogged which would contribute to localized flooding conditions. It is recommended that the town engage in immediate maintenance actions to remedy some of these observed deficiencies, especially in areas with reported flooding issues. It is recommended to work with Clarendon County and SCDOT on addressing maintenance deficiencies.



(a)

(b)

(c)

(d)

Figure 21 – Extents of drainage infrastructure survey and/or evaluated by field investigations (a) and examples of maintenance concerns observed during field survey and site investigations including sink hole next to inlet (b), inlet with dislocated cover (c), and silted/clogged inlet (d).

4.2 Existing Conditions Flood Analysis

A total of 16 scenarios were analyzed using the existing conditions model to investigate the study area's response to high- and low-frequency rainfall events. Specifically, the impact of high intensity (NRCS/SCS Type-II) and realistic or average intensity (SC Long) rainfall across a range of return intervals (2-, 10-, 25-, and 100-year return intervals) and climate scenarios (current and future) were analyzed (see **Section 3.2.4** and **Table 4**). Results of the existing conditions flood analysis for each of these scenarios can be found in **Appendix B**. These results assume a "clear pipe" condition in which maintenance concerns (clogged inlets/pipes, etc.) have been identified and resolved. In addition to the 15 areas identified by the town, an additional eight areas were identified using these results that should be addressed by any proposed improvements (see **Figure 22**). A summary table of the existing conditions flood results for each of these identified areas (citizen reported and modeled), including how it compares to the original areas of concern (as applicable) and a description of what likely causes flooding in the area, can be found in **Table 7**.

Many of the areas of concern identified by citizens of the town were confirmed by results of the existing conditions flood analysis. Areas with contradictory results between simulated and reported flooding concerns were largely in areas with substantial maintenance deficiencies (clogged inlets, damaged drainage structures, etc.). A tabulated summary of these results by scenario can be found in **Table 6**. Several neighborhoods were identified as a high risk for severe and repetitive flooding based on flood extent and buildings impacted across high intensity (Type-II NRCS/SCS) and realistic, but lower intensity (SC Long) rainfall scenarios. Specifically, the areas around M1, M3, R1, R2, and R7 (see **Figure 22**) were observed to be the most at-risk.

Table 6 – Summary of existing conditions flood results for all scenarios analyzed in this study.

Scenario			**Results**	
Annual Exceedance Probability (Recurrence Interval)	Precipitation Depth (in)	Distribution	Flood Extent (acres)	Buildings Impacted[1]
50% (2-Year)	3.59	Type-II NRCS/SCS	24	94
10% (10-Year)	5.48	Type-II NRCS/SCS	61	174
4% (25-Year)	6.80	Type-II NRCS/SCS	91	219
1% (100-Year)	9.24	Type-II NRCS/SCS	135	260
50% (2-Year)	3.59	SC Long	4	11
10% (10-Year)	5.48	SC Long	12	43
4% (25-Year)	6.80	SC Long	21	66
1% (100-Year)	9.24	SC Long	40	104
Future 50% (2-Year)	4.33	Type-II NRCS/SCS	37	128
Future 10% (10-Year)	6.59	Type-II NRCS/SCS	86	213
Future 4% (25-Year)	8.16	Type-II NRCS/SCS	117	242
Future 1% (100-Year)	11.11	Type-II NRCS/SCS	166	276
Future 50% (2-Year)	4.33	SC Long	7	25
Future 10% (10-Year)	6.59	SC Long	19	64
Future 4% (25-Year)	8.16	SC Long	31	88
Future 1% (100-Year)	11.11	SC Long	56	130

[1]Flooding occurs within 5 feet of building footprint. Does not account for building's first floor elevation or flood depth.

5.0 Alternatives Analysis and Project Recommendations

Alternatives to existing drainage infrastructure that may mitigate observed flooding were investigated using results from the existing conditions analysis. This was an iterative process in which the existing drainage infrastructure in the model was improved to explore how those changes may impact flooding within areas of concern. Once it was determined that these improvements could potentially mitigate flooding, these infrastructure improvements were grouped into projects. Comprehensive cost estimating and benefit-cost analyses were then performed to determine which projects would provide the most benefit and how such projects should be prioritized.

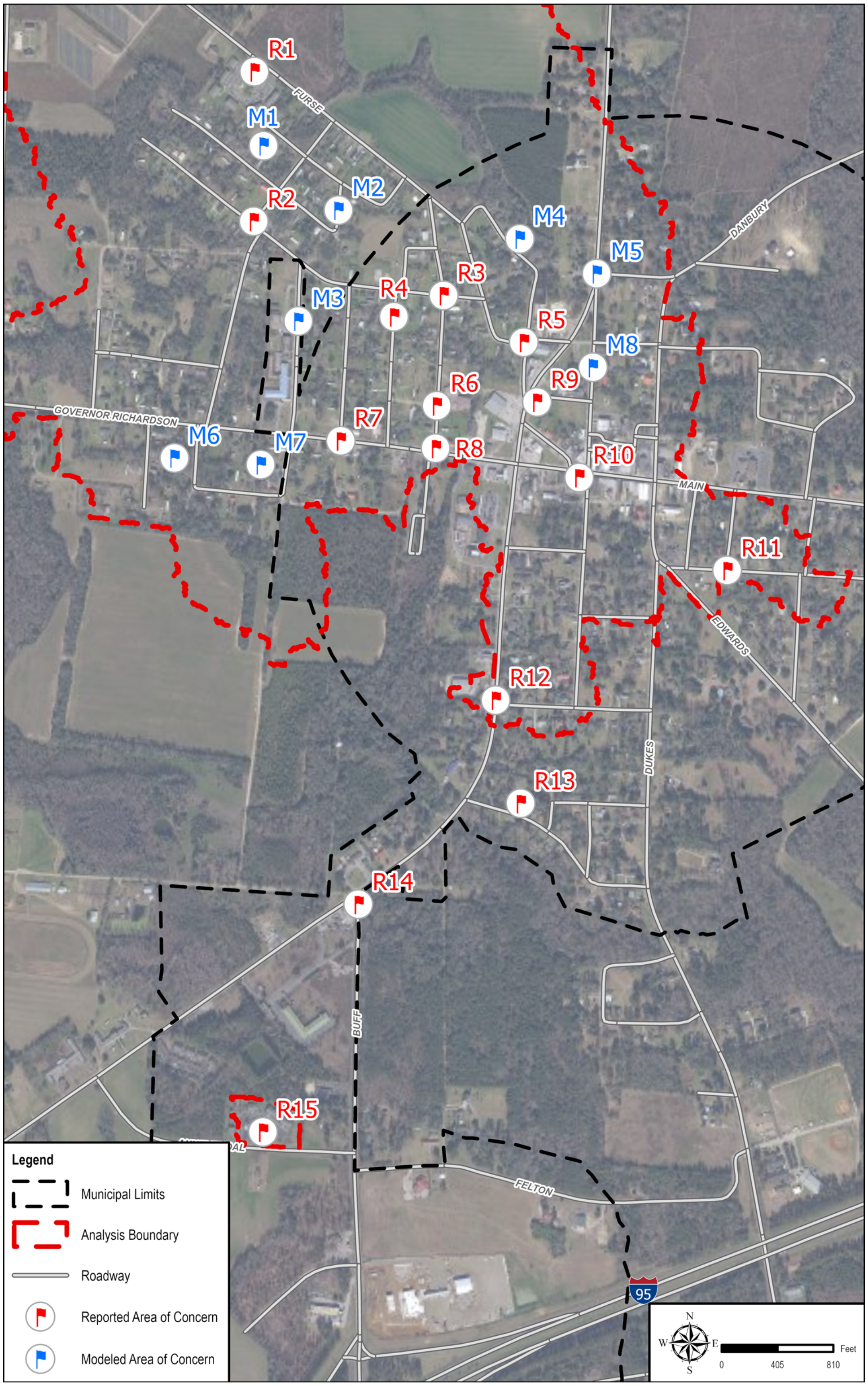


Figure 22 – Reported and modeled areas of concern.

