"The Point and Downtown Drainage Study" for

City of Beaufort

Final Report – August 2022

Project No. 031959.01

PREPARED FOR:

City of Beaufort

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List of Abbreviations and Acronyms

ac	Acres
ac-ft	Acre-Feet
ASOS	Automated Surface Observation System
CCTV	Closed Circuit Television Video
CIPP	Cured In Place Pipe
CMA	Corrugated Metal Arch
CMP	Corrugated Metal Pipe
CN	Curve Number
EPA	Environmental Protection Agency
FFE	Finished Floor Elevation
ft	Feet
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
hr	Hour
in	Inch
mi	Mile
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NPDES	National Pollutant Discharge Elimination System
PRF	Peak Rate Factor
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RTK	Real Time Kinematic
ROW	Right of Way
SCDNR	South Carolina Department of Natural Resources
SCDOT	South Carolina Department of Transportation
SCS	Soil Conservation Service
SWMM	Stormwater Management Model

SWMU .... Solid Waste Management Unit

T_c .... Time of Concentration

USDA .... United States Department of Agriculture

VRS .... Virtual Reference Station

yr .... Year

1.0 – Introduction, Background, and Overview of the Project

Over the past few years, the City of Beaufort (City) has been subjected to natural hazards that have tested the resiliency of its stormwater infrastructure. Hurricane Matthew (2016), Hurricane Irma (2017), and King Tide events are examples of such hazards that have proved overwhelming to the City's current drainage system.

Figure 1 – Beaufort River overflowing into Waterfront Park during King Tides in October 2015. *Photo credits: Jeramie Stanley/S.C. Department of Health and Environmental Control MyCoast.*

The overall purpose of the drainage study was to analyze and assess the capacity and condition of drainage infrastructure within the study limits (see **Figure 2**). The project was initiated with a public information meeting where the community was able to present their perception of flooding and point out problem areas to the team. A web-based flood reporting tool was developed and deployed to allow community members to easily document historical flood concerns, as well as document any damage that occurred during such flood events. Beaufort County provided access to their existing drainage infrastructure database within the project study area extents. This data was used to guide surveyors through the data collection process.

Figure 2 – The Point and downtown study area.

Hydrologic and hydraulic modeling was completed for the project study area (see **Figure 2**) using field observations and collected survey data. Hydrologic and hydraulic modeling results were used to form the baseline for drainage improvements. Recommendations for improvements were identified based on a combination of observed structural failures and modeling results. Individual system component recommendations were grouped into projects and prioritized using hydraulic modeling results and engineering judgement. The final and critical step of the master planning process was to develop estimated project costs and identify potential external funding sources. Estimated project costs and project prioritization will allow the City to allocate internal funds for implementing improvements, as well as form the basis for future grant applications to support project implementation.

1.1 – Study Area

The project study area was determined by approximating the limits of the stormwater system and accompanying drainage basins serving downtown Beaufort and residents of the Point. The study area encompasses drainage networks east of Newcastle Street and south of Greene Street. In total, the study area covers approximately 155 acres of the City. All drainage systems contained within the Point/downtown study area outfall to the Beaufort River. The study area boundary is presented in **Figure 2**.

2.0 – Assumptions and Limitations

Assumptions and limitations associated with this study are identified in this section of the report. Generally, assumptions made will result in limitations in model results for certain areas, conditions, or analysis points. Understanding this, any assumptions that were made were carried out were based on engineering judgement in accordance with commonly accepted engineering practice.

As previously stated, limitations are inherent to any engineering analysis and are due to limits in the available information, scope of work to be performed, engineering methodology, and budgetary considerations. While scope, budget, and methodology limitations are normally understood at the beginning of the project, input data limitations are generally not completely quantified until the analysis has begun.

It is essential that model input data accurately reflects existing conditions when performing stormwater analyses for supporting improvement recommendations. While thorough survey and condition assessment practices were utilized across the study area, modeled geometry may vary slightly from actual existing geometry conditions where no access to the closed piping system was available or survey accuracy was limited. In such cases, system geometries were inferred using engineering judgement. Efforts were made to accurately record and simulate occurrences of siltation, debris accumulation, and restrictions caused by structural failures in the modeled drainage system structures. Results produced under these conditions are not exact replications of reported flooding; however, they reasonably represent current system capacities for the purposes of this study.

2.1 – Assessment of Climate Conditions

Historical, current, and future climate conditions were used to evaluate the performance of the Point and downtown drainage systems. Climate condition scenarios involved the use of varying rainfall data and outfall boundary conditions. Results from each climate condition analysis were compared to develop a wholistic assessment of current system capacity. The same climate conditions were used again to reevaluate proposed system improvements to ensure long term reliability and resiliency.

2.1.1 – Current Conditions Assessment

The current conditions assessment served as a representation of the present-day climate. Rainfall data were obtained from the National Oceanic and Atmospheric Administration (NOAA) precipitation frequency data server, specifically from the local NOAA rain gauge located in Southside Park (ID 38-0559). Total precipitation depths were combined with the dimensionless Type-III National Resource Conservation (NRCS)/Soil Conservation Service (SCS) rainfall distribution to generate design cumulative rainfall curves for current condition assessments. Additional design cumulative rainfall curves were developed from a less intense, South Carolina based rainfall distribution for the current conditions assessments. More information on the methodology used for current conditions rainfall data is provided in **Section 4.1.4.2**.

Tide monitoring stations deployed on Federal Street between the retention pond and tidal creek were used to collect data to represent the outfall boundary under current conditions (see **Section 3.3** for more details). The observed higher-high tide was also used as an outfall boundary for the current conditions assessment. More information on the methodology used to develop current condition outfall boundaries is provided in **Section 4.2.2.2**.

2.1.2 – Historic Conditions Assessment

Historical storm events with known significant impacts on the Point and downtown drainage systems were analyzed as part of the historic conditions assessment. Namely, Hurricane Matthew (October 2016) and Hurricane Irma (September 2017) were selected as storms to be included in the analysis. Historical rainfall data was recovered for both storms from radar rainfall. This data was processed and used to generate rainfall patterns for the two hurricanes. More information on methodology used for historic rainfall data acquisition and processing is provided in **Section 4.1.4.1**.

Storm surge data for Hurricanes Matthew and Irma were downloaded from the United States Geological Survey (USGS) Flood Event Viewer. Surge data was processed and applied to the outfall boundaries during the hurricane simulations. More information on the methodology used for historical storm surge data acquisition and processing is provided in **Section 4.2.2.1**.

2.1.3 – Future Conditions Assessment

With growing concerns over rising sea levels and increases in rainfall depth and intensity, a future conditions assessment on the Point and downtown drainage system was completed. The year 2072 was selected as the basis for the future conditions assessment to represent 50-years into the future. Increases in 24-hour design storm depths (Hutton et. al, 2015) were applied to current rainfall data reported for NOAA rain gauge ID 38-0559 located in Beaufort. These increased rainfall depths were combined with the dimensionless Type B NOAA rainfall distribution to generate design cumulative rainfall curves for future condition assessments. The Type B NOAA distribution was selected as the basis for future condition rainfall curves due to its higher intensity compared to the traditional Type-III NRCS/SCS distribution. More information on the methodology used for future rainfall acquisition and processing is provided in **Section 4.1.4.3.**

Predicted sea level rise data was retrieved from the Interagency Sea Level Rise Scenario Tool for the Fort Pulaski NOAA station (ID 8670870). The 50-year sea level rise was added to the tide data collected from the Federal Street monitoring stations to serve as the outfall boundary for the future conditions assessment. More information on the methodology used for historical storm surge data acquisition and processing is provided in **Section 4.2.2.3**.

2.1.4 – Analysis/Design Conditions

Analysis of the City's existing drainage system was completed using results from all three climate conditions assessments: current, historic, and future. Current conditions were utilized in the initial set up and execution of the hydrologic and hydraulic modeling efforts. Results of the current conditions assessment were validated by comparing to observed conditions using monitoring data, historic assessment results, and photo documentation. Model calibrations were carried out to address major differences between datasets.

Next, improvements were developed and analyzed using stormwater design standards set forth by South Carolina Department of Transportation (SCDOT). This was done because all roads in the study area are currently owned and maintained by SCDOT. SCDOT generally requires that roadside drainage systems be designed to the 10-year design event with peak flow depths not exceeding 94% capacity in closed piping. Accordingly, improvement recommendations were developed using 10-year design event current conditions. Recommendations were further evaluated under future conditions to evaluate resiliency to withstand potential climate change impacts and develop project prioritization rankings.

2.2 – Flow through Private Property

In some instances, portions of the stormwater system serving the City is located beneath yards and homes of private residences. The nearest size, material, and slope of pipes observed in these locations were assumed based on observations made at the accessible upstream or downstream structure or inlet. Assumed structure locations were modeled, and recorded as such, on private property where the path of drainage appeared to change direction, based on observations made at the pipe's inflow and outflow location.

3.0 – Field Survey and Data Collection

An inventory of existing stormwater and drainage features was required to evaluate existing system capacities and evaluate any upgrades needed to improve existing flood risk. Typically, a system inventory is composed of pipes, inlets, manholes, channels, ponds, and outfall structures. Collection of this data is usually accomplished by field survey. Other data sources needed to conduct the analysis include topographic data, roadway as-built plans from the SCDOT, and recent aerial imagery. Topographic data provides a mechanism to determine where runoff will drain, and allows for the delineation of drainage basins, as well as relevant parameters for the subject basins, which are then served by the stormwater system. Aerial imagery allows for the quantification of land cover/use which is utilized in determining relevant hydrologic parameters.

Figure 3 – Example of drainage system inventory using GPS units at outfall near Pinckney Street and Bayard Street.

3.1 – Field Survey and Visual Condition Assessments

Inventory and visual condition assessments were completed for all drainage systems within the Point and downtown study area. Specific attention was given to each system such that field investigations could be completed in an efficient manner, and that the data needed to complete modeling efforts was collected as completely and accurately as possible.

First, a review of drainage inventory data provided by Beaufort County and recent aerial imagery was completed to identify system features required to evaluate system capacity and subsequent flood risk. Flow paths generated from topographic data and known conveyance paths were used to identify probable system paths and outfall locations required for system evaluation. Second, ESRI ArcGIS Field Maps and GPS survey units were used to catalogue drainage feature data previously identified, as well as those discovered in the field. Data collected during field investigations included existing conditions assessment (e.g., visual review of level of clogging, material), geometric parameters (e.g., size), and elevations. Lastly, quality assurance/quality control reviews of system data were completed to ensure reasonably accurate data was cataloged. Any system features flagged during the quality assurance/quality control review were revisited, and additional field data was collected and/or verified.

Survey efforts for the inventory portion of the drainage study were carried out by Andrews Engineering Company, Inc. Survey data (e.g., location and elevation) was collected using Topcon HIPER VR Global Navigation Satellite System (GNSS) Real-Time Kinematic (RTK) base and rover receivers paired with a Topcon FC-5000 Field Controller (see **Figure 3**). In some cases, tree cover or other site features (e.g., building shadows) interfered with GNSS accuracy. In such cases, surrounding/nearby system data was used to interpolate/estimate geospatial information.

In addition to elevation and geometric data, the survey team completed visual assessments and collected photographic documentation of the system. Photos were geotagged within geographic information system (GIS) databases based on the respective infrastructure feature for which they were collected. This enabled office personnel to have a visual reference to structures or conduits where photographs were taken.

3.2 – Citizen Input and Flood Data Collection

Coordination with the City's employees and citizens was very important to gain an additional understanding of drainage concerns. An online flood reporting tool was developed and made available to the public to document known flooding and flood damage across the study area (see **Figure 4**). A public interest meeting was also held in the initial stages of the study to further understand community perception of the City's drainage issues. These data were used to validate hydraulic modeling results and recommended improvements.

3.3 – Rainfall and Water Level Monitoring

To support the hydrologic and hydraulic modeling efforts of the study, water level and rain gauges were installed at the tidal pond located near the intersection of Federal Street and Hamilton Street. One real-time remote monitoring station, complete with water level gauge and rain gauge, was installed upstream of the Federal Street crossing on the outfall structure of the pond. A second real-time remote monitoring water level gauge was installed on the downstream side of the crossing above the tidally influenced channel. Data collected from these monitoring stations was used in the validation of hydrologic and hydraulic modeling parameters. Approximate locations of the monitoring stations and pictures showing monitoring station configurations are provided in **Figure 5** and **Appendix A.2**.

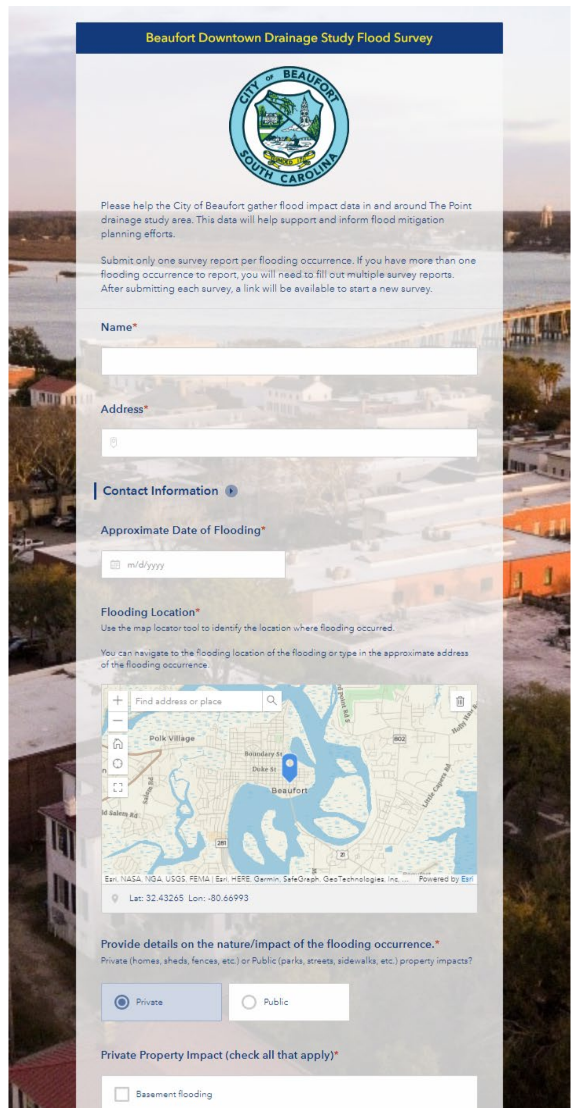


Figure 4 – Online flood reporting tool interface used to collect information on flood locations and damage.

4.0 – Hydrologic and Hydraulic Modeling Platform

Hydrologic and hydraulic models were constructed and used to identify system capacity deficiencies and evaluate existing flood risk. Simulated existing flood risk was then used to develop drainage improvement recommendations. The following sections outline hydrologic and hydraulic analysis modeling methods used to evaluate existing system capacity and flood risk, as well as evaluate improvements and develop recommendations to mitigate existing flood risk.

Figure 5 – Real-time monitoring stations installed near intersection of Federal Street and Hamilton Street. Tidal pond monitoring station (a) equipped with water level and rain gauges. Tidal creek monitoring station (b) equipped with water level gauge.

Hydrologic and hydraulic modeling was completed using Computational Hydraulics Incorporated's (CHI's) PCSWMM software. This software uses version 5 of the Environmental Protection Agency stormwater management model (EPA SWMM). PCSWMM is a GIS integrated, highly advanced, comprehensive, hydrologic, hydraulic, and water quality simulation model used to analyze the management of urban stormwater, wastewater, and water distribution systems. Existing and proposed hydraulic models were developed using unsteady shallow water momentum equations (i.e., full dynamic wave or Saint Venant equations).

