Island-Wide Stormwater Master Plan and Infrastructure Improvement Strategy – Final Report

TOWN OF SULLIVAN'S ISLAND, SC

DECEMBER 10, 2024

SEAMONWHITESIDE

Island-Wide Stormwater Master Plan and Infrastructure Improvement Strategy – Final Report

Project Name:
Town of Sullivan’s Island
Island Wide Stormwater Master Plan and Infrastructure Improvement Strategy

Project Address/Location:
Town of Sullivan’s Island, SC

Prepared For:
Joe Henderson, AICP
Town Administrator
Town of Sullivan’s Island
2056 Middle Street, P.O. Box 427
Sullivan’s Island, SC 29482

Prepared By:
SeamonWhiteside
Aaron Akin, Ph.D. and Ryne Phillips, Ph.D., P.E.
501 Wando Park Boulevard, Suite 200
Mt. Pleasant, SC 29464
(843) 884-1667

December 10, 2024

Table of Contents

List of Figures

List of Tables

List of Appendices

1. Background

The Town of Sullivan's Island is a low-lying barrier island that is mostly residential in nature but serves as a recreational haven for tourists and neighboring communities. This unique coastal community is full of history and has done a great job at preserving an outstanding quality of life. However, extreme flood events and aging drainage infrastructure are beginning to create challenges in maintaining and achieving long-term coastal resiliency.

As a proactive approach, the town engaged SeamonWhiteside (SW+) to holistically investigate drainage deficiencies and develop an island-wide comprehensive strategy to address flooding experienced today while also preparing for tomorrow's changing coastal environment. Specifically, by inspecting and cataloging existing drainage infrastructure, leveraging innovative technologies, and welcoming resident feedback, a holistic hydrologic and hydraulic model was created to identify drainage system deficiencies and coastal flood risk. From this, solutions to mitigate existing and future (e.g., sea level rise, increasing rain depths) flooding were recommended, which included an estimate of total implementation costs and identification of potential project funding.

The purpose of this report is to detail the methodology and results of this Island-Wide Stormwater Master Plan and Infrastructure Improvement Strategy.

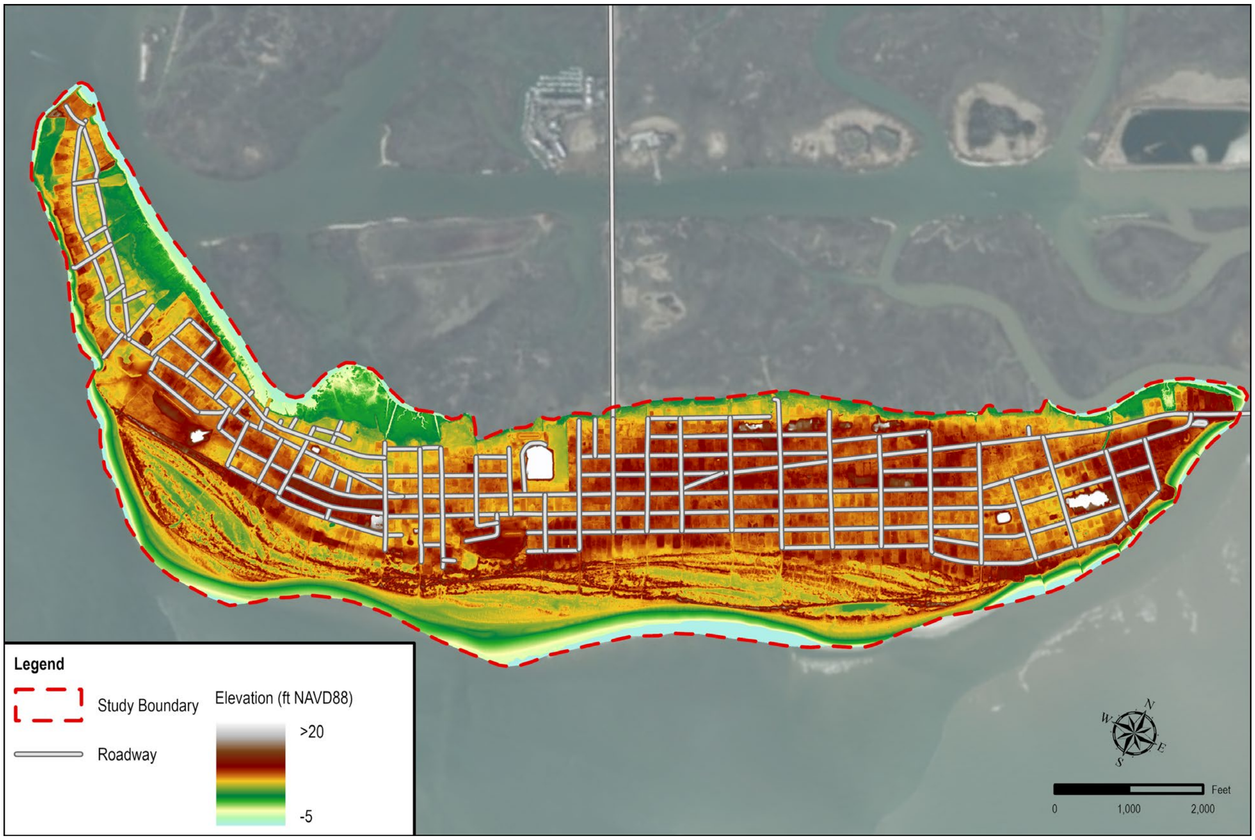


Figure 1 - Study boundary of this analysis.

2. Inventory of Drainage Infrastructure

The existing drainage network was surveyed using GPS survey-grade equipment to identify all visually apparent drainage infrastructure hydraulically connected to the study area (see **Figure 1**). Data collected during field survey efforts included drainage structure elevations (e.g., inverts and rims), ditch cross sections, size (e.g., pipe diameter), and material (e.g., concrete). Photo documentation of infrastructure conditions were also collected during field investigations. It is important to note that all elevation data was collected based on the North American Vertical Datum of 1988 (NAVD88). The full results of this Inventory of Drainage Infrastructure can be found within **Appendix A**.

Overall, it was observed that the majority of drainage infrastructure was severely undersized with most systems consisting of 12-inch to 18-inch diameters pipe systems leading to flooding during larger rainfall events. Compounding on this issue was the condition of the drainage infrastructure, with significant portions of drainage systems in a minor or severely clogged state with other sections simply inaccessible due to debris or standing water. Damage along the main trunk lines servicing several drainage systems (i.e., STA 18, STA 19, STA 25, and STA 28 ½) were observed which should be immediately remedied to prevent larger, more expensive problems (sink holes due to collapsed pipes, clogged infrastructure, etc.).

Clogged Inlet **Damaged Inlet Structure**

Clogged Pipe **Damaged Pipe**

Figure 2 – Examples of observed maintenance issues or damaged drainage infrastructure.

3. Community Engagement

In order to create a more collaborative and comprehensive stormwater master plan, several methods of community engagement were deployed throughout this project. In addition to more traditional strategies, such as public meetings and forums, web-based community engagement tools were developed and deployed as a part of this study.

The primary tool deployed during this study was a web-based flood reporting tool that was invaluable in efficiently capturing public feedback, such as photos and locations of flooding, and other flooding details (e.g., structural damage, date of occurrence, etc.). Collected information was used to validate the results of the existing conditions flood analysis to ensure that results were representative of documented flooding conditions. Additionally, collected information (especially photos; see **Figure 3**) is useful supplemental information to include on any competitive grant applications when applying for funding to implement flood mitigation solutions.

Osceola Avenue (near STA 9 ½)

Bayonne St (near STA 26 ½)

Marshall Boulevard (near STA 29)

Atlantic Avenue (near STA 18)

Figure 3 – Examples of documented flooding submitted by residents to the web-based flood reporting tool.

4. Hydrologic and Hydraulic Analysis

A comprehensive hydrologic and hydraulic model of the study area's drainage infrastructure was constructed to evaluate the performance of the existing drainage network, identify drainage system deficiencies, and recommend improvements. First, the results of the existing conditions survey and visual conditions assessment were used to determine the location and properties (i.e., size, invert elevation, etc.) of the existing drainage network servicing Sullivan's Island (see study boundary in **Figure 1**). Then, a comprehensive hydrologic assessment was performed to delineate watershed boundaries and hydrologic properties required to estimate rainfall-runoff processes. The resulting watersheds and existing drainage network were then used to create an existing conditions combined 1D/2D hydraulic model. A combined 1D/2D hydraulic model quantifies not only drainage system deficiencies (1D) but also the extent, depth, and duration (2D) of flooding. The 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). Using this existing conditions model, alternatives to mitigate flooding were explored.

4.1 Assumptions and Limitations

A model is a representation of a system and is therefore limited in its ability to completely replicate observed conditions. However, by understanding the assumptions made and limitations encountered during a model's creation, the results can lead to more pragmatic solutions. Each of the subsequent sections outline limitations or assumptions associated with their respective investigations or analyses.

