Cub Creek Watershed

Geomorphic Analysis and Potential Site Identification for Stormwater Structures and Retrofits

Town of Wilkesboro
North Carolina

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Project Summary
Cub Creek Geomorphic Analysis

Introduction

AECOM provided services to the Town of Wilkesboro during the spring, summer and fall of 2009 to evaluate the geomorphic stability of a portion of the Cub Creek Watershed and to identify potential sites for stormwater BMPs and BMP retrofits. The study area consisted of the portion of the Cub Creek watershed that falls within the municipal limits and extra-territorial jurisdiction of the Town of Wilkesboro. The ultimate goal of this study was to aid the Town in the identification, prioritization and evaluation of individual BMP projects that could help improve the water quality of Cub Creek and which, over time, could be separately implemented through grant funding. The funds for this study were provided by a Clean Water Management Trust Fund (CWMTF) stormwater mini-grant, with matching funds provided by the Town of Wilkesboro.

Methods

This study consisted of undertaking both field work and desktop analysis to systematically identify sources of stream impairment and evaluate solutions to treat this impairment. The field work consisted of a semi-quantitative geomorphic survey of all perennial and intermittent streams within the study area. Ephemeral systems were surveyed when a specific geomorphic instability indicated that further investigation of the ephemeral system was necessary to fully understand the cause and magnitude of the problem. The survey was conducted in September and October, 2009. Prior to the survey, GIS data was used to create a field map atlas of 13 pages showing hydrological and infrastructure features. The streams on each page were systematically walked by two two-person field crews from the upper watershed to the lower watershed. Each field crew carried a global positioning system (GPS) unit, a digital camera and a field assessment form for recording relevant geomorphic data.

When specific areas of instability were identified, they were semi-quantitatively surveyed in order to fill out a field assessment form. The parameters recorded on the forms were helpful in understanding the cause of the problem, and stability of the reach at each location. In addition, at each location a GPS coordinate was recorded, a photograph was taken, and notes were recorded in a field book and on field maps for later reference. The “Raw Data” for each of these locations was compiled together and is included in **Appendix C** for use in future evaluations of the watershed’s condition.

After completion of the stream surveys, areas of geomorphic instability were reviewed and from these 25 sites were selected for further consideration by AECOM as potential BMP sites. To prioritize these sites, AECOM used a scoring system and professional judgment to give each site a qualitative score (see discussion below). Following the prioritization, the top eleven sites were re-visited to gather more data for further analysis.

From these, the top six sites were selected to be presented in this report for consideration by the Town of Wilkesboro as those most in need of implementation. However, the remaining sites shown in the scoring table and on the raw data maps should also be addressed in the future as funding and grant opportunities become available.

Each of the six final sites were analyzed for feasibility, cost benefit, net reduction in loading of nutrients and suspended solids, anticipated reductions in runoff quantity and potential baseflow augmentation to the receiving channel. A brief GIS analysis of each site was then undertaken, consisting of delineation of the site watersheds, analysis of land use in each watershed, and calculation of percent imperviousness. The inputs of drainage area, percent imperviousness, and land use type were used to estimate pollutant load rates for each watershed using the Simple Method (Schueler et al., 2007). An annual rainfall depth of 48 inches was assumed for the calculation, based on Wilkes County rainfall data available from the National Oceanographic and Atmospheric Association.

For sites where sediment reduction through stabilization of streambanks was the primary focus, a modified BANCS model was used to estimate annual stream bank erosion rates (Rosgen, 2006). The BANCS model uses field measurements of Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) with an empirically-derived graph showing a relationship between these variables and stream bank erosion rates (called an erosion rate curve). For this study, estimates of BEHI and NBS were measured for the banks at each stream stabilization site and then combined with an erosion rate curve for North Carolina to estimate stream bank erosion rates in tons per year.

Conceptual construction costs were estimated for each of the sites using a combination of standard quantities and prices following North Carolina Department of Transportation (NCDOT) specifications, recent cost estimates for other projects calculated by professionals at AECOM, and equations that predict the cost of BMP construction as a function of potential storage volume (Schueler, et. al. 2007). The contingency cost for each project was adjusted depending on site conditions. Sites that are harder to access or near utility right of ways were given a higher contingency cost.

In addition to construction costs, yearly maintenance costs were developed for each BMP site. Research has shown that maintenance costs for stormwater wetlands and bio-retention areas typically range from 3-5% of the base construction cost per year (Center for Watershed Protection, 2007). To err on the side of caution, the higher figure of 5% was used to estimate annual BMP maintenance costs for all the proposed BMP sites.

The results of this analysis, along with site descriptions and photos are found in the project specific reports that follow.

Ranking Criteria

Stream reach BMP and restoration site selection was based on a combination of 6 independent characteristics of the identified stream reach. The characteristics used in the site selection process were: severity of problem, number and type of landowners (municipal vs. private), construction access, public visibility of project, likelihood of project success, and degree of downstream benefit. All six characteristics were ranked by the four member team that participated in the field identification of potential BMP or restoration sites in the Cub Creek basin. The rankings ranged from 1-5 with 5 representing conditions favorable for project implementation and 1 representing unfavorable site conditions. The rankings of all six characteristics were added together to give a maximum possible sore of 30 points. The maximum rank represents a project that is most suited to a restoration project. Additional BMP-only sites were also observed within the Cub Creek basin and noted. Some of these potential BMP projects were chosen to be included in the final report outlining the best BMP or restoration projects in the Cub Creek basin.

Severity of erosion and stream damage was ranked such that a ranking of 1 represented negligible erosion and/or potential for further damage or sediment/nutrient input. Observed increases in erosion, sediment and nutrient input and potential impacts to capital improvement projects equated in higher rankings with 5 representing severely eroded areas that are contributing large amounts of sediment/nutrients downstream and/or have high potential to damage capital improvement projects.

Land adjacent to the stream reach was ranked on the public or private nature of ownership and the number of landowners that would be stakeholders in potential projects. Generally, larger numbers of landowners that have a stake in a project make it more difficult to negotiate terms that are acceptable to all landowners. Higher numbers of adjacent landowners also reduces the likelihood of a project commencing. Rankings ranged from 1-5 and a ranking of 1 represented a reach that had 4 or more adjacent private landowners. A ranking of 2 represented 3 adjacent private landowners while a ranking of 3 represented 2 private landowners. A ranking of 4 represented a reach in which there was only 1 adjacent private landowner or 2 landowners (1 of which was a public entity) and a ranking of 5 represented a reach in which all adjacent landowners were public entities.

Construction access was included in the ranking due to the importance of access in performing a project and the role access plays in determining the final cost of implementing a project. The degree of proximity of an identified stream reach to roads, utility easements, and/or agricultural fields and pastures typically increases the reaches rank. Construction access was ranked on a 1 to 5 scale with increasing rank representing areas with increasing ease of access for construction vehicles. A ranking of 1 represents a landlocked area that would be very difficult to access with construction vehicles. A ranking of 5 represented an area that is easily accessible via a public or private road.

Project visibility was included in the ranking due to the importance of educating the public about need and benefit of BMP implementation and stream restoration. Stream reaches that received a ranking of 1 are located in areas on private land that are only visible to the landowner. Increasing visibility of identified stream reaches to adjacent landowners and the public-at-large resulted in higher visibility rankings. A ranking of 5 was given to reaches that were highly visible and provided an opportunity to install kiosks or other educational material to educate the public on the restorative processes completed or underway.

Potential for project success was included due to the physical nature of the identified stream reaches and/or problems encountered that make some areas more difficult to remediate successfully over the long term. A ranking of 1 represented an area with a very low probability of long-term success whereas a ranking of 5 represented a project that would involve a standard restoration or BMP and has an excellent probability of success.

The final criteria considered in the ranking process was the degree of downstream benefit to water quality in Cub Creek that would result from a BMP implementation or stream restoration along an identified reach. Rankings are based on a number of factors, including stream size. High ranking benefits include the reduction of sediment and/or nutrient load in the stream, elimination of headcutting or further damage along the reach, and the size of the water body (its overall contribution to downstream water quality problems). A ranking of 1 represents negligible improvement to downstream water quality as a result of the BMP or restoration project or a small stream that has little contribution to problems observed in Cub Creek. A ranking of 5 represents a project that provides large increases in water quality in Cub Creek.

A summary of the scoring of each of the initial sites is shown in **Table 1**. The final six sites presented in this report are summarized in **Table 2**. This table indicates whether the site is located within the municipal limits or extra-territorial jurisdiction (ETJ) of the Town of Wilkesboro, the type of project, the primary water quality goal, the cost of construction, the annual maintenance cost (where applicable), landowner willingness to implement the project, and a cost-effectiveness of each site. It should be noted that the sites at which sediment reduction is the primary goal were analyzed for cost-effectiveness separately from the sites at which nutrient reduction is the primary goal. For the sediment reduction sites, cost-effectiveness was measured on a cost per tons of sediment reduced; whereas the nutrient/pollutant reduction sites were analyzed based on cost per pounds of nutrients removed.

Table 1. Scoring of All Identified Sites

Site Name	Problem Severity		Landowners		Construction Access		Project Visibility		Probability of Success		Degree of Downstream Benefit		Total Score
		(pts)		(pts)		(pts)		(pts)		(pts)		(pts)	(pts)
1-A	High	4	All public	5	Excellent	5	Excellent	5	Likely	4	Superior	5	23
1-B (2)	High	4	1/2 public	4	Excellent	5	Excellent	5	Likely	4	Substantial	4	22
1-C	Very High	5	All public	5	Excellent	5	Excellent	5	Likely	4	Superior	5	24
3	High	4	1	4	Very good	4	Good	4	Somewhat likely	3	Fair	3	19
4	HIgh	4	3	2	Excellent	5	None	1	Extremely likely	5	Substantial	4	17
5	Very High	5	2	3	Very Good	4	Fair	3	Extremely likely	5	Fair	3	20
6	Very High	5	2	3	Good	3	None	1	Somewhat likely	3	Substantial	4	15
7	High	4	1	4	Good	3	Poor	2	Somewhat likely	3	Fair	3	16
8	Moderate	3	1	4	Good	3	None	1	Likely	4	Fair	3	15
9	Moderate	3	2	3	Poor	2	Poor	2	Likely	4	Substantial	4	14
10	HIgh	4	2	3	Good	3	None	1	Likely	4	Fair	3	15
11	Moderate	3	2	3	Poor	2	Poor	2	Extremely likely	5	Negligible	1	15
12	Moderate	3	2	3	Poor	2	Poor	2	Extremely likely	5	Negligible	1	15
13	Very High	5	3	2	None	1	None	1	Likely	4	Fair	3	13
14	Low	2	2	3	Good	3	Poor	2	Extremely likely	5	Negligible	1	15
15	High	4	2	3	Poor	2	None	1	Somewhat likely	3	Fair	3	13
16	Moderate	3	1	4	None	1	None	1	Extremely likely	5	Negligible	1	14
17	HIgh	4	2	3	None	1	None	1	Somewhat likely	3	Fair	3	12
18	Moderate	3	3	2	None	1	None	1	Likely	4	Little	2	11
19	High	4	4+	1	Poor	1	None	1	Likely	4	Negligible	1	11
20	Moderate	3	4+	1	None	1	None	1	Likely	4	Little	2	10
21	Not rated												NA
22	Not rated due to opportunity for unique BMP												NA
24	Pond outfall												NA
25	Not rated due to opportunity for unique BMP												NA