4.1 – Hydrologic Analysis

A hydrologic analysis of the study area was completed to develop direct runoff time series used in the hydraulic analysis. Beaufort County 2013 LiDAR topographic data was analyzed and used to develop drainage basins and sub-basins. Field inventory and inspections of the drainage system were used to confirm basin boundaries. A runoff hydrograph was developed for each basin/sub-basin and all runoff was assumed to flow to an outlet (i.e., inlet or channel).

Herein, the Natural Resource Conservation Service (NRCS)/Soil Conservation Service (SCS) method was selected to estimate direct runoff. Parameters estimated for the NRCS runoff method are explained in the following sections.

4.1.1 – Hydrologic Soil Groups

The analysis completed for this study adopted United States Department of Agricultural (USDA) soils data from the soil survey geographic (SSURGO) database for South Carolina published on September 18, 2018. Based on this dataset, there are 71 different soil mapping units (MUSYM) with hydrologic soils groups (HSGs) ranging from A, A/D, B, B/D, C, and C/D in the study areas. **Figure 6a** displays soils data across the Point and downtown study area. A soils data exhibit is also provided in **Appendix A.2**.

Hydrologic soil groups were determined based on the published SSURGO database when single soil groups were encountered. When dual soil groups were encountered (e.g., A/D), SSURGO soil drainage classes were used to determine the hydrologic soil group. For example, soils classified as excessively drained, somewhat excessively drained, well drained, or moderately well drained were assigned the higher drainage soil group (e.g., A/D would be assigned A). Soils that did not fall into a well-drained classification were assigned the lower drainage group.

4.1.2 – Land Use Classification

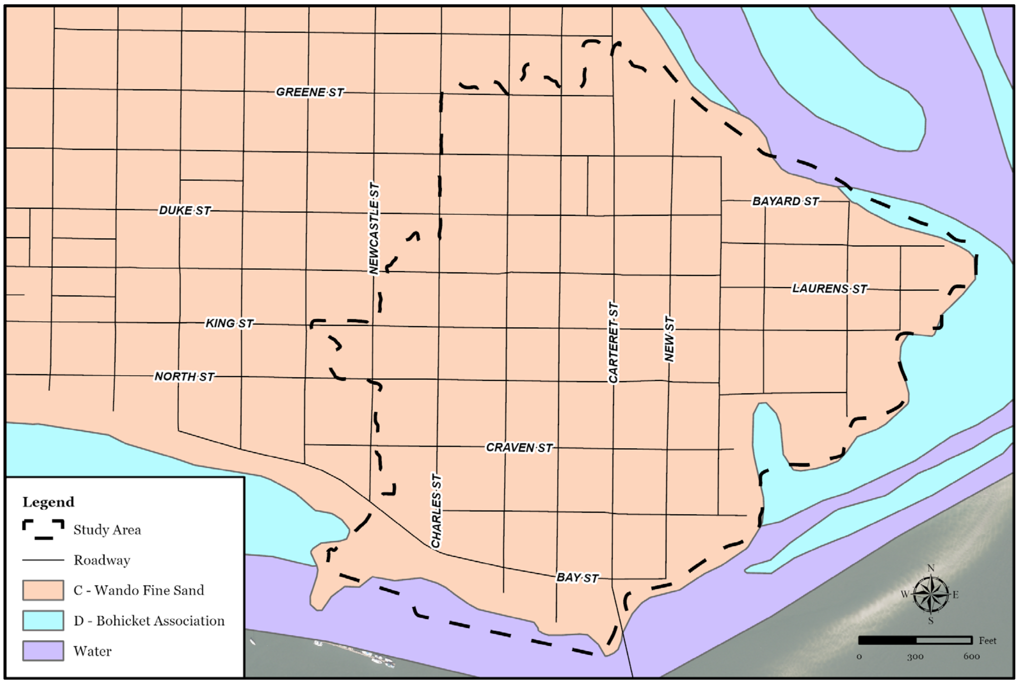
Land cover conditions were used to derive runoff potential for each basin/sub-basin according to NRCS methodology. Ground cover conditions were derived from a land cover dataset developed by EarthDefine, LLC in 2019. EarthDefine used proprietary artificial intelligence to generate high-resolution (60 cm) land cover data, making it a reliable representation of study area conditions. **Figure 6b** displays land cover data across the Point and downtown study area. A land cover data exhibit is also provided in **Appendix A.2**.

Table 1 – Curve numbers based on EarthDefine 2019 land cover types and hydrologic soil groups.

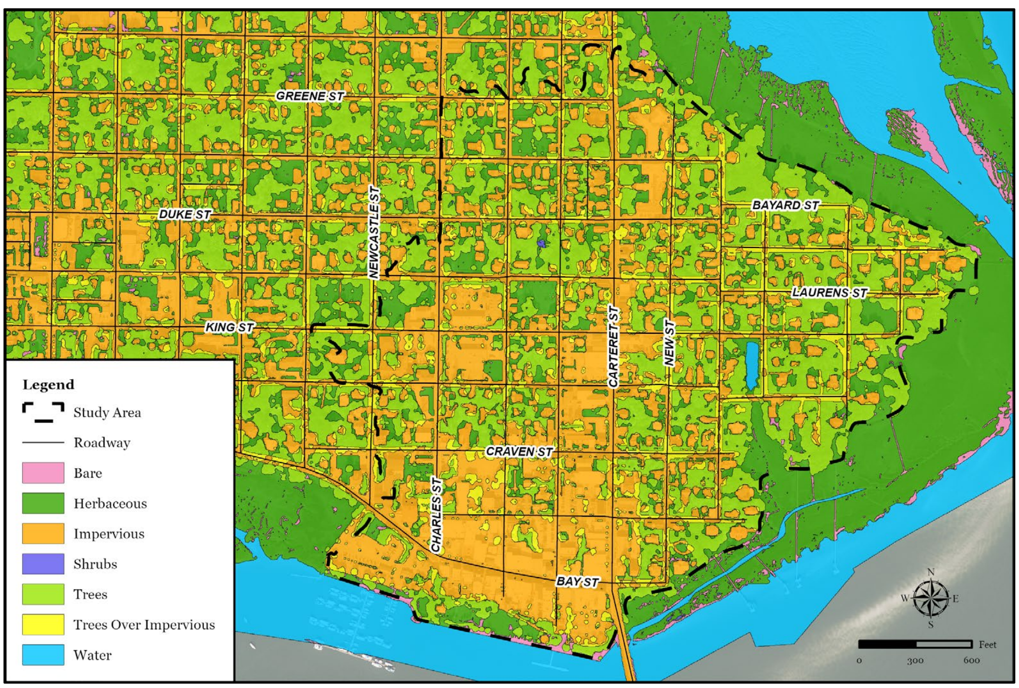
Land Cover Type	Hydrologic Soil Group			
	A	B	C	D
Herbaceous	39	61	74	80
Bare	77	86	91	94
Impervious	98	98	98	98
Water	98	98	98	98
Trees	36	60	73	79
Shrubs	30	48	65	73

4.1.3 – Runoff Curve Numbers

The curve number (CN) is a parameter used in the NRCS/SCS method for estimating runoff volume. The CN parameter was originally developed based on agricultural land, but with proper modifications and assumptions has been adapted for use in predicting runoff volumes for urban areas. The calculation of CN for a specific sub-basin is typically based upon three input data sources which include basin area, USDA soils data (i.e., hydrologic soil group of each soil type), and land use/land cover. **Table 1** summarizes land cover classifications and CN values used in the analysis. From these input variables, an area-weighted CN value was determined for each basin/sub-basin.



(a) USDA Soils Data



(b) EarthDefine Landcover

Figure 6 – Parameters required to perform NRCS/SCS method estimation for runoff: (a) USDA soils data from the SSURGO database and (b) landcover data acquired from EarthDefine dataset.

4.1.4 – Rainfall Data

4.1.4.1 – Historic Conditions Rainfall

Hourly rainfall stations are currently maintained at the Marine Corps Air Station and Beaufort County Airport. Data was obtained at both stations for Hurricane Matthew and Hurricane Irma. Cumulative daily rainfall totals were computed and then compared to daily totals recorded by the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) network. Data from each station and event was found to be inaccurate and erroneous. As a result, radar-based rainfall data acquisition techniques were implemented to obtain historical rainfall data.

NOAA's next generation radar (NEXRAD) level 3 data products were used to obtained Hurricane Matthew and Hurricane Irma rainfall data. These data were downloaded and processed which provided hourly spatiotemporal rainfall raster data sets. These data were directly imported within the hydrologic model and were used to estimate historical runoff resulting from each event. Storm totals derived from NEXRAD products were validated by comparing to local CoCoRaHS data and found to be representative.

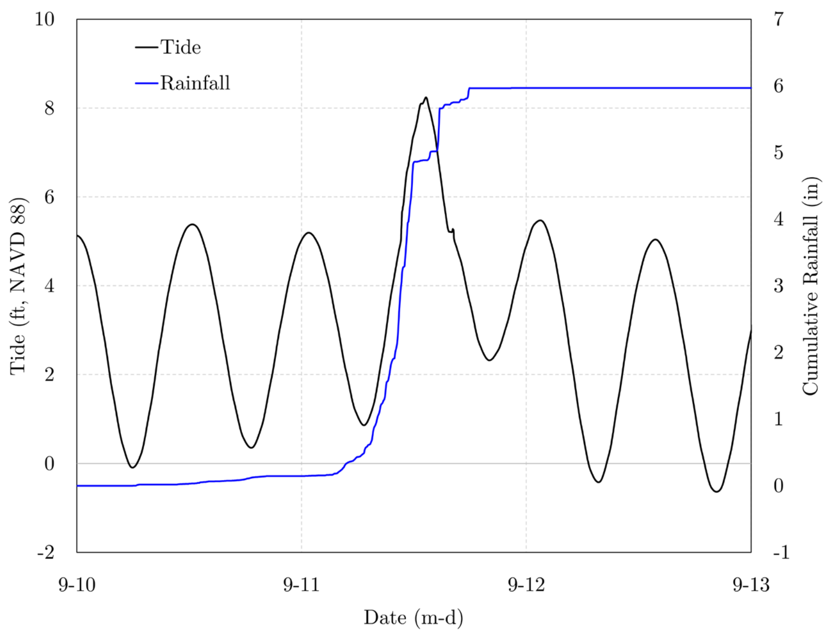


Figure 7 – Historical rainfall and tide observations for Hurricane Irma in Beaufort, SC.

4.1.4.2 – Current Conditions Rainfall

Current stormwater design standards dictate that closed collection systems be designed using 24-hour, SCS rainfall distributions based on rainfall totals published by NOAA, SCDHEC, or other appropriate source. Herein, the 24-hour, type III SCS rainfall distribution paired with 24-hour storm totals from NOAA station 38-0559 (see **Table 2**) were adopted. The SCS distribution and 24-hour storm totals were combined to provide an overall cumulative rainfall distribution curve for each recurrence interval evaluated herein (i.e., 2-, 10-, and 25-year).

SCS rainfall distributions were developed based on the frequency storm method wherein all events with durations less than 24 hours are nested around hour 12. For example, the 10-year, 24-hour event, is comprised of all 10-year events with durations less than 24 hours. In this sense, all instantaneous rainfall intensities at any point during the design storm are representative of the 10-year event. Although low duration high intensity events most certainly occur, such a 24-hour event is statistically unlikely. As a result, a lower intensity event was evaluated to explore sensitivity of the system to overall rainfall intensities.

A lower intensity 24-hour rainfall event was developed using NOAA rainfall totals combined with a rainfall distribution recommendation from Powell et al. (2007), known as the SC Long distribution. The SC Long distribution was developed using NOAA rainfall data from Georgia, South Carolina, and North Carolina and is meant to be representative of an expected 24-hour event (i.e., dimensionless event). The SC Long distribution was developed using similar techniques as Huff (1967) and the Texas Department of Transportation (Asquith et al., 2005).

4.1.4.3 – Future Conditions Rainfall

Future rainfall conditions were developed to consider changes in both rainfall total and storm intensity (see **Table 2**). Fifty-year rainfall totals were forecasted for the City of Beaufort (i.e., NOAA station 38-0559) based on estimates provided by Hutton et al. (2015). These estimates were based on historical NOAA rainfall records accompanied with 134 realizations of 21 global climate models across the state of South Carolina. Although 24-hour rainfall totals are expected to increase over the next 50 years, the overall average increase was estimated at approximately 0.30 inches for 2- through 25-year design events.

Future rainfall totals were paired with recently revised design storm distributions (i.e., NOAA distributions) published by NRCS (Merkel et al., 2015). Herein the NOAA B rainfall distribution was adopted for the City of Beaufort and is estimated to have a 4-inch per hour increase in the 10-year, 24-hour peak intensity. It is important to note that revised NRCS distributions were developed based on the frequency storm method using recent NOAA Atlas 14 data.

Table 2 – Current and future 24-hour cumulative rainfall data for NOAA station 38-0559.

Recurrence Interval (yr.)	Depth (inches)		Intensity (inches/hour)	
	Current	Future	Current (Type III SCS)	Future (NOAA B)
2	4.20	4.36	3.53	5.76
10	6.42	6.69	5.39	8.85
25	7.82	8.15	6.57	10.78

4.1.5 – Runoff Time Series

Runoff time series, $Q(t)$, were developed for each basin/sub-basin based on area-weighted curve numbers and rainfall hyetographs defined as

$$Q(t) = \begin{cases} 0 & \text{for } P \leq I_a \\ \dfrac{(P - I_a)^2}{P - I_a + S} & \text{for } P > I_a \end{cases} \tag{1}$$

where P is rainfall, I_a is the initial abstraction (estimated as $0.2S$), and S is the potential maximum soil moisture retention defined as

$$S = \frac{1000}{\text{CN}} - 10. \tag{2}$$

4.1.6 – Time of Concentration

Time of Concentration (T_c) is the next detailed parameter which must be determined in the NRCS/SCS method. It is defined as the time required for water to flow from the most hydraulically remote point in the drainage basin to the outlet, or more simply, the time required for the entire basin to contribute runoff and reach equilibrium.

For this analysis, the watershed lag method was selected. Outlined in Chapter 15 of the National Engineering Handbook in section §630.1502, Methods for Estimating Time of Concentration, several input parameters are required to calculate the time of concentration. The first is flow length, which is defined as the longest path along which water flows from the drainage basin divide to the outlet, the second is the average basin slope in percent, and the third is the maximum potential retention (which is directly related to the basin CN value).

Flow lengths and average basin slopes were determined using geospatial tools and Beaufort County's 2013 LiDAR. Using these variables and tools, basin/sub-basin times of concentration were estimated as

$$\mathrm{T_c} = \frac{l^{0.8}(S+1)^{0.7}}{1{,}140Y^{0.5}} \tag{3}$$

where T_c is in hours, l is the flow length in feet, and Y is the average drainage basin land slope in percent. It is important to note that a minimum T_c value of 6 minutes was assumed.

