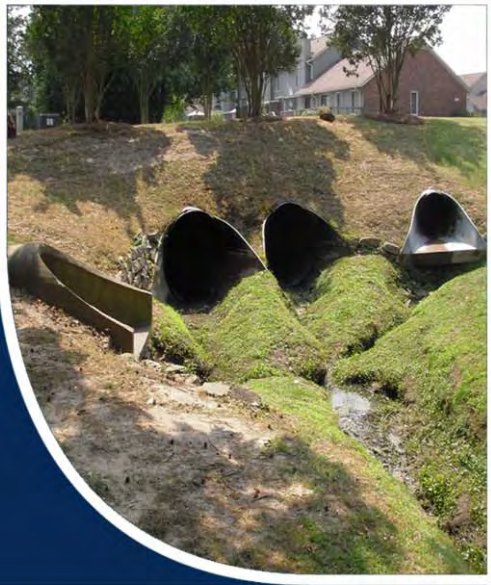
WK DICKSON
community infrastructure consultants

City of Greenville
Meetinghouse Branch Watershed Master Plan



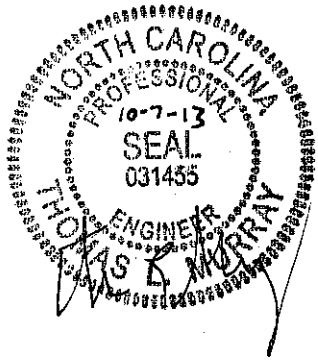
October 2013

CITY OF GREENVILLE

MEETINGHOUSE BRANCH WATERSHED MASTER PLAN

WKD # 20100174.00.RA

October 2013



Prepared for

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The City of Greenville has retained WK Dickson to complete a Master Plan for the Meetinghouse Branch and Bells Branch watersheds. The goals of this master plan include: (1) evaluate the watershed for existing flooding, water quality, and erosion problems, (2) recommend and prioritize capital improvements to control existing flooding by reducing the frequency and severity of flooding for property owners, and (3) identify stream stabilization projects to reduce the risk of property loss along streams and to reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, WK Dickson also completed a stormwater drainage infrastructure inventory for drainage structures and features within the Meetinghouse Branch and Bells Branch watersheds. Over 1,200 drainage structure and approximately 18 miles of drainage pipes were located and incorporated in a GIS database as part of this effort.

The project included a broad range of stakeholders to collect as much data, information and tacit knowledge of the watershed as feasible. The general public was solicited through questionnaires mailed to all property owners in the watershed and through an open house public meeting where residents and business owners were encouraged to provide feedback on stormwater issues in the watershed. Information collected from the questionnaires and public meeting can be found in Section 2.1 and Appendix D. As part of the Meetinghouse Branch Watershed Master Plan the City of Greenville also partnered with the Pamlico-Tar River Foundation (PTRF) and East Carolina University (ECU) to identify erosion and water quality problems in the Meetinghouse Branch Watershed and to develop potential solutions to those problems. The sharing of information between the City and PTRF resulted in cost savings for both organizations and continued partnering will enable the City to continue to leverage other revenue sources for the improvement of water quality throughout the Meetinghouse Branch watershed and overall city boundary. Pertinent sections of the PTRF report for the Meetinghouse Branch watershed are included in Appendix N. Finally City staff served as a critical stakeholder by providing valuable information on historical flooding and erosion problems in the watershed as well as providing feedback on potential capital improvements and the prioritization of those improvements.

The project watershed is approximately 3 square miles and is located in the eastern portion of Greenville just south of the Tar River. The watershed is generally bound by Charles Blvd to the west, Greenville Blvd and Red Banks Rd to the northwest and 10th St to the north. The Meetinghouse Branch watershed was selected by the City as the first watershed plan in the City as the stormwater issues in this watershed are generally representative of the stormwater issues citywide.

WK Dickson conducted an Existing Conditions Analysis in order to evaluate the existing hydrologic and hydraulic characteristics of the Meetinghouse Branch and Bells Branch watersheds. Noted in this report as the Primary System, Meetinghouse Branch and Bells Branch were hydraulically studied in detail based on historical flooding of residential areas and roadways. Furthermore, high storm flows have eroded channel banks over time causing impacts to private yards, fences, and other property improvements. In addition to the Primary Systems, select conveyance systems that drain to Meetinghouse Branch and Bells Branch were analyzed to determine if those systems met the desired City design requirements outlined in Section 1.2. Those Secondary Systems were identified based on feedback from public residents and City staff.

As a result of the Existing Conditions Analysis, multiple capital projects were identified to

reduce the severity and frequency of flooding, stabilize stream banks, and improve water quality through stormwater treatment practices. The proposed capital projects are as follows with the locations of each project shown in Figure ES-1:

Flood Control Projects

Bells Branch Primary System

East 14th Street – The 48″ corrugated metal pipe (CMP) culvert at this crossing is in poor condition and is providing between a 2- and 10-year level of service. Consequently, it is recommended that this culvert be replaced. The recommended alternative includes replacing the existing culvert with twin 42″ reinforced concrete pipe (RCP) and providing the desired 50-year level of service. Additional alternatives including floodplain benching were investigated at this location, but the other alternatives did not provide significant cost savings or increased benefits.

York Road/Railroad Crossing – The York Road and Railroad Crossing were combined into one project because the backwater caused by the railroad crossing impacts the York Road culvert. Therefore to maximize the effectiveness of the proposed project, both crossings should be addressed together.

The 60″ CMP at York road provides between a 2-year and 10-year level of service. The 60″ RCP located at the railroad provides a 25-year level of service. The desired level of service for York Road and the railroad are the 25-year and 100-year storms respectively. Alternative 1 for this location would include replacing the existing culvert at York Road with a 72″ RCP and providing no improvements at the railroad. The 10-year level of service would be provided at York Road and the railroad would continue to operate at a 25-year level of service.

Alternative 2 for this location would include replacing the existing culvert at York Road with a 72″ RCP and installing a 36″ steel floodplain culvert at the railroad crossing with the existing culvert to remain in place. To maintain rail service for the duration of the project, it is assumed the floodplain culvert would be installed using tunneling techniques such as jack and bore. This alternative would provide a 25-year level of service at York Road and a 100-year level of service at the railroad. Additionally this alternative would provide additional flood protection to floodprone residences along York Road and Glenn Court that have reported finished floor flooding in the past.

Oxford Road – The closed system located at the downstream end of Bells Branch is undersized. It is currently operating below a 2-year level of service. Portions of the system are in poor condition requiring the City to perform frequent maintenance due to the formation of sinkholes in the right-of-way. Until the system is replaced the potential for sinkhole formation will remain which will result in a public safety hazard to motorists and residents in the area. It is proposed that the existing 60″ CMP be replaced with 7′ x 5′ reinforced concrete box culvert (RCBC) to provide the desired 10-year level of service.

Meetinghouse Branch Primary System

Charles Boulevard – The twin 48″ CMP at this crossing is in good condition and is currently providing a 25-year level of service. Since Charles Boulevard is a major thoroughfare the

desired level of service is the 50-year storm, however construction of a larger culvert at this location would be difficult due to the high traffic volume at this location. Alternative 1 is a no action option with monitoring of flood conditions during significant storm events. While the desired level of service would not be met, City funds could be reallocated to other areas with more significant flooding issues.

Alternative 2 includes installation of two additional 48″ floodplain culverts. To provide a 50-year level of service at the crossing and to significantly reduce water surface elevations in the Colindale Court Townhomes located immediately upstream of the culverts. In existing conditions 7 townhomes at this location are potentially floodprone during the 25-year storm event and over 50 townhomes/apartments are at risk of flooding during the 100-year event. At a minimum the parking areas are likely flooded on a frequent basis. The proposed Alternative 2 improvements would decrease flood elevations upstream of the culvert in excess of 1 foot during the 25-year storm.

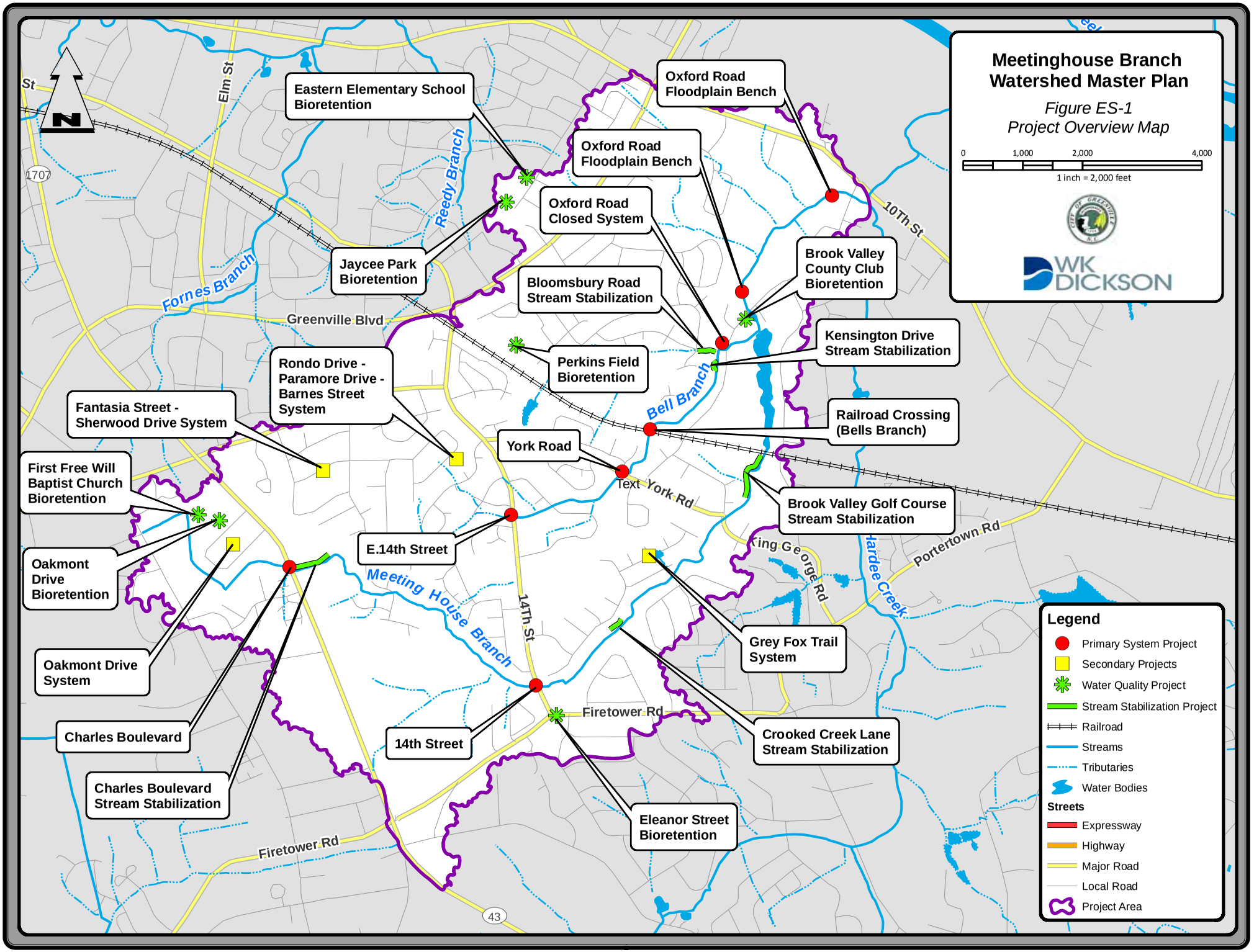
Tucker Drive – The 60″ and 72″ CMP at this crossing is in good condition with the exception that the 60″ culvert is approximately 50% filled with sediment. If the culvert is cleaned out then Tucker Drive crossing would provide a 25-year level of service. Therefore, no capital improvements at this location are proposed.

14th Street – The twin 60″ CMP at this crossing is currently providing less than a 2-year level of service and is in poor condition. Consequently, it is recommended that this culvert be replaced. The desired level of service at this location is the 50-year storm, however due to high flows, limited space, and existing erosion concerns downstream the proposed alternatives both provide a 25-year level of service which will significantly reduce flooding at this location.

Alternative 1 includes replacing the existing culvert with twin 11′ x 6′ RCBC. This is a significant increase in the capacity of the culvert which could be a concern since there are existing erosion issues downstream. Alternative 2 was developed to minimize the proposed culvert size to the extent possible while still providing a 25-year level of service. To reduce the culvert size, the tailwater at 14th Street will be lowered by grading floodplain benches downstream of 14th Street in the right and left overbank for approximately 1,300 feet. With the floodplain benches installed the proposed culvert for Alternative 2 is a twin 9′ x 5′ RCBC that would provide a 25-year level of service when built in conjunction with the floodplain bench. The size of the culvert for Alternative 2 is approximately 70% of the size of the proposed culvert for Alternative 1.

Oxford Road North – The existing bridge at the northern crossing along Oxford Road meets the desired 25-year level of service. However during a routine NCDOT inspection, several issues were identified. It is recommended that issues be resolved as outlined in the bridge inspection report (See Appendix L).

Upstream of the Oxford Road North crossing floodplain benching is recommended for Alternative 2 to offset water surface increases in the watershed as a result of increasing upstream conveyance. The proposed floodplain benches include approximately 800 linear feet of benching along the right bank immediately downstream of the Oxford Road South crossing and approximately 900 linear feet of benching along the left bank upstream of the Oxford Road North crossing.


Meetinghouse Branch
Watershed Master Plan
Figure ES-1
Project Overview Map
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1,000
2,000
4,000
1 inch = 2,000 feet
WK DICKSON
Eastern Elementary School Bioretention
Oxford Road Floodplain Bench
Oxford Road Floodplain Bench
Oxford Road Closed System
Jaycee Park Bioretention
Bloomsbury Road Stream Stabilization
Brook Valley County Club Bioretention
Kensington Drive Stream Stabilization
Perkins Field Bioretention
Rondo Drive - Paramore Drive - Barnes Street System
Fantasia Street - Sherwood Drive System
Railroad Crossing (Bells Branch)
York Road
First Free Will Baptist Church Bioretention
Brook Valley Golf Course Stream Stabilization
E.14th Street
Oakmont Drive Bioretention
Grey Fox Trail System
Oakmont Drive System
Crooked Creek Lane Stream Stabilization
Charles Boulevard
14th Street
Charles Boulevard Stream Stabilization
Eleanor Street Bioretention
Elm St
Reedy Branch
Fornes Branch
Greenville Blvd
Bell Branch
10Th St
Text York Rd
King George Rd
Portertown Rd
Hardee Creek
Meeting House Branch
14Th St
Firetower Rd
Firetower Rd
1707
43
Legend
Primary System Project
Secondary Projects
Water Quality Project
Stream Stabilization Project
Railroad
Streams
Tributaries
Water Bodies
Streets
Expressway
Highway
Major Road
Local Road
Project Area

Secondary Systems

Grey Fox Trail System – The majority of the system is operating below a 10-year level of service. Therefore, the proposed improvements include upsizing the existing pipe system along Grey Fox Trail to the outlet at Meetinghouse Branch. The proposed pipe improvements range in size from 24″ RCP to 36″ RCP.

Barnes Street – Paramore Drive – Rondo Drive System – The lower section of this system is performing at a 2-year level of service caused partially by backwater from Bells Branch. The improvements for this system focused on the portion of the system downstream of Paramore Drive to the outfall. The proposed improvements will provide a 10-year level of service taking into account the backwater from Bells Branch. Proposed pipe improvements range in size from 42″ RCP to 48″ RCP.

Fantasia Street – Sherwood Drive System – The existing conveyance system does not provide a 10-year level of service. A significant portion of the drainage system is currently located in backyards between Sonata Street and Rondo Drive. The proposed improvements will include new pipes and inlets along Sonata Street, Tucker Drive, and Fantasia Street to direct runoff to a conveyance system with City right-of-way which will more easily facilitate future maintenance of the system. Proposed pipe improvements range in size from 15″ RCP to 48″ RCP. In some locations with limited cover, twin 24″ RCP's are proposed.

Oakmont Drive System – This system is operating below a 2-year level of service. Local business owners have reported frequent flooding of parking lots and occasional finished floor flooding. The existing conveyance system is located in close proximity to businesses. Therefore the proposed pipe improvements ranging in size from 24″ RCP to 48″ RCP may require vertical trenching due to space constraints.

Flood Control Prioritization

To appropriately allocate City resources, the flood control projects listed above were prioritized based on the following categories as described in Appendix M:

- Public health and safety;
- Severity of street flooding
- Cost effectiveness
- Effect of improvements
- Water quality – BMP
- Open Channel – erosion control
- Implementation constraints
- Grant funding
- Constructability

Scores were assigned to each project for the factors listed above to determine the priority list. In some instances project prioritization will be impacted by the required sequencing of projects to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. While both alternatives are shown for some projects, it is acknowledged that only one of the two alternatives would need to be constructed. Once an alternative has been selected, the remaining alternative for the same project can be removed from

the prioritization list. Table ES-1 shows the proposed prioritizations and conceptual cost estimates for the Flood Control Improvements. The City should re-visit the prioritization lists annually to determine if the priorities should change. The prioritization scoring for each project and a description of the aforementioned categories is included in Appendix M. The total cost for Alternative 1 improvements and the secondary system improvements is approximately $7 Million. As noted above in some instances Alternative 1 does not result in the desired level of service. The total cost for Alternative 2 improvements and the secondary system improvements is approximately $8 Million. With the exception of 14th Street and Meetinghouse Branch the Alternative 2 improvements result in the desired level of service.

Table ES-1: Flood Control Prioritization

Prioritization	Project	Cost
1	Oxford Road Closed System (Bells Branch)	$1,423,000
2*	Oxford Road Floodplain Bench (Meetinghouse Branch) – Alternative #2	$559,000
3	York Road & Railroad Crossing (Bells Branch) - Alternative #2	$316,800
4	14th Street (Meetinghouse Branch) - Alternative #2	$1,476,300
5	York Road & Railroad Crossing (Bells Branch) - Alternative #1	$183,600
6	14th Street (Meetinghouse Branch) - Alternative #1	$576,600
7**	Eastwood Subdivision System	$2,158,500
8	Charles Boulevard (Meetinghouse Branch) - Alternative #2	$549,300
9	Oakmont Drive	$490,400
10	Grey Fox Trail	$848,500
11	East 14th Street (Bells Branch) - Alternative #1	$159,100
12	Fantasia Street - Sherwood Drive	$1,760,600
13	Barnes Street- Paramore Drive -Rondo Drive	$594,600

* The Oxford Road Floodplain Bench was initially ranked as the 6th highest priority project however the project needs to be constructed prior to the York Road & Railroad Crossing project to offset water surface increases caused by the proposed increase of flow capacity at the Railroad crossing.

**Eastwood Drainage System is located in the Project Watershed, but has been designed by others. The estimated project cost for the Eastwood Drainage System was provided by City staff.

Stream Stabilization and Water Quality Projects

During the Existing Conditions Analysis, the majority of streams were quantitatively assessed for stability. Based on this assessment five (5) stream stabilization projects were identified as shown in Figure ES-1. Potential components of the stabilization projects include, flattening the slope of the channel banks, installing erosion control matting and plantings, rock grade control structures, log grade control structures, retaining walls, and riprap. The stabilization projects will protect residential yards, fences, and structures from further erosion, and substantially decrease the instream sediment loads to downstream receiving waters.

In addition to the stream stability projects, water quality BMP retrofit projects were also identified. Potential project locations were initially identified using available GIS data by focusing on locations with contributing drainage areas that are highly impervious and ideally on publically owned land. Impervious areas typically generate the highest concentration of pollutants, so treating the runoff from these areas would provide more pollutant material than

treating water that carried fewer pollutants. Publically owned land is ideal for BMP retrofits to reduce or eliminate potential land acquisition costs. See Section 5.2 for additional evaluation criteria for BMP retrofit sites. Potential locations that were identified using GIS were then inspected to determine if the site conditions were conducive to a BMP. This inspection typically included verifying that GIS data and aerial photography were accurate and current and to determine if there were project constraints present that may not be visible from GIS data, such as utility conflicts, private property conflicts or limited access to the site. If possible, retrofit projects were located on public property to reduce any potential land acquisition costs.

The stream stabilization projects and water quality retrofit projects were prioritized using similar categories to the flood control projects as described above and are located in Appendix M. Cost effectiveness for stream stabilization projects was calculated based on a cost per linear foot of stabilized stream. Cost effectiveness for water quality retrofit projects was calculated based on a cost per impervious acre treated. Table ES-2 shows the prioritization of the Stream Stabilization and Water Quality projects along with preliminary cost estimates.

Table ES-2: Water Quality and Stream Stabilization Prioritization

Prioritization	Project	Cost
1	Charles Boulevard Stream Stabilization	$152,900
2	Perkins Field – Bioretention	$90,500
3	Eastern Elementary School – Bioretention	$80,200
4	Oakmont Drive – Bioretention	$41,200
5	Brook Valley Golf Course Stream Stabilization	$135,500
6	Bloomsbury Road Stream Stabilization	$59,500
7	Crooked Creek Road Stream Stabilization	$85,200
8	Jaycee Park - Bioretention	$151,100
9	Brook Valley Country Club – Bioretention	$55,500
10	Eleanor Street – Bioretention	$57,500
11	Kensington Drive Stream Stabilization	$174,200
12	Free First Baptist Church - Bioretention	$82,900

1.1 Project Description

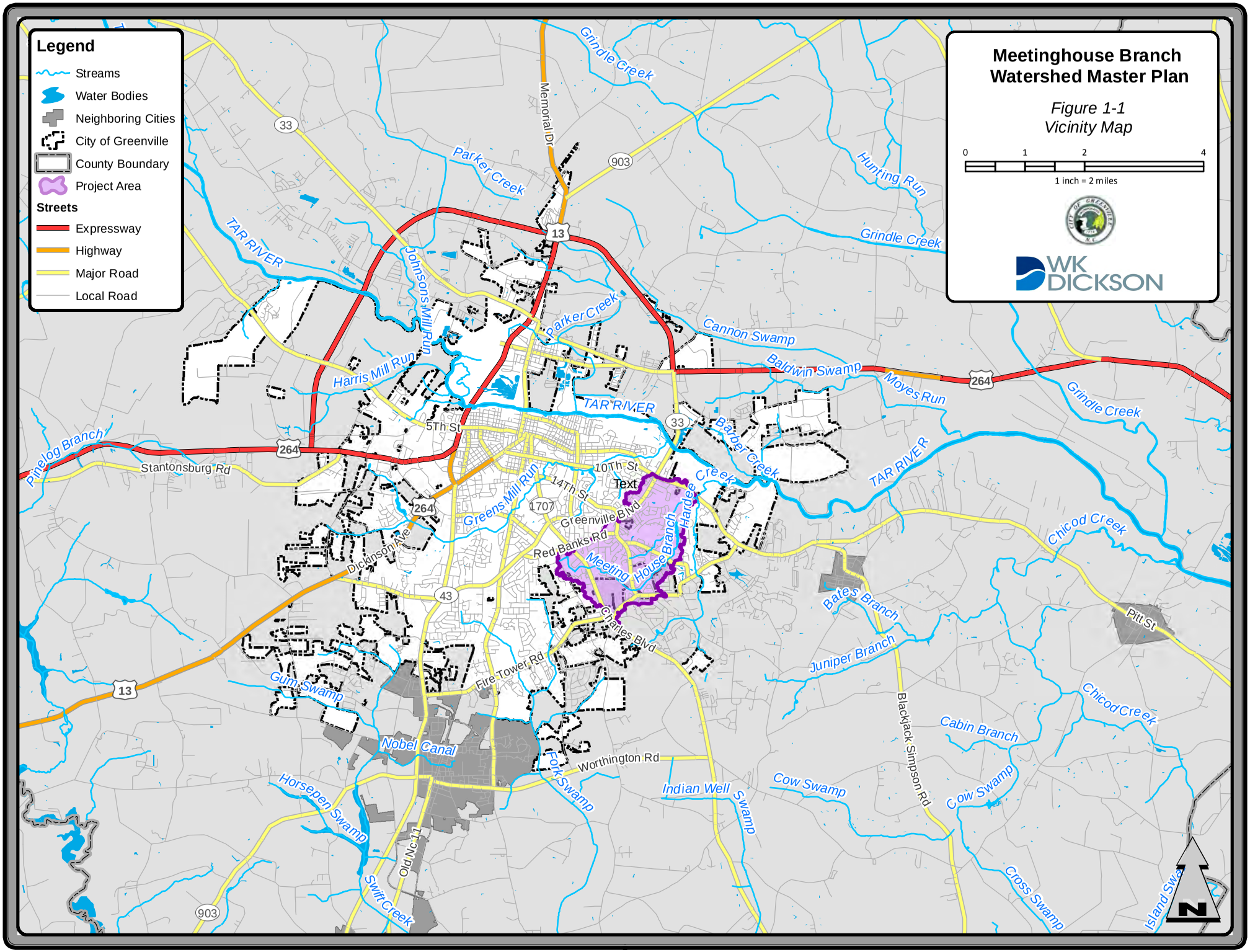
The City of Greenville has retained WK Dickson to complete a Watershed Master Plan for the Meetinghouse Branch and Bells Branch watersheds, collectively referred to as the Meetinghouse Branch Watershed. As shown in Figure 1-1, the Meetinghouse Branch Watershed is located in the western portion of Greenville and generally drains from south to north discharging to Hardee Creek and ultimately to the Tar River.

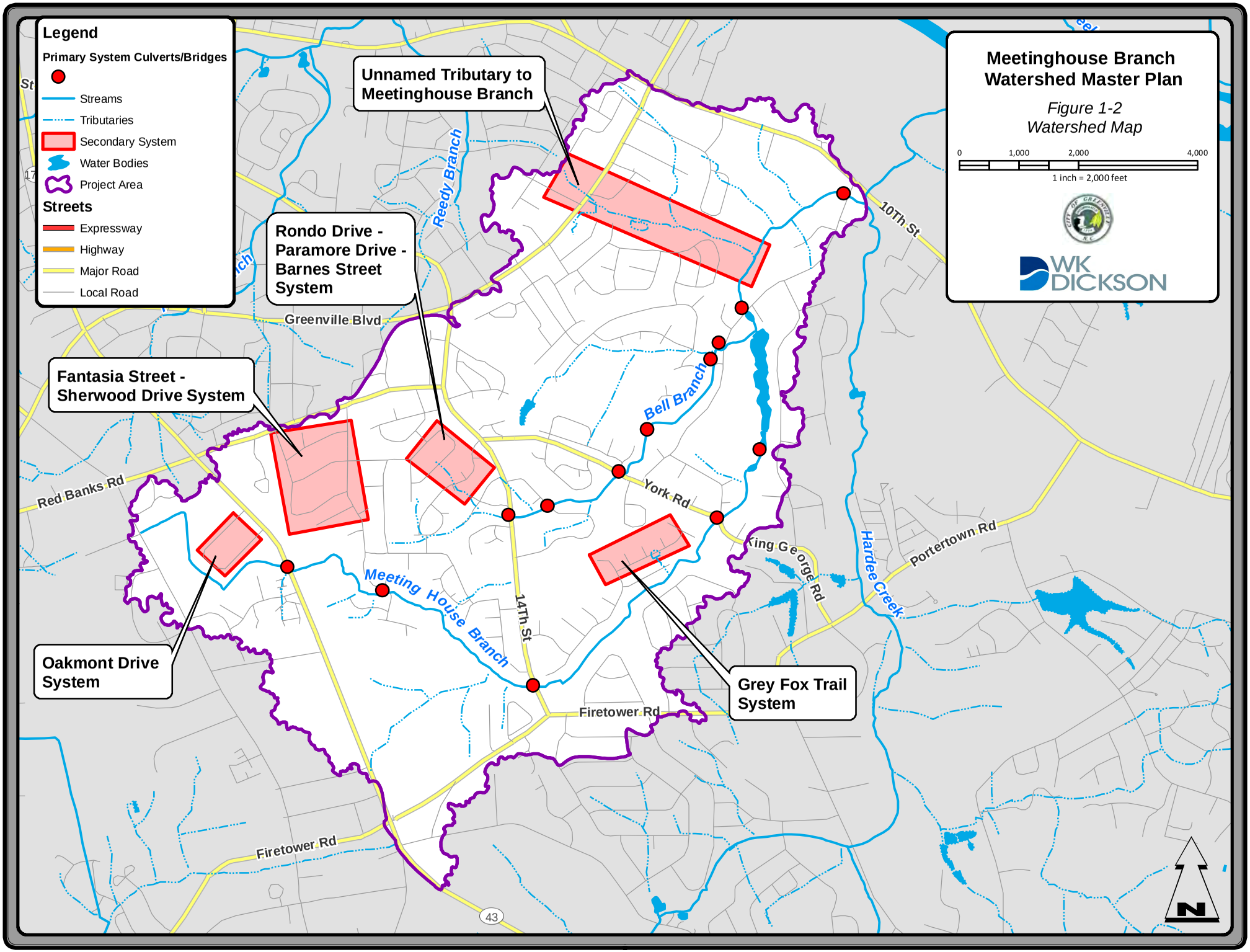
As noted in the Executive Summary the goals of this master plan include: (1) evaluate the watershed for existing flooding, water quality, and erosion problems, (2) recommend and prioritize capital improvements to control existing flooding by reducing the frequency and severity of flooding for property owners, and (3) identify stream stabilization projects to reduce the risk of property loss along streams and to reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, WK Dickson also completed a stormwater drainage infrastructure inventory for drainage structures and features within the Meetinghouse Branch and Bells Branch watersheds. The Master Plan includes an evaluation of Bells Branch from its confluence with Meetinghouse Branch at the downstream end to approximately 1,500 feet upstream of East 14th Street and Meetinghouse Branch from its confluence with Hardee Creek at the downstream end to approximately 1,300 feet upstream of Charles Boulevard, as well as several conveyance systems that drain to these two streams. For the purposes of this report, the main stems of Bells Branch and Meetinghouse Branch will be noted as primary systems and the conveyance systems that drain to them will be noted as secondary systems. A project area map showing the Meetinghouse Branch Watershed and the conveyance systems evaluated as part of this Master Plan is included as Figure 1-2. Detailed hydraulic analysis included the following:

- Primary System – Bells Branch
  - East 14th Street Culvert
  - Quail Ridge Road Culvert
  - York Road Culvert
  - Railroad Crossing Culvert
  - Kensington Drive Bridge
  - Oxford Road Closed System

- Primary System – Meetinghouse Branch
  - Charles Boulevard Culvert
  - Tucker Drive Culvert
  - 14th Street Culvert
  - King George Bridge
  - Railroad Crossing Bridge
  - Oxford Road South Bridge
  - Oxford Road North Bridge

- Secondary Systems
  - Unnamed Tributary to Meetinghouse Branch
  - Grey Fox Trail System
  - Rondo Drive – Paramore Drive – Barnes Street System
  - Fantasia Street – Sherwood Drive System
  - Oakmont Drive System


Legend
Streams
Water Bodies
Neighboring Cities
City of Greenville
County Boundary
Project Area
Streets
Expressway
Highway
Major Road
Local Road
Meetinghouse Branch
Watershed Master Plan
Figure 1-1
Vicinity Map
0
1
2
4
1 inch = 2 miles
WK DICKSON
Grindle Creek
Memorial Dr
Parker Creek
Hunting Run
TAR RIVER
Johnsons Mill Run
Harris Mill Run
Cannon Swamp
Baldwin Swamp
Moyes Run
5Th St
10Th St
14Th St
Text
Greens Mill Run
Greenville Blvd
Red Banks Rd
Meeting
House Branch
Hardee
Barber Creek
Pinelog Branch
Stantonsburg Rd
Dickinson Ave
Chicod Creek
Bates Branch
Pitt St
Juniper Branch
Blackjack Simpson Rd
Cabin Branch
Cow Swamp
Indian Well Swamp
Fire Tower Rd
Charles Blvd
Gum Swamp
Nobel Canal
Worthington Rd
Fork Swamp
Horsepen Swamp
Old Nc 11
Swift Creek
Cross Swamp
Island Swamp
33
903
13
264
43
1707
N


Legend
Primary System Culverts/Bridges
Streams
Tributaries
Secondary System
Water Bodies
Project Area
Streets
Expressway
Highway
Major Road
Local Road
Meetinghouse Branch Watershed Master Plan
Figure 1-2
Watershed Map
0
1,000
2,000
4,000
1 inch = 2,000 feet
WK DICKSON
Unnamed Tributary to Meetinghouse Branch
Rondo Drive - Paramore Drive - Barnes Street System
Fantasia Street - Sherwood Drive System
Oakmont Drive System
Grey Fox Trail System
Reedy Branch
Bell Branch
Meeting House Branch
Hardee Creek
Greenville Blvd
Red Banks Rd
York Rd
King George Rd
Portertown Rd
14Th St
10Th St
Firetower Rd
Firetower Rd
43
N

1.2 Design Standards and Criteria

The following design storms were used to evaluate the performance of the primary and secondary systems in this Master Plan:

- 10-year storm event – piped collection systems;
- 25-year storm event – non-thoroughfare roadway bridges and culverts;
- 50-year storm event – thoroughfare roadway bridges and culverts;
- 100-year storm event – structural flooding of homes; and
- 100-year storm event – overtopping of railroad.

Thoroughfare roadway crossings were identified based on the City's Thoroughfare Plan. Table 1-1 shows the applicable storm for the project areas evaluated as part of this Master Plan. The corresponding rainfall depths for the design storms are included in Appendix A.

Table 1-1: Project Area Design Standards and Criteria

Drainage Type	Desired Level of Service (Frequency Storm event)	Project Area
Piped Collection Systems	10	• Oxford Road Closed System • Grey Fox Trail System • Rondo Drive – Paramore Drive – Barnes Street System • Fantasia Street - Sherwood Drive System • Oakmont Drive System
Non-Thoroughfare Roadway Crossings	25	• Quail Ridge Road Culvert • York Road Culvert • Kensington Drive Bridge • Tucker Drive Culvert • King George Road Bridge • Oxford Road South Bridge • Oxford Road North Bridge
Thoroughfare Roadway Crossings	50	• East 14th Street Culvert • 14th Street Culvert • Charles Boulevard Culvert
Railroad Crossing	100	• Bells Branch – Culvert • Meetinghouse Branch – Bridge

2.1 Citizen Input

The Master Plan included a citizen input component to solicit feedback and information regarding stormwater impacts and the future of stormwater management in the City. In April of 2011, the City mailed out approximately 3,600 questionnaires related to stormwater management to all property owners within the Meetinghouse Branch Watershed. Approximately 5% (169) of questionnaires were completed and returned to the City for consideration. The questionnaire results were georeferenced according to the address of the questionnaire respondent (See Figures 2-1 and 2-2). Approximately 15 percent of the responses indicated some level of property flooding, with 9 property owners experiencing living space flooding at least once per year. Approximately 30 percent of the completed questionnaires noted yard flooding and another 15 percent noted street flooding. The majority of the respondents, over 50 percent reported that they were not experiencing any type of flooding. A total of 59 residents reported erosion threatening either streets, yards, garages, or fences. Of the 59 reports or erosion, 51 indicated yard erosion. See Figure 2-2 for locations of reported erosion. A sample questionnaire and the tabulated results are provided in Appendix D.

On April 19th, 2011, the City provided another avenue for obtaining citizen input by holding a public meeting. An open house format allowed property owners to attend at their convenience, and speak to City Staff or representatives from WK Dickson. Sixteen residents from the watershed attended the meeting. Minutes from this meeting are included in Appendix D.

The results and comments from the citizen's input contributed significantly to the identification and prioritization of problem areas, and the validation of model results.

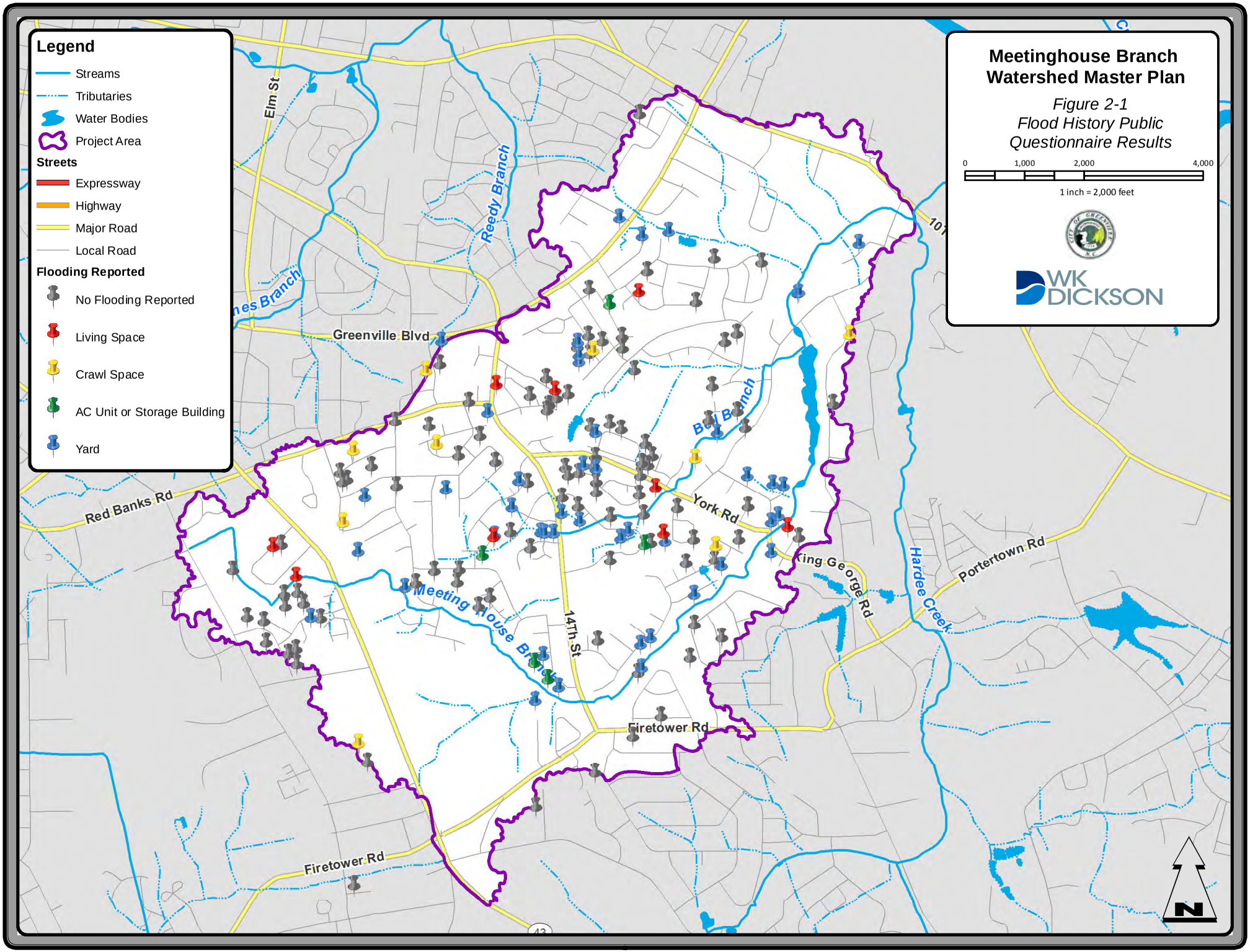
2.2 Watershed Characteristics

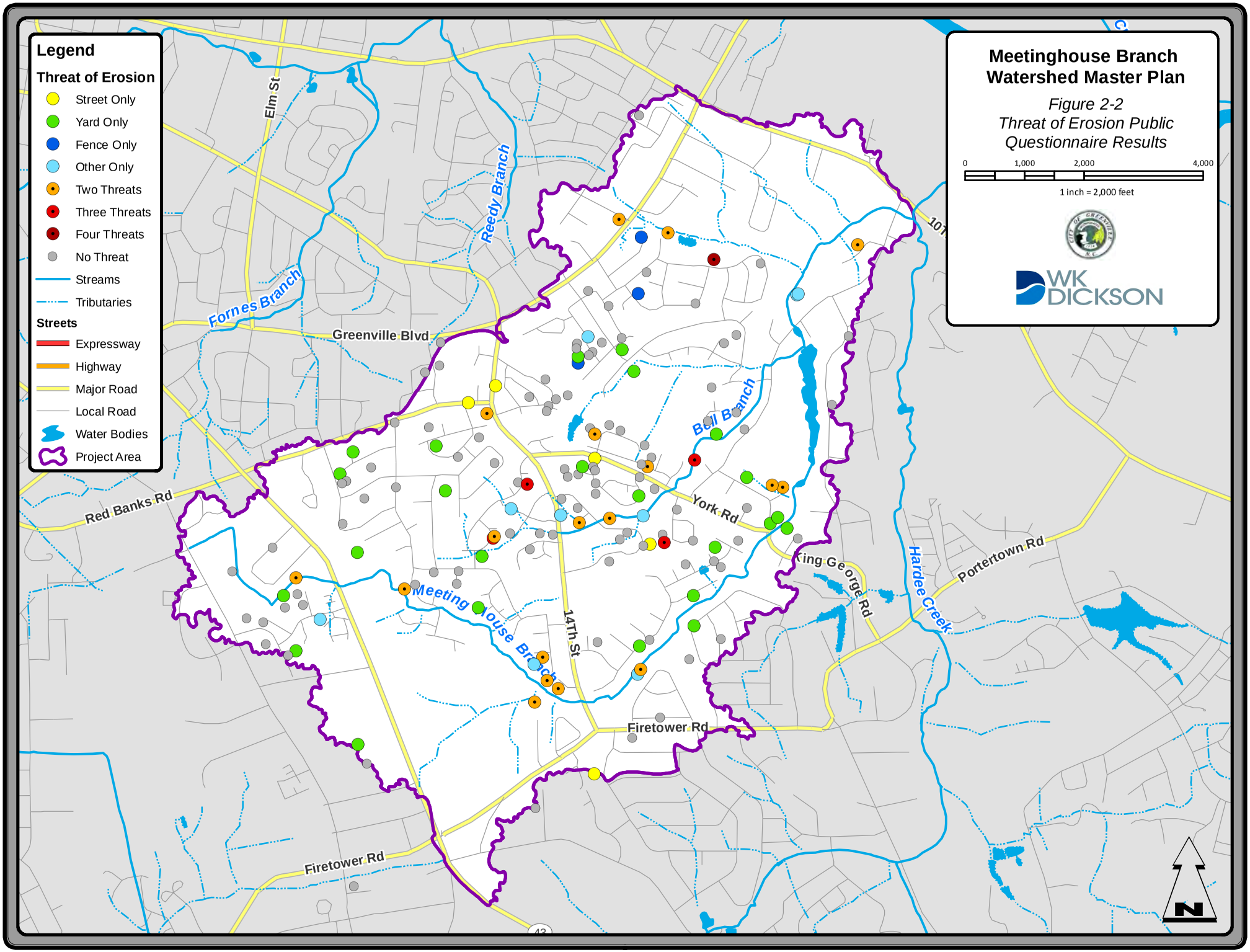
The Meetinghouse Branch Watershed is approximately 1,920 acres (3.0 square miles) between its downstream boundary along East 10th Street and its upstream boundary in the vicinity of East Arlington Boulevard. Land use in the watershed is over 90 percent built out as shown on the Existing Conditions Land Use Map included in Appendix C. The existing land use in the watershed is primarily residential with a small percentage of commercial, office, and agricultural (See Table 2-1). For the purposes of this Master Plan, the future conditions land use is assumed to be the same as the existing conditions land use since it is largely built out.