4.2 Hydrologic Analysis

A comprehensive hydrologic analysis was performed to delineate watershed boundaries within the study area by determining drainage paths where runoff will flow and accumulate. Watershed boundaries were delineated using Charleston County 2017 LiDAR topographic data and the results from the inventory of drainage infrastructure (see **Section 2** and **Appendix A**). Once watersheds were delineated, hydrologic parameters required to estimate runoff rates and volumes (e.g., curve numbers, soil classification, etc.) were determined. The methodology for estimating these hydrologic parameters is discussed in subsequent sections. Overall, 812 watersheds were delineated for the purposes of this study (see **Figure 4**) including disconnected watersheds ("sinks") which do not flow to existing drainage infrastructure but accumulate runoff within the developed portion of the island. This study did not examine watersheds which flow to areas outside of the developed portion of the island (i.e., accreted land, marsh, etc.).

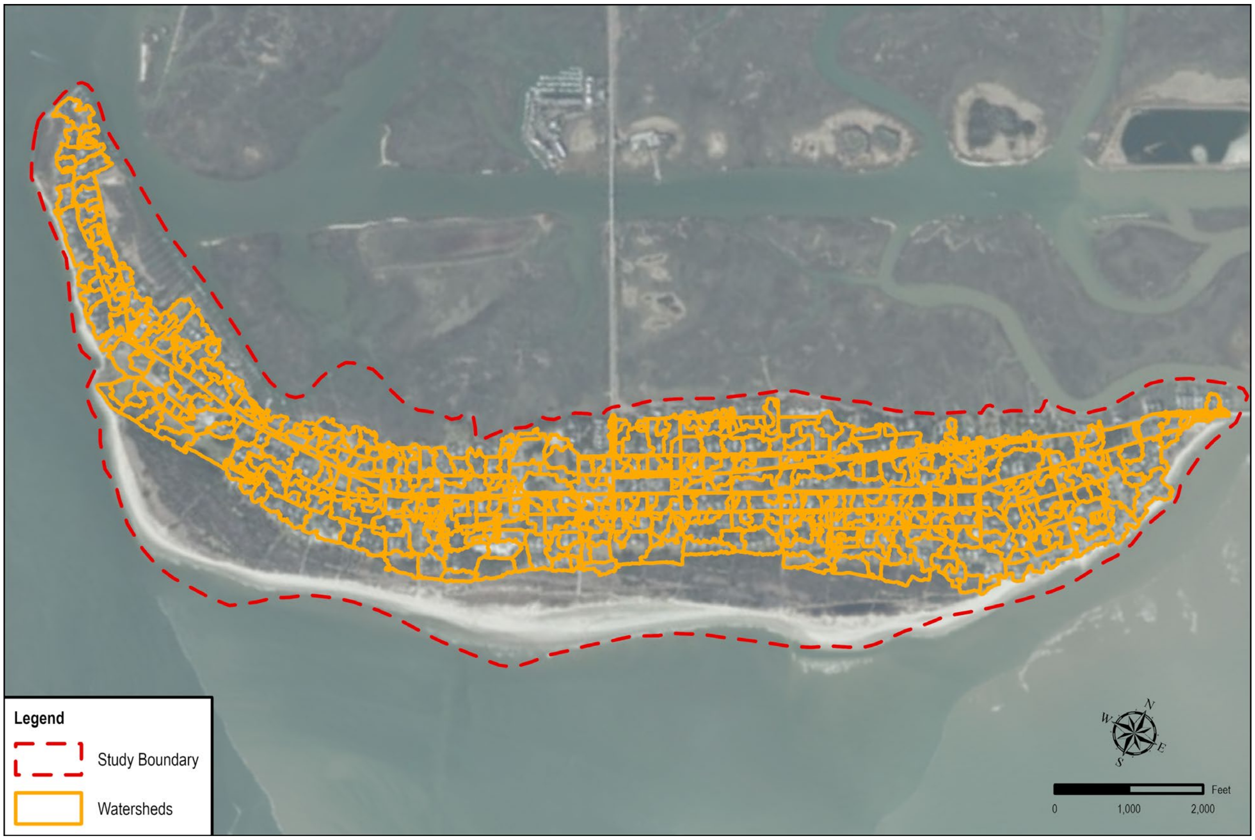


Figure 4 - Watersheds delineated for the purposes of this study.

4.2.1 Soil Analysis

The analysis presented herein adopted United States Department of Agriculture (USDA) soil data from the soil survey geographic (SSURGO) database published on August 30, 2021. Based on this dataset, the dominant soil group in the study area is Ma (see **Figure 5**).

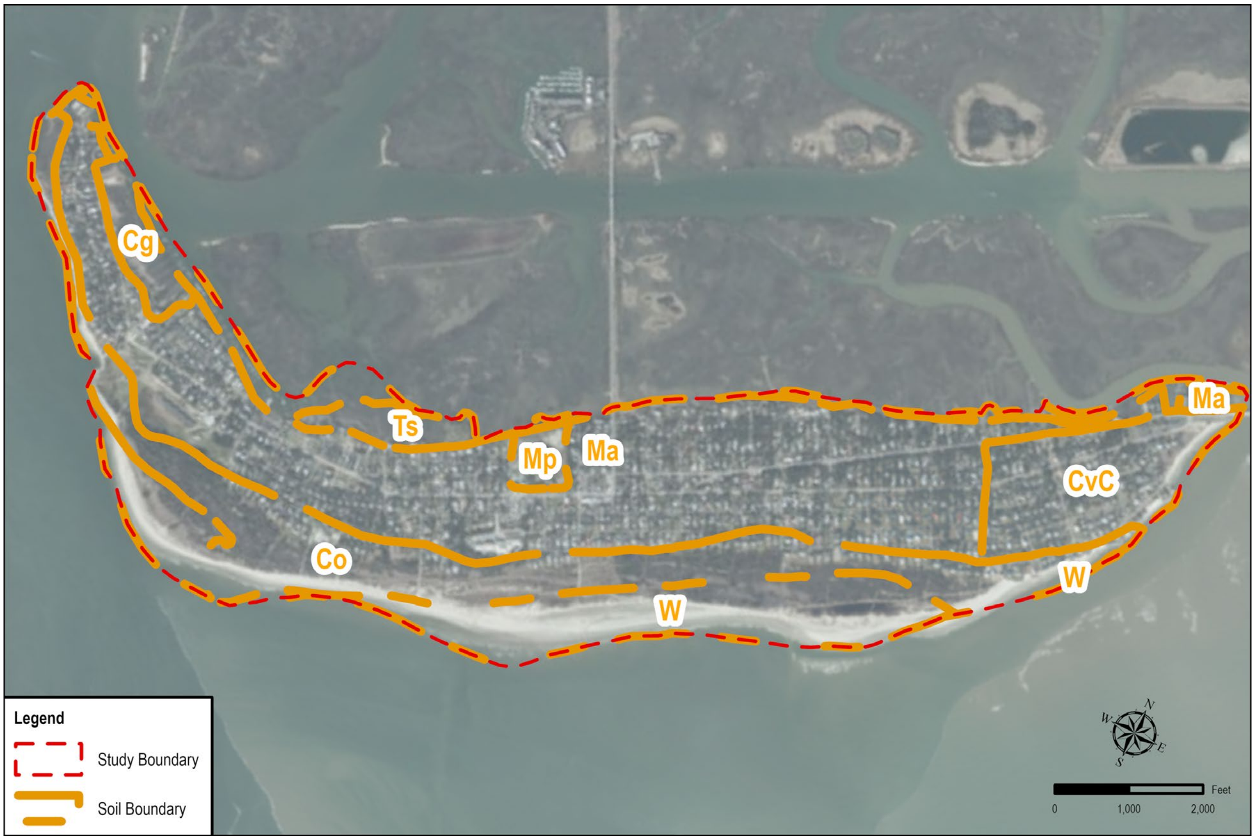


Figure 5 - Soil classifications within the study area according to USDA classifications.

Hydrologic soil group classifications are a qualitative measurement of a soil's infiltration capacity. These classifications assign soils into one of four single classes (A, B, C, or D) or one of three dual classes (A/D, B/D, and C/D). Generally, these classifications are evaluated on a scale from A to D, with A soils exhibiting high infiltration capacities (i.e., low runoff potential) and D soils exhibiting low infiltration capacities (i.e., high runoff potential). 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.

4.2.2 Land Use/Land Cover Classifications

While soil conditions generally describe underlying hydrologic processes, land cover and land use classifications describe the impact that surface cover has on a watershed's potential to generate surface runoff. These qualitative classifications can range from urban scenarios with high runoff potential (i.e., developed, high intensity) to more natural ecosystems (i.e., wetlands). Land use and land cover classifications were assigned to each watershed based on the Natural Resources Conservation Service's (NRCS) methodology using the 2021 national land cover dataset (NLCD) published by the United States Geological Survey (USGS). The 2021 NLCD resolution for this region is approximately 100 feet (30 meters).

Due to the low resolution of the available NLCD for this region, the NLCD was supplemented with building and roadway footprints to provide a more representative land cover within the developed portions of the island. Specifically, the areas within building and roadway footprints were reclassified as "Impervious" with the remaining space within the developed portion of the island reclassified as "Developed, Open Space". Undeveloped areas of the island (i.e., marsh, maritime forest, beaches, etc.) remained classified according to the 2021 NLCD classification. **Figure 6** shows the land use/cover classification for the study area.