4.1.7 – Runoff Hydrographs

Runoff time series and times of concentration for each basin/sub-basin were combined to develop runoff hydrographs using the NRCS standard dimensionless unit hydrograph (i.e., peak rate factor of 484). First, the unit hydrograph times to peak was defined as

$$\mathrm{t_p} = 0.6\mathrm{T_c} + D/2 \tag{4}$$

where t_p is in minutes rounded up to the nearest burst duration interval, D, which is assumed to be 5 minutes herein. Next, the unit hydrograph peak was estimated as

$$q_{\mathrm{p}} = \frac{PRF \cdot A}{t_p} \tag{5}$$

where PRF is the peak rate facture, q_p is the peak runoff flow rate in cubic feet per second (cfs) per inch of runoff, and A is the basin/sub-basin area in square miles. Finally, the incremental runoff rate in cfs at time t was estimated as

$$q(t) = q_p \cdot UH(t) \cdot Q(t). \tag{6}$$

The hydrologic peak rate factor is a numeric parameter which describes the drainage basin's runoff response to rainfall. Peak rate factors generally range from 100 to 575, where higher factors represent flashy drainage systems (e.g., steep urban drainage). Such rate factors can vary based on slope and runoff potential and can significantly affect the simulated peak runoff and hydrograph duration (i.e., time to peak and time to recession). A 284 peaking factor (i.e., Del Marva unit hydrograph) was considered for the analysis due to the region's relatively flat topography and low relief. However, expansive impervious surface cover and lack of depressional surface storage encourage higher runoff rates than typical low-lying coastal regions. Ultimately, the NRCS standard 484 peaking factor was selected and used herein based engineering judgement and desire to remain conservative in the calculation of peak runoff flow. Sensitivity in system performance due to changes in peak rate factor was evaluated for values of 284 versus 484. Due to the small size of sub-basins and low times of concentration, durations in peak rate factors did not appear to affect modeling results.

4.2 – Hydraulic Analysis

A hydraulic analysis was completed by routing runoff time series generated from the hydrologic analysis through the City's drainage system (e.g., pipes, channels, ponds, etc.). The focus of the hydraulic analysis was to evaluate existing system capacity and simulate potential flooding due to limited system capacity. Results from the existing conditions analysis were then used to develop recommended system improvements.

4.2.1 – Development of Model Domain

Field survey data was used to establish horizontal/vertical elevations (i.e., inverts and top of banks/rim elevations) of pipelines, ditches, and channels included in the hydraulic model. Hydraulic and geometric attributes (e.g., size and manning's roughness) were also assigned to drainage features based on field survey. A combined one-dimensional (1D)/two-dimensional (2D) hydraulic modeling domain was created and used to model the extents of the Point and downtown study area. In this approach, piping and channels were represented as 1D links while overland flow was represented using 2D links. A summary of 1D Manning's n values used in the study are presented in **Table 3**.

Channels were modeled if they were in-line with a trunk system or they were needed to provide connections between closed conveyances in 1D portions of the model. In most cases, channel sections were irregular and were derived from LiDAR data. Storage relationships for ponds and other inline storage facilities were generated based on LiDAR data or field survey. Storage contained within offsite drainage systems (i.e., channels, swales, and depressions) was accounted for through the development of a basin stage-storage relationship and applied to a storage node on the upstream node of the hydraulic structure.

2D hydraulic modeling domains used throughout the study were developed using a 25-foot to 50-foot mesh resolution wherein underlying elevations were based on 2013 Beaufort County LiDAR. Homes and detached building footprints were developed based on aerial imagery and were considered in the 2D domain. Due to the urban nature of the study area, a general 2D surface roughness (i.e., Manning's n) value of 0.014 was assigned. This assumption was validated by testing the sensitivity of modeling results as a function of 2D surface roughness. The sensitivity analysis showed that variations in 2D surface roughness did not significantly affect the model output.

Additional adjusted roughness coefficients were developed according to the level of blockage present in drainage system pipes as recorded during field survey efforts. These values were applied to accurately depict effects of sediment and debris build up in the existing drainage system. Roughness adjustments were determined through a systematic process of varying fill depths versus Manning's roughness coefficients in separate but identical systems within a simple hydraulic model. The adjusted Manning's n values used in the study are presented in **Table 3**.

4.2.2 – Outfall Boundary Conditions

Runoff from the Point and downtown study area drains to 13 outfalls (see **Figure 9**). Each outfall is tidally influenced and could cause varying flood conditions depending on when runoff occurs relative to the tide. As such, multiple tide conditions were analyzed to thoroughly investigate possible flood scenarios.

Table 3 – Summary of Manning's n roughness values for 1D (Chow, 1959) hydraulic modeling domains. Materials with adjusted roughness values listed as "-" indicate no blockage was detected at the time of field investigations.

Material/Description	Level of Blockage		
	Clear	Moderate	Heavy
Brick	0.015	-	-
Cast Iron	0.013	0.024	0.074
Concrete	0.012	0.022	0.068
Corrugated HDPE	0.018	0.033	0.101
Corrugated Metal	0.024	0.041	0.136
Ductile Iron	0.011	-	-
Grass Channel	0.040	-	-
PVC	0.010	0.018	0.057
Smooth HDPE	0.009	-	-
Smooth Metal	0.012	0.022	0.068
Steel	0.016	-	-
Vitrified Clay	0.012	0.022	0.068

4.2.2.1 – Historic Conditions Tide Data

Tide data representative of coastal conditions observed during Hurricane Matthew and Hurricane Irma were obtained from a rapid deployment gauge installed on the US 21 bridge south of the study area. The gauge is maintained by the USGS and is only deployed prior to large coastal storm events. High-resolution data was available for the gauge for both events. However, data was only collected above elevation 5.25 feet (NAVD88) since the gauge is a pressure transducer and was installed above the water.

A full tidal hydrograph was constructed using the rapid deployment USGS gauge data, historical observations made at the NOAA Charleston gauge site, projections made at the NOAA Charleston gauge site, and a NOAA published site correction factor between Beaufort and Charleston. The result was a continuous tidal hydrograph for both Hurricane Matthew and Hurricane Irma (see **Figure 7** for Hurricane Irma tidal hydrograph).

4.2.2.2 – Current Conditions Tide Data

A representative tide hydrograph was developed and used for all current conditions scenarios based on observations made at the Federal Street gauge. Although variable high and low tide water surface elevations were observed throughout the data collection period, a dynamic elevated high tide (or King Tide) scenario was selected for the basis of the analysis. This was done primarily because King Tide conditions have occurred and are expected to continue to occur (Sweet et al., 2022). Notably, higher-high conditions observed from December 2021 through June 2022 were on average approximately 1 foot higher than the historical mean high-higher high (MHHW) benchmark established by NOAA (see **Figure 8**).

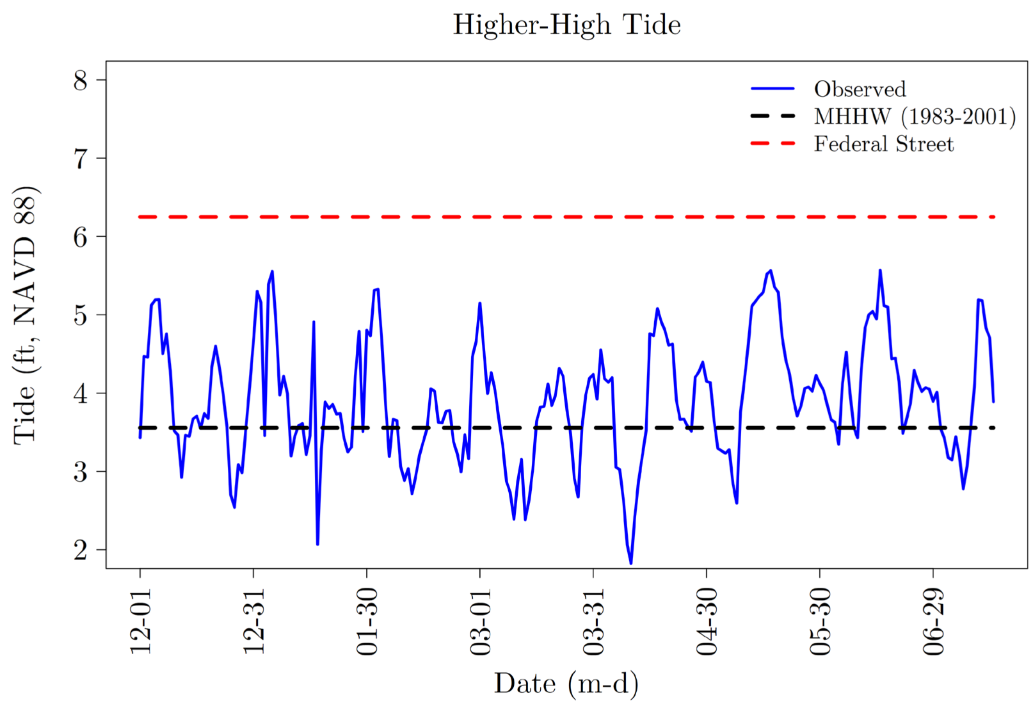


Figure 8 – Daily higher-high tide observations made from December 2021 through June 2022. The dashed black line represents the mean higher-high water (MHHW) benchmark established by NOAA based on the 1983 to 2001 epoch.

4.2.2.3 – Future Conditions Tide Data

Sea level rise is apparent in most historical tide data throughout the world. Although it has occurred over the past 100 years, scientists around the globe have been working together to develop projections for planning purposes. Most recently, the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force developed global mean seal level (GMSL) projections for six scenarios: low, intermediate-low, intermediate, intermediate-high, high, and extreme (Sweet et al., 2022).

Each of the aforementioned scenarios provides a good basis for accounting for future sea level rise. However, the fate of what the actual future sea level rise will be remains a debatable topic. Rather than argue the value and degree of sea level rise, this study adopted the notion that sea level rise will occur, and it should be accounted for in infrastructure recommendations.

Herein, the intermediate-low 50-year sea level rise projection scenario was adopted. Since there is no long-term historical gauge site available in Beaufort, regional projections at Fort Pulaski, Georgia (station 395) were assumed to be representative of conditions expected to occur in Beaufort. Based on the findings of Sweet et al. (2022), the intermediate-low scenario was estimated to be 1.72 feet above current conditions. Accordingly, the current conditions tide hydrograph was increased by a 1.72-foot constant.

5.0 – Results

5.1 – Field Survey and Visual Conditions Assessment

The drainage systems serving the study area are entirely composed of closed stormwater piping from their upper reaches to their individual outfalls along Beaufort River (see **Figure 9** and **Appendix A.2**). Approximately 4.5 miles of pipe were surveyed, visually assessed, and documented (see **Table 4**). Most of the drainage pipes were located in the roadside rights-of-way and City-owned property. In addition to basic piping infrastructure, the study area contains three discernable storage areas. The tidal retention pond located along Hamilton Street between King Street and Federal Street is the largest of the storage areas with approximately 1,700 cubic yards of available storage capacity. Detention facilities located near the West Street/Prince Street and Carteret Street/Duke Street intersections are much smaller, with approximately 23 cubic yard and 17 cubic yard storage capacities, respectively.

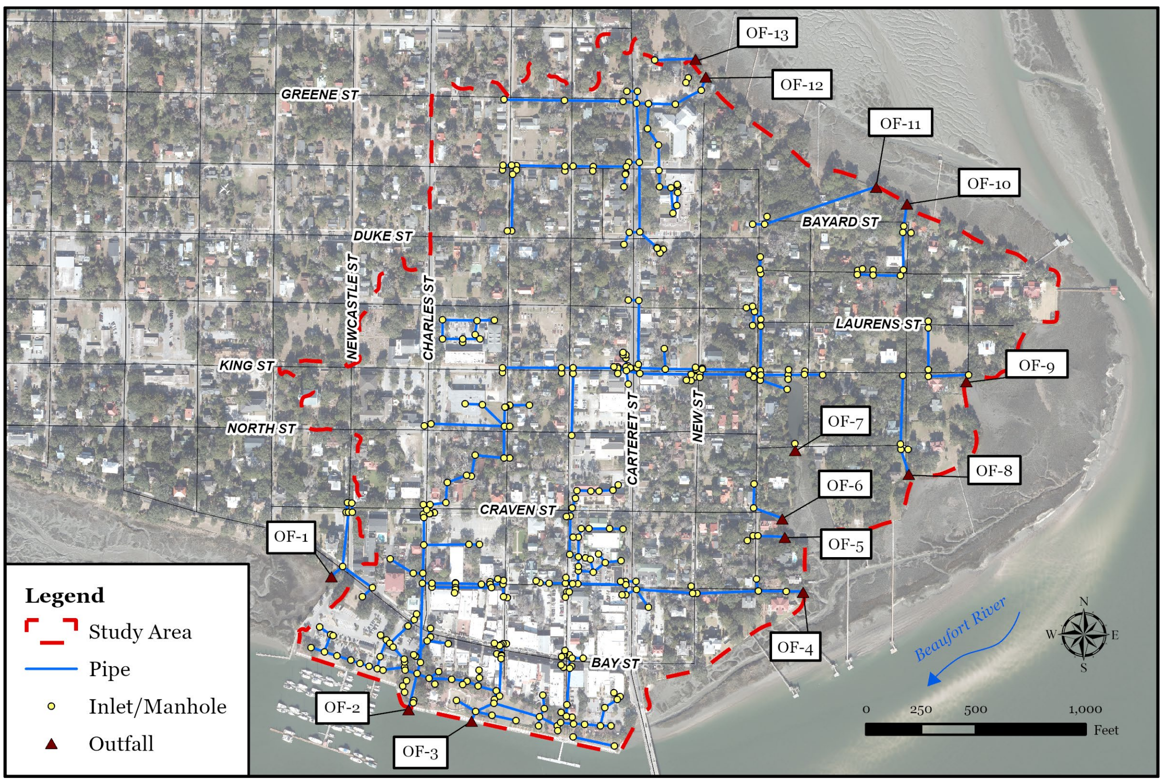
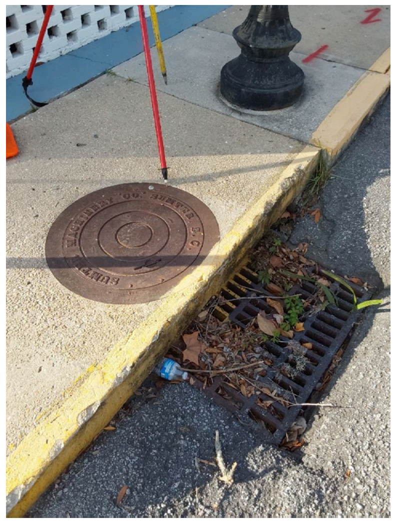


Figure 9 – Extents of survey data collected during field investigations.

Multiple cases of inlet/pipe clogging were documented across the study area. These occurrences ranged from light foliage/debris build up to complete blockage of inlets and pipes. Additionally, partial to full structural failures were present in multiple drainage system assets. Examples of observed drainage system deficiencies are presented in **Figure 10**. All visual occurrences of clogging and/or damage in inlets and pipes were documented during the data collection process and are included in the final geodatabase deliverable to the City.

(a)



(b)

(c)

(d)

(e)

(f)

Figure 10 – Examples of visual existing conditions assessments documenting general maintenance deficiencies for: (a) silted type 1 grate inlet; (b) type 1 grate inlet with debris build up; (c) manhole covered junction containing broken stormwater pipe and exposed water line; (d) ageing brick lined conveyance structure; (e) clogged outfall pipe; and (f) degrading disjointed outfall pipe.

Drainage infrastructure located along King Street directly north of the tidal pond was found to have notable levels of standing water. This condition is understandable as the system drains to the tidal pond wherein the pipes were submerged at the time of survey. Standing water within pipes/structures and submerged outfall pipes indicate a potential cause of flooding for the upstream facilities in the King Street system, since the system is not able to fully drain under dry conditions. Similar occurrences of submerged outlets were noted at the Waterfront Park drainage systems, all of which provide drainage services to Charles Street, West Street, and Scott Street.

Table 4 – Existing drainage system conveyance summary.