Table 2-1: Meetinghouse Branch Watershed Existing Land Use

Land Use Category	Area (acres)
Commercial	79
Conservation/Open Space	151
Low Density Residential	251
Medium Density Residential	685
High Density Residential	188
Office/Institutional/Multifamily	268
Row Crops	206
Right-of-Way	92

The soils within the watershed are predominately NRCS hydrologic soils groups A and C as shown on the Soils Map included in Appendix C. More detailed information about the land use and soils in the Meetinghouse Branch Watershed is contained in Appendix A.


Legend
Streams
Tributaries
Water Bodies
Project Area
Streets
Expressway
Highway
Major Road
Local Road
Flooding Reported
No Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Meetinghouse Branch Watershed Master Plan
Figure 2-1
Flood History Public Questionnaire Results
0
1,000
2,000
4,000
1 inch = 2,000 feet
WK DICKSON
Elm St
Reedy Branch
Greenville Blvd
Bell Branch
Red Banks Rd
York Rd
King George Rd
Portertown Rd
Hardee Creek
Meeting House Branch
14Th St
Firetower Rd
Firetower Rd
N


Legend
Threat of Erosion
Street Only
Yard Only
Fence Only
Other Only
Two Threats
Three Threats
Four Threats
No Threat
Streams
Tributaries
Streets
Expressway
Highway
Major Road
Local Road
Water Bodies
Project Area
Meetinghouse Branch
Watershed Master Plan
Figure 2-2
Threat of Erosion Public
Questionnaire Results
0
1,000
2,000
4,000
1 inch = 2,000 feet
WK DICKSON
Elm St
Reedy Branch
Fornes Branch
Greenville Blvd
Bull Branch
York Rd
Red Banks Rd
King George Rd
Portertown Rd
Hardee Creek
Meeting House Branch
14Th St
Firetower Rd
Firetower Rd
43
N

2.3 Existing Conditions Survey and Field Data Collection

For the Meetinghouse Branch Watershed Master Plan, stormwater utility infrastructure throughout the watershed was collected by WK Dickson personnel to compile a Geographic Information System (GIS) stormwater inventory database for the City. This was accomplished by using Global Positioning Systems (GPS) as the primary means of data capture. WK Dickson employed survey grade GPS to locate the x, y, and z coordinates of each visible stormwater system structure and conventional surveying techniques to obtain other attributes including but not limited to size, material, slope, and length. The data was collected using horizontal datum NAD 1983 and vertical datum NAVD 1988. A total of 1,233 closed system structures and 95,936 linear feet of pipe were collected as part of the inventory. Tables 2-2 and 2-3 summarizes the inventory collected in the Meetinghouse Branch Watershed.

Table 2-2: Inventory Summary – Closed System Structures

Structure Type	Number Surveyed
Yard Inlet	148
Drop Inlet	34
Junction Pipe	79
Pipe End	273
Pond Structure	2
Chimney Top	44
Catch Basin	628
Underground Pipe Junction	25

Table 2-3: Inventory Summary – Pipes

Size	Length (Linear Feet)
12″ Diameter	2,126
15″ Diameter	19,743
18″ Diameter	23,936
24″ Diameter	26,040
30″ Diameter	12,205
36″ Diameter	5,580
42″ Diameter	2,267
48″ Diameter	1,972
54″ Diameter	874
60″ Diameter	1,109
72″ Diameter	84

Data was obtained for those open channels required to complete connectivity for modeling purposes. Attributes such as shape, lining type, bed type, flow, bottom width, top width, and bank heights were collected for 143 open channel sections totaling over 10.5 miles in length. For those sections of open channel where more detailed information was required for model input, cross sections were surveyed. Data including elevations for the top of bank, bottom of bank, and channel centerline was obtained at 42 cross sections throughout the Meetinghouse Branch Watershed. Five bridges were also included in the inventory. Refer to the City of Greenville Storm Water System Inventory Standard Operating Procedures for additional details on the processes and details of the inventory database.

3.1 Primary System Hydrologic and Hydraulic Analyses

3.1.1 Hydrology

The purpose of the hydrologic analysis is to estimate the magnitude of selected frequency floods for the Meetinghouse Branch Watershed. The United States Army Corps of Engineers (USACE) HEC-HMS was selected to model the primary systems. HEC-HMS simulates the surface runoff response to precipitation for an interconnected system of surfaces, channels, and ponds. Input data for the HEC-HMS model was developed using topographic, land use, and soils maps in GIS to delineate and calculate the basin areas and Natural Resources Conservation Service (NRCS) hydrologic parameters. Detailed descriptions of the model parameters can be found in Appendices A and B.

The HEC-HMS model offers a variety of methods for simulating the rainfall-runoff response, hydrograph development, channel and pond routing. The selection of methods for the analyses is based on the study objectives, data availability, and watershed characteristics. The precipitation data for the 24-hour duration, Type III storm was used to represent the synthetic rainfall event. The Type III storm was selected based on the location of the City of Greenville. The geographic boundaries for the different NRCS rainfall distributions are shown on Figure B-2 of NRCS document Urban Hydrology for Small Watersheds, dated June 1986 and commonly referred to as TR-55 (See Appendix A). As shown in TR-55 for the coastal regions of North Carolina including Greenville, a Type III storm is more characteristic. The NRCS curve number approach was selected to calculate runoff volumes from the precipitation data, and the sub-basin unit hydrographs for these flood volumes were developed using the NRCS lag times.

Peak flows for the primary systems were developed for the 2-, 10-, 25-, 50-, and 100-year storm events. The existing conditions flows were developed assuming attenuation occurs at the following locations:

- Bells Branch
  - East 14th Street
  - Quail Ridge Road
  - York Road
  - Railroad Crossing
- Meetinghouse Branch
  - 14th Street
  - Brook Valley Country Club pond

Storage routing was modeled just upstream of the culverts listed above because of the large storage volume available behind the pipe's entrance. The culverts that have not been included provide little to no accessible storage volume in the area upstream of its respective crossing. The pond located at the Brook Valley Country Club provided significant storage capacity therefore; attenuation was also modeled at this location. The results of the hydrologic model used as input for HEC-RAS are summarized in Table 3-1. A hard copy of the HEC-HMS output is included as Appendix H. The CD found in Appendix J contains this digital information.

Table 3-1: Existing Conditions Flows from HEC-HMS

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
BELLS BRANCH							
BB – 1	U/S Limit of Bells Branch	11194	30	59	80	98	118
14th St – BB	14th Street	9780	45	109	149	183	220
Quail Ridge Rd	Quail Ridge Road	9132	50	138	189	230	271
York Road	York Road	7435	77	181	230	264	360
Railroad Crossing	Railroad Culvert	6760	81	188	232	259	295
ADD – 14	Kensington Drive	4687	113	272	367	438	517
MEETINGHOUSE BRANCH							
MHB-1	U/S Limit of Meetinghouse Branch	14470	48	83	108	129	152
ADD – 1_2	Charles Boulevard	13233	76	132	170	204	241
ADD – 3	Tucker Drive	11180	146	259	339	408	484
ADD – 7	King George Road	3507	309	583	772	937	1,119
ADD – 8	Railroad Bridge	2045	327	635	854	1,048	1,263
ADD – 15	Oxford Road	-532	508	1,143	1,570	1,935	2,351
OUTLET	D/S Limit of Meetinghouse Branch	-3630	484	1,124	1,552	1,914	2,331

3.1.2 Hydraulics

The purpose of the hydraulic analysis is to determine an existing level of flooding for the storm drainage network and to develop proposed solutions to mitigate flooding. The USACE HEC-RAS was selected to model the primary systems to remain consistent with the existing FEMA modeling. HEC-RAS calculates water surface profiles for steady, gradually varied flow in channels and floodplains. The standard backwater analysis for sub-critical flow was modeled for the Meetinghouse Branch Watershed. The model calculates the effect of obstructions, such as culverts, and building structures in the channel and floodplain on the water surface profile. The hydraulic computations are based on the solution of a one-dimensional energy equation with energy loss due to friction evaluated by Manning's equation. Input data for HEC-RAS include the following:

- Cross-section geometry of the channel and floodplain;
- Roughness coefficients to describe characteristics of the channel and floodplain;
- Size, shape, and characteristics of culverts and roadways along the stream reach; and
- Energy loss coefficients for flow in the channel and at roadway crossings.

Channel cross sections utilized in the HEC-RAS model were based on the existing FEMA cross sections and WK Dickson surveyed cross sections. The channel cross sections were merged with North Carolina State LiDAR data (2007) to develop cross sections spanning the entire floodplain area.

The starting water surface elevations for the HEC-RAS models were calculated using the slope-area method. They are as follows:

- 0.003 feet/feet for Bells Branch; and
- 0.008 feet/feet for Meetinghouse Branch.

Hydraulic Performance

Thirteen roadway crossings were analyzed for flooding potential for the primary system. Six were located along Bells Branch while the remaining seven were located along Meetinghouse Branch. Descriptions of the existing primary system crossings analyzed are summarized in Table 3-2. Pictures 3-1 through 3-12 of this report provide a visual image of the primary system crossings.

Table 3-2: Existing Condition of Primary System Crossings

Location	Size/Material	Condition
Bells Branch		
East 14th Street	48″ CMP	Poor – Pipe Collapsed with Rusted Invert
Quail Ridge Road	Twin 54″ CMP	Fair
York Road	60″ CMP	Fair
Railroad Crossing	60″ RCP	Fair – Misaligned Joints with Visible Rebar
Kensington Drive	Precast Girder Bridge	Fair/Good
Oxford Road	60″ CMP	Poor – Rusted Bottom and Sinkholes Developing
Meetinghouse Branch		
Charles Boulevard	Twin 48″ RCP	Good
Tucker Drive	60″ CMP and 72″ CMP	Good – 60″ CMP Partially Obstructed by Sediment
14th Street	Twin 60″ CMP	Poor – Pipe Crushed at Invert
King George Road	Precast Girder Bridge	Poor
Railroad Crossing	Trestle Bridge	Fair
Oxford Road South	Precast Arch Bridge	Good
Oxford Road North	Precast Girder Bridge	Fair

Picture 3-1. Bells Branch: East 14th Street – Downstream Pipe

Picture 3-2. Bells Branch: Quail Ridge Road – Downstream Pipe

Picture 3-3. Bells Branch: York Road – Downstream Pipe

Picture 3-4. Bells Branch: Railroad Crossing – Upstream Pipe

Picture 3-5. Bells Branch: Kensington Drive Bridge – Downstream Face

Picture 3-6. Bells Branch: Oxford Road Closed System – Upstream Pipe

Picture 3-7. Meetinghouse Branch: Charles Boulevard – Upstream Face

Picture 3-8. Meetinghouse Branch: Tucker Drive – Downstream Pipe (Right Side Looking Downstream)

Picture 3-9. Meetinghouse Branch: 14th Street Culvert – Upstream Face (Right Side Looking Downstream)

Picture 3-10. Meetinghouse Branch: King George Road Bridge – Downstream Face

Picture 3-11. Meetinghouse Branch: Oxford Road South – Upstream Face

Picture 3-12. Meetinghouse Branch: Oxford Road North– Upstream Face

The 2-, 10-, 25-, 50- and 100-year existing conditions flood elevations for the primary system crossings are identified in Table 3-3. The minimum elevations at the top of the road for each crossing are also listed in Table 3-3. Along Bells Branch, two out of the six crossings are meeting its desired level of service. East 14th Street, York Road, the railroad crossing and Oxford Road do not meet the desired level of service as shown in Table 3-3. East 14th Street and Oxford Road both currently have a 2-year level of service. The desired level of service for East 14th Street and Oxford Road are the 50-year and 10-year storms, respectively. York Road is located immediately upstream of the railroad crossing. Currently York Road provides a 2-year level of service and the railroad provides a 50-year level of service. The desired level of service for York Road and the railroad are the 25-year and 100-year storms, respectively.

Along Meetinghouse Branch, four out of the seven crossings are meeting its desired level of service. Charles Boulevard and 14th Street are desired to meet a 50-year level of service. As shown in Table 3-3, 14th Street is not providing a 2-year level of service while Charles Boulevard is providing a 25-year level of service. The desired level of service at Tucker Drive is the 25-year storm. Currently Tucker Drive provides a 10-year level of service. It should be

noted that the Tucker Drive culvert was modeled partially blocked since the opening of the 60" CMP is obstructed by sediment deposits.

Table 3-3: Hydraulic Performance for Existing Conditions Roadway Flooding

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Bells Branch							
East 14th Street (Culvert)	63.90	50-yr	62.59	**64.35**	**64.62**	**64.70**	**64.84**
Quail Ridge Road (Culvert)	62.75	25-yr	57.23	59.24	60.49	61.50	62.61
York Road (Culvert)	52.00	25-yr	47.80	**52.14**	**52.76**	**54.21**	**54.48**
Railroad Crossing (Culvert)	54.02	100-yr	42.97	46.51	51.52	**54.20**	**54.44**
Kensington Drive(Bridge)	33.70	25-yr	23.59	25.46	25.87	26.16	26.49
Oxford Road (Closed System)	24.04	10-yr	23.17	**24.91**	**25.12**	**25.30**	**25.51**
Meetinghouse Branch							
Charles Boulevard (Culvert)	68.00	50-yr	63.80	65.92	67.56	**68.16**	**68.31**
Tucker Drive (Culvert)	63.64	25-yr	59.97	62.26	**63.98**	**64.48**	**64.80**
14th Street (Culvert)	53.83	50-yr	**54.10**	**54.89**	**55.23**	**55.45**	**55.66**
King George Road (Bridge)	35.91	25-yr	33.16	34.62	35.69	**36.68**	**38.14**
Railroad Crossing (Bridge)	43.41	100-yr	32.22	32.71	33.01	33.25	33.52
Oxford Road South (3-Sided Arch Bridge)	25.96	25-yr	22.76	24.93	25.95	**26.77**	**27.50**
Oxford Road North (Bridge)	18.16	25-yr	12.68	14.45	15.51	16.82	**19.62**

*Bold text indicates the existing water surface has exceeded the crest or low point in the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

In addition to evaluating the roadway crossings, an evaluation was performed to determine the residences along Bells Branch and Meetinghouse Branch that are at risk of flooding during the 25- and 100-year storm event. The existing 25- and 100- year floodplains for Bells Branch and Meetinghouse Branch are shown in Figures 3-1 through 3-3. The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying individual property owners of the potential risk of flooding.

Tables 3-4 and 3-5 list the lowest adjacent grade elevations along with the existing 25- and 100-year water surface elevation for those properties that are at risk of flooding. The lowest adjacent grade (LAG) elevations shown in the table are not surveyed and are estimated based on the State of North Carolina's LiDAR data. LAG flooding shown below may not result in actual LAG or finished floor flooding, but it is indicative of structures being at risk of flooding.

Table 3-4: Existing Conditions At-Risk Properties/Structures – Bells Branch

Address	LAG	Calculated Water Surface Elevation (feet NAVD)	
		25-year flood	100-year flood
2100 Sir Raleigh Court	54.35	51.53	**54.44**
2101 Sir Raleigh Court	54.12	51.53	**54.44**
2103 Sir Raleigh Court	54.29	51.53	**54.44**
2201 Sir Raleigh Court	54.27	51.55	**54.46**
2203 Sir Raleigh Court	51.67	51.55	**54.46**
335 Glenn Court	46.53	**51.53**	**54.44**
412 Oxford Road	53.67	51.54	**54.45**
414 Oxford Road	49.25	**51.54**	**54.45**
500 Westchester Drive	53.52	52.76	**54.48**
1963-A Quail Ridge Road	52.86	**53.64**	**54.91**
1929-A Quail Ridge Road	56.00	**58.70**	**59.09**
1929-B Quail Ridge Road	56.00	**58.70**	**59.09**
1908-O Quail Ridge Road	61.72	60.49	**62.61**
1874-A Quail Ridge Road	61.76	60.49	**62.61**
1874-B Quail Ridge Road	61.59	60.49	**62.61**
1874-C Quail Ridge Road	61.55	60.61	**62.66**
1874-D Quail Ridge Road	61.26	60.72	**62.83**
1874-E Quail Ridge Road	60.99	60.72	**62.70**
1874-F Quail Ridge Road	60.61	**60.84**	**62.70**
1872-G Quail Ridge Road	62.01	61.18	**62.86**
2621 East 14th Street	62.00	61.64	**63.01**
1799 Scarborough Road	64.21	**64.62**	**64.84**
79 Barnes Street	65.29	64.95	**65.36**
80 Barnes Street	64.64	**64.95**	**65.36**
81 Barnes Street	64.33	**64.95**	**65.36**
82 Barnes Street	64.27	**64.95**	**65.36**
83 Barnes Street	64.49	**65.04**	**65.48**

*Bold text indicates LAG flooding.

As shown in Table 3-4, eleven (11) properties along Bells Branch were identified for being at risk of flooding in the 25-year storm event and, an additional sixteen (16) properties were identified for the 100-year event. Several of these residences submitted questionnaires indicating that they are experiencing yard flooding.

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard

- Primary System Crossings
- 100-Year FEMA Floodplain
- 500-Year FEMA Floodplain
- 25-Year Existing Floodplain
- 100-Year Existing Floodplain
- Basin Boundary

EX Closed System

EX Bridge

EX 60" RCP

EX 60" CMP

Limits of Detailed FEMA Study

EX 48" CMP

EX Twin 54" CMP

WILKSHIRE DR
MUIRFIELD DR
ADAMS BV
BLOOMSBURY RD
VAUXHALL CT
CARNOUSTIE DR
N THAMES CT
BLOOMSBURY RD
WESTMINSTER CI
KENSINGTON DR
PADDINGTON DR
Bells Branch
OXFORD RD
JUNIPER LN
BUXTON RD
TIFFANY DR
WELLONS DR
WESTMINSTER CT
BIG BEN DR
KING RICHARD CT
YORKSHIRE DR
KING LEAR CT
RED BUD CI
GLENN CT
SIR RALEIGH CT
HARNESS CT
RONDO DR
STIRRUP CT
BELLS ST
BROOKRIDGE CI
MCDONALD CT
KING GEORGE RD
PARAMORE DR
REINS CT
E 14TH ST
YORK RD
KENDALL CT
WESTCHESTER DR
SADDLE RIDGE PL
SURREY LN
SCARBOROUGH RD
QUAIL RIDGE RD
GREY FOX TR
Meetinghouse Branch

Meetinghouse Branch Watershed Master Plan

Figure 3-1
Bells Branch
Existing Conditions Floodplain

0 200 400 800

1 inch = 400 feet

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Table 3-5: Existing Conditions At-Risk Properties/Structures – Meetinghouse Branch

Address	LAG	Calculated Water Surface Elevation (feet NAVD)	
		25-year flood	100-year flood
102 Oxford Road	17.88	17.54	**20.35**
106 Christenbury Drive	18.26	**19.10**	**21.35**
206 Oxford Road	23.15	**23.53**	**24.87**
208 Oxford Road	21.94	**24.71**	**25.84**
104 Cheshire Drive	21.78	**25.13**	**26.30**
102 Cheshire Drive	22.65	**25.34**	**26.53**
216 Oxford Drive	23.28	**25.54**	**26.75**
109 Steward Lane	22.54	**25.95**	**27.46**
213 Steward Lane	23.81	**25.95**	**27.47**
226 York Road	32.12	**36.27**	**38.41**
2200 Saddle Ridge Road	36.18	**36.77**	**38.75**
3221 Old Oak Walk	38.39	**38.40**	**39.88**
3216 Old Oak Walk	38.07	**39.70**	**40.79**
3214 Old Oak Walk	40.24	39.94	**41.03**
3212 Old Oak Walk	40.71	40.18	**41.28**
3210 Old Oak Walk	39.47	**40.34**	**41.44**
3208 Old Oak Walk	39.90	**40.50**	**41.60**
3206 Old Oak Walk	40.79	40.50	**41.60**
600 Lancelot Drive	40.13	39.94	**41.03**
602 Lancelot Drive	39.18	**40.18**	**41.28**
700 Lancelot Drive	40.10	**40.50**	**41.60**
1802 Crooked Creek Road	52.43	**52.96**	**53.61**
106 Casual Circle	55.31	**56.43**	**57.24**
104 Casual Circle	55.75	**56.76**	**57.57**
1902 Tempo Court	60.43	**60.51**	**61.34**
3800 Tucker Drive	64.38	63.99	**64.85**
3719 Cancion Street	63.32	**63.99**	**64.85**
3717 Cancion Street	63.78	64.05	**64.93**
3715 Cancion Street	62.55	**64.10**	**65.00**
2700 Thackery Road Units 41 - 45	68.00	67.47	**68.30**
2700 Thackery Road Unit 40	67.25	**67.47**	**68.30**
2700 Thackery Road Unit 39	66.50	**67.47**	**68.30**
2700 Thackery Road Unit 38	66.49	**67.47**	**68.30**
2700 Thackery Road Units14 - 30	68.00	67.62	**68.40**
2700 Thackery Road Unit 31	66.30	**67.62**	**68.40**
2700 Thackery Road Unit 32	66.58	**67.62**	**68.40**
2700 Thackery Road Unit 33	67.34	**67.65**	**68.43**
2700 Thackery Road Units 34 - 36	68.00	67.65	**68.43**
140 Oakmont Drive	68.00	67.65	**68.43**

220 Cape Point Lane	68.04	67.65	**68.43**
222 Cape Point Lane	68.00	67.67	**68.45**
224 Cape Point Lane	68.00	67.69	**68.47**
225 Cape Point Lane	68.00	67.72	**68.49**
223 Cape Point Lane	68.03	67.74	**68.51**
221 Cape Point Lane	68.11	67.77	**68.54**
136 Oakmont Drive Units B4 - B7	68.32	67.72	**68.47**
136 Oakmont Drive Units A1 – A10	68.00	67.69	**68.47**
126-28 Oakmont Drive	68.29	67.88	**68.65**

*Bold text indicates LAG flooding.

As shown in Table 3-5, twenty-eight (28) properties along Meetinghouse Branch were identified for being at risk of flooding in the 25-year storm event and, an additional twenty (20) properties were identified for the 100-year event. Several of these residences submitted questionnaires indicating that they are experiencing structural and yard flooding.

As noted above, the lowest adjacent grade (LAG) elevations shown in the table are not surveyed and are estimated based on the State of North Carolina's LiDAR data. LAG flooding shown below may not result in actual LAG or finished floor flooding, but it is indicative of structures being at risk of flooding.

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard

- Primary System Crossings
- 100-Year FEMA Floodplain
- 500-Year FEMA Floodplain
- 25-Year Existing Floodplain
- 100-Year Existing Floodplain
- Basin Boundary

EX Twin 48" RCP

EX 72" CMP & 60" CMP

EX Twin 60" CMP

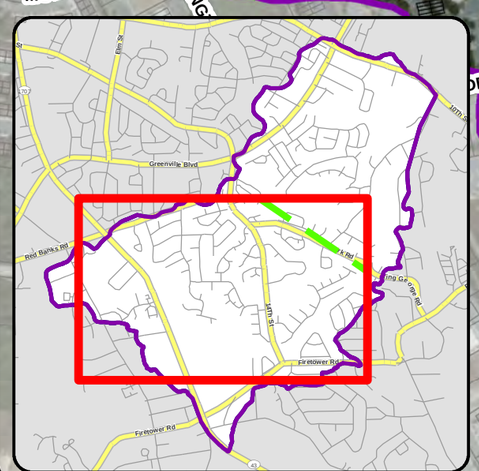
Limit of Detailed FEMA Study

Meetinghouse Branch

Bells Branch

Match Line

HOLLYBRIAR PL
HOLLYBRIAR LN
BAYTREE DR
SONATA ST
TUCKER DR
RONDO DR
EDWARDS CT
CADENZA CT
STIRRUP CT
TRACE CT
PARAMORE DR
REINS CT
BARNES ST
SCOTT ST
E 14TH ST
BIG BEN DR
BLOOMSBURY RD
KENSINGTON DR
PADDINGTON DR
OXFORD RD
YORKSHIRE DR
YORK RD
BELLS ST
BROOKRIDGE CI
GLENN CT
KING GEORGE RD
KENDALL CT
WESTCHESTER DR
SADDLE RIDGE PL
WEDGEWOOD DR
CHEYENNE CT
FANTASIA ST
MINUETTE PL
CAROL CT
CADENZA ST
OAKMONT DR
CORPORATE DR
CONFERENCE DR
LARGO RD
SURREY LN
WOODWIND DR
SCARBOROUGH RD
QUAIL RIDGE RD
CROOKED CREEK RD
GREY FOX TR
OLD OAK WK
LANCELOT DR
GUINEVERE LN
GAWAIN RD
OLD MILL CT
PLANTATION CI
PHEASANT RN
PLANTERS WK
TURTLE CREEK RD
CAPE POINT LN
THACKERY RD
TOWNES DR
MULBERRY LN
CANCION ST
TEMPO CT
BACH CI
CANTATA DR
TUCKAHOE DR
14TH ST
CASUAL CI
HYDE DR
CHARLES BV
EXCHANGE DR
TARA CT
MEETING PL
CLEERE CT
PINETREE LN



Meetinghouse Branch Watershed Master Plan

Figure 3-2
Meetinghouse Branch - West
Existing Conditions Floodplain

0 300 600 1,200

1 inch = 600 feet

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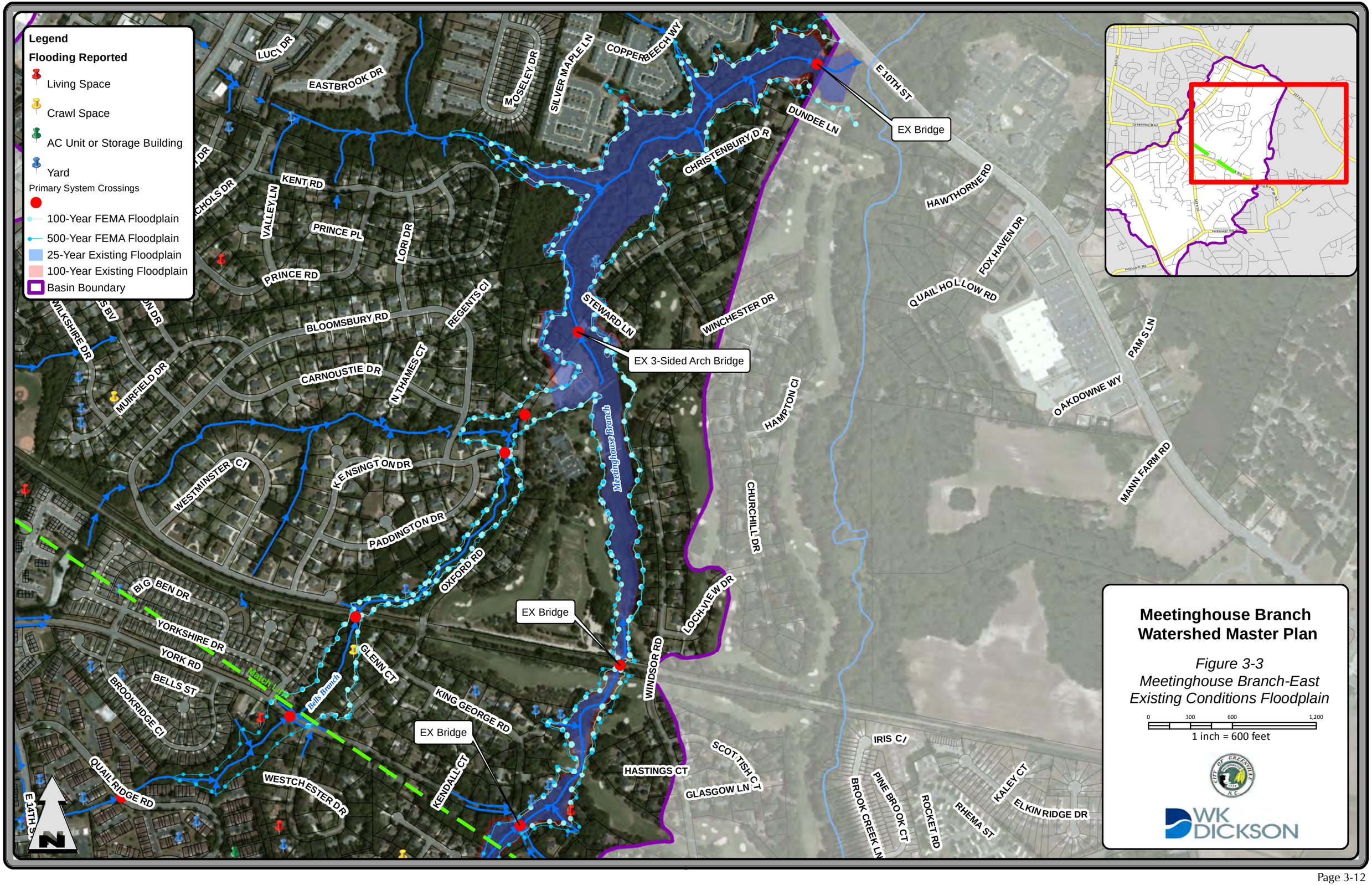
Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Primary System Crossings
100-Year FEMA Floodplain
500-Year FEMA Floodplain
25-Year Existing Floodplain
100-Year Existing Floodplain
Basin Boundary
LUCI DR
EASTBROOK DR
MOSELEY DR
SILVER MAPLE LN
COPPER BEECH WY
E 10TH ST
DUNDEE LN
EX Bridge
CHRISTENBURY DR
HAWTHORNE RD
FOX HAVEN DR
QUAIL HOLLOW RD
PAM S LN
OAKDOWNE WY
MANN FARM RD
KENT RD
VALLEY LN
PRINCE PL
LORI DR
PRINCE RD
REGENTS CI
BLOOMSBURY RD
STEWARD LN
WINCHESTER DR
EX 3-Sided Arch Bridge
HAMPTON CI
WILKSHIRE DR
MUIRFIELD DR
CARNOUSTIE DR
N THAMES CT
WESTMINSTER CI
K ENSINGTON DR
PADDINGTON DR
OXFORD RD
Meetinghouse Branch
CHURCHILL DR
BIG BEN DR
YORKSHIRE DR
YORK RD
BELLS ST
BROOKRIDGE CI
Match Line
Bells Branch
GLENN CT
KING GEORGE RD
EX Bridge
EX Bridge
WINDSOR RD
LOCH VIEW DR
QUAIL RIDGE RD
WESTCHESTER DR
KENDALL CT
HASTINGS CT
SCOTTISH CT
GLASGOW LN
IRIS CI
BROOK CREEK LN
PINE BROOK CT
ROCKET RD
RHEMA ST
KALEY CT
ELKIN RIDGE DR
E 14TH ST
N
Meetinghouse Branch Watershed Master Plan
Figure 3-3
Meetinghouse Branch-East
Existing Conditions Floodplain
0
300
600
1,200
1 inch = 600 feet
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3.2 Secondary System Hydrologic and Hydraulic Analyses

While Bells Branch and Meetinghouse Branch are the primary source of flooding within the watershed, undersized systems can also lead to structural and roadway flooding. Based on the questionnaire responses, public meeting, and feedback from City staff, five secondary systems were identified for further evaluation. The secondary systems evaluated are as follows:

- Unnamed Tributary to Meetinghouse Branch;
- Grey Fox Trail System;
- Barnes Street – Paramore Drive – Rondo Drive System;
- Fantasia Street – Sherwood Drive System; and
- Oakmont Drive System.

3.2.1 Hydrology

Three models were used in the evaluation of the secondary systems: HEC-HMS, EPA SWMM, and Hydraflow Storm Sewers. For the larger more complex secondary systems, Fantasia Street – Sherwood Drive and Barnes Street – Paramore Drive – Rondo Drive, SWMM was selected as the hydrologic and hydraulic model. Smaller systems that were completely closed systems including Grey Fox Trail and Oakmont Drive were modeled using Hydraflow Storm Sewers. HEC-HMS was used to model the Unnamed Tributary to Meetinghouse Branch. A detailed description about the hydrologic modeling methodology is included in Appendix A.

3.2.2 Hydraulics

Unnamed Tributary to Meetinghouse Branch

The Unnamed Tributary to Meetinghouse Branch is located in the northern section of the Meetinghouse Branch Watershed. This section is highly impervious and includes a segment of Southeast Greenville Boulevard and East 10th Street. It collects approximately 300 acres and discharges directly to Meetinghouse Branch 1,100 feet downstream of the Oxford Road South Bridge. There is one resident adjacent to the unnamed tributary that reports experiencing yard flooding up to three times per year.

Figure 3-4 shows the 25- and 100-year existing conditions floodplain for the Unnamed Tributary to Meetinghouse Branch. The model shows that while there is yard flooding, there is no expected structural flooding in the 25-year and 100-year storm event. The channel velocities calculated by the model range between 2.3 and 6.3 feet per second in the 10-year storm event. The velocities are highest downstream at the confluence with Meetinghouse Branch and upstream where another large channel outfalls to the Unnamed Tributary to Meetinghouse Branch in the backyard of the resident at 99 Nichols Drive. Streambank erosion can be a concern when channel velocities exceed 4.0 feet per second for the types of soil present in the streambed, however the velocity at which erosion can occur will vary based on the site specific soil type and vegetative cover. This reach of stream was walked and evaluated by WK Dickson personnel for erosion potential. Based on the erosion potential predicted by the Bank Erosion Hazard Index (BEHI) assessment completed, it is recommended that bank pins be installed to monitor the bank stability and rate of erosion at the locations where channel velocities are highest, such as north of Nichols Street and south of Silver Maple Lane. No additional stream

stabilization projects or improvements are proposed at this time, however the project should be revisited based on the monitoring of the bank pins.

More detailed information about BEHI assessments is contained in Section 3.3.

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard

- Catch Basin
- Yard Inlet
- Difficult Access
- Drop Inlet
- Junction Box
- Flared End Section
- Headwall
- Pipe End

- Chimney Top
- Underground Pipe Junction
- Pipes
- Channels
- 25-Year Floodplain
- 100-Year Floodplain
- Primary - Drainage Basins
- Drainage Basin

ALEXANDER CI
JOHN AV
SE GREENVILLE BV
MOSELEY DR
RIVER BLUFF RD
S WRIGHT RD
CHERRY COURT DR
EASTBROOK DR
COPPER BEECH WY
CEDAR LN
GOLDEN RD
LUCI DR
CEDAR CT
KINGSTON CI
EMERSON RD
BELMONT DR
NICHOLS DR
KENT RD
PRINCE RD
LORI DR
VALLEY LN
TEMPLETON DR
BRYAN CI
ADAMS BV
WILKSHIRE DR
HARDEE RD
HARDEE CI
BLOOMSBURY RD
MUIRFIELD DR
LAURA LN
DAVID DR
SILVER MAPLE LN
DUNDEE LN
Install Bank Pins
Unnamed Tributary to Meetinghouse Branch
Meeting House Branch
Install Bank Pins

Meetinghouse Branch Watershed Master Plan

Figure 3-4
Unnamed Tributary to Meetinghouse Branch
Existing Condtions Floodplain

0 100 200 400 600

1 inch = 400 feet

WK DICKSON

Grey Fox Trail System

The Grey Fox Trail System collects drainage from approximately 12 acres in the Planters Trail subdivision and discharges directly to Meetinghouse Branch. The conveyance system is comprised of reinforced concrete pipe (RCP) ranging from 15 to 30 inches in diameter in good condition based on data collected during the inventory. There are three reports of flooding in this area. The two residential flooding issues shown in Figure 3-5 include a resident located near the 30″ outfall that experiences yard flooding and a report of yard flooding that approaches the crawl space at a separate location. The third reported flooding issue is general street flooding along Grey Fox Trail several times within the last five years.

Figure 3-5 shows the level of service being provided by the existing closed system. Model results show that the majority of the system operates at or below a 2-year level of service. Backwater from Meetinghouse Branch coupled with the long, flat sections of pipe contribute to this system not performing at its desired 10-year level of service.

