1. GENERAL WATERSHED CONDITIONS

1.1 Watershed Characteristics

The Sugar Creek watershed study limit extends to include 12.1 miles of Sugar Creek from the Mecklenburg County border to the headwaters of Taggart Creek, and 6.3 miles of Coffey Creek. Taggart Creek extends 3.4 miles above the confluence with Sugar Creek. The Sugar Creek watershed also includes McCullough Creek (1.5 miles) and Kings Branch (4.3 miles).

Sugar Creek

The main Sugar Creek channel is wide and typically has steep banks - a characteristic of entrenchment. These steep, tall banks can limit the stream from using its natural floodplain. The channel in some areas is about 50 feet wide at the lower bank (Figure 1). Sand and silt bed material characterizes a majority of the stream length. At many sites, riprap has been added into the channel as well as along the banks, i.e., at sanitary sewer line crossings. Continual bank erosion has the potential to expose sanitary sewers located in alternating banks. Bank erosion at a few locations has caused trees to collapse into the channel. Previous field work in June 2000 identified an area where dozens of tires litter the channel bottom, effectively creating riffles in some locations between W. Arrowood Road and S. Tryon Street (Spring 2001 Flood Hazard Mitigation & Bank Stabilization Study, Study No. 4). Natural rock material was only observed in a few locations.

Figure 1. Typical Channel, Sugar Creek at Yorkmont Road and Billy Graham Parkway, Facing Downstream (Roll #2, Photo #14)

Coffey Creek

Coffey Creek, the largest of Sugar Creek's tributaries included in this study, begins north of West Boulevard near the Charlotte/Douglas International Airport. Its confluence with Sugar Creek is near the I-77 and I-485 interchange. This tributary exhibits many of the same characteristics of Sugar Creek (Figure 2). A well-established riparian zone lines most of the creek; however, development does encroach on this zone in some reaches. For instance, new residential development is occurring along the stream corridor at Shopton Road and near Yorkmont and Byrum Roads. Steep banks were observed for the length of the stream, while bottom material was mostly silt with some pebbles and riprap in the channel. Down-cutting of the channel was observed at many locations including culvert crossings at West Boulevard, Piney Top Drive, and Shopton Road. Some culverts (West Boulevard, Piney Top Drive, and York and Arrowood Roads) also exhibited sediment accumulation.

Figure 2. Typical Channel, Coffey Creek Upstream of Byrum Drive (Roll #1, Photo #8)

Kings Branch

Figure 3. Typical Channel, Kings Branch Looking Upstream of Hebron Street (Roll #2, Photo #2)

Kings Branch, with its headwaters near Tyvola Road and I-77 and mouth at Sugar Creek just south of I-485, has established vegetation for most of its stream length. Kings Branch was realigned during the 1960s to accommodate I-77. Its banks along this reach are stabilized by an invasive species, kudzu. Banks are not as steep as other portions of the Sugar Creek watershed. Sediment deposition was observed at the inside bends of meanders, with primarily silt and sand bottom material. These deposited bars are created as the stream tries to create meanders within its wide banks. One area of excellent habitat was observed at Hebron Road (Figure 3). Here riparian vegetation shades the channel, and a cluster of boulders provides a pool and riffle sequence of instream habitat for aquatic life. However, the banks in this area are suffering from erosion problems.

McCullough Creek

The headwaters of McCullough Creek begin west of Nation's Ford Road, and its confluence with Sugar Creek is just north of the state border with South Carolina. This is the smallest of Sugar Creek's major tributaries included in this study. Banks observed during field work appeared fairly stable. Riparian vegetation was established in most areas, with pastures reaching to the stream banks. The McCullough Creek culvert at US 51 shows head cutting (Figure 9). The culvert itself is also suffering from erosion and should be closely monitored by the County for maintenance needs.

Taggart Creek

Figure 4. Typical Channel, Taggart Creek Looking Upstream of Morris Field Road (Roll #2, Photo #2)

Taggart Creek, comprising the headwaters of Sugar Creek upstream of its confluence with Irwin Creek, begins north of Wilkinson Boulevard. Taggart Creek and Irwin Creek merge near the Billy Graham Parkway to become Sugar Creek. Vegetated riparian zones shade this shallow stream and stabilize the banks (Figure 4). Mild lower bank erosion was observed at Winston Container Road, Wilkinson Boulevard, and West Boulevard. The majority of bed material is silt and sand, with some rocks and riprap in the stream at road crossings. The larger material serves multiple functions -- providing habitat, riffle sequences, and preventing erosion. At one particular location, the railroad crossing Morris Field Road and Billy Graham Parkway, the channel is lined with riprap.

1.2 Development in the Watershed

For the purposes of land use and development analysis and discussion in this PER, the Sugar Creek watershed was divided into three sub-watersheds: lower Sugar, upper Sugar, and Coffey Creek (Figure E-7). Lower Sugar extends from the County boundary to the confluence with Coffey Creek. Upper Sugar extends north from the confluence of Coffey Creek to the Taggart Creek headwaters. Its land use and hydraulic input influence water quality and flow conditions in the study watershed. Since Irwin Creek watershed is one of the major watersheds and distinctive within Mecklenburg County major drainage basins, it is not included in this Sugar Creek Watershed Study.

Both Interstate I-85 (northern portion of watershed) and I-485 (southern portion) traverse the watershed, and I-77 crosses the watershed diagonally. These highways, along with the expansion of I-485 west of I-77, will encourage continual development and continue to impact land use development patterns.

The Charlotte/Douglas International Airport is located in the headwaters of Coffey Creek. Coffey Creek watershed is the least developed sub-watershed, but is a rapidly developing suburban area. The lower portion of Sugar Creek is developing as well.

Table 1 summarizes development in the Sugar Creek watershed as a whole. Tables 2 through 4 summarize development within each of the sub-watersheds (Lower Sugar, Upper Sugar, and Coffey Creeks) that eventually drain into Sugar Creek. More than half of the Sugar Creek watershed was developed before 1970 (60.5 percent), with infill development occurring through the present, leaving 20 percent of the parcels vacant. The majority of the parcels in the watershed support residential land uses (69.2 percent). Review of historical aerial photographs indicates agricultural activity, especially in the southern portion of the watershed. Non-residential land uses constitute a small portion, 10.5 percent, of development. Field visits in November 2000 revealed that infill development is continuing throughout the watershed. Although the land use and land cover in the entire watershed influence conditions in a stream, it is particularly sensitive to riparian corridor development.

The upper Sugar Creek sub-watershed reflects the average Sugar Creek watershed characteristics, with 20 percent of the area remaining vacant or unclassified (Table 2). Less than 10 percent of the developed area is non-residential land use.

The Coffey Creek sub-watershed encompasses the western side of the Sugar Creek watershed and has experienced the most recent development (Table 3). Before 1970, only 20 percent of the watershed was developed. Land use as of 2000 indicates that 69 percent of the sub-watershed is now developed (Figure 5). Thirty-one percent remains vacant or unclassified. The type of development is similar to the rest of the Sugar Creek watershed, with a majority (62 percent) of residential land use. As with the upper Sugar Creek watershed, non-residential land use is relatively low (6.8 percent).

Figure 5. Coffey Creek Sub-Watershed Development Near Yorkmont Road (Roll #1, Photo #9)

The lower Sugar Creek sub-watershed has the highest percentage of non-residential land use (21 percent) and the least amount of vacant parcels (18 percent) (Table 4). This area is bisected by I-485 and includes McCullough Creek and Kings Branch.

Table 1 Development in the Sugar Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	13,724	5,361	2,148	2,123	1,788	64,111	31,555
Percentage	43.5%	17.0%	6.8%	6.7%	5.7%	20.3%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	21,337	497	3,310	6,411	31,555
Percentage	67.6%	1.6%	10.5%	20.3%	100%

* Entire Sugar Creek watershed within Mecklenburg County, including all tributaries (68.9 mi^2).

Table 2 Development in the Upper Sugar Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	1,718	1,139	295	392	454	1,018	5,016
Percentage	34.2%	22.7%	5.9%	7.8%	9.1%	20.3%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	3,503	52	443	1,018	5,016
Percentage	69.8%	1.0%	8.8%	20.3%	100%

* Upper Sugar Creek watershed (14.5 mi^2) including Sugar and Taggart Creeks, total drainage area 44.4 mi^2.

Table 3 Development in the Coffey Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	163	124	111	303	266	437	1,404
Percentage	11.6%	8.8%	7.9%	21.6%	18.9%	31.1%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	861	10	96	1.3	1,404
Percentage	61.3%	0.7%	6.8%	31.1%	100%

* Coffey Creek watershed (10.5 mi^2).

Table 4 Development in the Lower Sugar Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	468	907	514	270	163	505	2,827
Percentage	16.6%	32.1%	18.2%	9.6%	5.8%	17.9%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	1,715	18	589	505	2,827
Percentage	60.7%	0.6%	20.8%	17.9%	100%

* Lower Sugar Creek watershed within Mecklenburg County (14.0 mi^2) including Kings Branch and McCullough Creek, total drainage area 68.9 mi^2.

Sanitary sewers are present along most of Sugar Creek and its major tributaries; consequently, any stream-side capital improvement projects should accommodate the existing utilities (Figure 6). The Irwin Creek Wastewater Treatment Plant is located on Irwin Creek just upstream of the confluence with Sugar Creek. This facility influences the water quality and flow volumes in Sugar Creek. The County's Year 2000 Inter-Agency Coordination of Capital Improvement Projects (CIPs) map (Figure E-11) indicates MCSWS has proposed action along Sugar Creek from Shopton Road to Arrowood Road. No other activities are currently planned for the remainder of the watershed. MCSWS should continue to coordinate with CMU to identify any potential projects or conflicts that arise in the future. If MCSWS is aware of CMU projects, it may influence the alignment of the relief sanitary sewer to coincide with the recommendations of this PER.

Figure 6. Sanitary Sewer Crossing at Kings Branch Below Archdale Road (Roll #1, Photo #22)

Although there are no existing greenways within the Sugar Creek watershed, the 1999 Mecklenburg County Greenway Master Plan recommends that the greenway system be expanded as a floodplain management buffer and water quality program to include all creeks and streams throughout the County. Future plans include a greenway along Coffey Creek from Shopton Road to Sugar Creek and along Sugar Creek from Billy Graham Parkway to the Lancaster, South Carolina, city line. A typical greenway with a creek identification sign within the County is shown in Figure 7. MCSWS should monitor future MCPRC plans for the Mecklenburg County Greenway System because this study reach could be included in future greenway development.

Figure 7. MCSWS Creek Identification Sign

1.3 Aquatic Habitat and Environmental Monitoring

Throughout the watershed, bank conditions vary considerably, but for most of the stream channels both banks are heavily vegetated with brush, willows, and some trees. Typcial current conditions are illustrated in Figures 1 through 5 (additional field photos are included in Appendix B and referenced in Figure A-1). The abundant vegetation protects most of the channel banks from severe erosion, provides intermittent shade, and some habitat for wildlife. Instream aquatic habitat such as boulders and large woody debris was limited in many areas. Very little aquatic wildlife was observed in Sugar Creek and its major tributaries. However, note that field surveys for this study were conducted within close proximity to road crossings, and did not include walking along all of the stream channels. Bank stabilization problems are discussed in Section 1.5, and improvements to erosion problem areas are included in the Flood Mitigation Improvement Analysis in Section 3.