Conveyance Summary (Total Length = 4.5 mi)		
Material	Length (ft)	Average Geometry
Circular Pipe		
Concrete	14,619	18-in
Ductile Iron	1,988	15-in
Corrugated HDPE	1,393	15-in
Vitrified Clay	1,288	8-in
PVC	1,202	8-in
Corrugated Steel	687	15-in
Smooth HDPE	270	18-in
Brick	36	24-in
Smooth Steel	17	12-in
Elliptical Pipe		
Corrugated Steel	337	18-in x 28.5-in
Concrete	121	15-in x 22-in
Concrete Box Culvert	28	3-ft x 4-ft
Inaccessible Closed Pipe	1,576	-

More observations of debris and standing water were noted along the Port Republic Street drainage system, from Carteret Street to its outfall. Inspection of one of the system's manholes located northeast of the Port Republic Street/Carteret Street intersection revealed the presence of broken stormwater pipe and an apparent water main with fittings. Portions of the Charles Street drainage system also exhibited signs of blockage; however, lack of available access made it difficult to determine the extent of obstructions along the drainage system between Bay Street and Craven Street. Inspection of the first accessible manhole along the Charles Street system, located in the intersection of Charles Street and Craven Street, revealed aging brick-formed drainage pipe. From the Chares Street/Craven Street intersection, the drainage system appeared to route through private property to the intersection of North Street and West Street, where it then extended to its upper reaches. All of drainage system pipes north of Craven Street contained notable levels of standing water and sediment.

Of the 13 surveyed drainage systems in the Point and downtown study area, four outfalls were unable to be directly surveyed and inspected in the field. Three of these outfalls (i.e., one near Bay Street/Newcastle Street intersection and two along the Waterfront Park wall) were unreachable to surveyors but were confirmed by the nearest upstream connection. The fourth unconfirmed outfall serves the small drainage system at the intersection of Bayard Street and East Street. Inspection of the furthest downstream inlet suggested that the outfall is located north of Bayard Street along the Beaufort River marsh edge. However, surveyors were unable to locate the exact location of the outfall.

5.2 – Hydrologic Analysis Results

Twelve of the thirteen surveyed outfall drainage systems were included in hydrologic analysis. Basin delineations for each of the 12 analyzed drainage systems are presented in **Figure 11** and **Appendix A.2**. The analyzed outfall drainage areas were further sub-delineated into 255 sub-basins with a total basin area of 140 acres, an average sub-basin size of 0.6 acres, and an average calculated time of concentration of 6.8 minutes. Sub-basin curve numbers ranged from 73 to 98, with an average sub-basin curve number of 87. Average hydrologic parameters for the Point and downtown study area are summarized in **Table 5**. It is important to note that outfall 13 in **Figure 9** exclusively serves the University of South Carolina Beaufort Grayson House parking lot and was thereby excluded from the analysis.

Table 5 – Hydrologic soil group, land use, and hydrologic parameter summaries.

Hydrologic Soil Group Summary		
Soil Group	Soil Name	% of Area
C	Wando Fine Sand	96%
D	Bohicket Association	1.5%
-	Water	2.5%

Land Use Summary	
Use	% of Area
Bare	< 1%
Herbaceous	13%
Impervious	40%
Shrubs	< 1%
Trees	31%
Trees Over Impervious	14%
Water	< 1%

Hydrologic Parameter Summary	
Parameter	Average Value
Sub-Basin Area	0.6 ac
Curve Number	87
Time of Concentration	6.8 min

5.3 – Existing Hydraulic Conditions

Results from the 1D/2D hydraulic model were reviewed and analyzed to identify causes of flooding across the Point and downtown study area. Results from each of the three analyzed climate conditions (i.e., historic, current, and future) are presented in the subsequent sections.

5.3.1 – Historic Conditions Results

Archived tidal and rainfall gauge data from two of Beaufort's most recent and impactful hurricanes were acquired for use in the historic conditions assessment. Data from the selected historic events, Hurricane Matthew and Hurricane Irma, were integrated into the 1D/2D hydraulic model. Using these parameters, flooding results were generated for the two historic hurricane conditions. Results were processed, independently analyzed, then compared with observed data recorded at the time of the actual storm events to evaluate the reliability of the model to predict hydraulic conditions for the study area.

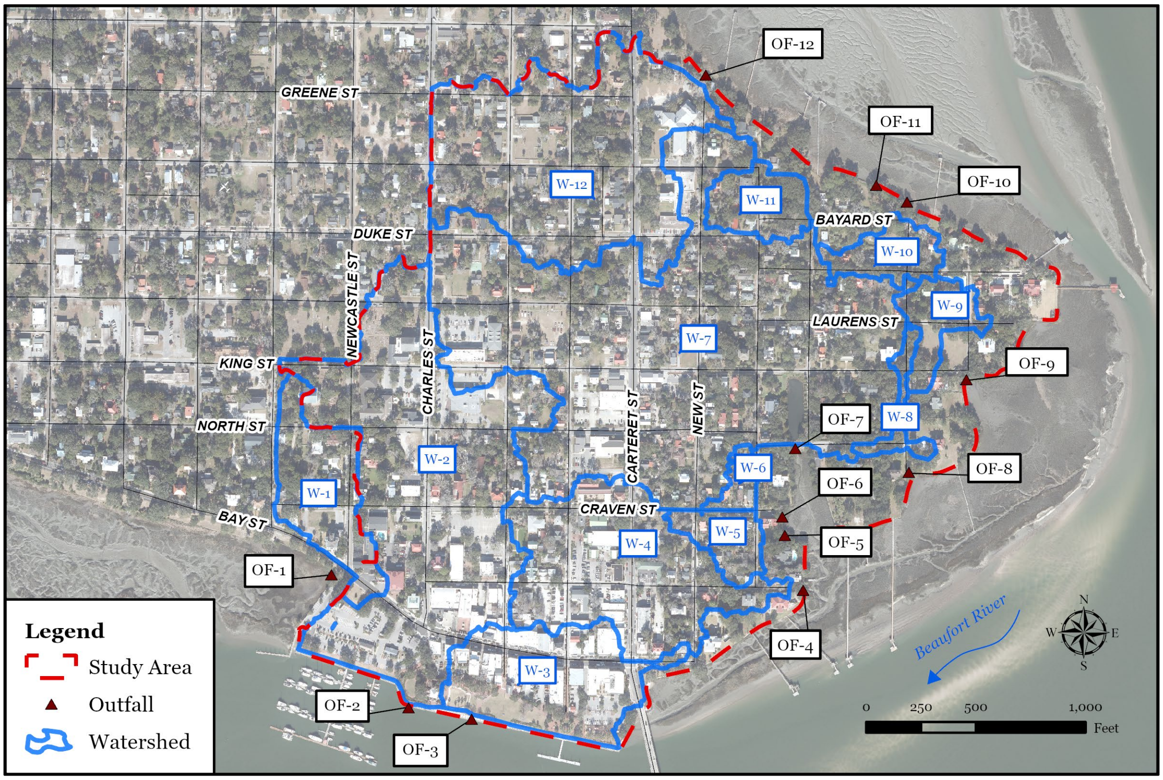
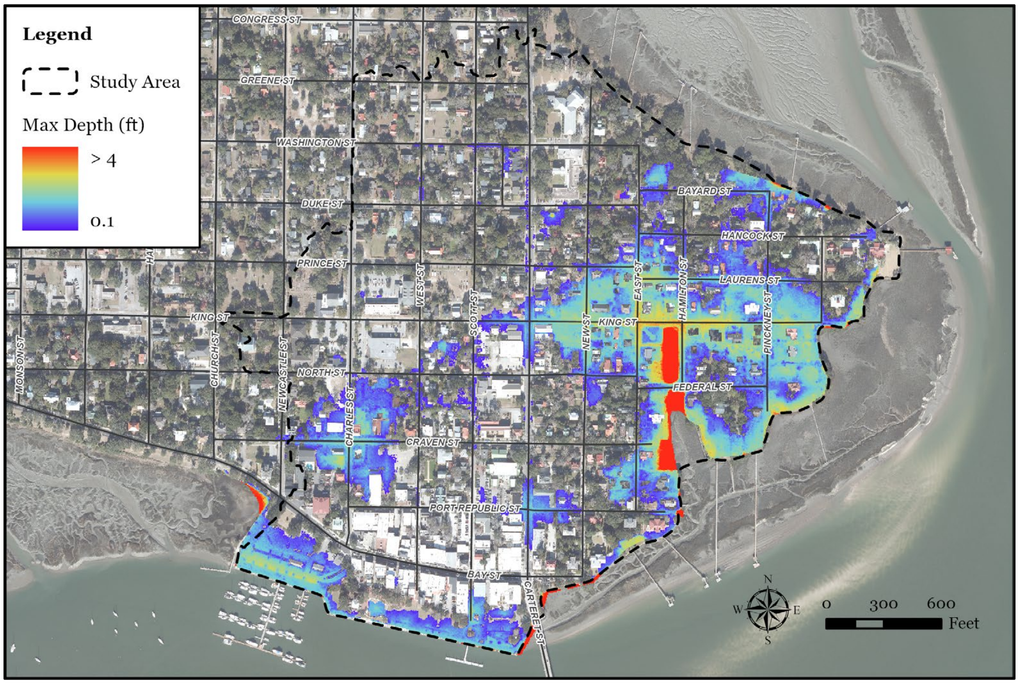


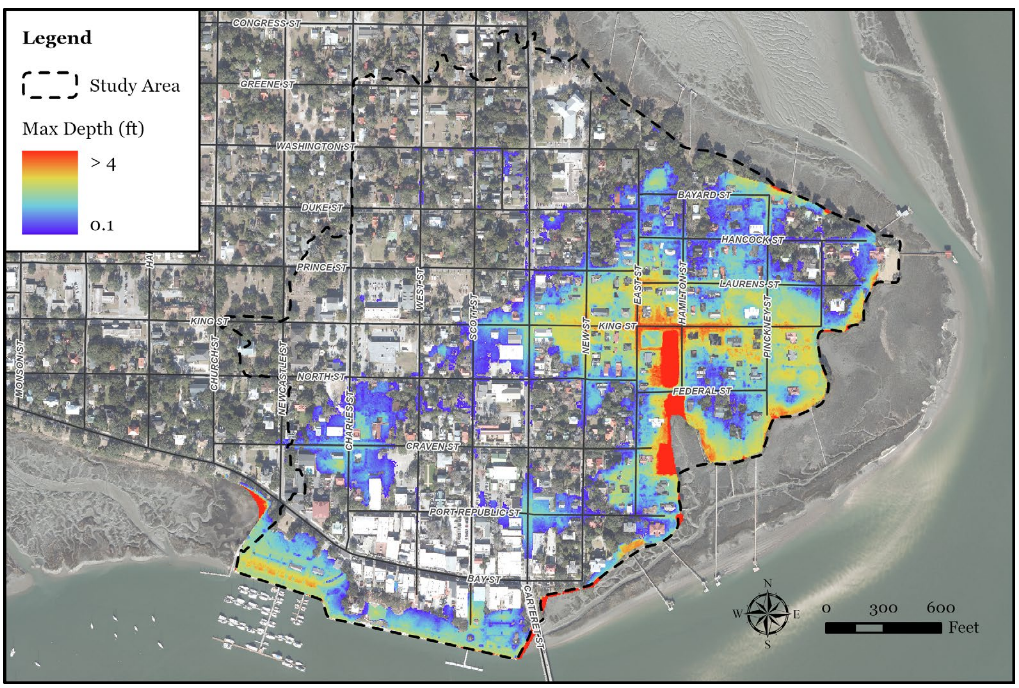
Figure 11 – Extents of survey data collected during field investigations. Watersheds represent the entire upstream area that flows directly to an outfall. Remaining areas within the study area sheet flow directly to the marsh or river.

Maximum flood depth grids were developed from Hurricane Matthew and Hurricane Irma simulations. Maximum flood depths were rendered between 0.1-foot and 4-feet to visually contrast flood levels. Simulated conditions for Hurricane Matthew (see **Figure 12a** and **Appendix B**) produced large levels of flooding along the King Street drainage system. Most of the flooding along King Street appeared to occur between Carteret Street and Short Street. Flooding also extended north of King Street to portions of Laurens Street and Prince Street. South of King Street, flooding appeared to overtop the banks of the tidal pond and the road crest of Federal Street. Severe flooding was noted in the center of the Charles Street/Craven Street intersection. Similar but reduced flooding extents were depicted at the intersection of Port Republic Street and Carteret Street. Additional flooding was simulated along the tidal outfalls, including the Waterfront Park property and portions of Bayard Street.

Simulated flooding from Hurricane Irma conditions (see **Figure 12b** and **Appendix B**) occurred in similar locations as those produced from Hurricane Matthew conditions. Hurricane Irma flood results, however, are notably larger in terms of depth and extents when compared to those for Hurricane Matthew. Flooding along the King Street drainage system was approximately 0.8-feet greater under Hurricane Irma conditions when compared to Hurricane Matthew conditions. Increased flood depths of approximately 0.7-feet, 0.4-feet, and 0.8-feet were also observed at Waterfront Park, Port Republic Street/Carteret Street intersection, and Bayard Street, respectively. Ironically, simulated maximum flood depths did not significantly change at Charles/Craven intersection.



(a) Hurricane Matthew (October 2016)



(b) Hurricane Irma (September 2017)

Figure 12 – Simulated maximum flood depths for (a) Hurricane Matthew (October 2016) and (b) Hurricane Irma (2017).

Flood data gathered from citizens through the online flood reporting tool, as well as basic correspondence with residents, were compared to simulated flood depth results. Through this process, the developed 1D/2D model was validated. Documented historic flooding (see **Figure 13**) photographs were reported for Hurricane Irma and used to evaluate the accuracy of the model. Flood depths of approximately 2 to 3 feet were simulated at the intersection of Hamilton Street and Laurens Street under Hurricane Irma conditions. Documented flooding (see **Figure 13a**) confirmed the accuracy of these findings. Similarly, simulated flood depths of 1.5 feet to 2.5 feet depicted at the Craven Street/Charles Street intersection were also confirmed by the submitted historic flood documentation (see **Figure 13b**). Documented flooding at the intersection of Prince Street and New Street (see **Figure 13c**) likewise validated 1 to 2 feet simulated flood depths. It is important to note that no historic flood data submissions were made regarding Hurricane Matthew; therefore, comparisons could not be made between observed flooding and simulated flooding for this storm.

5.3.2 – Current Conditions Results

Current conditions simulated maximum flood depth grids were developed across the Point and downtown study area for the 2-, 10-, and 25-year SCS Type III and SC Long design events. The 10-year SCS Type III design storm is presented in **Figure 14a** while the remaining results are included in **Appendix C.1**. Results were further post-processed to develop flood inundation footprints. Inundation footprints are presented in **Figure 15a** and **Appendix C.1**. It is important to note that both sets of results are representative of the current drainage system maintenance deficiencies (i.e., clogged pipes/inlets). In general, results show that flooding occurs at the same locations across the study area for all design storms, and that the extent of flooding increases as the design storm recurrence interval increases (i.e., 2-year to 25-year).

Modeling results present three major contiguous flood areas: King Street, Charles/Craven Street intersection; and the intersection of Port Republic and Carteret Street. King Street flooding is shown to experience the most extensive flooding across the study area, covering approximately five city blocks from Pinckney Street to Scott Street. The next largest area of flooding originates at the intersection of Charles Street and Craven Street. From there, flooding extends to the surrounding blocks to create an inundated bowl bordered by North Street, West Street, Port Republic Street, and Newcastle Street. The third major flood site is located at the intersection of Port Republic Street and Carteret Street. This location typically serves higher volumes of traffic and pedestrians than either of the other two observed flood areas. Because of this, flooding at this intersection poses great concern even as the smallest of the three major occurrences of flooding.

Additional smaller pockets of flooding were simulated by the model near the intersection of Bayard Street and East Street. Flooding in this area is regularly reported by locals and is the suspected result of downstream drainage system failures (i.e., pipeline failure between Bayard Street and outfall). Because of these factors, the Bayard Street/East Street intersection received further investigative attention along with the three major flood-prone areas in the Point and downtown study area.