Barnes Street – Paramore Drive – Rondo Drive System

The Barnes Street – Paramore Drive – Rondo Drive System collects drainage from approximately 24 acres in the Tucker Estates subdivision and Windy Ridge condominiums and discharges directly to Bells Branch. The conveyance system is comprised of a combination of RCP and corrugated metal pipe (CMP) ranging from 15 to 36 inches in diameter predominantly in good condition based on data collected during the inventory. The downstream 36″ CMP outfall pipe is listed in fair condition and may be nearing the end of its useful design life. The CMP is located in the downstream portion of the system. There are two reports of yard flooding in this area. Figure 3-6 shows the level of service being provided by the existing closed system. The lower portion of the system operates at or below a 2-year level of service due to the backwater from Bells Branch. The desired level of service for this system is the 10-year storm.

Fantasia Street – Sherwood Drive System

The Fantasia Street – Sherwood Drive System drains approximately 40 acres in the Tucker Estates subdivision. It discharges to a trapezoidal channel located adjacent to Carriage House and Oakmont Square apartments. The conveyance system is comprised of CMP ranging in size from 15 to 30 inches in diameter. The conveyance system is predominantly in good condition however the downstream 24″ CMP pipe segment along Fantasia Street has a rusted bottom that is in fair to poor condition. This pipe segment will likely need to be replaced in the near future. There are several residents in the area who have reported both street and yard flooding. As shown in Figure 3-7, there are segments of the system that are not providing the desired 10-year level of service.

Oakmont Drive System

The Oakmont Drive System drains approximately 10 acres of highly developed area and outfalls directly to Meetinghouse Branch. The conveyance system is comprised of a combination of RCP and CMP ranging in size from 15 to 24 inches in diameter in good condition based on data collected during the inventory. As shown in Figure 3-8, the entire system is operating below a 2-year level of service. The desired level of service is the 10-year storm.

One business owner located at 107 Oakmont Drive reported street and parking lot flooding. During a field visit, the business owner at 105 Oakmont Drive reported structural, parking lot, and street flooding along Oakmont Drive. The owner also explained the parking lot directly

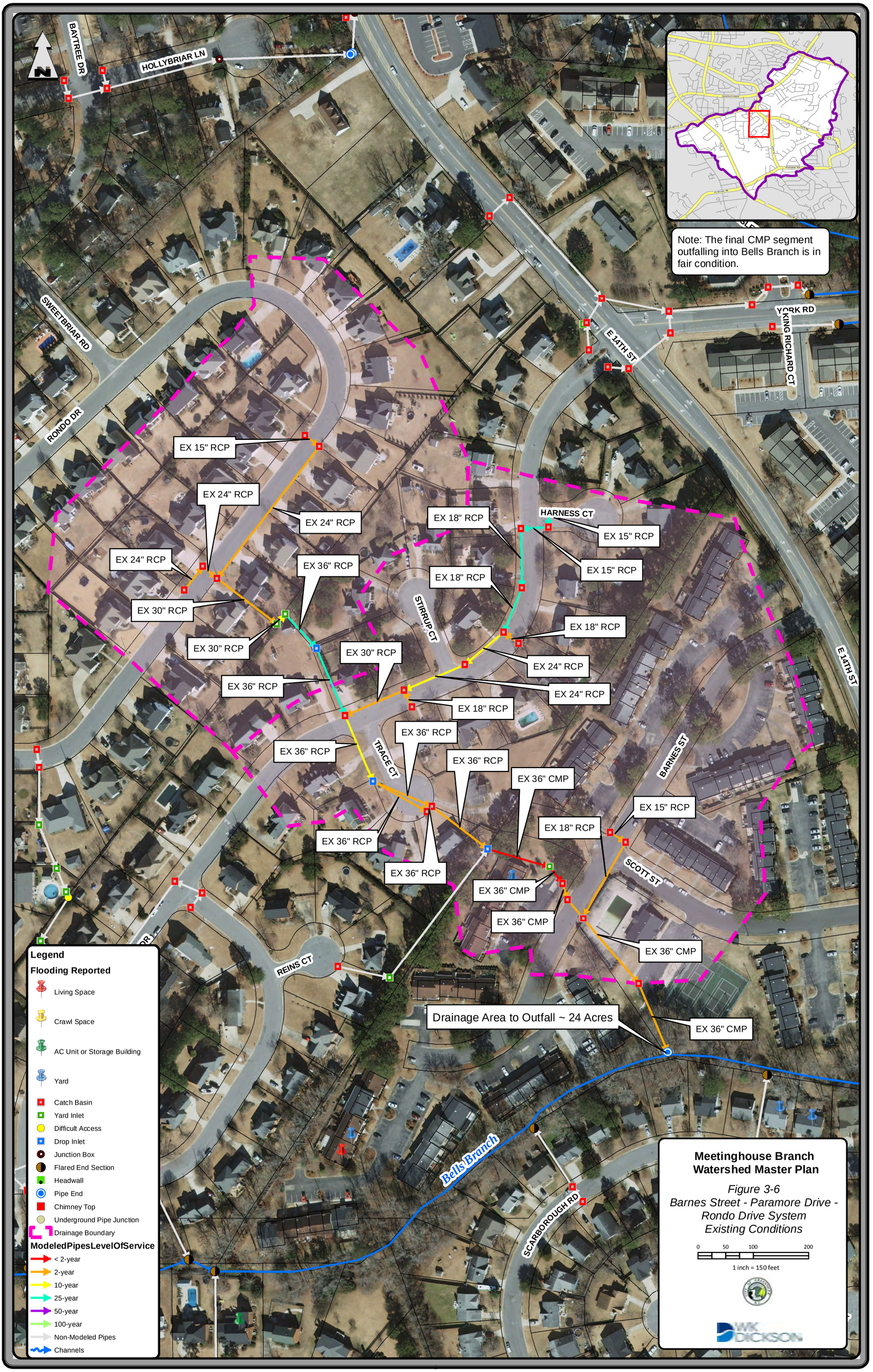
across the street at 104 Oakmont Drive is much higher in elevation than the road and his parking lot. Consequently when it rains, water flows away from the parking lot at 104 Oakmont Drive across the road and ponds in Mr. Baker's parking lot. Occasionally, the water also enters his building. There are no inlets in either parking lot to capture the runoff. The nearest inlets are located along Oakmont Drive adjacent to the parking lots. These inlets connect to the undersized Oakmont Drive System.

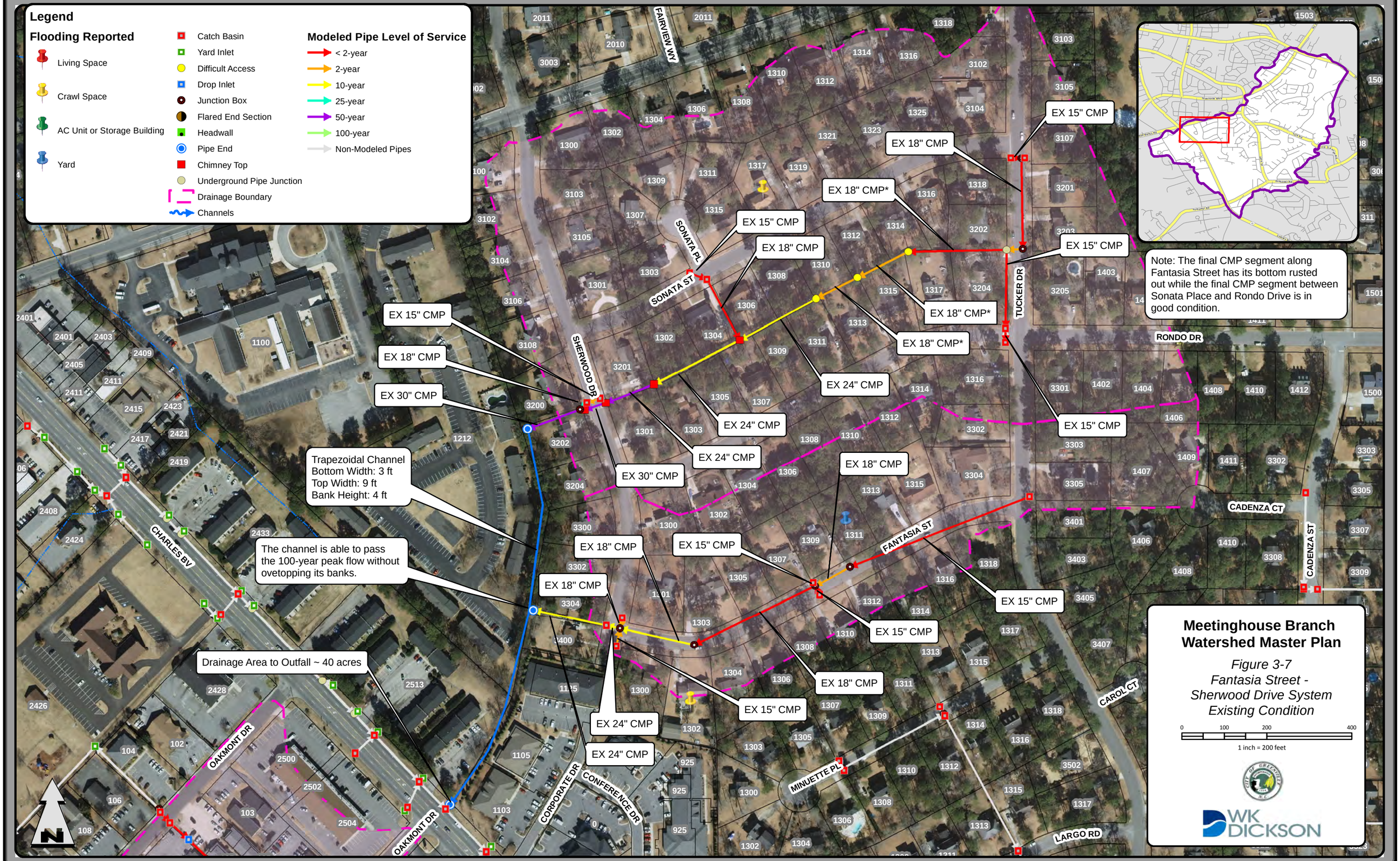
Eastwood Subdivision System

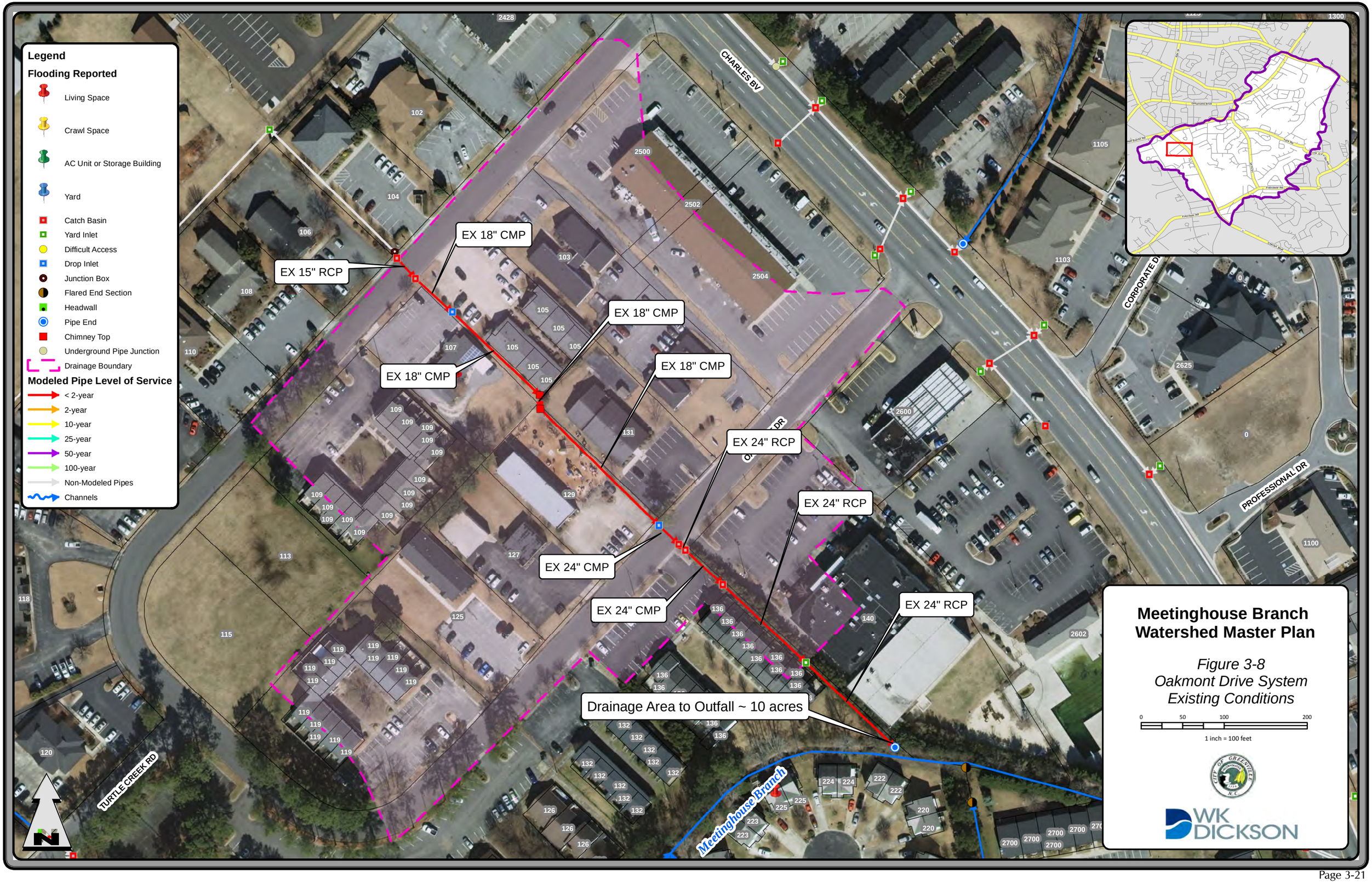
Concurrent with the development of this watershed master plan, the City contracted with A. Morton Thomas & Associates to complete a final design for storm drainage improvements within the Eastwood Subdivision. This final design was developed and supported by the Eastwood Subdivision Drainage System Analysis completed by A. Morton Thomas and Associates, Inc. on November 3, 2010.

The Eastwood System collects drainage in a northeasterly direction from approximately 87 acres in Eastwood Subdivision and discharges into an unnamed tributary of Meeting House Branch. The conveyance system is comprised of a combination of RCP and CMP ranging from 18 to 48 inches in diameter. The RCP is located within the lateral portions of the system while the main trunk lines of the system are comprised of CMP. Several residents reported both street and yard flooding. Model results show that a majority of the system operates at or below a 2-year level of service and since the project was modeled separate from this plan no figure is provided illustrating the levels of service.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Non-Modeled Pipes
Channels
Drainage Boundary
Modeled Pipe Level Of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
WESTCHESTER DR
HARVEST MANOR
FIELDSTONE PL
AUTUMN CHASE CT
GREY FOX TR
CROOKED CREEK RD
OLD OAK WK
Meetinghouse Branch
EX 15" RCP
EX 30" RCP
EX 15" RCP
EX 30" RCP
EX 15" RCP
EX 24" RCP
EX 15" RCP
EX 18" RCP
EX 15" RCP
EX 24" RCP
Drainage Area to Outfall ~ 12 acres
Meetinghouse Branch Watershed Master Plan
Figure 3-5
Grey Fox Trail System
Existing Conditions
0
50
100
200
1 inch = 100 feet
WK DICKSON


N
BAYTREE DR
HOLLYBRIAR LN
SWEETBRIAR RD
RONDO DR
E 14TH ST
YORK RD
KING RICHARD CT
HARNESS CT
STIRRUP CT
TRACE CT
REINS CT
BARNES ST
SCOTT ST
SCARBOROUGH RD
Bells Branch
Note: The final CMP segment outfalling into Bells Branch is in fair condition.
EX 15" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 36" RCP
EX 30" RCP
EX 30" RCP
EX 30" RCP
EX 36" RCP
EX 36" RCP
EX 36" RCP
EX 36" RCP
EX 36" RCP
EX 36" RCP
EX 18" RCP
EX 15" RCP
EX 15" RCP
EX 18" RCP
EX 18" RCP
EX 24" RCP
EX 24" RCP
EX 18" RCP
EX 36" CMP
EX 18" RCP
EX 15" RCP
EX 36" CMP
EX 36" CMP
EX 36" CMP
EX 36" CMP
Drainage Area to Outfall ~ 24 Acres
Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Drainage Boundary
ModeledPipesLevelOfService
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
Channels
Meetinghouse Branch Watershed Master Plan
Figure 3-6
Barnes Street - Paramore Drive - Rondo Drive System
Existing Conditions
0
50
100
200
1 inch = 150 feet
WK DICKSON


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Drainage Boundary
Channels
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
FAIRVIEW WY
SONATA PL
SONATA ST
SHERWOOD DR
TUCKER DR
RONDO DR
FANTASIA ST
CADENZA CT
CADENZA ST
CAROL CT
MINUETTE PL
CORPORATE DR
CONFERENCE DR
OAKMONT DR
CHARLES BV
LARGO RD
EX 15" CMP
EX 18" CMP
EX 18" CMP*
EX 24" CMP
EX 30" CMP
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 9 ft
Bank Height: 4 ft
The channel is able to pass the 100-year peak flow without ovetopping its banks.
Drainage Area to Outfall ~ 40 acres
Note: The final CMP segment along Fantasia Street has its bottom rusted out while the final CMP segment between Sonata Place and Rondo Drive is in good condition.
Meetinghouse Branch Watershed Master Plan
Figure 3-7
Fantasia Street - Sherwood Drive System
Existing Condition
0 100 200 400
1 inch = 200 feet
WK DICKSON


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Drainage Boundary
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
Channels
EX 15" RCP
EX 18" CMP
EX 18" CMP
EX 18" CMP
EX 24" CMP
EX 24" CMP
EX 24" RCP
EX 24" RCP
EX 24" RCP
Drainage Area to Outfall ~ 10 acres
CHARLES BV
CORPORATE DR
PROFESSIONAL DR
TURTLE CREEK RD
Meetinghouse Branch
Meetinghouse Branch Watershed Master Plan
Figure 3-8
Oakmont Drive System
Existing Conditions
0 50 100 200
1 inch = 100 feet
WK DICKSON

3.3 Stream Stability Field Assessments

There are 8.6 miles of streams located in the Meetinghouse Branch Watershed. Within the watershed, 5.7 miles of stream, including Meetinghouse Branch and Bell Branch, are classified for secondary recreation and aquatic wildlife survival and propagation (Class C) by NCDWQ. These two streams are also classified as nutrient sensitive waters (NSW) by NCDWQ, indicating they are subject to excessive growth of microscopic or macroscopic vegetation, or they contribute to downstream nutrient loading (NCDWQ 2010). None of the streams in the watershed are listed on the NC Water Quality Assessment and Impaired Waters List (also known as the Integrated 305(b) and 303(d) Report).

Over 60 percent of the residents who completed questionnaires reported erosion issues. Most residents reported that their yards were being threatened by erosion while a small percentage reported a risk to their fences or garages. A total of four residents located at the following locations have reported risk to structures:

- 95 Barnes Street (utility room);
- 225 Cape Point Lane;
- 335 Glenn Court (basement); and
- 99 Nichols Drive (20' x 28' barn)

Field assessments measuring bank stability were conducted on all of the major stream channels within the Meetinghouse Branch Watershed. The Bank Erosion Hazard Index (BEHI) developed by Rosgen was used to evaluate the streams in the watershed. BEHI is an assessment tool that is used to quantify the erosion potential of a stream bank. Characteristics assessed as part of the BEHI rating include bank height ratio (stream bank height/maximum bankfull depth), ratio of rooting depth to bank height, root density, bank angle, and percent surface protection, and bank material composition. Each of these variables that affect the potential rate of stream bank erosion is assigned points based on specific evaluation criteria. BEHI scores range from five to fifty, with a score of fifty indicating the highest potential for erosion. A BEHI score of 5 to 19.5 indicates a very low or low potential for erosion; a score between 20 and 29.5 indicates a moderate potential for erosion; scores from 30 to 45 represent a high to very high potential for erosion; and scores between 46 and 50 indicate extreme erosion potential. The completed BEHI scores are provided in Appendix K.

There are four main drainage features within the Meetinghouse Branch Watershed (See Figure 3-9). The largest of these is Meetinghouse Branch. UT2 and its tributaries are included in this drainage feature. UT5 and its tributaries lie in the northeast portion of the watershed and constitute the second drainage feature. The remaining two drainage features are Bell Branch and UT4 (including its tributary, UT4-1). BEHI scores for each of these drainage areas are discussed below.

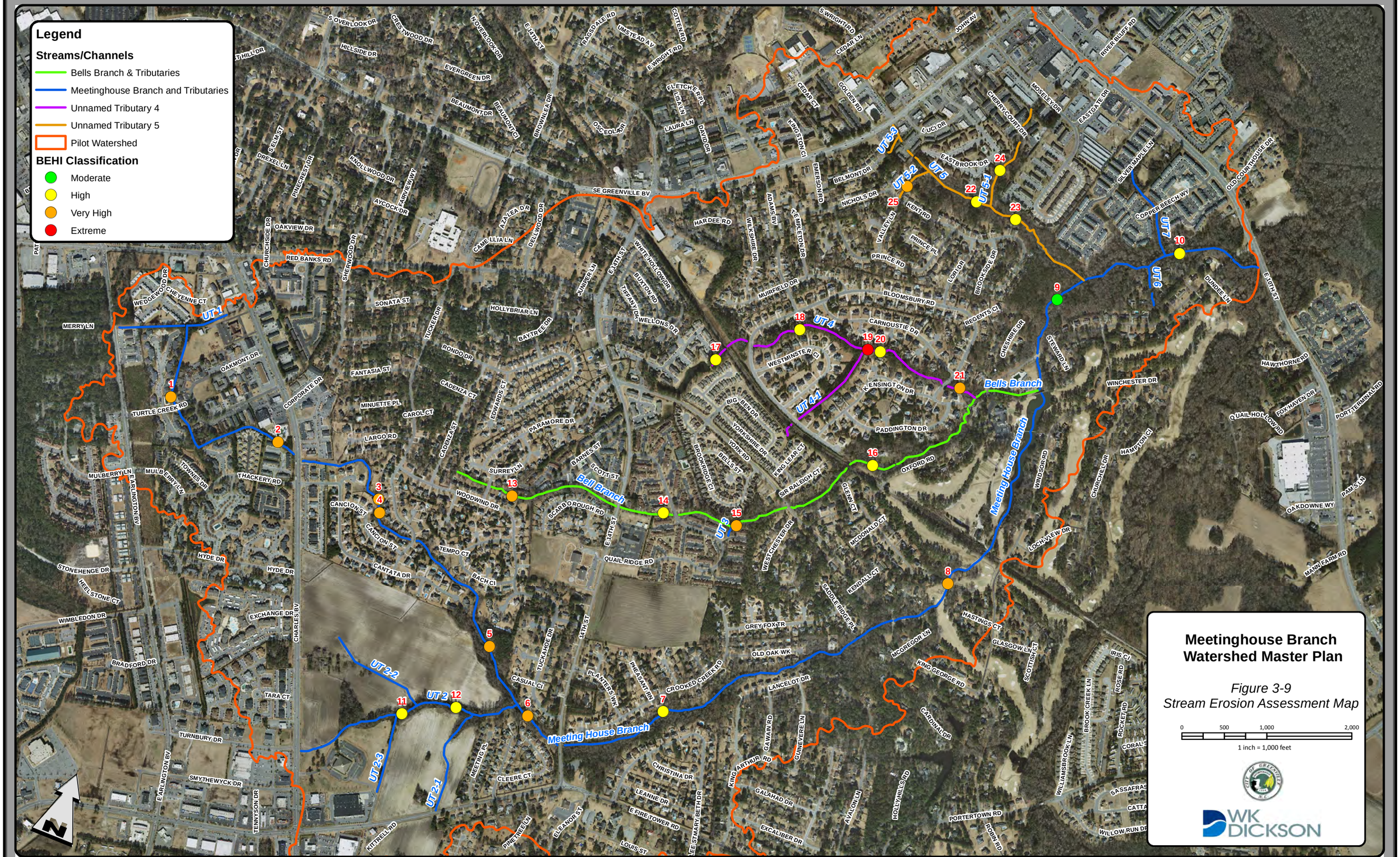
Twelve BEHI assessments were performed along the Meetinghouse Branch drainage. Two of these assessments were performed on UT2. Of the ten assessments on Meetinghouse Branch, seven had a BEHI rating of Very High. Sampling locations 1 and 10, the upstream-most and downstream-most samples, respectively, each had a rating of High. Sampling location number 9, 400 feet upstream of the confluence with UT5, had a rating of Moderate. Sample location 7 had a rating of high. Immediately downstream of sampling location 7, the City has recently

completed a stream stabilization project with gabion baskets. Stream Project 2 detailed in Section 5-1 addresses additional stabilization issues downstream of the recently completed City project. The assessments showed that Meetinghouse Branch is primarily a sand and gravel channel with bank height/bankfull height ratios mostly in the extreme range. Most of the sampling points also had little surface protection and low to moderate bank angles. Both of the sampling points on UT2 scored in the High range. UT2 is primarily a sand bed channel with low to moderate ratings for bank angle and surface protection.

Four BEHI assessments were performed on the Unnamed Tributary to Meetinghouse Branch (UT5) and its tributaries. Three of these assessments (two on UT5 and one UT5-1) scored in the High range, and the one on UT5-2 scored in the Very High range. These are primarily sand bed channels with high bank height/bankfull height ratios, low to moderate bank angles, and moderate amounts of surface protection.

Four BEHI assessments were performed on Bell Branch. Two of these assessments scored in the High range, and two scored in the Very High range. Bell Branch is primarily a sand and gravel channel with high to very high ratings for root density and surface protection. This stream had mostly moderate to very high bank height/bankfull height ratios, and low to moderate bank angles.

Five BEHI assessments were performed on the unnamed tributary to Bell Branch (UT4). The two upstream-most sampling locations scored in the High range, the sampling location at the confluence with UT4-1 one scored in the scored in the Extreme range, and the two downstream-most locations scored in the Very High range. UT5 is a sand bed channel with very high root density scores and moderate to extreme surface protection scores. Bank height/bankfull height ratios ranged from very low to extreme, and root depth/bank height ratios were mostly low.


Legend
Streams/Channels
Bells Branch & Tributaries
Meetinghouse Branch and Tributaries
Unnamed Tributary 4
Unnamed Tributary 5
Pilot Watershed
BEHI Classification
Moderate
High
Very High
Extreme
Bells Branch
Meeting House Branch
UT 1
UT 2
UT 2-1
UT 2-2
UT 2-3
UT 3
UT 4
UT 4-1
UT 5
UT 5-1
UT 5-2
UT 5-3
UT 6
UT 7
SE GREENVILLE BV
RED BANKS RD
HARDEE RD
BELMONT DR
NICHOLS DR
KENT RD
PRINCE RD
MUIRFIELD DR
BLOOMSBURY RD
CARNOUSTIE DR
PADDINGTON DR
OXFORD RD
CROOKED CREEK RD
LANCELOT DR
OLD OAK WK
QUAIL RIDGE RD
SURREY LN
WOODWIND DR
SCARBOROUGH RD
TURTLE CREEK RD
MULBERRY LN
THACKERY RD
CANCION ST
TEMPO CT
CANTATA DR
HYDE DR
STONEHENGE DR
WIMBLEDON DR
BRADFORD DR
TARA CT
TURNBURY DR
SMYTHEWYCK DR
KITTRELL RD
LARGO RD
PARAMORE DR
CLEERE CT
CHRISTINA DR
LEANNE DR
E FIRE TOWER RD
LOUIS ST
PINETREE LN
ELEANOR ST
LEE ST MARY BETH DR
KING ARTHUR RD
GALAHAD DR
AVALON LN
EXCALIBER DR
PORTERTOWN RD
ROBIN RD
WILLOW RUN DR
GREY FOX TR
OLD OAK WK
KENDALL CT
SADDLE RIDGE PL
WESTCHESTER DR
MCDONALD CT
GLENN CT
SR RALEIGH CT
KINGSTON CT
CEDAR CT
GOLDEN RD
CEDAR LN
LUCI DR
EASTBROOK DR
CHERRY COURT DR
MOSELEY DR
EASTGATE DR
RIVER BLUFF RD
JOHN AV
S WRIGHT RD
E WRIGHT RD
UMSTEAD AV
RAGSDALE RD
COTTEN RD
E 14TH ST
FLETCHER PL
LISA LN
LAURA LN
DAVID DR
OSCEOLA DR
BROWNLEA DR
BEAUMONT DR
BEAUMONT CI
EVERGREEN DR
HILLSIDE DR
S OVERLOOK DR
CRESTWOOD DR
N OVERLOOK DR
SELIM ST
DREXEL LN
PINECREST DR
KNOLLWOOD DR
FAIRVIEW WY
AYCOCK DR
AZALEA DR
DELLWOOD DR
CAMELLIA LN
OAKVIEW DR
CHURCHSIDE DR
SHERWOOD DR
WEDGEWOOD DR
CHEYENNE CT
MERRY LN
SONATA ST
HOLLYBRIAR LN
TUCKER DR
BAYTREE DR
RONDO DR
FANTASIA ST
CADENZA CT
EDWARDS CT
MINUETTE PL
CAROL CT
CORPORATE DR
OAKMONT DR
JUNIPER LN
E 14TH ST
WHITE HOLLOW DR
BUXTON RD
TIFFANY DR
WELLONS DR
TUCKAHOE DR
CASUAL CI
PLANTERS WK
PHEASANT RW
MEETING PL
GAWAIN RD
GUINEVERE LN
CARDINAL DR
BROOKRIDGE CI
YORK RD
BELLS ST
KING LEAR CT
YORKSHIRE DR
BIG BEN DR
WESTMINSTER CI
KENSINGTON DR
REGENTS CI
CHESHIRE DR
STEWARD LN
BROOKSIDE DR
LORI DR
VALLEY LN
ADAMS BV
TEMPLETON DR
WILKSHIRE DR
EMERSON RD
SILVER MAPLE LN
COPPER BEECH WY
OLD COURTHOUSE DR
DUNDEE LN
E 10TH ST
WINCHESTER DR
HAWTHORNE RD
FOX HAVEN DR
PORT TERMINAL RD
QUAIL HOLLOW RD
HAMPTON CI
CHURCHILL DR
WINDSOR RD
LOCH VIEW DR
OAKDOWNE WY
PAMS LN
MANN FARM RD
HASTINGS CT
GLASGOW LN
SCOTTISH CT
MCGREGOR LN
KING GEORGE RD
IRIS CI
ROSE RD
ROCKET RD
BROOK CREEK LN
WILLIAMSBROOK LN
SASSAFRAS
CATTA
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Meetinghouse Branch
Watershed Master Plan
Figure 3-9
Stream Erosion Assessment Map
0
500
1,000
2,000
1 inch = 1,000 feet
WK DICKSON

4.1 Primary Systems

Developing flood control alternatives in an urban environment is a complex process based on limitations imposed by the constraints within the environment such as floodplain encroachment, increased peak flows due to impervious areas, public and private utilities, and private property. Improvements in this portion of the study were identified through an iterative process of infrastructure improvements, increasing floodplain storage, and evaluating detention options. Alternatives were finalized based on discussions with City staff. The top alternatives that achieve the goals of the project while minimizing impacts to residents and traffic are presented.

4.1.1 Bells Branch

East 14th Street – As determined by the existing conditions analysis, the existing 48″ CMP culvert at East 14th Street is undersized and does not meet the desired 50-year level of service without overtopping. Currently, it provides between a 2- and 10- year level of service. Since the City's design standards are not being met and the existing culvert is in poor condition, it is proposed that the existing system be replaced.

- Alternative #1 – As part of this alternative, the existing culvert will be replaced with twin 42″ RCP. The upsized culvert will provide the desired 50-year level of service with 0.30 feet of freeboard. Figure 4-1 summarizes the improvements proposed at East 14th Street as part of Alternative #1. The resulting upstream water surface elevations will be reduced by 0.43 to 1.63 feet in the 25-year storm event.

  There are five properties upstream of East 14th Street, located in the existing conditions 25-year floodplain, that have the potential to experience structural flooding. Although the water surface elevations are reduced for these properties, only two will be removed from the 25-year floodplain. The remaining three will continue to be exposed to structural flooding in the 25-year storm event, although the depth will be reduced. The total estimated cost for this project is $159,100.

Additional alternatives for East 14th Street were investigated including floodplain benching upstream and downstream of East 14th Street, and installing one culvert instead of twin culverts. However, the other alternatives evaluated did not provide cost effective improvements when compared to Alternative 1.

During a field inspection, there were several potential site restrictions and utility conflicts that were identified including overhead power lines that are located above the East 14th Street culvert. There also appears to be sanitary sewer lines that may need to be replaced or relocated. Impacts to traffic flow during construction were considered. This section of East 14th Street is a major thoroughfare and it is anticipated that a road closure or a flagged two-way one-lane operation will be required. The road is maintained by NCDOT, therefore coordination with NCDOT and an encroachment agreement will be required.

Quail Ridge Road – The existing twin 54″ CMP culvert at Quail Ridge Road meets the desired 25-year level of service. The culverts appear to be in fair condition therefore, no improvements

are proposed at this location (See Figure 4-1).

York Road & Railroad Crossing – As determined by the existing conditions analysis, the 60″ CMP at York Road is undersized and does not meet a 25-year level of service without overtopping. Currently, it provides between a 2- and 10- year level of service. The 60″ RCP culvert located at the Railroad Crossing along Bells Branch does not meet the 100-year level of service typically desired at railroad crossings. It is undersized and providing a 25- year level of service. The hydraulic performance at York Road is affected by the backwater from the downstream Railroad Crossing. Backwater impacts from the railroad extend approximately 900 feet upstream of York Road, but do not affect the East 14th Street crossing. If improvements to the Railroad Crossing are not constructed, any benefits from improving the York Road crossing would be reduced.

- Alternative #1 – The goal of Alternative 1 is to provide as much improvement to the level of service at York Road without making improvements to the railroad crossing. Improvements to railroad crossings can be time consuming due to coordination with the railroad owner as well as costly since new railroad culverts are typically installed with tunneling techniques to avoid interruptions in service.

  Alternative 1 includes replacing the existing 60″ CMP at York Road with a 72″ RCP culvert that provides a 10-year level of service. Installing a culvert larger than 72″ at York Road would not improve the level of service past a 10-year storm due to the backwater effects from the railroad. The desired level of service at York Road is the 25-year storm.

  Moderate reductions in water surface elevation ranging from 0.2 to 0.6 feet in the 25-year storm event will be realized from the proposed improvements between the railroad and Quail Ridge Road. Twenty-two (22) residential structures are located along the stretch of stream that will have water surface reductions. Four (4) townhomes located in the existing conditions 100-year floodplain would be removed from the 100-year floodplain as a result of the proposed improvements. The remainder of the structures would have the same level of service as existing conditions although the depth and anticipated damage from flooding would be reduced.

  Of the twenty-two residential structures shown to be floodprone based on the hydraulic models, four (4) property owners reported flooding during the public input phase of the project as follows:

  - 2024 York Road – living space flooding
  - 500 Westchester Drive – LAG flooding
  - 1963A Quail Ridge Road – LAG
  - 335 Glenn Court – crawl space flooding

  The proposed improvements for Alternative 1 would not substantially reduce the risk of flooding at these locations, although the depth and duration of flooding may be reduced. Figure 4-2 summarizes the improvements proposed for Alternative #1. The total estimated cost for completing the culvert improvements at York Road is $183,600.

- Alternative #2 – The goal of Alternative 2 is to provide the desired level of service at both York Road and the Railroad Crossing, which is the 25-year and 100-year storm, respectively. The same improvements proposed as part of Alternative #1 are proposed for this alternative at York Road. However, the hydraulic performance of the proposed 72″ RCP at York Road will change due to the differences between Alternative #1 and #2 at the Railroad Crossing. Instead of operating at a 10-year level of service, the upsized culvert at York Road will provide the desired 25-year level of service. At the Railroad Crossing similar to Alternative #1, the existing 60″ RCP will be left in place. A single 36″ steel floodplain culvert is proposed to be added to the 60″ RCP to help provide a 100-year level of service at the Railroad Crossing.

  In addition to the improved level of service at York Road and the Railroad Crossing, the Alternative 2 improvements provide substantial reductions in water surface elevations for the twenty-two (22) floodprone residential structures between the railroad and Quail Ridge Road. Water surface reductions for the 25-year storm range between 0.3 to 4.3 feet. The most significant reductions occur between the Railroad Crossing and York Road where five (5) structures will be removed from the 100-year floodplain and water surface reductions during the 25-year storm range between 3.9 and 4.3 feet resulting in substantial decreases in the risk and frequency of structural and yard flooding. Improvements for the four (4) structures with documented flooding listed above as a result of Alternative 2 are as follows:

  - 2024 York Road – 100-year level of service with 0.8 foot reduction in 25-year water surface elevation and 1.4 foot reduction in 100-year water surface elevation.
  - 500 Westchester Drive – 100-year level of service with 1.0 foot reduction in 25-year water surface elevation and 1.5 foot reduction in 100-year water surface elevation.
  - 1963A Quail Ridge Road – 0.5 foot reduction in 100-year water surface elevation
  - 335 Glenn Court – 4.3 foot reduction in 25-year water surface elevation and 2.0 foot reduction in 100-year water surface elvation.

  Figure 4-2 summarizes the improvements proposed for Alternative #2. The total estimated cost for completing the culvert improvements at York Road and the Railroad Crossing is $316,800.

During a field inspection, there were several potential site restrictions and utility conflicts that were identified including overhead power lines that are located above the York Road culvert. The impacts to traffic flow during construction were also considered. York Road is a two-lane residential roadway. It is anticipated that a road closure or a flagged two-way one-lane operation will be required.

Picture 4-1. Downstream Invert - Railroad Culvert Crossing (Bells Branch)

The Railroad Crossing presents a unique set of constraints including access limitations. As shown in Picture 4-1, the Railroad Crossing is located in a wooded area. The railroad will need to remain in service therefore it is assumed that tunneling techniques such as jack and bore will be utilized to install the proposed floodplain culverts. In order to gain access for installing the proposed floodplain culvert, trees must be removed. The installation of construction staging areas and entrances will require additional tree removal and temporary construction easements. There are also sanitary sewer lines located adjacent to the Railroad Crossing that may need to be replaced or relocated.

The size of the floodplain culvert installed at the Railroad Crossing will impact the proposed flow reaching the downstream Oxford Road Closed System. Alternative #2, the option that provides a higher level of service for York Road and the Railroad Crossing will lead to a higher flow. The flow calculated for Alternative #2 at the downstream Oxford Road Closed System is approximately 5 percent higher than the flow calculated for Alternative #1.

Kensington Drive – The existing bridge at Kensington Drive meets the desired 25-year level of service. A routine inspection was completed by North Carolina Department of Transportation (NCDOT) on March 20, 2012. The inspector identified minor issues with the structure including hairline cracking, scaling, and rusting. There were also checks and splits pointed out in one of the bridge piles. The Kensington Drive bridge was determined to be structurally sound therefore no maintenance repairs were recommended. A complete

Picture 4-2. Bank Erosion Upstream of Kensington Drive Bridge Crossing (Bells Branch)

copy of the bridge inspection report is included in Appendix L. Based on a review of the bridge inspection report and a field visit, no improvements are proposed for the Kensington Drive crossing (See Figure 4-3).

The reach of stream located directly upstream of the bridge crossing is experiencing bank erosion (See Picture 4-2). The Kensington Drive Stream Stabilization Project discussed in Section 4.3 helps to reduce this identified instream erosion.

Oxford Road Closed System – As determined by the existing conditions analysis, the closed system at the downstream end of Bells Branch is undersized. It is currently operating below a 2-year level of service. There are portions of the system that are in poor condition. The bottom of the 60″ CMP upstream invert is beginning to rust out. The upstream section is also showing signs of failure which is evidenced by the development of sinkholes. Currently, the location of the sinkholes is limited to the grass area bordering Oxford Road and the Brook Valley Country Club parking lot. However, there is the risk of these sinkholes expanding to the parking lot or Oxford Road which would cause a significant safety hazard.