The County's Water Quality Program maintains four ambient water quality sampling and bio-monitoring locations along Sugar Creek and Taggart Creek with three other monitoring sites on Coffey Creek and Kings Branch. An effort was made to look for trends and impacts of individual sub-watersheds (Table 5). Macroinvertebrate and fish community health indices reflect both water quality and habitat conditions.

Macroinvertebrate Taxa Richness sampling produced "Good" rankings for Taggart Creek location MC52 at Billy Graham Parkway. However, downstream of this site "Poor" Water Quality rankings in both 1994 and 1996, and 1997 "Fair" rankings indicate that, while improvements have occurred, Sugar Creek does not support a large diversity of aquatic fauna at the macroinvertebrate level. Consistently "Poor" rankings in the Coffey Creek (Sites MC25 and MC25A) and Kings Branch (MC26A) tributaries also indicate water quality and habitat problems.

Fish sampling in June of 1995 and 1996 at two Sugar Creek locations, Arrowood Road (MC23A) and NC Highway 51 (MC27), produced "Fair" Water Quality rankings. Fish diversity is similar in the two major tributaries, with "Poor-Fair" and "Fair" Water Quality rankings in Coffey Creek and "Poor-Fair" Water Quality rankings in Kings Branch.

Figure 8. Heavy Sedimentation and Debris on Coffey Creek at Arrowood Drive (Roll #1, Photo #14)

Ambient water quality sampling of Sugar Creek at the Arrowood Road location (MC23A) in June of 1996 and 1997 produced "Fair-Good" Water Quality Index ratings. Downstream near the state line, location MC27 at NC Highway 51 produced "Average" Water Quality rankings in 1994 and "Good" Water Quality rankings in 1997. The smaller tributaries show higher, consistent water quality. The upstream Coffey Creek location, MC25A, produced "Good-Excellent" Water Quality Index rankings in 1996 and 1997. Locations MC26A, Kings Branch at Arrowood Road, and MC52, Taggart Creek at Billy Graham Parkway, both produced "Good" Water Quality Index rankings.

Overall, water quality has remained fairly consistent in the Sugar Creek watershed since 1994. The Water Quality Index indicates that water quality conditions in the area are better than indicated by the presence of fish and macroinvertebrate communities. This may indicate that aquatic habitat conditions limit these communities to some extent. Review of ambient water quality data dating back to 1968 does not reveal significant trends in most of the data over time or by location. However, fecal coliform levels have dropped and pH has increased since the 1968-1970 data. This may be due to improvements to the sanitary sewer infrastructure that eliminated clogged and broken sewer pipes. The Irwin Creek Wastewater Treatment Plant also discharges into this watershed. The Sugar Creek channel bottom material consisted mainly of gravel, sand, and silt. Much of this material is probably transported downstream from upstream channel erosion and watershed surface runoff. While there are aquatic life forms present in the creek, the sand and gravel benthic material (without instream features such as boulders and woody debris) does not provide a protective habitat, and bottom dwelling communities are not as abundant and diverse as may be desired. One invasive species, the Asiatic Clam (*Corbicula flumine*), was observed throughout the watershed. This non-native freshwater clam may displace native species and is found throughout North Carolina.

Problems throughout the watershed include sediment transport (sediment accumulation in road crossing culverts) and urban debris (trash, shopping carts), as seen in Figure 8. The vegetated riparian zones also may not be providing their full filtering functions because of channel entrenchment throughout the watershed. Entrenchment of a stream channel lowers the water table, with the effect being a loss of water quality improvement for infiltrated water.

Table 5
Water Quality Program Water Quality Monitoring Summary

NC Piedmont Macroinvertebrate Taxa Richness		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating
MC52	Taggart Creek - Billy Graham Pkwy									5	Good
MC23	Sugar Creek - York Road	3	Poor								
MC23A	Sugar Creek – Arrowood Road					6	Poor	8	Fair		
MC25A	Coffey Creek - Byrum Drive					5	Poor	4	Poor		
MC25	Coffey Creek - York Road	6	Poor					9	Fair		
MC26A	Kings Branch - Arrowood Road	3	Poor					3	Poor		
MC27	Sugar Creek - NC Hwy 51	4	Poor					8	Fair		

Fish Bioassessment		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating
MC52	Taggart Creek - Billy Graham Pkwy			42	Fair						
MC23A	Sugar Creek – Arrowood Road					42	Fair				
MC25A	Coffey Creek - Byrum Drive					38	Poor-Fair				
MC25	Coffey Creek - York Road			40	Fair	40	Fair				
MC26A	Kings Branch - Arrowood Rd			38	Poor-Fair	38	Poor-Fair				
MC27	Sugar Creek - NC Hwy 51					42	Fair				

Water Quality Index		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating
MC52	Taggart Creek - Billy Graham Pkwy									74	Good
MC23	Sugar Creek - York Road	68	Average								
MC23A	Sugar Creek – Arrowood Road					64	Fair-Good	61	Fair-Good		
MC25A	Coffey Creek - Byrum Drive					76	Good - Excellent	77	Good-Excellent		
MC25	Coffey Creek - York Road	71	Good					71	Good		
MC26A	Kings Branch - Arrowood Road	74	Good					73	Good		
MC27	Sugar Creek - NC Hwy 51	52	Average					65	Good		

1.4 Rosgen Stream Morphology Assessment

Figure 9. Headcutting on McCullough Creek at Highway 51, Looking at Downstream Face (Roll #1, Photo #18)

River form and fluvial processes evolve simultaneously and operate through mutual adjustments toward self-stabilization (Rosgen 1994). The stream tries to balance the combination of sediment load and sediment size with the stream slope and discharge (Lane 1955). If any one of these components is altered (i.e., smaller sediment load), the opposing side of the balance must adjust proportionally (i.e., decrease in bed slope). If bed slope on a main channel changes, often tributaries will change to meet the main channel. Sediment contributions from this head cutting and degrading also occur. Due to intense development and increased peak flows, fluvial processes in streams may change more rapidly in an urban environment than if the stream were undisturbed. Sugar Creek is a developing watershed with increasing flow from increasing imperviousness and ample sources of sediment from construction, eroding banks, and channel downcutting. During the construction phase of development, mostly before 1970 in the Sugar Creek watershed, the sediment load was most likely quite high. However, now that the watershed is 80 percent developed with imperviousness, grassed lawns, and armored stream banks, this sediment source has most likely decreased.

When humans interfere with fluvial processes by increasing watershed imperviousness and change stream channels by realignment and armoring the banks, the stream counteracts by gradually lowering the bed slope (the flow remains fairly constant once the watershed is developed) in the upstream direction from a control point, such as the confluence with a larger stream or at a culvert. The slope for the main channel of Sugar Creek is low, 0.1, partially as a result of these processes. Heavy sediment deposition on the channel bottom indicates an aggrading stream. Evidence of other stream changes was also observed. Headcutting in the Sugar Creek watershed was found on the downstream end of the US 51 culvert crossing over McCullough Creek, where there is a drop-off from the culvert outlet to the stream channel (Figure 9).

Rosgen Level 1 analysis is intended for obtaining a course geomorphic characterization that results from the integration of basin relief, landform, and valley morphology (Rosgen 1996). Aerial photos, elevations from HEC-RAS input, 2-foot interval topographic contours, soil survey reports, and field observations were used to conduct Level 1 Analysis.

For this Level 1 Analysis, sinuosity and channel slope were calculated for each major tributary and Sugar Creek, both above and below the confluence with Coffey Creek. Rosgen analysis should be done using unique conditions to define each reach, not arbitrary segments chosen from a map. Sinuosity, or the measure of a channel's meanders, varies in the different streams. Typical Piedmont streams are expected to be more sinuous in their natural condition; however, realignment to accommodate urban development often restricts the channel's path. If the channel is the same length as the valley, the sinuosity is 1.0 percent, indicating that the channel has been straightened. Naturally, streams with higher sinuosities generally have lower slopes, and streams with steeper slopes have lower sinuosities. This relationship was observed in the Sugar Creek watershed, as seen in Table 6. McCullough Creek has the lowest sinuosity (1.15) and the highest channel slope (0.51%). Conversely, Sugar Creek below the confluence with Coffey Creek has the greatest sinuosity (1.48) and the lowest slope (0.10%). Sugar Creek above the confluence with Coffey Creek is very similar to the lower reaches, with slightly less sinuosity (1.30) over about the same valley length. Taggart Creek, the headwaters of Sugar Creek, has a high channel slope at

0.50 percent. Note that sinuosity is typically underestimated when calculated from topographic maps due to course contour refinement.

Table 6
Rosgen Level 1 Assessment: Geomorphic Characterization

Sugar Creek (County Line - Coffey)	6.5	4.4	1.48	0.10
Sugar Creek (Coffey - Taggart)	5.6	4.3	1.30	0.11
McCullough Creek	1.5	1.3	1.15	0.51
Kings Branch	4.3	3.5	1.23	0.40
Coffey Creek	6.3	5.3	1.19	0.31
Taggart Creek	3.4	2.7	1.26	0.50

Review of historical aerial photos shows changes in stream channel alignment. For instance, Coffey Creek has been channelized below Tryon Street and between Byrum Road and West Boulevard. Kings Branch has been realigned to accommodate I-77 (Figure 10). Taggart Creek has been channelized between Tyvola Road and West Boulevard. McCullough Creek appears to have little realignment. Sugar Creek has also been aligned to accommodate sanitary sewer lines. These straightening activities have influenced Rosgen Level 1 assessment values by lowering calculated sinuosity. Meanders have been removed, shortening the overall stream length and therefore lowering the ratio between stream length and valley length.

Figure 10. Kings Branch Along I-77 Corridor, Facing Downstream (Roll #2, Photo #2)

The urban development of Charlotte has significantly altered the natural stream system; therefore, the influence of the valley type is diminished. The channel types were not selected because they vary greatly, and observations were only taken from road crossings. However, the Rosgen stream type E is typical of Charlotte area urban streams (Doll et. al. 2000). A Type E stream in an urban setting can have moderate entrenchment ratios and lower sinuosities than other Type E streams, as was observed in the Sugar Creek watershed. Channel bottom material was estimated visually for this study; however, detailed grain size distribution analysis (or representative pebble counts) and shear stress calculations should be conducted to assess the sediment transport capacity of the stream before modifications are made to the channel.

Soils in the Sugar Creek watershed influence how water moves to the streams; however, impervious surfaces can prevent infiltration. Soils in the upper reaches of the watershed are generally Cecil-Urban, with nearly level to strongly sloping urban areas on well-drained soils that have predominantly clayey subsoil, formed in residuum from acid igneous and metamorphic rock. Soils in the upper reaches of the Coffey Creek sub-watershed are mostly Cecil, with similar characteristics to Cecil-Urban soil. Wilkes-Enon soils are also present in the watershed. These well drained soils also have a clayey subsoil and are formed in residuum from more basic rock. The southern portion of the watershed is generally of a different soil type, Iredell-Mecklenburg. This soil type has different origins, formed from rock high in ferromagnesian minerals. Along the Taggart Creek and Sugar Creek channels lies another soil type, Monacan. These somewhat poorly drained floodplain soils are loamy because they are formed from fluvial deposits of sediment (USDA SCS 1980). Much of this soil material has been cut, filled, and graded as development has occurred. These activities have altered the physical characteristics and functions of the soils.

1.5 Bank Stability Problem Identification

Channel instability problems typically fall into two general categories: isolated areas of bank erosion and long-term equilibrium adjustments to changes in the watershed and stream system. The former may be caused by rapid inflow from tributaries, unstable banks, or encroachment of development. The latter is related to larger scale changes in the land use of the watershed and flows in the stream, which manifest in the form of changes to the channel bottom level. Both of these are present in the Sugar Creek watershed.