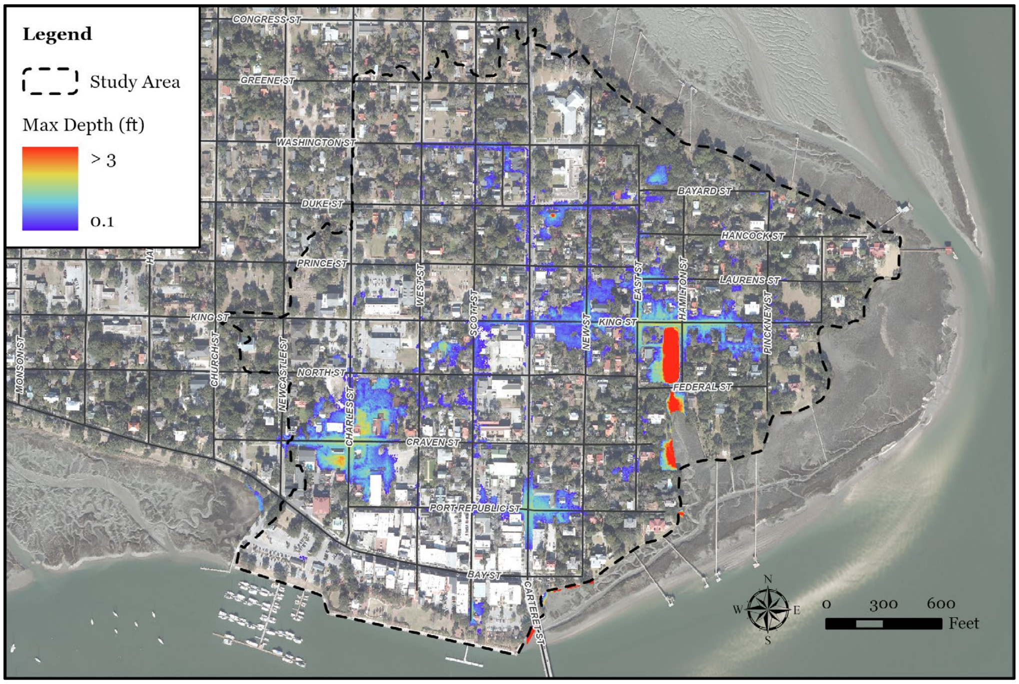
(a) Hamilton Street and Laurens Street

(b) Craven Street and Charles Street

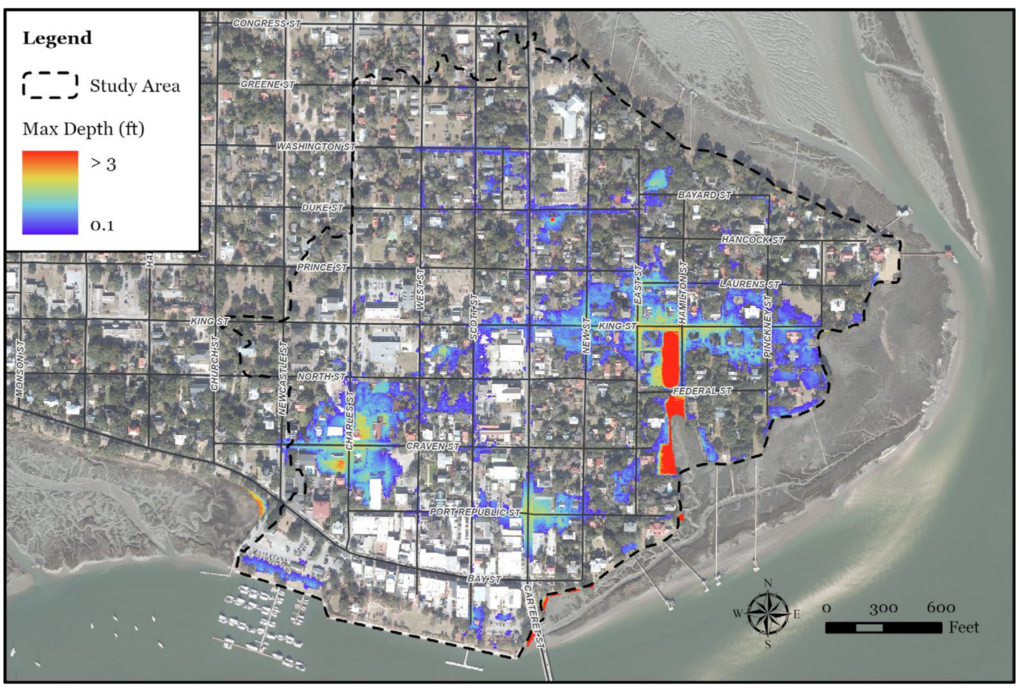
(c) Prince Street and New Street

Figure 13 – Historic flooding photo documented during Hurricane Irma (September 2017).

Further evaluation of the existing drainage system performance was conducted by comparing flood inundation footprints generated from two different rainfall distributions: SCS Type III and SC Long. Resulting data from this comparison are presented in **Figure 15b** and **Appendix C.1**. It is apparent that the 10-year flood extents are significantly reduced under the SC Long distribution as opposed to the SCS Type III distribution. This result is expected considering the reduction in peak rainfall intensity under the SC Long distribution. While this condition is favorable for modeling commonly experienced rain events (i.e., less intense storms), it does not replicate intense flashes experienced in extreme weather events such as “rain bombs.” Therefore, it was decided that the SCS Type III distribution would be used as the basis of analysis and design under the current conditions assessment to ensure a conservative evaluation of the drainage system. However, the SC Long distribution was used to rank and prioritize construction recommendations.



(a) Current Conditions



(b) Future Conditions

Figure 14 – Existing conditions simulated maximum flood depths for (a) current conditions 10-year SCS Type III and (b) future conditions design rainfall events.

(a)

(b)

Figure 15 – Existing conditions simulated flood extents for current conditions (a) 2-, 10-, and 25-year design rainfall events using the SCS Type III distribution curve and (b) 10-year design rainfall event using SCS Type III and SC Long distributions.

5.3.3 – Future Conditions Results

The future conditions assessment was undertaken as the final step in the evaluation of the existing Point and downtown stormwater drainage systems. As previously mentioned, estimated increases in total rainfall depth and intensity and sea level rise were calculated for the year 2072 (50 years into the future). Estimated increased rainfall totals were combined with the dimensionless NOAA Type B distribution to generate future condition design storms. Estimated sea level rise was combined with data collected from the tide monitoring station to generate future conditions tidal data.

Flood depth grids were developed from future conditions hydraulic modeling results. Results for 10-year future condition design storm are presented in **Figure 14b**, and results for other design storms are provided in **Appendix C.2**. In general, future conditions appeared to increase peak flooding footprints. However, very few new flooding locations emerged when compared to the existing current conditions results, namely southeast of the Laurens Street/Pinckney Street intersection and along the Waterfront Park parking lot.

Increased flood depths were noted at the previously determined major flood areas (e.g., King Street, Charles/Craven, and Port Republic/Carteret), and overall inundation footprints were larger compared to current conditions. However, changes in maximum simulated flood depths were generally less than 6 inches. For example, computed flood depths at King Street, Port Republic/Carteret, and Bayard/East increased by approximately 0.4 feet, 0.3 feet, and 0.3 feet, respectively.

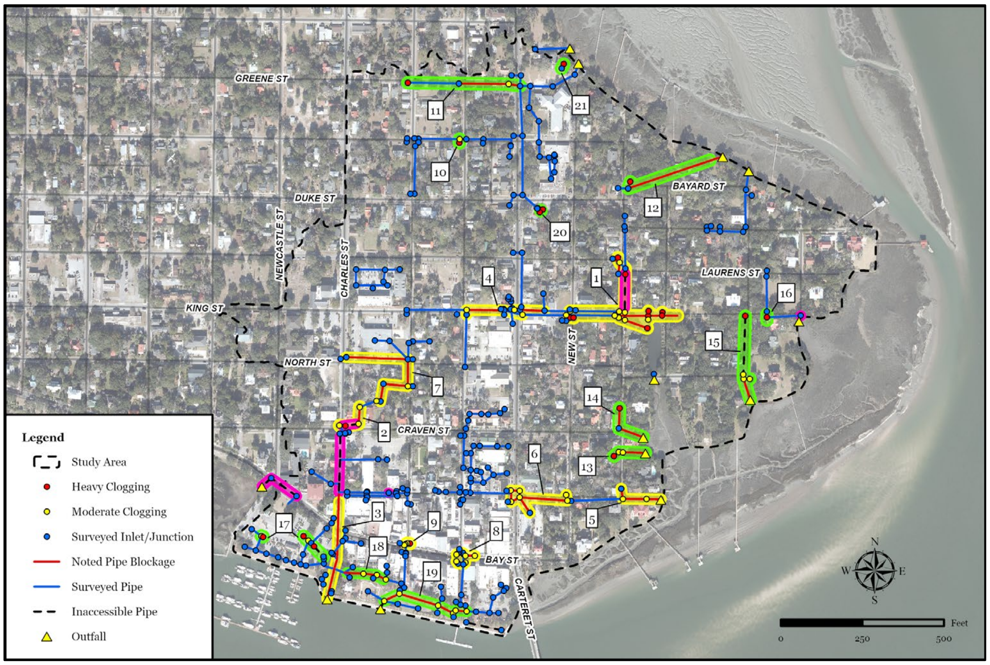
6.0 – Recommendations for Improvements

6.1 – Maintenance Recommendations

Visual observations of debris build up and structural failures during the data collection process were prominent during field investigations. Of the 357 structures and inlets documented in the Point and downtown study area, 4 major structural failures and 31 heavy debris blockages were documented. Of the 337 pipes documented in the study areas, 1 major structural failure and 17 heavy debris blockages were documented. It is important to note that maintenance only projects were not developed for this study since most of the drainage components requiring significant maintenance require replacement to provide adequate capacity. However, maintenance priorities for cleaning pipelines and inlets/manholes were provided to aid in addressing nuisance flooding during low intensity rainfall events.

Maintenance priorities were formed by first creating maintenance priority zones which grouped together debris ridden inlets and pipes located within proximity of each other along the same branch of the system. In total, 21 separate maintenance priority zones were formed. Rankings of the maintenance priority zones were then established by comparing contributing runoff areas, quantities of heavy-to-moderate blockage, upstream drainage systems served, and high-volume traffic routes. Maintenance priority zones were ultimately subdivided into two categories, high priority and medium priority, to enable the City to target the most important maintenance groupings while leaving some ambiguity in the specific order of maintenance proceedings.

Maintenance priorities (see **Figure 16a** and **Appendix E.1**) were shared with the City to begin planning and executing maintenance orders on the Point and downtown drainage system facilities. To expedite maintenance priorities, the City acquired assistance from Beaufort County and SCDOT. Vacuum trucks (whether owned, rented, or externally contracted) were deployed to conduct the required maintenance services. Maintenance efforts were still on-going at the time of this report.



(a) Maintenance Priorities

(b) Potential Flood Reductions from Maintenance

Figure 16 – Maintenance priorities ranked on a per zone basis (a) and potential reductions in flooding after maintenance for the 10-year design current conditions rainfall event (b). High priority maintenance zones ranked 1 to 9 (highlighted in yellow). Medium priority zones ranked 10 to 21 (highlighted in green). Drainage systems with no apparent access are marked as inaccessible (highlighted in magenta).

Potential reduction in flooding due to maintenance priorities were evaluated. Flood conditions from the hydraulic model for the clogged and clear existing drainage system facilities were post-processed to develop flood inundation footprints using the 10-year SCS Type III design rainfall event. Results for both clogged and clear conditions are presented in **Figure 16b** and **Appendix E.1**. Results show that some reduction in flooding footprints could occur as a result of the maintenance measures. However, little-to-no changes were noted along King Street, Charles/Craven, Port Republic/Carteret, and Bayard Street. As a result, improvements to system performance beyond cleanout of the existing system are needed to produce noticeable performance improvements under 10-year design conditions. Although maintenance of existing pipelines and inlets/structures does not appear to aid in preventing flooding conditions under a design scenario, it is expected that cleaning activities will help resolve nuisance flooding under low intensity low volume rainfall events.

6.2 – Construction Recommendations

Drainage system components identified in the analysis to be undersized or inadequate in terms of capacity were analyzed to determine what improvement(s) would be necessary to provide the desired level-of-service. Individual improvements were analyzed along the entire sub-system reach to ensure that recommended improvements on the upstream portion of the sub-system reach would not create adverse conditions on the downstream portion of the sub-system reach. Improvements were generally limited to increased pipe capacity, additional piping, and increased number of drainage inlets. Storage system improvements were evaluated during the analysis and recommended if deemed economically cost effective from both a capital investment cost and long-term maintenance costs. However, much of the sub-basins requiring significant improvements did not have sufficient room for storage due to the highly developed nature of the study area.

Closed collection piping system improvements included the addition of laterals and inlets to the in-place drainage systems of the Point and downtown study area. This recommendation was made to increase the capture capacity of closed drainage networks above the existing capture capacity. Curb and gutter replacement and full road width asphalt milling and overlay was also included as part of the recommendations, where necessary, since damage to these components would be inevitable during construction.

Improvements were recommended based on bringing existing systems up to current design standards based on the 10-year, 24-hour current conditions design scenario adopted herein wherein pipes were at 94% or less capacity. This was done because this design condition is generally conservative and would provide relief even under the future conditions scenario. Improvement recommendations generally followed a two-step approach. First, existing drainage system trunk lines were upsized to reduce simulated flooding. Second, modifications to existing drainage system alignments were made to further reduce flooding until the desired level-of-service was achieved. These additional modifications included extending drainage system service to areas with no existing service via lateral pipes and inlets, developing storage facilities where space permitted, and supplementing existing storage performance with stormwater pumping stations.

System improvements were developed and aimed at installation drainage system upgrades or new facilities within existing public rights-of-way. This was done to minimize the need for easements, as well as aiding in easier access during maintenance after construction. After developing an initial list of improvement recommendations were re-evaluated under the future conditions design scenario to ensure long-term flood resiliency.

Individual system improvements were grouped together to form capital improvement projects. Generally, projects were divided so that conveyance upgrades of similar size and/or drainage service (i.e., trunk line versus branch) would be carried out at the same instance. In total, 28 drainage improvement projects were recommended across the Point and downtown study area with a total estimated cost of approximately $33 million. The effective service areas of all 28 drainage improvement projects are presented in **Figure 17**. Components for each of the 28 proposed projects are presented in greater detail in **Appendix E.2**.

