DRAFT

Hazard Mitigation Drainage Study
SCEMD Hazard Mitigation
City of Hartsville, SC

Prepared for:

City of Hartsville
100 East Carolina Avenue
Hartsville, South Carolina 29550



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SECTION 1. INTRODUCTION

Background

As part of the FEMA Hazard Mitigation Grant Program, the City of Hartsville was awarded a grant that included some local funds and administered through the SC Emergency Management Division. The City of Hartsville requested proposals to provide consulting engineering services to develop drainage designs for localized flooding reductions at three areas within the City as required by the grant. The requested services are listed below in order of sequential project task.

- surveying
- hydrology & hydraulics studies
- feasibility analysis
- engineering design (if projects are feasible) and
- permitting

The funding for these projects is provided through the FEMA Hazard Mitigation Grant Program with local funds through the SC Emergency Management Division and the City of Hartsville. At the end of the project, FEMA WILL review the drainage report and plans to determine if the benefits outweigh the cost. A benefit-cost analysis was the vehicle to determine the feasibility of the projects. The completed project must be technically feasible, cost effective and Emergency Hazard Plan (EHP) compliant prior to initiating Phase II construction.

FEMA Flood Mitigation Assistance (FMA) Program

The FMA program is authorized by Section 1366 of the National Flood Insurance Act of 1968, as amended with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FMA provides funding to states, territories, federally recognized tribes and local communities for projects and planning that reduces or eliminates long-term risk of flood damage to structures insured under the NFIP. FMA funding is also available for management costs. Funding is appropriated by Congress annually.

FEMA requires state, tribal, and local governments to develop and adopt hazard mitigation plans as a condition for receiving certain types of non-emergency disaster assistance, including funding for HMA mitigation projects.

Climate Change and Resiliency

FEMA recognizes challenges posed by climate change, including more intense storms, frequent heavy precipitation, heat waves, drought, extreme flooding, and higher sea levels. These phenomena may have impacts on mitigation, preparedness, response, and recovery operations as well as the resiliency of critical infrastructure and various emergency assets. FEMA encourages Recipients and subrecipients to consider climate change adaptation and resiliency in their planning and scoping efforts. To aid in these efforts, FEMA incorporated sea level rise into the HMA Benefit-Cost Analysis (BCA) tool.

Additionally, the EHP review process promotes informed decision-making and uses all practical means and measures to protect, restore, and enhance the quality of the environment, to avoid or minimize adverse impacts to the environment, and to attain the objectives of:

- Achieving mitigation goals without degradation or undesirable and unintended consequences
- Preserving historic, cultural, and natural aspects of national heritage and maintaining, wherever possible, an environment that supports diversity and variety of individual choice
- Achieving a balance between resource use and development within the sustained carrying capacity of the ecosystem involved and
- Enhancing the quality of renewable resources and working toward the maximum attainable recycling of non-renewable resources.

City officials have long recognized that the main ingredient in a successful storm water management program is the development of a stormwater (drainage) master plan (SWMP). The stormwater master plan incorporates the design of a comprehensive, system-wide, proactive plan that addresses the needs for a municipality. A systematic method for implementing the necessary improvements is also required to ensure the funds are expended in the most cost-effective way. The term *proactive* in the above definition means developing a drainage design prior to major development within a watershed. The stormwater utility that was created several years ago will provide a method to fund the requirements of the Municipal Separate Stormwater System program and other necessary improvements to the current drainage system.

The development of a SWMP provides a technically defensible method for prioritizing the needed improvements and allocating costs. While this project does not address a SWMP, it can be the first step in developing an overall SWMP for the City which is outside of the scope of this project.

The watershed is located within the Piedmont physiographic province and is characterized by a wide range of elevations and soil types. Approximately 35 percent of the State's land area is in the Piedmont Province. Figure 1 shows the location of the study area and the Drainage systems watershed.

Problem Identification

Increased development over many years has produced increased runoff within the city limits. Drainage ditches that were originally created for agricultural irrigation and to collect runoff are now some of the major conveyance systems in the City. The systems over time have been ignored and not properly maintained.

The City, along with the South Carolina Department of Transportation (SCDOT), owns, operates and maintains a stormwater conveyance system within its municipal boundary. Runoff is collected and conveyed untreated to major outfalls through a typical system of catch basins, pipes and open channels/ditches. The Ninth Street Ditch, probably the most prominent component of the City's stormwater system, conveys excess runoff ultimately to Prestwood Lake. The other major systems include the Marion Street Ditch and the Fourth Avenue Ditch.

These drainage ditches were originally irrigation systems for low-lying agricultural fields. However, as the City developed and transitioned from agricultural to dense urban uses, the City no longer relied on agricultural lands and the irrigation system was rendered obsolete; however, the Ninth Street ditch was re-purposed and used for stormwater management.

Generally, the drainage systems have very slight slopes that create sediment deposition and clogging. The slopes do not have velocities that help scour the sediment and debris from the system. The following descriptions and basin parameters for each drainage area provides some insight for remedial measures to alleviate flooding. Figure 1, shown below, is taken from the Grant Application.

After field reconnaissance and field surveying was completed, it was confirmed that the overall drainage system did not have adequate slopes in the ditches and pipes to provide for the free flowing of stormwater during even the smaller storm events.

Figure 1. Location Map of Study of the Major Drainage Systems in Hartsville

SECTION 2. EXISTING CONDITIONS

MARION AVENUE DRAINAGE SYSTEM

The drainage area general boundaries for the Marion Avenue system are just below Russell Road to the south, above Marion Avenue to the north, South Eight Street to the east and South Sixth Street to the east where it flows into the 36-inch RCP along the railroad tracks. This drainage system connects to the Fourth Avenue drainage system via a 1925-ft long 36-inch and 48-inch culvert from 6th Street to and Fourth Street and follows on the south side of the CSX railroad. The system, both pipes and channels, has slopes that are not sufficiently steep enough to clean the sediment debris during storm events. The pipes and channels fill with stormwater before any significant flow is realized. This creates a "head" driven condition that is not efficient in conveying flow downstream.

Existing Drainage Patterns

The lack of existing construction drawings made it difficult for the surveying effort to determine system connectivity. This system begins below Russell Road and flows in a northerly direction to intersect the ditch just above Washington Street. The figure below shows the major connections of Marion Avenue drainage system. The blue lines represent the natural or man-made channels, and the red lines show the piping systems. Butler Street, while not part of the proposed improvements from the grant application, was surveyed and showed many catch basins filled with sediment.

Figure 2. Marion Avenue Drainage System (Showing major conveyances) – no scale

Most of the drainage system is clogged with debris that fills the channels after heavy rainfall. This in turn flows into the culverts and can clog the system and back up water in the streets and residents' property.

Photo 1 shows the major drainage system at Lincoln Avenue – looking upstream. Much debris can be seen within the diches after heavy rainfall that can cause blockages within the cross culverts. The open channel needs to be replaced with a piped system to increase capacity via reduced roughness. Also, stormwater filled channels presents a health hazard allowing mosquitos and other insects a place to breed and is could be toxic.

Photo 2 – Lincoln Avenue – looking downstream. Notice the proximity of the channel to the homes. This segment should have channel replaced with concrete pipe to increase capacity and reduce litter from entering the drainage system.

Photo 3 – Ditch just upstream of the railroad and downstream from Lincoln Avenue. This segment is also close to homes and should have channel replaced by a piped system to prevent exposure to litter and debris.

Photo 4 – Channel downstream of railroad looking east to 6th Street. The 36-inch culvert at this location flows into a 36-inch culvert just upstream of 6th Street that have a higher invert elevation. The culvert was half full of stones and dirt when surveyed. This probably causes flooding along this area.

Photo 5 – Tuskegee Street – Ditch draining to outlet toward Fifth Street that is not well defined and is filled with trash/debris. This ditch enters the outlet culvert that flows toward Fifth Street. See next figure.

Photo 6 – Tuskegee Street – looking east. This is culvert junction that drains the Tuskegee Street area and Campbell Street collector.

Photo 7 – Tuskegee Street – Ditch receiving stormwater from Campbell Street Collector. cross culvert in previous photo - flowing west toward Hampton Street. Note the debris filled channel.

Photo 8 – Ditch looking from Hampton Street toward Tuskegee. This segment also should have channel enclosed to prevent exposure to litter and children.

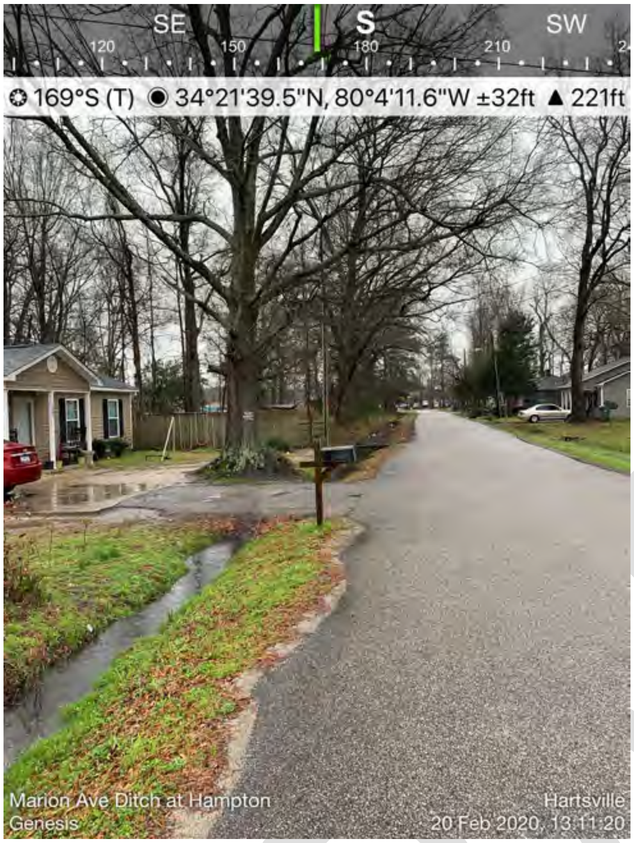


Photo 9 – Hampton Street – Roadside ditch looking south, downstream.

Photo 10 - Butler Street at Lincoln Street looking north. Catch basin in foreground fill with sediment. This is typical throughout the problem areas.

FOURTH STREET DRAINAGE SYSTEM

The Fourth Street drainage system also the ultimate outlet for the Marion Avenue System and connects via a 36-inch pipe that joins a 48-inch pipes under 6th Street to Fourth Street and runs parallel to the rail line. A network of pipes, inlets and ditches collect the stormwater runoff and discharge into Snake Branch.

Existing Drainage Patterns

The drainage system is composed of apparent manmade channels that flow into Snake Branch that have considerable sediment and debris in the system that contributes to the system backup and creating shallow flooding along roadways and channels. There are many connects that do not create a positive slope and create sump locations within the pipe system that clogs.

Fourth Street – The area around the Post Office has frequent shallow flooding that produces hazard conditions for vehicles traveling on Fourth Street and surrounding areas. This area drains into Swift Creek Road ditch.

Jordan Street – The main drainage line along Jordan Street has a large box culvert that can carry a significant amount of stormwater. This system discharges into the channel at Emmary Street that enters Snake Branch below Railroad Avenue.

Figure 3. Eastern segment of drainage system for Snake Branch Outfall (no scale)

Photo 11 - The Swift Creek Road Ditch at Fourth Street. The ditch has major constrictions and vegetation that reduces the capacity to drainage the system inflow. The channel, that drains the southern section of the Fourth Street drainage system, has many constrictions and inverted slopes that back up the drainage system. This segment is located on the north side of Swift Creek Road. It runs parallel to Swift Creek Road and connects to Snake Branch near the southern end of Easy Street

Photo 12 – Constriction in Swift Cr Rd Ditch. This location has a 169-ft long 36-inch RCP that is inverted (flows uphill) and represents a major drainage constriction from Fourth Street to Snake Branch near Dove Street. The culvert is partially filled with sediment and debris. The removal of this constriction and trees will greatly improve the upstream flooding along Fourth

Photo 13 - Constriction 300’downstream of Fourth Street in Swift Cr Rd Ditch. This channel has numerous vegetative constriction locations that reduce capacity and creates backwater conditions.

Photo 14 – Tree and vegetative constriction location that reduce capacity and creates backwater. This backs up the system and creates shallow flooding.

Photo 15 – Railroad Avenue bridge over Snake Branch looking at upstream side.

Photo 16 - Triple culverts under the CSX railroad embankment just downstream of the Railroad Avenue bridge. The culverts consist of 2 – 48-in RCPs and 1 – 72-in CMP. The culverts project outward from the embankment and are not aligned with the channel. This is considered an inefficient entrance condition and creates significant headloss through the culverts.

Photo 17 – Stream segment downstream of CSX railroad embankment on Snake Branch. Cleaning should improve conveyance of stormwater.

NINTH STREET DRAINAGE SYSTEM

The Ninth Street drainage system consist of a large, main ditch/channel that has been upgraded and deepened over time.   Several smaller ditches and drainage pipes discharge into the ditch from surrounding neighborhoods. Many of those piped systems are clogged and filled with sediment and trash and other debris that backs up the system. The main component is the very deep ditch (10+ feet) that collects lateral connections from the Richardson Circle area and roads.

The Ninth Street ditch collects runoff from the western side of Hartsville, generally between West Washington Street, Marlboro Avenue, South 10th Street and South 8th Street. The Marlboro Avenue area of 224 acres is drained, and at Washington Street upstream, 70 acres. The basin terrain is of low relief, with extremely gentle slopes and natural depressions (Carolina Bays) without natural outlets. The basin is generally developed with residential lots except for the upper basin near Washington Street, where about 20 acres remain wooded or cultivated cropland.

Figure 4. Ninth St Ditch Drainage System (no scale)

EXISTING DRAINAGE PATTERNS

Along Ninth Street, an excavated channel carries the primary flow. In the downstream segment, near Richardson Circle, flooding is controlled by a 54-inch culvert at Marlboro Avenue. This culvert is not capable of carrying the entire peak flood discharge, even with a ten-year flood. This creates backwater ponding in low lying areas near Richardson Circle and Village Street.

Richardson Circle - Backwater from the Ninth Street ditch spreads into lower lying areas which are only a few feet above ditch level. A system of inlets and pipes can drain the area during minor storms, but with high flood levels in the Ninth Street ditch, runoff has nowhere to go and ponds along the street during more extreme flooding events. Several residential lots may also be flooded.

Bell, Brewer. Logan, James, Jasper, Sumter Streets and Marion Avenue - This area is higher than the Ninth Street ditch level, and not as likely to be impacted by ditch flood levels. Instead, flooding is due to flat slopes and few outlets. The low relief results in street and yard flooding, as runoff either slowly drains to inlets or infiltrates. A system is proposed for each street, with multiple inlets, and an outlet to the Ninth Street ditch.

Marion Avenue and Village Street - In this area, flooding is aggravated by the berm along the ditch and low-lying areas. Drainage from about 30 acres is carried by a lateral ditch to a pipe through the berm. Much of Village Street is in a depression with no outlet.