Figure 11. Bank Erosion, Coffey Creek Near West Blvd. (Roll #1, Photo #2)

Bank stability problem areas were identified near some road crossings and are described with photos. Erosion on the right bank (looking downstream) of Coffey Creek near West Boulevard is creating a steep and unstable bank (Figure 11). Exposed roots are visible. The same problem was observed on Kings Branch at Archdale Road along the left bank (looking downstream) (Figure 12). The outer bank of a meander receives more sheer stress than the inner bank and is therefore more susceptible to erosion. In these cases, instability is the result. The right bank (looking downstream) of Sugar Creek south of S. Tryon Street is unstable and collapsing (Figure 14). This problem was identified during previous field work in June 2000 and is discussed as part of the flood hazard mitigation options. Changes in fluvial processes over time are most likely contributing factors to these erosion problems because vegetation along these banks is not providing adequate stability of the soil.

Figure 12. Bank Erosion, Kings Branch Near Archdale Road (Roll #1, Photo #23)

Other problems not visible from these vantage points may exist and should be researched before any bank stabilization projects are planned. In addition, bed material is mobile and is accumulating on point bars in some locations throughout the watershed, and specifically is scouring around the W. Arrowood Road westbound bridge piers (Figure 13). Erosion of the McCullough Creek box culverts is also a concern and should be investigated (Figure 9). Proposed solutions to bank stability problems are included in the Flood Hazard Mitigation Alternatives listed in Section 3. Further quantitative studies of bank erosion rates and aquatic habitat throughout the study area should precede future restoration efforts.

Figure 13. Pier Scouring, Sugar Creek on Westbound Bridge of W. Arrowood Road (Roll #5, Photo #18)

Figure 14. Bank Erosion, Sugar Creek Near S. Tryon Street (Roll #6, Photo #25)

2. BENEFIT:COST ECONOMIC ANALYSIS

2.1 Riverine and Coastal A-Zone Flood Model Overview

The Riverine and Coastal A-Zone Flood model (RCAZF) (Version 1.0, January 1995), a spreadsheet-based model developed by FEMA, was used for estimating damages in this study to be consistent with previous Mecklenburg County flood damage analyses. The estimated damages represent a foundation building block in the benefit:cost (B:C) analysis in this project. This B:C analysis compares benefits, or damages removed by the proposed project, with costs of the proposed flood hazard mitigation project.

Damages induced by flooding were estimated for structures with first finished floor elevations lower than the BFE and located within the 1% annual chance of Future Condition Floodplain (FCF). RCAZF requires four storm events: 10%, 2%, 1%, and 0.2% annual chance flood events, which are typically defined as 10-, 50-, 100-, and 500-year storm events, respectively. The WSEs were modeled using the US Army Corps of Engineers HEC-RAS model (Version 3.0, March 2001) for build-out conditions estimated to occur in year 2020.

RCAZF performs flood damage analysis at two levels. Level One analysis relies heavily on default values built into the model and requires minimum data input from users, while Level Two analysis allows the user to enter structure-specific information. The basic structure information required includes: structure type, size, replacement value, contents value, and various economic data about the use and function of the structure. Estimates of the flood damage vulnerability of the structure and its contents both before and after mitigation are particularly important. In addition to data about the structure under evaluation, B:C analysis of flood hazard mitigation projects requires a quantitative assessment of the degree of flood risk at the site. This assessment is performed automatically by the B:C program using flood data input from a Flood Insurance Study and a FIRM, along with data on the Zero Flood Depth (first finished floor) elevation of the building (RCAZF 1995). To utilize the model capability and site-specific and structure-specific data available to perform the best possible economic analysis, the Level Two analysis was performed for this study.

2.2 Economic Data

The numerous economic attributes were assigned to all flooding structures including the parcel identification number. Each structure was assigned a structure category, such as one-story building without basement, two-story building with basement, etc. The structure category determines which of the unique depth/damage curves is used by the model. Each depth/damage curve describes the relationship between the flooding depth and the damage to the structure expressed in percent of the structure value. The flooding depth was calculated as the difference between various WSEs and the first finished floor elevation. Watershed Concepts provided a family of depth/damage curves specific to Mecklenburg County.

The structures were also divided into commercial and residential occupancy types. In the model, these were described by the total area occupied by the owner. The residential structures were considered to be 100% occupied by the owner, and commercial structures 0% occupied by owner. The damages to residential structures consisted of both building and content damages. The model estimates damages to commercial buildings including a portion of the business income losses and displacement costs, leading to damage results slightly higher than those of residential structures of the same size and structure category.

The structure characteristic data was extracted from a database (1999 tax data) provided by Mecklenburg County. Structure values were increased by 25% to reflect the value in 2001 dollars. A content value of 25% of the structure value was used to be consistent with the previous Mecklenburg damage analysis. Using the heating area of each structure, the building replacement value was calculated.

The first finished floor elevations for all structures were taken from various sources, such as MCSWS GPS Elevation Certificates, Flood-Proofing Certificates, Dewberry and Davis surveys, and information provided by Watershed Concepts. Each structure was assigned a station value that is a stream distance in feet measured from the confluence of the stream in an upstream direction. The structure station equals the station of the stream cross-section on which the structure is located. Using the station data, the WSE for four frequency storms at each structure location was interpolated and assigned to each structure.

2.3 Hydraulic Data

The hydraulic data for future build-out conditions in the watershed was processed by the HEC-RAS model developed specifically for the Sugar Creek watershed by Watershed Concepts. The modeling output provided the WSEs for four frequency storms, 10%, 2%, 1%, and 0.2% annual chance of flood events, for each stream cross-section throughout the watershed. The WSEs were interpolated to retrieve data for the cross-sections attributed to each structure. Part of the model input includes these WSEs for each structure at each storm frequency. The hydraulic data pertaining to the each flooded structure is presented in Appendix Table A-2.

2.4 Modeling Process

RCAZF processes the economic and hydraulic data to estimate the damages to each structure during the four frequency storms. The damages for each storm are then statistically processed to account for the probability of the damage occurrence during any given year. The estimated damage output data is in the form of annual damages.

2.5 Economic Analysis

After assessing the damages to all flooded structures in the watershed, several improvements were evaluated for hydraulic and economic feasibility. Each proposed improvement was analyzed for the hydraulic feasibility of not increasing the 1% annual chance storm WSE to satisfy the County's no-rise criteria. The economic feasibility of improvement is measured by B:C ratio. The B:C ratio is a ratio of benefits obtained by the proposed improvement and cost of the improvement. A B:C ratio greater than 1.0 determines economic feasibility for structural improvements. For property buyout consideration, FEMA considers a B:C ratio greater than 1.0 economically feasible. In other words, if the estimated damages are greater than 100% of the property value, the buyout option is considered feasible.

The potential flood damages to the structure are estimated using the model. The structure attributes are then amended to reflect the improvement, such as elevated finished floor elevation, decreased WSEs, etc. The potential damages to the structure after the improvement is implemented are then calculated. These represent the residual damages after the improvement is implemented. The benefit is calculated as the difference between damages prior to improvement and damages after the improvement is in place. All benefits are calculated on an annual basis. In order to compare them with the cost of improvement and to clearly present them, these were brought to present value by using a 50-year life of the project and the Federal Discount Rate of 5.5 percent (as of January 29, 2001).

Each proposed improvement capital cost, depending on its character, can be represented by a construction cost, and can also include an operation and maintenance (O&M) cost as well as a buyout cost. These construction and buyout costs are estimated in the form of present values. The O&M cost is also given on an annual basis and is usually associated with pump stations and wetlands, which require constant operation and maintenance. In order to sum all costs associated with improvement, these costs were brought to present value by using a 50-year project life and a 5.5% discount rate.

The total cost used in B:C analysis includes, in addition to the above mentioned costs, the residual damages, or the damages that remain even after the proposed improvement is implemented. Storms with greater than a 1% annual chance generate damages and are included in the analysis, but the improvement is designed for a 1% annual chance storm.

2.6 Improvements

A number of flood damage mitigation improvement alternatives were carefully considered. Improvements selected due to their hydraulic feasibility include floodwalls, structure elevation, property buyout, and channel widening. In the case of a floodwall, the benefit was a sum of all damages to be removed by the proposed floodwall. In the Sugar Creek Watershed, floodwalls were found to provide cost-effective flood protection that offers, in some cases, creek habitat enhancement as well.

The flooded structures scattered throughout the watershed unsuitable for floodwall protection were analyzed for structure elevation or buyout. Of these two alternatives, the improvement with a greater B:C ratio was recommended for the improvement, where B:C ratio of greater than 1.0 for elevation and buyout was the determinant for improvement effectiveness. For those structures where damages caused by flooding were not severe enough to outweigh the cost of improvements, no actions were recommended. Section 3 summarizes the improvements and the economic analysis results for the alternatives. Detailed economic information is provided in the Appendix Table A-1.

3. FLOOD HAZARD MITIGATION

3.1 Storm Water Service Requests

There have been two requests for service recorded in the Sugar Creek watershed (see Figure A-1 in Appendix). The addresses for these requests are:

- 6729 Mounting Rock Road (December 27, 1997)
- 12601 Rock Hill-Pineville Road (January 6, 1998)

The parcel 6729 Mounting Rock Road is located on the right bank (looking downstream) 2,750 feet downstream of S. Tryon Street. The parcel 12601 Rock Hill-Pineville Road is located at the confluence of McCullough Creek with Sugar Creek, and includes both banks of McCullough Creek and the right bank (looking downstream) of Sugar Creek. Both parcels and their structures are in the FCF. However, the Storm Water Service Requests database provided by the County does not indicate what sort of service was requested. There were no apparent serious erosion problems at these locations. MCSWS indicates that main channel erosion is the major reason for property owners to request service.

3.2 Repetitive Loss Structures

Within the study area, the list of repetitive loss structures was obtained from MCSWS and is presented in Appendix Table A-3.

3.3 Permanent Storm Water Easements

There are 20 recorded permanent drainage easements within the limits of the Sugar Creek watershed; however, none of these provide access to Sugar Creek or its main tributaries.

3.4 Roadway Overtopping Problem Locations

From HEC-RAS modeling results of Sugar Creek watershed, roadway overtopping locations were investigated based on 1% annual chance of Future Conditions. Table 7 summarizes the roadway overtopping problem location for the study streams.

Table 7
Roadway Overtopping Problem Locations

Sugar Creek	Crossing Structure Type	Culvert Size	Top of Road El (FT. NAVD)	WSE of 1% FCF (FT. NAVD)	Overtopping Depth (FT)
Highway 51	Bridge	-	543.8	544.2	0.4
Nations Ford Road	Bridge	-	567.9	568.6	0.7
Interstate 77	Bridge	-	572.5	574.5	2.0
Arrowood Road	Bridge	-	577.4	582.1	4.7
Coffey Creek					
Arrowood Road Ext.	Culvert	4-12′x10′ Box	583.7	586.0	2.3
Kings Branch					
Old Nations Ford Road	Culvert	1-7′ RCP	548.6	550.9	2.3
E. Arrowood Road	Culvert	16.4′x10.2′ CMPA	594.8	595.6	0.8
Deanna Lane	Culvert	3-7′ RCP	600.4	601.8	1.4
Kings Branch Court	Bridge	-	611.8	613.9	2.1
Archdale Drive	Culvert	3-8.5′x7.5′RCPE	618.0	619.9	1.9
Taggart Creek					
Mulberry Church Road	Culvert	2-8′ RCP	678.2	681.1	2.9
Denver Road	Culvert	2-5′ RCP	680.9	682.2	1.3

Because motor vehicles can be swept away in as little as 24 inches of flood flow depth over the road, any roadway overtopping locations need to be identified for emergency response preparations for public safety purposes. The following items are listed for future action:

- Signage of roadway overtopping warning for avoiding road crossing during flood event.
- Coordination with Police Dept. and Fire Dept. for special attention during flood event.
- Routine inspection for bridge/culvert scour and safety conditions, such as a lack of guardrail (or handrail). Guardrail post would give indication of the edge of the structure when inundated during flood flows.