Table 7 – Summary of existing conditions flood analysis and how it compares to compares to reported areas of concern.

Location or Index	Source	Description of Citizen Concern	Analysis of Results
R1	Citizen Reported	The area around Meadowfield Apartments experiences significant and repetitive flooding, especially within the parking lot.	Flood analysis confirms elevated flood risk during multiple scenarios primarily caused by insufficient capacity of the closed piping network just south of the apartments to absorb incoming flow from the channel which drains the solar field to the northwest.
R2	Citizen Reported	Several of the ditch/culvert systems near intersection are filled with debris, clogged, or generally unmaintained.	Flood analysis confirms elevated flood risk during multiple scenarios primarily caused by insufficient capacity of the drainage network that would not be solved just through system maintenance.
R3	Citizen Reported	The nearby intersection floods during long storm events and that the inlets are clogged and nearby ditches are unmaintained.	Flood analysis did not observe substantial flooding at this location likely due to this analysis assuming maintenance concerns (clogged inlets) have already been resolved. Further investigation is recommended to see if flooding still occurs after the system has been cleaned.
R4	Citizen Reported	The apartment parking lot and adjacent lots are susceptible to flooding.	Flood analysis confirms elevated flood risk during high intensity rainfall scenarios throughout this neighborhood caused by insufficient drainage system capacity.
R5	Citizen Reported	Severe flooding in and around the intersection and reiterated as one of the worst flooded areas in town.	Flood analysis confirms elevated flood risk during high intensity rainfall scenarios likely caused by the main trunk line having insufficient capacity to absorb any additional stormwater during rainfall events. This combined with the area's substantially lower topography, increases the probability of the drainage system surcharging and flooding adjacent properties.
R6	Citizen Reported	The nearby intersection routinely floods due to clogged inlets, blocked culverts, and unmaintained ditches.	Flood analysis did not observe substantial flooding at this location likely due to this analysis assuming maintenance concerns (clogged inlets and culverts) have already been resolved. Further investigation is recommended if flooding still occurs after the system has been cleaned.
R7	Citizen Reported	Substantial flooding within properties adjacent to 3rd St, citing that the roadside ditches did not extent along the entire length of the road and had no outfall.	Field survey and investigations confirmed that the series of roadside ditches actually drain north towards Wassau St and eventually connect to the main trunk line at Mazyck St. Flood analysis confirmed elevated flood risk with substantial flooding observed in properties adjacent to 3rd St likely caused by insufficient drainage system capacity.
R8	Citizen Reported	Substantial flooding around the church located northeast of the nearby intersection which has caused a nearby trailer to sink due to overly saturated soil.	Flood analysis confirms elevated flood risk during high intensity rainfall scenarios likely caused by the main trunk line having insufficient capacity to absorb any additional stormwater during rainfall events. This combined with the area's substantially lower topography, increases the probability of the drainage system surcharging and flooding adjacent properties.
R9	Citizen Reported	Inlets in this area are clogged creating ponded water during storm events.	Flood analysis did not observe substantial flooding at this location likely due to this analysis assuming maintenance concerns (clogged inlets) have already been resolved. Further investigation is recommended if flooding still occurs after the system has been cleaned.
R10	Citizen Reported	The intersection floods regularly along with grassed area behind the police station. Inlets in area are clogged.	Flood analysis confirms elevated flood risk during high intensity rainfall scenarios caused by insufficient drainage system capacity. If maintenance issues are resolved, substantial flood reduction may be possible.
R11	Citizen Reported	Gutters along roadway regularly flood due to clogged inlets.	Flood analysis did not observe substantial flooding at this location likely due to this analysis assuming maintenance concerns (clogged inlets) have already been resolved. Further investigation is recommended if flooding still occurs after the system has been cleaned.

Location or Index	Source	Description of Citizen Concern	Analysis of Results
R12	Citizen Reported	Roadway floods during intense storm events. Inlets have accumulated debris. Lack of curb and gutter along roadway allows stormwater to runoff towards businesses.	Flood analysis confirmed elevated flood risk during high intensity rainfall scenarios caused by insufficient drainage capacity. If maintenance issues are resolved and curb/gutter added along roadway, substantial flood reduction may be possible.
R13	Citizen Reported	Nearby drainage ditch/channel subject to flooding during heavy rains.	Outside of study boundary analyzed. Not considered in this analysis.
R14	Citizen Reported	Intersection experienced flooding during 2015 floods. Not a site of repetitive flooding due to topography.	No severe or repetitive flooding reported. Not considered in this analysis.
R15	Citizen Reported	Apartment parking lot and adjacent lawn flood regularly during storm events. Flooding has damaged apartment buildings.	Small channels which converge to drain parking lot (from flumes) are inversely graded which may cause water to back up into parking lot. Outlet to drain grassed swale behind apartment buildings is 6" flexible corrugated pipe loosely inserted into berm, appears to be inversely sloped. Recommend replacing with non-flexible, correctly graded pipe, ensuring properly graded flow paths, and reassessing flood conditions.
M1	Modeled Flooding	N/A	Flood analysis suggests that the entire neighborhood between Wilson Ave and Furse Rd is at an elevated flood risk due to the system being capacity limited and receiving flows from drainage infrastructure near Hall St and 4th St. Even if maintenance issues are resolved, inlets may surcharge into the roadway and adjacent properties.
M2	Modeled Flooding	N/A	Flood analysis suggests that drainage system along Louis St is capacity limited causing inlets to surcharge into adjacent properties.
M3	Modeled Flooding	N/A	Flood analysis suggests that drainage system along 4th St is capacity limited causing inlets to surcharge into the roadway and adjacent properties.
M4	Modeled Flooding	N/A	Flood analysis suggests that the local topography and lack of inlets create flood conditions behind the homes located northeast of Parson St.
M5	Modeled Flooding	N/A	Flood analysis suggests that flooding within the roadway right-of-way may occur. This series of inlets was unable to be connected to the larger drainage system within the model as connections were not found (due to sediment accumulation) and could not be assumed (significant distance from nearest known drainage structure). If maintenance issues are resolved, substantial flood reduction may be possible.
M6	Modeled Flooding	N/A	Flood analysis suggests significant within the roadway and adjacent properties during multiple scenarios. This is likely caused by insufficient drainage capacity and the contributing watershed's high slope (which generates substantially more runoff).
M7	Modeled Flooding	N/A	Flood analysis suggests significant flooding between Oliver St and Chalise St during multiple scenarios. This is likely caused by the area's substantially low topography and lack of drainage infrastructure.
M8	Modeled Flooding	N/A	Flood analysis suggests flooding may occur during high intensity rainfall scenarios. This is likely cause by the area's substantially low topography and capacity limited drainage ditch which connects the area to a larger drainage system.

5.1 Alternatives Analysis and Development of Proposed Improvements

The alternatives analysis consisted of an iterative process in which existing drainage infrastructure in the model was improved to investigate how those improvements could mitigate flooding. These improvements generally consisted of upgrading existing drainage infrastructure (upsizing pipes to a larger diameter or adding additional barrels), installation of new drainage infrastructure (new inlets or closed piping systems), installation of detention facilities, and re-routing watersheds that exacerbate flooding within their existing drainage systems.

5.1.1 Design Criteria and Level of Service Improvements

The criteria used to determine if the proposed improvements appropriately mitigated flooding was based on the ability to substantially mitigate flooding during the 2- and 10-year NRCS/SCS Type-II rainfall events. Secondary design criteria was based on an improvement's ability to mitigate flooding during the 2- and 10-year SC Long rainfall events.