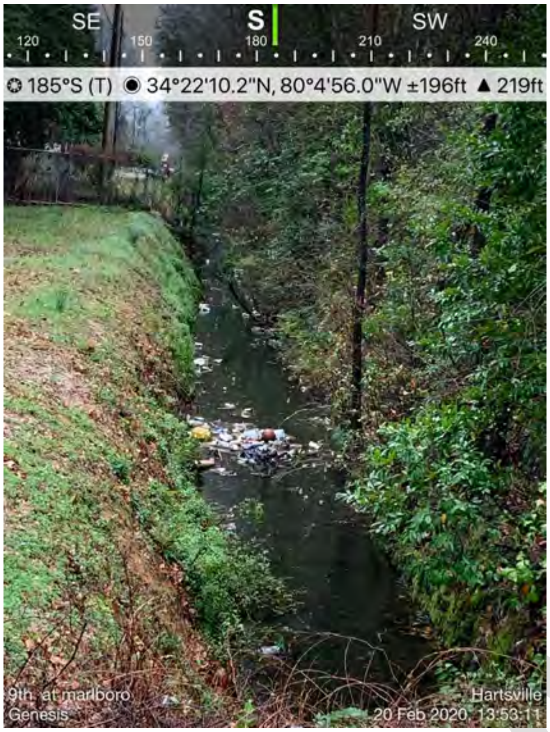


Photo 18 - Ninth Street Ditch at Marlboro Ave – looking south. Note trash and debris.

Photo 19 - James Street at Ninth Street looking eastward. Jasper, James, Logan Sumter and Bell Avenues are relatively flat and drain poorly.

Photo 20 - Ninth Street Ditch at Marlboro Avenue – looking downstream.

Photo 21 - Ninth Street Ditch at Marlboro Avenue and Ninth Street (shown on the left). Looking downstream). Thornwell School of the Arts is located on the right.

Photo 22 - Ninth Street Ditch at Marlboro Avenue and Ninth Street. Looking upstream. Thornwell School of the Arts is located on the left.

Photo 23 – Eighth Street at Bell Street, looking south – Flooding across road

Photo 24 – James Street – Rear yard flooding toward street. This is typical for this area. There is mostly shallow sheet, nuisance flooding.

SECTION 3. PROJECT APPROACH

The City of Hartsville requested consulting engineering services to develop drainage studies for three basins. The services were requested as part of a FEMA grant with the basic objectives to identify and evaluate the existing drainage systems and develop alternatives to relieve the shallow flooding.

The initial data collection and evaluation efforts for this project consisted of data collection and documentation of the existing stormwater system and flooding problems in each area. The City's Stormwater Management Plan and Ordinance were reviewed prior to the start of the project. There will be no oversight by the SCDOT based on correspondence with them phone conversations and email. The SCDOT considers these improvements as maintenance actions and no specific design criteria must be followed.

STAKEHOLDER MEETING/PUBLIC PARTICIPATION AND COORDINATION

Stakeholder meetings with the public could not be effectively conducted due to the coronavirus (COVID-19) pandemic. While gathering data from residents is an important effort that needs to occur early on, face-to-face meetings could not be accomplished. As an alternative, a survey/questionnaire was developed to gather information from residents concerning flooding in the entire City, not only the three study areas. A mailout questionnaire, in addition to the development of an interactive webpage was developed. The questionnaire was sent out with the general results. The questionnaire is shown in the Appendix E. The full report is available at the City of Hartsville.

The results are as follows:

- 4,075 questionnaires were sent via water bills to subject properties
- Online web-based responses and paper questionnaires were completed and returned
- Nine questions concerning flooding, type of flooding, frequency, inquiries about documentation they might have, and some types of remediation
- 199 completed questionnaires – 4.9%
- Accepted confidence rate is 5% but were hoping for 10%

The results showed that nearly half of responders said they were affected by flooding.

- 49% answered yes that they affected by flooding
- *Of those who said yes – 85% experienced 3 or more floods per year*
- Those who owned their own homes were more concerned

  - 68% were either moderately or greatly concerned

  - Homeownership for respondents was high – 82%
- If you ever got flooded, it greatly concerned you

  - 92% who reported flooding indicated concern about getting flooded again

- 65 Respondents indicated they knew of "choke points" and 35 had photos they could share
- 45% of the respondents were over 65 years of age
- Response to rain barrels was lukewarm while grass and vegetation was more popular – about ½ would like more information on individual solutions
- About half would attend an informational meeting

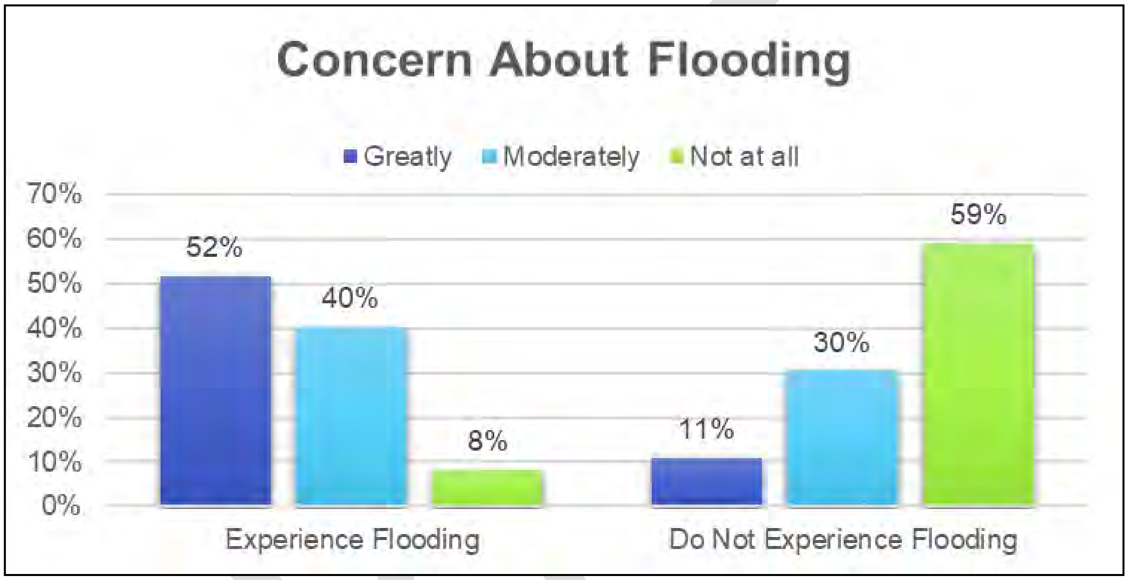


Figure 5. Graph Showing Citizens Concerned about Flooding

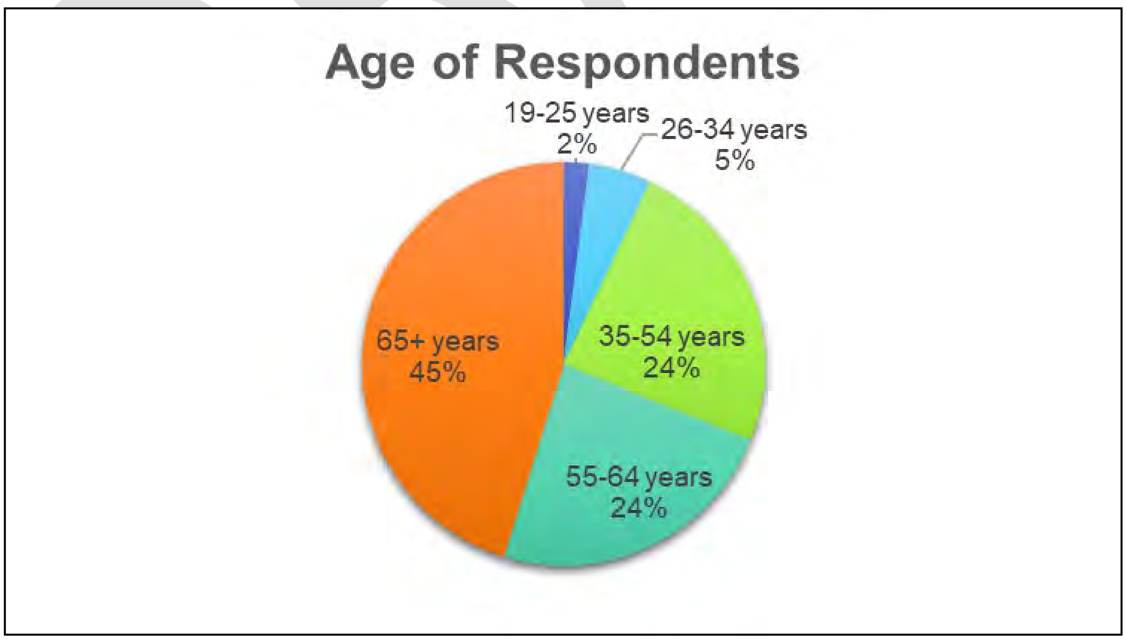


Figure 6. Graph Showing Age of Respondents

DATA COLLECTION & FIELD SURVEYS

Data Collection

This phase of the project involved identifying and collecting all available data that is pertinent to the investigation effort. Sources included:

- County mapping – from GIS
- Project-specific studies
- Previously published reports by
  - USGS
  - FEMA
  - Natural Resources Conservation Service (NRCS)
  - SCDHEC
  - City of Hartsville
- Historical Flood Records from
  - City of Hartsville
  - Newspaper Accounts
  - Maintenance Records
  - USGS Flood Event Reports
- Construction Drawings (if available) from
  - City of Hartsville
  - South Carolina DOT
- Ordinances and Regulations
- Physical observations

In addition to obtaining copies of previous studies performed, the E. L. Robinson team obtained copies of computer data files and other information used to prepare the studies. These files were used to the maximum extent possible during subsequent phases of the project. For example, the USGS regional flood frequency equations were used to calibrate the hydrologic models where the drainage area parameters were similar. Additionally, construction drawings from the SCDOT were used to supplement the data obtained during the drainage structure inventory and surveying process. However, the SCDOT drawings did not show enough of the drainage systems to be of significant value.

One primary objective for the Phase I tasks was to identify/verify/quantify the exact number and location of the problem areas as identified in the areas outlined in the FEMA Grant application. The survey/questionnaire, previously mentioned, provided a way for residents to describe flooding and clogged drainageways in the City. Any adverse conditions discovered that will require immediate attention for water quality control purposes will be identified and reported.

Field Reconnaissance

Additional field data will be obtained for the watershed at each problem area location to the extent necessary to obtain useable data for modeling. The extent of this effort will ultimately depend on the quantity and quality of the information obtained during data collection. Information gathered during the drainage structure inventory can be transferred to a data base for future use.

Field Survey

Developing a drainage structure inventory database is essential for the areas affecting the local problem areas. The survey crews collected the necessary data to be used in the hydraulic model. As previously noted, much of the drainage inlets and pipes were filled with sediment and presented.

The types of hydraulic structures that were surveyed included:

- Catch basins, drop inlets and pipes
- Cross culverts and other secondary culverts
- Paved ditches and channels
- Improved or constructed channels

The E. L. Robinson team's survey crews surveyed cross sectional areas for the channel sections only. Information on the overbank areas obtained from the State LiDAR mapping at 1-ft contour intervals.

HYDROLOGIC & HYDRAULIC ANALYSES

The USEPA-based Storm Water Management Model, SWMM, XP-STORM, was used in the modeling effort for both hydrology and hydraulics for the Marion Avenue and Fourth Street drainage systems. The Ninth Street Ditch system was modeled using the SEDCAD software because of the lateral street drainage from the eastern side and a simplistic system that did not have apparent flow reversals.

The XP software provides a fast solution for analyzing the design of the most complex hydraulic networks, including loops, hydraulic structures, regulators, multiple time varying boundary conditions, and distributed storage structures, using database connections to quickly exchange data to/from any existing hydraulic model, asset management database, or GIS. This model is appropriate to use in areas where conveyance systems have slight slopes that could result flow reversals.

SWMM is a comprehensive software package for modeling storm water, water quality, and river systems. EPA SWMM is used to develop link-node and spatially distributed two-dimensional hydraulic models by simulating natural rainfall-runoff processes. The model can represent drainage systems, including ponds, rivers, lakes, floodplains, and the interaction with groundwater, can be modeled. Using its intelligent connectivity and data checking, elements and parameters in the watershed can be identified, such as conduit lengths, slopes, sub-catchment areas, etc.

XP-STORM is a dynamic unsteady flow model and allows the effects of storage and backwater in conduits and floodplains and the timing of the hydrographs to yield a true representation of the HGL at any point in space and time. It can simulate the complete hydrologic cycle in rural and urban watersheds and use multiple rainfall events in one simulation. XP-STORM can model flows through collection, conveyance, and treatment systems to the final outfalls.

Flow Patterns and Condition of the Drainage System

Flow patterns for the drainage system was determined by field surveys, visual observations during storm events, and other existing drainage mapping. The Fourth Avenue drainage system and the Marion Avenue drainage systems connect via a long 36-inch RCP and a connecting 48-inch RCP that cross under South 5^{th} Avenue. Many flow patterns that were shown in the draft report of Hartsville Stormwater System Map Book were incorrect and others were confirmed by field reconnaissance and surveys.

One of the City's concern was that any improvements could increase flooding downstream. To address this concern, stormwater detention areas were designed that reduced the increase in flow that resulted in opening the drainage ways and culverts/pipes. As the design progressed, the approach taken in the overall design concept was to capture stormwater and detain it as not to increase the flow and elevation downstream. The design included ditch and pipe cleaning, in addition to new inlets and upsizing many of pipes. This could allow more capture of stormwater volume without an increase in downstream peak flows.

Hydrologic Analyses

Based on the field reconnaissance, LiDAR, field surveys and the drainage system mapping by others, drainage basin areas were delineated to show the area draining to selected locations. The TR-55 method was employed using the parametric determinations for curve numbers, time of concentrations, slope and stream segment length. Sub-basin parameters developed from these mapping sources were confirmed or changed during the field reconnaissance and survey tasks. The delineation of each subbasin was required prior to developing the hydrologic data. Subsequent efforts for basin parameter collection included determination of land use, impervious area, and soil types, soil surveys, and other sources. To establish a basis for comparison for the existing and proposed models, the SCS Type II rainfall distribution was used as the design storm for study.

The 2-, 10-, 25-, 50- and 100-year storm events were evaluated. The Type II distribution represents a 24-hour storm with an intense, short-duration peak typical of a thunderstorm. The SWMM/XP-STORM model computed rainfall losses, including infiltration using the SCS Curve Number Method to generate runoff hydrographs. These are the same accepted methods as used in the SCS TR-55 manual. Figure 5 below shows the rainfall frequencies values from NOAA Atlas 14 for Hartsville.