3.5 Flood Mitigation Improvement Analysis

Because 164 structures are within the limits of the 1% annual chance of Future Condition Floodplain (FCF) of the Sugar Creek Watershed, flood protection alternatives were investigated as the first priority for this study. The primary flood damage areas in the Sugar Creek Watershed are along Sugar and Coffey Creeks (see Figure A-1 for existing conditions). No structures flood along Kings Branch, McCullough Creek, or Taggart Creek. Of the 133 structures within the limits of the FCF along Sugar Creek, 83 structures flood (Table 8). Of these structures, 67 are residential land use and 16 are commercial structures. Structure tax values (1998) were inflated by 25 percent to reflect current 2001 market values. The single-family residential structure values range from $29,900 to $151,100. The commercial structure values range from $37,000 to $4,179,400. All Coffey Creek flooding structures are multi-family residential land use. Structure values range from $510,300 to $1,052,800. All values are presented in 2001 dollars.

Table 8
Flooding Structures Summary

	Total	Sugar Creek	Coffey Creek	Kings Branch	McCullough Creek	Taggart Creek
Within FCF Floodplain	164	133	27	1	2	1
Pre-FIRM*	51	43	5	1	2	0
Post-FIRM*	113	90	22	0	0	1
Finished Floor Inundated in FCF Storm Event	97	83	14	0	0	0
Pre-FIRM	14	23	0	0	0	0
Post-FIRM	73	60	14	0	0	0
Protected by Floodwalls	65	51	14	0	0	0
Pre-FIRM	8	8	0	0	0	0
Post-FIRM	57	43	14	0	0	0
Elevate Structures	11	11	0	0	0	0
Pre-FIRM	4	4	0	0	0	0
Post-FIRM	7	7	0	0	0	0
Recommended Buyout	2	2	0	0	0	0
Pre-FIRM	2	2	0	0	0	0
Post-FIRM	0	0	0	0	0	0
No Action	19	19	0	0	0	0
Pre-FIRM	10	10	0	0	0	0
Post-FIRM	9	9	0	0	0	0

* Pre-FIRM structures were constructed before 1973; Post-FIRM structures were constructed in 1973 or later.

3.5.1 *Pineville Levee*

HDR conducted field investigations of the levee system along Sugar Creek north of Downs Circle on August 7, 2001. No physical evidence was found of any levee on the westerly side of Sugar Creek.

The levee behind Brian Circle immediately upstream of Highway 51 was located, and evidenced some disturbance since originally constructed, possibly due to buried cable TV installation. Current elevation at top of the levee was surveyed, and the lowest spot was found to be at 541.7. Figure 15 shows the existing levee behind the houses on Brian Circle.

Pertinent facts concerning the levee are summarized below. The listed flood stage elevations in Table 9 are based on the Watershed Concepts HEC-RAS model. The property owners indicated no breach or flow-around of the existing levee during the floods of 1995 and 1997. The highwater mark surveyed in the 1997 flood was 543.7. While no recurrence interval was calculated for the 1995 and 1997 floods, the levee should have breeched in the 1997 flood if the surveyed levee height and highwater marks are correct. One possible explanation for the discrepancy is that the recent disturbance (of whatever nature) lowered the levee height.

The existing levee provides a level of protection equal to:

- 4% annual flood (25-year flood) for the existing land use condition.
- 10% annual flood (10-year flood) for the future land use condition.

Table 9
Flood Stages at Brian Circle

Annual Flood Chance	Existing Land Use	Δ h (FT)	Future Land Use	Δ h (FT)
10 % (10-year)	538.3	3.4	540.3	1.4
2 % (50-year)	541.6	0.1	544.1	-2.4
1 % (100-year)	542.6	-0.9	544.6	-2.9
0.2 % (500-year)	545.1	-3.4	546.4	-4.7

*Δh is difference between the annual stage and the lowest levee elevation of 541.7.

The existing levee should be improved or replaced to provide a level of protection against the 1% annual flood (100-year event) for both the existing land use and future land use conditions. HDR researched and investigated the original levee, and was not able to locate any engineering drawings or other data. Since it is unable to verify the suitability of the existing structure for inclusion in a higher levee, HDR recommends that the levee be replaced in its entirety with a properly designed and constructed structure. The economic analysis of levee improvement for the Brian Circle area is shown in Table 26. No Action is recommended for this area.

3.5.2 *Alternative Evaluation*

The improvement alternative analyses use the FCF, which is based on the future ultimate built-out condition. Figure 18 illustrates these recommended improvement alternatives.

There are 97 structures in Sugar Creek watershed that have their lowest floor below the BFE of FCF. These include structures with a basement that is possibly flooding or structures with their first finished floor below the BFE of FCF elevation. The structures were clustered into study areas based on their proximity and possible proposed improvements, such as a floodwall or levee. Each study area was separately analyzed for several improvement alternatives, such as purchase structures, culvert improvements, elevating structures, levees, channel widening, and upstream detention. The economic effect of the improvement was compared to the "No Action" alternative to determine economic feasibility of the improvement.

Alternative 1 – No Action

Potential flood damages were estimated as part of the damage assessment and improvement option analysis. These figures are based on the damages accrued by flooding structures within the limits of the FCF due to the 10%, 2%, 1%, and 0.2% annual chance of flood frequency storms. The total damages from flooding in Sugar Creek watershed, if "No Action" was taken, are estimated to be $19,473,500 over the 50-year life of the project (2001 dollars). Each proposed improvement alternative benefit is compared to the damages before the improvement to analyze its economic feasibility.

Alternative 2 – Purchasing Structures

The structures were analyzed as possible buyouts. FEMA justifies property buyout if the B:C ratio is greater than 1.0, or if the estimated structure damages due to flooding exceed 100% of the value of the property (land value and structure value in 2001 dollars). These same structures were also analyzed for possible elevation above the future condition BFE. In most cases, elevating the structure had a far greater B:C ratio than the buyout option, so buyout is not recommended. This is due to the larger expenses associated with property buyouts.

Alternative 3 – Culvert Improvements

The culvert improvements for the Sugar Creek watershed were found to be hydraulically infeasible, and therefore the detailed hydraulic analysis and cost estimates for Alternative 3 were not prepared for this study.

Alternative 4 – Elevating Structures

The structures were analyzed for economic feasibility to avoid flood damages by raising the structures. In the case of elevation, a structure is raised so the first finished floor is 1 foot above the 1% annual chance of future condition water surface elevation. For the purposes of analysis, $30,000 was used as the present value of the cost of elevating one structure.

Alternative 5 – Earthen Levee and Concrete Floodwall Alternatives

A combination of levees and floodwalls on both banks of Sugar and Coffey Creeks was considered as an alternative, while preserving peak flow storage by setting levees back from the edges of the existing banks. The proposed floodwall improvements did not result in any net increase in the Base Flood Elevation or flow velocity. Currently, Mecklenburg County has limited experience with levee construction for flood protection purposes. The following list shows existing flood levee constructed within the County with year built information:

- Little Sugar Creek – At CSX Railroad/Piedmont Court Apartments/Alexander Street Park (1994).

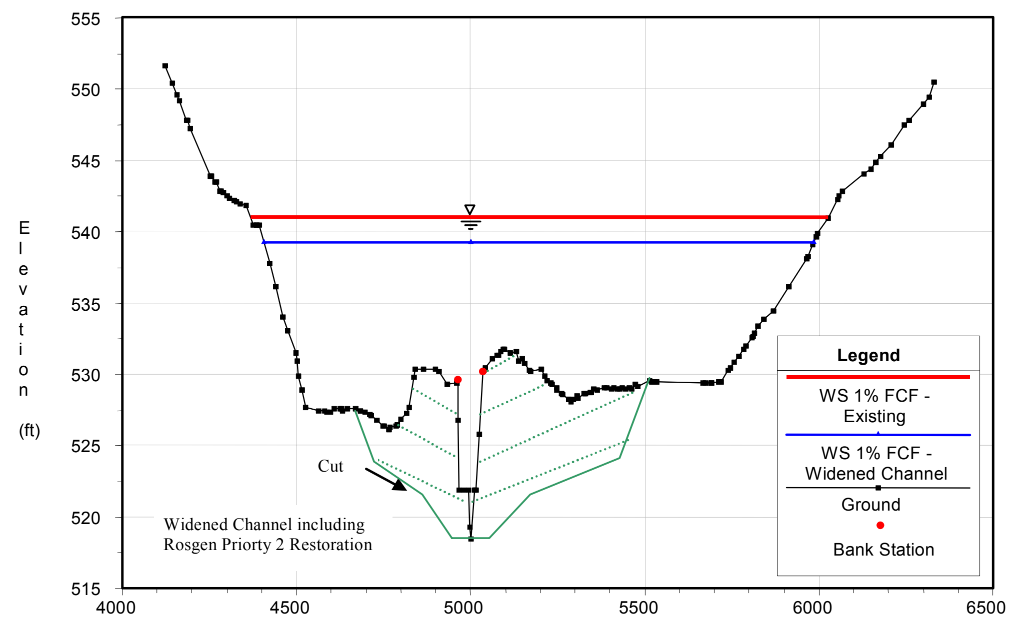
- Little Sugar Creek – At Allison-Erwin Company/North Tryon Street (2000).
- McMullen Creek – At The Cloisters Subdivision/Providence Road (1992).
- Sugar Creek - At Brian Circle (Unknown).

Alternative 6 – Channel Widening

Although a channel widening option is contradictory to Mecklenburg County Creek Use Policy and environmentally detrimental, this option was investigated to determine if there is any significant flood mitigation benefit for the particular flooding problem location area upstream of Highway 51. For 5,900 linear feet of Sugar Creek at Highway 51, channel widening was considered. A total estimated excavation of 1,135,500 cubic yards would be necessary. Fifty-one structures, 24 of which flood, would be impacted by this improvement option. Channel widening, and therefore increasing conveyance, lowered the water surface elevation during all four frequency storms (Figures 16 and 17). As a result, damages due to flooding were decreased. The benefit, or avoided damages, of this improvement did not outweigh a large construction cost including contingency of $10.3 million dollars (2001 dollars). Therefore, this alternative is not feasible with a B:C ratio of 0.2 and is not recommended. In addition to channel widening, bridge improvement at Highway 51 was evaluated. With the additional cost of $3 million, this improvement is also not economically justifiable with a B:C ratio of 0.3.

Alternative 7 – Upstream Detention

Upstream detention was not considered as a flood mitigation option because of its hydraulic infeasibility.