Based on the numerous constraints and the limited available space there is only one alternative presented for the Oxford Road Closed System. The proposed pipe alignment will be similar to the existing alignment. As shown in Figure 4-3, it is proposed that the existing 60″ CMP be replaced with 7′ x 5′ reinforced concrete box culvert (RCBC) to provide the desired 10-year level of service. The total length of the system is 653 linear feet. The inlets will be replaced and junction boxes will be installed in the parking lot. The proposed improvements will impact the Oxford Road right-of-way, the Brook Valley Country Club poolhouse parking lot, and the grass area adjacent to the Brook Valley Country Club tennis courts. The majority of the system is located on private property (Brook Valley Country Club) therefore an easement would be required to complete this project.

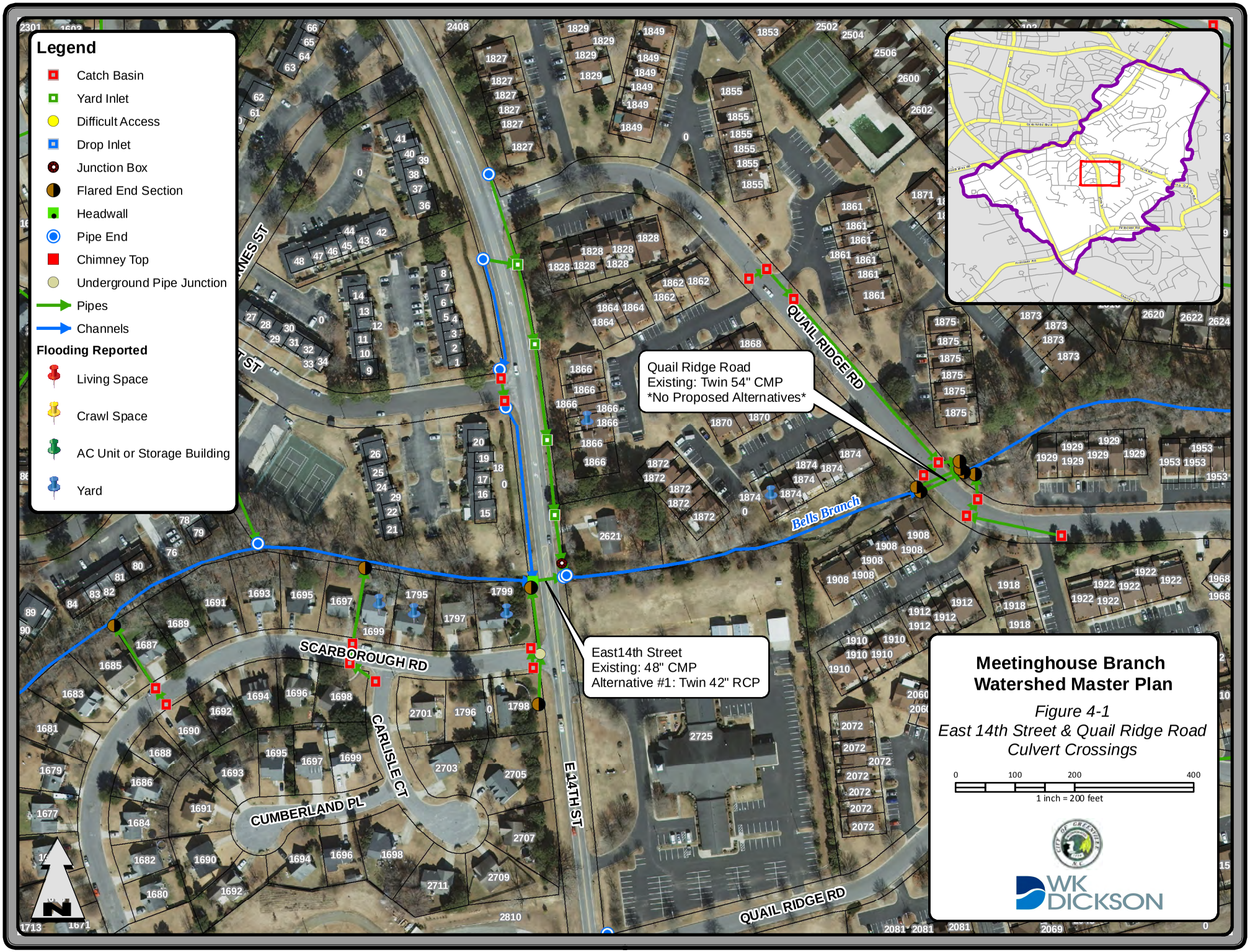
There were several other potential site restrictions and utility conflicts that were identified during a field visit including sanitary sewer lines that may need to be replaced or relocated. Impacts to traffic flow along Oxford Road during construction were also considered. Oxford Road is a two-lane residential roadway and it is anticipated that a road closure or a flagged two-way one-lane operation will be required. Communication with the Brook Valley Country Club will be critical prior to and during construction as access to the pool and tennis courts may be impacted.

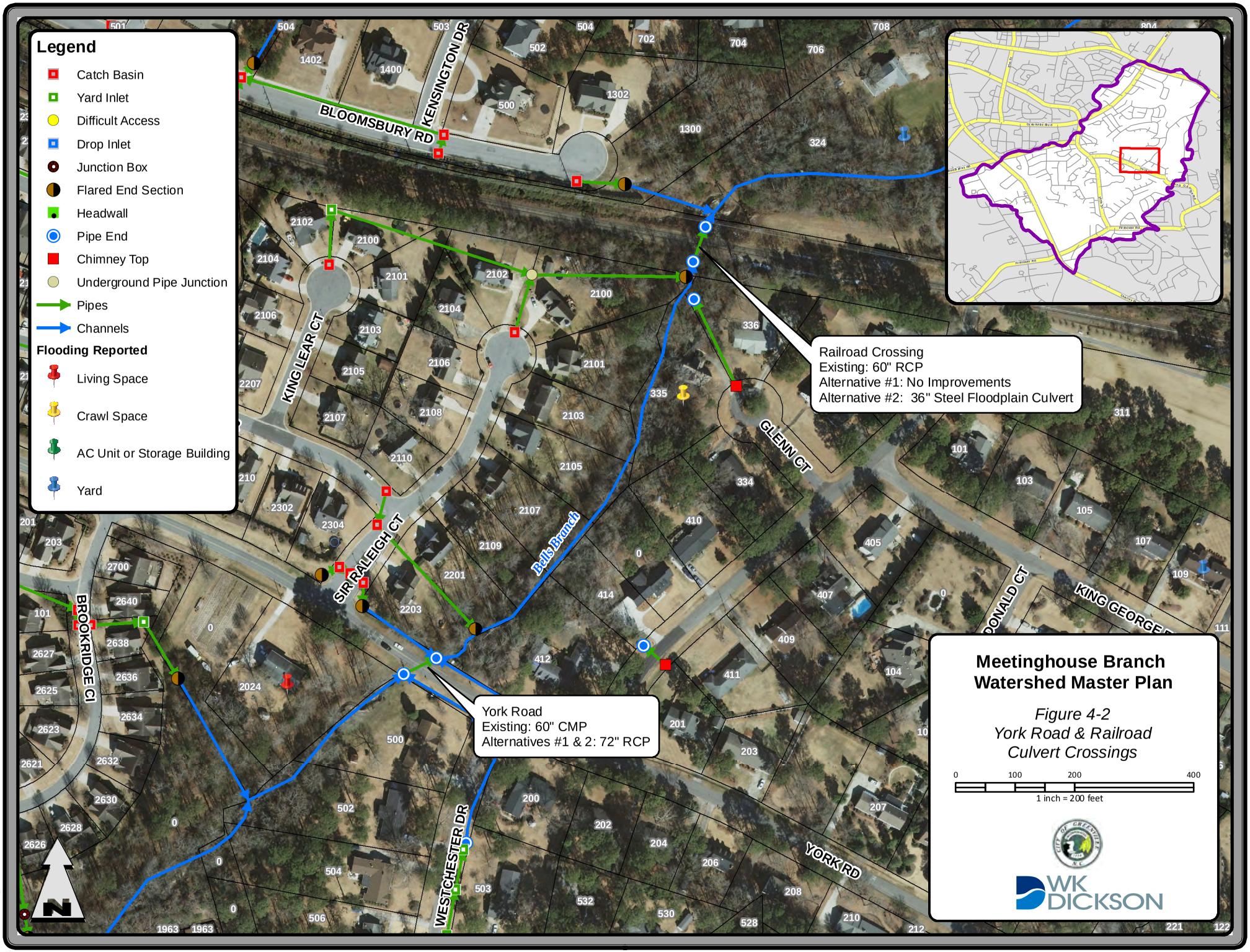
Picture 4-3. Upstream Invert – Oxford Road Closed System (Bells Branch)

As shown in Picture 4-3, there are several trees that will need to be removed near the upstream end of the closed system to install the RCBC. There are also trees located at the downstream end

and the grass area near the parking lot that may need to be removed or protected. The total estimated cost for this project is $1,423,000.

As noted above the size of the floodplain culverts installed at the Railroad Crossing will impact the proposed flow reaching the Oxford Road Closed System. The culvert size required to pass the 10-year storm event for the Oxford Road Closed System is the same (7′ x 5′ RCBC) for Alternative #1 and Alternative #2 at the Railroad Crossing. However, the amount of freeboard will differ. For Alternative #1 at the Railroad Crossing, 1.05 feet of freeboard will be provided. The freeboard provided for Alternative #2 will be 0.8 feet of freeboard for the Oxford Road Closed System in the desired 10-year storm event.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Quail Ridge Road
Existing: Twin 54" CMP
No Proposed Alternatives
East14th Street
Existing: 48" CMP
Alternative #1: Twin 42" RCP
QUAIL RIDGE RD
SCARBOROUGH RD
CARLISLE CT
CUMBERLAND PL
E 14TH ST
Bells Branch
Meetinghouse Branch
Watershed Master Plan
Figure 4-1
East 14th Street & Quail Ridge Road
Culvert Crossings
0 100 200 400
1 inch = 200 feet
WK DICKSON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Difficult Access
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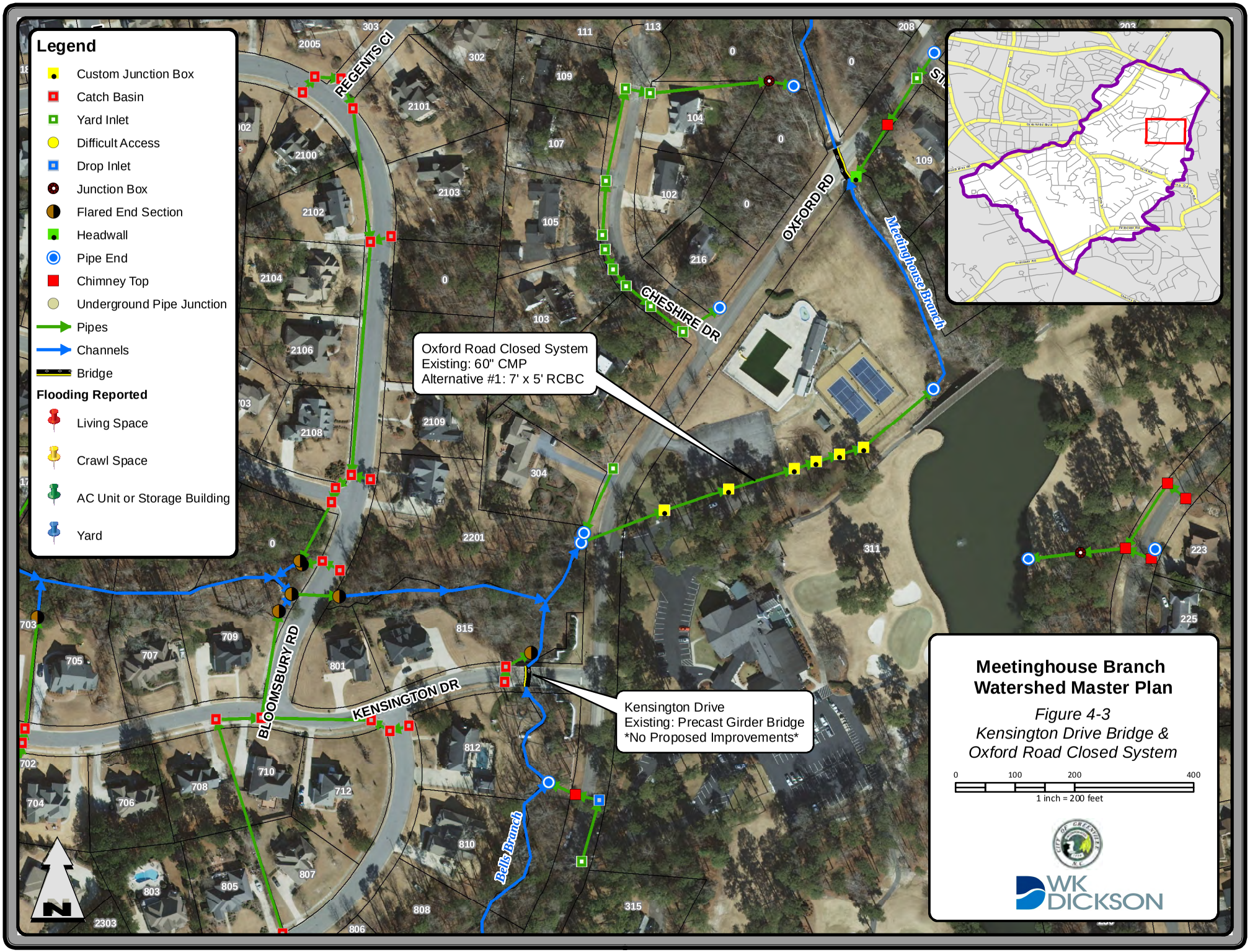
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
BLOOMSBURY RD
KENSINGTON DR
KING LEAR CT
GLENN CT
SIR RALEIGH CT
BROOKRIDGE CI
WESTCHESTER DR
YORK RD
KING GEORGE
Bells Branch
Railroad Crossing
Existing: 60" RCP
Alternative #1: No Improvements
Alternative #2: 36" Steel Floodplain Culvert
York Road
Existing: 60" CMP
Alternatives #1 & 2: 72" RCP
Meetinghouse Branch
Watershed Master Plan
Figure 4-2
York Road & Railroad
Culvert Crossings
0 100 200 400
1 inch = 200 feet
WK DICKSON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Junction Box
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Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
REGENTS CI
OXFORD RD
CHESHIRE DR
Meetinghouse Branch
BLOOMSBURY RD
KENSINGTON DR
Bells Branch
Oxford Road Closed System
Existing: 60" CMP
Alternative #1: 7' x 5' RCBC
Kensington Drive
Existing: Precast Girder Bridge
No Proposed Improvements
Meetinghouse Branch
Watershed Master Plan
Figure 4-3
Kensington Drive Bridge &
Oxford Road Closed System
0 100 200 400
1 inch = 200 feet
WK DICKSON

A summary of the hydraulic performance for the Bells Branch improvements proposed for Alternatives #1 and #2 are included in Tables 4-1 and 4-2, respectively. The water surface elevations shown assume all proposed primary system improvements for Bells Branch are constructed. The level of improvement will be reduced if all projects are not implemented.

Table 4-1: Hydraulic Performance for Alternative #1 – Bells Branch

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
East 14th Street (Proposed Twin 42″ RCP)	63.90	50-yr	61.19	62.28	62.91	63.47	**64.19**
Quail Ridge Road (Existing Twin 54″ CMP)	62.75	25-yr	57.87	59.20	60.11	60.85	61.50
York Road (Proposed 72″ RCP)	52.00	25-yr	48.33	50.77	**52.50**	**54.17**	**54.40**
Railroad Crossing (Existing 60″ RCP)	54.02	100-yr	43.92	47.54	51.16	**54.15**	**54.38**
Kensington Drive(Existing Bridge)	33.70	25-yr	23.37	24.81	25.43	25.78	26.12
Oxford Road (Proposed 7′ x 5′ RCBC)	24.04	10-yr	20.30	22.95	23.93	**24.29**	**24.52**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

Table 4-2: Hydraulic Performance for Alternative #2 – Bells Branch

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
East 14th Street (Proposed Twin 42″ RCP)	63.90	50-yr	61.19	62.27	62.91	63.46	**64.13**
Quail Ridge Road (Existing Twin 54″ CMP)	62.75	25-yr	57.88	59.20	60.10	60.86	61.50
York Road (Proposed 72″ RCP)	52.00	25-yr	47.77	49.98	51.79	**52.29**	**52.94**
Railroad Crossing (Existing 60″ RCP with 36″ Steel Floodplain Culvert)	54.02	100-yr	43.03	45.46	47.25	49.40	52.45
Kensington Drive(Existing Bridge)	33.70	25-yr	23.38	25.03	25.70	26.09	26.43
Oxford Road (Proposed 7′ x 5′ RCBC)	24.04	10-yr	20.30	23.20	**24.10**	**24.44**	**24.66**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

As noted in Table 3-4 a total of 27 structures along Bells Branch are located at least partially within the existing conditions 100-year floodplain as modeled for this study and 11 structures along Bells Branch are located at least partially within the 25-year floodplain. As a result of

Alternative 1, two (2) structures will be removed from the 25-year floodplain and five (5) structures will be removed from the 100-year floodplain. Water surface elevations for the 25-year and 100-year event will be lower for 26 of the 27 floodprone structures along Bells Branch resulting in a reduction in the frequency, severity, and duration of flooding.

As a result of Alternative 2, three (3) structures will be removed from the 25-year floodplain and twelve (12) structures will be removed from the 100-year floodplain. Water surface elevations for the 25-year and 100-year event will be lower for 26 of the 27 floodprone structures along Bells Branch resulting in a reduction in the frequency, severity, and duration of flooding.

4.1.2 Meetinghouse Branch

Charles Boulevard – The existing twin 48″ RCP at Charles Boulevard provide a 25-year level of service. The desired level of service at this location is the 50-year design storm as Charles Boulevard is a thoroughfare road maintained by NCDOT. Upstream of Charles Boulevard there are seven townhomes/apartments located in the 25-year existing conditions floodplain and over fifty in the 100-year existing conditions floodplain including the resident at 225-A Cape Point Lane reporting yard and structural flooding. There is also a reach of stream located downstream of the culvert crossing that is experiencing bank erosion. The Charles Boulevard Stream Project discussed in Section 5.1 helps to reduce this identified instream erosion.

- Alternative #1 – The culverts appear to be in good condition and the 50-year storm only overtops the road by 0.15 feet. Given the challenges in installing additional capacity under the 5-lane NCDOT roadway as described below and the condition of the existing culverts, Alternative 1 includes no improvements at this location (See Figure 4-4).

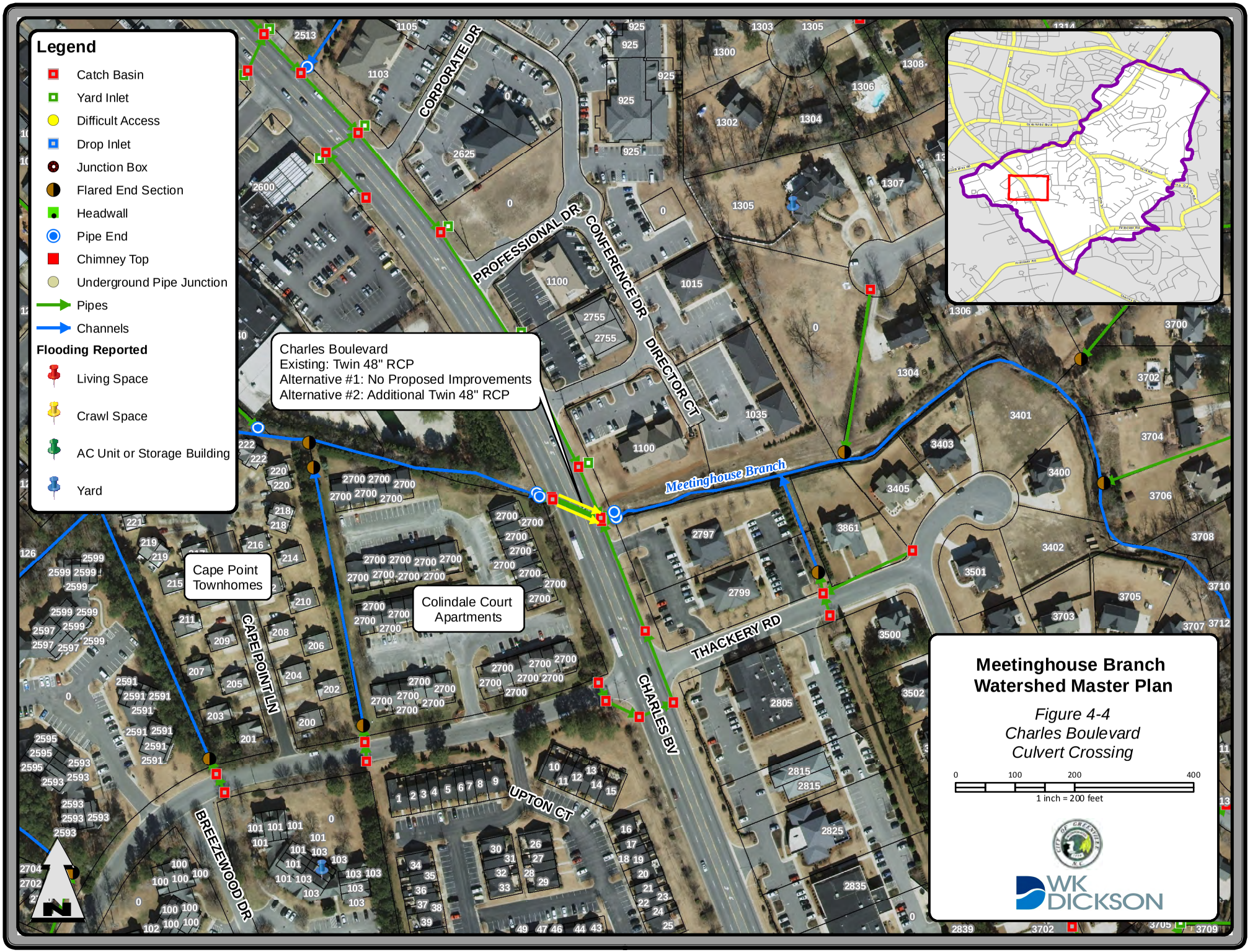
- Alternative #2 – This alternative was presented to provide a 50-year level of service for Charles Boulevard and to reduce the frequency and severity of flooding for the residents in the apartments and townhomes upstream of the Charles Boulevard culvert crossing. The existing twin 48″ RCP will be left in place. The installation of additional twin 48″ pipes will reduce the water surface elevations for the 25-year storm event by 0.9 to 1.6 feet upstream of Charles Boulevard. The proposed culvert improvements will remove all six properties from the 25-year floodplain and forty-seven properties from the 100-year floodplain including 225-A Cape Point Lane.

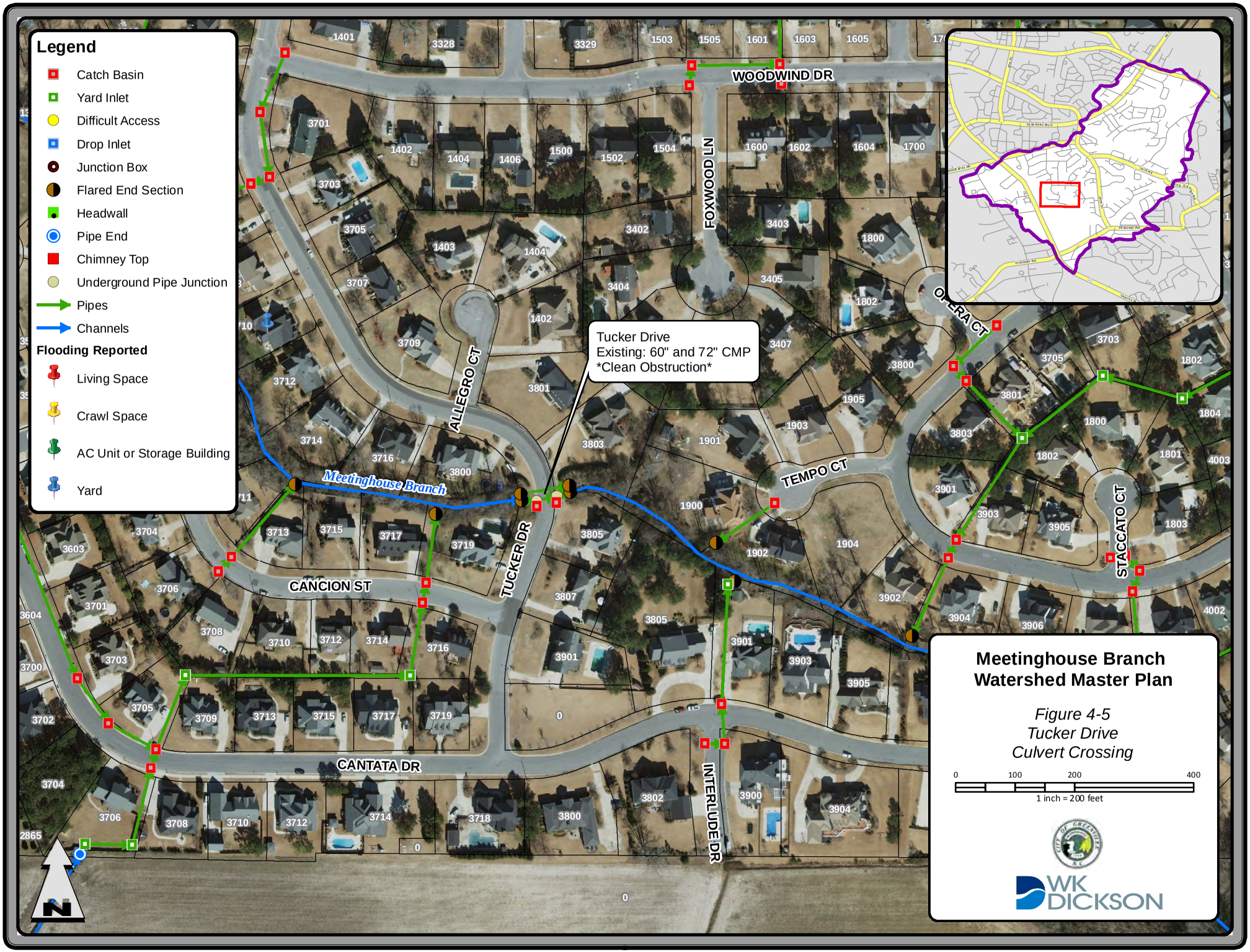
  Charles Boulevard is a major thoroughfare roadway maintained by NCDOT. Due to the high traffic volume, it is anticipated that tunneling techniques would be required to install the culverts. In order to gain access for installing the proposed culverts, trees must be removed. The installation of construction staging areas will likely require additional tree removal, temporary construction easements, and a NCDOT encroachment agreement. Coordination with NCDOT may require additional time to for permitting and design. The total estimated cost for this project is $549,300.

Picture 4-4. Obstruction at Tucker Drive Culvert Crossing (Meetinghouse Branch)

Tucker Drive – As determined by the existing conditions analysis, the existing 60″ and 72″ CMP culverts at this crossing do not meet the desired 25-year level of service. The culverts are in good condition but the opening of the 60″ CMP is currently obstructed by sediment deposits. As shown in Picture 4-4, the pipe is over 50 percent blocked thereby reducing the

pipe capacity. If this culvert is cleaned out and able to flow at full capacity, it will provide a 25-year level of service. Therefore, it is recommended that the 60″ CMP be cleaned out. No additional improvements are proposed at this location (See Figure 4-5).


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Charles Boulevard
Existing: Twin 48" RCP
Alternative #1: No Proposed Improvements
Alternative #2: Additional Twin 48" RCP
Meetinghouse Branch
Cape Point Townhomes
Colindale Court Apartments
CORPORATE DR
PROFESSIONAL DR
CONFERENCE DR
DIRECTOR CT
CAPE POINT LN
CHARLES BV
THACKERY RD
UPTON CT
BREEZEWOOD DR
Meetinghouse Branch Watershed Master Plan
Figure 4-4
Charles Boulevard
Culvert Crossing
0 100 200 400
1 inch = 200 feet
WK DICKSON


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Tucker Drive
Existing: 60" and 72" CMP
Clean Obstruction
WOODWIND DR
FOXWOOD LN
OPERA CT
ALLEGRO CT
TUCKER DR
TEMPO CT
STACCATO CT
CANCION ST
CANTATA DR
INTERLUDE DR
Meetinghouse Branch
Meetinghouse Branch
Watershed Master Plan
Figure 4-5
Tucker Drive
Culvert Crossing
0
100
200
400
1 inch = 200 feet
WK DICKSON

14th Street – As determined by the existing conditions analysis, the existing twin 60″ CMP culvert at 14th Street is undersized and does not meet a 50-year level of service. Based on the model results the road overtops during a 2-year storm event, however City staff has not observed flooding at this location. Since the City's design standards are not being met and the existing culvert is in poor condition, it is proposed that the existing system be replaced.

- Alternative #1 – As part of this alternative, the existing culvert will be replaced with twin 11′ x 6′ RCBC. The upsized culvert will provide a 25-year level of service. While the desired level of service is the 50-year storm at this location, the culvert is operating under outlet control due to high tailwater which limits the potential capacity at this location. A 50-year level of service was not considered to be cost feasible for this alternative. Since the tailwater elevation is impacting the conveyance of the culvert, the velocities are relatively low at the outlet of the culvert, approximately 4 ft/sec. Based on the velocities reported by the model, it does not appear stream stabilization in addition to those recommended in the Crooked Creek Road Stream Project described in Section 5.1. The City may want to consider installing bank pins as part of any project along the main stream to monitor long term bank stability. Figure 4-6 summarizes the improvements proposed at 14th Street as part of Alternative #1.

  The resulting upstream water surface elevations will be reduced by as much as 1.4 feet in the 25-year storm event. There are two properties (104 and 106 Casual Circle) upstream of 14th Street located in the existing conditions 25- and 100-year floodplain. In addition, residents located at 300 and 406 Tuckahoe Drive reported yard flooding and two residents at 402 Tuckahoe Drive and 102 Casual Circle reported storage building flooding. Although the water surface elevations are reduced for these properties, none will be removed from the 25- or 100-year floodplain. The properties will continue experiencing flooding but the severity and frequency will be slightly reduced.

  As a result of increasing the capacity of the 14th Street culvert, downstream of 14th Street, the water surface elevation will increase by as much as 0.13 feet in the 25-year storm event and 0.08 feet in the 100-year storm event. Twelve properties along Old Oak Walk and Lancelot Drive that are already located in the 25-year or 100-year floodplain may see minor increases in water surface elevation. To offset these increases, a small berm has been included in the improvements along both banks at these locations. The floodplain benching proposed as part of Alternative #2 will help to alleviate the increases generated by the upsized culvert at 14th Street.

  The total estimated cost for this project is $576,600.

- Alternative #2 – The purpose of Alternative 2 is to lower the tailwater at 14th Street to the extent possible to allow for a smaller culvert upgrade when compared to Alternative 1. This alternative involves lowering the right top of bank and adding a floodplain bench on the left and right overbank for approximately 1,300 feet downstream of 14th Street in conjunction with upsizing the existing culvert. The floodplain bench will range in width between 100 and 175 feet. Figure 4-6 shows the locations of floodplain benching proposed as part of Alternative #2. The intent of the floodplain bench is to lower the water surface elevations along the length of the project and to reduce the tailwater at 14th Street. This includes residents along Old Oak Walk and Lancelot Drive

that are in the 25- and 100-year floodplain.

The culvert for this alternative is sized to pass the 25-year storm event. This can be accomplished by replacing the existing twin 60″ CMP with twin 9′ x 5′ RCBC. The resulting upstream water surface elevations will be reduced by 2.8 feet immediately upstream of the culvert 25-year storm event. Improvements further upstream are more moderate which will reduce the severity and duration of flooding, however these reductions will not remove any properties from the 25-year floodplain.

Immediately downstream of 14th Street, the water surface elevation will decrease by two feet in the 25-year storm event. These water surface elevation reductions will remove two properties from the 25-year floodplain and one from the 100-year floodplain. Similar to Alternative #1, the increased conveyance capacity under 14th Street will increase downstream flows. To avoid water surface elevation increases for floodprone residents along Old Oak Walk and Lancelot Drive, Alternative #2 includes a floodplain bench approximately 500 linear feet along the right bank approximately 300 feet upstream of King George Road. The bench would be located on a landlocked parcel that appears to have limited potential for being developed. The width of the bench would range from 50 feet to 180 feet. As a result, the residents along Old Oak Walk and Lancelot Drive will not experience any water surface elevation increases as part of Alternative #2. Instead, they will have reductions between 0.2 and 0.9 feet during the 25-year storm event. The total estimated cost for this project is $1,476,300.

During a field inspection, there were several potential site restrictions and utility conflicts identified including overhead power lines that are located above the 14th Street culvert. There also appears to be sanitary sewer lines that may need to be replaced or relocated. Impacts to traffic flow during construction were considered. This section of 14th Street is a two-lane roadway. It is anticipated that a road closure or a flagged two-way one-lane operation will be required. Alternative #2 included additional impacts from the construction of the floodplain benching. For example, there are sanitary manholes located in the left overbank that will likely need to be replaced (See Picture 4-5). Portions of the floodplain benching will be constructed within existing easements along the stream but the large majority will require construction on private property. Easements will likely be required for at least seventeen properties as part of Alternative #2. The installation of the floodplain bench will also require tree removal and protection along the stream banks. Additional coordination may be required with the Pitt County Historical Society located along 14th Street and within the proposed project limits.

Picture 4-5. Left Overbank – Proposed Location of 14th Street Floodplain Bench (Meetinghouse Branch)

Both alternatives include double RCBCs. Permitting requirements state that one of the culverts must be buried below the streambed by at least one foot and the other must be baffled by the equivalent depth. It may be necessary to complete a geotechnical evaluation with borings to determine the feasibility of installing and burying the RCBCs the required one foot.

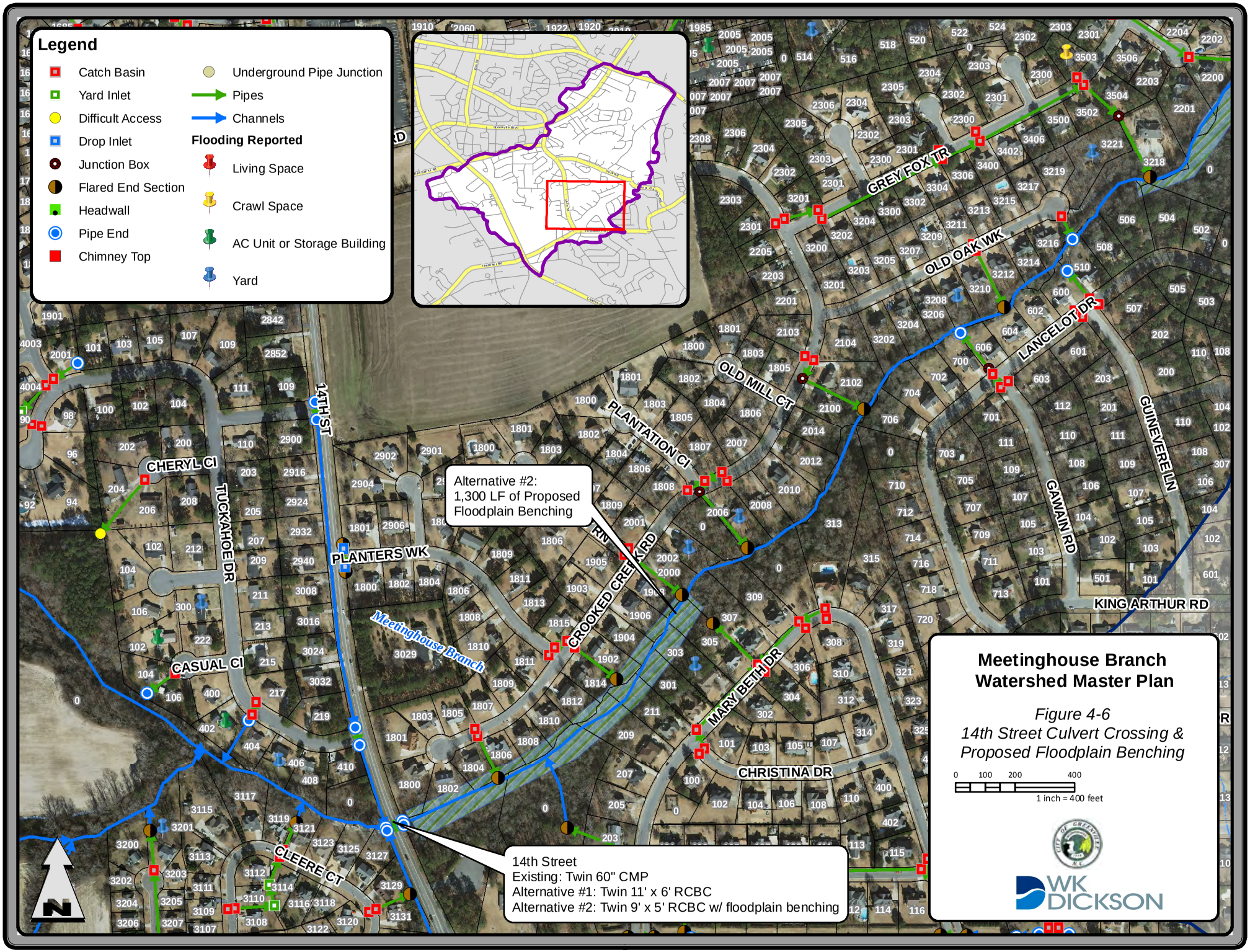
In addition to Alternatives #1 and #2, there were several other alternatives that were evaluated but are not proposed for implementation because they are cost prohibitive and impractical to construct. One such alternative involved constructing a detention facility on a 24-acre parcel (Parcel #06793) located along 14th Street south of Bells Branch. A detention area was sized to avoid or minimize required infrastructure improvements downstream at the 14th Street culvert crossing. As previously mentioned, the existing culvert is operating below a 2-year level of service. In order to bring it up to the desired 25-year level of service, the amount of flow reaching the culvert must be reduced by approximately 60 percent. To achieve this level of reduction, the total storage volume required is close to 3 million cubic feet. Assuming 4 feet of storage would be provided, the calculated footprint of the detention area is 16-acre.

Due to the location in the watershed and the flat topography, it would be difficult to convey a significant amount of runoff to the detention area and back to the stream. It is likely that due to the lack of elevation difference, pumping would be required to discharge runoff from the detention pond back to the receiving stream. Potential benefits from the proposed facility would be significantly overshadowed by the capital construction cost required to construct a 16-acre detention pond and the ongoing operation and maintenance costs associated with pumping.

Another parcel (Parcel #09010) located between Charles Boulevard and 14th Street was evaluated for detention potential. A detention facility at this location would provide limited storage due to the flat topography. Pumps could be used to provide some additional storage capacity. However as is the case with the previous parcel, the potential benefit is minimal at this location and any benefit would be offset by the cost of infrastructure required to construct the facility and route water to it.

King George Road – Based on the results obtained from the existing conditions analysis, the existing bridge at King George Road is passing the desired 25-year design storm. A routine inspection was completed by the NCDOT on March 20, 2012. The inspector identified several deep spalls and cracks in the structure. A complete copy of the bridge inspection report is included in Appendix L. It was concluded that the King George Road Bridge required priority maintenance repairs and the City has opted to replace it via a municipal agreement with NCDOT. The design for the replacement bridge was provided by the City from Wetherill Engineering and was not developed as part of this Master Plan. The proposed bridge improvements were modeled as part of Alternative #1 and #2 to evaluate any impacts the improvements may have on water surface elevations. The bridge configuration included in the proposed conditions models were based on preliminary design plans provided by the City. The proposed bridge will continue to provide the desired 25-year level of service therefore, no additional improvements are proposed at this location (See Figure 4-7).