NOAA Atlas 14, Volume 2, Version 3
Location name: Hartsville, South Carolina, USA*
Latitude: 34.3692°, Longitude: -80.0705°
Elevation: 215.06 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

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

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

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

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.432 (0.398-0.469)	0.504 (0.464-0.546)	0.583 (0.535-0.632)	0.652 (0.598-0.706)	0.731 (0.668-0.790)	0.794 (0.723-0.858)	0.853 (0.772-0.921)	0.910 (0.819-0.983)	0.979 (0.874-1.06)	1.04 (0.919-1.13)
10-min	0.689 (0.636-0.748)	0.806 (0.742-0.874)	0.934 (0.858-1.01)	1.04 (0.957-1.13)	1.17 (1.07-1.26)	1.26 (1.15-1.37)	1.36 (1.23-1.46)	1.44 (1.30-1.56)	1.55 (1.38-1.68)	1.64 (1.45-1.77)
15-min	0.862 (0.794-0.935)	1.01 (0.932-1.10)	1.18 (1.09-1.28)	1.32 (1.21-1.43)	1.48 (1.35-1.60)	1.60 (1.46-1.73)	1.71 (1.55-1.85)	1.82 (1.64-1.97)	1.95 (1.74-2.11)	2.05 (1.82-2.23)
30-min	1.18 (1.09-1.28)	1.40 (1.29-1.52)	1.68 (1.54-1.82)	1.91 (1.75-2.07)	2.19 (2.00-2.36)	2.41 (2.19-2.61)	2.63 (2.38-2.83)	2.83 (2.55-3.06)	3.10 (2.77-3.36)	3.32 (2.94-3.60)
60-min	1.47 (1.36-1.60)	1.76 (1.62-1.90)	2.15 (1.98-2.33)	2.49 (2.28-2.69)	2.91 (2.66-3.15)	3.27 (2.97-3.53)	3.62 (3.27-3.90)	3.97 (3.58-4.29)	4.45 (3.97-4.82)	4.85 (4.30-5.26)
2-hr	1.67 (1.54-1.82)	2.00 (1.84-2.18)	2.48 (2.28-2.70)	2.91 (2.66-3.16)	3.46 (3.16-3.75)	3.93 (3.57-4.26)	4.41 (3.98-4.77)	4.91 (4.40-5.31)	5.58 (4.95-6.04)	6.16 (5.41-6.68)
3-hr	1.76 (1.61-1.94)	2.11 (1.93-2.32)	2.63 (2.40-2.88)	3.10 (2.83-3.40)	3.73 (3.38-4.08)	4.28 (3.86-4.67)	4.85 (4.34-5.28)	5.46 (4.84-5.94)	6.31 (5.53-6.88)	7.06 (6.12-7.70)
6-hr	2.10 (1.92-2.32)	2.51 (2.30-2.77)	3.13 (2.86-3.44)	3.69 (3.36-4.06)	4.46 (4.03-4.89)	5.13 (4.61-5.61)	5.84 (5.20-6.37)	6.59 (5.82-7.18)	7.66 (6.68-8.35)	8.60 (7.41-9.39)
12-hr	2.46 (2.25-2.72)	2.95 (2.69-3.26)	3.68 (3.35-4.06)	4.37 (3.97-4.81)	5.31 (4.80-5.83)	6.15 (5.51-6.73)	7.04 (6.25-7.69)	8.00 (7.03-8.74)	9.38 (8.11-10.2)	10.6 (9.05-11.6)
24-hr	2.93 (2.71-3.18)	3.53 (3.27-3.83)	4.49 (4.16-4.88)	5.35 (4.93-5.81)	6.67 (6.09-7.25)	7.84 (7.10-8.53)	9.17 (8.19-10.0)	10.7 (9.41-11.7)	13.0 (11.2-14.4)	15.1 (12.8-16.8)
2-day	3.42 (3.19-3.72)	4.11 (3.83-4.47)	5.21 (4.84-5.67)	6.19 (5.72-6.72)	7.69 (7.04-8.36)	9.02 (8.18-9.84)	10.5 (9.43-11.5)	12.3 (10.8-13.5)	14.9 (12.8-16.6)	17.3 (14.6-19.5)
3-day	3.65 (3.41-3.95)	4.38 (4.09-4.74)	5.51 (5.12-5.96)	6.50 (6.02-7.03)	8.01 (7.36-8.68)	9.34 (8.49-10.1)	10.8 (9.74-11.8)	12.5 (11.1-13.7)	15.1 (13.1-16.8)	17.4 (14.9-19.5)

Figure 7. NOAA Rainfall Frequencies for the City of Hartsville

Sub-area parameters included the following:

- Sub-basin Node
- Watershed/Sub watershed Area
- Watershed/Sub watershed Length
- NRCS Runoff Curve Numbers
- Peak Rate Factor
- Land use
- Time of concentration/flow times
- Manning's "n" for channel and overbanks
- Peak discharge.

The same output hydrographs generated were used in both the existing and proposed conditions hydraulic models for each storm event. No future conditions scenarios were used in the proposed hydrologic or hydraulic models.

The model was able to generate runoff hydrographs at selected points along a stream segment. A general discharge per acre was computed for the drainage areas.

Ninth Street Area							
Location	Drainage Area, Ac		Dicharge, cfs				
	DA	DA*	2-yr	10-yr	25-yr	50-yr	100-yr
Washington St	65	70	61	93	106	115	124
Near Jasper St	145	134	75	124	147	162	177
Marlboro St	224	224	99	166	198	220	241
West Carolina Ave	304	282	116	193	230	255	279
West Home Ave	363	397	156	250	294	324	353
Marion St Area							
Butler St at Railroad Crossing	57.7	76.8	29	69	101	130	165
Campbell St near Cooley St.	70.1	na	20.9	46.6	67	85.8	107.6
Russell St.	6.4	na	9.1	20.6	29.8	38.1	47.7
Fourth Street Area							
Snake Br @ Confl Swift Cr Rd Ditch	41.8	41.8	70	89	95	98	101
Snake Br at RR Crossing	160	160	59	113	141	161	182
Railroad Ave @ Snake Br	826	na	266	501	664	785	885
DA = area calculated from mapping			DA* = Area from USGS StreamStats Pgm				

Table 1. Summary of Discharges

1301 Gervais Street, Suite 450
Columbia, SC 29201

Node Name	Subbasin	Area, ac	Tc, min	Composite Curve Number	Max Flow, cfs
DI-N3.7	1	1.8	12	72	5.5
DI-N5.5	1	0.6	5	72	2.2
DI-N5.7	1	0.5	5	72	1.9
DI-N5.6	1	1.5	5	72	5.6
DI-N6.5	1	0.3	5	72	1.1
DI-N6.7	1	2.0	17	72	5.2
DI-N6.6	1	1.5	17	72	3.9
DI-N7.3	1	2.9	5	72	11.2
DI-N3.9	1	0.9	9	72	3.0
DI-N7.5	1	0.2	5	72	0.8
DI-N8.6	1	0.6	15	72	1.7
DI-N8.7	1	0.1	5	72	0.4
DI-N8.3	1	0.1	5	72	0.4
DI-N10.5	1	0.4	5	72	1.5
DI-N10.7	1	0.4	5	72	1.5
DI-N10.3	1	0.4	5	73	1.6
DI-N10.6	1	3.0	5	72	11.2
DI-N11.6	1	2.3	6	72	8.3
DI-N11.4	1	1.0	5	72	3.7
DI-N11.3	1	1.5	6	72	5.4
HW-N11.1	1	159.0	90	72	128.1
DI-N9.8	1	3.6	16	72	9.6
DI-N9.13	1	1.6	11	72	5.0
DI-N9.4	1	0.6	5	72	2.2
DetPond	1	12.0	15	72	33.1
Ninth@Marion	1	53.0	35	72	86.4

Table 2. 10-yr Inflow for Ninth St Hydrology

Figure 8. Node Schematic for Ninth St Area Hydrology

Node Name	Subbasin	Area, ac	Tc, min	Composite Curve Number	Max Flow, cfs
8thUSRR	1	13.2	35.8	79	27.3
120.35	1	64.1	57.7	76	26.0
DI-D9	1	20.2	56.0	79	30.2
LincUS	1	17.6	23.0	73	69.3
	2	26.6	44.0	72	
DI-D2	1	10.5	21.7	69	20.8
HW-D2.1	1	13.5	21.7	68	25.6
DI-E2.3	1	0.7	5.0	76	2.9
DI-E4.1	1	0.8	10.0	75	3.0
DI-E2.5	1	1.3	5.0	76	5.5
DI-E3	1	0.5	5.0	76	2.2
111.23	1	73.2	64.1	78	47.4
	2	18.0	33.1	76	
RussUP	1	6.4	10.0	72	20.7
CB-D5.1	1	0.3	10.0	81	1.3

Table 3. 10-Yr Inflow for Marion Avenue Hydrology

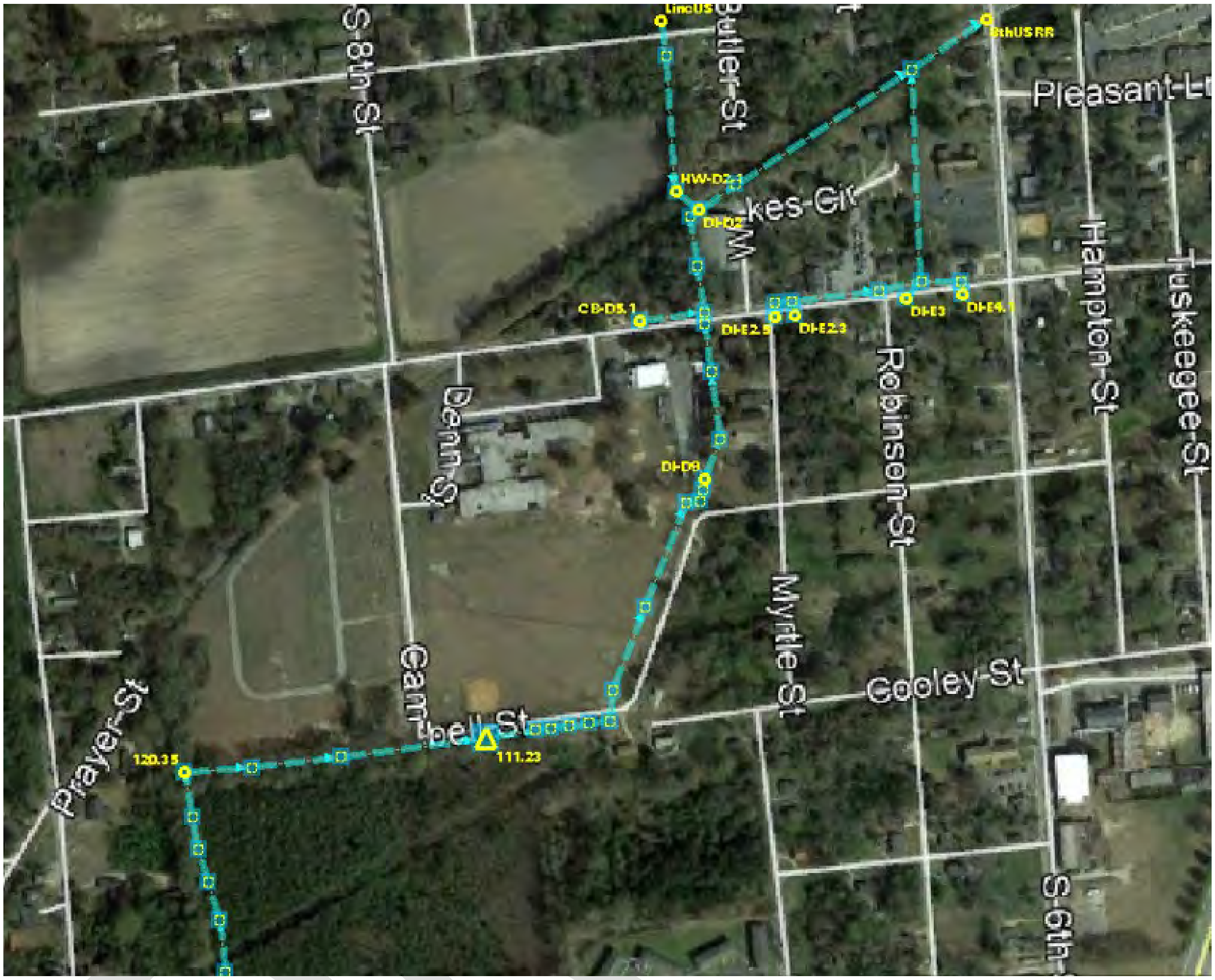


Figure 9. Node Schematic for Marion Ave Area Hydrology

Node Name	Subbasin	Area, ac	Tc, min	Composite Curve Number	Max Flow, cfs
CH-SW2	1	6.2	9.8	75	32.38
	2	11.2	23.4	68	
Snake2	1	16.7	20.1	72	88.46
	2	14.2	25.9	91	
EvanE	1	16.1	29.0	79	38.42
ChfldElm	1	5.1	5.6	86	23.01
JB-A9.1	1	1.9	10.0	92	10.51
DI-A1.4	1	0.3	18.0	78	1.02
CB-C1.1	1	0.9	10.0	81	3.73
DI-DD1	1	14.4	19.8	79	43.63
HW-DD5	1	18.5	22.3	85	61.88
DI-A1.3	1	0.5	18.3	68	1.1
CB-A8.2	1	0.7	7.0	92	3.92
CB-A4.2	1	0.4	9.0	82	1.67
ElmDav	1	28.8	24.9	94	108.4
JB-Elm	1	5.1	8.9	93	22.3
CB-C1.3	1	1.4	20.9	78	4.04
CB-C1.2	1	2.1	17.3	93	9.53
CB-A7.1	1	0.5	7.0	92	2.97
CH-SW	1	10.0	20.0	70	21.77
Snake1	1	24.7	30.8	61	25.53
DI-A11	1	0.1	7.0	78	0.42
DI-A10	1	0.1	7.0	78	0.42
CB-B3	1	2.2	15.0	81	8.17

Table 4. 10-yr Hydrology for Fourth Street Hydrology

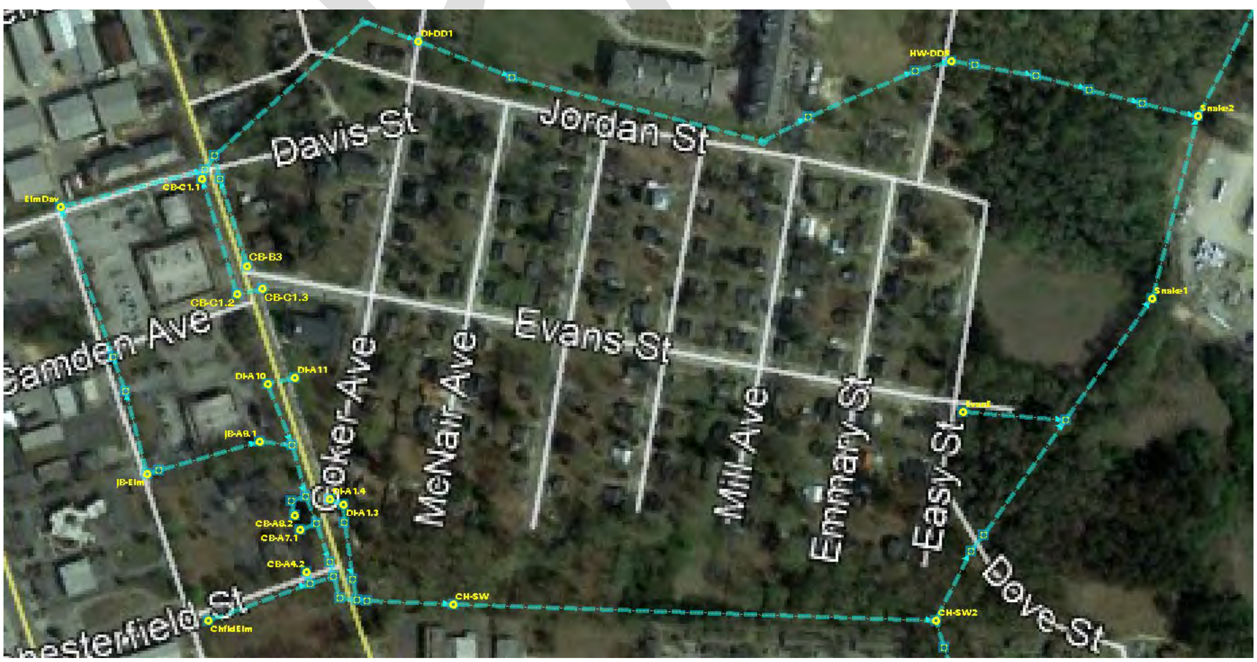


Figure 10. Node Schematic for Fourth St Area Hydrology

Node Name	Subbasin	Area, ac	Tc, min	Composite Curve Number	Max Inflow, cfs
Tusk1	1	0.4	12.4	82	4.8
	2	0.9	16.8	83	
Hamp2	1	1.3	17.7	80	6.5
	2	1.0	25.3	83	
Hamp1	1	1.2	20.2	75	2.9
Six2	1	0.9	20.2	83	2.6
CB-T4	1	0.9	12.1	86	6.4
	2	0.8	16.4	83	
Six1	1	2.5	24.3	81	6.4
Six4	1	1.0	15.7	70	2.3
Six3	1	2.2	21.6	76	5.2
R4	1	0.7	15.2	79	2.4
R3	1	0.8	19.0	79	2.2
R1	1	1.2	21.3	78	3.2
R2	1	0.5	14.8	79	1.8
Hamp3	1	1.0	7.1	73	3.6
Tusk3	1	0.6	8.1	96	3.3

Table 5. 10-yr Hydrology for Tuskegee St Area

Figure 11. Node Schematic for Tuskegee St Area Hydrology

Hydraulic Analyses

The hydraulic portion of the existing conditions model was developed for each drainage course for the existing conditions model using, to the extent possible, any existing and surveyed data. Additional surveyed data was obtained as necessary for each location where information was not available. Many inlets and pipe openings were filled with sediment and debris. The surveyors cleaned inlets and pipe inlets/outlets as much as possible to get correct invert elevations.