Figure 6 - Land cover data for the study area according to 2021 NLCD published by USGS and supplemental data.

4.2.3 Estimating Runoff

Runoff volumes and rates were generated for each watershed using NRCS and SWMM methodologies, respectively. To estimate runoff volume for a watershed using this method, multiple hydrologic parameters must be known: hydrologic soil group classification, land use and land cover classification, and watershed physical attributes (surface area, flow length, and slope). All parameters were estimated based on geospatial analyses and engineering judgement. The first two hydrologic parameters are used to determine a parameter called the curve number (CN), a variable which describes a watershed's ability to produce runoff during a rainfall event. While originally developed by researchers to estimate runoff volumes for agricultural watersheds, CNs have since been adapted for use in urban areas. CNs generally range from 30 to 98 wherein a watershed with a higher CN has a greater potential for generating runoff. **Table 1** summarizes CN values (based on the input data) used in this study. In instances where multiple land cover or soil conditions were encountered in a watershed, CNs were developed and assigned using an area-weighted (or composited) approach.

Table 1 - Curve numbers based on land cover/use and hydrologic soil group classification encountered within the study area (modified from Huffman, et al. 2013).

Land Cover/Use Classification	Hydrologic Soil Group Classification			
	A	B	C	D
Developed, High Intensity	88	92	93	94
Developed, Medium Intensity	84	89	93	94
Developed, Low Intensity	81	88	90	93
Developed, Open Space	52	68	78	84
Open Water	98	98	98	98
Barren Land	70	81	88	92
Emergent Herbaceous Wetlands	80	80	80	80
Evergreen Forest	30	55	70	77
Hay/Pasture	40	61	73	79
Herbaceous	63	63	75	85
Shrub/Scrub	42	42	55	62
Wood Wetlands	86	86	86	86
Impervious	98	98	98	98

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

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

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

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

4.3 Hydraulic Analysis

Using the established existing drainage network and the results from the hydrologic analysis, a combined 1D/2D hydraulic model was developed to analyze the existing drainage system. This model not only quantified drainage system deficiencies (1D), but the extent, depth, and duration (2D) of flooding. This model was developed using PCSWMM (PCSWMM; Computational Hydraulics International; version 7.6.3675), a comprehensive and complex modeling software for stormwater, wastewater, and water distribution applications. PCSWMM is considered a link-node model wherein inlets and junctions are represented as 1D nodes, pipes and channels are represented as 1D links, and overland flow is represented as a series of 2D nodes and links in the model domain.

4.3.1 Development of 1D Domain

Results from the inventory of drainage infrastructure (see **Section 2** and **Appendix A**) were used to develop the 1D domain of the model. Inlets, junctions, pipes, channels, and outfalls represented physical components of the drainage system (see **Appendix A**). Physical attributes for these components such as invert and rim elevations, geometry attributes (e.g., size, cross-sections, etc.), backflow prevention (e.g., tide gates or check valves), material (e.g., concrete, brick arch, etc.), and physical location were assumed directly from the inventory of drainage infrastructure.

Watersheds were then assigned to route runoff into their receiving drainage system components (i.e., inlet, channel, catch basin, etc.) based on topographic data and flow paths. Watersheds with no outlet ("sinks") were routed to the 2D domain (see **Section 4.3.2**) based on topographic data and flow paths. Once within the drainage network, stormwater was routed through the connected pipes and channels until it reached the outfall (i.e., the discharge point for the drainage system). Flow through these pipes and channels was determined using the diffusive wave equations which describe the relationship between flow and the physical attributes of the pipe/channel. The last variable incorporated into the model was Manning's roughness coefficient, n, which was assigned based on the material of a pipe/channel. **Table 2** summarizes the materials of pipes/channels encountered during this study along with the assigned Manning's roughness coefficient.

Table 2 - Summary of pipe/channel materials encountered during this study and the assigned Manning's roughness coefficient (modified from Huffman, et al. 2013 and Chow, 1959).

Material/Description	Manning's n
Concrete	0.014
Concrete (New)	0.012
Vitrified Clay Pipe	0.014
Ductile Iron Pipe	0.016
HDPE – Smooth	0.012
HDPE - Corrugated	0.020
Metal - Corrugated	0.025
PVC	0.010
Ditch	0.060
Cast Iron	0.016

4.3.2 Development of 2D Domain

Development of the model's 2D domain allowed the hydraulic analysis to extend beyond pipe capacity to include flood extent, depth, and duration results by enabling the model to replicate overland flow processes if the stormwater system were to surcharge and flood adjacent properties. It is important to note that the 2D elements (and their assigned parameters) developed for this model do not replace rainfall-runoff processes and are instead intended to represent overland flow if stormwater were to surcharge from the existing system, or if a watershed had no outlet. Runoff generated by watersheds was determined independently of any hydrologic parameters assigned to the 2D model domain and was still routed directly to its receiving 1D model element (or 2D model element in the case of disconnected watersheds).

The 2D domain was developed using topographic data and building footprints using an overland flow mesh, or set of discrete cells representative of a small area of land, through which water can flow and accumulate. The mesh developed for the study area consisted of a 15-foot resolution hexagonal mesh near roadways (within 50-feet), a 35-foot resolution hexagonal mesh within the remaining developed portion of the island, and a 100-foot resolution hexagonal mesh everywhere else (i.e., marsh, maritime forest, beach, etc.). While flood results using this mesh will not delineate every small pocket of flooding (i.e., small depression in landscape or improperly graded road preventing stormwater from reaching an inlet, etc.), it is useful for identifying areas of significant flooding potential across the study area.

Roughness coefficients (based on land cover classification; see **Table 3**) were assigned to the 2D elements of each cell within the mesh (using an area-weighted approach) to simulate the study area's response to flooding by replicating flow routing processes of the surrounding landscape. Finally, the 1D domain was connected to the 2D domain to allow the drainage system to surcharge and spill out (though openings in the drainage network such as inlets, channels/ditches, or open pipes) onto adjacent roadways and properties.

Table 3 – Summary of Manning's roughness coefficients assigned to 2D model elements based on land cover/use classificaiton (modified from Jung, et al. 2013).

Land Cover/Use Classification	Manning's n
Developed, High Intensity	0.100
Developed, Medium Intensity	0.075
Developed, Low Intensity	0.050
Developed, Open Space	0.013
Open Water	0.030
Barren Land	0.030
Emergent Herbaceous Wetlands	0.100
Evergreen Forest	0.120
Hay/Pasture	0.040
Herbaceous	0.030
Shrub/Scrub	0.050
Wood Wetlands	0.100
Impervious	0.014

4.4 Scenarios Investigated

A diverse mix of rainfall and tidal conditions were analyzed as part of this study to assess existing conditions and make recommendations for improvements to mitigate current and future flood risk. A summary of these scenarios can be found below in **Table 4**.

4.4.1 Rainfall Data

Rainfall data were obtained from the National Oceanic and Atmospheric Administration (NOAA) precipitation frequency data server; specifically, the estimates for the Town of Sullivan's Island (32.7667°, -79.8500°). These precipitation depths were combined with the dimensionless SC Long rainfall distribution to generate rainfall event distributions (see **Table 4**).

SC Long rainfall distributions are generated by combining the NOAA precipitation depth estimates with a rainfall distribution established by Powell et al. (2007) using similar techniques as Huff (1967) and the Texas Department of Transportation (Asquith et al., 2005). This SC Long rainfall event distribution was originally developed based on regional (South Carolina, North Carolina, and Georgia) NOAA rainfall data to develop a rainfall distribution more representative of an expected 24-hour rainfall event in South Carolina. This allows the hydrologic and hydraulic study to analyze the impact of more realistic (less intense with equitable precipitation depth) rainfall events instead of a statistically unrealistically high intensity NRCS/SCS Type-III rainfall distribution. The use of the SC Long rainfall distribution in this analysis allows for the development of highly effective, but cost-conscious, solutions more tailored to the operational budgets of smaller communities. It is important to note that these SC Long rainfall distributions are often still more intense than observed hurricanes or tropical storm events. A comparison of the NRCS/SCS Type-III and SC Long distributions for the 1 percent (100-year) event is presented below in **Figure 6**.

Table 4 – Scenarios investigated as part of this study.