Railroad Crossing – The existing bridge at the railroad crossing along Meetinghouse Branch meets the desired 100-year level of service. The bridge appears to be in good condition therefore, no improvements are proposed at this location (See Figure 4-7).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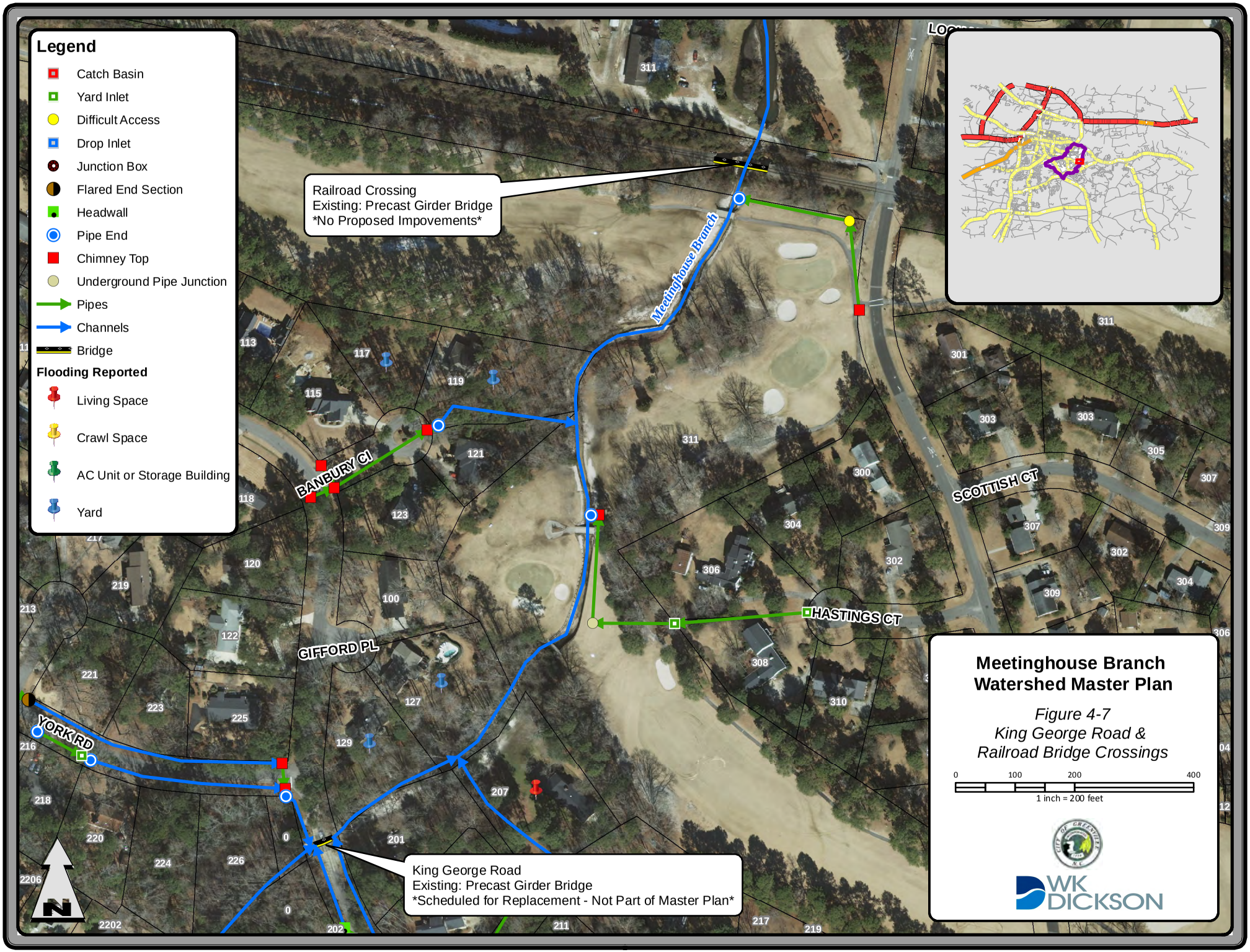
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Alternative #2:
1,300 LF of Proposed
Floodplain Benching
14th Street
Existing: Twin 60" CMP
Alternative #1: Twin 11' x 6' RCBC
Alternative #2: Twin 9' x 5' RCBC w/ floodplain benching
Meetinghouse Branch
14TH ST
GREY FOX TR
OLD OAK WK
LANCELOT DR
GUINEVERE LN
GAWAIN RD
KING ARTHUR RD
OLD MILL CT
PLANTATION CI
CROOKED CREEK RD
MARY BETH DR
CHRISTINA DR
PLANTERS WK
CHERYL CI
TUCKAHOE DR
CASUAL CI
CLEERE CT
Meetinghouse Branch
Watershed Master Plan
Figure 4-6
14th Street Culvert Crossing &
Proposed Floodplain Benching
0 100 200 400
1 inch = 400 feet
WK DICKSON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Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Railroad Crossing
Existing: Precast Girder Bridge
No Proposed Impovements
Meetinghouse Branch
BANBURY CI
SCOTTISH CT
HASTINGS CT
GIFFORD PL
YORK RD
King George Road
Existing: Precast Girder Bridge
Scheduled for Replacement - Not Part of Master Plan
Meetinghouse Branch Watershed Master Plan
Figure 4-7
King George Road &
Railroad Bridge Crossings
0 100 200 400
1 inch = 200 feet
WK DICKSON

Oxford Road South – The existing bridge at the southern crossing along Oxford Road is almost meeting the desired 25-year level of service with the completion of the proposed upstream improvements. It will overtop by less than 0.1 feet. The bridge was installed in 2002 and is in excellent condition therefore, no improvements are proposed at this location (See Figure 4-8).

Oxford Road North – The existing bridge at the northern crossing along Oxford Road meets the desired 25-year level of service. A routine inspection was completed by NCDOT on March 19, 2012. The inspector identified several defective items that need to be replaced or repaired. A complete copy of the bridge inspection report and the recommended repairs are included as Appendix L.

Additionally, it is recommended that the following minor improvements be made to prevent any additional erosion issues (See Figure 4-9):

- Install 20 linear feet of curb and gutter on the southern side of the bridge along with two inlets;
- Raise the existing curb and gutter to be flush with the bridge on the northern side; and
- Relocate the existing 18″ CMP away from the bridge wingwall (See Picture 4-6).

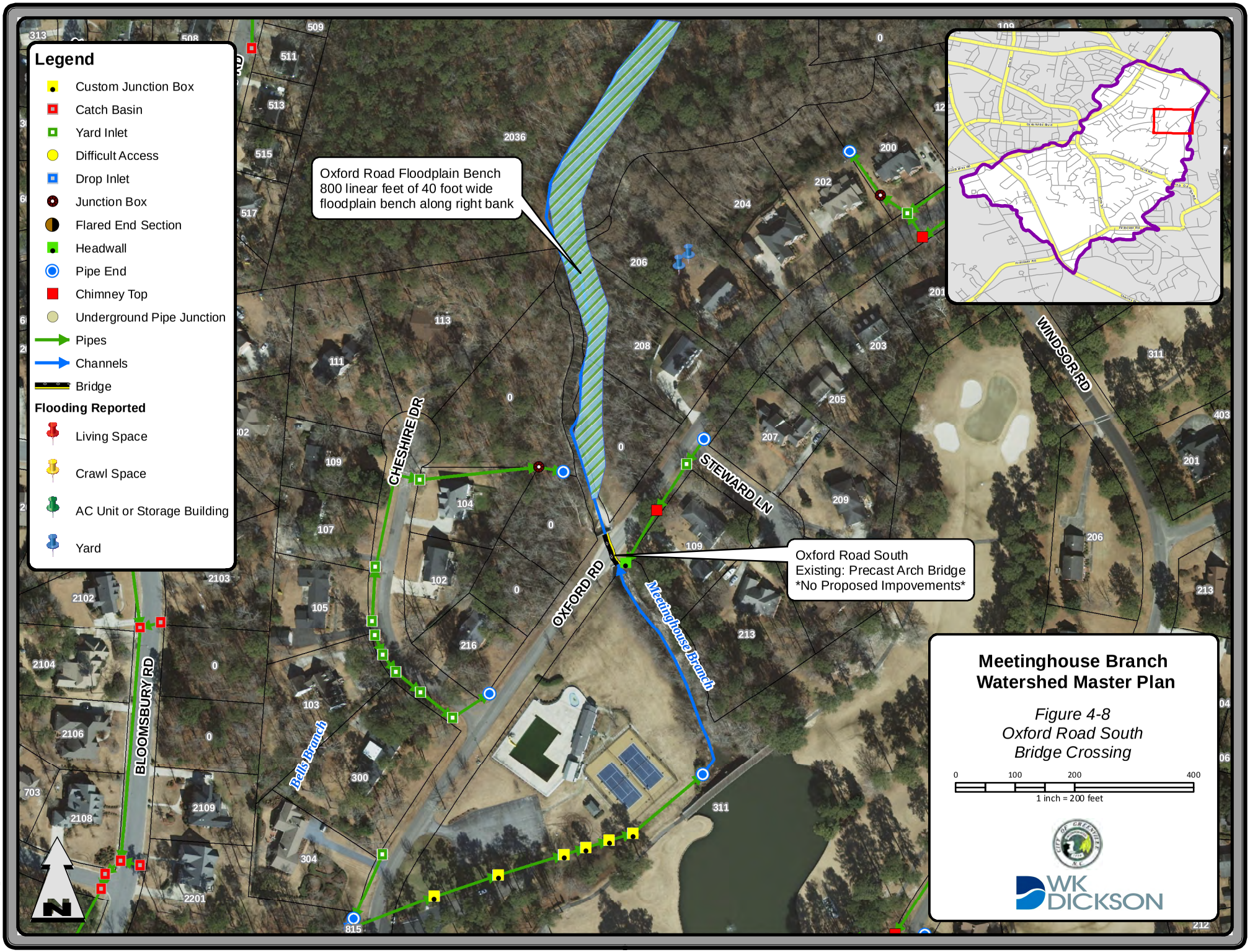
Picture 4-6. Downstream Right Wingwall - Oxford Road North Bridge (Meetinghouse Branch)

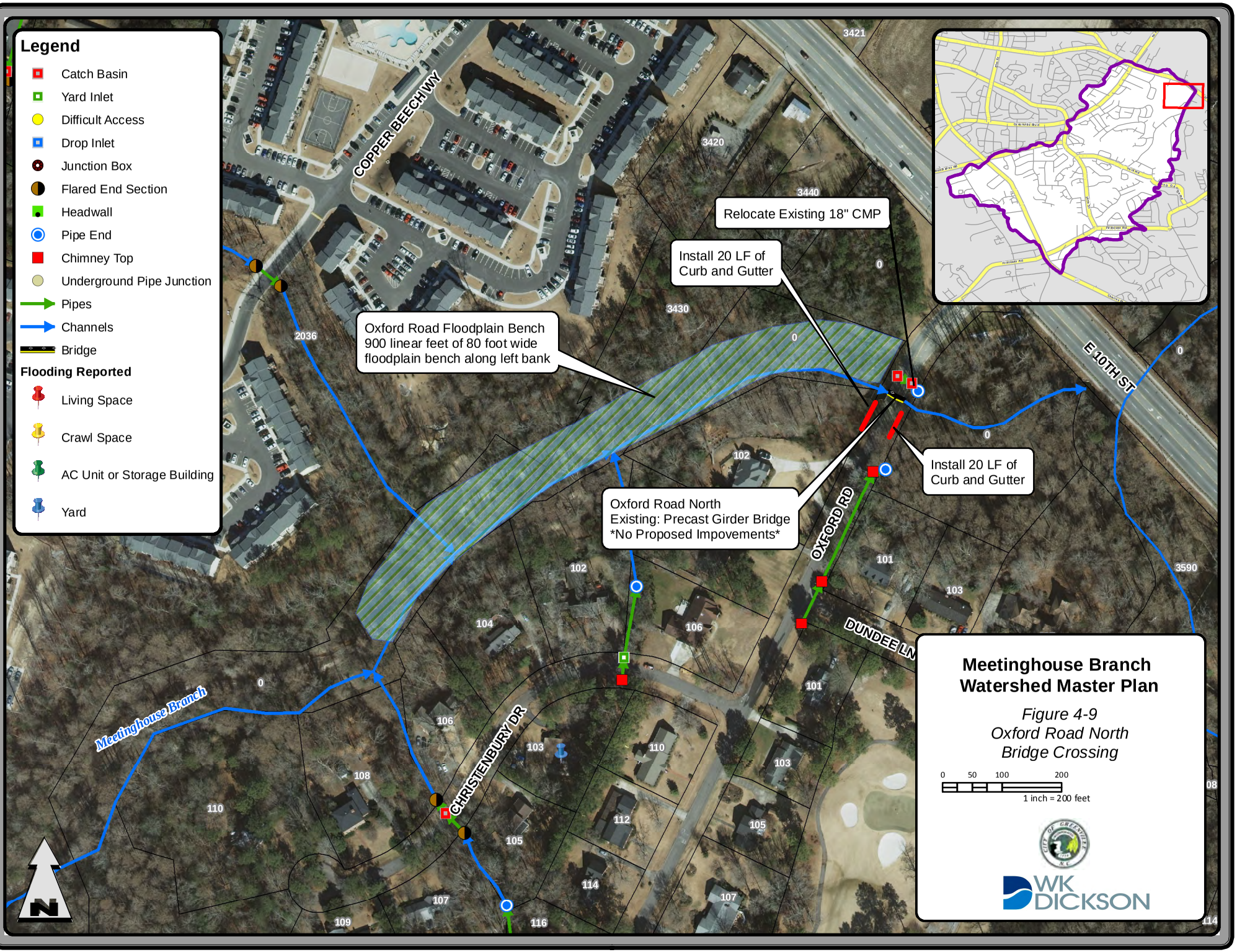
During a field inspection, there were several potential site restrictions and utility conflicts identified including an electrical box. There also is a sanitary sewer line that may need to be replaced or relocated. Impacts to traffic flow during construction were considered. This section of Oxford Road is a two-lane roadway and it is anticipated that a road closure or a flagged two-way one-lane operation will be required.

Between the two crossings at Oxford Road water surface elevations increase for the 25-year and 100-year storms as a result of increasing conveyance capacity in the upper portions of the watershed and reducing the storage behind roadways. There are nine (9) homes in this section of stream that are already floodprone. Water surface increases for the 25-year storm range from

0.1 to 0.2 feet and water surface increases in the 100-year storm range between 0.0 to 0.1 feet. The floodprone properties are located along Steward Lane, Oxford Road, Cheshire Drive and Christenbury Drive. Alternative #1 does not include improvements to offset the increases in water surface elevation. Based on the projects implemented some type of floodproofing or protection may be required for individual houses that are located in the floodplain based on finished floor elevations.

Alternative #2 includes floodplain benching between the two Oxford Road crossings that will mitigate all of the water surface increases except for the house located along 102 Oxford Road immediately upstream of the Oxford Road North Bridge. Based on surveyed finished floor elevations additional floodproofing measures such as a berm or floodwall could be installed to protect the residence at that location. The floodplain bench is located for approximately 800 linear feet along the right bank immediately downstream of the Oxford Road South crossing. A second floodplain bench is located for approximately 900 linear feet along the left bank upstream of the Oxford Road North crossing. As noted above, the benching will offset the water surface increases for the majority of this stretch of stream except for the locations immediately upstream of the Oxford Road South crossing. The total estimated cost for this project is $559,000.


Legend
Custom Junction Box
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Oxford Road Floodplain Bench
800 linear feet of 40 foot wide
floodplain bench along right bank
Oxford Road South
Existing: Precast Arch Bridge
No Proposed Impovements
CHESHIRE DR
STEWARD LN
OXFORD RD
WINDSOR RD
BLOOMSBURY RD
Bells Branch
Meetinghouse Branch
Meetinghouse Branch
Watershed Master Plan
Figure 4-8
Oxford Road South
Bridge Crossing
0 100 200 400
1 inch = 200 feet
WK DICKSON


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
COPPER BEECH WY
Relocate Existing 18" CMP
Install 20 LF of Curb and Gutter
Oxford Road Floodplain Bench
900 linear feet of 80 foot wide floodplain bench along left bank
Oxford Road North
Existing: Precast Girder Bridge
No Proposed Impovements
Install 20 LF of Curb and Gutter
E 10TH ST
OXFORD RD
DUNDEE LN
CHRISTIENBURY DR
Meetinghouse Branch
3421
3420
3440
3430
3590
2036
102
101
103
104
106
110
108
105
112
107
109
116
114
Meetinghouse Branch Watershed Master Plan
Figure 4-9
Oxford Road North
Bridge Crossing
0 50 100 200
1 inch = 200 feet
WK DICKSON

A summary of the hydraulic performance for the improvements proposed for Alternatives #1 and #2 are included in Tables 4-3 and 4-4, respectively. The water surface elevations shown assume all proposed primary system improvements for Meetinghouse Branch are constructed. The level of improvement will be reduced if all projects are not implemented.

Table 4-3: Hydraulic Performance for Alternative #1 – Meetinghouse Branch

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Charles Boulevard (Existing Twin 48″ RCP)	68.00	50-yr	63.80	65.87	67.39	**68.15**	**68.30**
Tucker Drive (Existing 72″ CMP and 60″ CMP)	63.64	25-yr	59.76	61.68	63.16	**64.15**	**64.57**
14th Street (Proposed Twin 11′ x6′ RCBC)	53.83	50-yr	51.70	52.43	53.82	**54.30**	**54.67**
King George Road (Proposed NCDOT Bridge)	37.09	25-yr	33.02	34.22	34.97	35.59	36.45
Railroad Crossing (Existing Bridge)	43.41	100-yr	32.23	32.72	33.02	33.26	33.52
Oxford Road South (Existing 3-Sided Arch Bridge)	25.96	25-yr	22.94	25.04	**26.04**	**26.84**	**27.48**
Oxford Road North (Existing Bridge)	18.16	25-yr	12.74	14.58	15.65	16.95	**19.81**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

Table 4-4: Hydraulic Performance for Alternative #2 – Meetinghouse Branch

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Charles Boulevard (Existing Twin 48″ RCP with add'l Twin 48″ RCP)	68.00	50-yr	63.53	65.05	66.07	66.91	67.67
Tucker Drive (Existing 72″ CMP and 60″ CMP)	63.64	25-yr	59.76	61.69	63.16	**64.15**	**64.58**
14th Street (Proposed Twin 9′ x5′ RCBC Floodplain Bench)	53.83	50-yr	50.04	51.48	52.45	**53.98**	**54.53**
King George Road (Proposed NCDOT Bridge)	37.09	25-yr	33.02	34.23	34.98	35.60	36.47
Railroad Crossing (Existing Bridge)	43.41	100-yr	32.23	32.73	33.02	33.26	33.53
Oxford Road South (Existing 3-Sided Arch Bridge)	25.96	25-yr	22.34	24.56	25.63	**26.45**	**27.23**
Oxford Road North (Existing Bridge)	18.16	25-yr	12.74	14.58	15.73	17.05	**20.08**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

4.1.3 Hydrology

As previously stated for the purposes of this Master Plan, the future conditions land use is assumed to be the same as the existing conditions land use since it is largely built out. Based on this assumption, the hydrologic parameters, such as curve numbers, time of concentration, and land cover, remain consistent with the existing conditions models.

Peak flows for the primary systems were developed for the 2-, 10-, 25-, 50-, and 100-year storm events. The proposed conditions flows were developed taking into account attenuation for the proposed culvert sizes. Attenuation was assumed upstream of all four culvert crossings along Bells Branch and at one culvert crossing (14th Street) along Meetinghouse Branch. Additionally, the pond located in the Brook Valley Country Club was included as an attenuation area. The proposed peak flows used for sizing the proposed culverts for the various alternatives are summarized in Tables 4-5 and 4-6. The flows assume all proposed improvements within the watershed are completed based on the Alternative selected. If individual projects are implemented or combined with projects from another Alternative, the peak flows should be updated to make sure downstream impacts are sufficiently analyzed. A hard copy of the HEC-HMS output is included as Appendix H. The CD found in Appendix J contains this digital information.

4.1.4 Hydraulics

The hydraulic analysis for the proposed conditions was similar to the analysis completed for the existing conditions. The model was updated to reflect the proposed culvert improvements, as well as proposed floodplain benching locations. The starting water surface elevations were the same for both existing and proposed conditions models.

Table 4-5: Proposed Conditions Flows from HEC-HMS (Alternative #1)

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
BELLS BRANCH							
BB – 1	U/S Limit of Bells Branch	11194	30	59	80	98	118
14th St – BB	14th Street	9780	58	112	145	170	192
Quail Ridge Rd	Quail Ridge Road	9132	75	143	185	214	238
York Road	York Road	7435	102	203	271	336	397
Railroad Crossing	Railroad Culvert	6760	111	205	253	285	323
ADD – 14	Kensington Drive	4687	134	281	377	456	539
MEETINGHOUSE BRANCH							
MHB-1	U/S Limit of Meetinghouse Branch	14470	48	83	108	129	152
ADD – 1_2	Charles Boulevard	13233	76	132	170	204	241
ADD – 3	Tucker Drive	11180	146	259	339	408	484
ADD – 7	King George Road	3507	320	588	778	942	1,124
ADD – 8	Railroad Bridge	2045	338	641	861	1,054	1,270
ADD – 15	Oxford Road	-532	549	1,198	1,627	1,985	2,386
OUTLET	D/S Limit of Meetinghouse Branch	-3630	547	1,197	1,626	1,984	2,385

Table 4-6: Proposed Conditions Flows from HEC-HMS (Alternative #2)

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
BELLS BRANCH							
BB – 1	U/S Limit of Bells Branch	11194	30	59	80	98	118
14th St – BB	14th Street	9780	58	112	145	170	192
Quail Ridge Rd	Quail Ridge Road	9132	75	143	185	214	238
York Road	York Road	7435	102	203	271	335	397
Railroad Crossing	Railroad Culvert	6760	112	221	285	328	369
ADD – 14	Kensington Drive	4687	134	288	395	483	570
MEETINGHOUSE BRANCH							
MHB-1	U/S Limit of Meetinghouse Branch	14470	48	83	108	129	152
ADD – 1_2	Charles Boulevard	13233	76	132	170	204	241
ADD – 3	Tucker Drive	11180	146	259	339	408	484
ADD – 7	King George Road	3507	320	590	780	946	1,129
ADD – 8	Railroad Bridge	2045	338	643	863	1,058	1,275
ADD – 15	Oxford Road	-532	549	1,200	1,655	2,025	2,435
OUTLET	D/S Limit of Meetinghouse Branch	-3630	547	1,200	1,654	2,024	2,434

4.2 Secondary Systems

Developing flood control alternatives for the secondary systems typically included increases in pipe capacity and/or rerouting flows where more space was available for improvements. In general the proposed improvements for the secondary system are less complex from a permitting perspective since they typically do not require FEMA or 401/404 permits. However, the proposed improvements for the secondary system are oftentimes constrained by private property as space is typically limited between houses or other structures. Utility conflicts are another constraint that is typical for secondary system improvements. Secondary system improvements also considered feedback from City staff and residents as well as maintenance needs based on findings from the inventory and/or feedback from City staff.

The projects described are the recommended alternatives for each of the secondary systems.

Grey Fox Trail System
WK Dickson recommends the following improvements for the Grey Fox Trail System as shown in Figure 4-10:

- Replace 231 linear feet of 30″ RCP with 36″ RCP with flared end section along 3218 Old Oak Walk;
- Replace 158 linear feet of 30″ RCP with 36″ RCP between 3502 and 3504 Grey Fox Trail;
- Replace 394 linear feet of 30″ RCP with 36″ RCP along Grey Fox Trail;
- Replace 141 linear feet of 24″ RCP with 36″ RCP along Grey Fox Trail;
- Replace 33 linear feet of 15″ RCP with 18″ RCP along Grey Fox Trail;
- Replace 451 linear feet of 24″ RCP with 30″ RCP along Grey Fox Trail;
- Replace 33 linear feet of 18″ RCP with 24″ RCP along Grey Fox Trail;
- Replace 116 linear feet of 15″ RCP with 24″ RCP along Grey Fox Trail; and
- Replace 33 linear feet of 15″ RCP with 24″ RCP along Crooked Creek Road;
- Install 8 inlets; and
- Install 1 junction box.

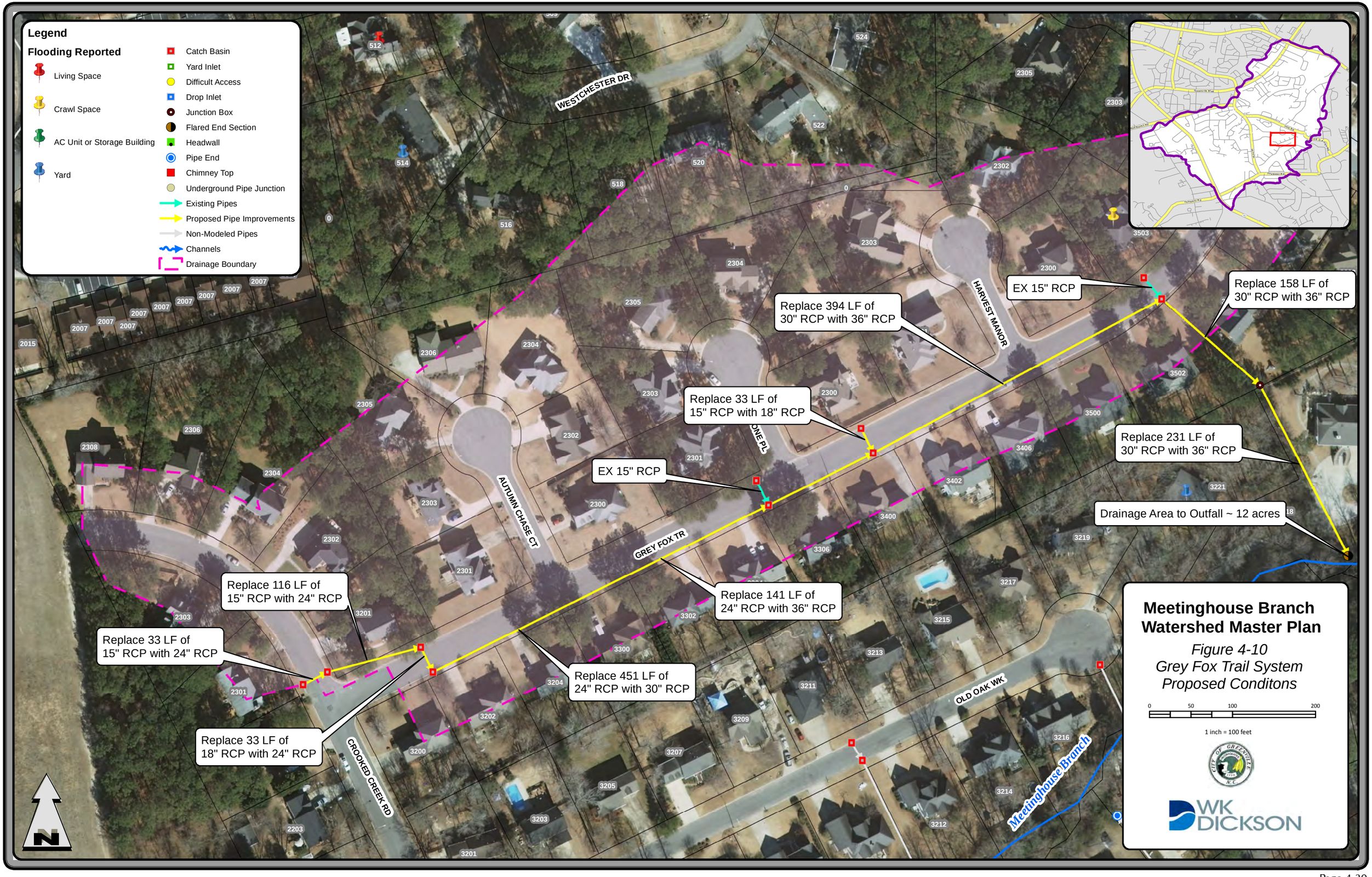
The proposed improvements will provide a 10-year level of service for the Grey Fox Trail System. The total estimated cost for the recommended alternative is $848,500. The majority of the project will be located in the right-of-way however, there will be impacts to the driveways, landscaping, and fencing at the following private properties:

- 3502 Grey Fox Trail;
- 3504 Grey Fox Trail; and
- 3218 Old Oak Way.

There is curb and gutter located along Grey Fox Trail that will need to be removed and replaced as part of this project. Overhead power and sanitary sewer lines were also identified as potential site restrictions and utility conflicts in the project area.

There is one resident at 3503 Grey Fox Trail that has reported crawl space flooding. The recommended improvements will reduce the frequency and severity of the reported flooding,

however without the elevation of the crawl space, it cannot be determined if the flooding will completely be eliminated during the design event. Yard flooding has been reported at 3221 Old Oak Way, however this flooding is likely caused by Meetinghouse Branch and the proposed improvements for the Grey Fox Trail System will have little impact on the yard flooding.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Existing Pipes
Proposed Pipe Improvements
Non-Modeled Pipes
Channels
Drainage Boundary
WESTCHESTER DR
HARVEST MANOR
AUTUMN CHASE CT
GREY FOX TR
CROOKED CREEK RD
OLD OAK WK
Meetinghouse Branch
EX 15" RCP
Replace 394 LF of 30" RCP with 36" RCP
Replace 158 LF of 30" RCP with 36" RCP
Replace 33 LF of 15" RCP with 18" RCP
Replace 231 LF of 30" RCP with 36" RCP
EX 15" RCP
Drainage Area to Outfall ~ 12 acres
Replace 116 LF of 15" RCP with 24" RCP
Replace 141 LF of 24" RCP with 36" RCP
Replace 33 LF of 15" RCP with 24" RCP
Replace 451 LF of 24" RCP with 30" RCP
Replace 33 LF of 18" RCP with 24" RCP
Meetinghouse Branch Watershed Master Plan
Figure 4-10
Grey Fox Trail System
Proposed Conditons
0 50 100 200
1 inch = 100 feet
WK DICKSON

Barnes Street – Paramore Drive – Rondo Drive System

WK Dickson recommends the following improvements for the Barnes Street – Paramore Drive – Rondo Drive System as shown in Figure 4-11:

- Replace 134 linear feet of 36″ CMP with 48″ RCP along the Windy Ridge Common Area between Barnes Street and Scott Street;
- Replace 199 linear feet of 36″ CMP with 42″ RCP along the Windy Ridge Common Area between Barnes Street and Scott Street;
- Replace 40 linear feet of 15″ RCP with 18″ RCP along Barnes Street;
- Replace 30 linear feet of 36″ CMP with 42″ RCP along the Windy Ridge Common Area perpendicular to Barnes Street;
- Replace 39 linear feet of 36″ CMP with 42″ RCP along the Windy Ridge Common Area perpendicular to Barnes Street;
- Replace 117 linear feet of 36″ CMP with 42″ RCP along the Windy Ridge Common Area between 49 and 74 Barnes Street;
- Replace 126 linear feet of 36″ RCP with 42″ RCP between 2403 and 2405 Trace Court;
- Replace 115 linear feet of 36″ RCP with 42″ RCP along Trace Court;
- Replace 129 linear feet of 36″ RCP with 42″ RCP along 1504 Trace Court;
- Replace 292 linear feet of 18″ RCP with 36″ RCP behind 1502 Reins Court and 2405 Trace Court;
- Install 375 linear feet of 18″ RCP southeast of Surrey Lane to connect to system behind Reins Court and;
- Install 14 inlets.

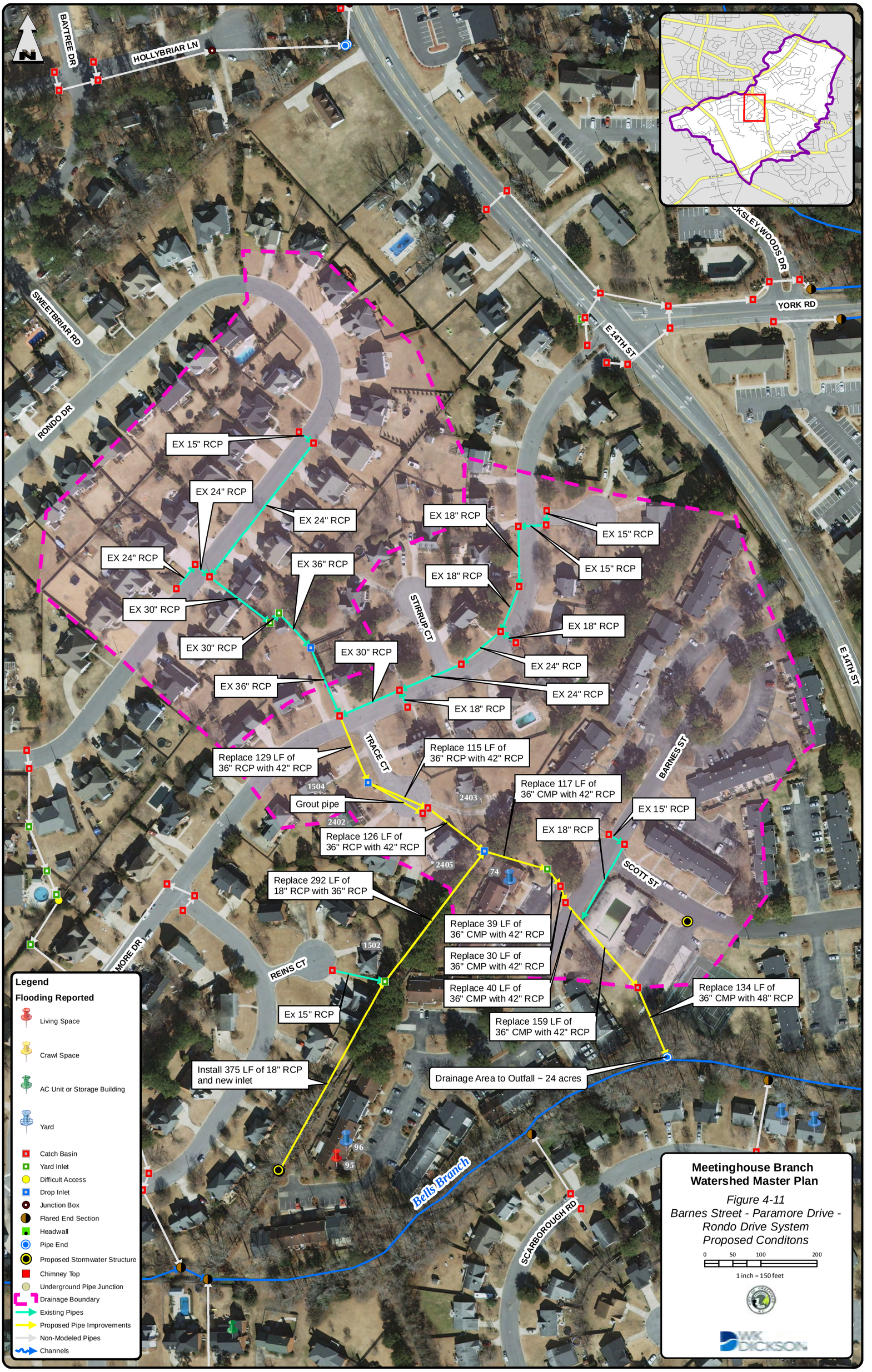
The proposed improvements will provide a 10-year level of service for the Barnes Street – Paramore Drive – Rondo Dive System. The total estimated cost for the recommended alternative is $594,600. Small segments of the project are located in the Paramore Drive, Trace Court, and Barnes Street right-of-way. The curb and gutter along these roadways will need to removed and replaced. Overhead power and water lines were also identified as a potential site restrictions and utility conflicts in the project area.

The majority of the proposed improvements will cause significant impacts to private property. There will be impacts to the driveways, landscaping, and fencing at the following private properties:

- 1502 Reins Court;
- 1504 Trace Court;
- 2402 Trace Court;
- 2403 Trace Court; and
- 2405 Trace Court.

Several common areas throughout the Windy Ridge Condominiums will be impacted including the tennis courts, the clubhouse parking lot, and swimming pool area. There is also a grass area adjacent to 74 Barnes Street that will be impacted. The resident at 74 Barnes Street has reported yard flooding. The system runs directly beside the property. Upsizing the system will reduce the frequency and severity of the reported yard flooding. The new pipe behind Surrey

Lane that connects to the system behind Reins Court will address flooding complaints received at 95 and 96 Barnes Street. Yard flooding complaints along Paramore Drive appear to be private drainage issues related to the grading of individual lots and are not included in the proposed improvements.


N
BAYTREE DR
HOLLYBRIAR LN
SWEETBRIAR RD
RONDO DR
YORK RD
E 14TH ST
STIRRUP CT
TRACE CT
BARNES ST
SCOTT ST
REINS CT
MORE DR
SCARBOROUGH RD
Bells Branch
EX 15" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 36" RCP
EX 30" RCP
EX 30" RCP
EX 30" RCP
EX 36" RCP
EX 18" RCP
EX 15" RCP
EX 15" RCP
EX 18" RCP
EX 18" RCP
EX 24" RCP
EX 24" RCP
EX 18" RCP
Replace 129 LF of 36" RCP with 42" RCP
Replace 115 LF of 36" RCP with 42" RCP
Replace 117 LF of 36" CMP with 42" RCP
EX 15" RCP
EX 18" RCP
1504
Grout pipe
2402
Replace 126 LF of 36" RCP with 42" RCP
2403
2405
74
Replace 292 LF of 18" RCP with 36" RCP
Replace 39 LF of 36" CMP with 42" RCP
Replace 30 LF of 36" CMP with 42" RCP
Replace 40 LF of 36" CMP with 42" RCP
Replace 134 LF of 36" CMP with 48" RCP
Replace 159 LF of 36" CMP with 42" RCP
1502
Ex 15" RCP
Install 375 LF of 18" RCP and new inlet
Drainage Area to Outfall ~ 24 acres
96
95
Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Proposed Stormwater Structure
Chimney Top
Underground Pipe Junction
Drainage Boundary
Existing Pipes
Proposed Pipe Improvements
Non-Modeled Pipes
Channels
Meetinghouse Branch
Watershed Master Plan
Figure 4-11
Barnes Street - Paramore Drive - Rondo Drive System
Proposed Conditons
0
50
100
200
1 inch = 150 feet
WK DICKSON

Fantasia Street – Sherwood Drive System

WK Dickson recommends the following improvements for the Fantasia Street – Sherwood Drive System as shown in Figure 4-12:

- Replace 33 linear feet of 15″ CMP with 15″ RCP along Tucker Drive;
- Replace 214 linear feet of 15″ CMP with twin 24″ RCP along Tucker Drive;
- Replace 38 linear feet of 15″ CMP with twin 15″ RCP along Tucker Drive;
- Replace 185 linear feet of 15″ CMP with twin 18″ RCP along Tucker Drive;
- Replace 33 linear feet of 15″ CMP with twin 18″ RCP along Tucker Drive;
- Install 50 linear feet of twin 18″ RCP along Tucker Drive;
- Install 192 linear feet of twin 24″ RCP along Tucker Drive;
- Install 171 linear feet of twin 24″ RCP along Tucker Drive;
- Replace 52 linear feet of 15″ CMP with twin 24″ RCP along Tucker Drive;
- Replace 403 linear feet of 15″ CMP with twin 24″ RCP along Fantasia Street;
- Replace 93 linear feet of 18″ CMP with twin 24″ RCP along Fantasia Street;
- Replace 24 linear feet of 15″ CMP with 24″ RCP along Fantasia Street;
- Replace 317 linear feet of 18″ CMP with twin 24″ RCP along Fantasia Street;
- Replace 178 linear feet of 18″ CMP with 48″ RCP along Fantasia Street;
- Replace 9 linear feet of 15″ CMP with 24″ RCP along Fantasia Street;
- Replace 25 linear feet of 15″ CMP with 15″ RCP along Sherwood Drive;
- Replace 33 linear feet of 24″ CMP with 48″ RCP along Sherwood Drive;
- Replace 25 linear feet of 18″ CMP with 18″ RCP along Sherwood Drive;
- Replace 176 linear feet of 24″ CMP with 48″ RCP between 3304 and 3400 Sherwood Drive;
- Replace 131 linear feet of 18″ CMP with 42″ RCP between 3200 and 3202 Sherwood Drive;
- Replace 23 linear feet of 18″ CMP with 30″ RCP along Sherwood Drive;
- Replace 33 linear feet of 15″ CMP with 30″ RCP along Sherwood Drive;
- Install 166 linear feet of 30″ RCP along Sherwood Drive;
- Install 139 linear feet of 24″ RCP along Sonata Drive;
- Install 153 linear feet of 218″ RCP along Sonata Drive;
- Install 17 inlets; and
- Install 7 junction boxes.