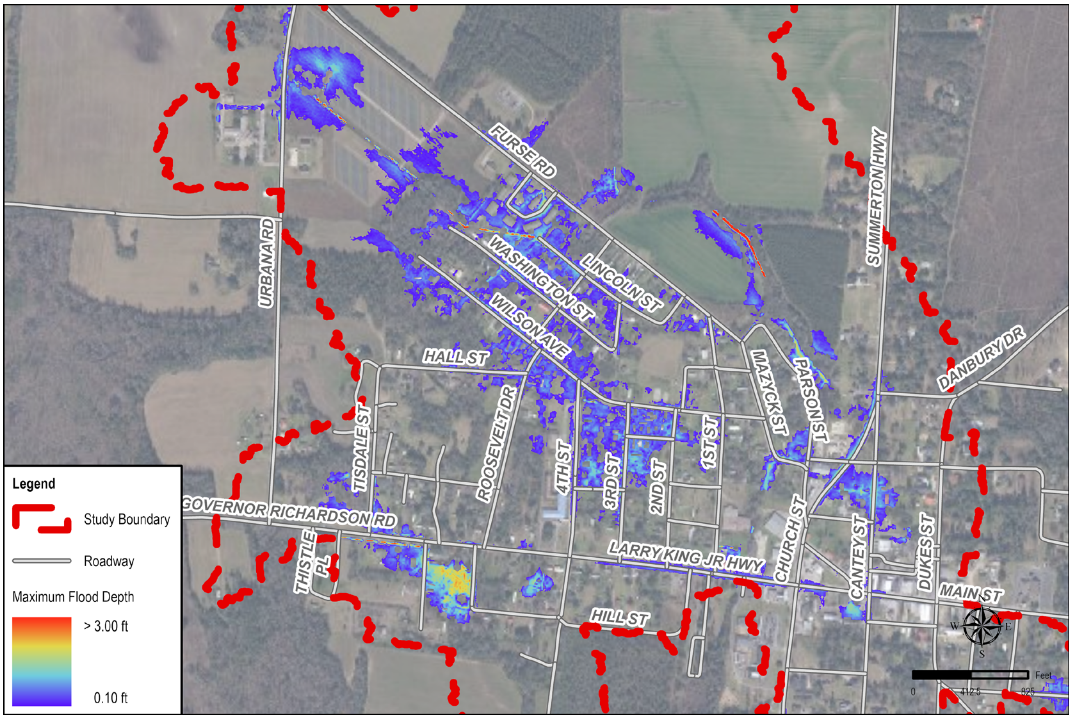
5.2 Proposed Conditions Flood Analysis

The final inventory of proposed improvements necessary to mitigate flooding within the study area was quite extensive. Several neighborhoods required near-complete replacement and upgrades of existing drainage infrastructure to substantially reduce flooding. A complete inventory of these proposed improvements can be found in **Appendix C** and the results of the proposed conditions flood analysis using the same rainfall scenarios as the existing conditions analysis can be found in **Appendix D**. Overall, the proposed improvements show promising results in terms of mitigating flooding for both the 2- and 10-year NRCS/SCS Type-II as well as up to the 100-year SC Long rainfall scenarios for several neighborhoods and across the study area (**Table 8**; **Appendix D**). An example of this can be found in **Figure 23** and **Figure 24** in which the existing and proposed conditions are compared for the 10-year rainfall events.

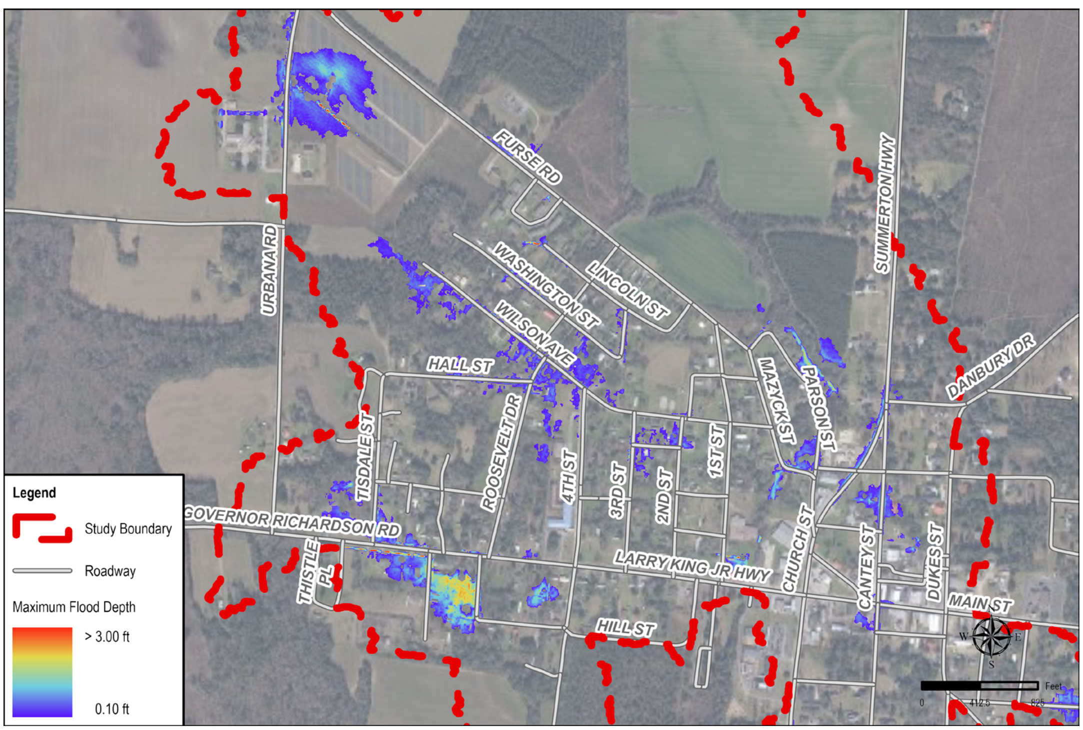
Table 8 – Summary of proposed conditions flood results for all scenarios analyzed in this study.

Scenario			Results (% Reduction from Existing Conditions)	
Annual Exceedance Probability (Recurrence Interval)	Precipitation Depth (in)	Distribution	Flood Extent (acres)	Buildings Impacted[1]
50% (2-Year)	3.59	Type-II NRCS/SCS	8 (67%)	19 (80%)
10% (10-Year)	5.48	Type-II NRCS/SCS	30 (51%)	87 (50%)
4% (25-Year)	6.80	Type-II NRCS/SCS	55 (40%)	143 (35%)
1% (100-Year)	9.24	Type-II NRCS/SCS	107 (21%)	209 (20%)
50% (2-Year)	3.59	SC Long	1 (75%)	1 (91%)
10% (10-Year)	5.48	SC Long	6.5 (46%)	6 (86%)
4% (25-Year)	6.80	SC Long	9 (57%)	9 (86%)
1% (100-Year)	9.24	SC Long	13 (68%)	15 (86%)
Future 50% (2-Year)	4.33	Type-II NRCS/SCS	14 (62%)	34 (73%)
Future 10% (10-Year)	6.59	Type-II NRCS/SCS	51 (41%)	134
Future 4% (25-Year)	8.16	Type-II NRCS/SCS	84 (28%)	193
Future 1% (100-Year)	11.11	Type-II NRCS/SCS	142 (14%)	246 (11%)
Future 50% (2-Year)	4.33	SC Long	4 (43%)	1 (96%)
Future 10% (10-Year)	6.59	SC Long	8 (58%)	8 (88%)
Future 4% (25-Year)	8.16	SC Long	11 (65%)	14 (84%)
Future 1% (100-Year)	11.11	SC Long	20 (64%)	22 (83%)

[1]Flooding occurs within 5 feet of building footprint. Does not account for building's first floor elevation or flood depth.