Scenario	Current or Future Conditions	Tidal Boundary Condition	Rainfall Condition	
			Annual Exceedance Probability (Recurrence Interval)	Precipitation Depth (inches)
1	Current	Typical Tide (3.31 ft NAVD88)	None	0.00
2			10% (10-Year)	6.60
3			4% (25-Year)	8.03
4			1% (100-Year)	10.40
5		Extreme Tide (4.55 ft NAVD88)	None	0.00
6			10% (10-Year)	6.60
7			4% (25-Year)	8.03
8			1% (100-Year)	10.40
9	Future	Future Typical Tide (5.39 ft NAVD88)	None	0.00
10			Future 10% (10-Year)	7.26
11			Future 4% (25-Year)	8.83
12			Future 1% (100-Year)	11.44
13		Future Extreme Tide (6.63 ft NAVD88)	None	0.00
14			Future 10% (10-Year)	7.26
15			Future 4% (25-Year)	8.83
16			Future 1% (100-Year)	11.44

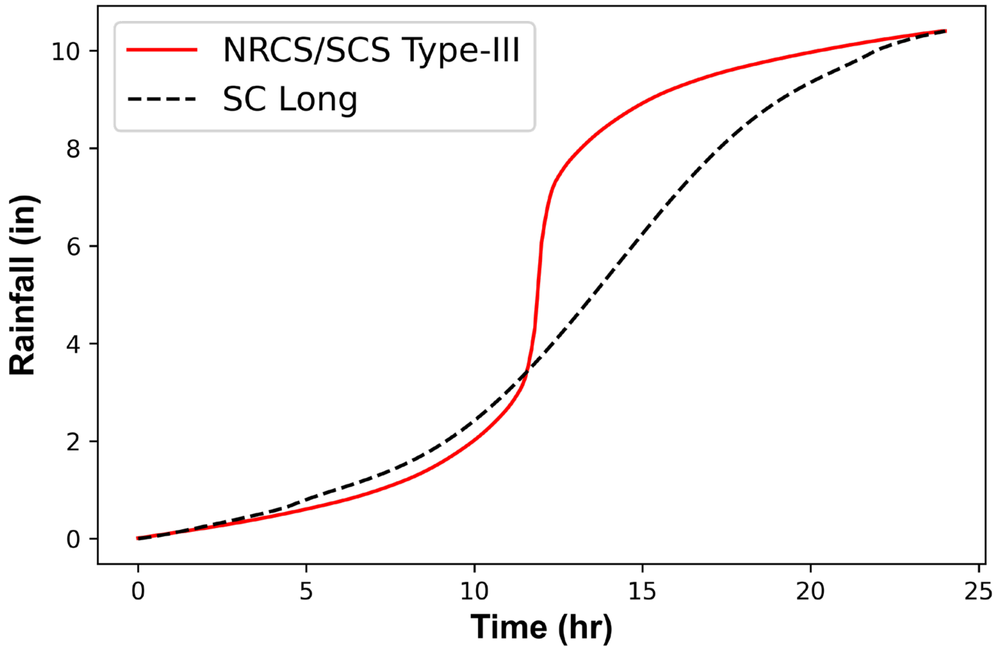


Figure 7 – Comparison of the NRCS/SCS Type-III and SC Long rainfall distributions for the 1% AEP (100-year), 24-hour duration rainfall event for Sullivan's Island, SC (10.40").

4.4.1.1 Future Rainfall Data

With the cumulative impacts of climate change becoming a growing concern, it is imperative to understand and quantify these impacts when evaluating drainage system performance. As a result, future rainfall conditions were also explored within this study to understand how changes in rainfall may impact flood conditions across the study area. These changes were evaluated by increasing current rainfall depths (see **Table 4**) by 10 percent to provide conservative estimates for future rainfall events. This 10 percent increase is based on the South Carolina Office of Resilience's Strategic Statewide Resilience and Risk Reduction Plan chapter on Climate Trends in which it is recommended to plan for an average increase of 5 to 10 percent in precipitation statewide.

4.4.2 Tidal Boundary Conditions

The study area is tidally influenced due to its proximity to the Atlantic Ocean and tidal marsh which may cause varying flood conditions depending on the tide cycle and when rainfall occurs relative to these tidal fluctuations. Four tidal boundary conditions were investigated as part of this analysis: 1) typical tide, 2) extreme tide, 3) future typical tide, and 4) future extreme tide. All tidal boundary conditions used the observed tidal data from the Charleston Harbor (NOAA Station 8665530) for the year 2023 as a baseline (see **Figure 8**). The year 2023 represents an excellent baseline of quantifying current and future flood risk because: 1) it is the most recent observation year, 2) the mean higher-high tide for the year aligns with long-term data trends, and 3) several extreme tidal events occurred during 2023 with the most extreme occurring outside of a hurricane or tropical storm event.

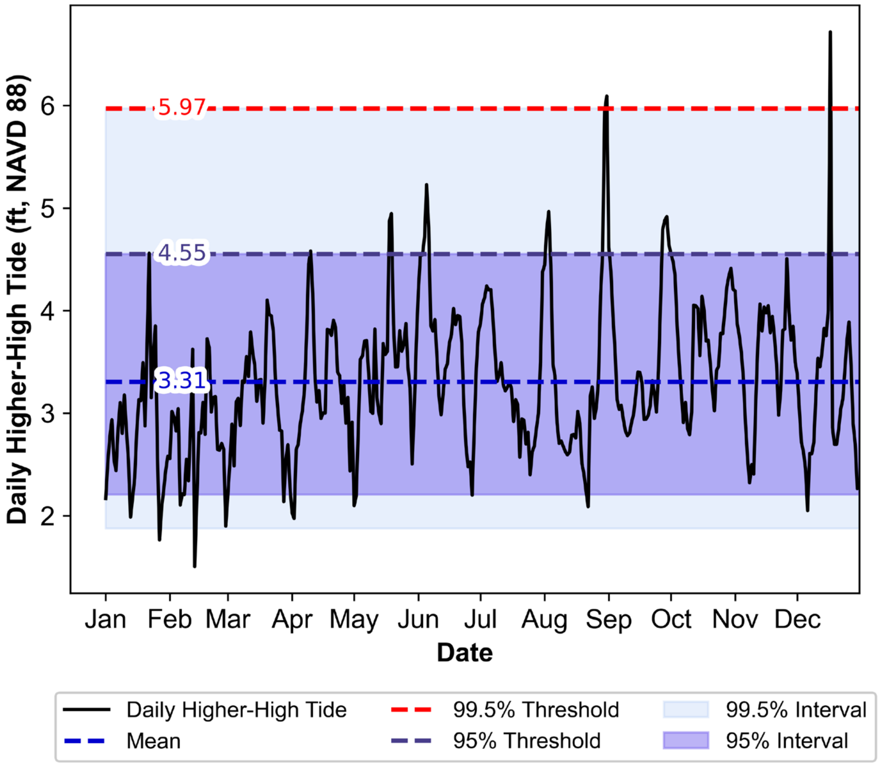


Figure 8 – Daily higher-high tides for Charleston, SC (NOAA Station ID 8665530) during 2023 along with quantile thresholds.

The typical tide boundary condition used in this analysis was developed based on an idealized tide cycle with a frequency of 12.5 hours wherein the peak and amplitude were determined using the MHHW (2.62 feet NAVD88) and MLLW (-3.14 feet NAVD88) tidal values from the Charleston Harbor NOAA Station (Station 8665530) and vertically shifted to match the mean higher-high tide for 2023 (3.31 feet NAVD88; see **Figure 8**). The extreme tide boundary condition was developed using the same methodology but vertically shifted to match the 95% daily higher-high tide (4.55 feet NAVD88) for the year 2023.

4.4.2.1 Future Tidal Boundary Conditions

To examine the impacts of sea level rise, future tidal boundary conditions were developed based on established projections from the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force. The projections and scenarios presented by this task force represent the most comprehensive and current (last updated 2022) information when investigating the impact of sea level rise along the United States coastline.

Overall, sea level rise projections presented by the task force represent the results of scenarios based on climate models which result in varying levels of risk and probability. Individual components included in these projections include sterodynamic sea level change (changes in ocean circulation, temperature, and salinity), impacts from glaciers, changes in land water storage (variability in the global water cycle), changes to the Greenland and Antarctic ice sheets, and estimates for land subsidence. For the purposes of this study, the intermediate projection for the year 2074 was selected as the sea level rise scenario to determine the local impact of future sea level rise. The projection year of 2074 is appropriate to ensure that drainage improvements recommended as part of this plan can function effectively across the typical lifespan of drainage infrastructure (approximately 50 years).

An additional hazard affecting coastal communities is vertical land subsidence, or the rate at which the surrounding landscape is sinking. It is hypothesized that the major contributors to this phenomenon include ground-water extraction and soil compaction in urban areas. While sea level rise projections from the interagency task force do account for some level of vertical land subsidence, these estimates are not based on localized, higher-resolution data. The full interagency report recommends integrating higher-resolution data when available to be able to assess the impact of vertical land motion at finer scales (i.e., at the community level) whose rates may not be representative (i.e., communities with increased vertical land motion rates) of what is approximated in the sea level rise projections.

Higher resolution data for the Town of Sullivan's Island is available. Research has quantified these rates for the entirety of the United States eastern coastline based on vertical land motion data from 2007 to 2020 published by the Unites States Geological Survey (Ohenhen et. al., 2024). Analysis of the data points available within the study boundary concluded that the landscape was sinking at a rate of approximately 0.15 inches/year. This rate far outpaces what is estimated in the interagency sea level rise projections. Therefore, this data was incorporated into the study as a replacement for the vertical land motion rates included in the original sea level rise projections.