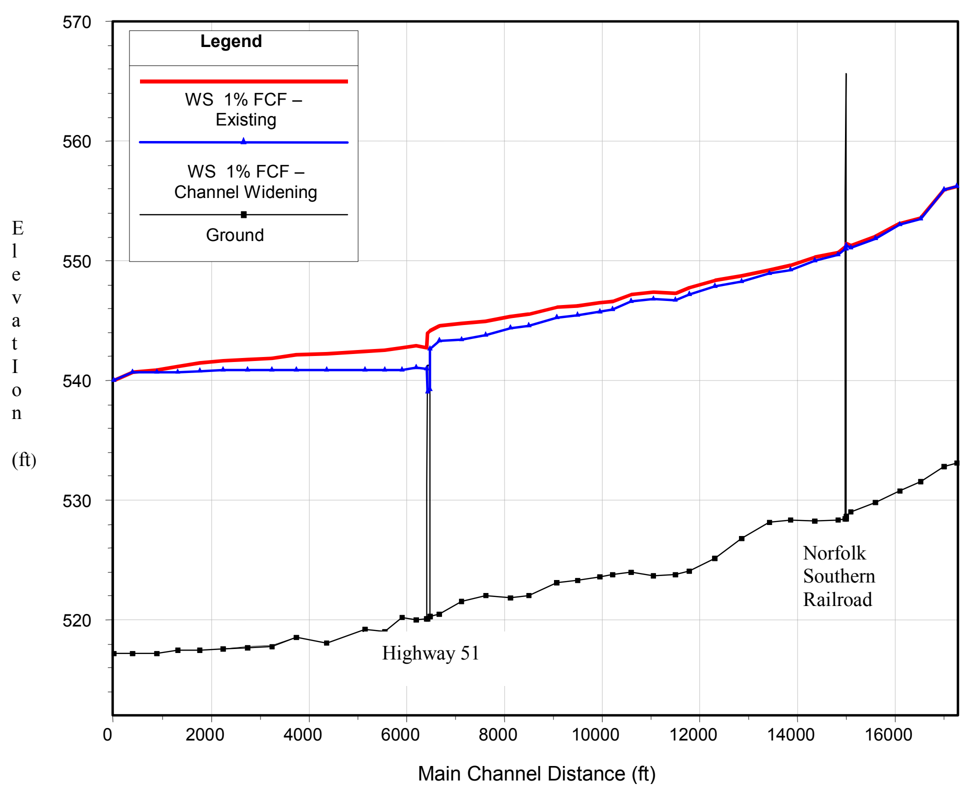


Figure 17: Sugar Creek, Water Surface Profile, Channel Widening Flood Hazard Mitigation Option

Problem Area A

In Area A, there are 26 residential houses along Mounting Rock Road that are flooding in FCF. Average depth of BFE of FCF flooding is 2.3 feet (with flood depths ranging from 0.2 to 4.3 feet). In FIRM, 20 houses have flooded depths greater than 0 feet. Their mean depth of flooding is 1.4 feet (with flood depths ranging from 0.2 to 3.0 feet).

The analysis in Problem Area A showed three feasible alternatives: purchasing structures, elevating structures, and protecting structures with Floodwall A. Floodwall A includes a 2,700 LF earthen levee with two pump stations to protect residential structures along Mounting Rock Road with lowest finished floors below the FCF flood elevation (see Figure E-8). The Floodwall A alternative also includes the construction of an approximate 6-acre wetland to replace flow conveyance removed by the levee, resulting in no net increase in the Base Flood Elevation. The proposed constructed wetland will also enhance water quality within the study limit as well as downstream. Bank stabilization is also included for the length of the levee. The benefits, costs, and B:C ratios for each alternative in Area A are shown in Table 10.

The recommended improvement option for Problem Area A is Flood Levee A; a combination of earthen levee, wetland creation, and bank stabilization. This recommended earthen levee on the right bank of Sugar Creek not only provides flood damage protection and a walking path for public recreation, but also enhances water quality in the constructed wetlands and channel meanders. This alternative is favored based on the invaluable benefits of water quality enhancement and aquatic habitat associated with the proposed wetland. This site is a strong candidate for the siting of a created wetland. In addition, the nuisance flooding of backyards that remains if houses are elevated makes structural elevation undesirable in this case. Note that the recommended improvement alternative is still subject to change due to unforeseen hardships such as utility or construction conflicts.

Water quality enhancing benefits can be estimated by applying the procedures and values developed for the Neuse River Rules. The drainage area of Sugar Creek at South Tryon Street is approximately 26,000 acres (41 sq. mi.) and has an overall impervious area of approximately 15%. A constructed wetland will enhance water quality by reducing sediments and nutrients, as well as enhancing die-off of fecal coliforms. The proposed 6-acre wetland can produce water quality benefits exceeding $210,000 of present value.

Table 10
Problem Area A

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$3,033,600	-	-	-
2	Purchasing Structures	-	$3,033,600	$3,761,500	0.8
4	Elevating Structures	$179,400	$2,854,200	$780,000	3.0
5*	Levee Options: Levee Wetland O & M	-	-	$749,700 $1,467,700 $338,600	-
	Flood Levee Options Total (w/o Water Quality Benefit)	-	$3,033,600	$2,556,000	1.2
	Flood Levee Options Total (w/ Water Quality Benefit)	-	$3,243,600	$2,556,000	1.3

* Recommended Alternative

The recommended improvement alternative was also examined for any adverse impact on the 1% annual chance storm WSE to satisfy the County's no-rise criteria. Table 11 shows comparison of the WSE of the existing and improved conditions. Since there might be unforeseen constraints, such as utility crossings, the proposed improvement was designed with a slightly lower WSE than the existing condition.

Table 11
1% Annual Flood Stages at Area A

	Existing Condition	Improved Condition	Δ h (FT)
X-49,669	588.7	587.6	-1.1
X-49,164	588.2	587.6	-0.6
X-48,665	587.9	587.6	-0.3
X-48,164	587.8	587.5	-0.3
X-47,800	587.6	587.4	-0.2
X-47,464	587.3	587.3	0.0

Problem Area B

In Area B, there are 10 residential houses located at Flooden Field Court and Yorkdale Drive that are flooding in BFE of FCF. Average depth of FCF flooding is 1.6 feet (with flood depths ranging from 0.5 to 2.5 feet). In FIRM, six houses have flooded depths greater than 0 feet. Their mean depth of flooding is 0.8 feet (with flood depths ranging from 0.1 to 1.2 feet).

The analysis in Problem Area B showed three feasible alternatives: purchasing structures, elevating structures, and protecting structures with Floodwall B. The benefits, costs, and B:C ratios for each alternative in Area B are shown in Table 12. The recommended alternative, Floodwall B, a concrete floodwall with pump station, extends 400 LF and protects 10 residential structures with lowest finished floor elevations below the BFE of FCF.

Table 12
Problem Area B

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$559,400	-	-	-
2	Purchasing Structures	-	$559,400	$1,396,700	0.4
4	Elevating Structures	$71,900	$487,400	$300,000	1.3
5*	Floodwall Options	-	$559,400	$339,300	1.7

* Recommended Alternative

Problem Area C

In Area C, there are five residential houses located at Bangor Road that are flooding in BFE of FCF. Average depth of FCF flooding is 2.8 feet (with flood depths ranging from 0.1 to 4.2 feet). In FIRM, four houses have flooded depths greater than 0 feet. Their mean depth of flooding is 2.2 feet (with flood depths ranging from 0.6 feet to 2.9 feet).

The analysis in Problem Area C showed three feasible alternatives: purchasing structures, elevating structures, and protecting structures with Floodwall C. The benefits, costs, and B:C ratios for alternatives considered in Area C are shown in Table 13. Alternative 5 is recommended. Floodwall C, a concrete floodwall with pump station, extends 500 LF and protects four residential structures along Bangor Road with lowest finished floor elevations below the FCF flood elevation. The floodwall construction requires purchasing one structure. Although the B:C ratio is higher for Alternative 4, elevation of the structures, construction of a floodwall is preferred because of the residual nuisance yard flooding that remains if structures are elevated.

Table 13
Problem Area C

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$840,000	-	-	-
2	Purchasing Structures	-	$840,000	$514,700	0.4
4	Elevating Structures	$30,800	$809,200	$150,000	4.4
5*	Floodwall Options	-	$840,000	$498,400	1.7

* Recommended Alternative

Problem Area D

In Area D, there are three residential houses located at Ranchwood Drive that are flooding in BFE of FCF. Average depth of FCF flooding is 1.3 feet (with flood depths ranging from 0.7 to 1.7 feet). In FIRM, two houses have flooded depths greater than 0 feet. Their mean depth of flooding is 0.4 feet (with flood depths ranging from 0.3 to 0.4 feet).

The analysis in Problem Area D showed two feasible alternatives, purchasing structures and elevating structures. The benefits, costs, and B:C ratios for the alternatives in Area D are shown in Table 14. No action is recommended in this case because all alternative B:C ratios are less than 1.0.

Table 14
Problem Area D

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1*	No Action	$106,700	-	-	-
2	Purchasing Structures	-	$106,700	$296,900	0.4
4	Elevating Structures	$18,200	$88,500	$90,000	0.8

* Recommended Alternative

Problem Area E

Area E on Coffey Creek represents five multi-residential structures located at Whitehall Estates Drive that are flooding in BFE of FCF. Average depth of FCF flooding is 2.6 feet (with flood depths ranging from 0.4 to 6.0 feet). In FIRM, one apartment building has a flooded depth greater than 0 feet, and that is 2.0 feet.

The analysis in Problem Area E showed two feasible alternatives: purchasing structures and protecting structures with Floodwall E. This concrete floodwall extends 1,000 linear feet and is equipped with one pump station. Structure elevation was not considered in this case due to the extensive size of the apartment buildings. The benefits, costs, and B:C ratios for alternatives in Area E are shown in Table 15. Floodwall E is recommended because the B:C ratio is 11.0.

Table 15
Problem Area E

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$4,091,600	-	-	-
2	Purchasing Structures	-	$4,091,600	$5,746,000	0.7
5*	Floodwall Options	-	$4,091,600	$371,700	11.0

* Recommended Alternative

The recommended improvement alternative was also examined with the feasibility of not increasing the 1% annual chance storm WSE to satisfy the County's no-rise criteria. Table 16 shows comparison of the WSE of the existing and improved conditions. Since there might be unforeseen constraints, such as utility crossings, the proposed improvement was designed to show a slightly lower WSE than the existing condition.

Table 16
1% Annual Flood Stages at Area E

	Existing Condition	Improved Condition	Δ h (FT)
X-8,196	587.2	587.1	-0.1
X-7,768	586.8	586.7	-0.1
X-7,368	586.5	586.3	-0.2
X-6,806	556.0	585.8	-0.2

Problem Area F

Area F on Coffey Creek represents nine multi-residential structures located at Arrowcreek and Yager Creek Drives that are flooding in BFE of FCF. Average depth of FCF flooding is 1.9 feet (with flood depths ranging from 0.5 to 2.9 feet). In FIRM, four apartment buildings have a flooded depth greater than 0 feet. Their mean depth of flooding is 0.5 feet (with flood depths ranging from 0.2 to 0.9 feet).

The analysis in Problem Area F showed two feasible alternatives: purchasing structures and protecting structures with Floodwall F. The benefits, costs, and B:C ratios for each alternative in Area F are shown in Table 17. Alternative 5, construction of floodwalls, is the recommended option because of its high B:C ratio, 9.9. Floodwall F, consisting of two floodwalls on either side of Coffey Creek, is designed to protect nine multi-family residential structures. Along the left bank, a 500-linear foot concrete floodwall is necessary. Along the right bank, the longer 1,000-linear foot floodwall consists of 500 feet of 4-foot high concrete and 2-foot high brick wall. Each floodwall is equipped with a pump station. Structure elevation was not considered due to the extensive size of the apartment buildings.