Table 2. Final Site Summary

Final Site Name	Type of Project	Primary Water Quality Goal	Cost of Construction	Annual Maintenance Cost	Location	Landowner Willingness	Cost/ lb nutrients Removed	Cost/ton of sediment Reduced
1a	Stream Restoration/Stabilization	Sediment reduction	$207,000	N/A	Town Limits	Willing	---	$2,202.13
1b	Stream Restoration/Stabilization	Sediment reduction	$258,750	N/A	Town Limits	Willing	---	$1,250
1c	Stream Restoration/Stabilization	Sediment reduction	$213,900	N/A	Town Limits	Willing	---	$4,609.91
5	Stream Bank Stabilization	Sediment reduction	$86,250	N/A	ETJ	Not Investigated	---	$322.55
22	New BMP	Nutrient/Pollutant Removal	$22,660	$2,136	Town Limits	Not Investigated	$2,604.6	---
25	New BMP	Nutrient/Pollutant Removal	$34,578	$3,488	Town Limits	Not Investigated	$124.4	---

Discussion of Specific Sources of Instability

The project sites included in this report present potential solutions to many of the water quality issues that affect Cub Creek. Included below is a summary of key sources of instability that were observed during the field investigation:

1. Stream Channelization – Stream channelization is a significant impact that has occurred to the reaches in the Cub Creek Watershed. Channelization was, at one time, a common means of dealing with a stream that was in the way, or that flooded neighboring properties. By deliberately lowering the stream elevation, overtopping of the banks would often be eliminated. The intentional carrying of higher flows within the channel is exactly opposite of natural processes where a stable stream will utilize access to a floodplain to dissipate the energy that is above the capacity of the stream channel. As a result, the higher flows which are now contained within the streambank are flows that greatly exceed the allowable shear stress of the channel. In the end, channelization results in steams that down cut to bedrock or saproilte and then begin to widen as exceedingly high shear stresses causes bank scour and thus a lateral movement of the streambank due to its erosion. The mass wasting of these banks is a significant cause of excess sediment in this watershed. Several of these selected projects are bank stabilization projects and the anticipated reductions in sediment loading indicate the magnitude of this problem.

   Another result of channelization is the loss of instream habitat and structure that can be found in the stable pool-riffle sequence of natural channel. Pools provide essential habitat and drought refuge areas for proper biological function. It should be noted that this is a problem on many reaches that are not a part of one of the proposed sites for stormwater BMPs included in this report.

2. Culverts and Channel Crossings - A significant amount of the instability in the Cub Creek Watershed may have been started by the construction of stream crossings for roadways. The resulting channel contraction that occurs at most culverts may have caused the erosion on the downstream side that leads to a tail cut, and thus channel incision (no longer accessing the floodplain), a lowering of groundwater base, and continued instability that may exist for decades. Head-cuts can result from a depressed invert elevation, and work upstream until it hits some form of grade control. Overly wide crossings cause deposition of sediments when the wider channel becomes shallower in depth, thus reducing the shear stress needed

to carry sediment. Backwater from floodplain encroachment of roadways causes a loss of velocities, thus lowering shear stress, and a lack of sediment transport results.

It is difficult to have a road crossing and maintain a natural cross section, flood plain relief for proper sediment transport and flow capacity. Current DOT standards have improved with this regard and in the future, road crossings in this watershed should utilize floodplain culverts and main channel culverts that maintain a wider flow path with a base flow channel at the natural bed elevation.

3. Utility Impacts – The installation of sewer lines and other utilities within the floodplains of streams was the perceived cause of apparent channel relocations in several locations in the watershed. For the most part, these impacts occurred long ago and the remaining degradation is primarily in the form of channel instability from channelization, as mentioned in item #1. Current impacts were observed in several locations in the form of unstable channel crossings, culvert installations, and removal of woody riparian vegetation that is essential to channel stability. It will require a continued effort between the towns and the utility providers to minimize these future impacts, as well as to monitor them.

4. Bank Wasting – Streambank wasting is probably the largest cause of the degradation of the biological integrity of the streams within the Cub Creek watershed, because of the large amount of sediment that is exported through bank wasting processes. There are very few streams in the watershed that do not possess mass wasting banks on outer meander bends and lower riffle sections. Any effort to manage stormwater in the future by reducing peak flow rates of runoff and total volume will aid in establishing stability in the watershed by reducing the shear stress experienced by these banks. Direct modification of all streams within the watershed is impractical, thus particular reaches that are identified as supplying the greatest amounts of sediment should be targeted and treated. While the Geomorphic Assessment identified the most unstable reaches within the watershed, an analysis of the estimated quantities of sediment produced by all unstable reaches within the watershed was beyond the scope of this effort. Notwithstanding this, many of the BMPs proposed in this report are targeted at treating what were observed to be the worst reaches.

5. Direct Discharges to the Channel – In many cases, a definite impact was observed at the location of stormwater outlets within, or very near the channel. This concentrated and sediment-starved stormwater causes

channel instability in the form of mass wasting of banks and channel incision. Even when discharges occur onto the floodplain, but within 10-15 feet of the channel itself, mass wasting of downstream banks is present as well as a headcut through the stream bank up to the point of discharge. The placement of BMP outlets in the floodplain, unfortunately, may also have the same effect. When possible, any discharge in a near-channel region should be diffused by use of level spreaders or substantial energy dissipation basins. Observations indicate that an "apron" at the outlet is grossly insufficient at energy dissipation and flow diffusion.

6. Stormwater Runoff – As with any urban or suburban watershed, the development in some portions of the Cub Creek watershed has caused an increase in the peak flow rates and total runoff volume that reaches the receiving channels. This was particularly noted in the UT to Cub Creek watershed draining the downtown area. It is evident that increases and the concentration of runoff are the major problem in these portions of the watershed. However, specific observations, such as a headcut in an intermittent channel, are indicators that the instability created by stream crossings or direct alterations of the channel may be the more significant catalyst for channel instability in many cases. Increased stormwater flows that are "trapped" down inside a channel and not allowed to dissipate energy via a floodplain only serve to exacerbate the instability of an incised channel. AECOM strongly believes that, based on our field experiences and completed restoration projects, the increase in stormwater flows can be accommodated by reconnection with the floodplain and proper bank stabilization practices. AECOM encourages the use of these practices to stabilize problematic reaches where the sediment contributions are degrading the biological integrity of the system.

7. Cattle impacts- In several locations in the upper portions of the watershed, it was observed that cattle operations are impacting the stability of Cub Creek. When cattle are allowed to directly access the stream for watering, their hoofs create shear and erosion on the banks, causing sediment entrainment into the channel. Additionally, their waste can introduce pollutants such as fecal coliform bacteria into the water. In recent years, researchers have developed alternative cattle watering devices which allow farmers to harness the streamflow as a means of watering their cattle while keeping cattle out of the stream. Fencing out cattle has proven to be a successful means of stabilizing streams throughout the state. The Natural Resource Conservation Service (NRCS) offers grants to farmers and local extension agencies to implement projects that will improve water quality associated with cattle operations.

The BMPs outlined in the 6 conceptual projects address some of the various causes of instability that were observed. By using these projects as a guide, the Town of Wilkesboro should be able to conceive and implement other projects to improve the biological integrity of Cub Creek in the years to come.

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APPENDICES

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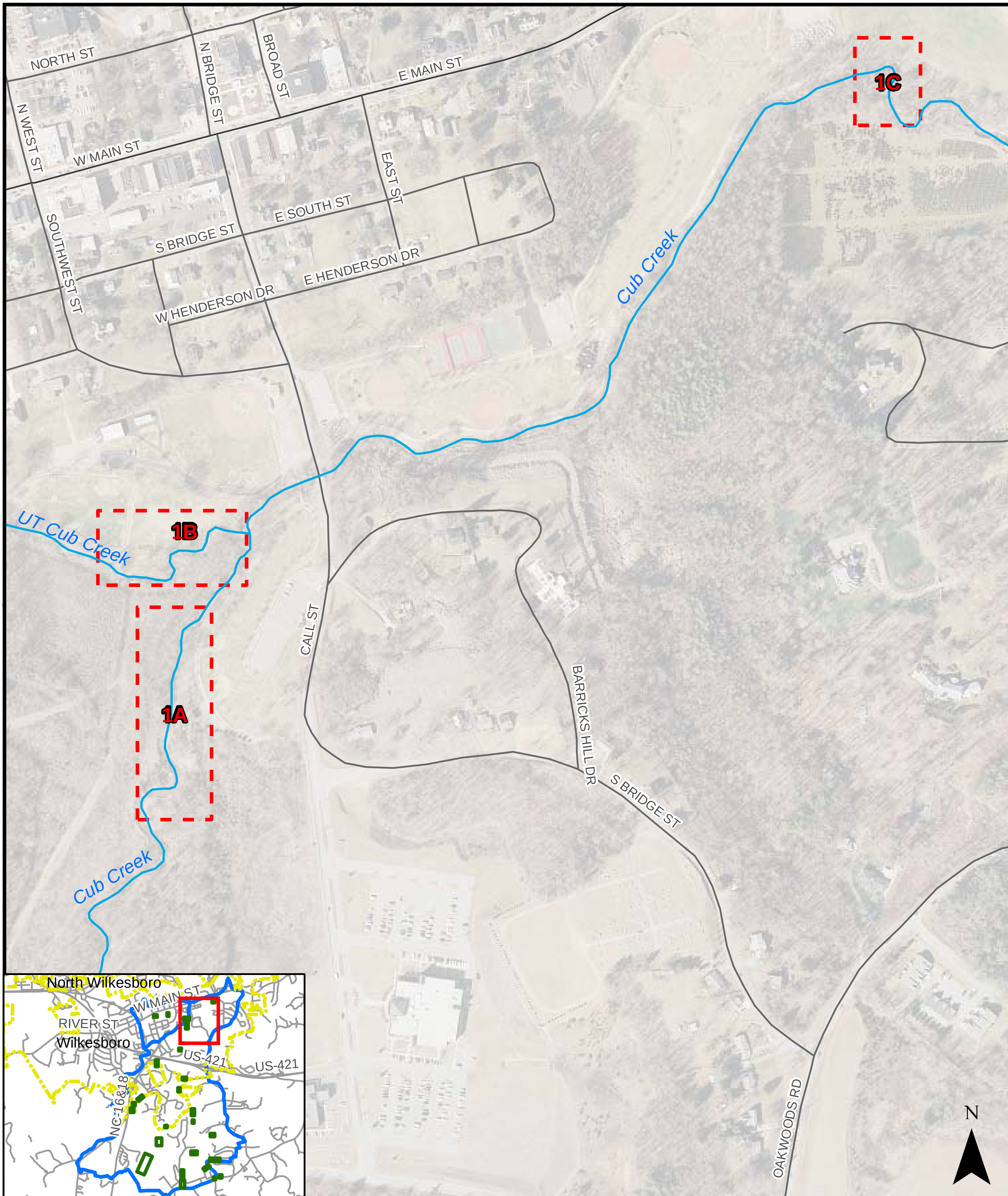
SITE 1 (Options A, B, and C)

Stream Restoration/Stabilization in Park
Index Sheet No.: 2, 3

Option A Estimated Construction Cost: $207,000
Option B Estimated Construction Cost: $258,750
Option C Estimated Construction Cost: $213,900



Legend

- Impoundments (NC Floodmap)
- Streams (NC Floodmap)
- Roads (DOT)
- Problem Areas

SITE 1A, 1B, and 1C Vicinity Map

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Wilkes County, NC

0 200 400 800 Feet

Project Description

	Drainage Area (sq. mi.)
Site 1 Option A	12.7
Site 1 Option B	0.37
Site 1 Option C	13.4

Site 1 is comprised of three different sites that are presented here as one site with three different options. It was decided to group these sites in this way because all three sites are located within Wilkesboro park property. The three options could be implemented together or separately, depending on funding availability. A separate cost-estimate has been provided for each site.