Integrating the localized vertical land motion rates with the 2074 intermediate sea level rise projections results in a projected increase in sea level rise of approximately 2.08 feet over the next 50 years. Future tidal boundary conditions for this analysis were then developed by vertically shifting the typical tide and extreme tide boundary conditions by 2.08 feet (see **Table 4**).

4.4.3 Future Land Cover Conditions

All future scenarios (scenarios 9-16 in **Table 4**) investigated as a part of this study also accounted for increased impervious coverage (i.e., continued redevelopment, larger houses, etc.). This increase was developed by quantifying the impervious coverage of the typical residential lot (~14 percent) within the study area and investigating what the curve number impacts would be if the impervious coverage were increased to 30 percent (as allowed by current ordinances). This analysis concluded that future scenarios would need to increase watershed curve numbers by 7 percent above current conditions to account for these potential changes in land cover.

4.5 Existing Conditions Analysis

Following the development of the existing conditions model (see **Section 4.3** for details), the study area's response to all the scenarios outlined in **Table 4** were investigated. An example of the results from the existing conditions analysis can be seen in **Figure 9**. These results provided a benchmark for investigating the impact of proposed improvements and alternatives investigated as part of this analysis. Results from all scenarios investigated as a part of this study can be found in **Appendix B**.

Figure 9 - Example flood stage results from the combined 1D/2D model developed for this study area.

4.6 Proposed Conditions Analysis

Alternatives to existing drainage infrastructure that may mitigate observed flooding were investigated using results from the existing conditions analysis. This was an iterative process in which the existing drainage infrastructure was improved/altered to explore how those changes may impact flooding within areas of concern. These improvements generally consisted of upgrading existing drainage infrastructure (e.g., upsizing pipes to a larger diameter), installation of new drainage infrastructure (e.g., new inlets or closed piping systems, etc.), raising roadways for perimeter tidal protection, and leveraging pump stations for flood control. It is important to note that this study focused on examining improvements that could be constructed within public rights-of-way outside of private property. Improvements or strategies that private property owners can implement is discussed in subsequent sections. Once it was determined that these improvements could potentially mitigate flooding, these infrastructure improvements were integrated into a proposed conditions model and analyzed using the same scenarios (see **Table 4**) as the existing conditions analysis.

Specifically, scenario 12 (future typical tide of 5.39 ft NAVD88, 1% AEP rainfall depth of 11.44 inches; see **Table 4**) was used as the target scenario for evaluation of potential flood mitigation for proposed improvements. Developing solutions to mitigate flooding under these conditions should provide an appropriate, yet cost-effective, level of service required to improve the town's long-term coastal resiliency.

5. Proposed Improvements

Overall, 18 projects were recommended to holistically mitigate flooding within the Town of Sullivan's Island (see **Appendix C**). These projects were typically divided into two categories: 1) major drainage improvements along the main trunk line of existing systems (outfall to high-risk areas) and 2) future lateral improvements to increase the service area of drainage systems. The results of the proposed conditions analysis with these improvements can be found in **Appendix D**.

It is important to note that ongoing drainage improvement projects such as the SCIIP Drainage Improvements Project (STA 16, STA 25, STA 28 ½, and STA 31) and Station 18-19 Stormwater Improvements Project (HMGP 4241) were assumed to be completed for the purposes of this analysis. If these improvement projects are not completed within their full scope, then the remaining work should be integrated into this master plan and prioritized based on the results of the analyses presented herein. For example, if the Station 18-19 Stormwater Improvements Project is not fully implemented and/or does not provide adequate flood mitigation, then this project should immediately become a high priority for the town based on the observed severity of flooding as presented in **Appendix B** and documented by citizens as part of the web-based flood reporting tool (see **Section 3**).

Proposed improvements presented herein were observed to provide substantial flood mitigation across most of the scenarios investigated as a part of this study. The largest exception were areas on the island whose topographic elevations are below the peak tidal elevation for a given scenario (i.e., properties along the marsh, Osceola Avenue, intersection of STA 30 and Brownell Avenue, etc.). Since the simulations were set to have peak tide coincide with peak rainfall, all the stormwater systems were full, which caused surcharging of the stormwater system in areas lower than the tidal elevation. However, once the tide receded, stormwater was quickly drained from these locations. In these cases, it is recommended that additional strategies are pursued by private property owners such as targeted fill of low-lying lots or constructing vegetated berms (see **Section 7.2**) to provide additional flood mitigation.

5.1 High Priority Projects

While all projects developed as a part of this plan should be implemented to improve the town's long-term coastal resiliency, three projects were identified as high priority that should be implemented as immediately as possible: Osceola Avenue, Station 22 ½, and Station 26 ½. Each of these areas experiences severe systemic flooding that will only become exacerbated in the future if not addressed.

5.1.1 Osceola Avenue

Osceola Avenue from approximately Point Street through Station 12 has been subject to severe tidal-driven flooding. With the road centerline as low as 4.65 feet NAVD88 in some locations, tidal water can crest over the roadway multiple times a year, flooding adjacent properties and making the road impassible. Compounding on this issue is the clogged drainage infrastructure and blocked outfall servicing the most impacted area near the intersection of Station 9 ½ and Osceola Avenue leading to extended flood durations well after the tide recedes.

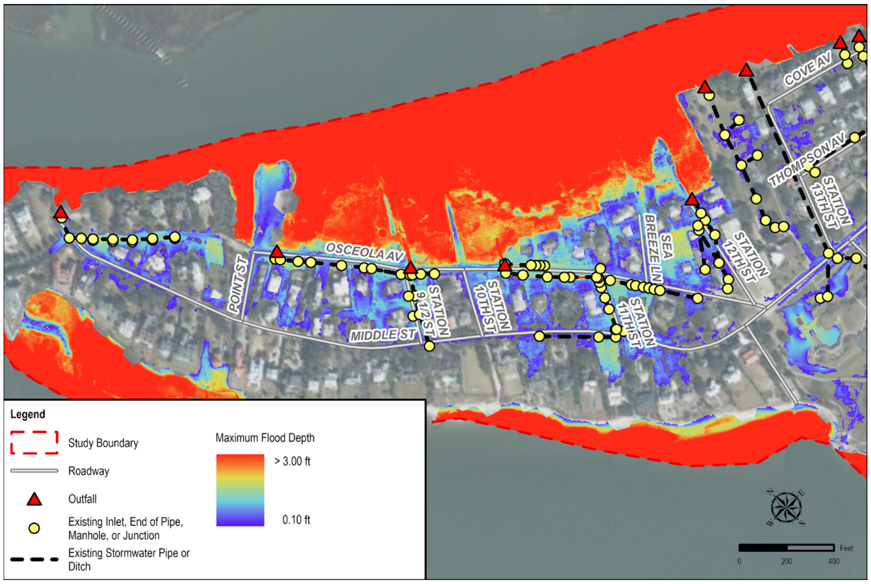
It was determined that due to the low elevations of this area (often lower than the future tides explored in this study) gravity stormwater systems would no longer be adequate to effectively service this area. Therefore, it was proposed that a new collection system should be installed which routes stormwater to a pump station at the end of Station 10 (discharging directly to marsh). This would allow this system to operate independently of the tide, creating a more reliant system for addressing rainfall-driven flooding. To reduce the risk of tidal-driven flooding, it was proposed that Osceola Avenue be raised to at least elevation 6 feet NAVD88. This will not mitigate all extreme tidal events but was selected as an adequate starting elevation for the roadway as this represents a nearly 18-inch increase over the existing roadway. In the future, it is recommended that this roadway (and all tidal perimeter protection) should be elevated to at least 7 feet NAVD88.

A comparison of the existing and proposed conditions flood analysis results for the future 1% AEP SC Long (11.44") storm event with a future typical tide (5.39 ft NAVD88) boundary condition (scenario 13; design scenario for improvements) can be seen in **Figure 10**.

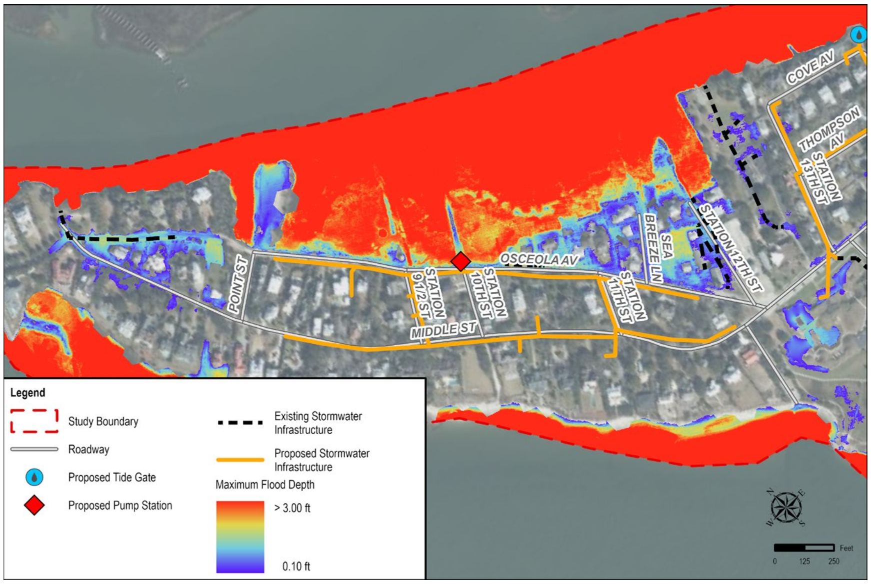
5.1.2 Station 22 ½

Station 22 ½ from approximately Middle Street through Atlantic Avenue (and along Ion Avenue) experiences severe and frequent rainfall-driven flooding leading to property damage and flooded roads within residential and commercial districts. It is hypothesized that a blockage or issue currently exists along the existing drainage line between Middle Street and Jasper Boulevard. While solving this issue may lead to reduced flood durations, it will not adequately mitigate flooding within this area. Therefore, it has been proposed that the existing collection system be substantially upgraded to accommodate larger flows along with the installation of a tidal backflow preventer and the outfall channel of this system being re-established to provide positive flow.