Channel and pipe roughness coefficients were assigned based on field inspections. Inflow hydrographs were inserted at appropriate locations and incorporated in the existing conditions hydraulic model to establish water surface profiles and flow histories for the 2-, 10-, 25-, 50- and 100-year return periods. The model was then reconfigured and recalculated using the design alternatives selected to establish a second set of water surface profiles and flow histories for proposed conditions. This provided for a comparison for the existing conditions and proposed conditions scenarios.

Open channel modeling was conducted for both natural and man-made channels. Geometry for overbank areas were taken from the State LIDAR data and tied into the bank-to-bank surveyed cross sections. SWMM/XP-STORM is especially adept at modeling closed conduit systems and flow reversals.

The results of the analyses were used to locate both existing and probable future problem areas within each drainage area noted in the grant application and to develop design level remedial measures. Remedial measures included culvert/pipe cleaning and replacement, channel realignment, channel cleaning and shaping, flow diversion, clearing, and other measures.

The tables below show the results for the pipes and channels of the 10-year event output from the XP-STORM program. Detailed maps of pipes or channels for each drainage system is included in the appendices.

Channel or Pipe Name	Upstream Node Name	Downstream Node Name	Diameter, ft	Length, ft	Shape	Upstream Invert Elevation, ft	Maximum Water Elevation, ft	Downstream Invert Elevation, ft	Conduit Slope	Max Flow, cfs	Max Velocity, ft/s	Roughness Coeff.
LN37	DI-N3.7	DI-N3.6	1.5	27	Circular	214.00	215.51	213.87	0.48	5.5	3.1	0.014
LN36	DI-N3.6	DI-N3.5	1.5	298	Circular	213.87	215.42	213.27	0.20	5.4	3.2	0.014
LN35	DI-N3.5	DI-N3.4	1.5	124	Circular	213.27	214.53	213.02	0.20	5.4	3.8	0.014
LN34	DI-N3.4	DI-N3.3	2.0	245	Circular	212.52	214.32	212.03	0.20	7.9	3.4	0.014
LN33	DI-N3.3	DI-N3.2	2.0	29	Circular	212.03	214.32	211.94	0.31	7.6	3.9	0.014
LN32	DI-N3.2	HW-N3.1	2.5	237	Circular	211.47	214.32	211.00	0.20	7.4	1.6	0.014
CH2	HW-N3.1	HW-N5.1	8.0	154	Trapezoidal	211.00	214.31	211.00	0.00	-10.3	0.3	0.014
LN3	DI-N3.8	DI-N3.5	1.5	33	Circular	213.53	214.53	213.37	0.49	-0.1	0.1	0.014
LN55	DI-N5.5	DI-N5.4	1.5	31	Circular	214.71	215.14	214.21	1.61	2.2	5.3	0.014
ln54	DI-N5.4	DI-N5.3	2.0	200	Circular	213.71	214.32	212.71	0.50	2.2	2.2	0.014
ln53	DI-N5.3	DI-N5.2	2.0	248	Circular	212.71	214.32	212.21	0.20	4.1	2.9	0.014
ln52	DI-N5.2	HW-N5.1	2.5	355	Circular	211.71	214.32	211.00	0.20	9.0	2.8	0.014
CH3	HW-N5.1	HW-N6.1	9.0	244	Trapezoidal	211.00	214.31	211.00	0.00	-10.6	0.5	0.04
ln57	DI-N5.7	DI-N5.3	1.5	30	Circular	213.51	214.32	213.21	1.00	1.9	4.3	0.014
ln56	DI-N5.6	DI-N5.2	1.5	28	Circular	212.99	214.32	212.71	1.00	5.6	5.6	0.014
LN65	DI-N6.5	DI-N6.4	1.5	36	Circular	216.00	216.41	215.82	0.50	1.1	2.9	0.014
LN64	DI-N6.4	DI-N6.3	1.5	201	Circular	215.82	216.24	214.82	0.50	1.1	2.9	0.014
LN63	DI-N6.3	DI-N6.2	2.0	247	Circular	214.32	215.33	213.58	0.30	5.8	3.6	0.014
LN62	DI-N6.2	HW-N6.1	2.5	360	Circular	213.58	214.65	212.00	0.44	9.7	4.2	0.014
CH4	HW-N6.1	HW-N7.1	9.0	287	Trapezoidal	211.00	214.32	211.00	0.00	-10.3	0.5	0.04
LN67	DI-N6.7	DI-N6.3	1.5	35	Circular	215.17	215.95	214.82	1.00	5.2	5.6	0.014
LN66	DI-N6.6	DI-N6.2	1.5	36	Circular	214.44	215.10	214.08	1.00	3.9	5.2	0.014
LN74	DI-N7.4	DI-N7.3	2.0	367	Circular	215.77	216.07	213.94	0.50	0.7	2.1	0.014
LN73	DI-N7.3	DI-N7.2	2.5	31	Circular	213.44	214.60	213.29	0.48	11.8	5.3	0.014
LN72	DI-N7.2	HW-N7.1	2.5	258	Circular	213.29	214.45	212.00	0.50	11.7	5.3	0.014
LN39	DI-N3.9	DI-N3.4	1.5	32	Circular	213.18	214.32	213.02	0.50	3.0	3.7	0.014
LN75	DI-N7.5	DI-N7.4	1.5	32	Circular	216.43	216.77	216.27	0.50	0.8	2.6	0.014
CH5	HW-N7.1	HW-N8.1	9.0	269	Trapezoidal	211.00	214.33	211.00	0.00	-10.5	0.6	0.04
LN86	DI-N8.6	DI-N8.5	1.5	33	Circular	216.61	217.27	216.54	0.21	1.7	2.2	0.014
LN85	DI-N8.5	DI-N8.4	1.5	203	Circular	216.54	217.21	216.13	0.20	1.6	2.6	0.014
LN87	DI-N8.7	DI-N8.4	1.5	32	Circular	216.29	216.53	216.13	0.50	0.4	2.1	0.014
LN84	DI-N8.4	DI-N8.3	2.0	248	Circular	215.63	216.11	214.39	0.50	1.8	3.1	0.014
LN88	DI-N8.8	DI-N8.3	1.5	35	Circular	215.24	215.24	214.89	1.00	0.0	0.0	0.014
LN83	DI-N8.3	DI-N8.2	2.0	332	Circular	214.39	214.89	212.73	0.50	2.1	3.2	0.014
LN82	DI-N8.2	HW-N8.1	2.5	47	Circular	212.23	214.33	212.00	0.49	1.8	2.2	0.014
CH6	HW-N8.1	HW-N9.1	7.0	216	Trapezoidal	211.00	214.33	211.00	0.00	-11.1	0.6	0.04
LN105	DI-N10.5	DI-N10.4	1.5	42	Circular	214.72	215.22	214.55	0.41	1.5	2.9	0.014
LN104	DI-N10.4	DI-N10.3	1.5	199	Circular	214.55	215.05	213.75	0.40	1.5	2.7	0.014
LN107	DI-N10.7	DI-N10.3	1.5	42	Circular	214.17	214.57	213.75	1.00	1.5	3.6	0.014
LN103	DI-N10.3	DI-N10.2	2.0	250	Circular	213.25	214.55	212.87	0.15	4.3	2.0	0.014
LN106	DI-N10.6	DI-N10.2	1.5	43	Circular	213.26	214.97	213.17	0.21	11.2	6.4	0.014
LN102	DI-N10.2	HW-N10.1	2.5	373	Circular	212.37	214.41	212.00	0.10	14.9	4.3	0.014
CH8	HW-N10.1	HW-N11.1	7.0	174	Trapezoidal	211.00	214.34	211.00	0.00	27.6	1.5	0.04
Link242	9 Out	Nout	4.5	88	Circular	210.07	213.72	209.91	0.18	122.9	9.4	0.014
LN116	DI-N11.6	DI-N11.5	1.5	209	Circular	212.44	217.87	212.02	0.20	8.3	4.6	0.014
LN114	DI-N11.4	DI-N11.3	1.5	198	Circular	212.00	215.58	211.70	0.15	3.7	2.1	0.014
LN115	DI-N11.5	DI-N11.3	1.5	159	Circular	212.02	216.41	211.70	0.20	8.3	4.6	0.014
LN113	DI-N11.3	DI-N11.2	1.5	219	Circular	211.70	215.29	211.37	0.15	11.0	6.5	0.014
LN112	DI-N11.2	HW-N11.1	2.0	43	Circular	211.07	214.34	211.00	0.16	10.9	4.6	0.014
CH9	HW-N11.1	9 Out	7.0	133	Trapezoidal	211.00	214.34	210.07	0.70	122.9	4.2	0.04
LN95	DI-N9.5	DI-N9.4	3.0	368	Circular	213.03	214.72	212.48	0.15	14.2	3.4	0.014
LN96	DI-N9.6	DI-N9.5	3.0	181	Circular	213.30	214.98	213.03	0.15	14.3	3.5	0.014
LN97	DI-N9.7	DI-N9.6	3.0	58	Circular	213.39	215.06	213.30	0.16	14.4	3.6	0.014
LN98	DI-N9.8	DI-N9.7	3.0	215	Circular	213.71	215.38	213.39	0.15	14.4	3.6	0.014
LN99	DI-N9.9	DI-N9.8	3.0	47	Circular	213.78	215.39	213.71	0.15	4.9	1.3	0.014
LN910	DI-N9.10	DI-N9.9	2.0	200	Circular	214.58	215.70	214.28	0.15	5.0	2.9	0.014
LN911	DI-N9.11	DI-N9.10	1.5	44	Circular	215.15	216.21	215.08	0.16	5.0	4.2	0.014
LN912	DI-N9.12	DI-N9.11	1.5	199	Circular	215.45	216.82	215.15	0.15	5.0	3.3	0.014
LN913	DI-N9.13	DI-N9.12	1.5	48	Circular	215.52	216.93	215.45	0.15	5.0	2.9	0.014
LN94	DI-N9.4	DI-N9.3	3.0	275	Circular	212.48	214.34	212.07	0.15	14.7	3.4	0.014
LN93	DI-N9.3	DI-N9.2	3.0	304	Circular	212.07	214.34	211.61	0.15	14.5	3.0	0.014
LN92	DI-N9.2	HW-N9.1	4.0	37	Circular	211.11	214.33	211.05	0.16	14.3	1.7	0.014
CH7	HW-N9.1	HW-N10.1	7.0	183	Trapezoidal	211.00	214.33	211.00	0.00	23.9	1.2	0.04
Link238	DI-N1	HW-N1.1	2.0	225	Circular	211.15	213.81	210.70	0.20	-9.8	1.4	0.014
CH1	Ninth@Marion	HW-N3.1	9.0	156	Trapezoidal	210.35	214.31	211.00	-0.42	-11.8	0.3	0.04
Link240	HW-N1.1	HWN1.2	3.0	365	Trapezoidal	210.70	214.29	210.58	0.03	-9.9	0.6	0.014
Link241	HWN1.2	Ninth@Marion	3.0	33	Circular	210.58	214.30	210.35	0.70	-10.2	0.8	0.014
Link244	DetOut	DI-N1	2.0	70	Circular	212.00	213.43	211.15	1.21	-9.8	2.5	0.014