Location

Site 1, Options A, B and C are located within city park property. Site 1 Option A can be accessed from the parking lot located on the eastern side of Cub Creek, at the intersection of S. Bridge St. and Barricks Hill Dr. Option B, which consists of a length of an Unnamed Tributary to Cub Creek that flows through the park, can be accessed from a parking lot located adjacent to the dog park that connects to S. Bridge St. Option C is located to the northeast of the park, and extends along Cub Creek from the end of the recently restored section of the creek to the bridge over Cub Creek on Oakwoods Rd. Option C is best accessed from a gravel lot located south of the intersection of Main St. and Oakwoods Rd.

Problem Description- Option A

Option A consists of approximately 1,200 feet of Cub Creek that flows through the park from the southeast corner of the park to S. Bridge St. A section of Cub Creek downstream of S. Bridge St. has already been restored. The upstream length of Cub Creek consists of an incised channel, with actively eroding banks, primarily along the right bank of the creek. A bank erosion hazard index (BEHI) analysis was conducted along the right bank, and showed that the predominant BEHI rating along this stretch is “High”, with some shorter stretches of “Very High” banks. These ratings confirm what can be readily observed along the right bank: areas of mass wasting where there are no trees on the bank, and deeply undercut roots where trees are present. A scarcity of trees along the right bank has led to little protection from the erosive force of water against this bank. The channel is overly wide, with a bankfull width of approximately 30 feet, which is creating some areas of deposition within the channel. This is further causing stress against the banks as the thalweg is redirected towards the outside of the stream and into the banks.

The chief problem water quality with this site is the significant amount of sediment that is estimated to be exported due to the instability of the channel and erosion on the banks.

Based on erosion rates shown to be associated with this BEHI rating in North Carolina, it is predicted that these "High" rated banks are eroding at a rate of approximately 0.2 feet per year, with the "Very High" banks eroding at a rate of approximately 1.2 ft/year. Using a modified BANCS model for predicting streambank erosion rates (Rosgen, 2006), a total bank entrainment rate of approximately 95 tons/year was estimated for this site, as shown in **Table 1.1**. Given this significant contribution of sediment from bank erosion, and the presence of a restored section of channel downstream, restoration of this section of Cub Creek is needed to ensure that the integrity of the downstream restoration site is not undermined.

Table 1.1

Pre-Treatment	
Estimated Total Sediment Export	94.4 tons/year
Erosion per length of Channel	0.1 tons/yr/ft
Pounds of Nitrogen	188.7 lbs/year
Pounds of Phosphorus	94.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.1 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.1 lbs/year
Pounds of Phosphorus	0.1 lbs/year

Problem Description- Option B

Option B consist of approximately 1,500 feet of a deeply incised section of an unnamed tributary to Cub Creek (UT to Cub Creek) that flows through the park from upstream at College St. to downstream at it's confluence with Cub Creek. UT to Cub Creek possesses actively eroding streambanks along its entire length. The channel is overly wide and shallow at the bankfull stage, which is causing deposition within the channel. Furthermore, the pattern of the channel exhibits very tight meanders, which are creating areas of extreme near bank stress on the outer meanders of the stream and exacerbating the problem of bank erosion. It is likely that the impairment of this stream has occurred with the development of the Town of Wilkesboro, as this stream is the primary drainage feature of the downtown area. The lowering in bed elevation of Cub Creek downstream, the flowing of the stream through culverts along College street and upstream at the Tyson plant, and the presence of numerous direct discharges into the stream have likely all contributed to the downcutting, widening and subsequent aggradation of the channel which is now occurring. As a result of the present state of the channel, this section of UT to Cub Creek is contributing significant amounts of sediment to Cub Creek downstream. A BEHI evaluation showed that the predominant BEHI along this length is “Very High”. Coupled with near bank stress ratings of “Extreme” on the outer meanders, some of the streambanks are likely eroding as much as 1.5 feet/year. Using the BANCS model, approximately 207 tons/year are estimated to be exported from this site **(Table 1.2**).

Table 1.2

Pre-Treatment	
Estimated Total Sediment Export	207 tons/year
Erosion per length of Channel	0.1 tons/yr/ft
Pounds of Nitrogen	414.1 lbs/year
Pounds of Phosphorus	207 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.1 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.1 lbs/year
Pounds of Phosphorus	0.1 lbs/year

Problem Description- Option C

Option C consists of approximately 1,240 feet of an incised and unstable section of Cub Creek, starting immediately downstream of the restored portion of Cub Creek, and flowing downstream to Oakwoods Rd. This section of Cub Creek suffers from the similar state of instability as the upstream section of Cub Creek described in Option A: overly wide morphology and aggradation, incision and eroding streambanks. However, whereas the planform of the Option A section of Cub Creek is relatively straight, this section possesses many overly tight meanders, which are creating conditions of extreme near bank stress. The presence of more trees along the banks gives the stream a “Moderate” BEHI rating in most areas, but with “High” and “Very High” ratings on the outer meanders. Based on the lower BEHI ratings, the total amount of sediment being contributed by the bank erosion on this reach is estimated at approximately 46 tons/year **(Table 1.3**). While still significant, this is considerably less than the upstream section of Cub Creek described in Option A, and the section of UT to Cub Creek described in Option B.

Table 1.3

Pre-Treatment	
Estimated Total Sediment Export	46.4 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	92.8 lbs/year
Pounds of Phosphorus	46.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.1 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.1 lbs/year
Pounds of Phosphorus	0.1 lbs/year

Proposed Solutions

The solution to limiting annual erosion rates at these three sites is to implement stream restoration and bank stabilization measures based on natural channel design principles.

Option A

The primary solution along Cub Creek through the upstream portion of the park would be to lay both banks back at a lower slope (2:1 or flatter) to eliminate the eroding streambanks. Since the stream possesses a relatively straight planform through here, minimal changes to the plan and profile would be necessary. The banks would be lined with a geotextile netting, such as Coir fiber matting, and re-vegetated with native tree, shrub and herbaceous species. To ensure that the banks are protected in the future, the geometry of the channel must be altered to match the bankfull cross-sectional area, mean depth and width of an upstream stable section. This will ensure that this section of Cub Creek possesses the necessary capacity to transport the sediment load being delivered from its watershed without aggrading or degrading, and therefore limit the stress on the banks. To also ensure the viability of the channel, an interior floodplain or “bankfull bench” should be constructed, which will greatly reduce shear stress and velocity during above-bankfull flows. In-stream structures such as rock or log vanes and spurs should be used on banks with higher erosion to turn the flow away from the eroding bank. These structures also create fish habitat. While visiting the site to collect measurements, it was observed that there is a stockpile of boulders on the right bank (south end of the park) that could possibly be used to create some of these structures.

Option B

The solution to reduce erosion at Option B would be to restore the channel to possess a stable planform, profile and cross-section, based on stable reference reach criteria. Currently, UT to Cub Creek possesses several overly-tight meanders. Increasing the radius of curvature of these bends through realignment will significantly reduce the near bank stress against these banks, ensuring long-term viability and helping to reduce bank erosion. Moreover, there appears to be ample room in the area adjacent o the dog park to realign the channel. The profile of the stream here can be addressed by providing a stable riffle-pool sequence. Based on the length of the project reach and the elevation of the upstream invert and the elevation of the downstream confluence with Cub Creek, it may be difficult or impractical to raise the channel bed through this section, thus a new floodplain will have to be built at a lower elevation than the relict floodplain. It is important that this new floodplain provide a straight path for flood flow and not parallel the sinuosity of the realigned channel.

As with Option A, the cross-sectional area of the stream should be modified so that the channel can transport the sediment delivered from upstream without aggrading or degrading. Immediately upstream of College St. a section of UT to Cub Creek seems to be relatively stable where it flows in between a road and a the parking lot of a business. This short section may provide a suitable comparison of a stable cross-section in which to evaluate the capacity of the restored channel.

The restored section of UT to Cub Creek should have a vegetated buffer planted with native vegetation. In order to obtain the required US Army Corps of Engineers (USACE) and NC Division of Water Quality (DWQ) approvals, this buffer will have to be at least 30 feet, measured perpendicular to the streambank, as Wilkes County is considered a “mountain county” in the USACE and DWQ guidelines (USACE, 2003). Based on measurements taken at the site, this distance should be able to be obtained as the left bank consists mostly of fields adjacent to the dog park.

Option C

The solutions at Option C are identical to those of the work recommended for the upstream section of Cub Creek, and can continue the measures undertaken at the restored section of Cub Creek immediately upstream: reducing the bank angle, restoring the cross-section of the stream, installing structures for fish habitat and bank protection, creating an interior floodplain, and providing for a minimum-30 ft vegetated riparian buffer. Unlike the upstream sections of Cub Creek, however, a wide field on the left bank of the creek provides an opportunity for restoration of the pattern and profile in addition to the cross-section. Restoration of the pattern is necessary as this section of the creek possesses several overly-tight meanders creating sections of extreme near bank stress.

Constraints

The chief constraint at Option A is the lateral room in which to work. The right bank is in close proximity to a greenway path, and so any reshaping of these banks must be accomplished through backfilling the right bank, rather than through excavation.

Option B possesses very few constraints, but raising the profile as would be preferred in any restoration project may not be possible due to the upstream and downstream invert elevations.

The chief constraint at Option C will be the private landownership of the right bank, which at the time of this report, is listed in the Wilkes County Parcel Data as being owned by Furches Evergreens, Inc. Coordination with this landowner will need to be conducted in order to successfully implement this project. The left bank and adjacent floodplain are owned by the Town of Wilkesboro.

Alternatives

No alternatives are anticipated at this site.

Cost-Estimate Breakdown

Tables 1.4 through 1.6 show a conceptual itemized cost estimate for each site. These costs represent construction and maintenance costs only.