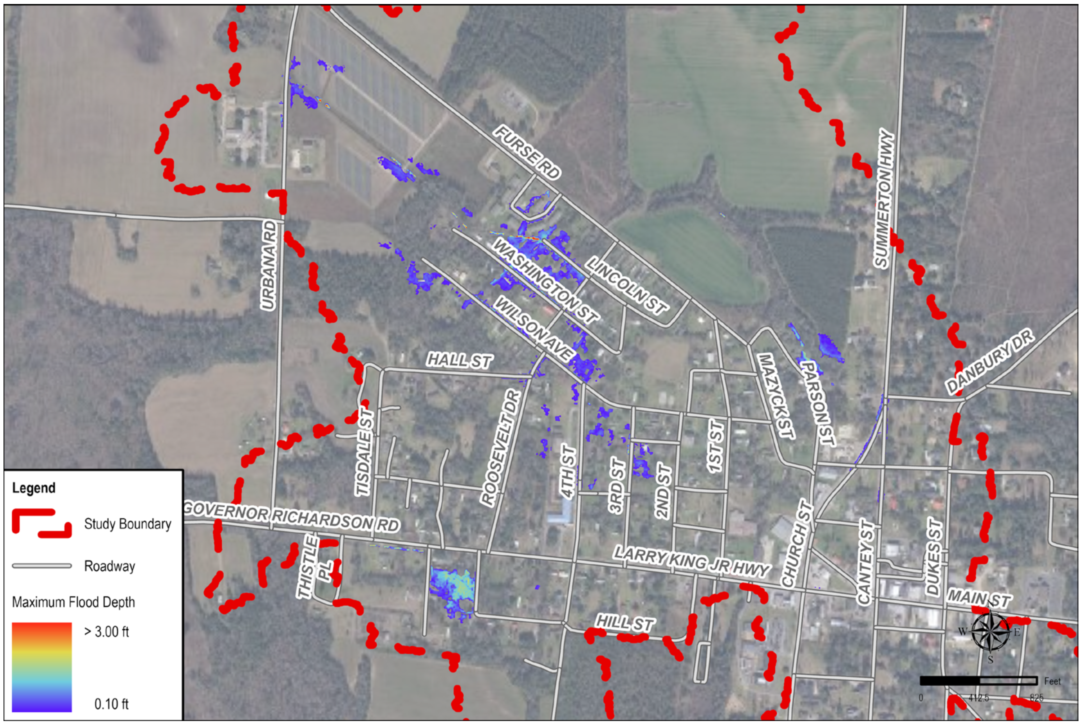


(a)

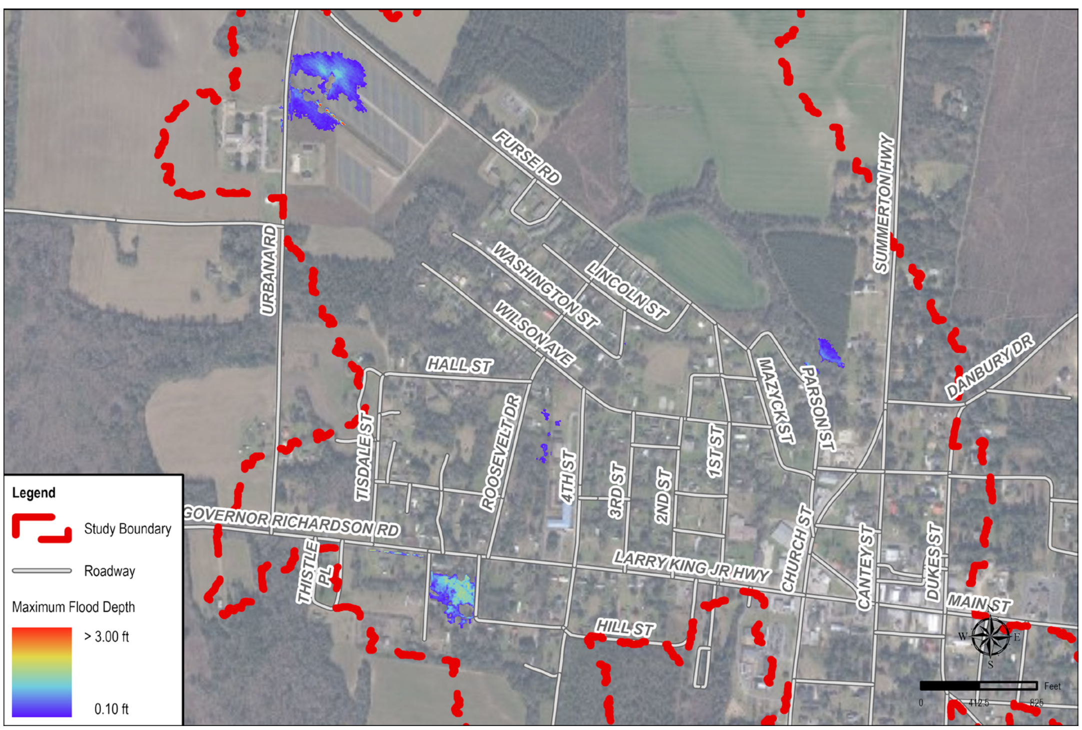


(b)

Figure 23 – Comparison of existing (a) and proposed (b) flood results for an intense 10-year (NRCS/SCS Type-II) rainfall event.



(a)



(b)

Figure 24 – Comparison of existing (a) and proposed (b) flood results for a realistic 10-year (SC Long) rainfall event.

5.3 Project Recommendations

The results from the proposed conditions flood analysis and a series of "what-if" scenarios were investigated to determine which improvements needed to be implemented concurrently (as a single infrastructure improvement project) as well as how projects should be prioritized and scheduled. Overall, proposed improvements were divided into 14 infrastructure improvement projects. Service areas (**Figure 25**) for these projects were determined by delineating which watersheds or neighborhoods would be directly affected by the proposed improvements for each project. However, this was not completely possible with projects that drain to the improvements within the "Main Trunk Line" project service area as the proposed upgrades to the main trunk line directly improve the level of service to adjacent project service areas. All projects are located within low-to-moderate income populations (see **Figure 1**) which will provide substantial flood relief for those communities.

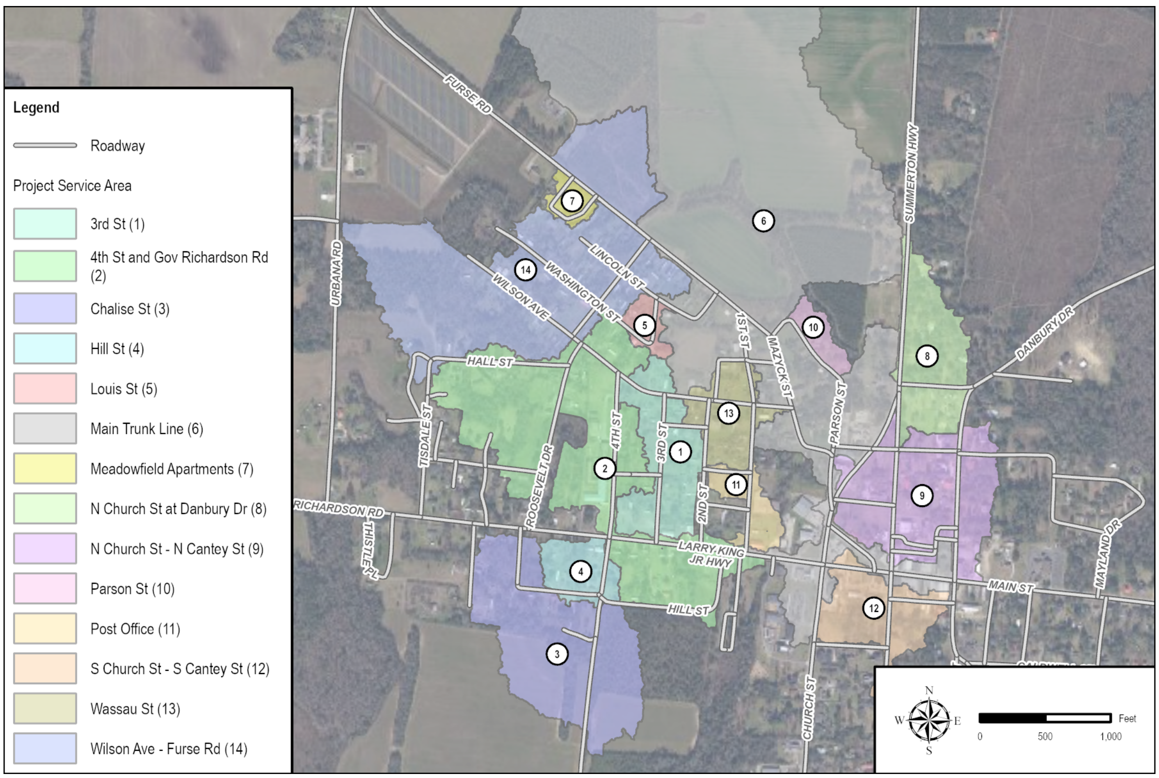


Figure 25 – Project service areas.