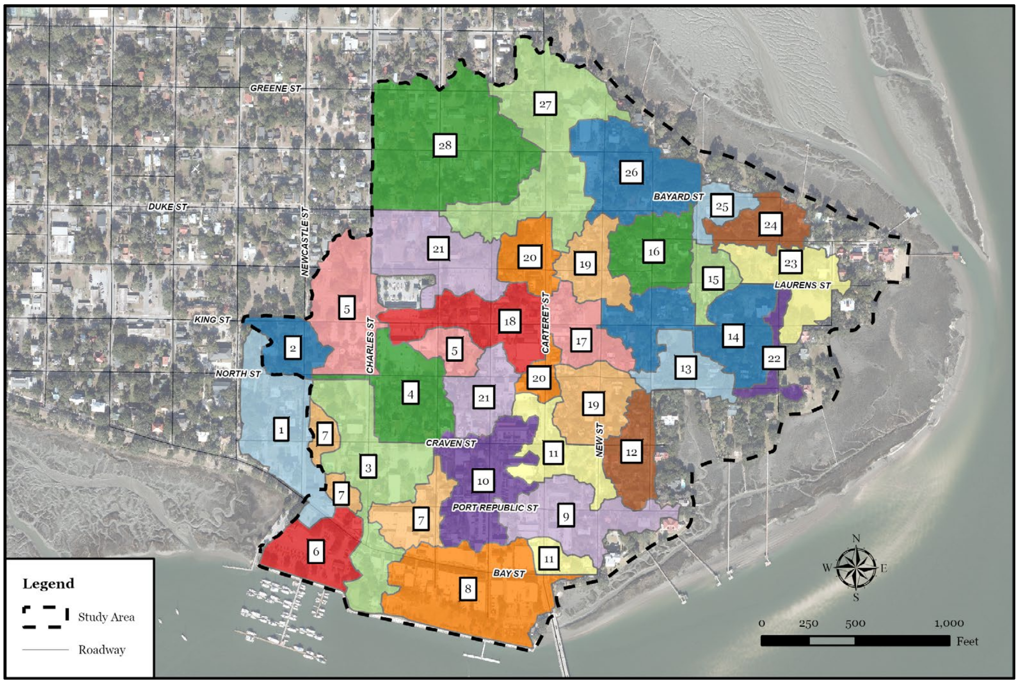


Figure 17 – Proposed drainage improvement projects and associated service areas.

Current conditions simulated maximum flood depth grids were redeveloped across the study area using for the 2-, 10-, and 25-year SCS Type III design events to evaluate the benefits of proposed drainage system improvements. The 10-year design storm is presented in **Figure 18a** while the remaining results are included in **Appendix D.1**. Results show that flooding is largely mitigated through proposed improvements for the current conditions scenarios, leaving only sparse pockets of potential ponding. Drainage improvements reduced simulated 10-year design rainfall flood extents from 17 acres to 1.1 acres and 25-year design rainfall flood extents from 22 acres to 2.3 acres. Under proposed drainage improvements, average current conditions maximum flood depths were reduced from 1.5 feet to 0.3 foot for the 10-year design rainfall and from 1.8 feet to 0.4 foot for the 25-year design rainfall. These quantities demonstrate the effectiveness of the proposed system improvements under current climate conditions.

Flood depth grids were also redeveloped from future conditions hydraulic modeling results for proposed drainage improvements. Results for the 10-year future condition design storm are presented in **Figure 18b**, and results for other design storms are provided in **Appendix D.2**. Proposed drainage improvements largely reduce flooding simulated during future conditions scenarios, though not as greatly as current conditions flooding. Simulated 10-year design rainfall flood extents are reduced from 25 acres to 5.9 acres, and 25-year flood extents are reduced from 28 acres to 10 acres. Under proposed drainage improvements, average future conditions flood depths are reduced from 1.8 feet to 0.5 foot for the 10-year design rainfall and from 2 feet to 0.8 foot for the 25-year design rainfall. Flood mitigation exhibited under future climate conditions demonstrate the resilient properties of the proposed improvements that will deliver adequate drainage performance in the event of significant climate changes.

(a) Current Conditions

(b) Future Conditions

Figure 18 – Proposed conditions simulated maximum flood depths for (a) current conditions 10-year SCS Type III and (b) future conditions design rainfall events.

6.2.2 – Water Quality Improvements

Water quality improvements are recommended to be completed in conjunction with system conveyance upgrades to help reduce the further degradation of the Beaufort River. Due to the heavily urbanized nature of the Point and downtown study area, flood waters can easily become severely polluted with contaminants. These contaminated waters will eventually make their way to the Beaufort River, which has an established total maximum daily load (TMDL) for dissolved oxygen. The river is also connected to adjacent waterways that are listed on the state's 303(d) impaired waters' list for fecal coliform. Treating the upstream runoff prior to its discharge to the Beaufort River can help promote healthier coastal water quality. As such, manufactured treatment devices (MTD) that will aid in the capture and removal of sediment, trash, and other debris are recommended to be installed at each of the system outfalls. For example, the CDS hydrodynamic separator by Contech Engineered Solutions LLC is designed to achieve 80% annual solids load reduction based on average particle sizes ranging from 125 microns down to 50 microns.

Additional opportunities to enhance water quality may become available during the design phase of each recommended project. Such opportunities should be considered for implementation to further improve water quality performance. For example, implementation of green infrastructure may contribute to additional water quality improvements.

6.2.3 – Potential for Green Infrastructure

Integration of green infrastructure designs in the stormwater improvement projects are recommended wherever feasible. Green infrastructure design techniques offer alternative methods to capture, filter, and reduce stormwater in a more natural process as compared to traditional "gray" infrastructure methods (e.g., storm drains, concrete pipes and channels, etc.). Examples of green infrastructure that could possibly be incorporated into the stormwater improvement designs include bioswales, underground infiltration chambers, and permeable pavement. Investigation into the feasibility of these and other green infrastructure alternatives should be pursued during the design phases of the recommended projects after detailed survey and geotechnical data are obtained.

Table 6 – Proposed improvement project prioritization ranking. Projects identified for high-priority construction recommendations are highlighted in red.

Project	Rank	Score
13	1	37.23
14	2	35.35
17	3	19.02
27	4	18.59
3	5	17.26
9	6	14.47
18	7	12.51
28	8	10.27
4	9	9.22
21	10	8.16
1	11	6.6
26	12	5.55
8	13	5.47
11	14	5.29
19	15	4.96
5	16	4.78
24	17	4.71
10	18	4.36
23	19	4.12
20	20	4.03
16	21	3.23
7	22	3.13
12	23	2.75
2	24	2.5
15	25	2.32
22	26	2.19
25	27	2.03
6	28	0.67

6.2.4 – Environmental Compliance, Permitting, and Utility Owner Coordination

Cooperation with multiple agencies and governmental agencies will be an important aspect in the execution of the pursued drainage improvement projects. Design standards and permit requirements that are anticipated to be faced during project execution are summarized as follows:

- All recommended drainage improvement projects will be carried out along SCDOT maintained roads. As such, applications for encroachment permits will be required to begin work on each project. Additionally, all aspects of the drainage design will need to follow SCDOT design standards, at a minimum.
- Conflicts with existing utilities are likely to occur as drainage projects are implemented. Communication with utility providers is encouraged throughout the design process. Beaufort Jasper Water and Sewer Authority (BJWSA) is the area provider for water and sanitary sewer services. Dominion Energy is the area provider for electricity and natural gas.
- Portions of the proposed drainage improvement projects will be located within coastal waters and critical areas as defined in South Carolina Code of Laws Section 48-39-10. Under this designation, critical area permitting through the South Carolina Department of Health and Environmental Control (SCDHEC) Office of Ocean and Coastal Resource Management (OCRM) will be required.
- Application for Nationwide Permits (NWP) from the United States Army Corps of Engineers (Corps) is anticipated to be required as proposed drainage projects will affect aquatic environments in the downstream Beaufort River and adjacent tidal waterways.
- Historical artifacts are possible to be unearthed during construction efforts. Coordination with local historic preservation groups will be critical in the event that items of historical artifacts are discovered during construction.

6.3 – Cost Estimating

Project costs were estimated by establishing unit costs for project elements and summing the cost of the associated elements for the identified projects. Unit costs were developed based on recently awarded projects and engineering judgement to generate sub-total construction costs. Allowances for incidentals (e.g., replacement of landscaping, signs, driveway aprons, etc.) and utility conflicts were then included as percentages of the sub-total construction cost. Based on the construction market at the time of this study, incidentals and utility conflicts were assumed to be 50% of the base construction price. Construction contingencies were included based on a cost contingency curve wherein contingencies ranged from 15% on larger projects to 300% on smaller projects. Contingencies were included as a part of each project estimate to account for unforeseen project elements and details that would only be known at the time of detailed design. Estimated permitting, engineering, and construction engineering and inspection costs were also included for each project so the city would be ready to pursue grant funding after completion of the study. Detailed cost estimate breakdowns for each project are presented in **Appendix F**.

Estimated costs are in 2022 dollars and are intended to provide rough order of magnitude costs for use in programming funds for implementation of improvements. These cost estimates should be carefully reviewed and updated in the future during programming/budgeting of projects to consider changes in the cost of construction materials and labor.

6.4 – Prioritization

Prioritization rankings were developed for each recommended project. Recommendations of proposed improvement projects were prioritized utilizing a weighting system that considered modeled flood depth and area results as well as affected road lengths and building counts. Flooding results from three different rainfall distributions, Type-III SCS, SC Long, and NOAA Type B, were used to rank and prioritize recommended projects.

Average flood depths and cumulative flooded area values were estimated on a project-by-project basis for the 50% (2-year), 10% (10-year), and 4% (25-year) current conditions (i.e., Type -III and SC-Long) and future conditions (i.e., NOAA Type B) scenarios. In addition to hydraulic parameters, cumulative length of roadways and buildings were estimated and assigned to each project for consideration in overall scoring. Unique weights were assigned to each parameter to develop an overall weighted project score. Resulting project rankings and scores are presented in **Table 6**.

It is recommended that proposed improvements be implemented based on a top-down approach (or upstream to downstream) for storage, and a bottom-down (or downstream to upstream) approach for conveyance. The governing principle behind this approach is to attenuate runoff at the top of the system using storage to provide relief to downstream facilities; then continuing downstream with storage improvements to further attenuate flows. Following storage improvements, conveyance upgrades and improvements are prioritized utilizing the aforementioned approach where system capacity is incrementally increased moving upstream. This approach generally serves to avoid adversely impacting downstream stormwater infrastructure and properties.

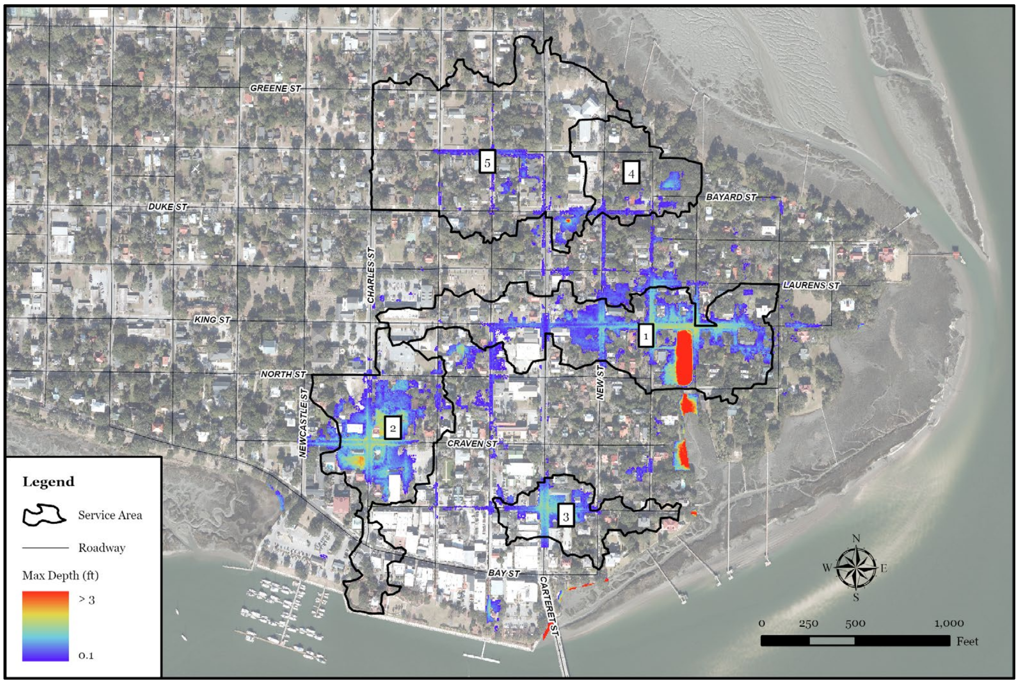
6.5 – High-Priority Projects

Of the total 28 drainage improvement projects developed for the Point and downtown study area, 10 projects were identified as high priority in terms of impact to the City, its residents, and visitors. These 10 projects have a total estimated cost of approximately $21 million and were organized into five project groupings based on inter-project connectivity and spatial proximity to each other. The five project groupings are presented in **Figure 19** with (a) project areas over simulated maximum flood depths for the 10-year design current conditions rainfall event and (b) anticipated project construction limits. Anticipated project limits are provided in the figure, and projects are labeled from 1 to 5, with 1 having highest priority and 5 having the lowest. Detailed exhibits for each of the five priority project groupings are provided in **Appendix E.2**. It is important to note that the project areas depicted in **Figure 19a** represent areas that will directly see an improvement in stormwater service/flood relief. However, areas upstream of these direct service areas will also see an indirect improvement due to improved downstream capacity.

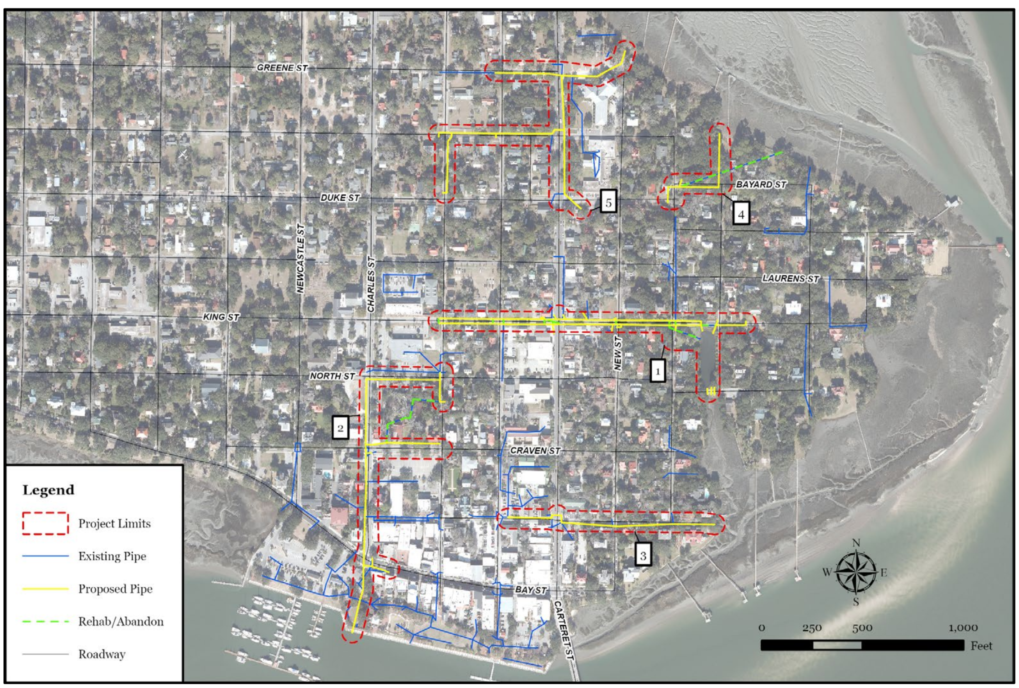
6.5.1 – King Street

Priority project grouping 1 was identified as the most impactful project grouping. It consists of four projects (projects 13, 14, 17, and 18; total estimated cost of ~$10.6 million) that will provide improved drainage along King Street where the majority of inundation was observed during the existing conditions analysis. The majority of these projects (projects 14, 17, and 18) will provide enhancements to the upstream systems along King Street such as upsizing existing drainage infrastructure to meet the desired level of service, installing new drainage infrastructure to expand service, and re-routing existing pipes into the right-of-way limits.

The most expensive and complex subproject in this overall priority group is project 13 which involves (in part) the installation of a stormwater pumpstation near the intersection of Hamilton Street and Federal Street. This pumpstation will be used to maintain the pond's water surface elevation low enough to allow the upstream gravity drainage systems to function properly by minimizing the impact of the tide. This will require the construction/installation of a pumpstation wet well structure, axial flow submersible pumps, force mains, disconnect building, power connection line, and building to house controls and a back-up generator (see **Appendix E.2**).