The proposed improvements provide a 10-year level of service for the Fantasia Street – Sherwood Drive System. The total estimated cost for the recommended alternative is $1,760,600. Runoff is rerouted along Tucker Drive and Sonata Place to avoid pipe replacements along private property. Replacing pipes in the same alignment as the existing system would impact several large hardwood trees, yard landscaping, and fences. It would also make construction access and future maintenance more difficult.

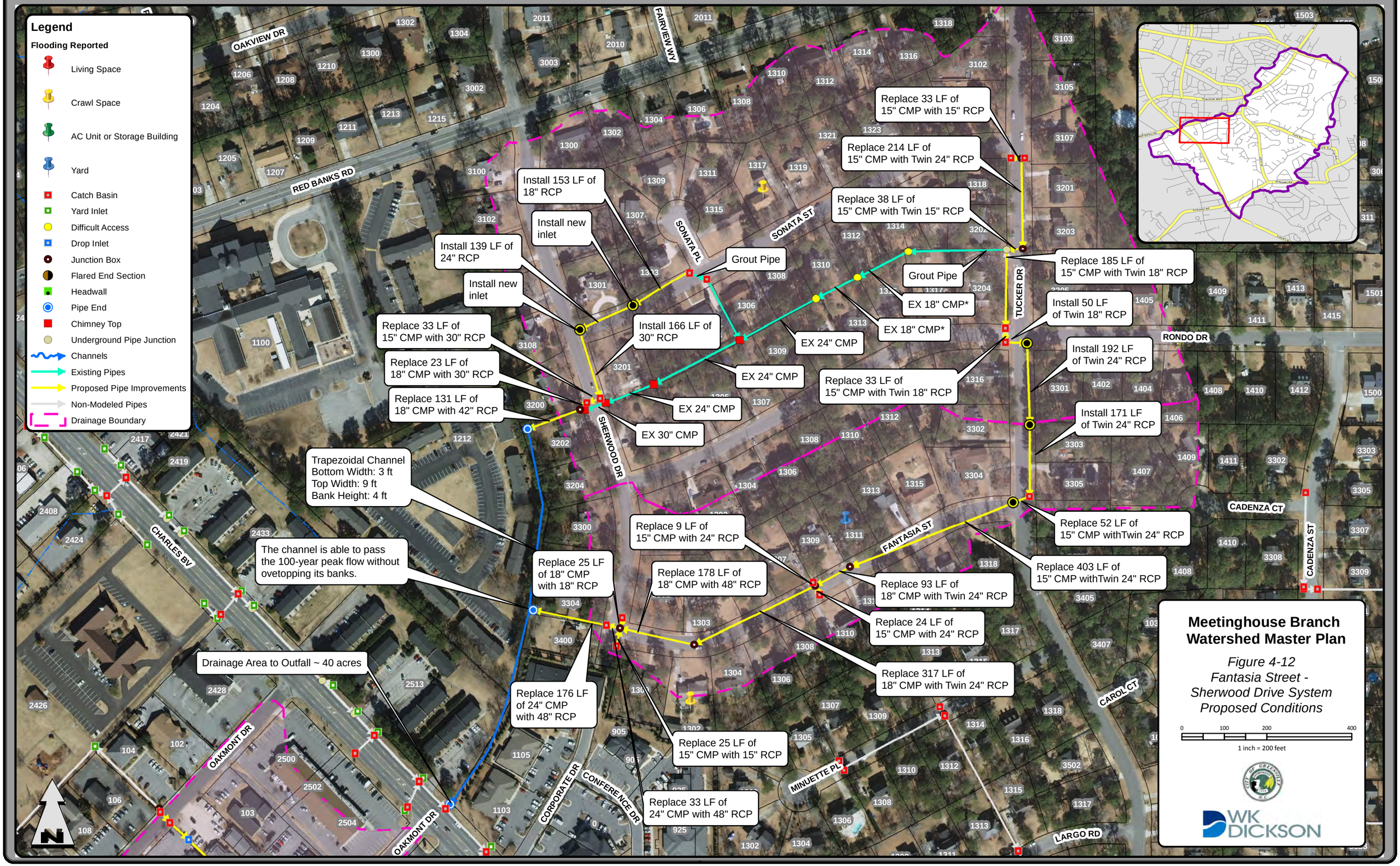
This presented alternative was selected because it impacts the least amount of private property and the majority of the work is completed in the right-of-way. Long term maintenance of the system will be facilitated by moving the conveyance system from private property to the right-of-way. The existing conveyance system in the backyards should remain in place to convey drainage from private properties; however the system will convey no public water, reducing the maintenance requirements. Based on data collected during the inventory, it appears that the

existing system is in good condition and does not currently require maintenance, although prior to final design, the City may want to inspect the system to determine if point repairs are needed. There will be impacts to the driveways, landscaping, and fencing at the following private properties:

- 3200 Sherwood Drive;
- 3202 Sherwood Drive;
- 3304 Sherwood Drive; and
- 3400 Sherwood Drive.

Sections of the curb and gutter along Sonata Street, Sherwood Drive, Fantasia Street, and Tucker Drive will need to removed and replaced to complete the proposed improvements. Overhead power, water, and sanitary sewer lines were also identified as potential site restrictions and utility conflicts.

There are three residents in the project area that reported flooding. The resident at 1311 Fantasia Street reported yard flooding and the residents at 1302 Fantasia Street and 1317 Sonata Street reported crawl space flooding. The recommended improvements will reduce the frequency and severity of the LAG and yard flooding for these residents. However without the elevation of the crawl spaces, it cannot be determined if the crawl space flooding will be eliminated.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Channels
Existing Pipes
Proposed Pipe Improvements
Non-Modeled Pipes
Drainage Boundary
OAKVIEW DR
RED BANKS RD
FAIRVIEW WY
SONATA PL
SONATA ST
TUCKER DR
RONDO DR
SHERWOOD DR
CHARLES BV
OAKMONT DR
CORPORATE DR
CONFERENCE DR
FANTASIA ST
MINUETTE PL
CADENZA CT
CAROL CT
LARGO RD
Install 153 LF of 18" RCP
Install new inlet
Install 139 LF of 24" RCP
Install new inlet
Grout Pipe
Replace 33 LF of 15" CMP with 30" RCP
Replace 23 LF of 18" CMP with 30" RCP
Replace 131 LF of 18" CMP with 42" RCP
Install 166 LF of 30" RCP
EX 24" CMP
EX 24" CMP
EX 30" CMP
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 9 ft
Bank Height: 4 ft
The channel is able to pass the 100-year peak flow without ovetopping its banks.
Replace 25 LF of 18" CMP with 18" RCP
Replace 176 LF of 24" CMP with 48" RCP
Drainage Area to Outfall ~ 40 acres
Replace 178 LF of 18" CMP with 48" RCP
Replace 25 LF of 15" CMP with 15" RCP
Replace 33 LF of 24" CMP with 48" RCP
Replace 9 LF of 15" CMP with 24" RCP
Replace 33 LF of 15" CMP with 15" RCP
Replace 214 LF of 15" CMP with Twin 24" RCP
Replace 38 LF of 15" CMP with Twin 15" RCP
Grout Pipe
EX 18" CMP*
EX 18" CMP*
Replace 33 LF of 15" CMP with Twin 18" RCP
Replace 93 LF of 18" CMP with Twin 24" RCP
Replace 24 LF of 15" CMP with 24" RCP
Replace 317 LF of 18" CMP with Twin 24" RCP
Replace 185 LF of 15" CMP with Twin 18" RCP
Install 50 LF of Twin 18" RCP
Install 192 LF of Twin 24" RCP
Install 171 LF of Twin 24" RCP
Replace 52 LF of 15" CMP withTwin 24" RCP
Replace 403 LF of 15" CMP withTwin 24" RCP
Meetinghouse Branch Watershed Master Plan
Figure 4-12
Fantasia Street - Sherwood Drive System Proposed Conditions
0 100 200 400
1 inch = 200 feet
WK DICKSON

Oakmont Drive System

WK Dickson recommends the following improvements for the Oakmont Drive System as shown in Figure 4-13:

- Replace 148 linear feet of 24″ RCP with 48″ RCP between Fitness Connection and Lexington Square Townhouses;
- Replace 137 linear feet of 24″ RCP with 48″ RCP between Fitness Connection's parking lot and Lexington Square Townhouses;
- Replace 61 linear feet of 24″ RCP with 48″ RCP between Fitness Connection's parking lot and Lexington Square Townhouses' parking lot;
- Replace 11 linear feet of 24″ CMP with 42″ RCP between Fitness Connection's parking lot and Lexington Square Townhouses' parking lot;
- Replace 33 linear feet of 24″ CMP with 42″ RCP along Oakmont Drive (downstream);
- Replace 200 linear feet of 18″ CMP with 42″ RCP between Montessori Today Learning Center and Unitarian Universalist Congregation Church;
- Replace 17 linear feet of 18″ CMP with 36″ RCP between behind Unitarian Universalist Congregation Church;
- Replace 145 linear feet of 18″ CMP with 30″ RCP perpendicular to Oakmont Drive adjacent to dentist/medical offices ;
- Replace 60 linear feet of 18″ CMP with 30″ RCP between perpendicular to Oakmont Drive adjacent to dentist/medical offices' parking lot;
- Replace 33 linear feet of 15″ RCP with 24″ RCP between along Oakmont Drive (upstream); and
- Install 8 inlets.

The proposed improvements will provide a 10-year level of service for the Oakmont Drive System. Upsizing the system will reduce the frequency and severity of the flooding experienced by neighboring business owners. The total estimated cost for the recommended alternative is $490,400.

The project will cause significant impacts to private property. The proposed improvements include upsizing segments of pipe between 105 and 107 Oakmont Drive and further downstream between 136 Oakmont Drive and 140 Oakmont Drive. These sections will involve construction in narrow corridors with limited space. This may require additional costs to protect the foundations of the adjacent properties (See Picture 4-7).

Picture 4-7. Area between 105 and 107 Oakmont Drive

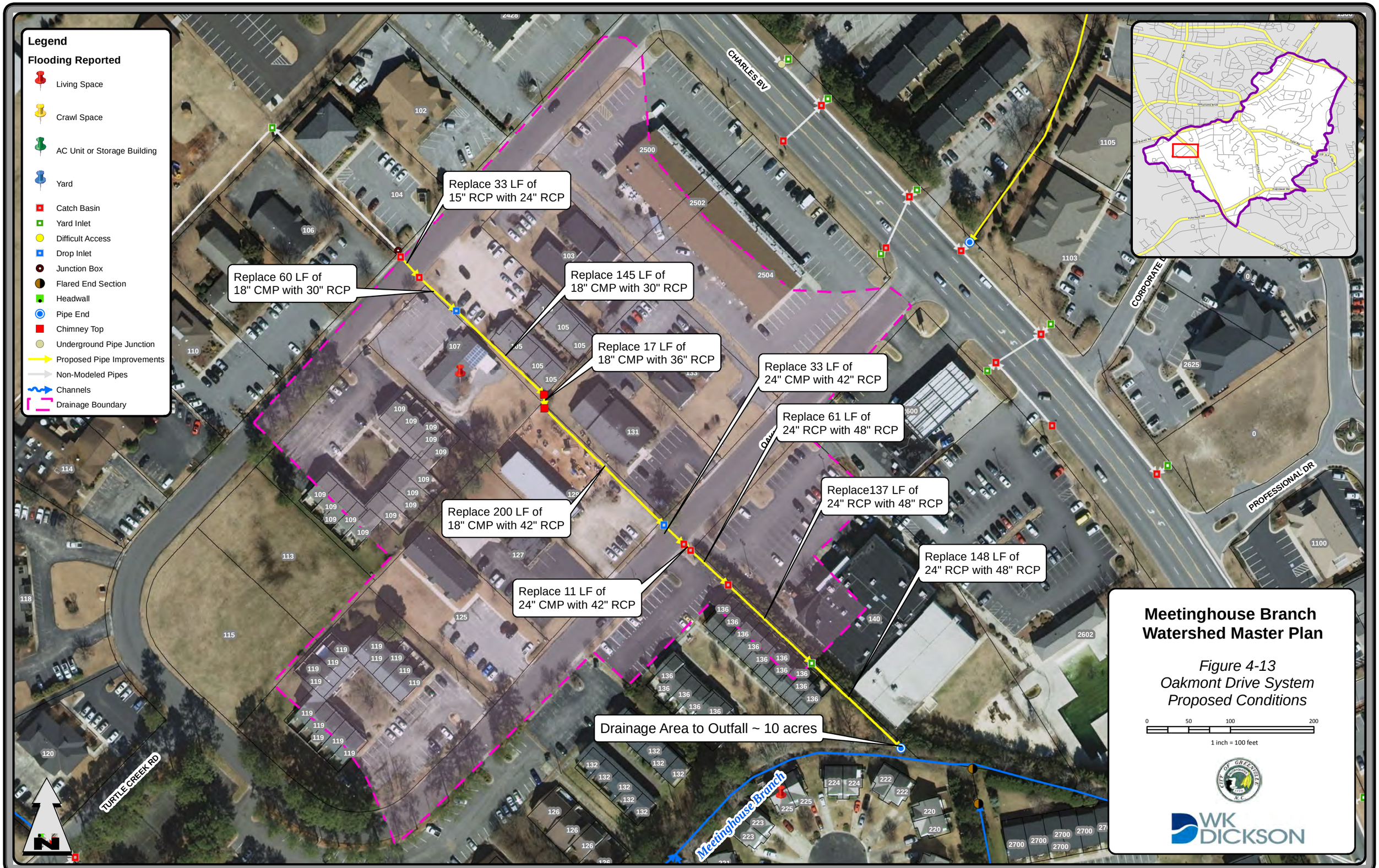
There will be potential impacts to the parking lots, landscaping, and fencing at the following

private properties:

- 105 Oakmont Drive;
- 107 Oakmont Drive;
- 129 Oakmont Drive;
- 131 Oakmont Drive;
- 136 Oakmont Drive ; and
- 140 Oakmont Drive.

There is a playground located at 131 Oakmont Drive that will need to be relocated or removed and replaced as part of the proposed improvements. Sections of the curb and gutter along Oakmont Drive will need to be removed and replaced to complete the proposed improvements. Underground utilities (electrical, water, and sanitary sewer lines) were also identified as potential site restrictions and utility conflicts.

A bioretention area has been recommended in the area upstream of proposed improvements for the Oakmont Drive System. Water Quality Project #2 for Oakmont Drive is discussed in Section 5.2. Due to the close proximity, the bioretention area and Oakmont Drive System improvements can be completed at the same time.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Proposed Pipe Improvements
Non-Modeled Pipes
Channels
Drainage Boundary
Replace 33 LF of 15" RCP with 24" RCP
Replace 60 LF of 18" CMP with 30" RCP
Replace 145 LF of 18" CMP with 30" RCP
Replace 17 LF of 18" CMP with 36" RCP
Replace 33 LF of 24" CMP with 42" RCP
Replace 61 LF of 24" RCP with 48" RCP
Replace137 LF of 24" RCP with 48" RCP
Replace 148 LF of 24" RCP with 48" RCP
Replace 200 LF of 18" CMP with 42" RCP
Replace 11 LF of 24" CMP with 42" CMP
Drainage Area to Outfall ~ 10 acres
CHARLES BV
TURTLE CREEK RD
PROFESSIONAL DR
Meetinghouse Branch
Meetinghouse Branch Watershed Master Plan
Figure 4-13
Oakmont Drive System
Proposed Conditions
0 50 100 200
1 inch = 100 feet
WK DICKSON

Traditional stormwater management has typically been designed to reduce flooding, but at times has neglected water quality by collecting runoff directly from impervious surfaces and discharging directly into a stream causing erosion and deterioration of water quality. Runoff from impervious areas collects high concentrations of pollutants and nutrients that if left untreated can cause negative impacts to water quality in the receiving waters. Negative impacts may include less biodiversity, hazards to the health of fish and wildlife, as well as human health hazards. High flows in streams cause bank erosion adding additional sediment into the riparian habitat. Many communities in North Carolina now require some form of water quality treatment for new development; however existing developments typically have little or no water quality treatment. The City of Greenville of Greenville developed a Stormwater Management Program (September, 2004) to outline its water quality requirements.

As part of the Meetinghouse Branch Watershed Master Plan the City of Greenville also partnered with the Pamlico-Tar River Foundation (PTRF) and East Carolina University (ECU) to identify erosion and water quality problems in the Meetinghouse Branch Watershed and to develop potential solutions to those problems. The sharing of information between the City and PTRF resulted in cost savings for both organizations and continued partnering will enable the City to continue to leverage other revenue sources for the improvement of water quality throughout the Meetinghouse Branch watershed and overall city boundary. Pertinent sections of the PTRF report for the Meetinghouse Branch watershed are included in Appendix N.

Stream stabilization projects can be constructed to reduce instream sediment loads and to protect private property from further erosion. Best management practices (BMPs) can be constructed to treat runoff prior to being discharged to the stormwater conveyance system and ultimately the receiving waters of the system. Retrofitting BMPs can be difficult due to limited space and other constraints. Stream stabilization projects and BMP retrofits identified in the Meetinghouse Branch Watershed are described below.

5.1 Stream Stabilization Projects

Based on the basin wide stream assessment completed as described in Section 3.3, five (5) stream stabilization projects were identified to help reduce instream erosion. Instream erosion can be a significant source of sediment that ultimately can impair the biodiversity of the downstream receiving waterbodies. Furthermore in urban watersheds such as Meetinghouse Branch, stream erosion is often a threat to private property and potentially the safety of structures adjacent to the stream. The proposed stream stabilization projects will have impacts to property owners that will require temporary construction easements to complete the work and permanent easements for maintenance access. Proposed projects assume that the riparian buffers can be restored to existing conditions. During final design the City will need to refer to the current buffer regulations to determine if more significant

Picture 5-1. Downstream view of bank erosion and sparse vegetation

buffer restoration is required. The projects (not presented in order of importance) are described as follows:

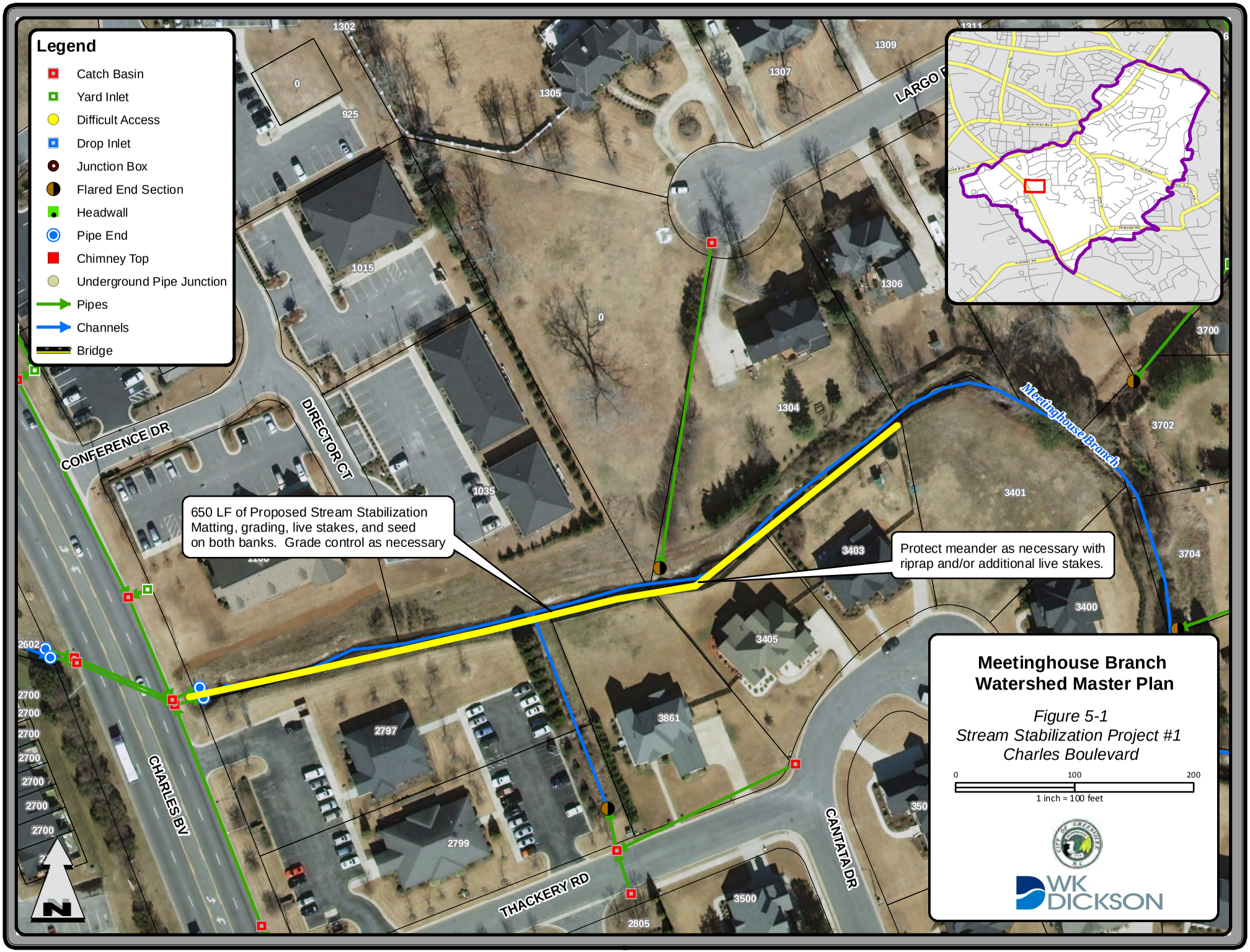
Stream Stabilization Project #1 – Charles Boulevard – The Charles Boulevard project begins on Meetinghouse Branch immediately downstream of Charles Boulevard. As shown on Figure 5-1, the project begins at the culvert crossing and continues downstream for approximately 650 linear feet. The Charles Boulevard project is a second order perennial section of Meetinghouse Branch and has a drainage area of 114 acres. Land use surrounding this project consists mainly of small business offices and residential houses. The proposed project reach flows west to east and is confined within a steep eroded channel feature. The bottom width (streambed) is approximately 3 to 4 feet wide. Both left and right banks are nearly 10 feet tall and have bank angles of 70 degrees. The average top channel width is 15 feet wide. This channel does not have a forested buffer making it highly susceptible to bank erosion. Herbaceous bank vegetation is dominant throughout and is being overtaken by the invasive species kudzu (*Pueraria montana*). Bank conditions are currently unstable and eroding at an accelerated pace due to loamy sand soil texture and lack of sufficient bank vegetation. Another factor contributing to erosion and down cutting of the streambed is the high flow velocity from flashy storm events. In some locations along the project reach, right bank erosion is extreme enough that it reaches landscape fences in adjacent property owners' lawns (See Picture 5-2).

Picture 5-2. Severe bank erosion along landscaping fence

The proposed project reach has opportunities for bank stabilization to prevent sediment loading and bank erosion to Meetinghouse Branch. Open lawn areas adjacent to this stream segment would make this project accessible. To improve bank stability and reduce bank erosion along the proposed reach, several tasks need to be performed. Bank erosion can be reduced by grading channel banks back to a minimum 2 to 1 slope and placement of coir erosion control matting along banks and bare areas. Live staking stream banks along both stream banks will also help prevent undercutting and bank failures in the future. The entire project area should be treated for invasive species (kudzu removal) and planted with a permanent riparian seed mix. To reduce water velocity, several large boulder structures or rip-rap can be placed within the streambed at the toe of bank. This will help to stabilize the streambed and toe.

The estimated cost for the Charles Boulevard project is $152,900. The stream stabilization project will run along the backside of several private properties, which may result in potential impacts to landscaping and fencing at the following private properties:

- 1100 Conference Drive;
- 1035 Director Court;
- 2797 Charles Boulevard;
- 3861 Thackery Road;
- 1304 Largo Road;
- 3403 and 3405 Canata Drive.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
650 LF of Proposed Stream Stabilization
Matting, grading, live stakes, and seed
on both banks. Grade control as necessary
Protect meander as necessary with
riprap and/or additional live stakes.
Meetinghouse Branch
CONFERENCE DR
DIRECTOR CT
CHARLES BV
THACKERY RD
CANTATA DR
LARGO
1302
1309
1307
1305
925
0
1015
1306
1304
1035
3700
3702
3401
3403
3704
3400
3405
3861
2797
2799
2805
3500
350
2602
2700
Meetinghouse Branch
Watershed Master Plan
Figure 5-1
Stream Stabilization Project #1
Charles Boulevard
0
100
200
1 inch = 100 feet
WK DICKSON

Stream Stabilization Project #2 – Crooked Creek Road – Stream Stabilization Project #2 is bound by Crooked Creek Road and Mary Beth Drive. As shown on Figure 5-2, the project begins at the downstream end of an existing stabilization project recently completed by the City and extends for approximately 260 linear feet to a sanitary sewer manhole on the left bank. The existing stabilization project upstream from the proposed Crooked Creek Road project consists of rock gabion basket step pools and bank armoring with rock boulders (See Picture 5-3). The reach for the proposed project is a third order perennial stream section of Meetinghouse Branch with a drainage area of approximately 650 acres.

Picture 5-3. Existing rock drop structure

The surrounding land use of the Crooked Creek Road project consists entirely of residential houses. This stream segment of Meetinghouse Branch flows from the southwest to the northeast with an average stream width of 5 feet. The depth ranges from 0.3 to 2.5 feet deep. Throughout this stream project, bank height varies with stream depth and the severity of erosion. On average the right bank is 12 feet high and the left bank is 9 feet. The proposed project reach has a young forested buffer along the right bank, and the left bank is mainly residential lawns with few trees and shrubs. Vegetation within the project area consists of red maple (*Acer rubrum*), laurel oak (*Quercus laurifolia*), sweetgum (*Liquidambar styraciflua*) and Chinese privet (*Ligustrum sinense*). Bank conditions are currently unstable and eroding at an accelerated pace due to loamy sand soil texture and lack of sufficient bank vegetation. In some locations along the Crooked Creek Road project, right bank erosion is extreme enough that it has caused bank failures and trees to fall into the stream creating debris jams. Debris jams may cause further bank instability and potential property flooding. Bank erosion is present along the left bank, as well, and extends up into residential lawns.

Picture 5-4. Severe bank erosion along right bank causing bank failures and trees to fall

Picture 5-5. Left bank erosion adjacent to residential lawns without stream buffer

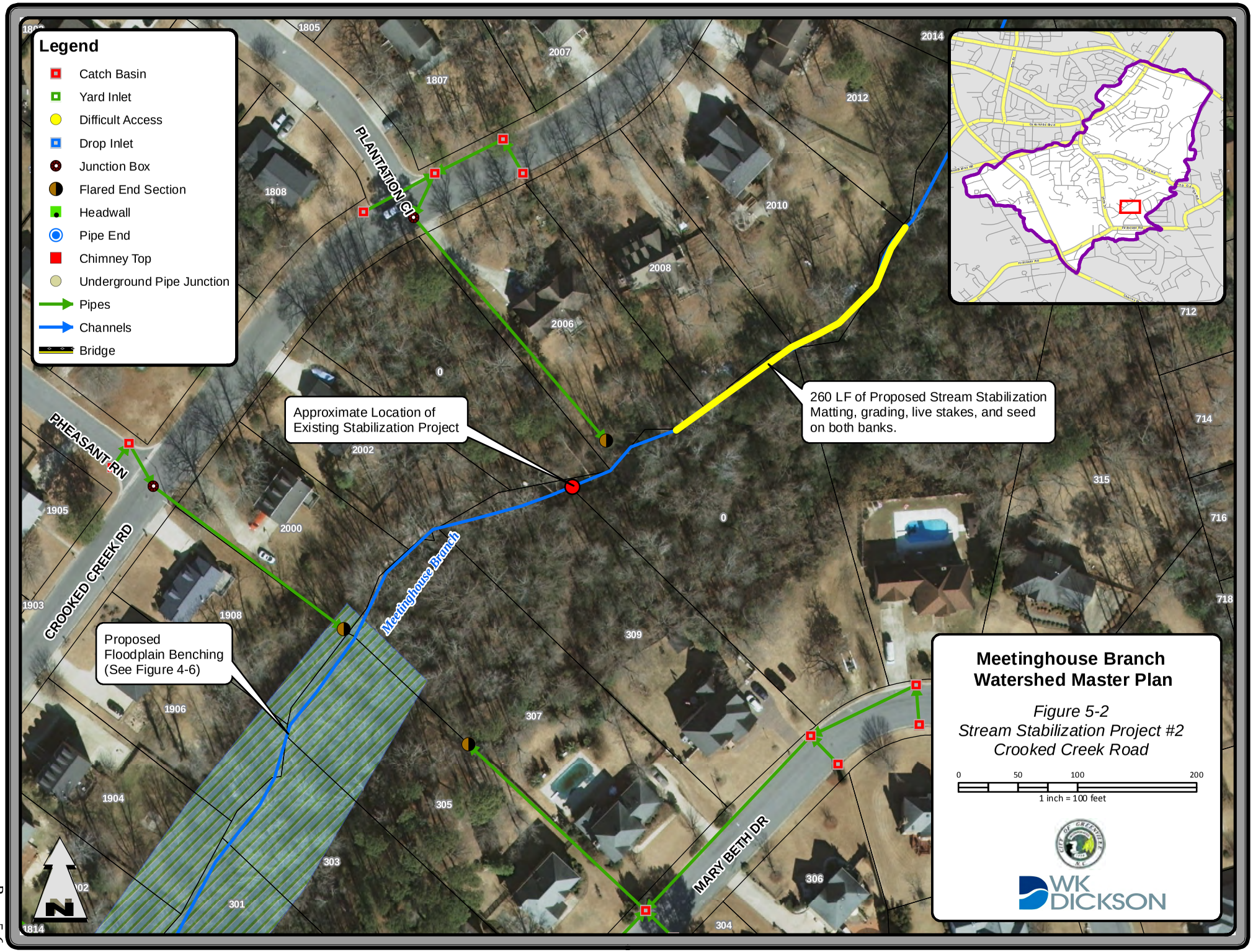
The proposed project has high potential for bank stabilization to prevent sediment loading to Meetinghouse Branch. This project area can be accessed from either Crooked Creek Road or Mary Beth Drive. To improve bank stability and reduce bank erosion along the Crooked Creek

Road project several tasks need to be performed. Bank erosion can be reduced by grading channel banks back to a minimum 2 to 1 slope and placing coir erosion control matting along banks and bare areas. Reinforcing the banks with rip-rap along bends and meanders will also help prevent bank failures in the future. Specific areas requiring rip-rap stabilization shall be identified during design based on current conditions of the stream bank. Several sections of the stream are already armored with rip-rap and present stable conditions. Any debris jams should be removed to prevent channel widening. The entire project area should be treated for invasive species (Chinese privet removal) and planted with a permanent riparian seed mix and live stakes along both banks. Private easements will likely be required for five (5) properties.

The estimated cost for the Crooked Creek Road project is $85,200. The stream stabilization project will run along the backside of several private properties, therefore there may be potential impacts to landscaping and fencing at the following private properties:

- 2006 Crooked Creek Lane;
- 2008 Crooked Creek Lane;
- 2010 Crooked Creek Lane;
- 311 Mary Beth Drive; and
- 313 Mary Beth Drive.

If the City moves forward with the floodplain benching proposed as part of the 14th Street Alternative #2 (See Section 4.1.2) located upstream of this project, the City may realize some cost savings by combining the Crooked Creek Road stabilization project with the floodplain benching work.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
PLANTATION CT
PHEASANT RN
CROOKED CREEK RD
MARY BETH DR
Meetinghouse Branch
Approximate Location of Existing Stabilization Project
260 LF of Proposed Stream Stabilization Matting, grading, live stakes, and seed on both banks.
Proposed Floodplain Benching (See Figure 4-6)
1805
2007
1807
2012
2014
1808
2010
2008
2006
0
2002
2000
1905
1903
1908
1906
1904
307
309
305
303
301
304
306
315
714
716
718
712
1814
Meetinghouse Branch Watershed Master Plan
Figure 5-2
Stream Stabilization Project #2
Crooked Creek Road
0 50 100 200
1 inch = 100 feet
WK DICKSON

Stream Stabilization Project #3 – Brook Valley Golf Course – The Brook Valley Golf Course project is located along a section of Meetinghouse Branch between King George Road and the railroad tracks. As shown on Figure 5-3, the project begins on the Brook Valley Country Club Golf Course and extends 840 linear feet downstream to the cart crossing just upstream of the railroad tracks. The proposed project reach is a third order perennial stream with a drainage area of 798 acres.

Picture 5-6. Right bank area sinking behind retaining wall along the Brook Valley Golf Course Project

The proposed project is located entirely on the Brook Valley Country Club Golf Course. This stream segment of Meetinghouse Branch flows northeast and has an average stream width of 6 feet. This stream ranges from 0.2 to 3.0 feet deep. For nearly 200 linear feet, the stream is confined to a wooden retaining wall. This section is relatively stable; however, there is a section on the right bank approximately 35 linear feet long that is sinking behind the retaining wall as shown in Picture 5-6. Just below the cart path bridge where the wooden retaining wall ends, the stream is eroding on both banks. This segment is 110 linear feet long. Erosion in this location is caused by the lack of a forested buffer on the stream banks. A forested buffer is located along the left bank for nearly 250 feet and then the buffer transitions to maintained grass as part of the golf course. The right bank in this area has been clear-cut. Trees have been cut flush with the ground leaving only stumps along the right stream bank. This 250 linear feet section of Meetinghouse Branch is fairly stable; although, planting the right bank and buffer area would prevent future erosion. Bank conditions for the remaining length of the Brook Valley Golf Course project are currently unstable and eroding. Several sections of the banks are collapsing and have vertical bank angles.

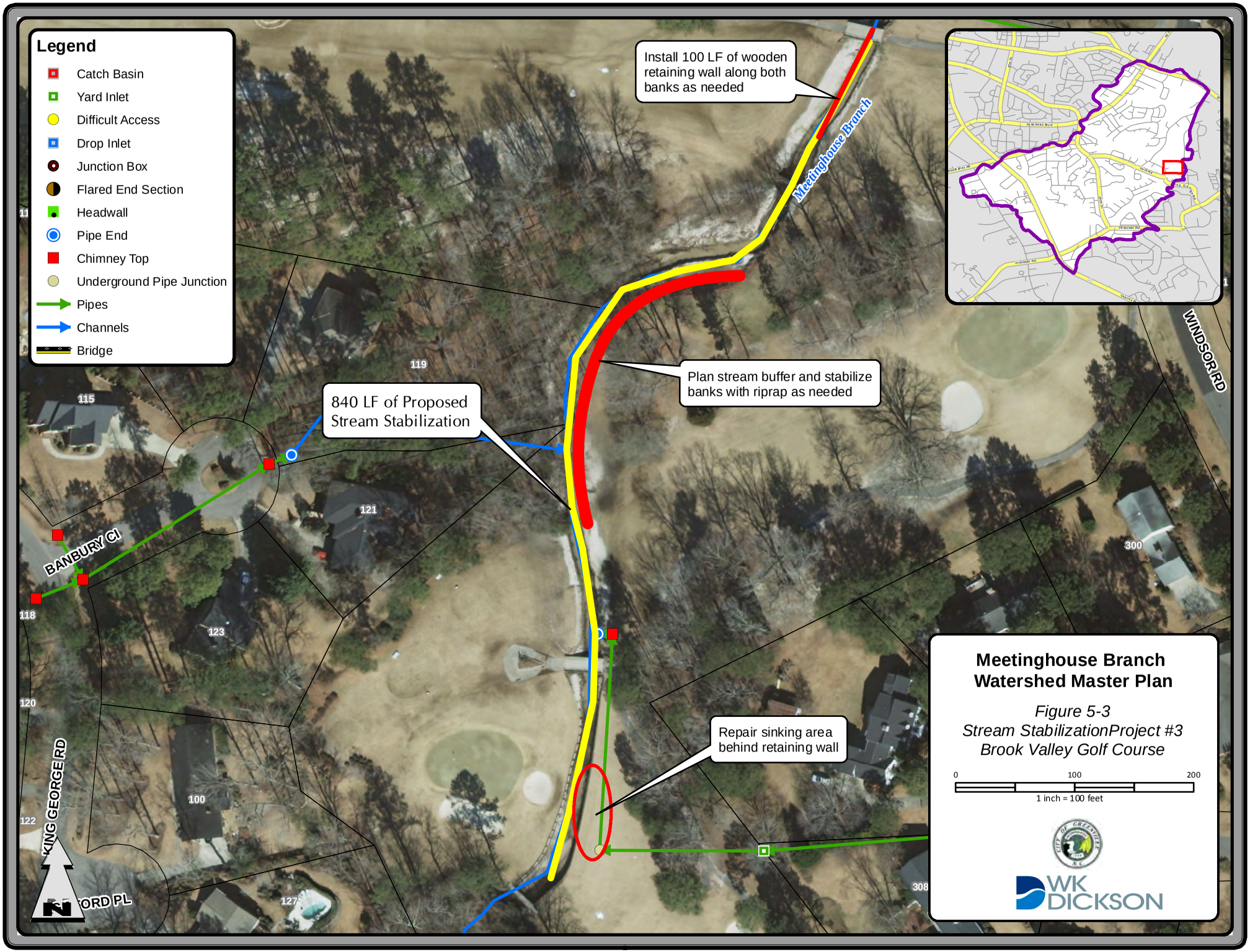
Picture 5-7. Vertical right bank erosion near the downstream end of the proposed project reach.

The proposed stream reach noted above has potential for bank stabilization to prevent sediment loading and bank erosion to Meetinghouse Branch. This project can be easily accessed from the golf course without any constraints. Bank stability along the Brook Valley Golf Course project can be obtained by performing several tasks. Stream banks that lack a forested buffer and are not confined within the wooden retaining wall should be stabilized by grading channel banks back to a minimum 2 to 1 slope and placing coir erosion control matting and planting live stakes along banks and bare areas. The banks should be reinforced with rip-rap along bends and meanders to prevent bank failures in the future. Another option for stream segments within the golf course playing area is to stabilize with additional wooden retaining walls similar to the

upstream portion. It is recommended that a sturdier retaining wall be used as part of this project so that the stream will be adequately restricted from widening and confined within the golf cart bridge wingwalls.

The sinking area behind the existing retaining wall should be properly compacted and replanted with golf course grass. If the retaining wall is found to be malfunctioning, it should be repaired accordingly to withhold the bank. A stream buffer should be planted along the 250 linear-foot (non-golf course area) section to prevent future erosion along the right bank.