Table 6. Ninth St Hydraulics Output – 10-year Event

Channel or Pipe Name	Upstream Node Name	Downstream Node Name	Depth or Diameter, ft	Length, ft	Shape	Upstream Invert Elevation ft	Maximum Water Elevation, ft	Downstream Invert Elevation, ft	Slope, %	Max. Flow, cfs	Max. Velocity, ft/s	Roughness Coeff.
L154	8thUSRR	5thUS	3.0	236	Circular	209.16	215.00	207.98	0.50	-54.3	5.0	0.013
L279	DI-D12	JB-D11	3.0	28	Circular	210.69	215.30	210.65	0.14	27.9	4.9	0.013
BF1	BallFd1	DI-D12	3.0	270	Circular	210.72	215.00	210.69	0.01	27.9	4.2	0.013
L20	BallFd2	BallFd1	3.0	231	Circular	211.33	215.21	210.72	0.26	27.9	4.1	0.013
CH-334	EW-E1	8thUSRR	5.8	244	Trapezoidal	209.18	215.12	209.16	0.01	58.6	1.4	0.040
Culvert1	CampDA1415	BallFd2	2.5	69	Circular	211.40	215.42	211.33	0.10	27.8	5.7	0.013
Campb30	Campb3	Campb2a	2.5	87	Circular	211.63	216.02	211.65	-0.02	27.8	5.6	0.013
12035	120.35	120	6.7	24	Natural	216.44	217.19	214.94	6.25	29.5	2.8	0.060
13886	RussDn	134.27	1.1	459	Natural	218.56	219.59	218.51	0.01	7.9	0.4	0.050
L111	Campb2b	CampDA1415	2.5	63	Circular	211.58	215.65	211.40	0.29	27.8	5.7	0.013
L335	DI-D9	DI-D8	4.0	140	Circular	210.54	215.34	210.33	0.15	29.1	3.7	0.013
CH-133	HW-D1	EW-E1	6.0	552	Trapezoidal	209.20	215.24	209.18	0.00	52.0	1.0	0.040
Lincoln	LincUS	LincDS	1.5	35	Circular	212.30	215.00	211.22	3.09	24.4	13.8	0.013
Ch134	LincDS	HW-D2.1	4.0	413	Trapezoidal	211.22	215.38	209.89	0.32	18.6	1.2	0.050
L138	DI-D2	HW-D1	4.0	109	Circular	209.36	215.27	209.20	0.15	38.4	3.0	0.013
L294	HW-D2.1	DI-D2	2.0	53	Circular	209.89	215.37	209.60	0.55	21.7	6.9	0.013
LW4	DI-E2.3	DI-E2.2	1.5	26	Circular	213.96	215.47	213.75	0.81	2.9	1.6	0.013
LW6	DI-E2.2	DI-E2.1	1.5	198	Circular	213.80	215.45	213.49	0.16	6.6	4.4	0.013
LW7	DI-E2.1	DI-E2	1.5	130.8	Circular	213.49	215.21	211.72	1.35	6.2	5.5	0.013
L147	DI-E2	EW-E1	2.5	537	Circular	211.72	215.17	210.06	0.31	9.9	2.9	0.013
LW9	DI-E4	DI-E2	1.5	99	Circular	213.99	215.21	211.72	2.29	3.2	3.1	0.014
LW10	DI-E4.1	DI-E4	1.5	27	Circular	213.71	215.22	213.99	-1.04	3.0	4.1	0.013
LW3	DI-E2.5	DI-E2.4	1.5	26.8	Circular	214.19	215.66	214.02	0.52	5.5	3.1	0.013
LW5	DI-E2.4	DI-E2.2	1.5	64	Circular	214.02	215.60	213.80	0.34	5.3	2.9	0.013
LW8	DI-E3	DI-E2	1.5	53	Circular	214.00	215.17	211.72	4.30	2.2	2.7	0.013
10200	JB-D11	DI-D10	4.0	14	Circular	210.59	215.33	210.57	0.14	27.9	3.8	0.013
10183	DI-D10	DI-D9	4.0	18	Circular	210.57	215.33	210.54	0.17	27.9	3.8	0.013
10928	Campb2a	1089	6.1	10	Natural	211.93	215.67	211.94	-0.10	27.8	2.1	0.055
10895	1089	Campb2b	6.1	33	Natural	211.94	215.66	211.94	0.00	27.8	2.0	0.055
12000	120	117	6.4	300	Natural	214.94	216.42	213.39	0.00	29.5	1.5	0.013
11700	117	111.23	5.0	377	Natural	213.39	216.13	212.15	0.00	30.0	2.2	0.013
Bench1	111.23	Campb3	5.0	395	Natural	212.15	216.10	211.63	0.29	27.7	1.1	0.060
13427	134.27	131.17	2.2	310	Natural	218.51	219.59	218.19	0.10	3.6	0.7	0.050
13117	131.17	130.17	2.4	100	Natural	218.19	219.06	217.75	0.44	3.6	0.9	0.050
13017	130.17	125.44	3.0	473	Natural	217.75	218.80	216.68	0.23	3.6	0.9	0.060
12544	125.44	124.6	3.7	84	Natural	216.68	217.78	215.16	1.81	3.6	1.0	0.050
12460	124.6	121.93	5.4	267	Natural	215.16	217.19	212.91	0.84	3.6	0.1	0.055
12193	121.93	120.99	6.9	94	Natural	212.91	217.19	213.03	-0.13	3.5	0.1	0.060
12099	120.99	120.35	8.0	64	Natural	213.03	217.19	214.44	-2.20	3.5	0.2	0.060
Russ18-in	RussUP	RussDn	1.5	42	Circular	218.19	220.00	217.17	2.43	11.0	6.1	0.013
L336	DI-D8	DI-D7	4.0	201	Circular	210.33	215.33	210.03	0.15	29.1	3.6	0.013
L337	DI-D7	CB-D6	4.0	139	Circular	210.03	215.31	209.82	0.15	29.1	3.4	0.013
LWash2	CB-D6	CB-D5	4.0	27	Circular	209.82	215.30	209.78	0.15	29.1	3.2	0.013
L362	CB-D5	DI-D4	4.0	135	Circular	209.78	215.30	209.58	0.15	29.2	3.1	0.013
L341	DI-D3	DI-D2	4.0	14	Circular	209.38	215.27	209.36	0.14	29.2	2.7	0.013
LWash1	CB-D5.1	CB-D5	1.5	128	Circular	212.64	215.31	212.00	0.50	1.2	2.9	0.013
L363	DI-D4	DI-D3	4.0	135	Circular	209.58	215.29	209.38	0.15	29.2	2.8	0.013

Table 7. Marion Avenue Hydraulics Output – 10-year Event

1301 Gervais Street, Suite 450
Columbia, SC 29201

Channel or Pipe Name	Upstream Node Name	Downstream Node Name	Depth or Diameter, ft	Length, ft	Shape	Upstream Invert Elevation, ft	Maximum Water Elevation, ft	Downstream Invert Elevation, ft	Slope, %	Max. Flow, cfs	Max. Velocity, ft/s	Roughness Coeff.
ChSn5	CH-SW2	DoveUS	6.0	131	Trapezoidal	201.84	206.56	201.44	0.30	189.5	4.1	0.040
DoveSt	DoveUS	DoveDS	11.4	32	Trapezoidal	201.50	206.05	201.50	0.00	189.5	3.1	0.050
ChSn4	DoveDS	EvansSnake	6.0	758	Trapezoidal	201.44	205.94	198.17	0.07	189.4	4.6	0.040
ChSn3	EvansSnake	Snake1	7.0	377	Trapezoidal	198.17	201.72	196.25	0.51	197.1	4.5	0.040
ChSnk1	Snake2	RRup27	4.5	33	Trapezoidal	195.23	199.43	194.88	1.06	472.6	10.1	0.040
RRave	RRup27	RRds	10.0	28	Rectangular	194.88	198.65	194.00	3.14	472.7	2.7	0.014
72cmp	RRds	RR Outfall	6.0	110	Circular	194.41	198.69	191.60	2.56	227.8	9.1	0.024
48rcp1	RRds	RR Outfall	4.0	106	Circular	194.71	198.69	192.24	2.33	129.7	10.4	0.013
48rcp2	RRds	RR Outfall	4.0	103	Circular	195.81	198.69	193.18	2.55	117.0	10.4	0.013
Link166	EvanE	EvansSnake	3.5	356	Circular	205.41	206.91	201.85	1.00	38.4	9.8	0.013
LChfd	ChfldElm	HW-A4.1	2.0	251	Trapezoidal	210.09	211.16	206.23	1.54	23.0	2.8	0.040
L352	HW-A4.1	CB-A4	2.5	88	Circular	206.23	207.97	205.79	0.50	24.5	6.8	0.013
ChSwf1	HW-A1	CH-SW	6.3	342	Natural	204.15	206.57	203.61	0.16	55.0	1.2	0.040
LPO	Elm	JB-A9.1	3.5	269	Trapezoidal	207.11	209.06	206.18	0.35	29.0	2.5	0.040
L316	Elm	JB-Elm	3.5	9	Circular	207.11	209.06	206.42	7.34	-29.2	1.2	0.014
LA9A91	JB-A9.1	CB-A9	3.5	72	Circular	206.03	208.16	205.81	0.31	34.9	5.7	0.013
LA810	CB-A8.1	CB-A8	1.5	74	Circular	207.56	208.39	207.27	0.39	3.9	4.1	0.013
Link331	DI-A1.4	DI-A1.3	1.5	13	Circular	207.72	208.14	207.69	0.23	1.0	2.7	0.014
LDaW	CB-C1.1	CB-C1	5.0	29	Rectangular	206.92	207.97	203.02	13.45	27.8	2.3	0.013
LJ1	CB-B1	DI-DD1	5.0	345	Circular	203.39	207.67	203.02	0.11	113.9	7.0	0.013
LJ2	DI-DD1	DI-DD2	5.0	246	Rectangular	201.83	206.78	201.73	0.04	156.6	6.7	0.013
LJ3	DI-DD2	DI-DD3	5.0	743	Rectangular	201.73	206.16	201.24	0.07	156.2	6.4	0.013
LJ4	DI-DD3	CB-DD4	5.0	391	Rectangular	201.24	204.86	200.71	0.14	156.1	7.8	0.013
GovCh1	HW-DD5	CH-DD5	8.3	11	Natural	200.23	203.59	198.00	20.27	217.6	9.3	0.060
LOut	RR Outfall	SnakeOut	10.0	100	Trapezoidal	192.24	197.93	191.00	1.24	472.6	6.9	0.065
LA2A1	DI-A3	JB-A2	4.0	70	Circular	204.33	206.57	204.12	0.30	57.4	9.5	0.013
L196	CB-DD4	HW-DD5	5.0	63	Rectangular	200.71	203.67	200.23	0.76	156.1	8.3	0.013

Table 8. Fourth St Hydraulics Output – 10-year Event

Channel or Pipe Name	Upstream Node Name	Downstream Node Name	Depth or Diameter, ft	Length, ft	Shape	Upstream Invert Elevation, ft	Maximum Water Elevation, ft	Downstream Invert Elevation, ft	Slope, %	Max. Flow, cfs	Max. Velocity, ft/s	Roughness Coeff.
T-rcp1	Tusk1	CB-T4	2.0	33	Circular	211.48	213.48	211.34	0.42	14.5	4.41	0.014
Link140	Hamp2	Trcp2	3.0	106	Trapezoidal	211.62	214.60	211.57	0.05	12.2	0.69	0.065
L20	Hamp1	Hamp2	1.5	29	Circular	211.65	213.15	211.62	0.10	9.2	5.20	0.013
L157	Six2	Campb	1.5	97	Circular	211.78	213.28	211.71	0.07	8.6	4.85	0.014
L154	CB-T4	HW-T4	2.5	100	Circular	211.34	213.84	211.27	0.07	22.5	5.10	0.014
L132	six1	Six2	1.5	33	Circular	212.00	213.50	211.78	0.67	7.1	3.99	0.014
T-rcp2	Trcp2	Trcp	2.0	30	Circular	211.57	213.57	211.54	0.10	11.3	3.48	0.014
L142	Trcp	Tusk1	2.6	72	Trapezoidal	211.54	214.19	211.48	0.08	10.7	0.61	0.065
L147	Six4	Six3	1.5	33	Circular	212.34	213.84	212.21	0.39	-7.2	1.01	0.014
L148	Six3	six1	1.5	33	Circular	212.21	213.71	212.00	0.64	3.1	1.76	0.014
L146	R4	Six3	2.8	288	Trapezoidal	216.94	219.73	212.31	1.61	4.5	2.42	0.020
L145	R3	R4	1.5	30	Circular	217.22	218.72	216.94	0.93	2.2	4.22	0.014
L143	R1	R2	1.5	25	Circular	217.06	218.56	217.00	0.24	3.2	4.54	0.014
L144	R2	six1	2.3	288	Trapezoidal	217.00	219.31	212.61	1.52	4.9	2.25	0.020
L149	Hamp3	Hamp1	1.5	33	Circular	212.18	213.68	211.78	1.21	3.6	2.02	0.014
L152	Tusk3	Tusk4	1.3	42	Circular	212.81	214.06	212.16	1.55	3.2	3.57	0.014
L153	Tusk4	CB-T4	3.2	179	Trapezoidal	212.16	215.38	211.34	0.46	2.6	0.53	0.050
LBench	HW-T4	CB-T2	4.0	267	Natural	211.27	215.27	211.12	0.06	16.6	0.56	0.040
L158	Campb	Hamp1	1.5	97	Circular	211.71	213.21	211.65	0.06	5.3	2.96	0.014
LOut	Nout	CB-T1 OUT	2.0	50	Circular	211.12	213.12	211.08	0.08	12.1	5.24	0.013

Table 9. Tuskegee St Hydraulics Output – 10-year Event

SECTION 4. DESIGN IMPROVEMENTS

Several proposed design improvements were evaluated at locations noted in the grant application. Each of these improvements were analyzed within the hydraulic model to determine the effectiveness and various impacts to the community. Design plans for those improvements that proved beneficial were developed along with specifications. Cost estimates for construction were also provided.

Increased runoff is anticipated as each of the drainage systems are cleaned out, inlets added and drainage lines enlarged. To offset this condition, the proposed concept used within each drainage system was to provide some detention/storage areas to detain runoff in the upstream areas. This would allow the hydrograph timing to be spread out and not allow coincidental lining up of the peak hydrographs. This design showed no increase in downstream flooding for the proposed design. An example of the proposed improvements performance is illustrated in the Figures

The improvements are described as follows:

Marion Avenue Drainage

The Marion Avenue improvements were based, in part, on the proposed areas as outlined in the grant application. Actual flow patterns in the system were determined by field inspection and surveying. Much of the drainage system as outlined in the grant application did not match what was determine in the field. For example, the ditch that runs parallel to east side MLK Drive from Russell Road to Campbell Street is located outside of the city limits and does not cross the railroad and flow north into the Ninth Street Ditch system.

While the improvements listed below include system cleaning, both channels and pipes; the entire system needs periodic cleaning to operate at maximum efficiency and alleviate some of the shallow flooding issues. Shallow flooding along Washington Street also poses a significant hazard on this narrow road.

As mention previously, the conveyance slopes for much of the system are below recommended values. For instance, the ditch running parallel along Wilkes Circle has a beginning invert elevation of 209.20 and flows into the existing 36-inch RCP at South Sixth Street with an invert elevation of 209.16. This is a change in elevation of only 0.04 feet (less than ½ inch) in nearly 800 feet of channel. This is typical for many conveyance sections throughout the system. This means the system is mainly “head” driven. As the water builds up vertically, it is “pushed” through the system and does not freely flow.

Below are the recommended major improvements and maintenance items.

- **Intersection of Myrtle and Campbell Streets to Wilkes Circle at ditch outfall** - Replace approximately 903 feet existing 36-inch pipe with 48-nch RCP. Construct a constant slope along line.
- **Washington Street** - Replace existing inlets along Washington Street from Sixth Street to past Wilkes Circle. Also, hydro-jet existing line and remove sediment. Add additional inlet along Washington Street.
- **Butler Street** - Clean existing ditch behind homes that parallel Butler Street from Lincoln Avenue to the rail line near Wilkes Circle.

- **Wilkes Circle** - Clean existing ditch along Wilkes Circle to Sixth Street 36-inch culvert outlet.
- **Campbell Street** - Construct new 5 ac detention area at south Campbell St.

The improvements reduce the water level and peak flow rates along the systems. The graphs below in figures 6 -8 show the potential reduction in flow (10-yr) from existing conditions to proposed conditions with detention area. Figure 6 is the intermediate graph that shows the proposed pipe system (enlarged) without the detention area. Note the changes in flow from each condition. With the detention area included the flow changes from 50 cfs (existing) to 40 cfs (proposed with detention area).