A comparison of the existing and proposed conditions flood analysis results for the future 1% AEP SC Long (11.44") storm event with a future typical tide (5.39 feet NAVD88) boundary condition (scenario 13; design scenario for improvements) can be seen in **Figure 11**.

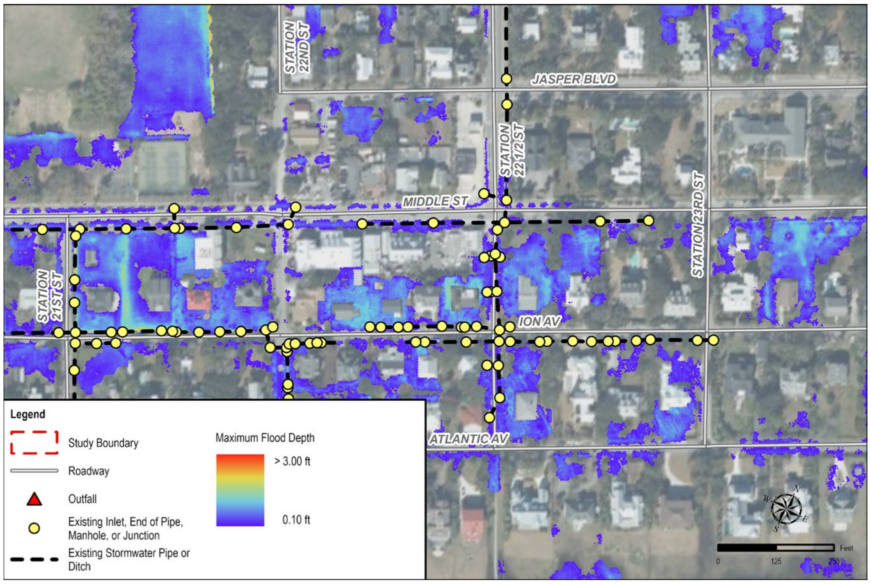


Existing Conditions

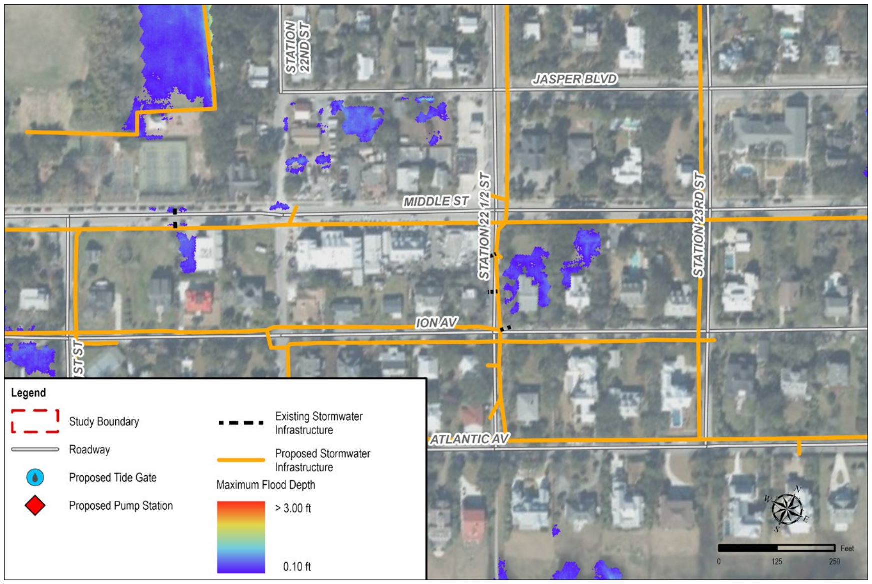


Proposed Conditions

Figure 10 - Existing and proposed flood results for the future 1% AEP SC Long (11.44") storm event with a future typical tide (5.39 feet NAVD88) boundary condition for the Osceola Avenue project area.



Existing Conditions



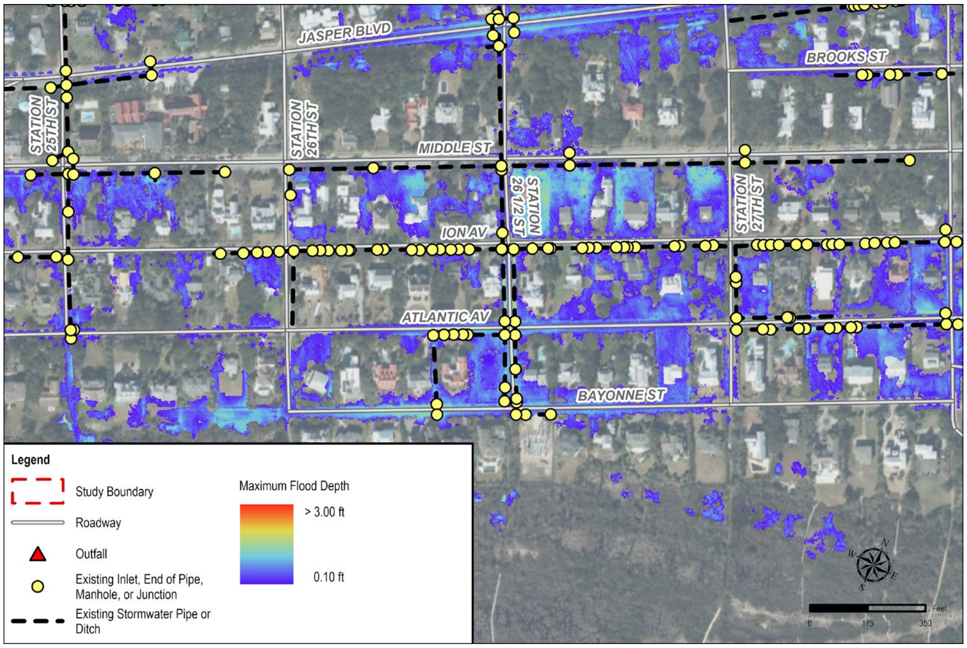
Proposed Conditions

Figure 11 - Existing and proposed flood results for the future 1% AEP SC Long (11.44") storm event with a future typical tide (5.39 feet NAVD88) boundary condition for the Station 22 ½ project area.

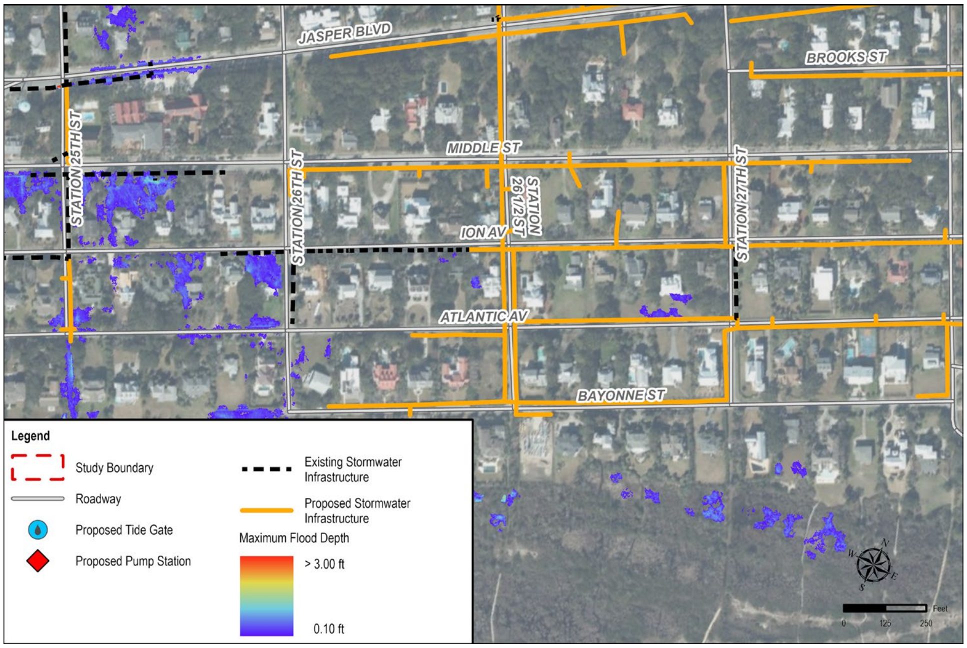
5.1.3 Station 26 ½

Bayonne Street (centered on Station 26 ½) experiences severe and frequent rainfall-driven flooding leading to severely flooded roads with evaporation as the only way to remove stormwater in some areas (leading to standing water remaining on the road for up to several weeks). Therefore, it has been proposed that the existing collection system be substantially upgraded to accommodate larger flows as well as significantly expanding the stormwater system along Bayonne Street and Atlantic Avenue. These improvements should occur alongside the installation of a tidal backflow preventer and the outfall channel of this system being re-established to provide positive flow.