(a) Current Conditions



(b) Future Conditions

Figure 19 – High priority project recommendations showing (a) project areas with simulated maximum flood depths for the 10-year design current conditions rainfall event and (b) anticipated project construction limits.

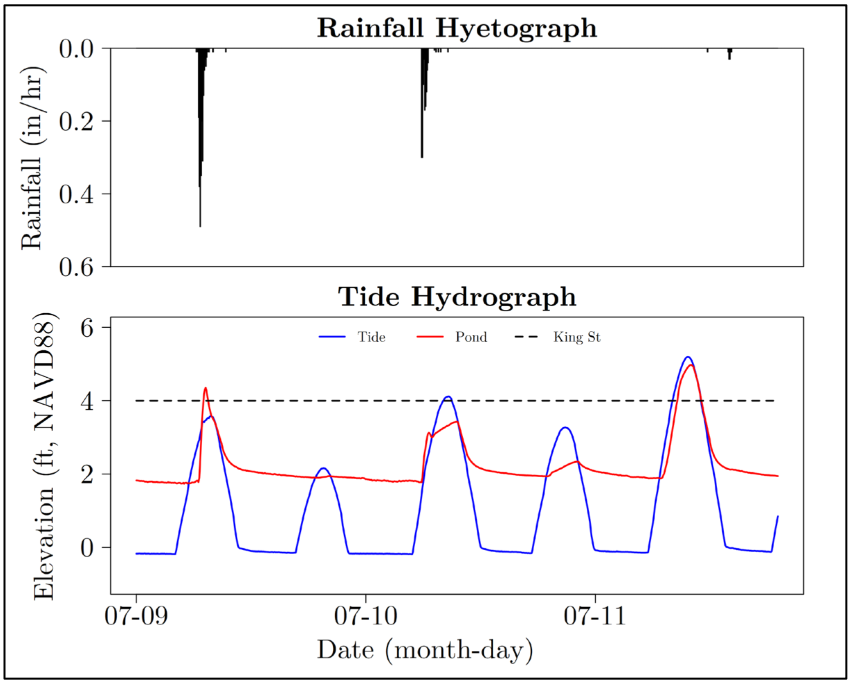


Figure 20 – Proposed drainage improvement projects and associated service areas.

While the proposed pumpstation will be critical to prevent flooding during extreme events (e.g., hurricanes), an innovative approach is also recommended to mitigate the impact of smaller rainfall events, in addition to everyday King Tides. The proposed approach includes retrofitting the existing gravity outfall structure (which drains the pond to the tidally influenced Beaufort River; see **Appendix E.2**) with real-time controllable infrastructure. In this embodiment, a real-time controllable weir will be installed and controlled by an electric actuator/motor to allow manipulation of the pond's water level and discharge rate. By integrating this real-time controllable weir with weather and tide forecasts, as well as with the data from the existing monitoring stations (see **Figure 5**), an automated control system can proactively create additional storage volume within the pond prior to a rainfall event. Thus, reducing the frequency at which the pond's elevated water surface impedes the capacity of the upstream drainage network (as included in projects 14, 17, and 18) and the need for the operation of the pump station.

An additional component of the real-time control system will be to maintain tidal flows to the existing pond but prevent upstream flooding from King Tides or storm surge. Based on elevations of upstream critical infrastructure (i.e., King Street), the system would "check" the tide to prevent "sunny day" flooding. Most importantly, during hurricane events, the system would close to any tidal inflow and trigger the pump station to turn on. Examples of these specific situations occurred during the study and are likely to continue. For example, **Figure 20** presents monitoring data at the tidal pond near Federal Street from July 9, 2022 to July 11, 2022. The first rainfall event 07-09) occurred at high tide and cause the pond to back up into Federal Street simply due to the inability to drain by gravity. The next event (07-10) produced much less intense rain and the pond was able to handle the flows. The last event produced significant flooding from the tide only and was attributed to failed flap gate on the existing outfall.

6.5.2 – Charles/Craven

Priority project grouping 2 is presented as the next high-priority area and comprises of two projects from the overall project list with a total estimated cost of approximately $4.2 million (i.e., projects 3 and 4). These projects will provide enhanced drainage performance along Charles Street beginning at Waterfront Park and extending to portions of Bay Street, Craven Street, and North Street. As part of the projects, existing 48-inch, 36-inch, and 24-inch drainage lines will be upsized to 72 inches, 60 inches, and 48 inches, respectively. In addition to existing drainage system improvements, new pipes and inlets will be incorporated into the system along Charles Street, Bay Street, Craven Street, and North Street. Placement of new infrastructure will be carried out to shift drainage paths into the right-of-way limits and to expand the system's runoff capture performance. Existing drainage located in the Craven Street/Charles Street/North Street block should be inspected via closed circuit television (CCTV) techniques to determine their current condition. Infrastructure located in this area should be left in service if deemed to be in acceptable condition and rehabilitated if necessary.

6.5.3 – Port Republic/Carteret

Priority project grouping 3 is adopted from a single project presented in the overall recommended projects list with an estimated cost of approximately $2.5 million (i.e., project 9). This project will provide increased conveyance capacities along Port Republic Street from East Street to Scott Street through the upsizing of existing drainage infrastructure. Pipe size increases range from the upsize of 30 inches to 60 inches at the project outfall to the upsizing of 18 inches to 30 inches at the upstream project extent between Scott Street and Carteret Street.

6.5.4 – Bayard Street

Priority project grouping 4 involves the implementation of another single project presented in the overall recommended projects list with an estimated cost of approximately $0.8 million (i.e., project 26). This project is comparably smaller than the other recommended priority projects and serves Bayard Street between Hamilton Street and East Street, then extends along East Street to Duke Street. The existing outfall currently serving the Bayard Street community could not be located during survey efforts and is suspected to be collapsed or buried. Flooding is routinely and expectedly experienced in this area, particularly northeast of the Bayard Street/East Street intersection. With this considered, project 9 was deemed worthy of high priority classification even though the project ranked just outside of the top 10 scores presented in **Table 6**. The proposed project involves upsizing existing undersized drainage along Bayard Street where possible, and additional new drainage infrastructure to be installed to re-route the downstream outfall path and expand the upstream drainage capturing range.

6.5.5 – Washington/Carteret

Priority project grouping 5 is the final high priority project grouping. It consists of two projects from the overall recommended project list with a total estimated cost of approximately $3.2 million (i.e., projects 27 and 28). These projects will enhance the existing drainage system serving the northeast section of the overall study area. Specifically, existing drainage along Carteret Street, Greene Street, Washington Street, Duke Street, and West Street will be upsized to attain the desired level of service throughout the system. For example, the system outfall was recommended to be upsized from 24 inches to 48 inches, while other areas within this grouping were recommended to be upsized from 15 inches to 18 inches along West Street between Washington Street and Duke Street.

7.0 – Funding Assessment

Solutions to address historical flooding within the Point and downtown study area have been developed as part of the master planning process. However, without proper funding to complete design and construction, solutions will not become reality. Hence, identification and capture of viable funding opportunities are critical. Considering the large-scale nature of the proposed solutions, combined with an overall budget of approximately $33 million (FY 2022 budget), a funding assessment has been completed to identify and target key programs the city can and must leverage to complete drainage improvements proposed herein.

7.1 – Current Capital Projects Funding Approach

Historically, the city has heavily relied on use of internal funds (e.g., general fund and stormwater fund) and community development block grant (CDBG) programs to complete drainage infrastructure projects. Specifically, several drainage projects have been re-packaged as dual-purpose drainage and streetscape projects to leverage use of grant funds traditionally designated for streetscape only projects (e.g., Calhoun Street). More recently, the city has been very successful in leveraging municipal bonds to complete drainage projects with a quick payback period through effective financial management strategies (e.g., Mossy Oaks). This approach undertaken by the city is often referred to as a "project portfolio funding" approach wherein multiple funding sources are combined and packaged to implement infrastructure projects.

7.2 – Potential Capital Projects Financing Sources

A project portfolio funding approach is recommended to finance the Point and downtown projects. However, additional grant and funding programs should be employed to provide additional project budget capacity and improve project implementation time. For example, the community infrastructure CDBG program typically caps applicant funding requests at $750,000, although additional funds can be requested up to $250,000 for special projects. Although CDBG funds are available on an annual basis, the city can generally only have three outstanding grants, and projects are dictated by direct service to low-to-moderate income (LMI) populations. As a result, these funds may not be most appropriate for large-scale projects that need to be implemented relatively quickly, especially in areas that do not meet LMI thresholds. Nevertheless, there are additional programs, both existing and new, the city can leverage.

Numerous existing and new capital project funding programs have been evaluated which would provide viable sources of funding for the Point and downtown area. Recently, many municipalities and governments have been focused on funds made available through the American Rescue Plan Act (ARPA) and the Infrastructure Investment and Jobs Act (IIJA). These funds provide a once in a lifetime opportunity to complete much-needed infrastructure projects. However, there are dozens of historical, whether annual or event-specific, funding programs available to implement the proposed solutions.

The following subsections serve to provide an overall summary of existing and new programs that have been flagged as appropriate funding mechanisms for which the city is eligible. It important to note that these programs do not necessarily represent the realm of available funding. Rather, programs identified herein were selected as most likely to succeed such that the city has a focused and programmatic financing path to implement proposed improvement projects. A funding summary is also provided in **Table 7**.

7.2.1 – American Rescue Plan Act

7.2.1.1 – Coronavirus State and Local Fiscal Recovery Fund

The American Rescue Plan Act (ARPA) was signed into law on March 11, 2021 and established the Coronavirus State and Local Fiscal Recovery Fund (SLFRF) to provide support to local governments in response to the COVID-19 pandemic. The City of Beaufort was allocated a total of $6,689,031 which will be provided in two allocations (i.e., Beaufort has received its first allocation and is expecting its second allocation in September 2022). These funds are currently being budgeted for personnel pay, broadband activities, and other miscellaneous projects (e.g., GIS database set up and training, security camera upgrades, etc.). However, as of April 1, 2022, the treasury issued its final ruling on the SLFRF which expanded eligible activities that can be covered to include stormwater infrastructure. As a result, these funds should be considered as a great resource for project implementation. **These funds should be considered first since funds through the SLFRF program must be obligated by December 31, 2024 and expended by December 31, 2026 (i.e., period of performance)**.

7.2.1.2 – Water and Sewer Infrastructure Account

State bill 4408 provides additional ARPA funding through the SLFRF and Capital Projects Fund which was passed by the General Assembly of the State of South Carolina on May 10, 2022 and signed into law by the Governor on May 13, 2022. This historic bill established several state accounts and disbursements to state agencies (e.g., SCDOT, SCDHEC, RIA) to finance capital projects. Of these accounts, the most noteworthy is the establishment of the ARPA Water and Sewer Infrastructure Account.

The ARPA Water and Sewer Infrastructure Account was allocated a total of $900 million, of which $800 million is set aside for a competitive infrastructure grant program to fund water, sewer, and stormwater infrastructure projects. Grants will be managed by the Rural Infrastructure Authority (RIA) and will be open to units of local government, special purpose districts, commissions of public works, and joint municipal organizations. Overall grant program requirements generally established by the bill dictate that:

- Applicants can apply for up to $10 million for a single project or multiple projects;
- A 15% local match will be required for populations less than 30,000 (i.e., City of Beaufort); and
- Eligible activities include design, permitting, and construction.

Specific grant application requirements outlined that consideration of funding will be prioritized in the following relative order of needs:

1. Regional solutions – projects that implement solutions that impact multiple systems;
2. Water quality – projects that address consent orders, violations, or other public health or environmental impacts;
3. Resilience and storm protection – projects that help utilities prepare for emergencies;
4. Other aging infrastructure – projects that upgrade or replace infrastructure that has exceeded its useful life; and
5. Capacity – projects that improve service for existing residents while preparing for future opportunities.

Most importantly, funds provided through the competitive grant program will be distributed equitably based on the following factors:

1. Documented priority needs;
2. Transformational impact of the project on the relevant community;
3. Extent to which additional funds may be leveraged by the grant;
4. Readiness of the applicant to proceed with the project(s) and meet program deadlines;
5. Overall project feasibility; and
6. Geographic diversity.

These funds have an initial application deadline of September 12, 2022. As a result, the city should work diligently to develop an application for high-priority recommendations.

7.2.1.3 – Office of Resilience Account

State bill 4408 also established the ARPA Office of Resilience Account with a beginning balance of $100 million. Funds in this account will be administered through the South Carolina Office of Resilience (SCOR) and must be used to complete stormwater infrastructure projects and acquisitions of property in the floodplain throughout the state to lessen impacts of future flood events. Out of the $100 million provided to SCOR, a total of $55 million will be allocated via a Stormwater Infrastructure Program with an overall program application deadline of October 31, 2022. It is anticipated that SCOR will notify all applicants by December of 2022.

The Office of Resilience's ARPA grant program is a great opportunity to fund high-priority projects. The program will cover up to 100% of all design, permitting, and construction-phase activities. Based on guidance published at the time of this report, the program is anticipated to fund any and all grey and/or green infrastructure projects based on the following criteria:

- Benefit Cost Analysis (20 points);
- Nature-Based Solutions (20 points);
- Level of Flood Risk Reduction (10 points);
- Environmental Impact (5 points);
- Low-to-Moderate Income Served (20 points);
- Permitting/Scheduling (10 points);
- Quantity of Flood Risk Reduction (10 points); and
- Mobility Improvement (5 points).

It is highly recommended to pursue funding through the Office of Resilience, especially since they fill fund 100% of the project cost. However, there are a few additional environmental requirements that may be necessary (e.g., Phase 1 Environmental Assessment). Most importantly, although each project will be scored individually, the overall rankings of projects will be based on the collective group.

7.2.2 – Grant Programs

Numerous existing and recurring grant programs are available for direct or indirect use to finance stormwater infrastructure projects. Based on infrastructural needs, project location, and a review of grant scoring criteria, five grant programs have been identified and flagged as possible funding sources classified by program goals as community development, coastal and environmental resiliency, and water infrastructure.

7.2.2.1 – Community Development

The United States Department of Housing and Urban Development (HUD) has provided funding for the South Carolina Community Development Block Grant (CDBG) program since 1982. These funds are distributed via grants through local council of governments (i.e., Lowcountry Council of Government) and are specifically available to local governments to improve economic opportunities and meet community revitalization needs for low-to-moderate income (LMI) populations. For the 2021 fiscal year, HUD allocated a total of $20,214,575 to the CDBG program in South Carolina.

The CDBG grant program is broken down based on three major programs:

1. Community development – address infrastructure, community facilities, and neighborhood priorities;
2. Business development – create new jobs, retain existing employment, stimulate private investment, and revitalize or facilitate competitiveness of local economy; and
3. Regional planning – assist in developing plans and building local community development capacity.

Of the CDBG programs, the community development program receives the most annual funds and provides the best opportunity for project funding. These funds are made available through a competitive grant program each February through the Lowcountry Council of Government. All projects must meet LMI thresholds set forth by the Department of Commerce and the city must provide a minimum match requirement of 10%. Overall, there are five grant programs available within the community development category with FY 2021 state obligations in parentheses:

- Community infrastructure ($12,378,139) – provides funding for water, sewer, drainage and roadway projects with a funding cap of $750,000 per application;
- Community enrichment ($3,000,000) – provides funding for streetscape projects with a funding cap of $750,000 per application;

- Special projects ($1,000,000) – provides funding for economic development, public health and safety, energy conservation and historic preservation, and parks/trails/greenways with a funding cap of $200,000 per application;
- Ready to go ($600,000) – provides funding for "shovel ready" projects that meet community infrastructure or community enrichment guidelines with a funding cap of $500,000 per application; and
- Neighborhood revitalization ($1,000,000) – provides funding for infrastructure, public facilities, housing, demolition, and public services with a maximum of $500,000 to $750,000 per application.