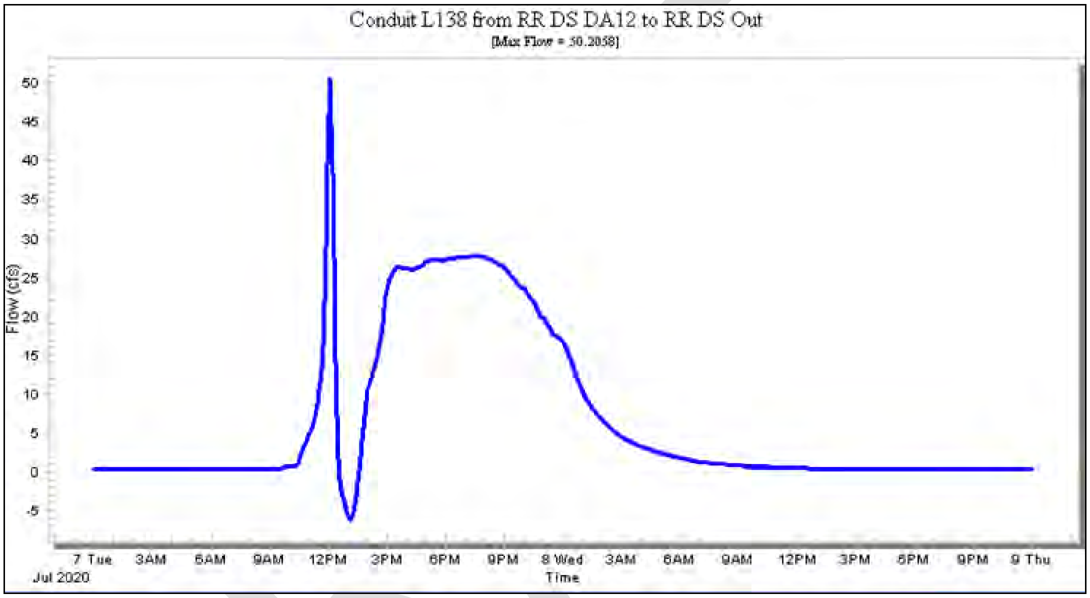


Figure 12. Outlet to Channel along Railroad at Wilkins Circle (Existing Conditions)

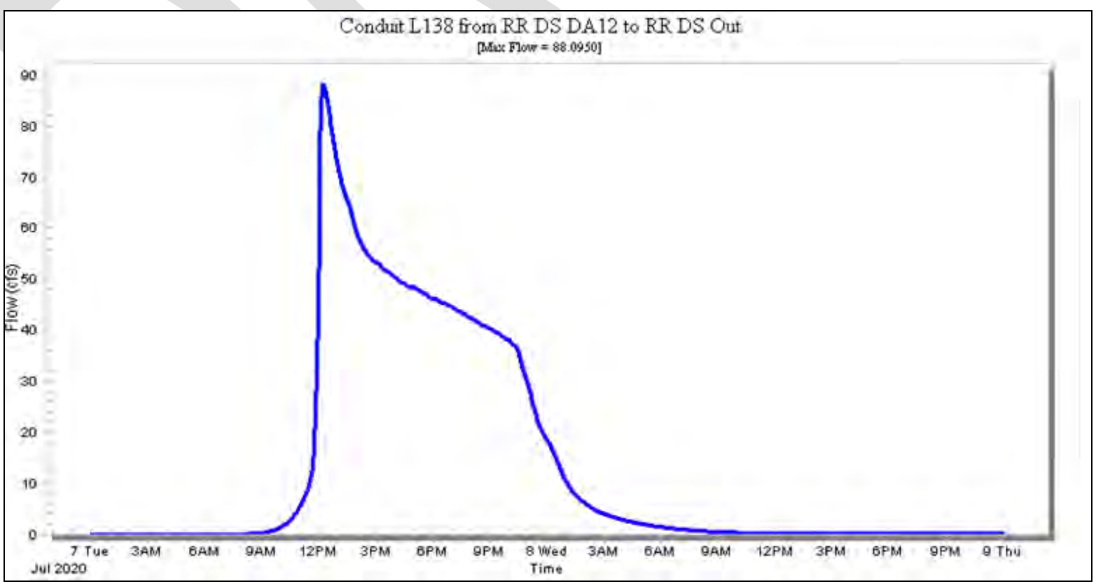


Figure 13. Outlet to Channel along Railroad at Wilkins Circle (Proposed Conditions w/o Detention)

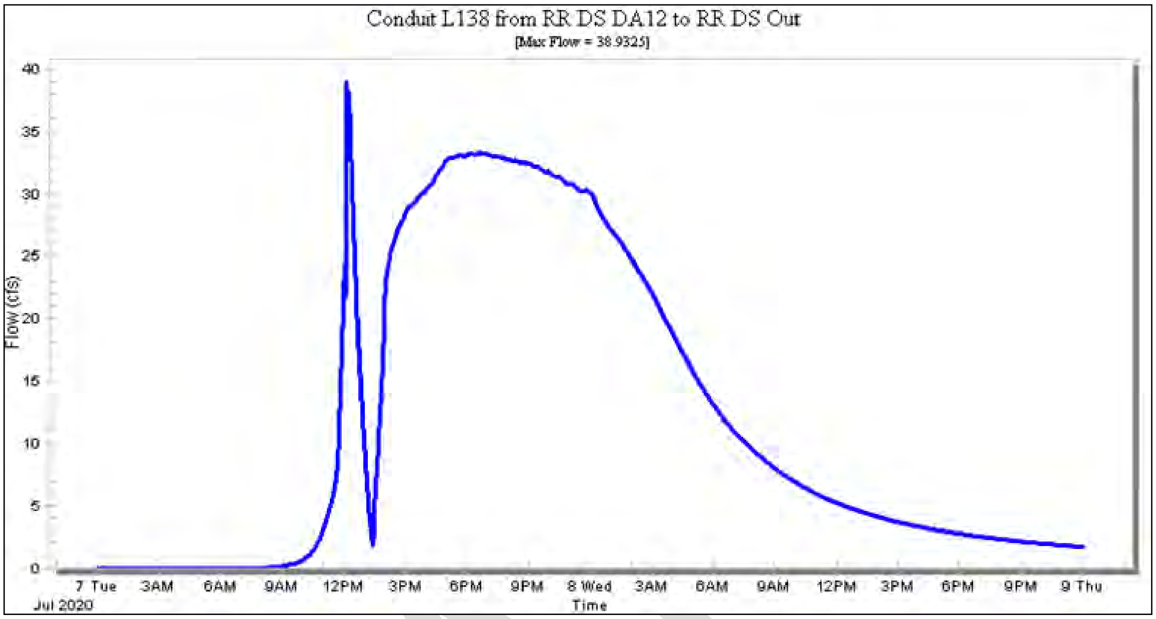
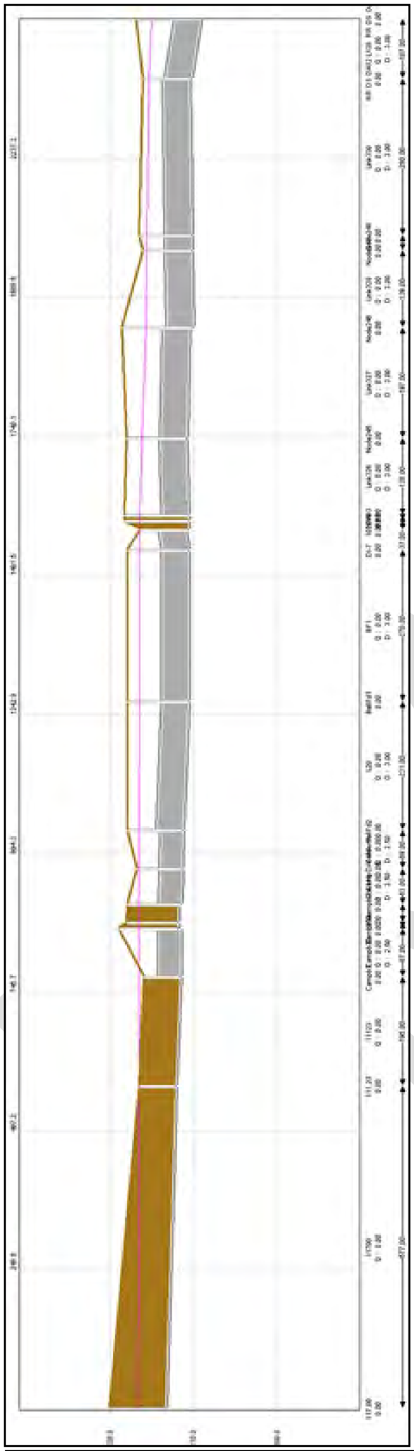
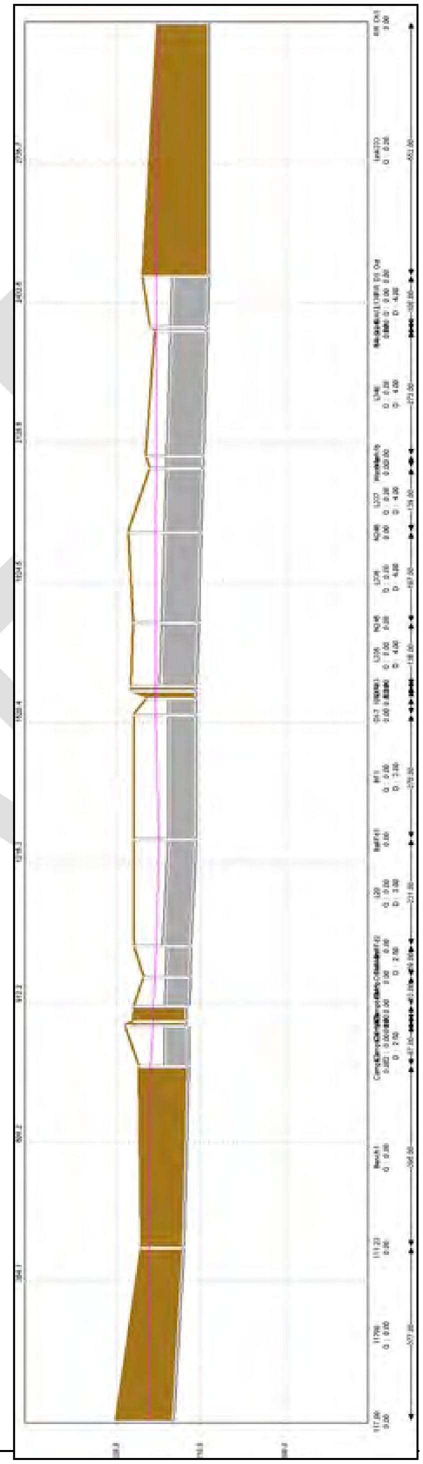


Figure 14. Outlet to Channel along Railroad at Wilkins Circle (Proposed Conditions w/Detention)

These graphs show the result of opening the drainage ways by regrading ditches and enlarging pipes/inlets. A decrease in the peak discharge and water surface elevation is noted.

The profiles in the graphs below show the conveyance system from Campbell Street ditch to the ditch outfalls along Wilkins Circle. The discharge at the outlet is reduced and the 10-year flood profile (water surface elevation) is reduced. This design reduces flooding and allows additional runoff to be intercepted along Washington Street.





Figures 15 & 16. Existing/Proposed Profile of Mainline Marion St Conveyance

Tuskegee Street Drainage

The Tuskegee Street Drainage system is in a low area that drainage toward South Fifth Street. Much of the lateral streets have no drainage. Ditch lines will be constructed where there is sufficient ROW. The roadside ditches will connect to the main line system.

- Construct V-ditches along Tuskegee Street, Hampton Street, Robinson Street, Myrtle Street, and Sixth Street that drain toward Campbell Street. Improve existing main line pipe that flows Robinson Street to Tuskegee Street.
- Replace approximately 100 feet of 24-inch RCP to 36-inch RCP from Tuskegee Street to South Fifth Street and 355 feet of benched channel for storage.

Fourth Street Drainage

The Fourth Street Drainage system has shallow flooding along Fourth Street that effects businesses and residents with shallow flooding. Besides the nuisance yard flooding, the street flooding poses a serious hazard to vehicles and especially to emergency vehicles.

- **Post Office Ditch** - Clean approximately 245 feet of existing ditch from Elm Street to Fourth Street located beside Post Office.
- **Fourth Street** - Replace approximately 570 feet of 42-inch, 24-inch and 18-inch RCP with 42-inch RCP from Post Office to Fourth Street at Swift Creek Road Ditch Outfall. Replace five existing inlets along Fourth Street and add three new inlets. The existing inlets on private property along Fourth Street will be connected to the new system. Hydro-jet the existing lines for system at Evans Street and Fourth Street.
- **Swift Creek Road Ditch** - Improve 572 feet of channel from Fourth Street to confluence with Snake Branch. Construct a 26 ft "bench" on the north side of channel. This provides storage for larger storm events and reduces flow downstream.
- **Snake Branch** - Clean and regrade approximately 1,900 feet of channel along Snake Branch to Railroad Avenue.

The profiles in the graphs below show the main conveyance system from the post office ditch to the outlet at Swift Creek Road Ditch. Note the differences in invert elevations (bottom slope) and hydraulic grade lines (red) for the 10-year event.

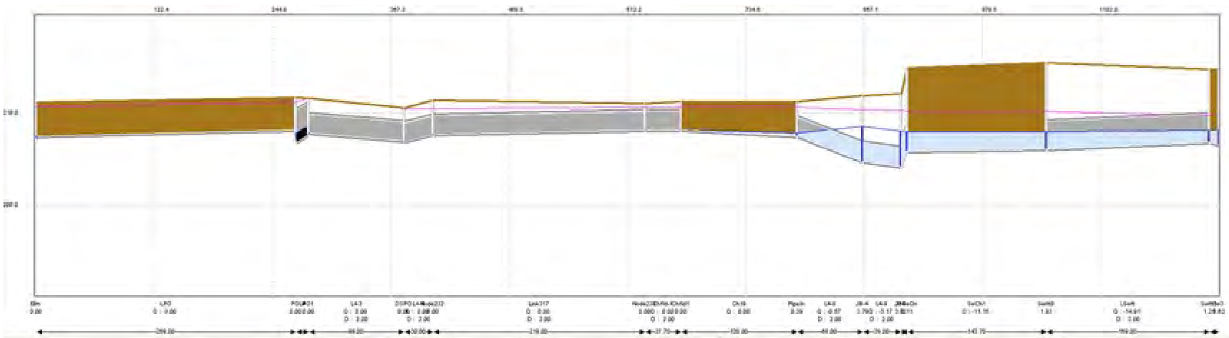


Figure 17. Existing System from Post Office Ditch Fourth St Ditch Outlet

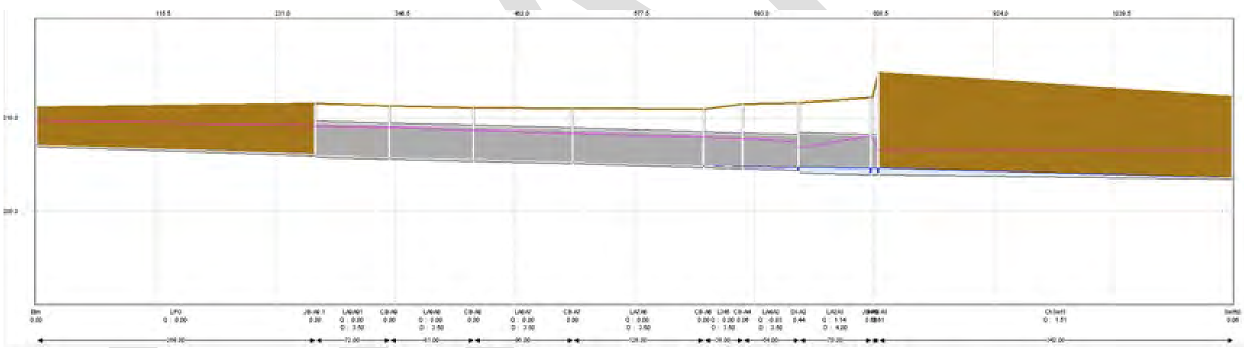


Figure 18. Proposed System from Post Office Ditch Fourth St Ditch Outlet

Ninth Street Drainage

- **Ninth Street Ditch** - Clean approximately xxx feet of existing ditch from ?? to Carolina Avenue
- **Marion Avenue** - Construct 324 ft of 24-in RCP and 2 new inlets along Marion Avenue to Ninth St Ditch.
- **Jasper Avenue** - Remove existing inlets and storm drain. Construct 8 new inlets and 514 ft of 18-in RCP, 274 ft of 24-in RCP and 237 ft of 30-inch RCP along Jasper Avenue to Ninth St Ditch. Construct new headwall in Ninth St Ditch.
- **James Avenue** – Construct 6 new inlets, 89 ft of 18-inch RCP, 448 ft of 24-inch RCP and 355 ft of 30-inch RCP. Construct new headwall in Ninth St Ditch.
- **Logan Avenue** – Construct 6 new inlets, 308 ft of 18-inch RCP, 247 ft of 24-inch RCP and 360 ft of 30-inch RCP. Construct new headwall in Ninth St Ditch.
- **Brewer Avenue** – Construct 4 new inlets, 63 ft of 18-inch RCP, 367 ft of 24-inch RCP and 256 ft of 30-inch RCP. Construct new headwall in Ninth St Ditch
- **Sumter Street** - Construct 7 new inlets, 303 ft of 18-inch RCP, 580 ft of 24-inch RCP and 47 ft of 30-inch RCP. Construct new headwall in Ninth St Ditch
- **Bell Avenue** – Construct 6 new inlets, 326 ft of 18-inch RCP, 250 ft of 24-inch RCP and 373 ft of 30-inch RCP. Construct new headwall in Ninth St Ditch
- **Eighth Street** – This system runs along Eighth St from James Ave to past Sumter St then turns west to Ninth St Ditch. Construct 12 new inlet, 291 ft of 18-inch RCP, 200 ft of 24-inch RCP, 1,448 ft of 36-inch RCP and 37 ft of 48-inch RCP. Construct new headwall in Ninth St Ditch
- Bell/Marion Avenue – This system is located between Bell Ave and Marlboro Ave and drains to Ninth St Ditch. Construct 5 new inlets, 785 ft of 18-ich RCP and 43 ft of 24-inch RCP. Construct new headwall in Ninth St Ditch.
- **Village St Detention Area** – Construct detention facility in demolished Village St Apartment area.