5.3.1 Cost Estimates

A comprehensive cost estimate (total implementation cost and annual maintenance cost) for each project was prepared wherein improved drainage infrastructure components were quantified. Quantities included the length and size of upgraded pipe, new or replaced inlets, improved ditches, and other associated construction costs (e.g., road milling, landscaping, etc.). Unit prices of materials and maintenance were estimated using the MD SHA price index for 2021 construction projects and adjusted to account for inflation and market conditions. It was assumed that inlets could be cleaned every two years, and pipes would be cleaned every 10 years. Since pipes are designed to be self-cleaning, the less-frequent maintenance interval was justified. The adjusted MD SHA prices were divided to estimate annual maintenance costs.

In addition to construction and maintenance costs, costs associated with engineering design, permitting, construction administration, and right-of-way acquisition were quantified (i.e., professional services) to estimate a total cost to implement each project. Professional services costs were estimated based on cost percentages of the total estimated construction costs.

Table 9 – Estimated project implementation costs including engineering, construction administration, and permitting.

Project	Estimated Project Cost	Estimated Annual Maintenance Cost
3rd St	$2,470,000	$8,400
4th St and Gov Richardson Rd	$8,631,000	$29,900
Chalise St	$1,022,000	$1,600
Hill St	$484,000	$100
Louis St	$952,000	$2,700
Main Trunk Line	$12,868,000	$26,700
Meadowfield Apartments	$759,000	$2,300
N Church St at Danbury Dr	$634,000	$1,500
N Church St – N Cantey St	$2,349,000	$7,300
Parson St	$294,000	$500
Post Office	$318,000	$300
S Church St – S Cantey St	$811,000	$2,900
Wassau St	$1,625,000	$4,400
Wilson Ave – Furse Rd	$9,107,000	$36,700

Total project implementation costs included a 20 percent contingency for both construction and professional services since project costs were based on a 10 percent concept design. All costs represent costs in 2023 dollars and should be re-evaluated in the future as the town begins to plan for and implement projects. A detailed breakdown of the implementation cost of each project (including engineering, construction administration, and permitting) and annual maintenance costs can be found in **Appendix E** with a summary found in **Table 9**.

5.3.2 Benefit-Cost Analysis

Many federal and state funding programs for infrastructure projects require an assessment of cost effectiveness. The drainage improvement projects presented in previous sections underwent a benefit-cost analysis (BCA) in which future benefits of a hazard mitigation project were calculated and compared to the project costs. For the flood mitigation projects described herein, benefits were derived in the form of avoided damage to structures and roadways. The analysis was done using FEMA's BCA Toolkit (v. 6.0). For a project to be eligible for FEMA and CDBG-MIT funding sources, the calculated BCA must be equal to or greater than 1.0 using a 7 percent discount rate. The total calculated benefit and cost (including annual maintenance) is approximately $86,527,510 and $44,035,925. The ensemble BCA for all improvement projects combined is 1.96.

The BCA analysis completed for this study was limited to the data and assumptions outlined in subsequent sections. For example, one major limitation of the BCA presented herein is that it does not account for loss of income for persons or businesses within the impacted areas. Furthermore, most building damage estimates were based on limited assessor data and recommendations provided by FEMA. Therefore, projects with a BCA slightly less than one (i.e., "Main Trunk Line" improvements) should be re-evaluated in the future with local, town-specific economic data if made available.

5.3.2.1 Modeled Damages Background Data

Improvement projects were subdivided into the 14 service areas previously defined. Each service area has an associated cost as well as modeled damages for existing and post-project conditions. The critical facilities and roads were treated as separate damages.

Building footprints in GIS format were used to identify locations of structures that may experience flooding within each service area. Clarendon County Tax Assessor data was used to estimate property value, size of the structure, year of construction, and building type (e.g., residential, commercial, etc.). Ground elevations adjacent to structures were extracted from topographic maps, and the height of the first floor relative to the ground elevation was estimated from photographs.

The number of persons per household was assumed to be 2.61 in accordance with census data for Clarendon County (2017-2021). The number of workers per residence was assumed to be one.

The relationship between flooding depth and damage (as a percentage of structure value) was estimated using data published by the United States Army Engineer Research and Development Center. These data include separate depth-damage functions for single-family residential, multi-family residential, mobile home, and commercial structure types. Separate functions were also used to estimate structure damage versus contents damage.

Road centerlines were obtained in GIS format with roadway widths estimated from aerial imagery. Traffic data for roads were collected from publicly available resources where available. When unavailable, traffic data was estimated from nearby datapoints and engineering judgement.

5.3.2.2 Flood Events and Depths

For the BCA, the 1-year, 2-year, and 10-year (NRCS/SCS Type-II) flood events were assessed for existing and post-project conditions. Inundation maps for each design event were used to identify structures that would flood and to what depth. By overlaying the structure footprints on the flood maps, maximum flooding depth for each structure and flood event were extracted. For road damages, impacted roads were identified using inundation maps for each flood event.

5.3.2.3 Residential and Commercial Building Damages

A total of 149 buildings are affected by at least one design flood for the existing conditions models compared to 59 buildings for the proposed conditions models. The majority of the buildings still impacted during the proposed conditions model are only impacted by the high-intensity 10-year NRCS/SCS Type-II rainfall scenario. A comparison of impacted buildings for the existing and proposed scenarios can be seen in **Figure 26**. Buildings were categorized by type (e.g., single-family residential, mobile home, barn, etc.), and lumped into groups based on service area. Expected damages for existing and proposed conditions were calculated for each building which included damage to the building, damage to the contents of the building, displacement cost for residents, and loss of water and sewer service for residents. Displacement costs and loss of services were assumed for a duration of one day and only applied to residential buildings.

5.3.2.4 Critical Facility Damages

Two critical facilities were identified in the study area. This includes Clarendon County Fire Station #3 and the local police station. Neither structure was damaged during the 1-year, 2-year, and 10-year floods.

5.3.2.5 Road Damages

Mitigation project benefits for roads involved reduced travel time and distance from reduced road closures and detours. For each flood event, impacted roads were itemized, and detour distances were estimated. It was assumed that roads were impassable if more than half of the road width was flooded, thus requiring a detour. The impact days for road closure was assumed to be 0.5 days for the 1-year and 2-year flood, and 1.0 days for the 10-year flood.

5.3.2.6 Assumptions

Several assumptions regarding the previously described background data were also required to be able to complete the BCA. An itemized list of these assumptions can be found in **Table 10**.

(a)

(b)

Figure 26 – Comparison of existing (a) and proposed (b) impacted buildings grouped by scenario analyzed in the benefit-cost analysis.

Table 10 – Itemized list of assumptions made during the benefit-cost analysis.