Table 1.4

Option A Construction Costs

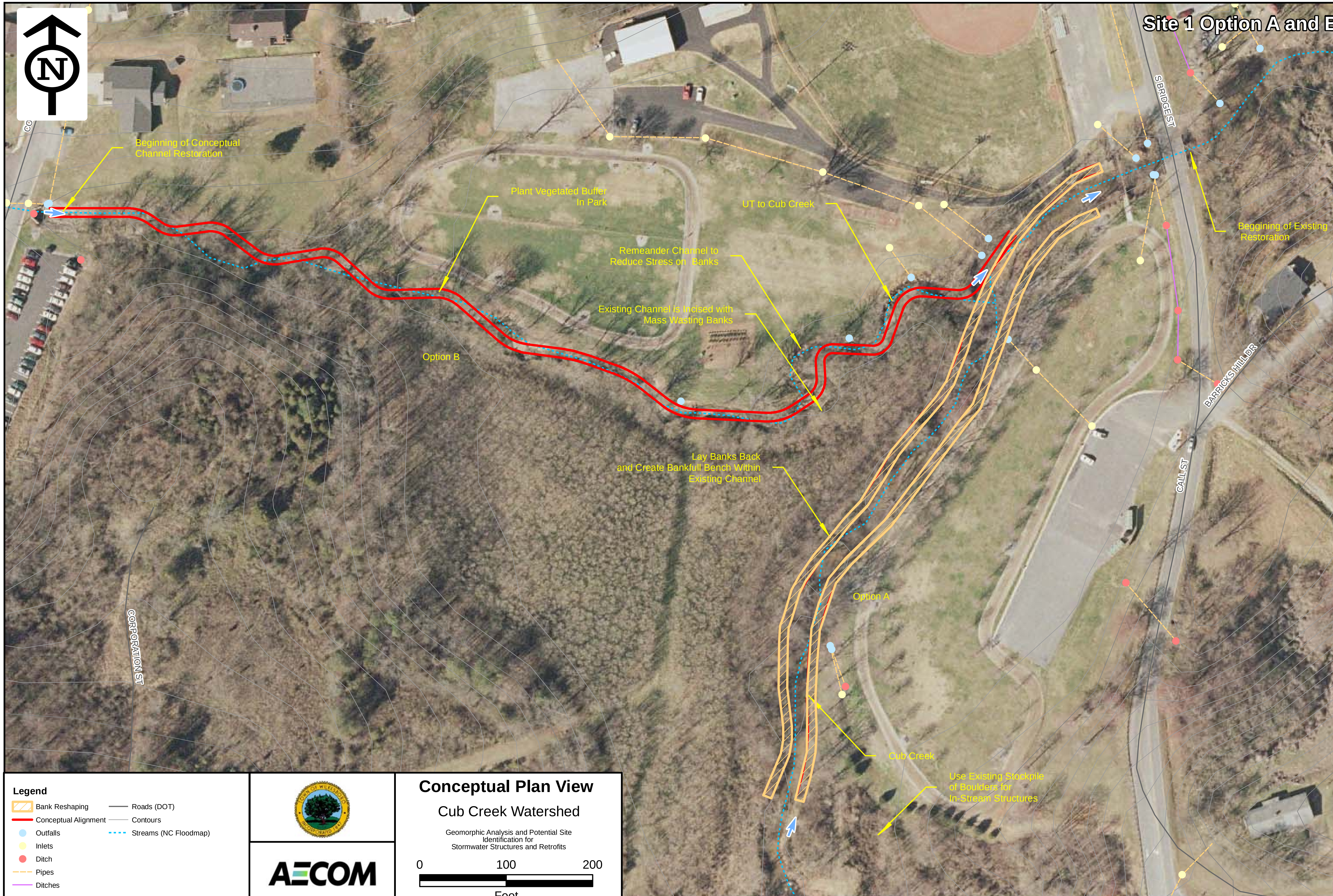
Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stream Restoration	1,200.00	LF	150.00	$180,000
			Total	$180,000
Mobilization (5%)	1.0	LS		$9,000
Contingencies (10%)	1.0	LS		$18,000
Total + Mobilization and Contingencies				**$207,000**

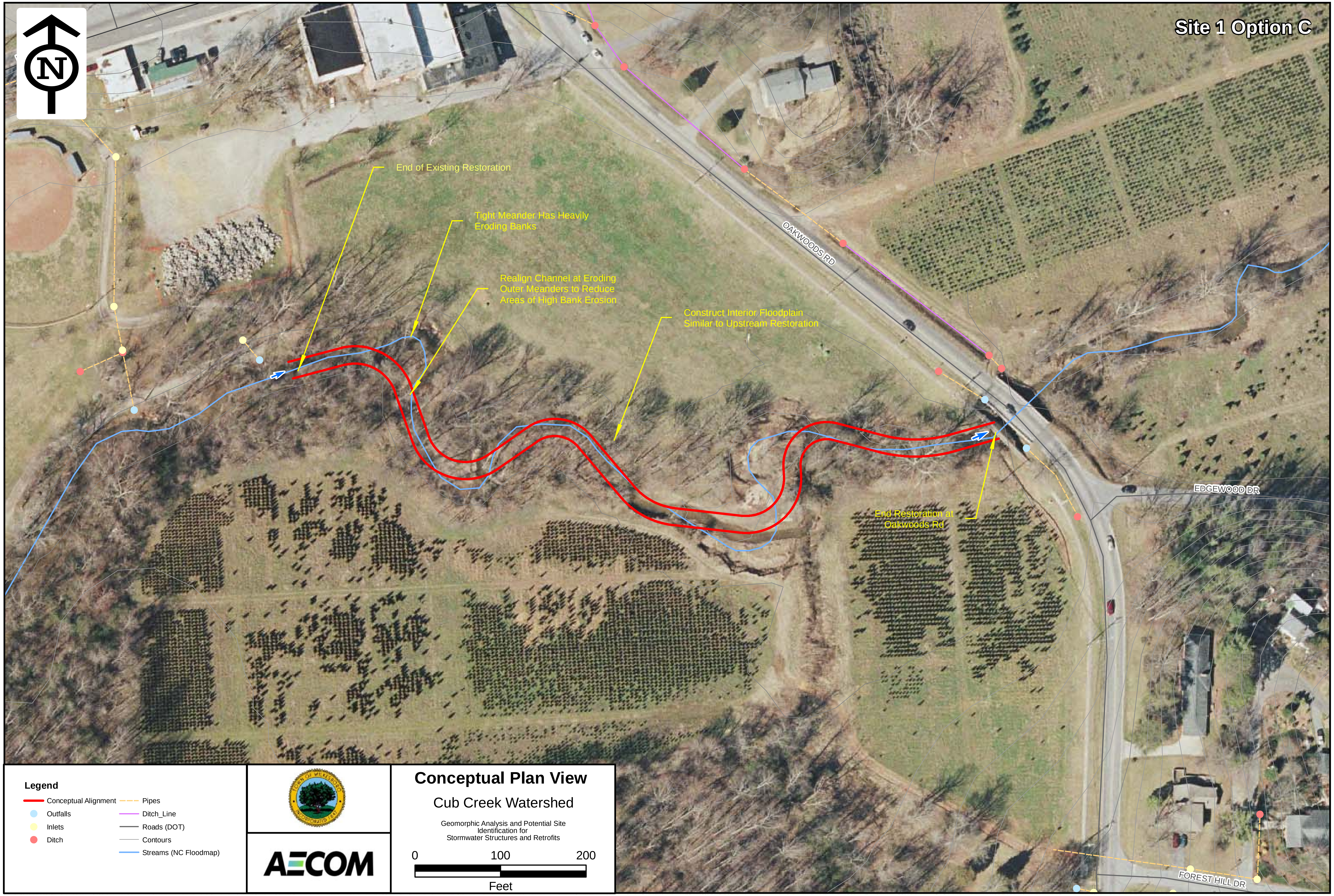
Table 1.5
Option B Construction Costs

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stream Restoration	1,500.00	LF	150.00	$225,000
			Total	$225,000
Mobilization (5%)	1.0	LS		$11,250
Contingencies (10%)	1.0	LS		$22,500
	Total + Mobilization and Contingencies			**$258,750**

Table 1.6
Option C Construction Costs

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stream Restoration	1,240.00	LF	150.00	$186,000
			Total	$186,000
Mobilization (5%)	1.0	LS		$9,300
Contingencies (10%)	1.0	LS		$18,600
	Total + Mobilization and Contingencies			**$213,900**


Site 1 Option A and B
N
Beginning of Conceptual
Channel Restoration
Plant Vegetated Buffer
In Park
UT to Cub Creek
Remeander Channel to
Reduce Stress on Banks
Existing Channel is Incised with
Mass Wasting Banks
Option B
S BRIDGE ST
Beggining of Existing
Restoration
BARRICKS HILL DR
CALL ST
Lay Banks Back
and Create Bankfull Bench Within
Existing Channel
Option A
CORPORATION ST
Cub Creek
Use Existing Stockpile
of Boulders for
In-Stream Structures
Legend
Bank Reshaping
Conceptual Alignment
Outfalls
Inlets
Ditch
Pipes
Ditches
Roads (DOT)
Contours
Streams (NC Floodmap)
AECOM
Conceptual Plan View
Cub Creek Watershed
Geomorphic Analysis and Potential Site
Identification for
Stormwater Structures and Retrofits
0
100
200
Feet