Utility Coordination

The GIS utility layer was obtained from the City in locating water and sewer lines, taps and manholes. The stormwater infrastructure mapping was incomplete, but some data was usable and accurate regarding location. This data was included in the CAD design file as shapefiles.

No geotechnical analysis was included in the project. General soil data was used from NRCS soil reports.

PERMITTING

No regulatory floodplain or floodway is located within the project area, so FEMA floodplain mapping and permitting is not required. Permitting considerations for the project included the following. The US Corps of Engineers 401/404 Pre-Construction Notice (PCN) has been submitted to the Conway office. The SCDHEC NPDES and Land Disturbances permits are being developed.

Only one historical property was located close to a project. Wetland delineations are being surveyed in the detention areas. for acceptance by the USACE.

Figure 19. Historical Cemetery near Proposed Ninth Street Detention Area

The cemetery has about 110 burials recorded by the Old Darlington District Chapter of the South Carolina Genealogical Society, although we expect a great many more burials are present but were never marked or were marked with impermanent objects. There are no maps or burial registers known to exist for either cemetery.

FEMA Review

After City review, the documents will be submitted to FEMA for review and acceptance.

BENEFIT – COST ANALYSIS

FEMA mitigation projects must be cost effective as demonstrated by a FEMA-validated Benefit Cost Analysis (BCA). A BCA evaluates the existing and future benefits of a project in relation to its cost. The BCA results in a benefit-cost ratio (BCR) and compares the future benefits to make sure they are equal to or greater than the project cost. If the BCR is equal to or greater than 1.0 then the proposed project is considered cost effective. If the benefits are less than the cost, then the BCR is less than 1.0, and the proposed project is not considered cost effective. Only projects that demonstrate a BCR of 1.0 or greater are considered for Hazard Mitigation Assistance (HMA) funding.

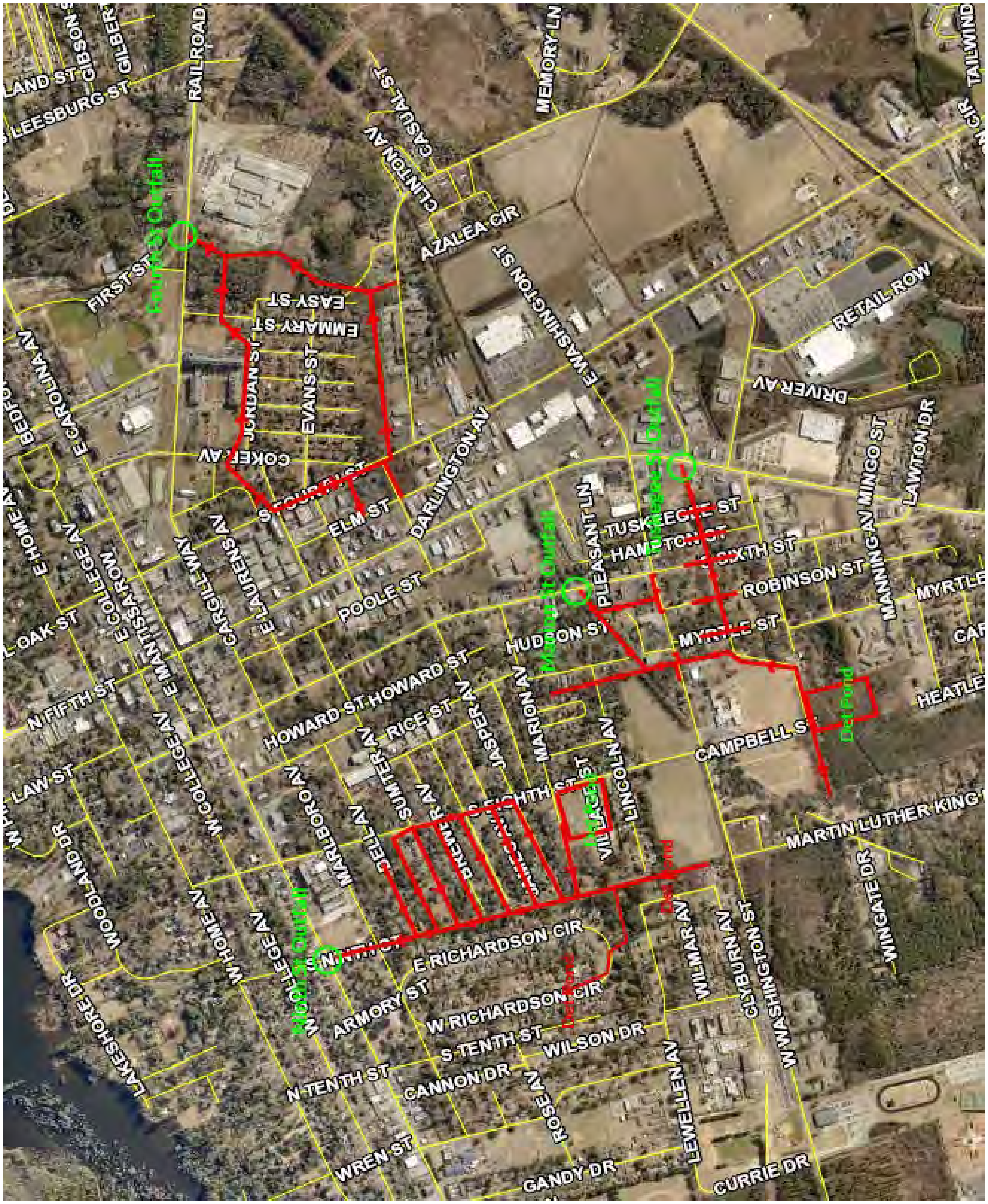
For projects submitted for funding under the Hazard Mitigation Grant Program (HMGP), an expedited cost-effectiveness determination can be made for property acquisition and structure demolition or relocation projects when certain conditions are met. Specifically, for structures identified in a riverine floodway or Special Flood Hazard Area (SFHA) on the current effective Flood Insurance Rate Map (FIRM) and declared substantially damaged due to the impacts of flooding by a local authority having such jurisdiction, property acquisition and structure demolition or relocation is considered cost effective and a BCA is not required to be submitted for the structure. There is some property acquisition proposed for drainage improvements, mainly for ditch widening, etc. but no structures.

To recognize their benefits, mitigation projects must reduce the potential future damages to a building and its contents, infrastructure, emotional stress and human lives. Additionally, loss of function—displacement of occupants, rerouting of emergency vehicle and from the building and/or loss of public services—may also be reduced by mitigation projects, thereby further increasing the benefits of the project.

The benefits when compared to construction costs for the drainage systems within the scope of this study will be less than 1. This will ensure the grant funds were expended in the most efficient manner.

Appendix A
Location Maps

OVERALL DRAINAGE IMPROVEMENT MAP



E.L. ROBINSON ENGINEERING
1301 Gervais Street, Suite 450
Columbia, SC 29201

Marion Avenue Improvements

Fourth Street Improvements

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Columbia, SC 29201

Tuskegee Street Improvements

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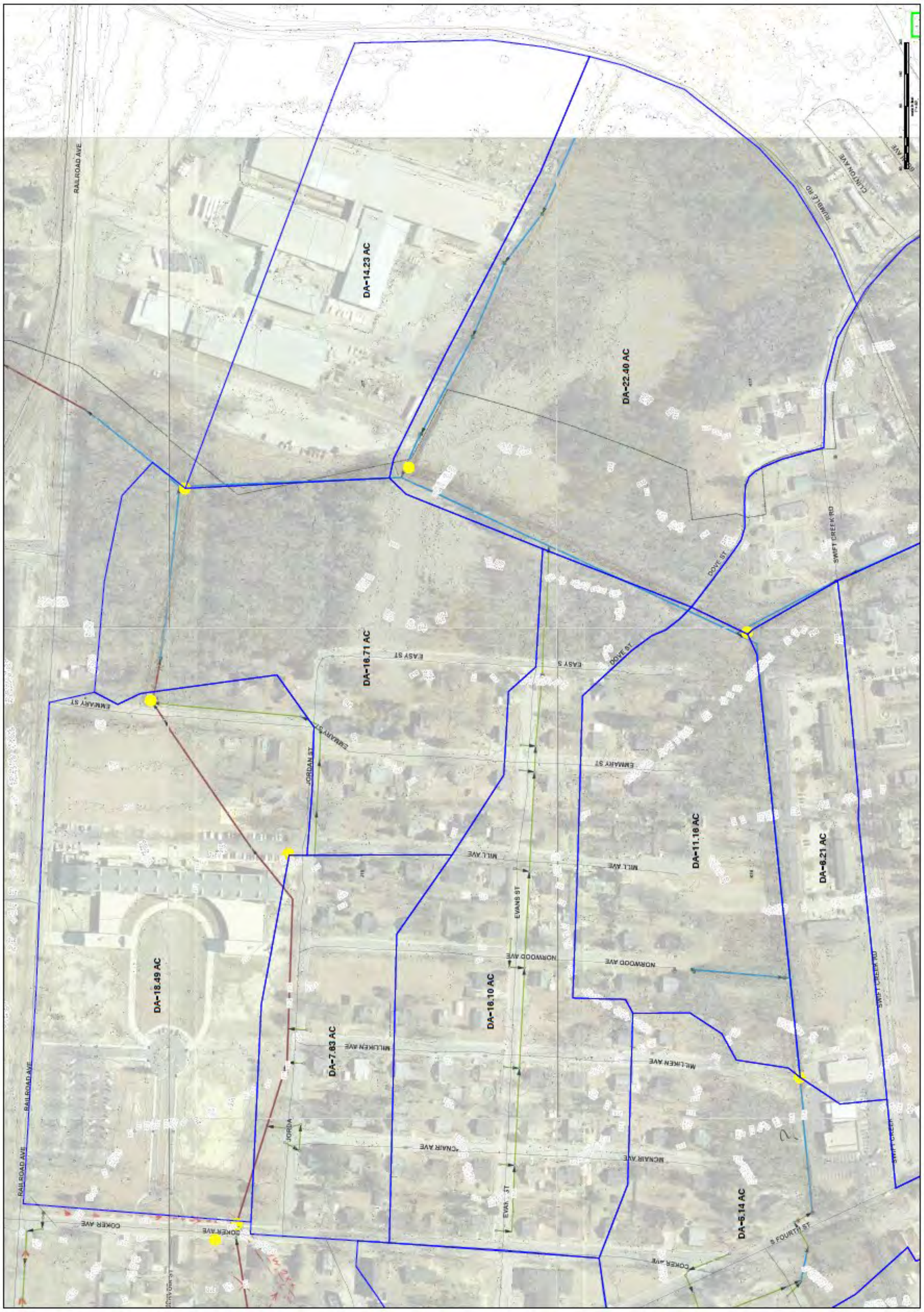
Ninth Street Improvements

APPENDIX B

Drainage Area Maps



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1301 Gervais Street, Suite 450
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S FOURTH ST
SWIFT CREEK RD


DA-18.49 AC
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DA-28.84 AC
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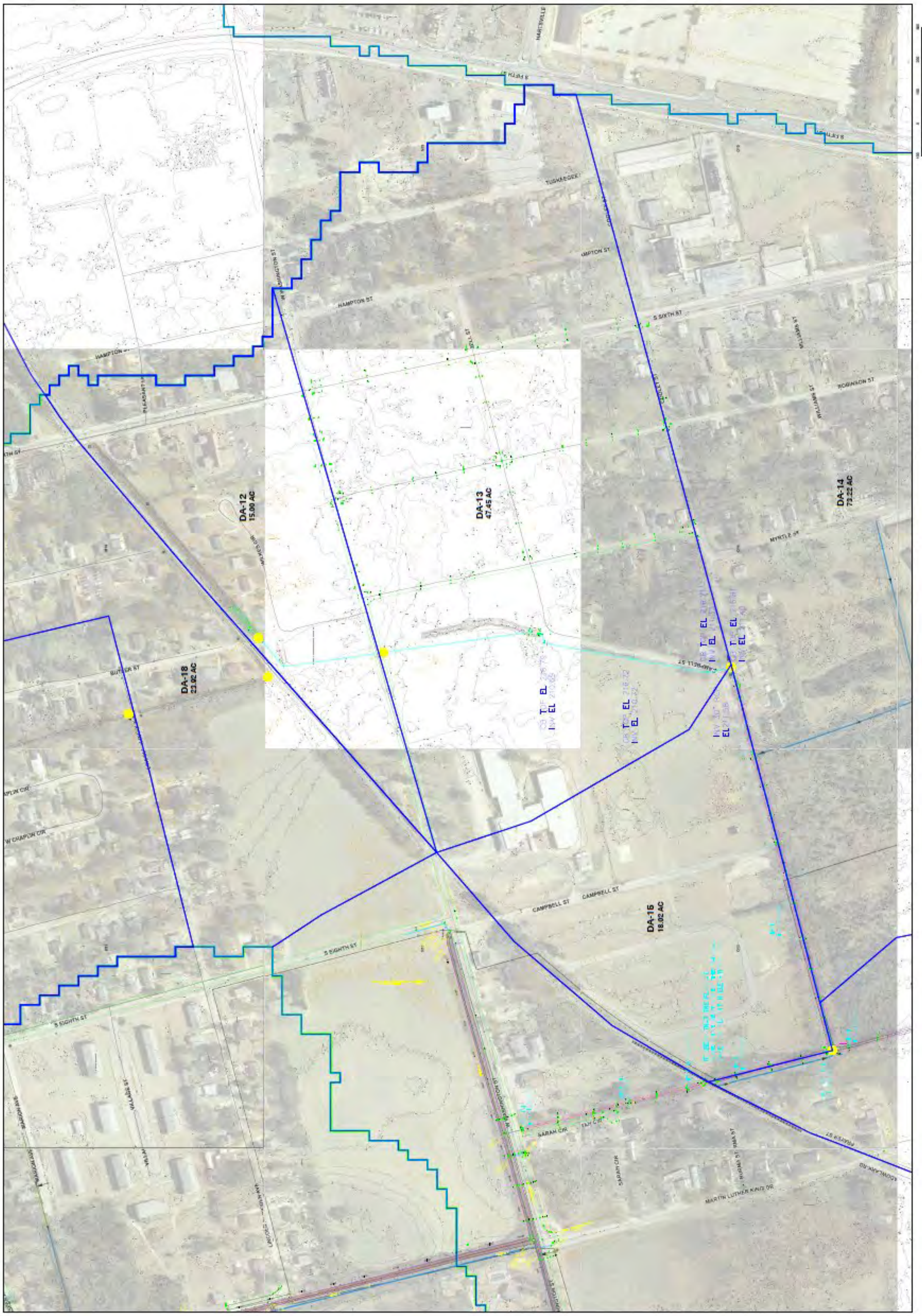
MILLIKEN AVE
MCNAIR AVE
COKER AVE
EVANS ST
RAILROAD AVE
CHINABERRY DR
S FOURTH ST
S FIFTH ST
S SIXTH ST
ELM ST
HOWARD ST
POOLE ST