1. Service areas	
a.	The proposed stormwater pond was grouped with the Wilson-Furse project area
b.	The Project Useful Life was set to the FEMA standard value for drainage improvements (50 years)
c.	The Year Property was Built value was set to the average value of all lumped structures per service area.
2. Buildings	
a.	If multiple buildings exist without individual parcel cards, the total value was weighed by each structure's square footage
b.	If no other data was available, the following assumptions were made for market value: i. Residential building = $140/square feet ii. Mobile home = $45/square feet + $20,000 for utility connections iii. Auxiliary structure (e.g., pole barn) = $12/square feet
c.	A corrected market value was calculated by taking the maximum of the parcel card value and the assumed value per square foot.
d.	If the year built was unknown, the year 1990 was assumed.
e.	The ground elevation at each building was measured at the centroids of the polygons of building footprints.
f.	The finished floor elevation was equal to the floor height plus ground elevation.
g.	The floor height was estimated from Google photographs. A standard value of 2.5 feet was assumed for mobile homes.
3. Occupancy details	
a.	The number of residents per residential structure was assumed to be 2.61
b.	The number of workers per residential structure was assumed to be 1.0.
c.	The number of workers per non-residential structure varied based on use.
4. Flood elevations	
a.	Flood depths at structures were measured 5 feet from the polygons of building footprints.
b.	The maximum flood depth affecting a structure for each recurrence interval was used
5. Depth-damage functions	
a.	Depth-damage functions for residential (non-mobile home) structures were extracted from: https://planning.erdc.dren.mil/toolbox/library/EGMs/egm04-01.pdf
b.	Depth-damage functions for mobile homes and commercial structures were extracted from: https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf
c.	Contents depth-damage functions were extracted from: https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf
d.	Depth of damages were extracted from the depth-damage functions by rounding the flood depth down to the nearest increment in the depth-damage function table.
6. Additional costs	
a.	Two optional cost categories were included: 1) Displacement costs, and 2) Loss of water and sewer (wastewater) services.
b.	The General Services Administration standard rate of $94/person/day was assumed for displacement costs.
c.	The FEMA standard value of $93/person/day of loss of water service was assumed.
d.	The FEMA standard value of $41/person/day of loss of wastewater service was assumed.
e.	Any flooded residential structure was eligible for those additional costs.
f.	One impact day was assumed for displacement and loss of service.
7. Roads	
a.	If a stretch of roadway had no outlet and no viable detour, the added travel time was set to 720 minutes (as per FEMA guidance).
b.	The default federal rate was used for mileage cost.
c.	One-way detour trips were extracted from SCDOT data where available.
d.	When unavailable, trip counts were estimated from the number of impacted structures and their use.
e.	Impact days were assumed to be 1.0 for the 10-year flood, and 0.5 days for the 2-year and 1-year floods.
f.	Detour speeds were assumed to be traveled at 30 miles per hour.

5.3.2.7 Benefit-Cost Analysis Results

The initial BCA treated each project service area as an independent system. However, the drainage system was found to be complex and improvements in some project service areas would be potentially dependent on improvements in other project service areas. For this study, this was primarily the case for project service areas connected to the main trunk line improvements since these project service areas may be directly benefitted by additional capacity at this connection and therefore able to better drain their respective areas. The BCA was therefore revised to account for this interdependency by investigating flood results across the study area with and without the main trunk line improvements (see **Section 5.3.3.1** for "what-if" details). Using these results, it was possible to determine the reduction in flooding for each event caused by the main trunk line improvements and adjust the benefits accordingly. Final results from the BCA for each of the 14 projects is presented in **Table 11**.

5.3.3 Project Prioritization, Rankings, and Scheduling

The impact of each project was originally assessed using a weighted scoring approach to determine an overall project score and rank based on reductions in flooded footprints and structures, total implementation cost, and BCA. Final rankings and then adjusted based on engineering judgement and the results of a series of "what-if" analyses.

5.3.3.1 "What-If" Scenarios and Analysis

Several "what-if" scenarios were investigated to determine the final ranking and prioritization of projects. Not only did the "what-if" analyses provide additional clarity on the codependence of proposed drainage improvements, but it also helped determine the order in which projects should be constructed to provide immediate flood relief. Each of the "what-if" scenarios outlined below were investigated using the 1-, 2-, and 10-year NRCS/SCS Type-II rainfall scenarios and compared to the proposed conditions flood analysis to provide this necessary context. These "what-if" scenarios included:

a. Removing any improvements within the "Main Trunk Line" project service area.
    i. **Purpose:** To investigate the dependency of adjacent projects on the main trunk line's proposed increase in capacity. This "what-if" scenario was previously discussed as part of the benefit-cost analysis (see **Section 5.3.2.7**).
    ii. **Results:** It was determined that a substantial portion of the flood reduction (across all rainfall scenarios) observed in the "Louis St" and "N Church St – N Cantey St" project service areas were caused by the "Main Trunk Line" improvements. The "Meadowfield Apartments", "Parson St", and "Wilson Ave – Furse Rd" project service areas only substantially benefitted during the 10-year high intensity (NRCS/SCS Type-II) rainfall scenario from the addition of the "Main Trunk Line" improvements.
b. Removing the detention basin from the "Wilson Ave – Furse Rd" project service area.
    i. **Purpose:** To investigate the efficacy of the remainder of the improvements in case easements cannot be granted for the construction of the proposed detention basin.
    ii. **Results:** Substantial flood reduction is still possible during the 1- and 2-year NRCS/SCS Type-II rainfall scenarios, however, additional flooding is observed in "Meadowfield Apartments" and adjacent properties during the 10-year NRCS/SCS Type-II rainfall scenario.
c. Removing the detention basin from the "Wilson Ave – Furse Rd" project service area and all improvements within the "Main Trunk Line" project service area.
    i. **Purpose**: To investigate the efficacy of the remaining improvements in case easements cannot be granted for the construction of the proposed detention basin and if the improvements within the "Wilson Ave – Furse Rd" improvements were constructed before the "Main Trunk Line".
    ii. **Results:** Substantial flood reduction is still possible during the 1- and 2-year NRCS/SCS Type-II rainfall scenarios, however, widespread flooding is observed during the 10-year NRCS/SCS Type-II event.
d. Removing any improvements within the "Meadowfield Apartments" project service area.
    i. **Purpose:** To determine if the observed flood reduction was caused by this service area's improvements or the adjacent "Wilson Ave – Furse Rd" project.
    ii. **Results:** Majority of observed flood reduction is caused by other projects, specifically the "Wilson Ave – Furse Rd" and "Main Trunk Line" projects.

Table 11 – Results of the benefit cost analysis for each project analyzed in this study.

Project	Estimated Project Cost	Rainfall Scenario*	Flood Extent (acres)		Buildings Impacted		Benefit-Cost Ratio
			Existing	Proposed	Existing	Proposed	
3rd St	$2,470,000	1-year	1.63	0.00	15	0	**7.05**
		2-year	2.42	0.00	20	0	
		10-year	4.08	0.54	25	9	
4th St and Gov Richardson Rd	$8,631,000	1-year	3.33	0.14	15	0	**1.10**
		2-year	4.44	0.27	16	1	
		10-year	7.22	2.94	19	12	
Chalise St	$1,022,000	1-year	1.23	1.35	3	5	0.00
		2-year	1.80	1.84	6	6	
		10-year	2.48	2.52	8	8	
Hill St	$484,000	1-year	0.22	0.10	0	0	0.09
		2-year	0.28	0.23	0	0	
		10-year	0.60	0.57	1	1	
Louis St	$952,000	1-year	0.07	0.01	0	0	0.33
		2-year	0.23	0.03	0	0	
		10-year	0.82	0.25	6	0	
Main Trunk Line	$12,868,000	1-year	0.24	0.00	0	0	0.85
		2-year	0.52	0.00	0	0	
		10-year	6.27	1.73	15	3	
Meadowfield Apartments	$759,000	1-year	0.00	0.00	1	0	**11.67**
		2-year	0.10	0.00	3	0	
		10-year	1.42	0.02	5	0	
N Church St at Danbury Dr	$634,000	1-year	0.28	0.00	0	0	0.13
		2-year	0.36	0.00	0	0	
		10-year	0.58	0.47	0	0	
N Church St – N Cantey St	$2,349,000	1-year	0.26	0.00	0	0	0.77
		2-year	0.89	0.00	1	0	
		10-year	3.21	1.36	3	1	
Parson St	$294,000	1-year	0.22	0.00	1	0	**4.47**
		2-year	0.27	0.05	1	0	
		10-year	0.85	0.66	4	3	
Post Office	$318,000	1-year	0.00	0.00	0	0	0.14
		2-year	0.02	0.02	0	0	
		10-year	0.34	0.39	1	1	
S Church St – S Cantey St	$811,000	1-year	0.06	0.00	0	0	0.01
		2-year	0.26	0.00	0	0	
		10-year	0.75	0.30	0	0	
Wassau St	$1,625,000	1-year	0.48	0.00	6	0	**3.63**
		2-year	0.73	0.00	7	0	
		10-year	1.80	0.46	16	6	
Wilson Ave – Furse Rd	$9,107,000	1-year	3.29	0.00	22	0	**2.96**
		2-year	5.86	0.07	33	1	
		10-year	13.09	3.16	46	15	