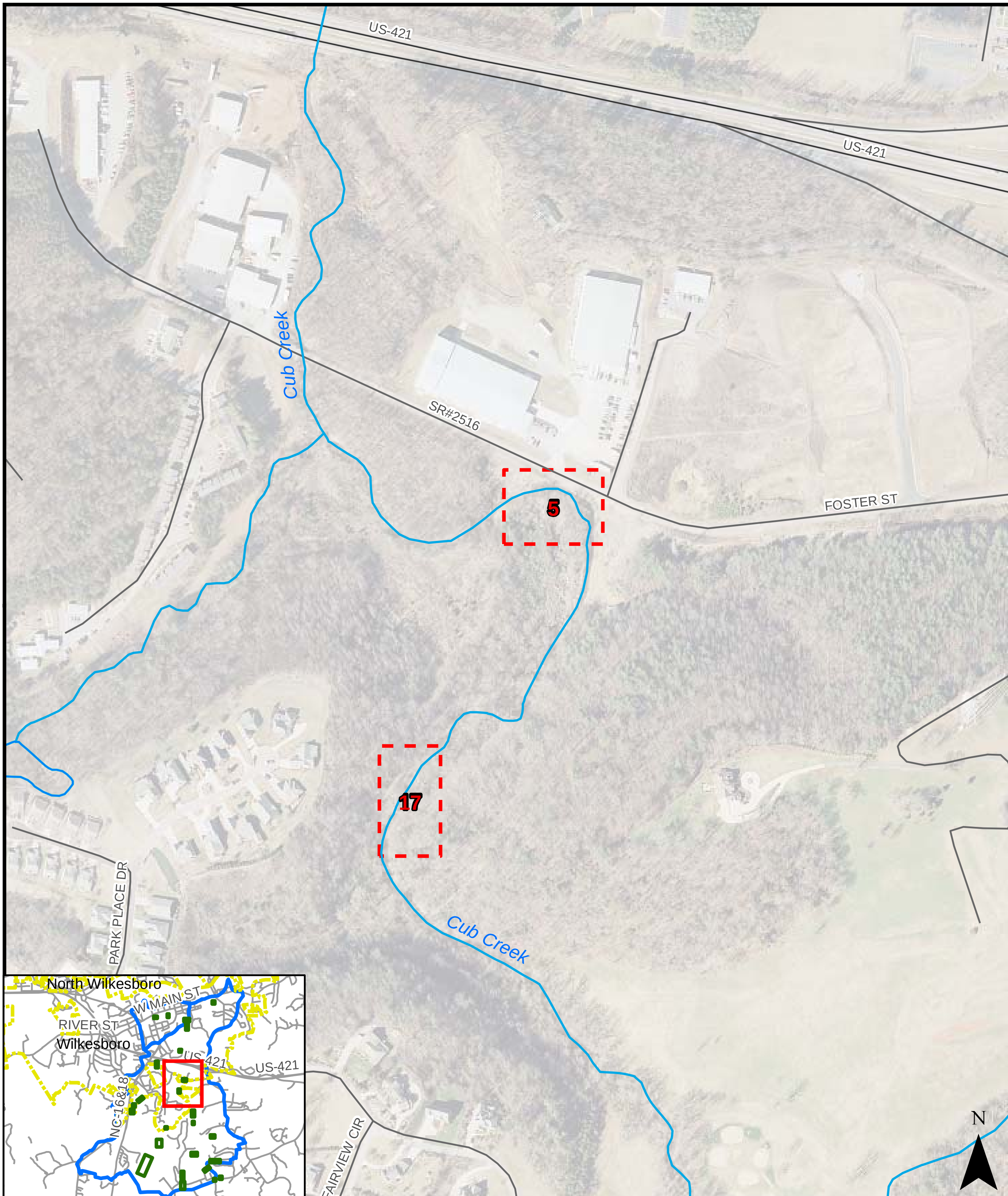
Site 1 Option C
N
End of Existing Restoration
Tight Meander Has Heavily
Eroding Banks
Realign Channel at Eroding
Outer Meanders to Reduce
Areas of High Bank Erosion
Construct Interior Floodplain
Similar to Upstream Restoration
OAKWOODS RD
EDGEWOOD DR
End Restoration at
Oakwoods Rd
FOREST HILL DR
Legend
Conceptual Alignment
Outfalls
Inlets
Ditch
Pipes
Ditch_Line
Roads (DOT)
Contours
Streams (NC Floodmap)
AECOM
Conceptual Plan View
Cub Creek Watershed
Geomorphic Analysis and Potential Site
Identification for
Stormwater Structures and Retrofits
0
100
200
Feet

SITE 5

Repair of Severely Eroding Streambank and Protection of Adjacent Road

Index Sheet No.: 7

Estimated Construction Cost: $86,250



Legend

- Impoundments (NC Floodmap)
- Streams (NC Floodmap)
- Roads (DOT)
- Problem Areas

AECOM

SITE 5
Vicinity Map

Geomorphic Analysis and Identification of
Potential Sites for Stormwater BMPs

Wilkes County, NC

0 200 400 800
Feet

Project Description

	Drainage Area (sq. mi.)
Site 5	11.6

Location

Site 5 is located to the south of Foster St., across from the Junior Johnson Country Ham facility.

Problem Description

Site 5 consists of an actively eroding streambank on Cub Creek that has cut into the road embankment of Foster St. and threatens to undermine the road. The eroding streambank is located on a tight outer meander of Cub Creek that is adjacent to the road embankment. Approximately 500 feet of the right bank of this outer meander is actively eroding. Where the stream has cut into the fill of the road embankment the bank is at its highest, and this relatively short stretch of bank is contributing a significant amount of sediment to the stream on an annual basis. A BEHI analysis done on this section of bank resulted in an “Extreme” BEHI rating for the bank immediately adjacent to the road, and a “Very High” rating for the banks leading up to and trailing away from the road. Coupled with a “Very High” to “Extreme” NBS rating, the bank is predicted to be contributing approximately 268 tons of sediment per year to the watershed (**See Table 5.1**). More than this, however, the threat to public infrastructure and safety posed by the eroding bank lends a critical nature to the project and warrants that the project should be considered a high priority.

Proposed Solution

The high rate of erosion and potential for undermining the road at this site warrants a harder bank stabilization solution than those proposed at other sites listed in the report. However, any hard solution that is undertaken to stabilize the bank can still incorporate natural elements such as planting native vegetation. The vegetation will help to stabilize the reinforced bank, ensure long term viability, provide riparian habitat and create aesthetic appeal. One possible solution is to build an EnviroLok wall and plant it with trees and shrubs. An EnviroLok wall is composed of sandbags made from filter fabric and filled with a mixture of topsoil and sand. The bags are reinforced together through the use of spikes or straps, to create a hardened retaining wall that can resist the erosive force of water. The sand and topsoil create a growth medium into which shrubs, trees and herbaceous species can be planted through the filter fabric. The basic principle is that the sandbag wall will provide the short term protection needed to prevent erosion, while over time the vegetation will grow and the wall will become naturally reinforced with the roots of trees and shrubs.

To construct the wall, the channel should be realigned towards the left floodplain to increase the radius of curvature, reduce the near bank stress, and move the right bank further away from the road where it no longer poses a threat to the infrastructure. The right bank will be backfilled towards the realigned channel and the EnviroLok wall constructed to the current height of the bank. The realigned channel would be given the appropriate bankfull cross-sectional area to have the capacity to move the sediment delivered from upstream without aggrading or degrading. This will further help to stabilize the channel along this reach and minimize any future bank erosion. To help protect the newly constructed wall even further, several log or rock vanes can be placed in the channel to direct flow away from the bank. Taken together, these measures would minimize the erosive force against the bank and help protect the existing road.

The current sediment export rates, and potential benefit of these measures, beyond the immediate benefit of removing threat to public infrastructure, have been calculated and are displayed in **Table 5.1**:

Table 5.1

Pre-Treatment	
Estimated Total Sediment Export	267.8 tons/year
Erosion per length of Channel	0.5 tons/yr/ft
Pounds of Nitrogen	535.6 lbs/year
Pounds of Phosphorus	267.8 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.4 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.7 lbs/year
Pounds of Phosphorus	0.4 lbs/year

Constraints

The biggest constraint at this site could potentially be landowner cooperation and land acquisition. Site 5 is located on private property, with two separate landowners. However, given the critical nature of this project and the threat to public infrastructure, the landowners may be willing to cooperate as it could mean the minimization of liability and property damage. Site access is very good as there are two relatively flat areas in between the creek and the road that would be provide easy construction access.

Alternatives

While a vegetated wall is recommended here, other non-bioengineering solutions could be undertaken to achieve the same effect of protecting the road from the eroding streambank. It should be noted, however, that hard measures such as a sheet-pile wall may tend to accelerate flows around the meander, creating erosion and scour downstream of the currently eroding bank.

Cost-Estimate Breakdown

Table 5.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only.

Table 5.2

Site 5

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stream Restoration	500.00	LF	150.00	$75,000
			Total	$75,000
Mobilization (5%)	1.0	LS		$3,750
Contingencies (10%)	1.0	LS		$7,500
	Total + Mobilization and Contingencies			**$86,250**

Conceptual Plan View

Cub Creek Watershed

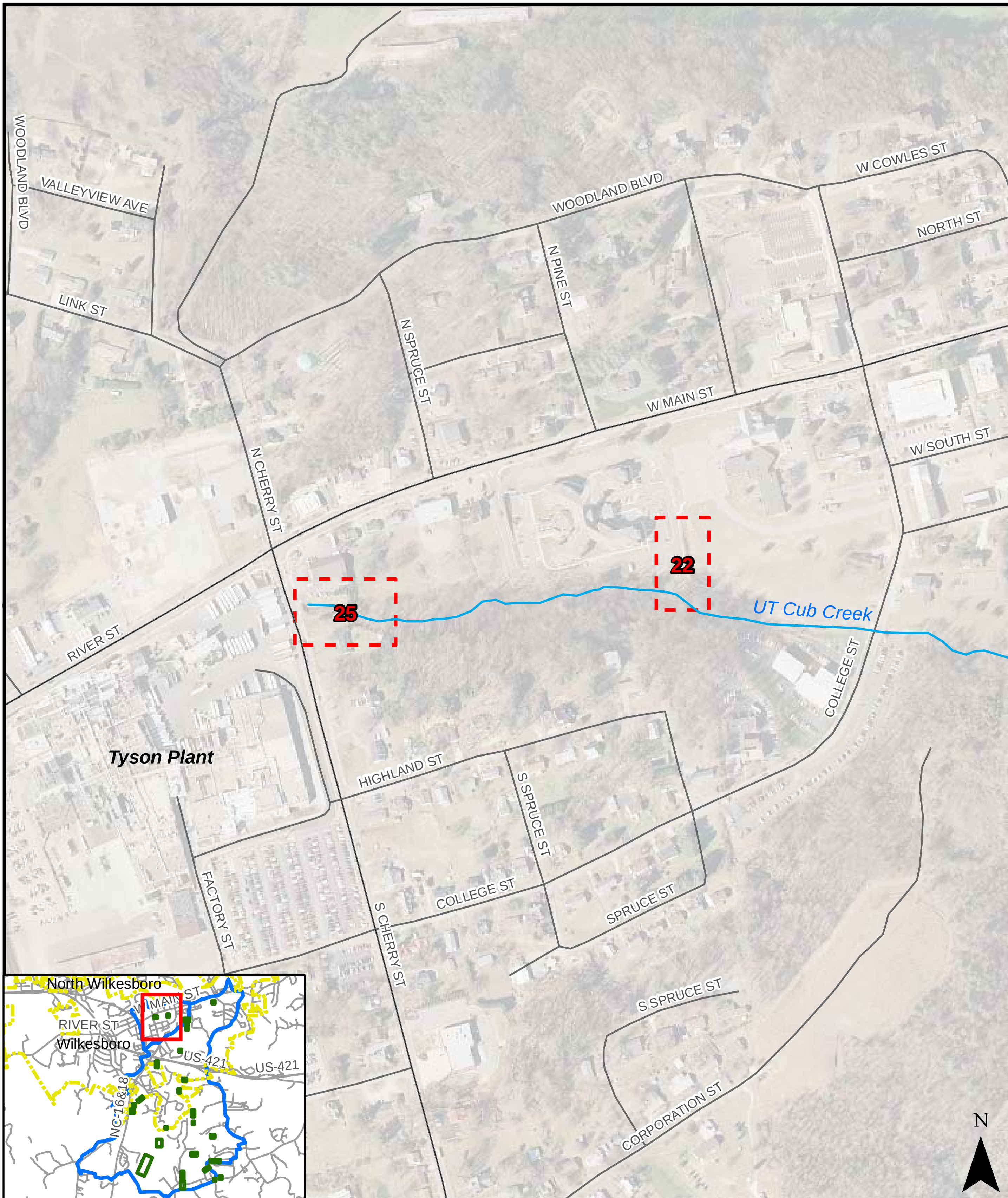
Geomorphic Analysis and Potential Site Identification for Stormwater Structures and Retrofits

SITE 22

Demonstration Site for BMP Retrofit Adjacent to Church

Index Sheet No.: 2

Estimated Construction Cost: $42,726



Legend

- Impoundments (NC Floodmap)
- Streams (NC Floodmap)
- Roads (DOT)
- Problem Areas

AECOM

SITE 22 & 25 Vicinity Map

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Wilkes County, NC

0 200 400 800 Feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 22	2.8	1.2	42.9%

Location

Site 22 is located on the property of Wilkesboro Methodist Church, off of W. Main Street in downtown Wilkesboro. Access to the site can be obtained from the southwest corner of the church parking lot. The ditch that comprises the site runs alongside the parking lot and is adjacent to a baseball field.