The estimated cost for the proposed stream stabilization project is $135,500. Property impacts as a result of the proposed project will be limited to the Brook Valley Golf Course.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Install 100 LF of wooden retaining wall along both banks as needed
Meetinghouse Branch
Plan stream buffer and stabilize banks with riprap as needed
840 LF of Proposed Stream Stabilization
Repair sinking area behind retaining wall
WINDSOR RD
BANBURY CI
KING GEORGE RD
119
115
121
123
118
120
100
122
127
300
308
Meetinghouse Branch Watershed Master Plan
Figure 5-3
Stream StabilizationProject #3
Brook Valley Golf Course
0
100
200
1 inch = 100 feet
WK DICKSON

Stream Stabilization Project #4 – Bloomsbury Road – Stream Stabilization Project #4 is located between Bloomsbury Road and Oxford Road. As shown on Figure 5-4, this project starts at the culvert under Bloomsbury Road and continues 300 linear feet downstream to the confluence of Bells Branch. The proposed project reach is an unnamed tributary to Bells Branch. This second order perennial stream has a drainage area of 193 acres.

Picture 5-8. Down cutting and steep bank angles typical throughout the proposed project reach.

Land use surrounding the Bloomsbury Road project is completely residential. This unnamed stream segment flow southeast and has an average stream width of 3.5 feet. Stream depth throughout this reach averages 0.3 feet and lacks the presence of many pools. Due to high flow events and steep bank angles, the incised channel is eroding at an increased rate. This stream has significantly down cut and now has bank heights ranging from 6.5 to 8.0 feet high. The channel width varies but on average is 10.0 feet. The Bloomsbury Road project has a sparsely forested buffer on both stream banks consisting of river birch (*Betula nigra*), loblolly pine (*Pinus taeda*), tulip poplar (*Liriodendron tulipfera*), and sweetgum (*Liquidambar* styraciflua). Invasive species along this stream reach include Chinese privet (*Ligustrum sinense*) and Japanese honeysuckle (*Lonicera japonica*).

The proposed project reach described above is a good candidate for bank stabilization. This project has few constraints limiting access. There is a sanitary sewer line crossing at the bottom of this reach so access can be gained through the existing easement. Bank erosion can be reduced by grading channel banks back to a minimum 2 to 1 slope, placing coir erosion control matting along banks and bare areas, and planting live stakes. To prevent additional down cutting of the streambed, log grade control structures can be added. The entire project area should be treated for invasive species and planted with a permanent riparian seed mix.

Picture 5-9. Undercut banks and erosion at the downstream section of the proposed project reach.

The estimated cost for the proposed stream stabilization project is $59,500. Two private properties may be impacted by the proposed project – 2201 Bloomsbury Drive and 815 Kensington Drive.

Stream Stabilization Project #5 – Kensington Drive – Stream Stabilization Project #5 is located at the intersection of Oxford Road and Kensington Drive directly across from Brook Valley Country Club. As shown on Figure 5-4, this project ends at the Kensington Drive Bridge and continues 225 linear feet upstream to the forested section. The proposed project reach is a perennial stream section of Bells Branch with a drainage area of 217 acres.

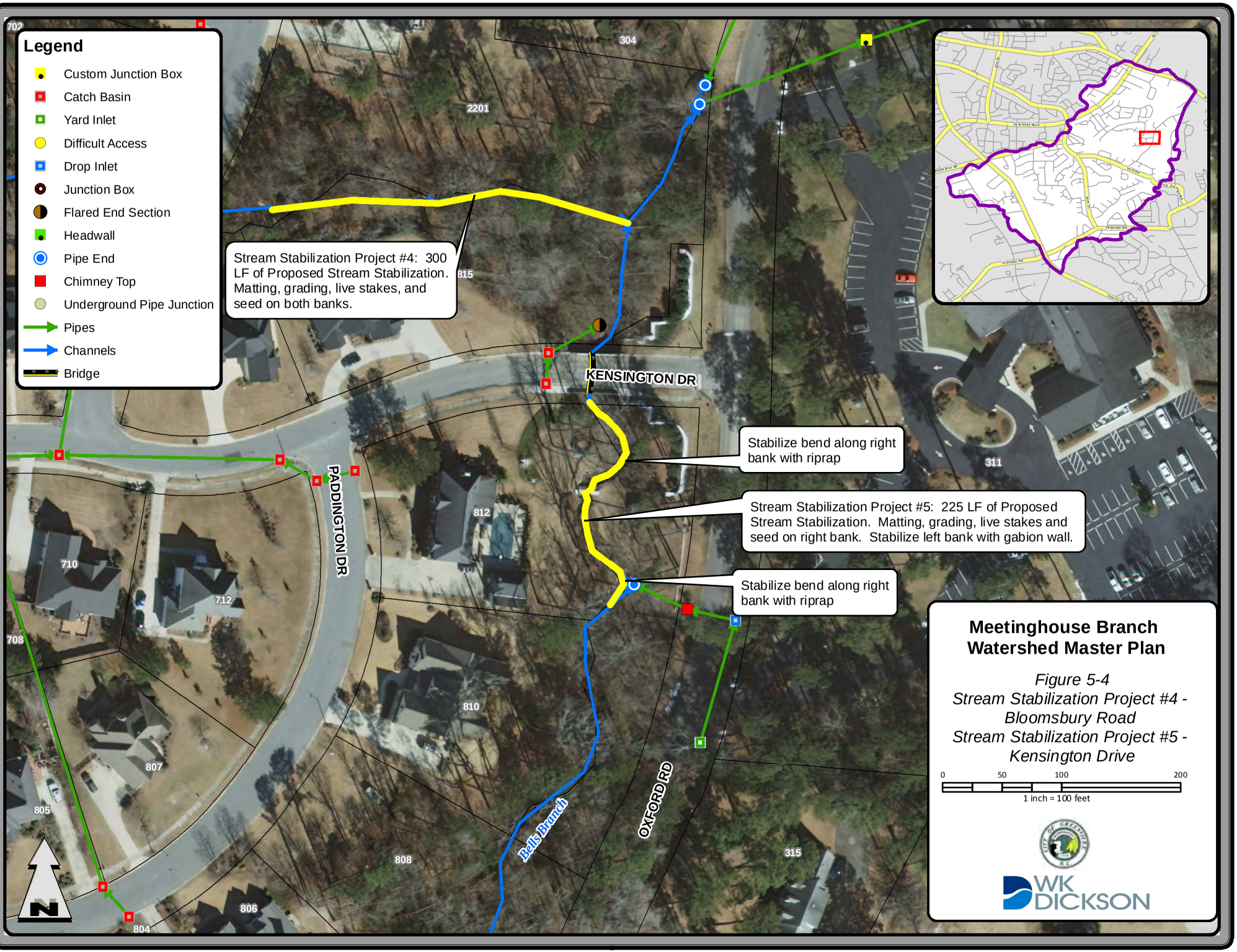
Picture 5-10. Vertical left bank erosion on the proposed project reach.

The Kensington Drive project is surrounded by residential houses on the left bank and a vacant lawn area on the right bank. This area is currently mowed and maintained with a pedestrian foot bridge across the stream. One storm water culvert is draining into the stream from the right bank near the upstream limits of this project. Evidence shows that this area is a location of high flow events and flooding. This stream segment of Bells Branch flows northeast and has an average width of 3.5 feet. Due to high flow events, sandy soil material, and near vertical bank angles, the incised channel is eroding at an accelerated rate. The proposed project reach is relatively sinuous through this section which helps reduce water velocity; however, the stream banks need some stability and armoring. The proposed project reach lacks a forested buffer and only a few mature trees are present along the banks. No invasive species were observed at this site.

Picture 5-11. Stream meander bends with absence of bank protection and buffer

The Kensington Drive project has opportunities for bank stabilization to prevent bank erosion along Bells Branch. This project is easily accessible due to its location adjacent to the road and the lack of trees. Bank erosion can be reduced by grading channel banks back to a minimum 2 to 1 slope, placing coir erosion control matting along banks and bare areas, and planting live stakes. Reinforcing the banks with rip-rap along bends and meanders will also help prevent undercutting and bank failures in the future. To prevent the left bank from eroding and encroaching further onto the adjacent property, a concrete or rock gabion retaining wall may be a constructed. The entire project area should be planted with a permanent riparian seed mix.

The estimated cost for the Kensington Drive project is $174,200. The impacts for this stream stabilization project are limited to 812 Paddington Drive.


Legend
Custom Junction Box
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Bridge
Stream Stabilization Project #4: 300 LF of Proposed Stream Stabilization. Matting, grading, live stakes, and seed on both banks.
Stabilize bend along right bank with riprap
Stream Stabilization Project #5: 225 LF of Proposed Stream Stabilization. Matting, grading, live stakes and seed on right bank. Stabilize left bank with gabion wall.
Stabilize bend along right bank with riprap
KENSINGTON DR
PADDINGTON DR
OXFORD RD
Bells Branch
702
304
2201
315
311
812
710
712
708
810
807
805
808
806
804
N
Meetinghouse Branch Watershed Master Plan
Figure 5-4
Stream Stabilization Project #4 - Bloomsbury Road
Stream Stabilization Project #5 - Kensington Drive
0
50
100
200
1 inch = 100 feet
WK DICKSON

5.2 BMP Project Identification

BMPs were initially identified using various layers in GIS including the following: aerial photography, parcels, land use, storm water inventory, and topography. Eleven (11) potential BMP locations were initially identified. These locations were field visited by WK Dickson staff in October 2012 to determine the feasibility of each site for a BMP. An overview map has been provided showing these sites (See Figure 5-5).

The proposed locations for the BMPs were evaluated based on the following criteria:

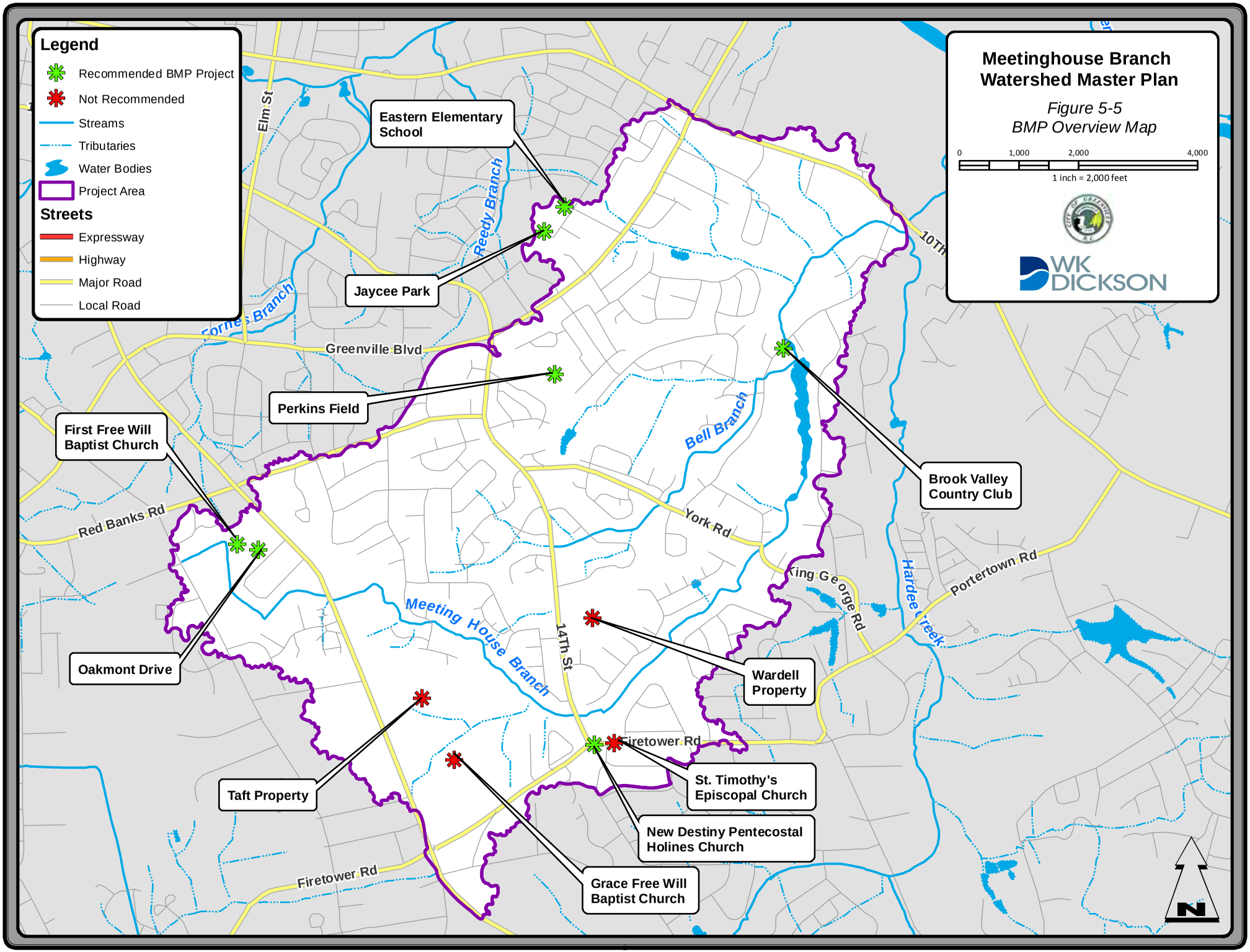
- Watershed Size / Drainage Area – Larger watershed sizes allow an opportunity for more treatment. A significant contributing drainage area would allow the use of a larger, more regional BMP such as a wet pond or extended detention wetland.
- Percentage of impervious area – Areas with high impervious percentages allow an opportunity for more treatment.
- Proximity to existing conveyance system – Runoff will need to be diverted into the BMP and then discharged back to the conveyance system. Locations in close proximity to the existing conveyance system will reduce the cost associated with constructing new drainage structures.
- Land Availability/Ownership – The proposed BMPs will require undeveloped land. Attempts were made to concentrate on publicly owned land because the high cost of private land can make a project unlikely.
- Topography – Sufficient vertical relief, up to 5 feet, is required to allow certain BMPs (i.e., bioretention and wet ponds) to function per NCDENR design requirements.
- Hydrologic conditions – BMPs such as wet ponds or extended detention wetlands need the proper hydrologic conditions for plants to survive. The soils or existing water table must allow for the BMP facility to permanently hold stormwater runoff.

There was one public school and two parks located in the Meetinghouse Branch Watershed. These locations were closely looked at due to the large impervious areas (i.e., parking lots) available for treatment and the educational benefits of installing a BMP onsite. Several of the sites identified met multiple criteria for a successful project and were therefore recommended in this Master Plan.

5.3 Recommended BMPs

Based on the field visits and the above criteria, seven sites were recommended for BMP retrofits. Factors that eliminated a site from consideration included the following: limited space, tree density, utility conflicts (i.e. high voltage transformers and other electrical distribution equipment), and insufficient topographic relief.

Preliminary conceptual design calculations were completed for each of the seven BMPs (see Appendix I). The design calculations were based on methodologies found in the North Carolina Department of Environment and Natural Resources (NCDENR) Stormwater BMP Manual. The size of the BMP is based on the contributing watershed area and the amount of impervious area within the watershed. Per NCDENR requirements, the recommended BMPs were designed to treat runoff from the first one-inch of rainfall. The treatment volume is


Legend
Recommended BMP Project
Not Recommended
Streams
Tributaries
Water Bodies
Project Area
Streets
Expressway
Highway
Major Road
Local Road
Meetinghouse Branch Watershed Master Plan
Figure 5-5
BMP Overview Map
0
1,000
2,000
4,000
1 inch = 2,000 feet
WK DICKSON
Eastern Elementary School
Jaycee Park
Perkins Field
First Free Will Baptist Church
Oakmont Drive
Taft Property
Grace Free Will Baptist Church
New Destiny Pentecostal Holines Church
St. Timothy's Episcopal Church
Wardell Property
Brook Valley Country Club
Elm St
Reedy Branch
Cornes Branch
Greenville Blvd
Bell Branch
Red Banks Rd
York Rd
Meeting House Branch
14Th St
King George Rd
Portertown Rd
Hardee Creek
Firetower Rd
Firetower Rd
10Th

directly correlated to the amount of impervious area. Watersheds with larger amounts of impervious area convert more of the rainfall into runoff, thereby requiring a larger sized BMP. The majority of the recommended BMPs for this watershed were bioretention areas for the following reasons:

- Large regional BMPs were not feasible in this watershed since the watershed was fully developed. The few large tracts of land available were not conducive to cost effectively siting a BMP.
- Given the characteristics of the watershed, one of the most effective forms of water quality treatment is to treat stormwater runoff at the source. Bioretention areas area excellent BMPs at treating runoff directly from impervious areas such as parking lots.
- Bioretention areas have some of the highest removal rates for nutrients per the BMP manual. The Tar-Pam river basin is identified as a nutrient sensitive watershed and monitoring efforts by PTRF support this designation.
- Bioretention areas provide excellent educational opportunities particularly at schools as they are visible features that can be aesthetically pleasing. Furthermore, multiple treatment processes are occurring within a bioretention area providing additional opportunities for education.

Water Quality Project #1: First Free Will Baptist Church

A bioretention area is proposed in the open space located between the First Free Will Baptist Church parking lot and the offices at 102 and 104 Oakmont Drive (See Picture 5-12). This area is adjacent to a parking lot that currently drains to the closed system that runs parallel to Oakmont Drive. The bioretention area will primarily provide water quality benefits by attenuating runoff prior to its discharge into Meetinghouse Branch.

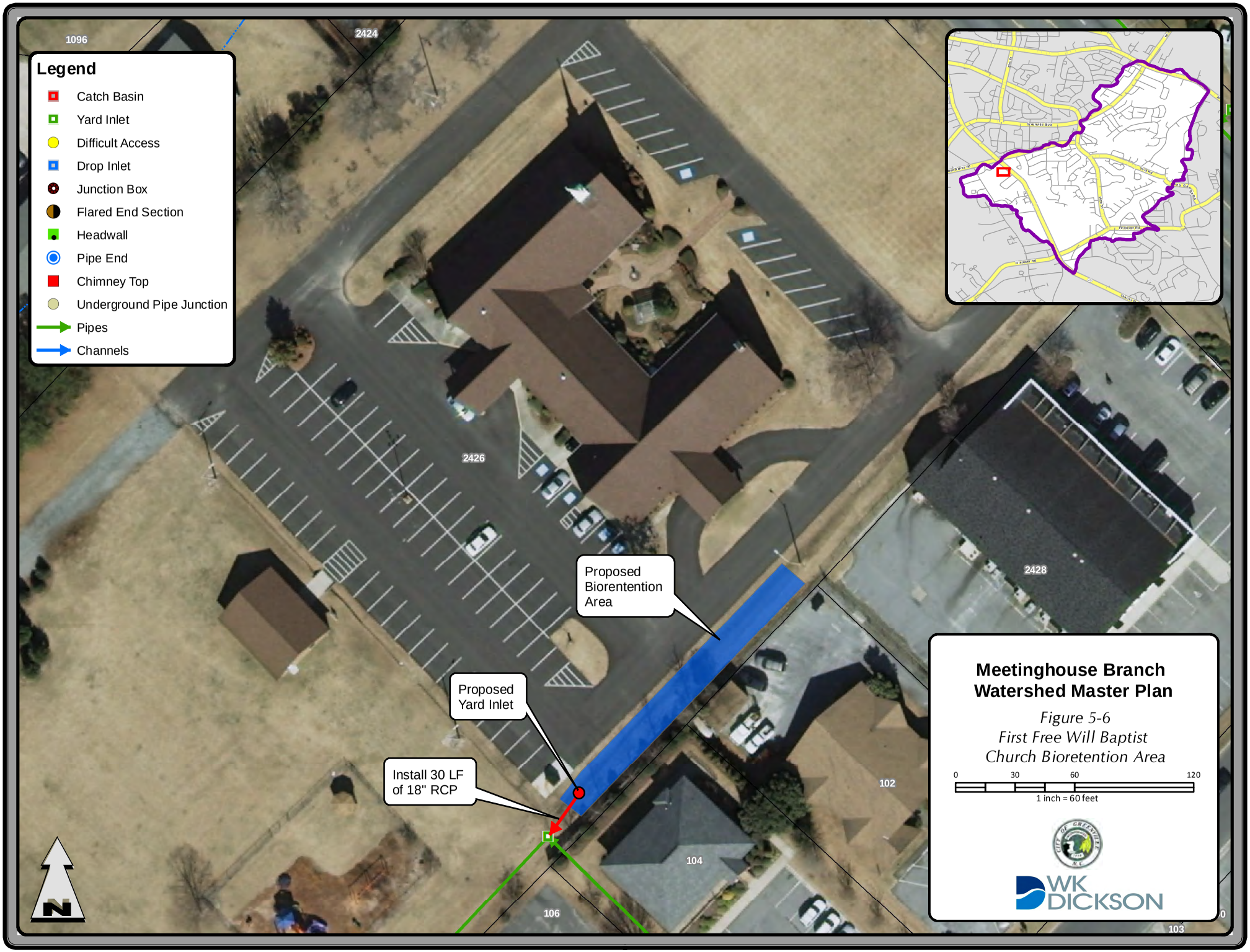
Picture 5-12. Proposed Location for First Free Will Baptist Church Bioretention Area

The required surface area for the proposed bioretention is approximately 2,600 square feet (0.06 acres). A concept level plan of the proposed improvements is shown in Figure 5-6.

The proposed bioretention project consists of the following improvements:

- Install a bioretention pond designed to treat runoff from the adjacent parking lot. The proposed impervious areas draining to the proposed pond is approximately 0.5 acres.
- Install a yard inlet with an 18″ outfall pipe directing flow into an existing conveyance system.

The proposed water quality project is located on private property. In order to construct the bioretention area, an easement agreement would be required with the church. The estimated construction cost for the bioretention area at First Free Will Baptist Church is $82,900.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
1096
2424
2426
2428
102
104
106
103
Proposed Biorentention Area
Proposed Yard Inlet
Install 30 LF of 18" RCP
Meetinghouse Branch Watershed Master Plan
Figure 5-6
First Free Will Baptist Church Bioretention Area
0
30
60
120
1 inch = 60 feet
WK DICKSON

Water Quality Project #2: Oakmont Drive

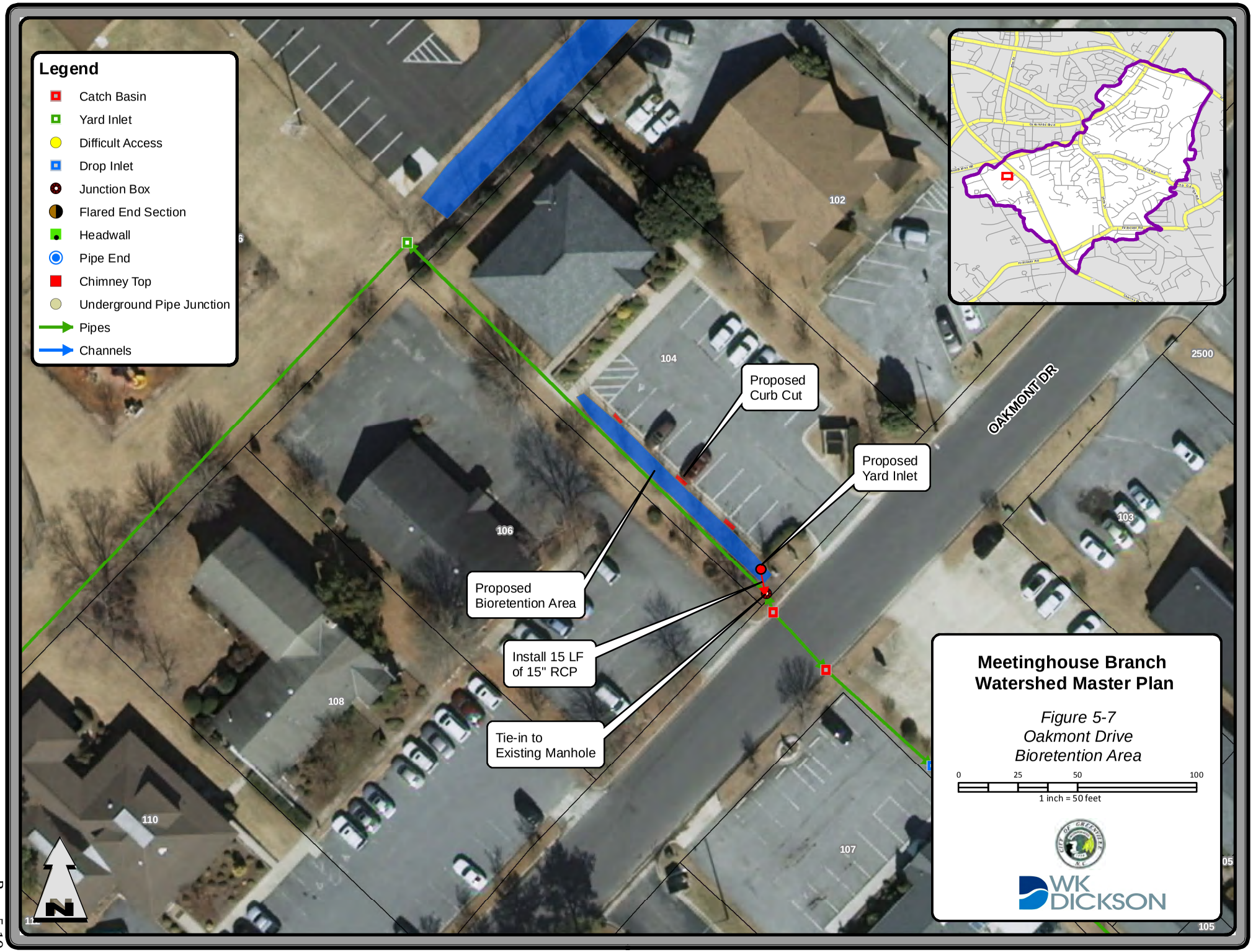
A potential project is located between the two parking lots for the offices at 104 and 106 Oakmont Drive. There is a large, rectangular grass area shown in Picture 5-13 that could be used to capture and treat the runoff from the parking lots. Currently, the parking lots drain to the undersized closed system along Oakmont Drive. This leads to flooding along Oakmont Drive and the bordering parking lots. As part of the Flood Control Alternatives in Section 4, it has been proposed that the Oakmont Drive Secondary System be upsized. This water quality project could be couple with those improvements.

Picture 5-13. Proposed Location for Oakmont Drive Bioretention Area

The required surface area for the proposed bioretention is approximately 730 square feet (0.02 acres). A concept level plan of the proposed improvements is shown in Figure 5-7. The proposed Oakmont Drive bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent parking lots. The proposed impervious areas draining to the proposed area is 0.2 acres.
- Install concrete curb cuts on the east side of the parking lot at 104 Oakmont Drive that will allow water to access the proposed bioretention area. There are currently no inlets in the parking lot. Consequently, the water flows out into Oakmont Drive and other nearby parking lots.
- Install a yard inlet with a 15" outfall pipe directing flow into upsized Oakmont Drive conveyance system.

The proposed water quality project is located on private property. In order to construct the bioretention area, an easement would be required from the property owner at 104 Oakmont Drive. The estimated construction cost for the bioretention project along Oakmont Drive is $41,200. This project will have both water quality and flood reduction benefits by reducing the volume of runoff.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Proposed Curb Cut
Proposed Yard Inlet
Proposed Bioretention Area
Install 15 LF of 15" RCP
Tie-in to Existing Manhole
OAKMONT DR
102
104
106
108
110
107
103
2500
105
Meetinghouse Branch Watershed Master Plan
Figure 5-7
Oakmont Drive
Bioretention Area
0
25
50
100
1 inch = 50 feet
WK DICKSON

Water Quality Project #3: Eleanor Street

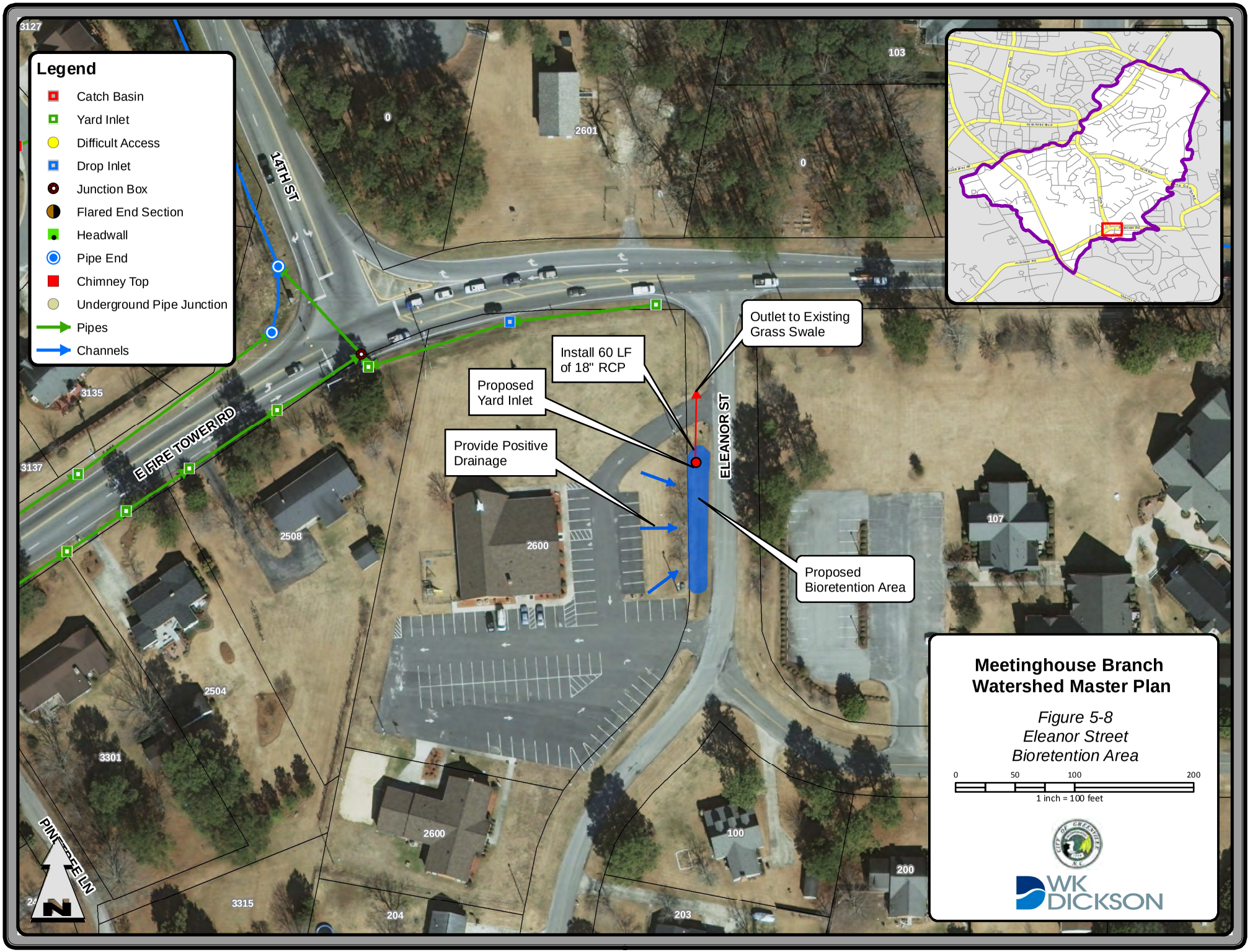
This potential project is located off of East Firetower Road on Eleanor Street adjacent to the New Destiny Pentecostal Holiness Church's parking lot. It is located on private property therefore in order to construct the bioretention area, an easement would be required. Currently, the area is functioning as a grass swale. It is proposed that it be converted to a bioretention area that would treat the runoff from the parking lot prior to it being discharged into the existing closed system.

Picture 5-14. Proposed Location for Eleanor Street Bioretention Area (Source: Google Earth)

The required surface area for the proposed bioretention area is approximately 1,230 square feet (0.03 acres). A concept level plan of the proposed improvements is shown in Figure 5-8. The proposed Eleanor Street bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent parking lot. The proposed impervious areas draining to the proposed area is 0.35 acres.
- Grade to provide positive drainage from the parking lot to the proposed bioretention area.
- Install a yard inlet with an 18″ outfall pipe directing flow into existing grass swale and ultimately to closed system along East Firetower Road.

The estimated construction cost for the bioretention project along Eleanor Street is $57,500.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
14TH ST
E FIRE TOWER RD
ELEANOR ST
PINEAPPLE LN
Outlet to Existing Grass Swale
Install 60 LF of 18" RCP
Proposed Yard Inlet
Provide Positive Drainage
Proposed Bioretention Area
3127
103
0
2601
0
3135
3137
2508
2600
107
2504
3301
2600
100
200
3315
204
203
Meetinghouse Branch Watershed Master Plan
Figure 5-8
Eleanor Street
Bioretention Area
0
50
100
200
1 inch = 100 feet
WK DICKSON

Water Quality Project #4: Brook Valley Country Club

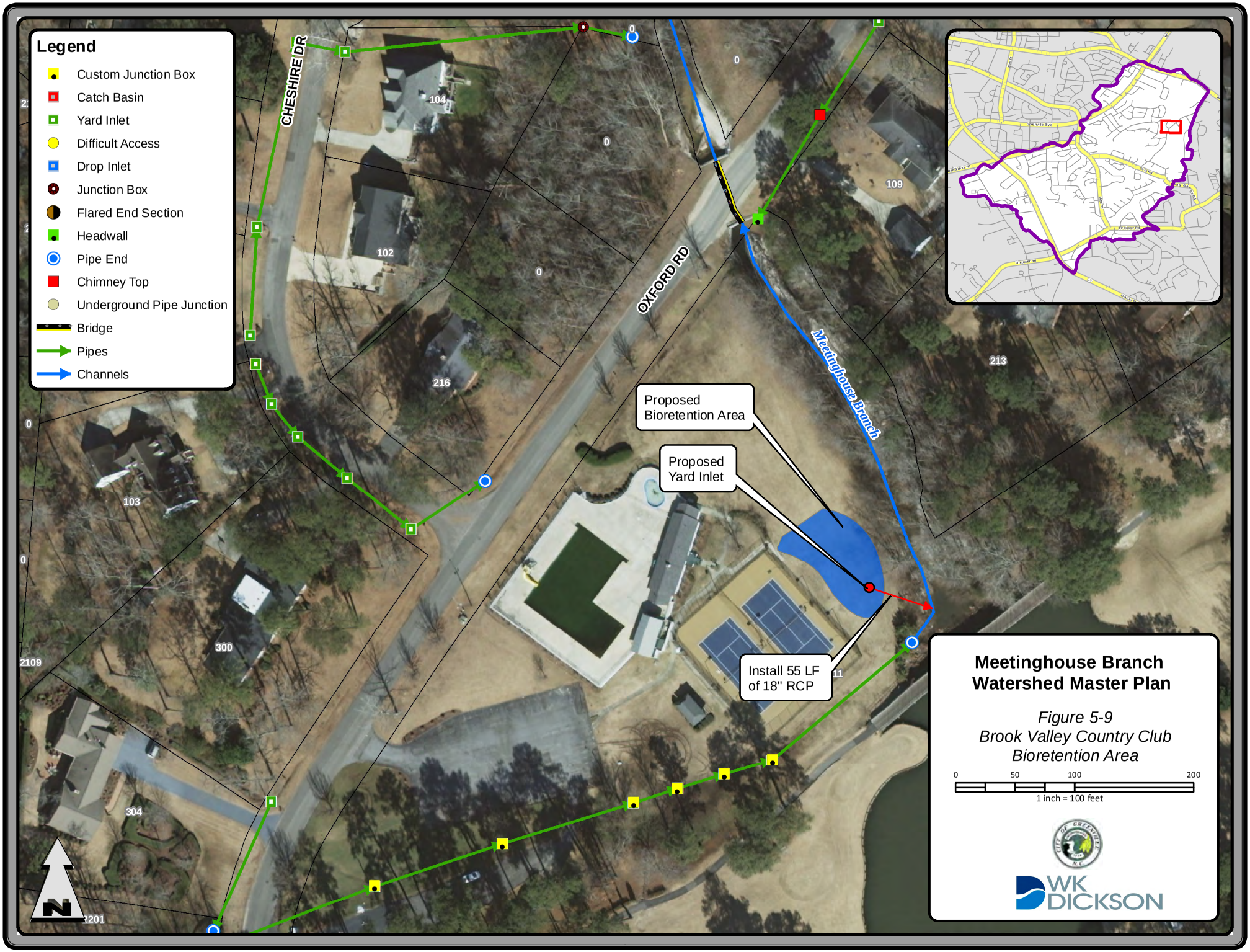
A potential project is located adjacent to the tennis courts and pool area of the Brook Valley Country Club. There is a large grass area shown in Picture 5-15 that could be used to capture and treat the runoff from the tennis courts, Oxford Road, and pool house's roof. Currently, these areas along with the parking lots drain to an undersized existing closed system that discharges to Meetinghouse Branch. As part of the Flood Control Alternatives in Section 4, it has been proposed that the Oxford Road closed system will be upsized. This water quality project could be couple with those improvements.

Picture 5-15. Proposed Location for Brook Valley Country Club Bioretention Area

The required surface area for the proposed bioretention area is approximately 1,200 square feet (0.03 acres). A concept level plan of the proposed improvements is shown in Figure 5-9. The proposed Brook Valley Country Club bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent tennis court, Oxford Road, and the redirected pool house roof leaders. The proposed impervious areas draining to the proposed area is 0.35 acres.
- Install a yard inlet with an 18″ outfall pipe directing flow into Meetinghouse Branch.

The proposed water quality project is located on private property. In order to construct the bioretention area, an easement agreement would be required with the owners of the Brook Valley Country Club. The estimated construction cost for the bioretention project along Oakmont Drive is $55,500.


Legend
Custom Junction Box
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Bridge
Pipes
Channels
CHESHIRE DR
OXFORD RD
Meetinghouse Branch
Proposed Bioretention Area
Proposed Yard Inlet
Install 55 LF of 18" RCP
104
102
216
103
300
304
109
213
2109
Meetinghouse Branch Watershed Master Plan
Figure 5-9
Brook Valley Country Club Bioretention Area
0
50
100
200
1 inch = 100 feet
WK DICKSON

Water Quality Project #5: Perkins Field

A bioretention project is proposed in the open space located between the Perkins Field parking lot and an open channel system. This area is adjacent to a ½-acre parking lot that currently drains to an existing closed system before discharging to an open channel. The proposed project location is shown in Picture 5-16.