The City of Beaufort may be eligible to apply for up to three CDBG grants (excluding business development and regional planning) at any one time provided that all open grants have not exceeded the 30-month period of performance. Moreover, the city may apply for a waiver and receive up to $1 million for high-priority projects. As a result, CDBG grants are a great recurring financial resource to fund small-to-medium stormwater infrastructure recommendations.

7.2.2.2 – Coastal and Environmental Resiliency

The City of Beaufort is surrounded by coastal waterways and is holistically devoted to long-term environmental resiliency. These two components provide the city with favorable funding options through the Federal Emergency Management Agency (FEMA), National Fish and Wildlife Foundation (NFWF), Department of the Interior (DOI), and many others. Of the available programs, the two most applicable programs to the Point and downtown study area are made available by FEMA and are administered by the South Carolina Emergency Management Division (SCEMD): FEMA's Hazard Mitigation Grant Program (HMGP) and FEMA's Building Resilient Infrastructure and Communities (BRIC).

Although many other programs are available, and the city is most certainly eligible to apply, most of these programs may be better suited for areas outside of the Point and downtown area. For example, NFWF has a National Coastal Resilience Fund that is distributed via grants but is generally targeted towards preservation and restoration activities. Since most of the Point and downtown area are built out and most open space is already preserved through conservation easements, a strong application may not be possible. However, it is important to note that other coastal communities like City of Charleston have been successful in applying for and receiving NFWF grants for preservation and restoration projects.

Hazard Mitigation Grant Program

Funding made available through HMGP opportunities can be used to finance design, permitting, and construction activities of infrastructure that has been impacted by historical events or is at risk from future events. Although there is no direct stipulation on the type of infrastructure funding can be used towards, funding must address risk reduction. For example, funding could be used to make water treatment plant improvements such that residents are provided a more resilient source of drinking water during times of extreme events.

This **program receives funding following federal declaration of a natural disaster** and is generally subject to a 25% local match requirement. As a result, the city must be ready to respond to notice of funding opportunities when they become available. Generally speaking, South Carolina has received a steady stream of HMGP funding during recent years, but these monies may not always be available. For example, for fiscal year 2021, South Carolina received approximately $39 million in funding due to the COVID-19 pandemic. It is important to note that funds made available to HMGP are state competitive.

Building Resilient Infrastructure and Communities

The BRIC program was established in fiscal year 2020 to support state and local governments and tribes through capability and capacity building to enable them to identify mitigation actions and implement projects that reduce risks from natural hazards. Similar to HMGP funding, all infrastructure projects are eligible for funding provided a project will reduce risk from natural hazards and promote resilience of critical facilities, public infrastructure, public safety, and public health. Projects are submitted through SCEMD as sub applicants wherein SCDEMD is the applicant.

The BRIC program is a nationally competitive program with a minimum 25% local match requirement. Communities such as the City of Beaufort are eligible to apply on an annual basis and may receive up to $50 million per application. Over $377 million was distributed for fiscal year 2020 projects and over $919 million was made available for fiscal year 2021. Noteworthy projects funded for fiscal year 2020 included $32.64 million to Columbia, South Carolina; $10.97 million to Princeville, North Carolina; $16.38 million to Hickory, North Carolina; $1.93 to Lumberton, North Carolina; and $1.85 million to Duck, North Carolina. For fiscal year 2021, the City of Conway and Town of Mount Pleasant were announced as finalists for nearly $8 million combined.

A key component of the BRIC program is that the applicant (i.e., state of South Carolina) **must have received a major disaster declaration under the Stafford Act seven years prior** to the annual grant application period start date. Henceforth, funding is made available, and the City of Beaufort may apply for up to seven years from any federally declared disaster. Due to the timing and level of effort required for a nationally competitive grant application, and the current availability of one-time use funds (i.e., ARPA), the BRIC program may be better suited in years to come.

7.2.2.3 – Water Infrastructure

Two existing federal programs were flagged as possible funding opportunities which have historically been used to fund large water management infrastructure projects: Water Infrastructure Finance and Innovation Act (WIFIA) Program administered by the Environmental Protection Agency (EPA) and the Defense Community Infrastructure Pilot Program administered by the Department of Defense (DOD).

Defense Community Infrastructure Pilot Program

The Department of Defense administers the Defense Community Infrastructure Pilot (DCIP) Program to address community infrastructure deficiencies supportive of a military installation. Projects must have a direct impact and uplift on installation resilience and quality of life for military personnel and/or family. Provided the proximity of the city to the Marine Corps Air Station and historical military significance, this program would be an ideal source of funding.

Applicable projects include water/wastewater, stormwater, and other infrastructural needs (e.g., telecommunications, power, or other utility project). **Projects must be shovel ready**, applicants must provide a minimum 30% local match requirement, and projects should be endorsed by the local installation commander. Funding is made available on an annual recurring basis. The fiscal year 2022 solicitation opened in May and included a total of $90 million made available to local governments, nonprofits, and member-owned utilities. It is important to note that **projects may require at least two applications to receive funding**.

Rural Infrastructure Program

The Rural Infrastructure Authority (RIA) administers two separate grant programs the city can use to complete stormwater water infrastructure projects:

- Basic infrastructure – assists communities in bringing systems into compliance with environmental quality standards, protection of public health from environmental concerns, or improve the capacity and sustainability of existing infrastructure
- Economic infrastructure – supports building local infrastructure capacity to provide economic development activities that will lead to the creation or retention of jobs and boost opportunities for economic impact within communities

Each RIA program will only provide funding for construction activities up to $500,000. The city would be required to provide a local match equal to 25% of the total construction costs. Although applicant funding caps may seem relatively low, grant applications are accepted each spring and fall. It is worth noting that these programs received approximately $30 million in available funding for fiscal year 2022. As a result, these grant programs are ideal for small infrastructure projects.

7.2.3 – Earmarks

Funding opportunities can be made available during Congress' annual appropriations process by requesting congressionally directed spending (CDS) (i.e., earmarks). These funds are highly volatile on the political climate but have provided billions of dollars for public infrastructure over the years. Besides seeking general funding requests from senators, the EPA has established the State and Tribal Assistance Grant (STAG) Program to complete water related infrastructure projects.

The STAG account is technically an earmark request that must be made through the city's designated senator (i.e., Lindsey Graham) but has been used for decades to direct funds to local wastewater, drinking water, and stormwater infrastructure projects. Any activity eligible under South Carolina's Clean Water or Drinking Water State Revolving Fund programs is eligible under the STAG program.

The STAG program is made available annually and requires a 20% local match requirement. Although the application process is relatively simple, and $1 to $3 million is the general applicant award amount, successful funding is heavily reliant on proactive coordination with the senator's office. Over $11 billion was made available to the STAG account for fiscal year 2022. It is important to note that the city did pursue $1 million in STAG funding for improvements near Bayard Street at the time of this study.

7.2.4 – Congressional Authorizations and Preliminary Actions

Over the last four congresses, the Water Resources Development Act (WRDA) has been successfully enacted to carry out the United States of Army Corps of Engineers (USACE) Environmental Infrastructure (EI) program. On a biennial basis, Congress can seek EI authorizations for geographic areas of interest to complete studies and infrastructure projects within the USACE's civil works mission areas (i.e., navigation, flood damage reduction, shoreline protection, and ecosystem restoration).

Congressional authorizations under the WRDA can provide up to 75% of the federal cost share for infrastructure projects. The 2022 WRDA draft is available and the Beaufort region is currently seeking approximately $7.5 million. It is expected that the $7.5 million would be made available by fall of 2022 following Congress approval. Although heavily reliant on agreement within the United States Congress, it is recommended that the city continue seeking authorizations through congressional representatives (e.g., Nancy Mace).

7.2.5 – Infrastructure and Investment Jobs Act

The Infrastructure and Investment Jobs Act (IIJA) established funding for existing and new programs. Of the programs addressed within the IIJA, approximately 73% of the program vehicles are existing while approximately 27% are new. Of the new programs, there are four that were established that are directly related to the recommended improvements within the Point and downtown study area:

- Department of Transportation's (DOT's) Healthy Streets Program – established program to deploy cool pavements and porous pavements and expand tree cover to mitigate urban heat islands, improve air quality, and reduce the extent of impervious surfaces, runoff, flood risks, and heat impacts on infrastructure and road users.
- DOT's Promoting Resilient Operations for Transformative, Efficient, and Cost Saving Transportation (PROTECT) Competitive Grant Program – established program to support planning, resilience improvements, community resilience and evacuation routes, and at-risk coastal infrastructure
- EPA's Clean Water Infrastructure Resiliency and Sustainability Grant Program – established program to complete infrastructure projects that increase resilience of public infrastructure to natural hazards.

- EPA's Stormwater Control Infrastructure Grant – offers opportunities to carry out stormwater infrastructure projects that incorporate new and emerging stormwater control infrastructure technologies and protecting or restoring interconnected networks of natural areas that protect water quality.

The Healthy Streets Program and two EPA programs were unfunded at the time of this study; however, it is anticipated that each of these programs may receive up to $100 million in future years. **The PROTECT program did receive funding for the next five years, and it is estimated that South Carolina will receive a total of $128 million**.

Table 7 – Summary of applicable funding opportunities identified based on project setting and infrastructure recommendations. Available funds represent the total funding availability at the government level.

Category	Government Level	Agency	Program	Eligible Projects	Match	Available Funds	Applicant Cap	Past/Current Solicitation	Next Solicitation
ARPA	State	RIA	ARPA Water and Sewer Infrastructure Account	Water, Wastewater, and Stormwater	15%	$800 Million	$10 Million	N/A	TBD
ARPA	State	SCOR	ARPA Office of Resilience Account	Stormwater	TBD	$100 Million	TBD	N/A	TBD
ARPA	State	SCDA/ MASC	ARPA Coronavirus State and Local Fiscal Recovery Fund	Water, Wastewater, and Stormwater	0%	$435 Million	$6.6 Million	N/A	Now
Grants - Community Development	State	HUD/C OG	Community Development Block Grant - Community Infrastructure	Public Amenities and Infrastructure	10%	$11.3 Million	$1 Million	February 2022	February 2023
Grants - Coastal and Environmental Resiliency	State	FEMA	Hazard Mitigation Grant Program (HMGP)	Public Infrastructure	25%	$39 Million	N/A	Winter 2021	TBD-Next Federally Declared Disaster
Grants - Coastal and Environmental Resiliency	Federal	FEMA	Building Resilient Infrastructure and Communities (BRIC)	Public Infrastructure	25%	$1 Billion	$50 Million	Winter 2021	Fall 2022
Grants - Water Infrastructure	State	RIA	Basic Infrastructure and Economic Infrastructure Programs	Water, Wastewater, and Stormwater	25%	$30 Million	$500,000	Spring 2022	Fall 2022
Grant - Water Infrastructure	Federal	DOD	Defense Community Infrastructure Pilot Program	Public Amenities and Infrastructure Supporting Military Installation	30%	$90 Million	$20 Million	May 2022	May-23
Earmarks - Water Infrastructure	Federal	EPA	State and Tribal Assistance Grant (STAG) - SRF, CDS	Water, Wastewater, and Stormwater	20%	$19.8 Billion	$1 to $3 Million	Summer 2022	Summer 2023
Congressional Authorizations - WRDA	Federal	USACE	Water Resources Development Act	Stormwater	20%	$7.5 Million	TBD	2022	2024
IIJA	Federal	DOT	Healthy Streets Program	Streetscapes/Stormw ater	20%	$100 Million	$15 Million	N/A	TBD
IIJA	Federal	DOT	PROTECT	Public Infrastructure within Transportation Corridors	20%	$7.3 Billion	TBD	2022	2023
IIJA	Federal	EPA	Clean Water Infrastructure Resiliency and Sustainability Grant Program	Water, Wastewater, and Stormwater	25%	$100 Million	TBD	N/A	TBD
IIJA	Federal	EPA	Stormwater Control Infrastructure Grants	Stormwater	25%	$100 Million	TBD	N/A	TBD

8.0 – Conclusion and Recommended Plan of Action

Assessment of the City's drainage infrastructure in the Point and downtown study area was completed to identify existing maintenance and/or capacity deficiencies. Debris build up and structural damage in the City's drainage infrastructure were noted during field investigations. Plans to perform necessary maintenance on stormwater assets and provide short-term drainage capacity enhancements were recommended and are currently being coordinated between the City, Beaufort County, and SCDOT.

Existing drainage performance was evaluated under three climate conditions using varying rainfall data and outfall boundary conditions to develop a holistic assessment of current system capabilities. Historic conditions, represented by rainfall and storm surge data gathered during Hurricane Matthew (October 2016) and Hurricane Irma (September 2017), were used to determine the accuracy of the developed computer models against documented historic flooding. Current conditions, represented by present day design rainfall and collected tide data, were used as the basis of design for the initial evaluation of drainage improvements. Future conditions, represented by forecasted increases in rainfall depth, rainfall intensity, and sea level rise, were used to assess the economic value of initially proposed improvements and develop a revised list of the most beneficial drainage improvement projects.

In total, 28 drainage improvement projects were recommended across the Point and downtown study area, with a total estimated cost of approximately $33 million. Of these 28 total projects, 10 projects with a total estimated cost of approximately $21 million were identified as highest priority based on considerations of modeled flood depths and areas, impacted road lengths, and affected number of buildings per project direct service area. These 10 high priority projects were grouped into five specific executable projects across the study area: King Street between Hamilton Street and West Street (projects 13, 14, 17 and 18 – $10.6 million); Charles Street between Waterfront Park and North Street (projects 3 and 4 – $4.2 million); Port Republic Street between Beaufort River and Scott Street (project 9 – $2.5 million); Bayard Street between Hamilton Street and East Street (project 26 – $0.8 million); and Carteret Street between Greene Street and Duke Street (projects 27 and 28 – $3.2 million). Recommended priority project costs and potential external funding sources are summarized in **Table 8**.

Table 8 – Priority project rankings, estimated costs, and potential funding sources.

Project Grouping	Included Projects	Estimated Cost	Potential Funding Source
1 – King Street	13, 14, 17, 18	$10,573,562	RIA / SCIIP
2 – Charles/Craven	3, 4	$4,184,743	SCOR / ARPA
3 – Port Republic/Carteret	9	$2,474,142	SCOR/ARPA/EDA
4 – Bayard Street	26	$794,029	EPA / STAG
5 – Washington/Carteret	27, 28	$3,164,626	CDBG
Total Estimated Priority Project Cost		$21,191,104	

Projects should be implemented in a top-down approach for storage and a bottom-down approach for conveyance. For example, increasing the size of an upstream road crossing before providing additional downstream capacity could negatively affect downstream properties, homeowners, and business owners. There were relatively few storage improvements recommended due to available property; therefore, implemented project recommendations should begin construction at the furthest downstream point. Recommendations and costs associated with recommendations provided herein represent a plan to provide an acceptable level-of-service for the majority of the existing drainage infrastructure within the study area (i.e., generally up to the 25-year current conditions event). These recommendations are meant for planning and programming purposes only and should always be re-evaluated during the design phase of implementation. Moreover, costs are representative of 2022 dollars estimated using historical data and engineering judgment and may not necessarily represent the actual cost of a particular project now or in the future. Furthermore, recommendations are based on synthetic design rainfall events and should continually be validated and re-validated as more historical events are documented throughout the Point and downtown study area. Projections of future rainfall conditions and sea level rise should also continually be re-evaluated as the accuracy of climate change predictions are improved.

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