A comparison of the existing and proposed conditions flood analysis results for the future 1% AEP SC Long (11.44”) storm event with a future typical tide (5.39 feet NAVD88) boundary condition (scenario 13; design scenario for improvements) can be seen in **Figure 12**.



Existing Conditions



Proposed Conditions

Figure 12 - Existing and proposed flood results for the future 1% AEP SC Long (11.44") storm event with a future typical tide (5.39 feet NAVD88) boundary condition for the Station 26 ½ project area.

5.2 Cost Estimates

A comprehensive cost estimate for each recommendation was prepared wherein improved drainage infrastructure components were quantified and unit costs assigned. Unit costs were based on recent construction projects and engineering judgement, considering inflation and current construction market conditions. Quantities included the length and size of upgraded pipe, new or replaced inlets, pump station quantities, and other associated construction costs (e.g., road milling, incidentals, utility relocation, etc.). In addition to construction costs, costs associated with engineering design, permitting, and construction administration (i.e., professional services) to estimate the total cost to implement each project. Professional services costs were estimated based on percentages of the total estimated construction costs.

Total project implementation costs included a 20- and 15-percent contingency for construction and professional services, respectively, since project costs were based on a conceptual design. Additionally, a 50-percent water/sewer allowance (based on construction costs sub-total) was included in the total cost for each project as a conservative contingency for sewer/water conflicts given that detailed utility data was not considered in this study.

It should be noted that all costs represent 2024 dollars and should be re-evaluated in the future as the town begins to plan for and implement projects (e.g., cost escalation). A detailed breakdown of the implementation cost of each proposed project, including engineering services, construction administration, and permitting costs can be found in **Appendix E** with a summary found in **Table 5**.

Table 5 – Estimated project implementation costs including engineering, construction administration, and permitting.

Proposed Improvements	Estimated Project Cost
Osceola Avenue	$9,802,000
Station 14	$2,588,000
Station 16 Extension	$1,663,000
Station 17	$2,337,000
Station 18	$4,095,000
Station 19	$1,608,000
Station 20 ½	$3,914,000
Station 20 ½ Extension	$3,121,000
Station 22 ½	$3,627,000
Station 22 ½ Extension	$1,877,000
Station 23	$3,153,000
Station 24	$3,802,000
Station 24 Extension	$1,462,000
Station 26 ½	$6,312,000
Station 26 ½ Extension	$7,054,000
Station 28 ½ Extension	$6,652,000
Station 30 Extension	$3,273,000
Station 31 Extension	$1,603,000

5.3 Environmental Compliance, Permitting, and Utility Coordination

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

- Numerous components of recommended improvements (where located near or adjacent to the roadway) will be located along primarily SCDOT-maintained roads. As a result, SCDOT encroachment permits will be required.

- Conflicts with existing utilities (e.g., water and sewer) are likely to occur as projects are implemented. Coordinating with the town's water and sewer department and Charleston Water System is encouraged early in the design process. Electric, communications, and other utility providers should be coordinated with as well during design.
- Application for Nationwide Permits (NWP) from the United States Army Corps of Engineers (USACE) is anticipated to be required on some projects which may impact aquatic environments within adjacent waterways.
- Critical are general permits will be required for any portion of these projects which occur within the tidelands critical area. Entities such as SCDES and USACE would be responsible for such permits, if required.
- Historical artifacts are possible to be unearthed during construction efforts. Coordination with local historic preservation groups will be critical if items of historical significance are discovered during design and/or construction.
- Environmental assessments, such as phase 1 assessment, and historical and cultural assessments may be required prior to construction depending on funding sources. As a result, permitting requirements specific funding source should be carefully evaluated.
- Stormwater permits and/or land disturbance permits will likely be required to complete construction of the proposed projects. Entities such as Charleston County and SCDES would be responsible for such permits, if required.

5.4 Multipurpose Solutions and Project Synergies for Impactful Community Benefits

Recommendations provided herein were aimed at providing the town with high-level flood mitigation projects. However, during detailed design, the town should consider dual purpose projects that can provide community benefits beyond just flood risk reduction such as opportunities to enhance pedestrian safety and mobility (i.e., sidewalks and pedestrian paths). Furthermore, any water and sewer line improvements needed within project areas should be considered as well since impacts to those systems will likely be unavoidable. All these aforementioned items can add significant community benefits which have constructions costs that may be inconsequential compared to the cost of drainage infrastructure but are impactful in enhancing the community. Therefore, the town should consider all indirect infrastructure projects and/or needs of the town in the planning and design of the recommended projects.

5.5 Funding Assessment

While the simplest and quickest method for funding design/construction of these projects would be to use local government funds, the scale of these projects may strain the town's budget. As a result, one consideration would be for the town to harness external funding through local partnerships to finance the proposed projects. For example, there may be opportunities for the town to partner with Charleston County and SCDOT to boost the town's financial capacity for stormwater capital improvement projects.

An alternative to using town funds or available funding from Charleston County or SCDOT would be sourcing grants or long-term low interest loans to finance projects. This approach would require the town to pursue state and federal funds to finance projects in their entirety or portions thereof. In particular, it may be required to source funds from multiple grants to complete a single project (e.g., break each project into smaller sections). However, regardless of the program, the town will still be required to provide some level of local funding to be eligible (typically 20 to 25 percent), excluding certain funds from principal forgiveness loans.

Of the numerous programs currently available, the Town of Sullivan's Island should consider the following programs to fund the recommended projects partially or entirely:

- Building Resilient Infrastructure and Communities (BRIC) – FEMA
    - Ability to apply annually
    - Public infrastructure
    - Max applicant cap of $50 million
    - 25% match requirement
    - Only available within seven years of federally declared disaster
- Hazard Mitigation Grant Program (HMGP) – FEMA
    - Can only apply following a federally declared disaster
    - Public infrastructure

    - No maximum award amount, but dependent on available funding
    - 25% match requirement
- National Coastal Resilience Fund – NFWF
    - Can apply annually
    - Will only fund coastal resilience projects
    - No maximum award limit
    - No match requirement, but match is highly encouraged
- Water & Waste Disposal Loan and Grant Program – USDA
    - Applications are accepted year round
    - Combined grant and long-term (40 year) low interest loan program
    - No funding cap
    - Population must be less than 10,000
- Water Resources Development Act – USACE
    - Can apply every two years contingent upon congressional authorization
    - Funds water resources and resiliency projects
    - 20% match requirement
- State and Tribal Assistance Grant – EPA
    - Can apply annually contingent upon congressional authorization
    - $3,000,000 to $5,000,000 typical award amount
    - 20% match requirement
    - Will fund all activities from design through construction
- Basic Infrastructure Grant – RIA
    - Can apply twice per year
    - Up to $1,000,000
    - 20% match requirement
    - Will only fund construction activities (no engineering or permitting)
    - Can only have one grant open at a time
- Infrastructure Investment Jobs Act (IIJA)
    - Application frequencies may depend on specific program requirements, but most accept applications on an annual basis
    - There are several new programs with funding coming soon that would be available including:
        - Healthy Streets Program
        - PROTECT
        - Infrastructure Resiliency and Sustainability Grant Program
        - Stormwater Control Infrastructure Grants

The aforementioned programs offer various levels of funding in the form of grants, low interest loans, or principal forgiveness loans. The Town of Sullivan's Island may be eligible to apply for funding through each of these programs which would fund flood mitigation projects. Each program has varying applicant requirements, but the Town of Sullivan's Island could be well suited for each. It is important to note that the list of programs mentioned herein does not cover all possible state and federal financing options but rather provides a few key programs that could be considered. Grant programs are continually evolving, and more new programs are always becoming available. As a result, it is important to continually evaluate and re-evaluate funding options prior to applying for any external funding.

5.5.1 Procurement of Federal/State Funding Consultant

It is recommended that the town consider procuring a federal and/or state funding consultant to help the town navigate these continually evolving grant programs and available funding. Procurement of an outside consultant to assist in these processes would provide the town with dedicated assistance needed to obtain funding through competitive grant programs as well as identify more obscure pathways for acquiring funding for project implementation.