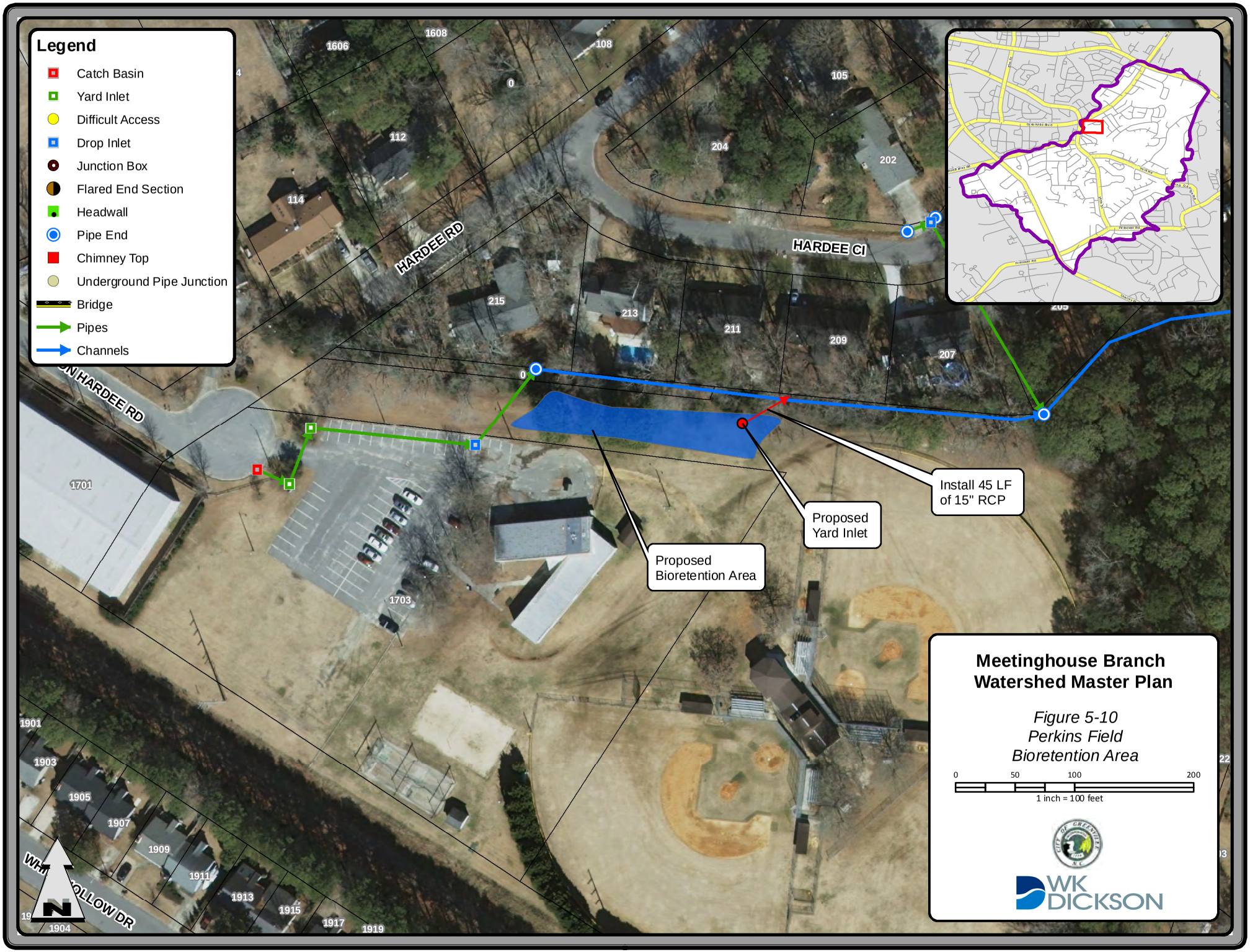
Picture 5-16. Proposed Location for Perkins Field Bioretention Area

The required surface area for the proposed bioretention area is approximately 2,800 square feet (0.06 acres). A concept level plan of the proposed improvements is shown in Figure 5-10. The proposed Perkins Field bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent parking lot.
- Install a yard inlet with an 18″ outfall pipe directing flow into the existing open channel system.

The estimated construction cost for the Perkins Field bioretention project is $90,500. The proposed water quality project is located on public property owned by the City of Greenville therefore no easement agreements are required. Another benefit of the bioretention area being located on public property with access to numerous residents, the BMP can provide an educational opportunity to discuss the water quality benefits of a bioretention area. Educational signage (See Picture 5-17) can be installed adjacent to the project.

Picture 5-17. Example Educational Signage


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Bridge
Pipes
Channels
HARDEE RD
HARDEE CI
HARDEE RD
1606
1608
108
105
112
204
202
114
215
213
211
209
207
205
1701
1703
1901
1903
1905
1907
1909
1911
1913
1915
1917
1919
1904
Install 45 LF of 15" RCP
Proposed Yard Inlet
Proposed Bioretention Area
Meetinghouse Branch Watershed Master Plan
Figure 5-10
Perkins Field
Bioretention Area
0
50
100
200
1 inch = 100 feet
WK DICKSON

Water Quality Project #6: Eastern Elementary School

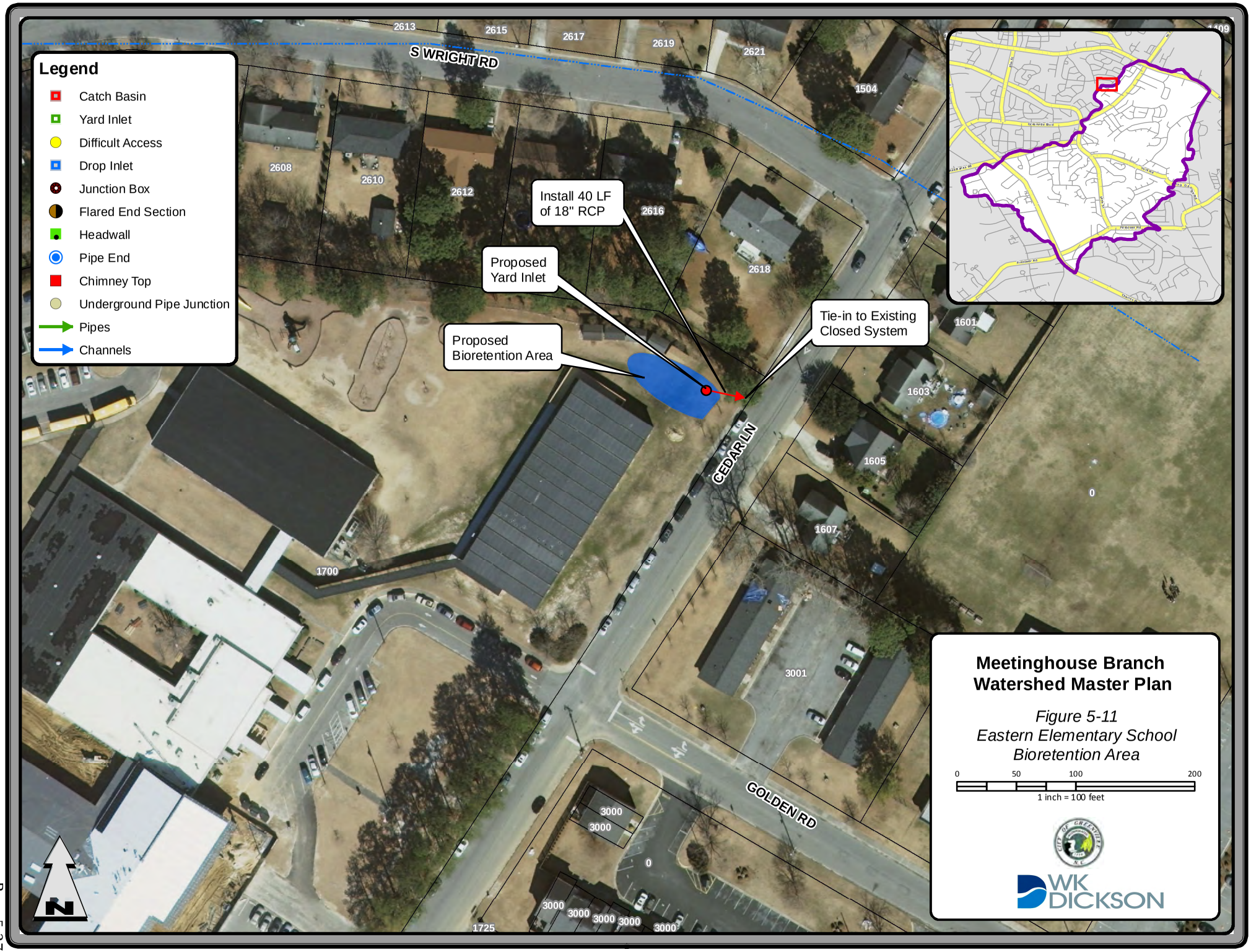
A bioretention area is proposed in the open space located in the northeastern corner of the parcel owned by the Greenville Board of Education (See Picture 5-18). This area is adjacent to one of the Eastern Elementary School parking lots and its entrance road. The open space is ideal for constructing a bioretention project that collects runoff from the parking lot that currently drains directly into the existing closed system. Currently, there is a curb cut that directs flow from the school's entrance road to the gutter along Cedar Lane. It is recommended that a similar curb cut be installed to direct flow to the proposed bioretention area. The proposed water quality project is located outside of the Meetinghouse Branch Watershed. However a portion of the school is located on the watershed boundary therefore this project was included as part of the Master Plan.

Picture 5-18. Proposed Location for Eastern Elementary School Bioretention Area

The required surface area for the proposed bioretention area is approximately 2,300 square feet (0.05 acres). A concept level plan of the proposed improvements is shown in Figure 5-11. The proposed Eastern Elementary School bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent parking lot and entrance road.
- Install a concrete curb that will allow water to access the proposed bioretention area.
- Install a yard inlet with an 18″ outfall pipe directing flow into the existing closed drainage system along Cedar Lane.

The estimated construction cost for the Eastern Elementary School bioretention area is $80,200. The proposed water quality project is located on public property therefore no easement agreements are required. Similar to the Perkins Field bioretention area, this project can also serve as an educational opportunity to discuss the water quality benefits of BMPs through signage and engagement with the student body of Eastern Elementary School.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
S WRIGHT RD
CEDAR LN
GOLDEN RD
Install 40 LF of 18" RCP
Proposed Yard Inlet
Proposed Bioretention Area
Tie-in to Existing Closed System
2613
2615
2617
2619
2621
1504
2608
2610
2612
2616
2618
1601
1603
1605
1607
1700
3001
3000
1725
0
1409
Meetinghouse Branch Watershed Master Plan
Figure 5-11
Eastern Elementary School Bioretention Area
0
50
100
200
1 inch = 100 feet
WK DICKSON

Water Quality Project #7: Jaycee Park

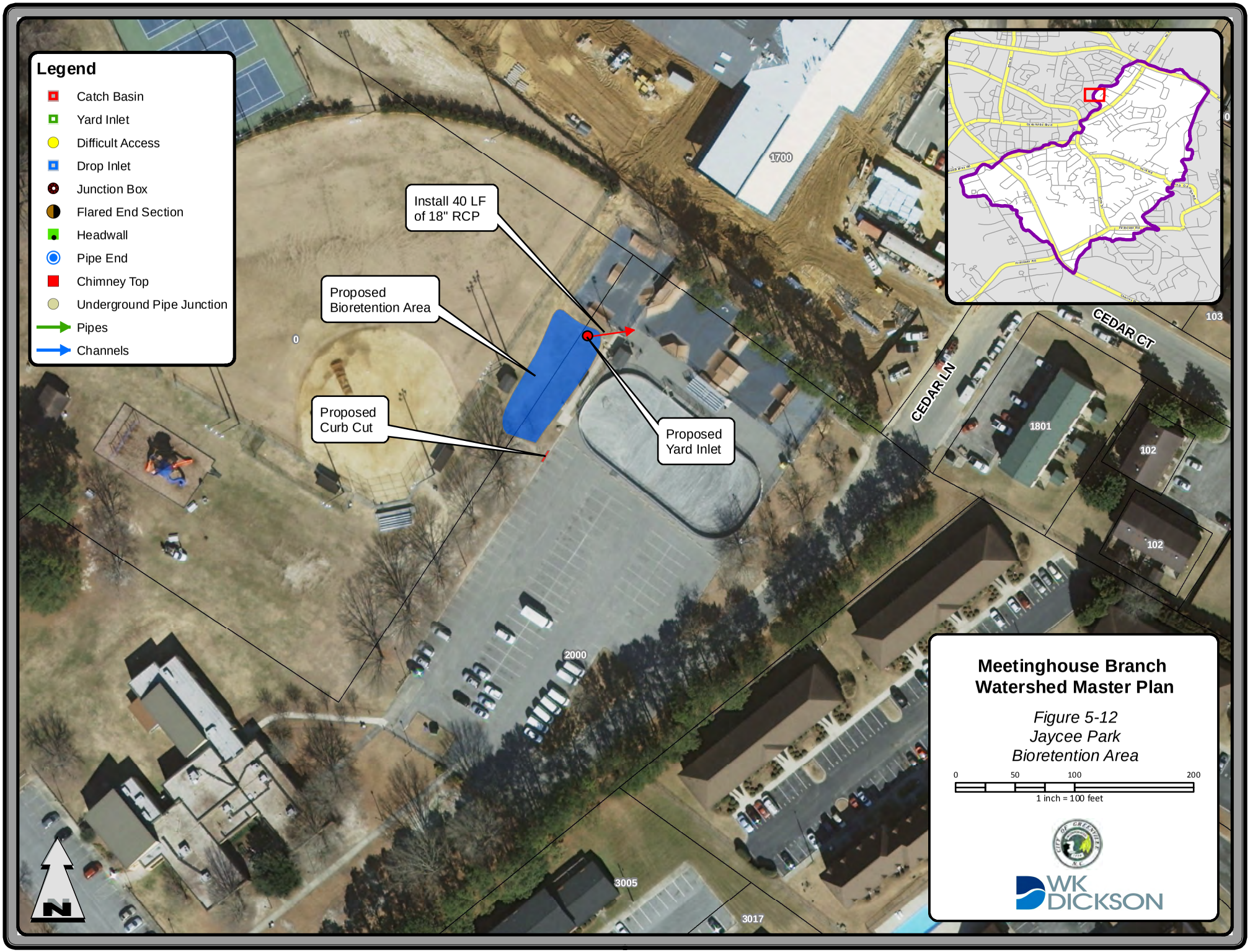
A potential bioretention project site is located between the Jaycee Park baseball field and parking lot. There is a grassy area shown in Picture 5-19 that could be used to capture and treat the runoff from the parking lot. The parking lots currently drain to the closed system along Cedar Lane. In addition to the bioretention area, it is recommended that concrete curb cuts be installed in the northeastern portion of the parking lot to allow water to access the proposed bioretention area.

Picture 5-19. Proposed Location for Jaycee Park Bioretention Area

The required surface area for the proposed bioretention area is approximately 5,500 square feet (0.13 acres). A concept level plan of the proposed improvements is shown in Figure 5-12. The proposed Jaycee Park bioretention project consists of the following improvements:

- Install a bioretention area designed to treat runoff from the adjacent parking lot.
- Install a concrete curb that will allow water to access the proposed bioretention area.
- Install a yard inlet with an 18″ outfall pipe directing flow into the existing closed drainage system along Cedar Lane.

The estimated construction cost for the Jaycee Park bioretention area is $151,100. The proposed water quality project is located on public property owned by the City of Greenville therefore no easement agreements are required. Educational signage can be installed near the proposed bioretention area to outline the water quality benefits of a BMP bioretention area.


Legend
Catch Basin
Yard Inlet
Difficult Access
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Chimney Top
Underground Pipe Junction
Pipes
Channels
Install 40 LF of 18" RCP
Proposed Bioretention Area
Proposed Curb Cut
Proposed Yard Inlet
CEDAR CT
CEDAR LN
1700
1801
102
102
103
2000
3005
3017
0
Meetinghouse Branch Watershed Master Plan
Figure 5-12
Jaycee Park
Bioretention Area
0
50
100
200
1 inch = 100 feet
WK DICKSON

5.4 PTRF Recommendations

As discussed in the Executive Summary the City of Greenville partnered with the Pamlico-Tar River Foundation (PTRF) and East Carolina University (ECU) to identify erosion and water quality problems in the Meetinghouse Branch Watershed and to develop potential solutions to those problems. The sharing of information between the City and PTRF resulted in cost savings for both organizations and continued partnering will enable the City to continue to leverage other revenue sources for the improvement of water quality throughout the Meetinghouse Branch watershed and overall city boundary.

PTRF was awarded a $50,000 Ecosystem Enhancement Grant from the Ecosystem Enhancement Program to develop a comprehensive water quality restoration plan for the Meetinghouse Branch watershed. Excerpts from the final PTRF report are included in Appendix N. The goals of the study were to identify impairment and its causes in the watershed and then to develop both structural and non-structural strategies and recommendations for restoration.

PTRF utilized the results of the questionnaires described in Section 2.1 and tabulated in Appendix D to assist in developing their recommendations. The PTRF recommendations focused particularly on Questions 7-12 of the questionnaire which include the following questions:

7. What is threatened by erosion?
8. Willingness to participate in a stream maintenance program;
9. If a cost-sharing program was made available along with training, would you be willing to install a stormwater BMP?
10. Please prioritize your concerns by placing the numbers from 1 through 10 next to the issue (see Appendix D for list of concerns)
11. What action, if any, have you taken in the last 5 years to lessen the threat of erosion and/or flooding?
12. Are you aware that the City of Greenville is currently analyzing and looking for possible solutions to erosion, flooding, and water quality issues along Meetinghouse Branch?

Based in part on the responses to the questions above, PTRF made the following recommendations:

- Educational efforts should target the benefits of stormwater BMPs particularly in areas with that have large amounts of impervious area. Efforts should target residences in the upper portions of the watershed to treat stormwater runoff closer to the source.
- Residences along the stream channels should reduce mowing in the buffer areas, and replant if possible.
- Educational efforts should target the natural characteristics of streams and flooding.
- The City should revisit its stormwater ordinances as it appears the impacts from development may have caused downstream impacts related to flooding, erosion, water quality, and habitat degradation.

In addition to the educational recommendations listed above, PTRF made other recommendations for implementation of restoration efforts to improve water quality in the

watershed. These recommendations included the following:

- Stormwater BMPs
- Stream and riparian restoration
- LID/GI practices
- Bank stabilization
- Sewer line leak detection surveys
- Removal of illicit connections
- Long term water quality monitoring

Appendix N includes the full list of recommendations from PTRF including specific sites for potential retrofit BMPs that can be implemented in addition to those listed in this study. Appendix O of this report includes a detailed citywide long term water quality monitoring plan for a variety of constituents. When implemented, the water quality monitoring network will provide valuable information to the City on areas to focus implementation efforts and source controls. Continued partnerships with PTRF, ECU, and funding agencies will be critical for effective management of funds and resources to implement the recommendations listed above.

SECTION 6
PUBLIC EDUCATION AND OUTREACH

Successful implementation of the Meetinghouse Branch Watershed Master Plan and stormwater management as a whole requires extensive public education and outreach. The City has taken important steps in public outreach within the Meetinghouse Branch Watershed through the use of direct mail questionnaires, web-based applications, and public meetings. Questionnaires were mailed to residents throughout the watershed in April of 2011 requesting feedback on flood-prone areas and any water quality concerns. Compiled results of the questionnaires can be found in Appendix D.

A public meeting was held on April 19, 2011 to introduce the project and facilitate further feedback from the public. The initial public feedback is critical to identifying flood-prone areas and validating model results. A follow-up meeting will be held to share results of the Master Plan with the public. As selected projects proceed into design and construction continuous public outreach will be critical to the success of the projects. Most of the proposed improvements include some impacts to private properties which will require permanent drainage easements and temporary construction easements. Public meetings and individual property owner meetings through the design process will help educate property owners on the benefits of the proposed projects and the temporary and permanent impacts from construction.

Aside from the public education and outreach completed for projects specific to the Meetinghouse Branch Watershed Master Plan, the City has several programs dedicated to educating the public about water quality and pollution. The City's website provides information about the Stormwater Program and the development of the Stormwater Utility and associated fees. Another outreach measure that could be considered would be to target those City residents that live adjacent to the stream. For this select group, quarterly newsletters could be mailed presenting information regarding the importance of not illegally discharging items (i.e. yard waste, car batteries, and other miscellaneous debris) into the stream. The newsletter should encourage the residents to keep the stream clean and report any blockage.

A different approach would be coordinating with the local schools to teach the students about age appropriate stormwater issues. There are many benefits to teaching children about stormwater issues including the students relaying the information they learn in school to their parents. A presentation can be done in conjunction with an afternoon spent visiting and cleaning up the nearby stream. Adding an educational BMP near the school would be another outreach opportunity. The bioretention project proposed at Eastern Elementary School would be an example. This along with the previously mentioned newsletter could be included in the Public Education section of the City's Action Report and Plan that must be completed annually to meet the requirements of Tar-Pamlico River Basin stormwater program.

The proposed improvements described in Section 4 may require local, State, and/or Federal permits or approvals prior to the onset of construction. Based on the types of projects identified in the Meetinghouse Branch Watershed, permits or approvals may be required for any of the following reasons:

- Stream and/or wetland impacts;
- FEMA floodway impacts;
- Land disturbance; and
- Potable water and sewer line adjustments.

The permitting matrix shown in Table 7-1 shows the different types of permits that are anticipated for each proposed flood control project. The water quality retrofits may require erosion control permits if the area of disturbance is greater than 1.0 acres, but permits or agreements from DWQ, USACE, FEMA, and NCDOT are not anticipated for these projects.

The types of 404/401 permits are described below and may vary based on the length of stream impacts and/or acreage of wetland impacts. Wetlands will need to be delineated to determine the acreage of impacts. Permit requirements for a given project may change based on the final design and any changes to the existing regulations. The appropriate permitting agencies should be contacted during the design process to determine if permits will be required for the proposed project.

7.1 North Carolina Division of Water Quality 401 Water Quality Certification and US Army Corps of Engineers 404 Permit

Proposed improvements within the City of Greenville must adhere to the requirements set forth in Sections 401 and 404 of the Clean Water Act. Required permitting can range from activities that are pre-authorized to those requiring a pre-construction notification (PCN) for a Nationwide Permit (NWP) to those requiring an Individual Permit (IP). Individual permits may be required for projects with stream impacts greater than 300 feet and wetland impacts greater than 0.5 acres. It is anticipated that NWP #3 (Maintenance) and NWP #13 (Bank Stabilization) may be required to support the projects that include work within streams or channels that are claimed jurisdictional by the US Army Corps of Engineers (USACE). Individual permits may be required for floodplain benches where significant wetland impacts may be encountered. More detailed explanations of the types of 404 permits are provided below.

NWP #3 – Maintenance

This permit authorizes the repair, replacement or rehabilitation of any previously permitted or currently serviceable structure. A PCN is not required if minor deviations in the structure's configuration or filled area that occur as a result of changes in materials, construction techniques, or safety standards necessary to make repair or replacement, provided that environmental impacts are minimal. A PCN to the USACE is required if a significant amount of sediment is excavated/filled within the channel. NC Division of Water Quality (DWQ) does not typically require a PCN for NWP #3 but usually receives one as a courtesy.

Other provisions imposed by the State of North Carolina require that culvert inverts must be buried a minimum of 1-foot below the streambed for culverts greater than or equal to 48 inches

in diameter to allow low flow passage of water and aquatic life. Culverts less than 48 inches in diameter should be buried to a depth of 20% or greater of the diameter of the culvert.

NWP #13 – Bank Stabilization

This permit authorizes the reshaping of channel banks or bank stabilization activities that are necessary for erosion prevention. The placement of material is prohibited in any special aquatic site in a manner that may impede surface water flow into or out of a wetland area, or in a manner that will be eroded during normal or high flows. The activity must be part of a single and complete project and cannot exceed 1 cubic yard per running foot placed below the high water mark line. If stabilization activities exceed 500 linear feet, then a PCN is required for both the USACE and DWQ. DWQ must also be notified should fill be placed within the streambed.

NWP #27 – Stream and Wetland Restoration Activities

This permit authorizes stream enhancement, stream restoration, and channel relocation for restoration purposes that provide gains in aquatic functions. Stream channelization and the conversion of streams to other aquatic uses such as impoundments or waterfowl habitat are not authorized. A PCN to the USACE is required for any restoration activities occurring on private or public lands. DWQ requires a PCN if impacts are proposed for greater than 500 feet of stream bank or if in-stream structures are used.

Impacts proposed to the streams may need evaluation under the State Environmental Policy Act (SEPA). An Environmental Assessment (EA) is required under SEPA if greater than 500 linear feet of perennial stream is disturbed and stream restoration or enhancement is not performed. Channel disturbances are defined as activities that remove or degrade stream uses such as channelization, culvert placement, riprap, and other hard structures.

A list of some other conditions that should be followed under regulations provided by the USACE and DWQ are as follows:

- Soil erosion and sediment controls must be used and maintained in effective operating conditions during construction, and all exposed soil and fills should be stabilized at the earliest possible date.
- No activity is authorized under any NWP that is likely to jeopardize the existence of a threatened or endangered species, or which will destroy or adversely modify the habitat of such species.
- No activity is authorized that may affect historic properties listed or eligible for listing in the National Register of Historic Places.
- More than one NWP used for a single and complete project is prohibited.
- Impacts to waters of the US should be avoided and minimized to the greatest extent practicable.
- Mitigation in all its forms will be required to the extent necessary to ensure that the adverse effects to the aquatic environment are minimal.
- Hardening techniques should be avoided and minimized to the greatest practicable extent.

7.2 Individual Permits

Individual Permits are required when stream or wetland impacts do not meet the conditions of a nationwide permit. Permit applications may be reviewed by multiple agencies including but not limited to USACE, DWQ, EPA, SHPO, NCWRC, and USFWS. The application is also made available for public review. There is no defined timeframe for review of the application for an IP; therefore the permitting process for an IP is typically significantly longer than the review time for a NWP. Typically 404 and 401 Individual Permits are applied for jointly and their review is concurrent.

7.3 Federal Emergency Management Agency (FEMA)

Streams with a drainage area greater than one square mile are typically modeled and mapped by FEMA for flood insurance purposes. The 100-year floodway and floodplain has been mapped for Bells Branch from the York Road culvert crossing to its confluence with Meetinghouse Branch. Approximately 250 feet upstream of Quail Ridge Road to York Road is defined as a Limited Detail Study where a floodplain is mapped, but no floodway has been defined. A floodway is the portion of the floodplain that must remain undeveloped to prevent an increase in the base flood elevation (BFE) of more than a specified amount. The specified amount as regulated by FEMA is typically 1.0 feet. For Meetinghouse Branch, the limits of the FEMA Detailed Study are King George Road to its confluence with Hardee Creek. The Limited Detail Study runs from King George Road to approximately 1,000 feet upstream.

Any proposed projects that will include grading within a FEMA defined floodway will require a Conditional Letter of Map Revision (CLOMR) submitted to FEMA for pre-approval purposes and a Letter of Map Revision (LOMR) upon completion of construction. Table 7-1 identifies the projects where FEMA permitting is expected.

7.4 Erosion and Sedimentation Control

North Carolina Department of Environment and Natural Resources (NCDENR) is another agency that requires notification before proposed activities are constructed. NCDENR requires that an erosion and sedimentation control plan be submitted to the Land Quality Section for approval before the start of construction for any disturbance greater than one acre. Erosion and Sedimentation Control permits are anticipated for most of the proposed projects as shown in Table 7-1.

Table 7-1: Permitting Matrix for Proposed Projects

	FEMA	404/401 (NWP)	404/ 401 (IP)	NCDENR/ NPDES	NCDOT	RAILROAD
PRIMARY SYSTEM PROJECTS						
East 14th Street – Alternative #1 (Bells Branch)		X		X	X	
East 14th Street – Alternative #2 (Bells Branch)		X		X	X	
York Road & Railroad Crossing – Alternative #1 (Bells Branch)	X	X		X	X	
York Road & Railroad Crossing – Alternative #2 (Bells Branch)	X	X		X	X	X
Oxford Road Closed System (Bells Branch)	X	X		X		
Charles Boulevard – Alternative #1 (Meetinghouse Branch)	N/A					
Charles Boulevard – Alternative #2 (Meetinghouse Branch)		X		X	X	
14th Street – Alternative #1 (Meetinghouse Branch)		X		X	X	
14th Street – Alternative #2 (Meetinghouse Branch)*		X		X	X	
Oxford Road North (Meetinghouse Branch)	X	X		X		
SECONDARY SYSTEM PROJECTS						
Grey Fox Trail				X		
Rondo Drive – Paramore Drive – Barnes Street				X		
Fantasia Street – Sherwood Drive				X		
Oakmont Drive				X		
STREAM STABILIZATION PROJECTS						
Project #1 – Charles Boulevard		X		X		
Project #2 – Crooked Creek Road		X		X		
Project #3 – Brook Valley Golf Course	X	X		X		
Project #4 – Bloomsbury Road	X	X		X		
Project #5 – Kensington Drive	X	X		X		
WATER QUALITY PROJECTS						
Project #1 – First Free Will Baptist Church (Bioretention)				X		
Project #2 – Oakmont Drive (Bioretention)				X		
Project #3 – Eleanor Street (Bioretention)				X		
Project #4 – Brook Valley Country Club (Bioretention)				X		
Project #5 – Perkins (Bioretention)				X		
Project #6 – Eastern Elementary School (Bioretention)				X		
Project #7 – Jaycee Park (Bioretention)				X		

*May require additional coordination/permitting with SHPO related to Historical properties.

8.1 Water Quality Improvement Funding

As the final designs of the proposed improvements are evaluated, the City is encouraged to investigate the potential funding mechanisms that are available for water quality projects. There are a wide range of funding mechanisms that may be available to the City. Sources include the Clean Water Act Part 319 funds administered by the US EPA and the North Carolina Cleanwater Management Trust Fund (CWMTF). CWMTF funding can include land acquisition costs, design fees, and construction costs to help finance projects that improve and protect water quality. In 2012, the CWMTF awarded $10.8 million to fund projects throughout North Carolina. The Clean Water State Revolving Fund (CWSRF) is another option. It offers low-interest loans that can be used to fund stormwater projects with water quality components. It should be noted that typically, grants require some type of matching funds. The matching requirements vary for each different type of grant. For example, the CWSRF requires a 20 percent match from State based on the amount of Federal dollars awarded while the CWMTF does not have a specified match requirement.

The NCDENR Division of Water Resources has a Water Resources Development Project Grant Program. The program provides cost-share grants and technical assistance. The grants are offered for the following purposes: general navigation, recreational navigation, water management, stream restoration, beach protection, land acquisition and facility development for water-based recreation, and aquatic weed control. The current matching limit for the program is 50 percent. This past spring, the program awarded grants ranging from $3,000 to $300,000. The total amount awarded across eleven recipients was $554,331.

8.2 Flood Mitigation Funding

FEMA's Flood Mitigation Assistance (FMA) is a pre-disaster grant program designed to provide funding to States and communities to help in their efforts to reduce or eliminate the risk of repetitive flood damage to building and structures insured under the National Flood Insurance Program (NFIP). In order to be eligible, communities must have completed and approved Flood Mitigation Plans that assess flood risk and identify actions to reduce that risk. Any State agency, participating NFIP community, or local agency is eligible to participate and should contact community officials.

Additional project grant eligibility criteria include a project that is:

- Cost effective;
- Cost beneficial to the National Flood Insurance Fund;
- Technically feasible; and
- Physically located in participating NFIP community or must reduce future flood damages in an NFIP community.

A project must also comply with (1) the minimum standards of the NFIP Floodplain Management Regulations, (2) the applicant's Flood Mitigation Plan, and (3) all applicable laws and regulations. The State is the grantee and program administrator for FMA. FEMA distributes FMA funds to States that in turn provide funds to communities. FEMA may provide up to 75% of the total eligible costs. The remaining costs must be provided by a non-Federal source of

which no more than half can be provided as in-kind contributions from third parties.

8.3 Revenue and General Obligation Bonds

Municipalities in North Carolina have the authority to use bonding for capital improvement projects under the State's General Statues. There are two types of bonds available for use – general obligation and revenue bonds. General obligation bonds are funds received after voter approval of bond referendum. A vote is required because general obligation bonds are secured using the City's taxing power. All revenues, including different taxes, can be used to pay off a general obligation debt. Revenue bonds, on the other hand, are backed by income generated by the City through fees collected (i.e. various utility fees including stormwater). Because their security is not as great as that of general obligation bonds, revenue bonds may carry a slightly higher interest rate.

8.4 Utility Rate Study

The City should consider completing a utility rate study to determine if the current rate is appropriate for funding the required operations of the Stormwater Division as well as capital projects. The enterprise fund was originally established in 2001 with collections beginning in 2003. Since that time the rates have not been adjusted based on the needs of the program. In May 2013, City staff requested a fee increase of $0.50/ERU each year for the next 5 years to support capital projects and completion of the citywide master plan. Once the planning is complete, the City should complete a detailed rate study based on the capital needs identified in the planning process.

The cost estimates provided in this study were prepared to assist City staff in making planning level decisions and prioritizing improvements. These cost estimates are not final design estimates. These costs were developed using recent bid tabulations from other communities and NCDOT projects within North Carolina and include easement acquisition, surveying, engineering, legal, and administrative costs. A detailed breakdown of the costs for the projects listed below in Table 9-1 is included in Appendix G. Projects are not listed based on priority. See Section 10 for the prioritization list. The cost estimates are approximate and are subject to change due to local costs for materials, delivery, construction, and other factors. BMP costs are based on the size of the BMP, the estimated excavation required, and any associated structure or planting costs.

The stormwater drainage systems evaluated in this report are composed of a series of culverts, closed drainage systems, open channels, floodplain grading, and BMPs. For these drainage systems to function as designed they must be properly maintained.

Table 9-1: Preliminary Project Cost Estimates

Projects	Preliminary Project Cost
PRIMARY SYSTEM PROJECTS	
East 14th Street (Bells Branch)– Alternative #1	$159,100
York Road & Railroad Crossing(Bells Branch) – Alternative #1	$183,600
York Road & Railroad Crossing(Bells Branch) – Alternative #2	$316,800
Oxford Road Closed System (Bells Branch)	$1,423,000
Charles Boulevard – Alternative #1 (Meetinghouse Branch)	No Action
Charles Boulevard – Alternative #2 (Meetinghouse Branch)	$549,300
14th Street (Meetinghouse Branch) – Alternative #1	$576,600
14th Street (Meetinghouse Branch)– Alternative #2	$1,476,300
Oxford Road Floodplain Bench – Alternative #2	$559,000
SECONDARY SYSTEM PROJECTS	
Grey Fox Trail	$848,500
Rondo Drive – Paramore Drive – Barnes Street	$549,600
Fantasia Street – Sherwood Drive	$1,760,600
Oakmont Drive	$490,400
Eastwood Subdivision System	$2,158,500
STREAM STABILIZATION PROJECTS	
Project #1 – Charles Boulevard	$152,900
Project #2 – Crooked Creek Road	$85,200
Project #3 – Brook Valley Golf Course	$135,500
Project #4 – Bloomsbury Road	$59,500
Project #5 – Kensington Drive	$174,200
WATER QUALITY PROJECTS	
Project #1 – First Free Will Baptist Church (Bioretention)	$82,900
Project #2 – Oakmont Drive (Bioretention)	$41,200
Project #3 – Eleanor Street (Bioretention)	$57,500
Project #4 – Brook Valley Country Club (Bioretention)	$55,500
Project #5 – Perkins (Bioretention)	$90,500
Project #6 – Eastern Elementary School (Bioretention)	$80,200
Project #7 – Jaycee Park (Bioretention)	$151,100

SECTION 10
PRIORITIZATION AND RECOMMENDATIONS

As previously noted, the primary goal of this study is to make improvement recommendations to reduce flooding within the Meetinghouse Branch Watershed. Currently, several conveyance systems do not meet the City hydraulic design requirements. WK Dickson has provided recommendations that help to reduce or eliminate the identified problems. Success criteria goals used to measure each proposed flood control project included the following:

- Providing improved level of service for roadways and structures;
- Economic feasibility;
- Minimizing stream and wetland impacts;
- Confirming physical feasibility using available GIS and survey data; and
- Minimizing easement acquisition.

Two different prioritization lists were developed for the proposed projects identified in Sections 4 and 5: Flood Control Improvements, and Water Quality/Stream Stabilization Improvements. Projects were prioritizing using a Prioritization Matrix provided in Appendix M. The improvements were prioritized based on the following factors:

- Public health and safety;
- Severity of street flooding
- Cost effectiveness
- Effect of improvements
- Water quality – BMP
- Open Channel – erosion control
- Implementation constraints
- Grant funding
- Constructability

In some instances project prioritization will be impacted by the required sequencing of projects to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. Downstream impacts are including in the scoring for Implementation Constraints, however upon completion of the scoring process, the prioritization list should be reviewed to ensure that projects are appropriately ranked based on sequencing. Some projects have two alternatives listed in the prioritization table. Once an alternative for that project has been selected, the alternative not selected can be removed from the prioritization list. Table 10-1 shows the proposed prioritizations for the Flood Control Improvements. The City should re-visit the prioritization lists annually to determine if the priorities should change.

Table 10-1: Flood Control Prioritization

Prioritization	Project
1	Oxford Road Closed System (Bells Branch)
2*	Oxford Road Floodplain Bench (Meetinghouse Branch) – Alternative #2
3	York Road & Railroad Crossing (Bells Branch) - Alternative #2
4	14th Street (Meetinghouse Branch) - Alternative #2
5	York Road & Railroad Crossing (Bells Branch) - Alternative #1
6	14th Street (Meetinghouse Branch) - Alternative #1
7**	Eastwood Subdivision
8	Charles Boulevard (Meetinghouse Branch) - Alternative #2
9	Oakmont Drive
10	Grey Fox Trail
11	East 14th Street (Bells Branch) - Alternative #1
12	Fantasia Street - Sherwood Drive
13	Barnes Street- Paramore Drive -Rondo Drive

* The Oxford Road Floodplain Bench was initially ranked as the 6th highest priority project however the project needs to be constructed prior to the York Road & Railroad Crossing project to offset water surface increases caused by the proposed increase of flow capacity at the Railroad crossing.

** The Eastwood Subdivision project was identified outside of the scope of the Master Plan. Estimated project costs and a ranking score were provided by the City.

Table 10-2 shows the recommended priorities for the water quality and stream stabilization projects.

Table 10-2: Water Quality and Stream Stabilization Prioritization

Prioritization	Project
1	Charles Boulevard Stream Stabilization
2	Perkins Field – Bioretention
3	Eastern Elementary School – Bioretention
4	Oakmont Drive – Bioretention
5	Brook Valley Golf Course Stream Stabilization
6	Bloomsbury Road Stream Stabilization
7	Crooked Creek Road Stream Stabilization
8	Jaycee Park - Bioretention
9	Brook Valley Country Club – Bioretention
10	Eleanor Street – Bioretention
11	Kensington Drive Stream Stabilization
12	Free First Baptist Church - Bioretention

Table 10-3 shows the recommended priorities for maintenance projects in the watershed. Maintenance locations were identified based on the condition assessment completed during the stormwater inventory. Structures receiving a condition of "poor" or "repair" are listed below for maintenance. In addition the Tucker Drive and Oxford Road North Bridge require maintenance to adequately convey flows and to minimize future risks to the structures as described in detail in Section 4.1.2. More immediate maintenance needs may present themselves if portions of a conveyance system fail.

Table 10-3: Maintenance Recommendations

Prioritization	Project
1	Tucker Drive Culvert
2	Spot repair of 6 inlets and pipe end along Oxford Road Closed System downstream of Oxford Road as needed prior to completion of capital project
3	Oxford Road North Bridge
4	48" Culvert under abandoned road north of Nichols Drive (MHUT0157 and MHUT0158)
5	Chimney top along King George Road (MHMB0074)
6	Broken FES northeast of Westminster Circle (BBUT0093)
7	24" Pipe end each of Nichols Drive (MHUT0155)
8	Catch Basin on Yorkshire Drive (BBUT0083)
9	Pipe end broken north of York Road (BBUT0124)
10	Pipe end south of Old Oak Walk (MHMB0116)
11	Pipe end south of Louis Street (MHMB0187)
12	Pipe end near intersection of 14th Street and Planters Walk (MHMB0194)
13	Crushed pipe end along King George Road (MHMB0081)
14	Pipe end between Christenbury Drive and Oxford Road (MHMB0015)

1. Hydraflow Storm Sewers Extension User's Guide Version 8, 2011.

2. Municipal Storm Water Management, by Debo and Reese, 1995

3. National Weather Service
   http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html

4. Stormwater Best Management Practices; North Carolina Department of Environment and Natural Resources, Division of Water Quality, July 2007.

5. Urban Hydrology for Small Watersheds, United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, Technical Release 55, June 1986.

6. Booth DB, Jackson CR (1997) Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation. Journal of the American Water Resources Association 33(5):1077-1090.

7. Brant, T. R. 1999. Community Perceptions of Water Quality and Management Measures in the Naamans Creek Watershed. *Masters Thesis for the Degree of Master of Marine Policy. 146 pp.*

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