Table 17
Problem Area F

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$4,411,500	-	-	-
2	Purchasing Structures	-	$4,411,500	$5,794,000	0.8
5*	Floodwall Options	-	$4,411,500	$444,700	9.9

* Recommended Alternative

The recommended improvement alternative was also examined with the feasibility of not increasing the 1% annual chance storm WSE to satisfy the County's no-rise criteria. Table 18 shows comparison of the WSE of the existing and improved conditions. Since there might be unforeseen constraints, such as utility crossings, the proposed improvement was designed to show a slightly lower WSE than the existing condition.

Table 18
1% Annual Flood Stages at Area F

	Existing Condition	Improved Condition	Δ h (FT)
X-5,818	580.2	579.7	-0.5
X-5,748	580.1	579.5	-0.6
X-5,503	579.5	579.2	-0.3
X-5,010	578.7	578.7	0.0
X-4,520	577.4	577.4	0.0

Problem Area G

Area G represents one office building located at 1263 Arrow Pine Drive that is flooding in BFE of FCF. The flooding depth of FCF is 1.7 feet. In FIRM, the flooding depth is 0 feet.

The analysis in Problem Area G showed two feasible alternatives: purchasing structures and protecting structures with Floodwall G. Structure elevation was not considered due to the extensive size of the office building. The recommended improvement, Floodwall G, an 800-linear foot concrete floodwall with one pump station, is designed to protect one commercial structure. The benefits, costs, and B:C ratios for each alternative considered in Area G are shown in Table 19.

Table 19 Problem Area G					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1	No Action	$1,006,600	-	-	-
2	Purchasing Structure	-	$1,006,600	$9,627,400	0.1
5*	Floodwall Options	-	$1,006,600	$177,300	5.7

* Recommended Alternative

Problem Area H

Area H represents two office buildings located at Southern Pine Boulevard that are flooding in BFE of FCF. Average depth of FCF flooding is 2.6 feet (with flood depths ranging from 1.4 to 3.7 feet). In FIRM, one building has a flooded depth greater than 0 feet, and that is 1.6 feet.

The analysis in Problem Area H showed two feasible alternatives: purchasing structures and protecting structures with Floodwall H. The recommended improvement, Floodwall H, a 1,100 linear foot concrete floodwall with one pump station, is designed to protect two commercial structures. Structure elevation was not considered due to the extensive size of the office buildings. The benefits, costs, and B:C ratios for alternatives considered in Area H are shown in Table 20.

Table 20 Problem Area H					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1	No Action	$1,392,200	-	-	-
2	Purchasing Structures	-	$1,392,200	$3,594,800	0.4
5*	Floodwall Options	-	$1,392,200	$446,300	3.4

* Recommended Alternative

Problem Area I – "Not Clustered"

Three structures were analyzed in the Area "Not Clustered." The structure locations do not permit the usual clustering, because they are scattered throughout the Sugar Creek watershed. The floodwall protection of these properties was not feasible, and therefore not considered.

One residential house at 809 Echo Cove Lane is flooding in BFE of FCF. The flooding depth of FCF is 2.3 feet. In FIRM, the house has a flooding depth of 0.1 feet. The analysis of this structure showed that purchasing and elevating the structure were feasible alternatives. The benefits, costs, and B:C ratios for the alternatives are shown in Table 21. No action is recommended in this case because all alternative B:C ratios are less than 1.0.

Table 21 Echo Cove Lane					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1*	No Action	$39,600	-	-	-
2	Purchasing Structure	-	$39,600	$68,000	0.6
4	Elevating Structures	$5,700	$33,900	$30,000	0.9

*Recommended Alternative

One commercial structure at 8350 Arrowridge Boulevard is flooding in BFE of FCF. The flooding depth of FCF is 0.2 feet. The structure is not flooding in FIRM. Structure elevation was not considered due to the extensive size of the warehouse. The benefits, costs, and B:C ratios for the alternatives are shown in Table 22. No action is recommended in this case because all alternative B:C ratios are less than 1.0.

Table 22 Arrowridge Boulevard					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1*	No Action	$34,300	-	-	-
2	Purchasing Structures	-	$34,300	$3,545,800	0.0

*Recommended Alternative

One commercial structure at 9220 Rodney Street is flooding in BFE of FCF. The flooding depth of FCF is 0.5 feet. The structure is not flooding in FIRM. Structure elevation was not considered due to the extensive size of the warehouse. The benefits, costs, and B:C ratios for the alternatives are shown in Table 23. No action is recommended in this case because all alternative B:C ratios are less than 1.0.

Table 23 Rodney Street					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1*	No Action	$53,600	-	-	-
2	Purchasing Structures	-	$53,600	$512,900	0.1

*Recommended Alternative

Problem Area J

In Area J, there are 10 commercial and two residential buildings located in the vicinity of Downs Road and Downs Circle that are flooding in BFE of FCF. Average depth of FCF flooding is 4.1 feet (with minimum depth at 1.0 feet and maximum depth at 7.7 feet). In FIRM, 10 structures have flooding depths greater than 0 feet. Their mean depth of flooding is 2.7 feet (with minimum depth at 1.0 feet and maximum depth at 5.6 feet).

The analysis in Problem Area J showed two feasible alternatives: purchasing structures and elevating structures. The benefits, costs, and B:C ratios for the considered alternatives in Area J are shown in Table 24. Both Alternatives 2 and 4 have B:C ratios greater than 1.0; however, Alternative 4 is recommended because it has the higher B:C ratio of the two. Eleven of the 12 structures are recommended for elevation in this cost estimate. One commercial structure is recommended for no action because its large size makes elevation infeasible.

Table 24
Problem Area J

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$2,540,900	-	-	-
2	Purchasing Structures	-	$2,540,900	$1,861,400	1.4
4*	Elevating Structures	$70,100	$2,470,700	$330,000	6.2

* Recommended Alternative

Problem Area K

In Area K, there are eight residential and one commercial buildings located on the south side of Main Street. The first finished floor of seven houses is below the BFE of FCF. Average depth of FCF flooding is 2.7 feet (with minimum depth at 0.3 feet and maximum depth at 5.7 feet). In FIRM, four houses have a flooding depth greater than 0 feet. Their mean depth of flooding is 1.7 feet (with minimum depth at 0.1 feet and maximum depth at 4.0 feet).

The analysis in Problem Area K showed two feasible alternatives, purchasing structures and elevating structures. The benefits, costs, and B:C ratios for the considered alternatives in Area K are shown in Table 25. These flooding structures are recommended for elevation, Alternative 4, because of the high B:C ratio associated with this improvement option.

Table 25
Problem Area K

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$1,214,200	-	-	-
2	Purchasing Structures	-	$1,214,200	$1,539,700	0.8
4*	Elevating Structures	$60,300	$1,153,900	$210,000	4.3

* Recommended Alternative

Problem Area L

In Area L, there are 12 residential houses flooding in BFE of FCF. The first finished floor of six houses is below BFE of FCF, and the average depth of FCF flooding is 1.0 feet (with minimum depth at 0.2 feet and maximum depth at 1.5 feet). The structures are not flooding in FIRM.

The analysis in Problem Area L showed three feasible alternatives: purchasing structures, elevating structures, and protecting structures with a new levee. The benefits, costs, and B:C ratios for each alternative in Area L are shown in Table 26. No Action is recommended for this area.

Table 26
Problem Area L

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1*	No Action	$149,400	-	-	-
2	Purchasing Structures	-	$149,400	$1,114,000	0.1
4	Elevating Structures	$54,200	$95,200	$180,000	0.4
5	Levee Construction	-	$149,400	$1,292,000	0.1

* Recommended Alternative

4. CONCLUSIONS AND RECOMMENDATIONS

While 164 structures are within the FCF boundaries along Sugar Creek and all its major tributaries, flooding problems were identified only for areas of Sugar Creek (83 structures) and Coffey Creek (14 structures). Of the 83 flooding structures on Sugar Creek, 67 are residential land use and 16 are commercial structures. All 14 structures along Coffey Creek are multi-family residential structures.

Several alternatives were considered to resolve flooding damage and bank stability problems in the Sugar Creek watershed. Based on the flood damage assessment and B:C analysis, the recommended improvements for Sugar Creek and Coffey Creek include a combination of floodwall and levee construction, leaving some flooded structures unprotected, elevating some structures, purchasing structures, and constructing a wetland (Figure 18). The damages removed from structures within 1 percent chance FCF are estimated to be $18,959,500 (2001 dollars). The total estimated cost for the recommended improvements is $5,373,700. Some structures are left unprotected because, relative to the damage assessment, it is not cost-effective to purchase/protect properties.

Along Sugar Creek, a series of floodwalls and levees mitigate flood damage for 51 structures. For those structures where floodwalls are infeasible as a protection option, analyzed options included the elevation of structures, buyout, or no action. Elevation protects 11 structures, two are recommended for buyout, and 19 are recommended for no action. Both structures recommended for purchase were constructed before the establishment of FEMA maps in 1973. For those structures recommended for no action, low B:C ratios indicate it is not cost-effective to take action. The present value of the total cost for flood hazard mitigation on Sugar Creek is $4,557,400. These actions would mitigate the damages of $10,456,400 caused by flooding.

The 14 multi-family residential structures along Coffey Creek with finished floors inundated in the FCF storm event can be protected with the recommended improvement options. These three floodwalls are successful in mitigating flood damage of $8,503,100 for all flooded structures along Coffey Creek while not increasing the base flood elevation. The present value of the total cost for flood hazard mitigation on Coffey Creek is $816,300, which includes operation and maintenance costs of $169,300.

The recommendations include the further exploration of bank stabilization and/or stream restoration needs within the Sugar Creek watershed. Note that the channels were only observed from road crossing vantage points, and further investigation is necessary to prioritize stream bank and channel repairs. Observed bank stabilization problems were identified on Sugar Creek and all its major tributaries. Surveys of some of the worst bank erosion sites are recommended to determine the rate at which erosion is occurring and to help prioritize future bank restoration projects in the study reach. One recommendation is to conduct a sediment transport study to ensure that sand and silt present on the channel bottom do not mobilize and fill up the recommended wetland along Sugar Creek at Floodwall A too rapidly. A bridge engineer should review scouring of the W. Arrowood Road westbound bridge piers over Sugar Creek and erosion of the Highway 51 box culvert over McCullough Creek. It is also recommended that MCSWS closely monitor the potential development of Coffey Creek and several parcels along the left bank (looking downstream) of Sugar Creek owned by investment companies. Several of these parcels are in the riparian corridor, and removal of the forest vegetation during development could be a water quality concern.

During field visits, little aquatic wildlife was observed in Sugar Creek and its major tributaries. According to the County's Water Quality Program, from 1994 to 1998 overall water quality remained fairly consistent in the Sugar Creek watershed. Review of ambient water quality data dating back to 1968 does not reveal significant trends in most of the data over time or by location along the creeks. Current Water Quality Index values indicate an average of "Good" water quality throughout the watershed, with the best water quality, "Good-Excellent," in the headwaters of Coffey Creek. Increasing development activities in the Coffey Creek watershed, including airport expansion and I-485, may impact water quality and aquatic diversity in the future. Overall, the Water Quality Indices indicate better water quality conditions than the fish and macroinvertebrate communities reflect. The aquatic fauna communities throughout the watershed have consistently ranked "Poor" and "Fair," while fish sampling ranked "Poor-Fair" and "Fair," which results in a less than desirable diversity of species. This may indicate that aquatic habitat conditions limit these communities to some extent. While aquatic life is present in the creeks, the sand and silt benthic material (without many instream features such as boulders and woody debris) does not provide a protective habitat, and bottom dwelling communities are not as abundant and diverse as may be desired.