Problem Description

Site 22 is presented here as priority site because it presents a good location in which to construct a demonstration BMP for treating runoff and reducing nutrient and pollutant input into UT to Cub Creek. There are many sites, particularly within the UT to Cub Creek watershed, in which similar BMP's could be constructed to help treat nutrients, given enough funding and depending on landowner cooperation. But this site was chosen as an initial location in which to retrofit a BMP because it is owned by a single landowner, has ease of access, high visibility and high potential for success.

Site 22 consists of a drainage ditch that collects the runoff from a church parking lot, where it flows approximately 100 hundred feet alongside a baseball diamond before collecting in a pipe inlet. Another pipe, which carries the flow from the rooftop of the church, also flows into this inlet. The pipe from the inlet then flows another 300 feet downhill before discharging into UT to Cub Creek.

Proposed Solution

The drainage ditch presents an excellent site for construction of a bio-grade step and the area around the inlet could be retrofitted into a bioretention area, for retention and treatment of the runoff from the church parking lot and rooftop. The “bio-grade step” consists of a series of small bio-retention cells filled with a filter media, such as a mixture of sand, fines and organic mater (see Appendix A-Details). Ideally, this media will have an infiltration rate of 1.0 to 2.0 inches per hour, to optimize pollution removal (Schueler, et al., 2007). Each cell is connected to the next cell down-slope by a pervious drain layer of sand or other media, thus allowing stormwater to filter through each cell without the expense of an under-drain. Each cell is designed to overflow to the next after reaching the desired backwater elevation. The surface areas of the “bio-grade step” should be planted with a mixture of woody and herbaceous native plants. The vegetation will provide filtration and stability.

At the bottom of the slope, an existing inlet already has a small impounded area surrounding it. This could be retrofitted into a bioretention area by raising the elevation of the inlet lip and the impoundment which will create ponding and retention of stormwater. The bioretention area would be filled with a porous medium and planted with wetland plants to provide a final means of nutrient removal before the stormwater reaches UT to Cub Creek. A detail of a typical bioretention area is included in Appendix A.

Potential pollution removal rates using this method have been estimated and are shown in **Table 22.1**.

Table 22.1

SITE 22	Annual Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	21.92	2.30	448.86
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
NET REDUCTION	7.67	1.03	381.53
FUTURE CONDITION	14.25	1.26	67.33

Constraints

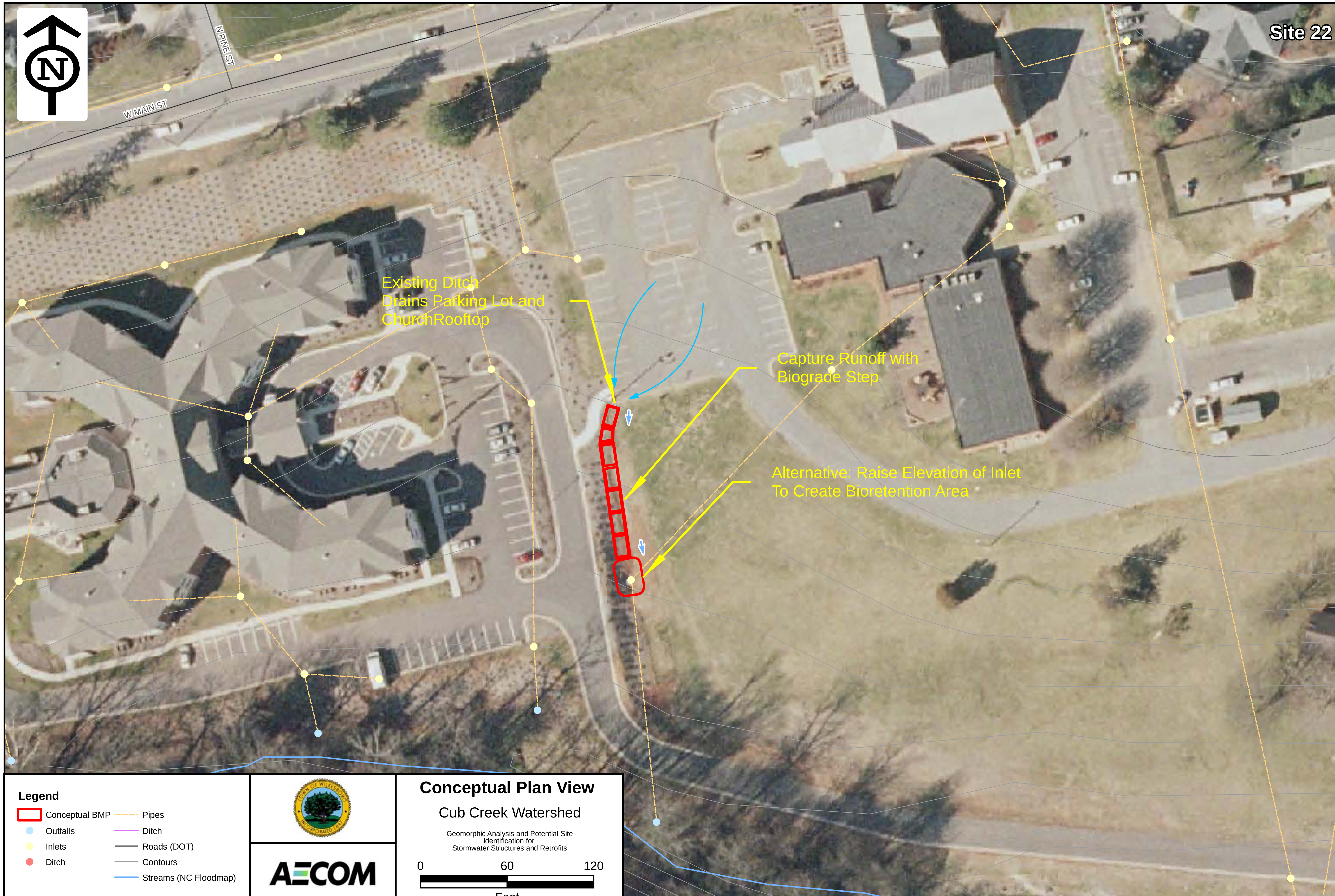
Periodic maintenance will be required for the biograde step and the bioretention area. DWQ may require a drainage easement to be established around the structure, and an operations and maintenance agreement will have to be signed by the landowner or owner of the easement.

Cost-Estimate Breakdown

Table 22.2 shows a conceptual itemized cost estimates for the site. These costs represent construction and maintenance costs only. The costs of the biograde step and the bioretention areas are derived from an equation developed by Brown and Schueler (1997).

Table 22.2

	Site 22 Construction Cost				
Pay Item	**Pay Item Description**	**Estimated Quantity**	**Unit**	**Unit Bid Price**	**Bid Amount**
	Bioretention Area	1720.0	CF	12.62	$21,706
	Biograde Step	1224.0	CF	12.62	$15,447
				Total	$37,153
	Mobilization (5%)	1.00	LS		$1,858
	Contingencies (10%)	1.00	LS		$3,715
		Total + Mobilization and Contingencies			**$42,726**
	Maintenance Costs				
	Maintenance (5% of base construction cost)	1.0	Year		**$2,136**



Conceptual Plan View

Cub Creek Watershed

Geomorphic Analysis and Potential Site Identification for Stormwater Structures and Retrofits

AECOM

SITE 25

Retrofit of Constructed Wetland Immediately Downstream of Tyson Plant

Index Sheet No.: 2

Estimated Construction Cost: $69,754

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 25	114.0	60.0	52.6%

Location

Site 25 is located to the southeast of the intersection of W. Main St. and S. Cherry St. in downtown Wilkesboro. The site can be accessed from a gravel lot that is located on the south side of W. Main St., approximately 500 feet from the intersection of W. Main St. and S. Cherry St.

Problem Description

Site 25 consists of the outfall from the Tyson plant storm sewer system into UT to Cub Creek and an adjacent area on the left relict floodplain of the creek. UT to Cub Creek most likely continued further upstream of the Tyson plant prior to development of the plant, but now is piped until reaching S. Cherry St. At this point the flow is discharged into a concrete channel that flows into the natural channel approximately 50 feet downstream. The watershed of the stream at this point is only approximately 0.3 sq. miles in size, but over 50% of it is covered in impervious surfaces such as rooftops, streets and the parking lots comprising the grounds of the Tyson plant. Thus, a significant amount of nutrients and other pollutants are estimated to be present in the runoff from this watershed (**Table 25.1**). In addition, water quality data collected by the Town of Wilkesboro in 2008 just below the Tyson plant shows high amounts of BOD_5, low dissolved oxygen, and high levels of fecal coliform bacteria. Based on this data, the site presents an opportunity to retrofit a stormwater BMP to treat this runoff and help to improve the water quality of UT to Cub Creek.

Proposed Solution

A stormwater wetland could be constructed on the north side of UT to Cub Creek, adjacent to the sanitary sewer easement, and just to the east of the outfall from the Tyson plant. This area is flat, and already contains a small depression which could be converted into a series of stormwater wetland cells along the left floodplain of the creek (see Photos, **Appendix C**). The stormflow from the plant would need to be diverted to these wetland cells by means of a diversion structure such as a weir placed on the side of the existing concrete channel. As the water level rises with the rising hydrograph of the storm, the stormflow will overflow the weir and be routed to the wetland cells for retention and pollutant removal. During times of normal baseflow, the water surface elevation will be below the elevation of the weir and will flow into UT to Cub Creek.

The stormwater wetland cells could be connected to each other with a porous medium such as sand that will allow infiltration of the stormflow through each cell for added treatment. An existing ditch that drains an area of approximately 8 acres is located on the northeast corner of the site, and the final wetland cell could be sited to capture this flow as well. An outlet device such as a riser barrel or a weir would be constructed in the final cell, and the flow would be routed to a level spreader adjacent to the stream by means of a grass swale. The level spreader is necessary to ensure that flow does not concentrate and erode the streambanks before returning to the stream.

Downstream of the existing concrete channel flowing out of the Tyson Plant is a high (approximately 20') eroding streambank. Any excess material that is available from excavation of the wetland cells could be used to repair this eroding bank, and a series of vanes could be installed along the high stress meander to protect the bank, and help reduce erosion rates.

Ideally, the first 1” of rainfall would need to be treated to capture the “first flush” of stormflow, which research has shown contains the highest concentration of pollutants (Schueler et al., 2007). Preliminary calculations of the depth needed at this site, based on the available surface area, show that the available depth is not sufficient to treat the entire “first flush”. However, a significant portion of it could still be treated with this solution.