*NRCS/SCS Type-II rainfall distributions were considered in this analysis.

e. Removing any improvements within the "Meadowfield Apartments" and "Main Trunk Line" service area.
    i. **Purpose:** To determine if significant flood reduction still occurred if the "Wilson Ave – Furse Rd" project was constructed first.
    ii. **Results:** Substantial flood reduction (1- and 2-year NRCS/SCS Type-II rainfall event) is possible for the "Meadowfield Apartments" project service area if "Wilson Ave – Furse Rd" project is constructed first. However, further flood reduction (specifically during the 10-year NRCS/SCS Type-II rainfall event) requires the addition of the "Main Trunk Line" improvements.

5.3.3.2 Project Prioritization and Rankings

A scoring metric was developed to quantitatively assess and assist with the prioritization of projects based on a project's ability to reduce the number of buildings impacted by flooding as well as reduce the overall flooding extent compared to existing conditions. This project score was calculated as

$$\text{Project Score} = (BCR \cdot 0.50) + \left(FER_{1-yr} \cdot 0.125\right) + \left(FER_{2-yr} \cdot 0.075\right) + \left(FER_{10-yr} \cdot 0.050\right) + \left(IBR_{1-yr} \cdot 0.125\right) + \left(IBR_{2-yr} \cdot 0.075\right) + (IBR_{10-yr} \cdot 0.050) \quad (3)$$

where BCR is the project's benefit-cost ratio, FER_{X-yr} is the flood extent reduction in acres within the project service area compared to existing conditions for the 1-, 2-, and 10-year NRCS/SCS Type-II rainfall scenarios, and IBR_{X-yr} is the impacted buildings reduction within the project service area compared to existing conditions for the 1-, 2-, and 10-year NRCS/SCS Type-II rainfall scenarios.

Based on these scores, projects were ranked against one another to determine initial ranking and prioritization (**Table 12**). These rankings were then adjusted based on the results of the "what-if" analyses and engineering judgement to elevate projects which would provide benefits to project service areas outside of their own respective service area. For example, "4th St and Gov Richardson Rd" was elevated above "3rd St" since improvements in the latter tie into a larger drainage system running along Gov Richardson Rd included in the "4th St and Gov Richardson Rd" improvements. Additionally, the "Main Trunk Line" improvements were elevated above any improvements in "Meadowfield Apartments" as this project service area was found to be largely dependent on improvements within the "Wilson Ave – Furse Rd" and "Main Trunk Line" project service areas based on results from the "what-if" analyses.

5.3.3.3 Scheduling and Sequencing Considerations

Design and construction of recommended projects should occur in the order presented in the final rankings (**Table 12**). Projects should be constructed starting from the furthest downstream point. Furthermore, projects should account for future projects during the design and construction phases such as constructing junction boxes that allow for adjacent project(s) to tie into in the future to reduce future construction costs and redundancies. Special considerations for the scheduling of "4th St and Gov Richardson Rd" and "Wilson Ave – Furse Rd" projects are considered below:

- Special consideration should be taken during the design and construction of "4th St and Gov Richardson Rd" to ensure that any improvements to the outfall (behind Evergreen cemetery) are completed such that the capacity of the outfall can accept any additional flows from any scheduled improvements. If the outfall is found to be at sufficient capacity for all projects currently being constructed, then these outfall improvements may be able to be scheduled later during the "Main Trunk Line" improvements.
- During the design phase of the "Wilson Ave – Furse Rd" project, procurement of the easements related to the detention basin should be pursued first. While substantial flood reduction is possible without the detention basin, further upgrades may need to be considered along the pipes connecting the channel behind Meadowfield Apartments to where the project service area connects to the town's larger drainage network.
- During the design phase of the "Wilson Ave – Furse Rd" project it should be assessed what the likelihood is of the "Main Trunk Line" improvements being constructed as well as what the timeline for implementation would be. If it is unlikely (i.e., funding limitations) that the "Main Trunk Line" improvements will be constructed anytime soon, then the closed piping network connecting Roosevelt Dr to Furse Rd will need to be designed to slope towards the channel just to the northeast, where the existing drainage system outfalls.

Table 12 – Summary of each proposed project and final ranking. Original ranking only uses scoring methodology while final rankings account for results of the "what-if" analyses and engineering judgement. Projects with a final ranking in bold represent projects with a BCA greater than 1.0.

Project	Estimated Project Cost	Benefit-Cost Ratio	Score	Original Ranking	Final Ranking
3rd St	$2,470,000	7.05	8.26	2	**3**
4th St and Gov Richardson Rd	$8,631,000	1.10	4.82	4	**2**
Chalise St	$1,022,000	0.00	-0.42	14	14
Hill St	$484,000	0.09	0.07	12	12
Louis St	$952,000	0.33	0.52	9	9
Main Trunk Line	$12,868,000	0.85	1.32	7	**4**
Meadowfield Apartments	$759,000	11.67	6.51	3	**5**
N Church St at Danbury Dr	$634,000	0.13	0.13	10	10
N Church St – N Cantey St	$2,349,000	0.77	0.75	8	8
Parson St	$294,000	4.47	2.54	6	**7**
Post Office	$318,000	0.14	0.07	11	11
S Church St – S Cantey St	$811,000	0.01	0.05	13	13
Wassau St	$1,625,000	3.63	3.77	5	**6**
Wilson Ave – Furse Rd	$9,107,000	2.96	9.52	1	**1**

5.4 Environmental Compliance, Permitting, and Utility Coordination

Implementation of recommended improvements will require regulatory permitting and coordination with surrounding utilities. As a result, it is important to understand cooperation with multiple local, state, and federal agencies and governmental entities will play a key role in the success of projects recommended herein. Design standards and permit requirements that are anticipated to be faced during project execution are summarized as follows:

- Most recommended projects will be located along SCDOT-maintained roads. As a result, SCDOT encroachment permits will be required. Most importantly, drainage design and any required roadway design will need to follow SCDOT design standards, at a minimum, unless variances are granted from SCDOT.
- Conflicts with existing utilities (e.g., water and sewer) are likely to occur as drainage projects are implemented. Coordinating with the town's water and sewer department is encouraged early in the design process. Electric, communications, and other utility providers should be coordinated as well during design.
- Application for Nationwide Permits (NWP) from the United States Army Corps of Engineers (USACE) is anticipated to be required on some projects as proposed drainage projects may impact affect aquatic environments within adjacent waterways.
- Historical artifacts are possible to be unearthed during construction efforts. Coordination with local historic preservation groups will be critical if items of historical artifacts are discovered during design and/or construction.
- Environmental assessments, such as a phase 1 assessment, and historical and cultural assessments may be required prior to construction depending on funding sources. For example, community development block grant (CDBG) funding typically requires these types of assessments. As a result, permitting requirements specific to each funding source should be carefully evaluated.
- Stormwater permits and/or land disturbance permits will likely be required to complete construction of the proposed projects. Entities such as the Town of Summerton, Clarendon County, and SCDHEC would be responsible for such permits, if required.