1301 Gervais Street, Suite 450
Columbia, SC 29201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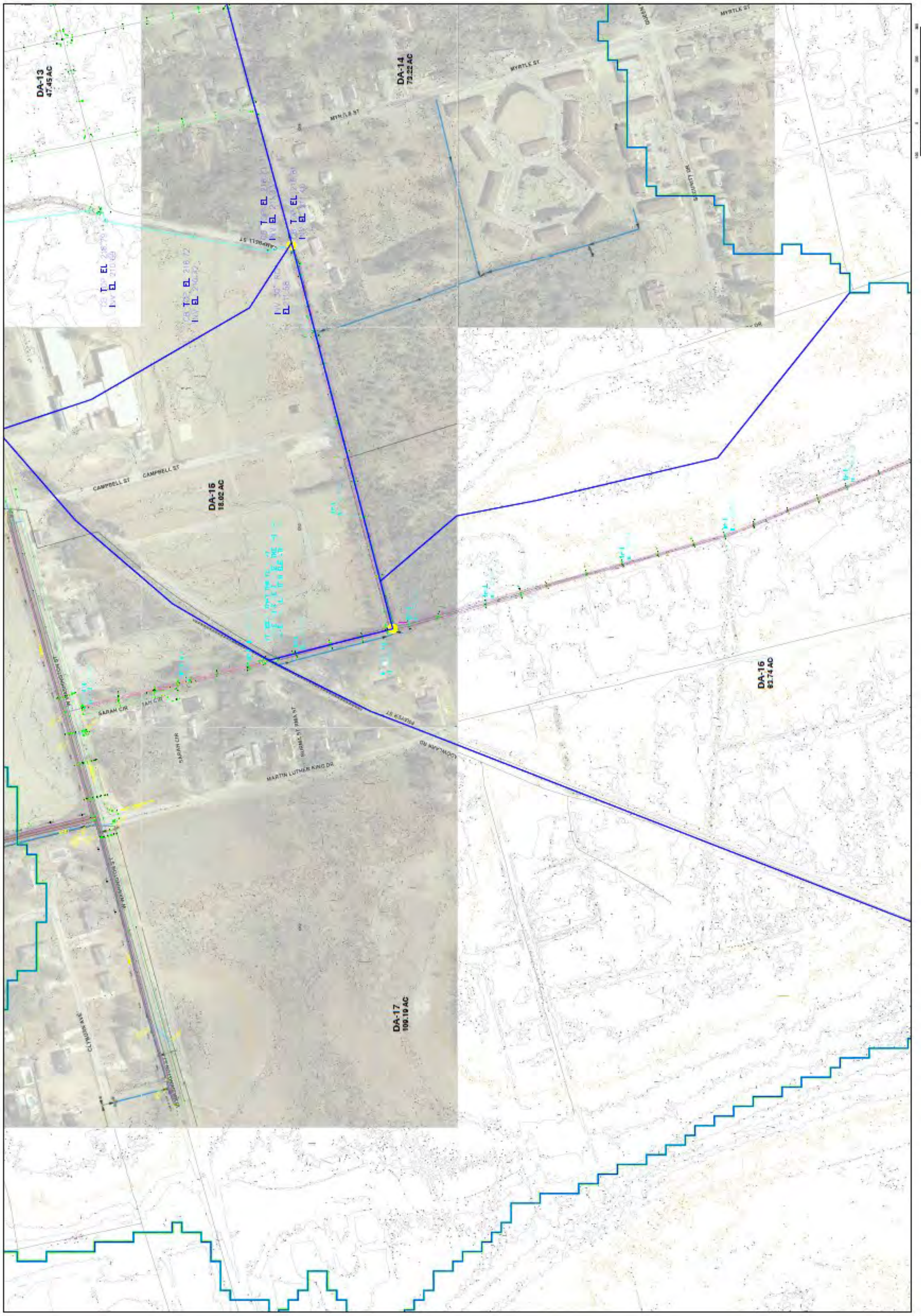
DA-15
18.02 AC


DA-13
47.45 AC
DA-14
72.22 AC
DA-15
18.02 AC
DA-16
82.74 AC
DA-17
109.19 AC

APPENDIX C

HYDROLOGIC PARAMETERS
(Existing / Proposed)

- Rainfall Frequency Data
- Soil Data

NOAA Atlas 14, Volume 2, Version 3
Location name: Hartsville, South Carolina, USA*
Latitude: 34.3692°, Longitude: -80.0705°
Elevation: 215.06 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

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

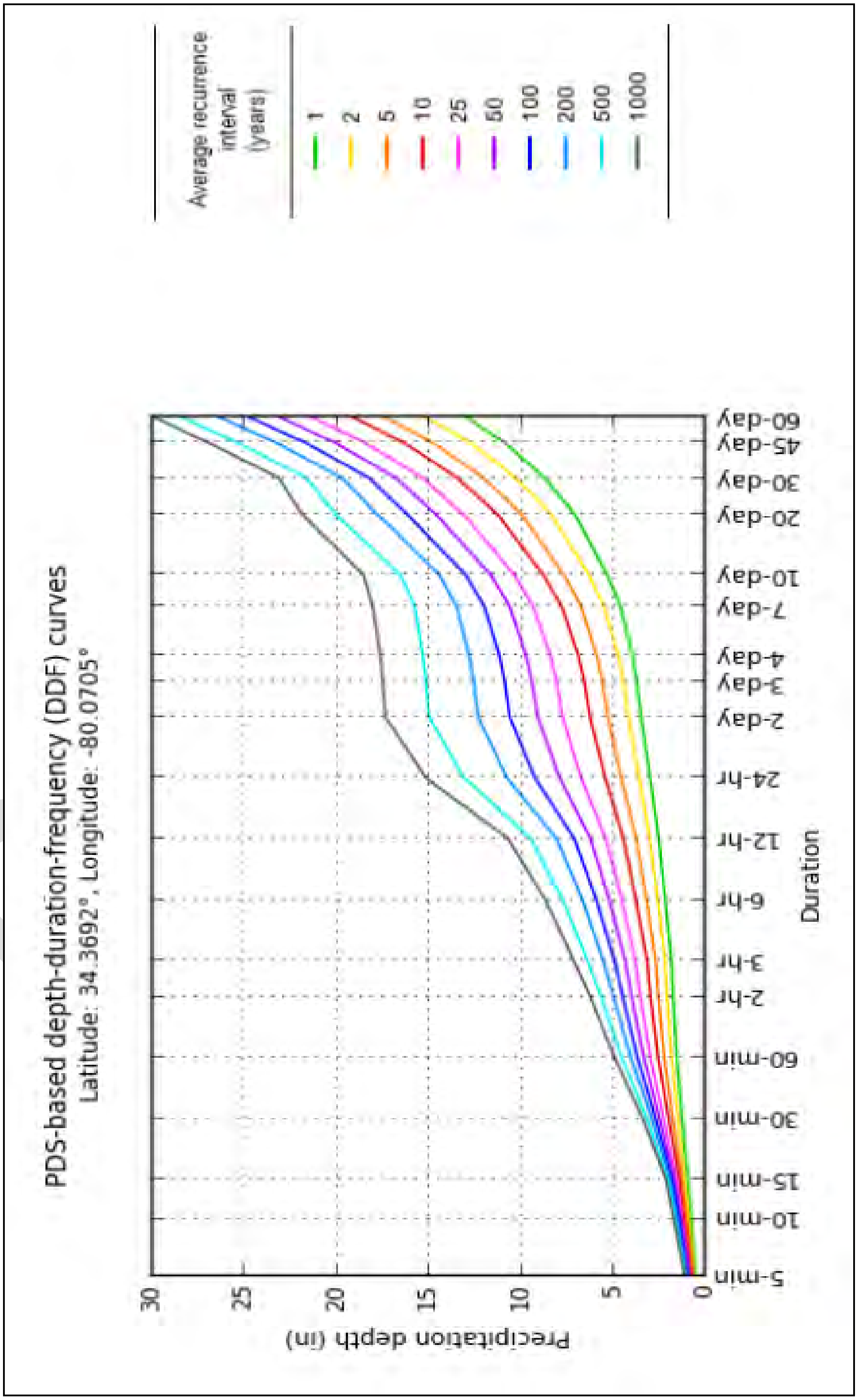
NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

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

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.432 (0.398-0.469)	0.504 (0.464-0.546)	0.583 (0.535-0.632)	0.652 (0.598-0.706)	0.731 (0.668-0.790)	0.794 (0.723-0.858)	0.853 (0.772-0.921)	0.910 (0.819-0.983)	0.979 (0.874-1.06)	1.04 (0.919-1.13)
10-min	0.689 (0.636-0.748)	0.806 (0.742-0.874)	0.934 (0.858-1.01)	1.04 (0.957-1.13)	1.17 (1.07-1.26)	1.26 (1.15-1.37)	1.36 (1.23-1.46)	1.44 (1.30-1.56)	1.55 (1.38-1.68)	1.64 (1.45-1.77)
15-min	0.862 (0.794-0.935)	1.01 (0.932-1.10)	1.18 (1.09-1.28)	1.32 (1.21-1.43)	1.48 (1.35-1.60)	1.60 (1.46-1.73)	1.71 (1.55-1.85)	1.82 (1.64-1.97)	1.95 (1.74-2.11)	2.05 (1.82-2.23)
30-min	1.18 (1.09-1.28)	1.40 (1.29-1.52)	1.68 (1.54-1.82)	1.91 (1.75-2.07)	2.19 (2.00-2.36)	2.41 (2.19-2.61)	2.63 (2.38-2.83)	2.83 (2.55-3.06)	3.10 (2.77-3.36)	3.32 (2.94-3.60)
60-min	1.47 (1.36-1.60)	1.76 (1.62-1.90)	2.15 (1.98-2.33)	2.49 (2.28-2.69)	2.91 (2.66-3.15)	3.27 (2.97-3.53)	3.62 (3.27-3.90)	3.97 (3.58-4.29)	4.45 (3.97-4.82)	4.85 (4.30-5.26)
2-hr	1.67 (1.54-1.82)	2.00 (1.84-2.18)	2.48 (2.28-2.70)	2.91 (2.66-3.16)	3.46 (3.16-3.75)	3.93 (3.57-4.26)	4.41 (3.98-4.77)	4.91 (4.40-5.31)	5.58 (4.95-6.04)	6.16 (5.41-6.68)
3-hr	1.76 (1.61-1.94)	2.11 (1.93-2.32)	2.63 (2.40-2.88)	3.10 (2.83-3.40)	3.73 (3.38-4.08)	4.28 (3.86-4.67)	4.85 (4.34-5.28)	5.46 (4.84-5.94)	6.31 (5.53-6.88)	7.06 (6.12-7.70)
6-hr	2.10 (1.92-2.32)	2.51 (2.30-2.77)	3.13 (2.86-3.44)	3.69 (3.36-4.06)	4.46 (4.03-4.89)	5.13 (4.61-5.61)	5.84 (5.20-6.37)	6.59 (5.82-7.18)	7.66 (6.68-8.35)	8.60 (7.41-9.39)
12-hr	2.46 (2.25-2.72)	2.95 (2.69-3.26)	3.68 (3.35-4.06)	4.37 (3.97-4.81)	5.31 (4.80-5.83)	6.15 (5.51-6.73)	7.04 (6.25-7.69)	8.00 (7.03-8.74)	9.38 (8.11-10.2)	10.6 (9.05-11.6)
24-hr	2.93 (2.71-3.18)	3.53 (3.27-3.83)	4.49 (4.16-4.88)	5.35 (4.93-5.81)	6.67 (6.09-7.25)	7.84 (7.10-8.53)	9.17 (8.19-10.0)	10.7 (9.41-11.7)	13.0 (11.2-14.4)	15.1 (12.8-16.8)
2-day	3.42 (3.19-3.72)	4.11 (3.83-4.47)	5.21 (4.84-5.67)	6.19 (5.72-6.72)	7.69 (7.04-8.36)	9.02 (8.18-9.84)	10.5 (9.43-11.5)	12.3 (10.8-13.5)	14.9 (12.8-16.6)	17.3 (14.6-19.5)
3-day	3.65 (3.41-3.95)	4.38 (4.09-4.74)	5.51 (5.12-5.96)	6.50 (6.02-7.03)	8.01 (7.36-8.68)	9.34 (8.49-10.1)	10.8 (9.74-11.8)	12.5 (11.1-13.7)	15.1 (13.1-16.8)	17.4 (14.9-19.5)



E.L. ROBINSON ENGINEERING

APPENDIX D
HYDROLOGIC AND HYDRAULIC MODEL RESULTS ON CD

- Marion Avenue System
- Tuskegee System
- Fourth Street System
- Ninth Street System

APPENDIX E
DRAINAGE QUESTIONNAIRE

HARTSVILLE
DRAINAGE STUDY

Water Drainage Survey

Please circle all that apply

(1) Do you live in an area affected by flooding? YES NO

(2) Are you concerned about flooding?
Not concerned Moderately concerned Greatly concerned

(3) Would you attend an information meeting on flooding? YES NO

(4) Do you own your own home? YES NO

(5) Would you consider implementing measures to reduce drainage from your property?
Please rate from 1-5 *(1 = highly unlikely 5 = highly likely)*
1 2 3 4 5

Rain barrel collection system

1 2 3 4 5

Grass and vegetated yard

1 2 3 4 5

(6) Would you be interested in getting more information about the benefits of these measures? YES NO

(7) Does it flood in your area more than two times per year? YES NO

(8) Do you have photos of recent flooding? YES NO

(9) Do you know locations of choke points (or clogs) in drainage system that might not be easily known? YES NO

(10) Gender: Male Female

(11) Education: Elemetary High School Some College College Grad Graduate Degree

(12) Age Group: Adult 19-25 Adult 26-34 Adult 35-54 Adult 55-64 65+

(13) What is your address or nearest Cross Street?______________________________

(14) What is your Zip Code? ____________________

If you would like to fill out this survey online Please go to:
www.HartsvilleDrainageProject.com