Potential pollution removal rates using this method have been estimated and are shown in Table 25.1.

Table 25.1

SITE 25	Annual Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	1036.01	139.86	30562.24
STORM WATER WETLAND TREATMENT REMOVAL %	40.00%	35.00%	85.00%
NET REDUCTION	414.40	48.95	25977.91
FUTURE CONDITION	621.60	90.91	4584.34

Constraints

The chief constraints at this site will be landowner agreement and working within the constraints posed by the sewer line that runs through the site. Additionally, a steep embankment has been built up adjacent to the concrete channel for a parking lot associated with an ATV Sales and Repair Shop. Relocation of the sewer lines may need to be coordinated in order to implement this project. Construction access may also be difficult. Equipment would most likely have to enter the site from the east along the sewer easement or from a gravel lot to the north, depending on landowner willingness.

Cost-Estimate Breakdown

Table 25.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for the stormwater wetland is derived from a cost per cubic foot stormwater wetlands reported by Schueler, et al. (2007). The contingency fee for this site has been increased due to the difficulty of access and site constraints.

Table 25.2
SITE 25 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	50267.0	CF	Equation Derived	$58,129
			Total	$58,129
Mobilization (5%)	1.0	LS		$2,906
Contingencies (15%)	1.0	LS		$8,719
		Total + Mobilization and Contingencies		**$69,754**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$3,488**


Site 25
N
W MAIN ST
N CHERRY ST
N SPRUCE ST
RIVER ST
S CHERRY ST
HIGHLAND ST
Tyson Plant
Wetland Cells
Use Excavated Material
From Wetland Construction
to Backfill Eroding Streambank
Level Spreader
Existing Sewer Line Poses
Constraint, Could Be Relocated
Redirect Flow into Wetland Cells
with In-Channel Weir
Existing Outfall and Concrete
Channel from Tyson Facility
Legend
Wetland Boundary
Level Spreader
SS Manhole
Outfalls
Inlets
Ditch
Pipes
Existing Ditch
Roads (DOT)
Contours
Streams (NC Floodmap)
AECOM
Conceptual Plan View
Cub Creek Watershed
Geomorphic Analysis and Potential Site
Identification for
Stormwater Structures and Retrofits
0
80
160
Feet

References

Center for Watershed Protection. October 30th, 2007. *Stormwater Management Fact Sheet: Stormwater Wetland.* Accessed online at [http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Wetland/Wetland.htm]..

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Rosgen. D. 2006. *Watershed Assessment of River Stability and Sediment Supply*. Wildland Hydrology. Fort Collins, Colorado.

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

Schueler, Hirschman, Novotney and Zielinski. 2007. *Urban Stormwater Retrofit Practices Version 1.0*. Center for Watershed Protection. Ellicott City, MD.

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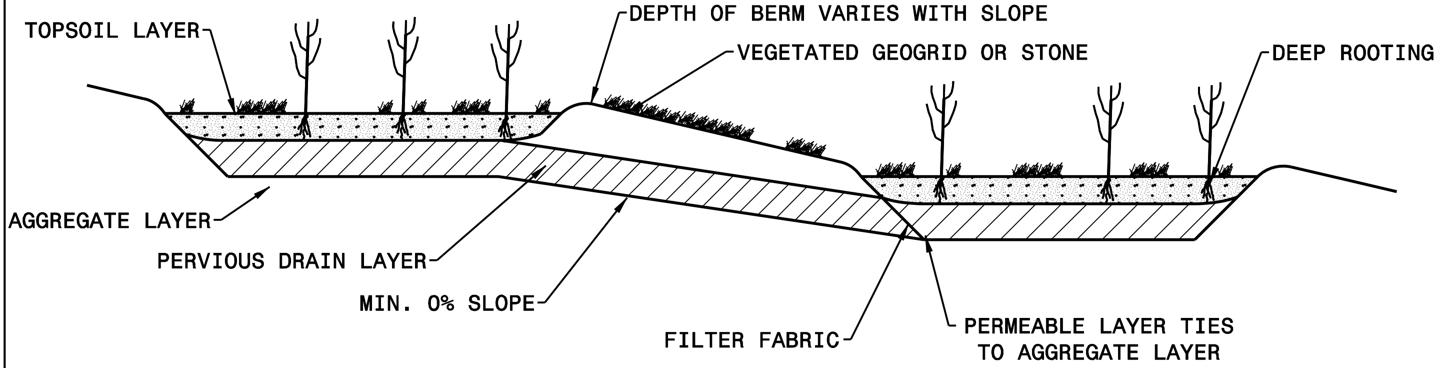
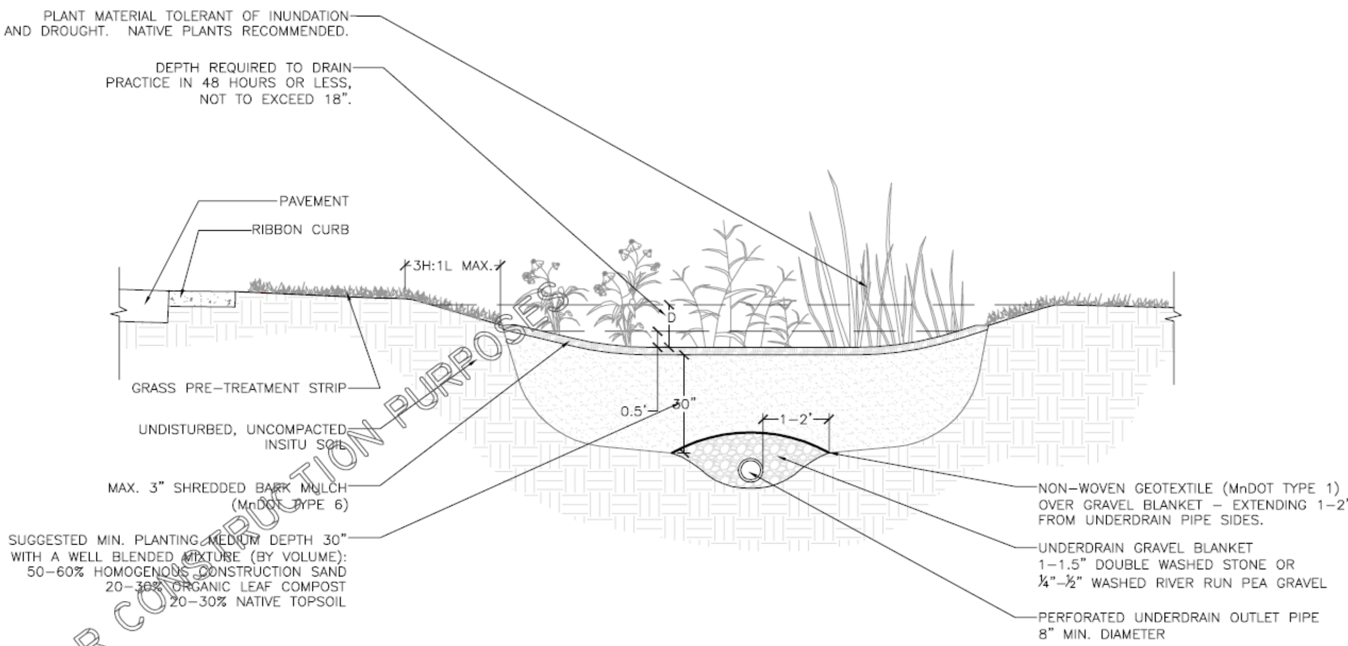
APPENDIX A

Details

STORMWATER BMP DETAILS



BIO-GRADE STEP
SCALE: NTS



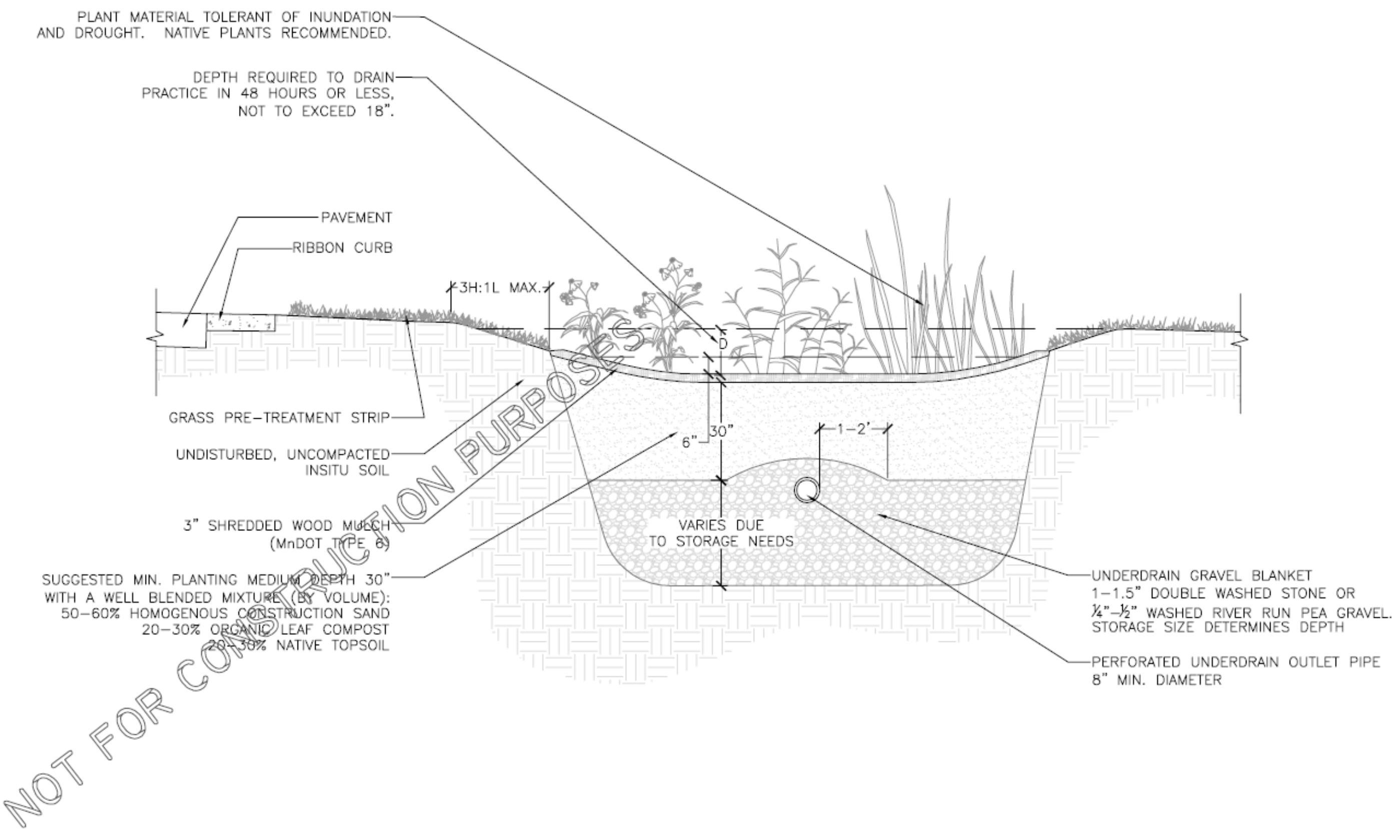
NOT FOR CONSTRUCTION PURPOSES

NOTE: NORTH CAROLINA SPECIFICATIONS MAY VARY

BIORETENTION AREA- FILTRATION AND PARTIAL RECHARGE
SCALE: NTS

Source: Minnesota Stormwater Manual. Version 1.1
Minnesota Pollution Control Agency