Finally, although there are no existing greenways within the Sugar Creek watershed, the 1999 Mecklenburg County Greenway Master Plan recommends that the Greenway System be expanded as a floodplain management buffer and water quality program to include all creeks and streams throughout the County. Future plans include a greenway along Coffey Creek from Shopton Road to Sugar Creek and along Sugar Creek from Billy Graham Parkway to the Lancaster, South Carolina, city line. The Sugar Creek watershed is a good candidate as a greenway corridor due to its proximity to residential developments. MCSWS should monitor future MCPRC plans for the Mecklenburg County greenway system because this study could be included in future greenway development.

5. REFERENCES

Doll, B.A., D.E. Wise-Frederick, C.M. Buckner, S.D. Wilkerson, W.A. Harman, and R.E. Smith. Hydraulic Geometry Relationships for Urban Streams throughout the Piedmont of North Carolina. Riparian Ecology and Management in Multi-Use Watersheds. American Water Resources Association Summer Symposium. Portland, Oregon. August 28-31, 2000, pp: 299-304.

Flood Insurance Rate Map (FIRM) including Future Condition Floodplain, Charlotte-Mecklenburg, North Carolina, Effective May 2000.

Harman, W.A. and G.D. Jennings. Application of the Rosgen Stream Classification System to North Carolina, North Carolina Cooperative Extension Service River Course Fact Sheet No. 2, 1999.

HDR Engineering, Inc. of the Carolinas. Mecklenburg Storm Water Services Preliminary Engineering Report for Spring 2001 Flood Hazard Mitigation & Bank Stabilization Study No. 4, Sugar Creek from W. Arrowood Road to S. Tryon Street, 2001.

Hydrologic Engineering Center River Analysis System (HEC-RAS), United States Army Corps of Engineers, Version 3.0, March 2001.

Lane, E.W. *The Importance of Fluvial Morphology in Hydraulic Engineering,* American Society of Civil Engineering, Proceedings, 81 paper 745: 1-17, 1955.

Mecklenburg County. Mecklenburg County Greenway Master Plan. Adopted May 18, 1999.

Mecklenburg County Department of Environmental Protection. Bioassessment of Stream in Charlotte and Mecklenburg County, North Carolina, 1995-1999.

Mecklenburg County Department of Environmental Protection. Fish Bioassessment of Stream in Charlotte and Mecklenburg County, North Carolina, 1996-1999.

North Carolina Department of Water and Air Resources, Water Quality Division. Report of Investigation of the Surface Waters of Mecklenburg County, 1970.

Riverine and Coastal A-Zone Flood Model (RCAZF), Federal Emergency Management Agency, Version 1.0, January 1995.

Rosgen, D.L. *A Classification of Natural Rivers*, Catena, Vol. 22: 169-199, Elsevier Science, B.V. Amsterdam, 1994.

Rosgen, D. *Applied River Morphology*, Wildland Hydrology, Pagosa Springs, Colorado, 1996.

United States Department of Agriculture Soil Conservation Service, (USDA SCS). *Soil Survey of Mecklenburg County, North Carolina*, 1980.