6. Maintenance Considerations

To ensure that improvements recommended herein continue to provide adequate flood mitigation, continued maintenance of these systems is required. It is recommended that the town consider a minimum 10-year revolving maintenance schedule in which each drainage system component is inspected, cleaned, and repaired (as needed) once every 10 years at a minimum. If budget allows, it is highly recommended that this maintenance schedule be adjusted to a 5-year timeframe

To determine the estimated annual cost of these maintenance operations, recent contracted maintenance work (using a third-party contractor) was used to establish an average unit cost. This unit cost was determined to be approximately $45/LF of drainage system inspected and cleaned. This unit cost may be able to be significantly decreased if the town were to employ and operate their own maintenance crews. Currently, there are approximately 55,000 linear feet of stormwater pipes installed on Sullivan's Island. If all of the proposed improvements recommended herein are installed, that number increases to approximately 92,000 linear feet of stormwater pipes (due to many ditch systems being replaced with closed conduit systems). Assuming 3-percent annual inflation, the estimated annual cost for each scenario over time is explored in **Figure 13**.

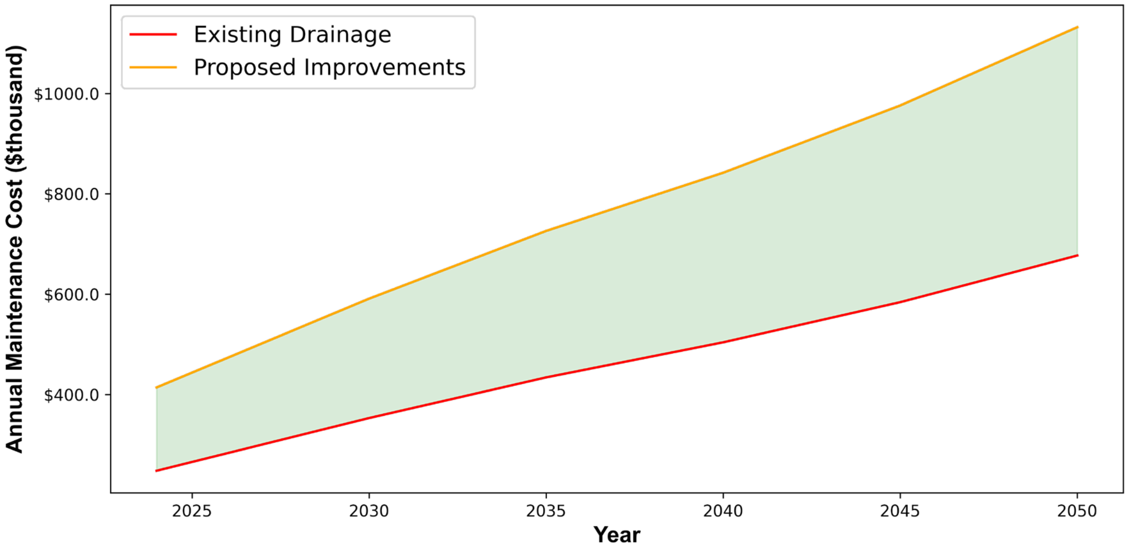


Figure 13 – Estimated annual maintenance costs over time comparing current conditions with a scenario where all recommended improvements have been implemented.

7. Resilience Strategies for Private Property Owners

While the objective of this study was to evaluate stormwater improvements that could be constructed within public rights-of-way, private property owners have the ability to implement smaller scale projects that can assist in bolstering their community's long-term coastal community resiliency.

7.1 Incentivizing Private GI/LID Stormwater Systems

Property owners can help overall water management through the implementation of green infrastructure (GI) or low-impact development (LID) systems to intercept and treat stormwater generated on their property. Widespread adoption of these practices can help alleviate the volume of stormwater that the town's drainage system needs to handle during storm events, increasing the performance of the connective drainage system (especially in areas where proposed improvements have yet to be implemented). Examples of these GI/LID strategies include rain gardens, bioswales, living shorelines (marsh-front properties only), replacing lawn with native plantings, rain barrels/cisterns, and increasing tree canopy.

The Town of Sullivan's Island can encourage property owners to install and maintain these systems through tax credits, water and utility rebates, group purchasing, or other incentives. Additionally, educational programs and pilot projects aimed at empowering residents with the knowledge and resources to properly implement/maintain these systems should also be developed.

7.2 Private Perimeter Protection

Many properties lack appropriate protection from tidal-driven flooding (primarily marsh-front properties) which will only become exacerbated by the impacts of sea level rise. The town should encourage and allow property owners to fill or protect their property against an appropriate tidal mitigation target. For example, the neighboring community of the City of Isle of Palms is considering a sea level rise mitigation target of 7 feet NAVD88, which should statistically provide protection for 99.5% of all tidal events experienced in the year 2050 excluding hurricanes and/or tropical storm events (City of Isle of Palms Sea Level Rise Adaptation Plan, 2024). Strategies that should be encouraged to provide this protection include living shorelines (to provide erosional control along the marsh), constructing vegetated berms (outside of the critical area), and filling low-lying lots (with careful consideration to the stormwater impacts to adjacent properties). It is not recommended that bulkheads or revetments be considered as perimeter protection along marsh-front properties as they have been observed to cause long-term erosion and degradation of the marsh ecosystem.

8. Summary and Conclusions

A comprehensive hydrologic and hydraulic analysis was performed to holistically analyze the drainage infrastructure currently servicing the Town of Sullivan's Island and develop an island-wide comprehensive strategy to address flooding experienced today while also preparing for tomorrow's changing coastal environment. The purpose of this report is to detail the methodology and results of this Island-Wide Stormwater Master Plan and Infrastructure Improvement Strategy.

A hydrologic and hydraulic model of the study area was constructed to evaluate the performance of the existing drainage network. First, the results of the existing conditions survey and field inventory were used to determine the location and properties (i.e., size, invert elevation, etc.) of the existing drainage network. Then, a comprehensive hydrologic assessment was performed to delineate watershed boundaries and hydrologic properties required to estimate rainfall-runoff processes. The resulting watersheds and existing drainage network were then used to create a combined 1D/2D hydraulic model which quantifies not only drainage system deficiencies (1D) but also the extent, depth, and duration (2D) of flooding.

Using this existing conditions model, the study area's response to diverse rainfall and tidal conditions were investigated. These results provided a benchmark for investigating the impact of the proposed improvements and alternatives investigated as part of this analysis.

Alternatives to existing drainage infrastructure that may mitigate observed flooding were investigated using results from the existing conditions analysis. This was an iterative process in which the existing drainage infrastructure was improved/altered to explore how those changes may impact flooding within areas of concern. These improvements generally consisted of upgrading existing drainage infrastructure (e.g., upsizing pipes to a larger diameter), installation of new drainage infrastructure (e.g., new inlets or closed piping systems, etc.), raising roadways for perimeter tidal protection, and leveraging pump stations for flood control. It is important to note that this study focused on examining improvements that could be constructed within public rights-of-way outside of private property. Once it was determined that these improvements could potentially mitigate flooding, these infrastructure improvements were integrated into a proposed conditions model and analyzed using the same scenarios as the existing conditions analysis.

Overall, 18 projects were recommended (including estimates of project implementation cost) to holistically mitigate flooding within the Town of Sullivan's Island. These projects were typically divided into two categories: 1) major drainage improvements along the main trunk line of existing systems (outfall to high-risk areas) and 2) future lateral improvements to increase the service area of drainage systems. While all projects developed as a part of this plan should be implemented to improve the town's long-term coastal resiliency, three projects were identified as high priority that should be implemented as immediately as possible: Osceola Avenue, Station 22 ½, and Station 26 ½. Each of these areas experience severe systemic flooding that will only become exacerbated in the future if not addressed.

9. References

Asquith, W. H., Roussel, M. C., Thompson, D. B., Cleveland, T. G., & Fang, X. 2005. Summary of dimensionless Texas hyetographs and distribution of storm depth developed for Texas Department of Transportation research project 0-4194.

Chow, V.T. 1959. *Open-channel hydraulics*. New York, New York: McGraw-Hill Book Co.

City of Isle of Palms. 2024. Sea Level Rise Adaptation Plan.

Huff, F. A. 1967. Time distribution of rainfall in heavy storms. Water Resources Research, 3(4), 1007-1019.

Huffman, Rodney L., Delmar D. Fangmeier, William J. Elliot, and Stephen R. Workman. 2013. *Soil and Water Conservation Engineering.* 7th. St. Joseph, Michigan: American Society of Agricultural and Biological Engineers.

Jung, Younghun, Venkatesh Merwade, Kyudong Yeo, Yongchul Shin, & Seung Oh Lee. 2013. "An Approach Using a 1D Hydraulic Model, Landsat Imaging and Generalized Likelihood Uncertainty Estimation for an Approximation of Flood Discharge." *Water* 5 (4): 1598-1621. doi:10.3390/w5041598.

National Resource Conservation Service. 2008. *National Engineering Handbook: Part 630 – Hydrology*. Washington, DC: USDA Natural Resources Conservation Service.

Ohenhen, L. O., Shirzaei, M., & Barnard, P. L. 2024. Slowly but surely: Exposure of communities and infrastructure to subsidence on the US east coast. PNAS nexus, 3(1).

Powell, D. N., Khan, A. A., Aziz, N. M., & Raiford, J. P. 2007. Dimensionless Rainfall Patterns for South Carolina. Journal of Hydrologic Engineering, 12(1), 130–133.