5.5 Multipurpose Solutions and Project Synergies for Impactful Community Benefits

Recommendations provided herein were aimed at providing the town with high-level drainage improvement projects that will mitigate flood risk. However, during detailed design, the town should consider dual purpose projects that can provide numerous community benefits beyond flood risk reduction. For example, green infrastructure and low-impact development designs could be considered along Main Street and the business district to enhance the aesthetics and feel of the community. Additionally, there may be opportunities to enhance pedestrian safety and mobility such as sidewalks and pedestrian paths. Furthermore, any water and sewer line improvements needed within each project services area should be considered as well since impacts to those systems will likely be unavoidable. All of these aforementioned items can add community benefits relative to their costs which are often inconsequential compared to the cost of drainage infrastructure but are impactful in enhancing the community. Therefore, the town should consider all indirect infrastructure projects and/or needs of the town in the planning and design of the recommended drainage improvement projects.

5.6 Funding Assessment

Recommended projects could be funded with local government funds (e.g., Town of Summerton general fund). Using these funds would be the easiest approach to funding projects. However, the cost of several recommended projects relative to the town's annual budget is likely too costly for the town. As a result, one consideration would be for the town to consider external funding through local partnerships to finance the proposed projects. For example, there may be opportunities for the town to partner with Clarendon County and SCDOT to boost the town's available funding.

An alternative to using town funds or available funding from Clarendon County or SCDOT would be sourcing grants to finance projects. This approach would require the town to pursue state and federal grants to fund projects in their entirety or portions thereof. In particular, it may be required to source funds from multiple grants to complete a single project (e.g., main trunk line upgrades). However, regardless of the grant program, the town will still be required to provide some level of local match to be eligible for funding (typically 10 to 15 percent), excluding certain funds from the South Carolina Office of Resilience.

Of the numerous grant programs currently available, The Town of Summerton should consider the following programs and/or grants to fund the recommended projects partially or entirely:

- Community Development Block Grant (CDBG) – Community Infrastructure Grant - State
- Rural Infrastructure Authority (RIA) Basic Infrastructure Grant – State
- South Carolina Office of Resilience CDBG-Mitigation Grant – State
- State Revolving Fund (SRF) Program - State
- FEMA Building Resilient Infrastructure Communities (BRIC) Grant – Federal
- USDA Water & Waste Disposal Loan & Grant Program – Federal
- EPA State and Tribal Assistance Grant (STAG) – Federal

The aforementioned grant programs offer various levels of funding in the form of grants, low interest loans, or principal forgiveness loans. The Town of Summerton is eligible to apply for funding through each of these programs which would fund stormwater and drainage improvement projects. Each program has varying applicant requirements, but the Town of Summerton would be well suited for each. However, of all programs currently available, it is strongly encouraged to focus on the South Carolina Office of Resilience CDBG-MIT funding first as this program finances 100 percent of the project costs. Moreover, the South Carolina Office of Resilience team will support the town in managing engineering, permitting, and construction contracts on behalf of the town.

6.0 Summary and Conclusion

A comprehensive hydrologic and hydraulic study was completed for the Town of Summerton to investigate the existing drainage system, identify drainage system deficiencies, and develop solutions to address systemic flooding. Meetings with town officials and residents helped shape the scope of this investigation and highlight areas of concern that were at an increased risk of flooding. The existing drainage network was surveyed to identify visually apparent drainage infrastructure within areas of concern. Most notably, it was discovered during these field investigations that most of the town north of Larry King Highway/Main Street drains to a central trunk line that routes stormwater to an outfall south of Evergreen Cemetery (see **Appendix A**).

Following completion of the inventory of existing drainage infrastructure, a comprehensive hydrologic assessment was completed to delineate watersheds which flow to the existing drainage system. During the hydrologic assessment hydrologic parameters (i.e., soil characteristics, land use/land cover classifications, etc.) were estimated and used to determine the volume and rate of runoff routed to the existing drainage system during various rainfall events. Using the results of the existing drainage infrastructure inventory and hydrologic assessment, a combined 1D/2D hydrologic and hydraulic model was developed. This combined 1D/2D model allowed for investigations to not only consider flow within the drainage network (1D) but also the depth, extent, and duration of flooding (2D) that occurred.

Using this existing conditions model, several rainfall scenarios were investigated to identify drainage system deficiencies. Specifically, existing conditions flood analysis investigated the existing drainage system's response to high-intensity (NRCS/SCS Type-II) and realistic-intensity (SC Long) rainfall events for the 2-, 10-, 25-, and 100-year design rainfall depths. Results from this analysis confirmed most residents' concerns (in addition to several more identified as part of this analysis) with the exceptions of those related to maintenance deficiencies within the system (i.e., clogged inlets, etc.). This was because the main focus of the hydraulic analysis was to assess capacity wherein the existing drainage network was assumed to be properly maintained so as to not falsely recommend an area for costly improvements if system maintenance would address flooding concerns.

Using results from the existing conditions flood analysis, drainage improvement alternatives were investigated. The alternatives analysis consisted of an iterative process in which existing drainage infrastructure in the model was improved to investigate how those improvements could mitigate flooding. These improvements generally consisted of upgrading existing drainage infrastructure (upsizing pipes to a larger diameter or adding additional barrels), installation of new drainage infrastructure (new inlets or closed piping systems), installation of detention facilities, and re-routing watersheds that exacerbate flooding within their existing drainage systems. The criteria used to determine if the proposed improvements appropriately mitigated flooding was based on the ability to substantially mitigate flooding during the 2- and 10-year NRCS/SCS Type-II rainfall events, as this is a standard engineering design requirement for roadways and residential areas. Secondary design criteria was based on an improvement's ability to mitigate flooding during the 2- and 10-year SC Long rainfall events. Final improvements underwent a proposed conditions flood analysis to investigate the proposed drainage system's response to all the same rainfall events as the existing conditions flood analysis which allowed for simple comparison of any proposed improvements' effectiveness across a wide range of scenarios.

Results from the proposed conditions flood analysis were then investigated to determine which improvements needed to be implemented concurrently as individual infrastructure improvement projects and to determine project prioritization and scheduling. Overall, proposed improvements were divided into 14 infrastructure improvement projects. Implementation cost of each project (including engineering, construction administration, and permitting) was estimated and a benefit-cost analysis (using FEMA methodology) was performed to determine the cost effectiveness of each project (benefits vs cost). Following a ranked scoring metric, which weighted each project's cost, benefit-cost ratio, and flood reduction, results from a series of "what-if" analyses, and engineering judgement, a final list of recommended projects was determined including their final priority/ranking (see **Table 13**). All final recommended projects are located within low-to-moderate income and socially vulnerable populations and should provide substantial flood relief for the community.

Table 13 – Summary of recommended priority projects including their estimated project cost, benefit-cost ratio, and final ranking/priority. Projects in bold represent high-priority projects that should be pursued first.

Project	Estimated Project Cost	Benefit-Cost Ratio	Final Ranking
Wilson Ave – Furse Rd	**$9,107,000**	**2.96**	**1**
4th St and Gov Richardson Rd	**$8,631,000**	**1.1**	**2**
3rd St	**$2,470,000**	**7.05**	**3**
Main Trunk Line	**$12,868,000**	**0.85**	**4**
Meadowfield Apartments	**$759,000**	**11.67**	**5**
Wassau St	**$1,625,000**	**3.63**	**6**
Parson St	**$294,000**	**4.47**	**7**
N Church St – N Cantey St	$2,349,000	0.77	8
Louis St	$952,000	0.33	9
N Church St at Danbury Dr	$634,000	0.13	10
Post Office	$318,000	0.14	11
Hill St	$484,000	0.09	12
S Church St – S Cantey St	$811,000	0.01	13
Chalise St	$1,022,000	0	14

Ahead of any project implementation or construction it is recommended that the town engage in two tasks. The first task is to engage with SCDOT to pursue maintenance (cleaning inlets and pipes) along SCDOT maintained roads, especially in areas of concern identified during this study, to provide some immediate flood relief to residents. The second task would be to deploy hydrologic monitoring equipment at key locations within the town's drainage system. Specifically, this monitoring equipment would need to measure (at a high resolution) water depth and rainfall for as long as possible to capture the hydrologic response of the existing drainage infrastructure to high intensity or infrequent rainfall events.

7.0 References

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