Figure 18 Study No. 3, Sugar Creek Watershed Proposed Improvements, Sheet 1

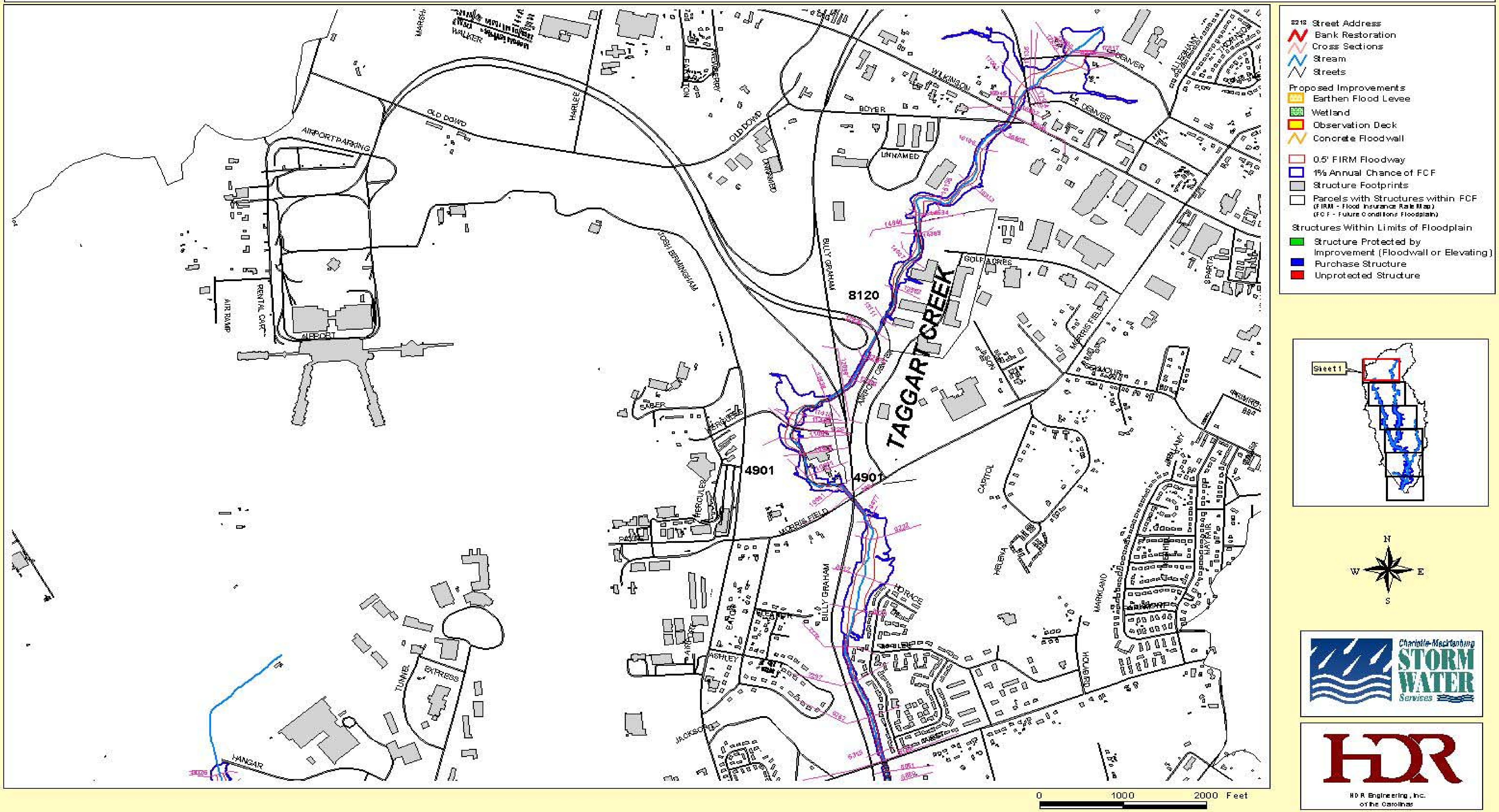


Figure 18 Study No. 3, Sugar Creek Watershed Proposed Improvements, Sheet 2

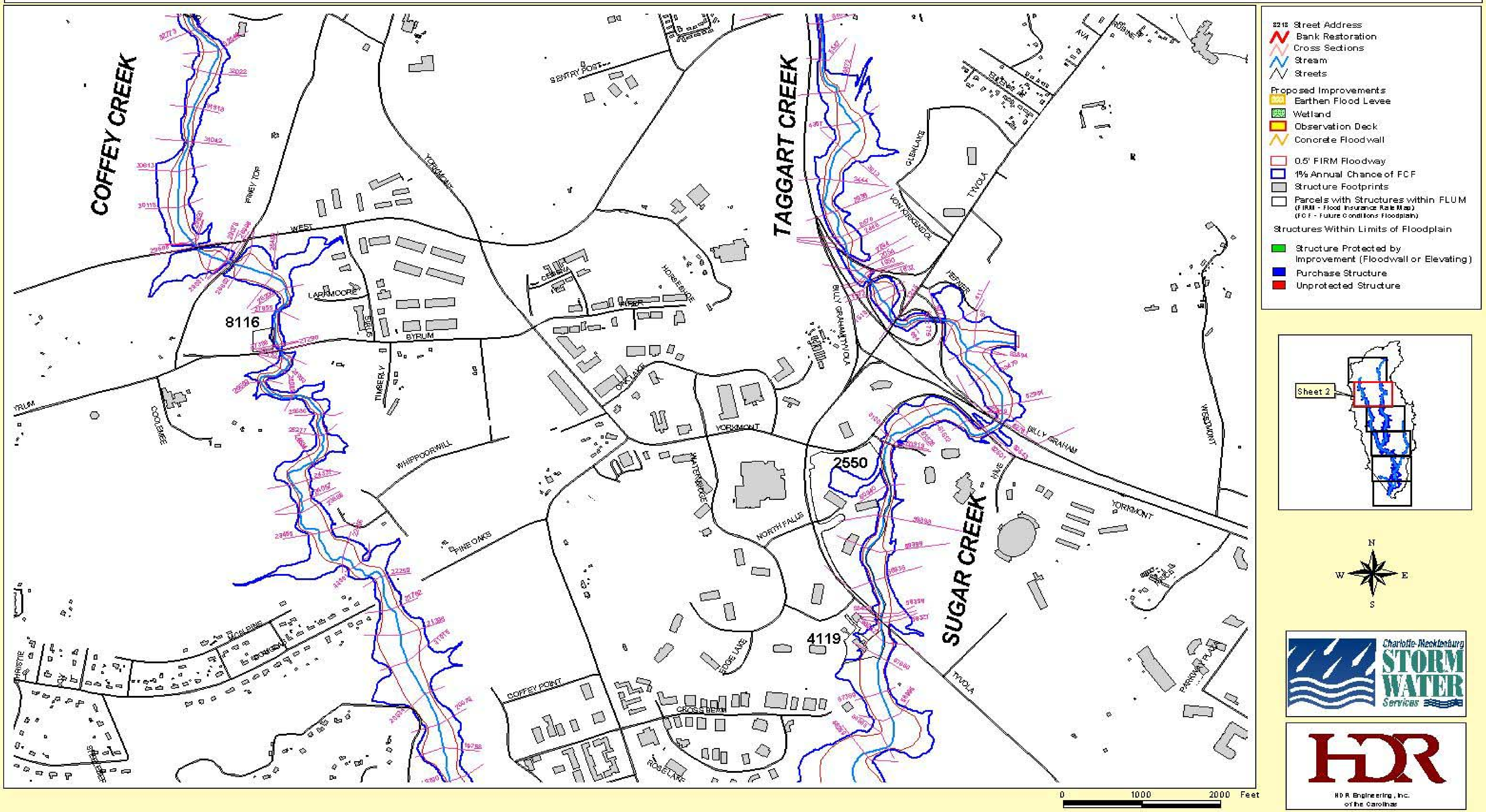


Figure 18 Study No. 3, Sugar Creek Watershed Proposed Improvements, Sheet 3

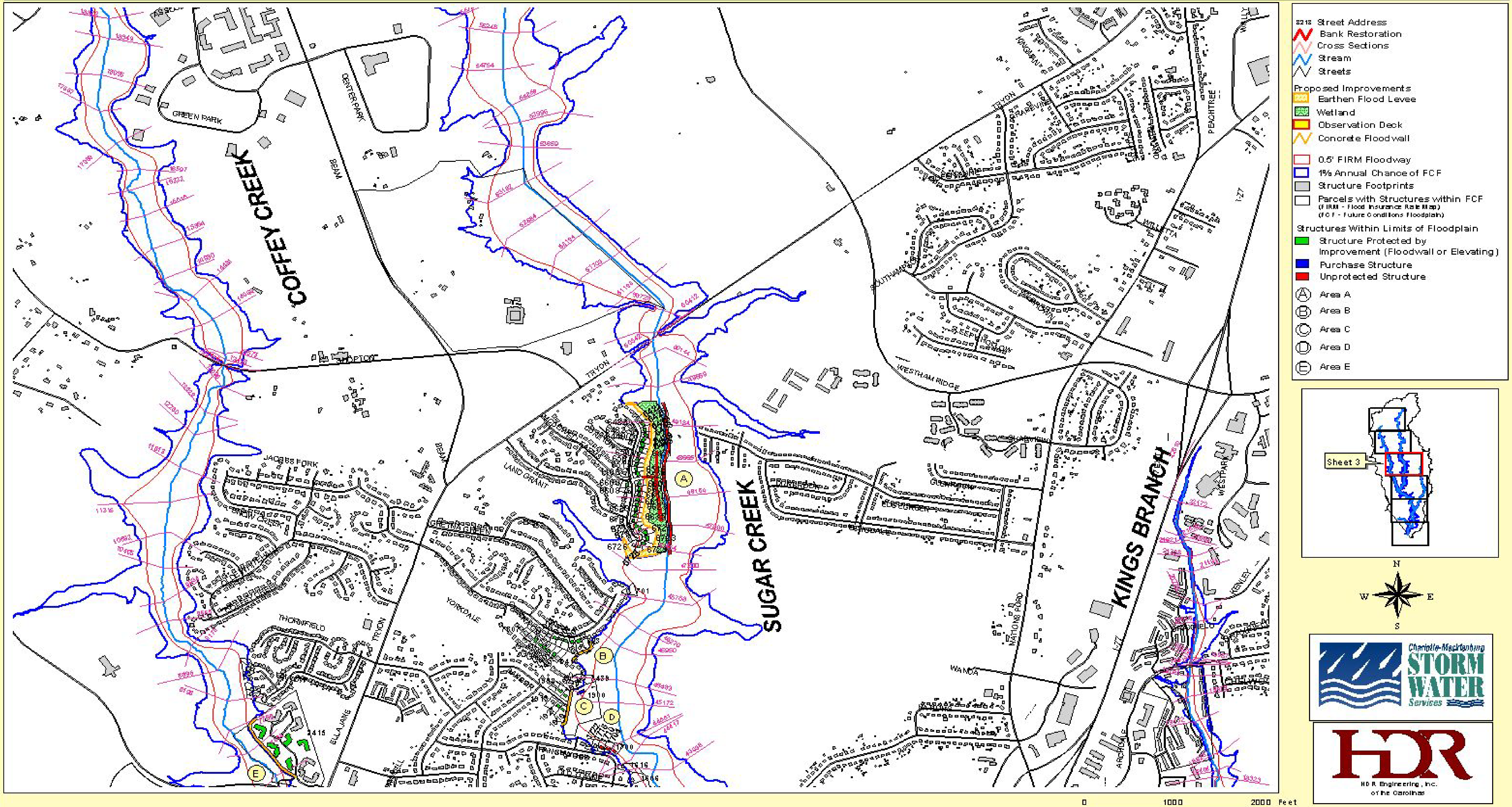


Figure 18 Study No. 3 Sugar Creek Watershed Proposed Improvements, Sheet 4

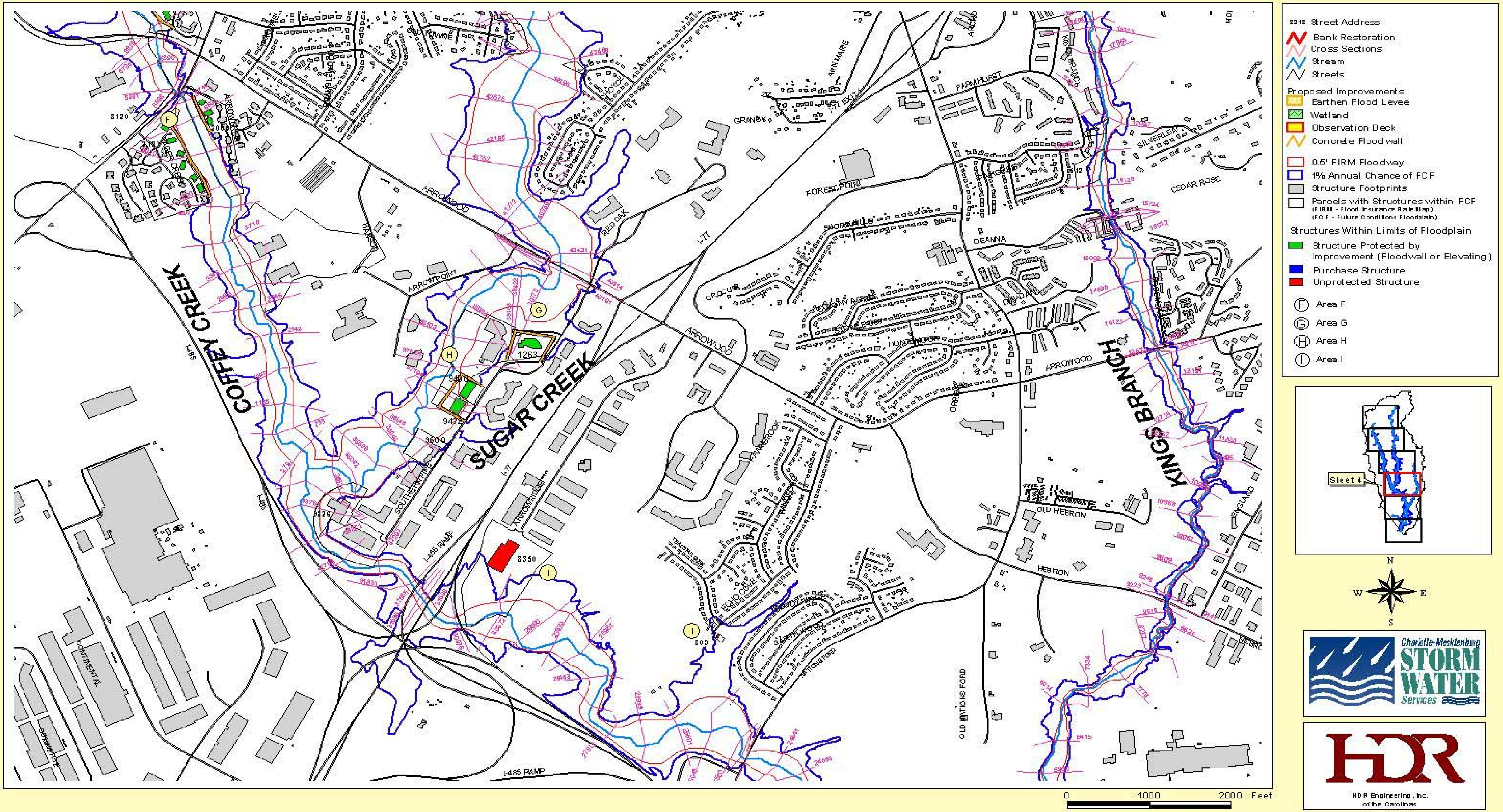


Figure 18 Study No. 3, Sugar Creek Watershed Proposed Improvements, Sheet 5

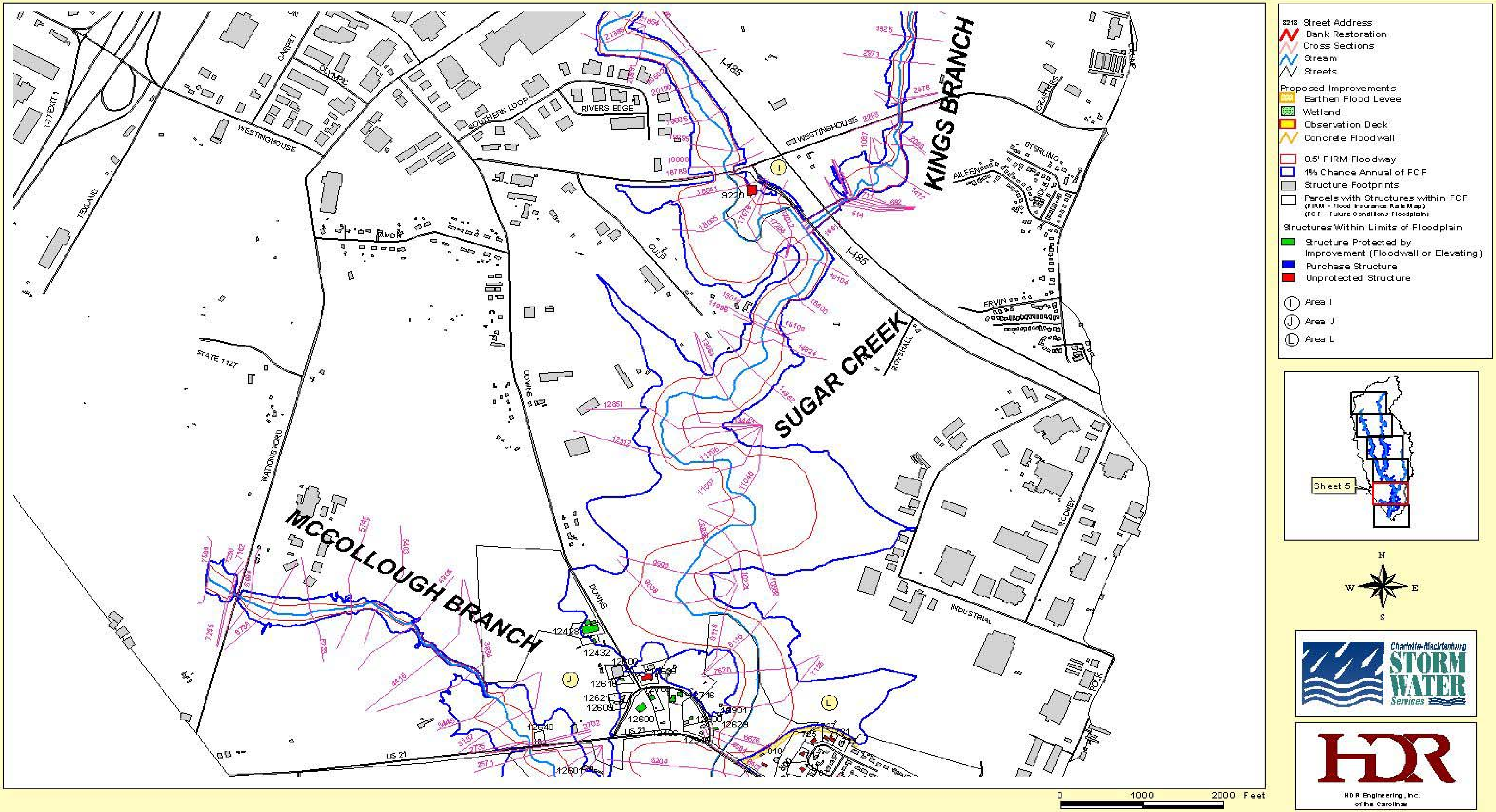


Figure 18 Study No. 3, Sugar Creek Watershed Proposed Improvements, Sheet 6