STORMWATER BMP DETAILS



NOT FOR CONSTRUCTION PURPOSES

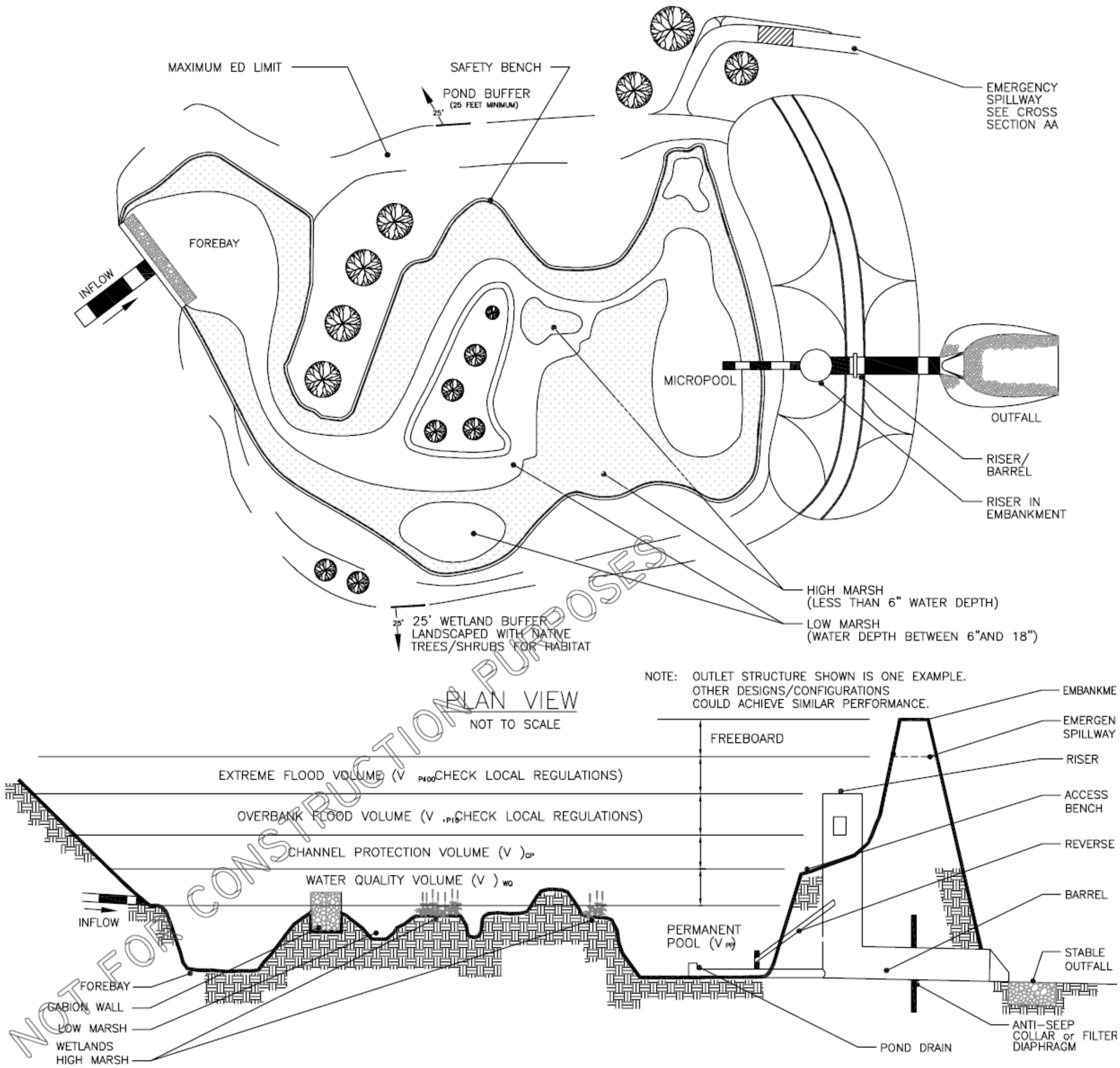
NOTE: NORTH CAROLINA SPECIFICATIONS MAY VARY

BIORETENTION AREA- FILTRATION/INFILTRATION/RECHARGE

SCALE: NTS

Source: Minnesota Stormwater Manual. Version 1.1
Minnesota Pollution Control Agency

STORMWATER BMP DETAILS



NOT FOR CONSTRUCTION PURPOSES

EXAMPLE STORMWATER WETLAND

SCALE: NTS

Source: Minnesota Stormwater Manual, Version 1.1
Minnesota Pollution Control Agency

APPENDIX B

Photo Log

Site 1- Option A

Eroding Streambank

Eroding Streambank

Existing Cub Creek Channel Looking upstream.

A small ditch flows through the right floodplain of Cub Creek.

Looking Upstream at Cub Creek from the right floodplain.

View of right floodplain and greenway in park.

Site 1- Option B

The channel of UT to Cub Creek is deeply incised and aggrading in most sections.

Typical view of the channel of UT to Cub Creek.

There are numerous outfalls into the channel along this reach of UT to Cub Creek.

A view of the right floodplain.

Site 1- Option C

Looking upstream at the end of the existing restoration on Cub Creek.

A typical bank on this reach of Cub Creek.

The overly wide channel is causing aggradation and increasing near bank stress on the outer meanders.

The first meander in this section of Cub Creek is overly tight, and is creating high conditions of erosion on the outer bank (shown in the left of the photo).

The left floodplain is comprised of a grassy field owned by the Town, which affords an opportunity to realign the stream.

Site 5

The extreme eroding bank on this outer meander. The guardrail for Foster St. can be seen at the top of the bank.

A view of the same bank after the vegetation has died-off, showing the mass wasting occurring on this bank.


Bank erosion starts where the outer meander begins.


Looking upstream at the eroding stretch of bank.

Site 22

The existing drainage ditch.

The existing drainage ditch.


An existing inlet at the base of the ditch could be raised to create a bioretention area.


Looking upslope at the ditch and the inlet area.

A view of the ditch and the baseball field along which it flows. The ditch flows into a pipe which discharges into UT to Cub Creek (top of photo).

Site 25

The outfall and concrete channel coming out of the Tyson plant, looking upstream.

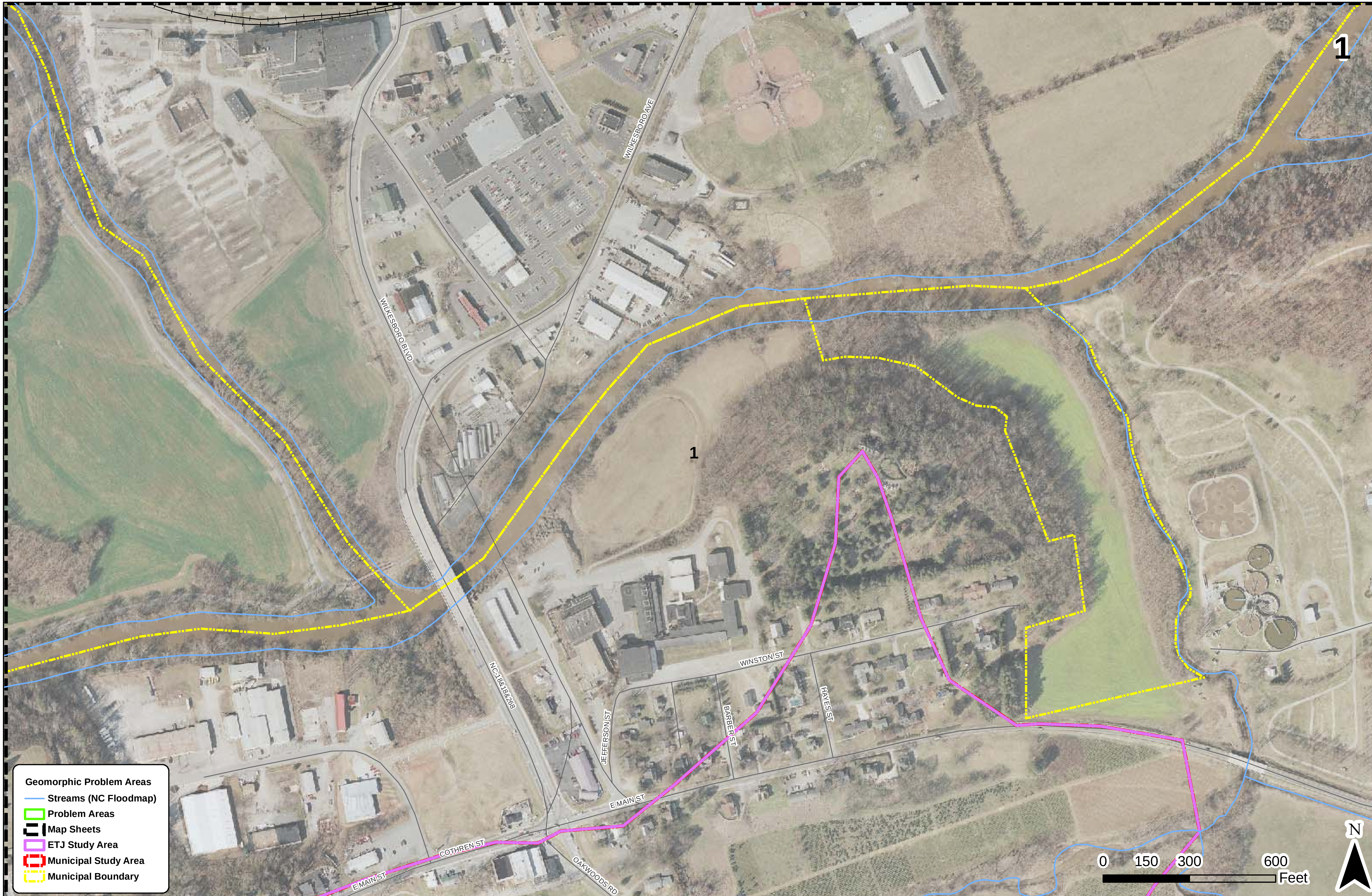
The concrete channel and where it discharges into UT to Cub Creek, looking downstream.

The bed of UT to Cub Creek has scoured significantly below the concrete channel. Water sampling here shows high concentrations of BOD_5.

A grassy, flat area on the left floodplain provides a good location to construct wetland cells for treatment of the stormwater.

APPENDIX C

Raw Data Maps


1
1
WILKESBORO AVE
WILKESBORO BLVD
NC-18&18&268
WINSTON ST
HAYES ST
BARBER ST
JEFFERSON ST
E MAIN ST
COTHREN ST
E MAIN ST
OAKWOODS RD
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
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Feet
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2
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
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2
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Feet
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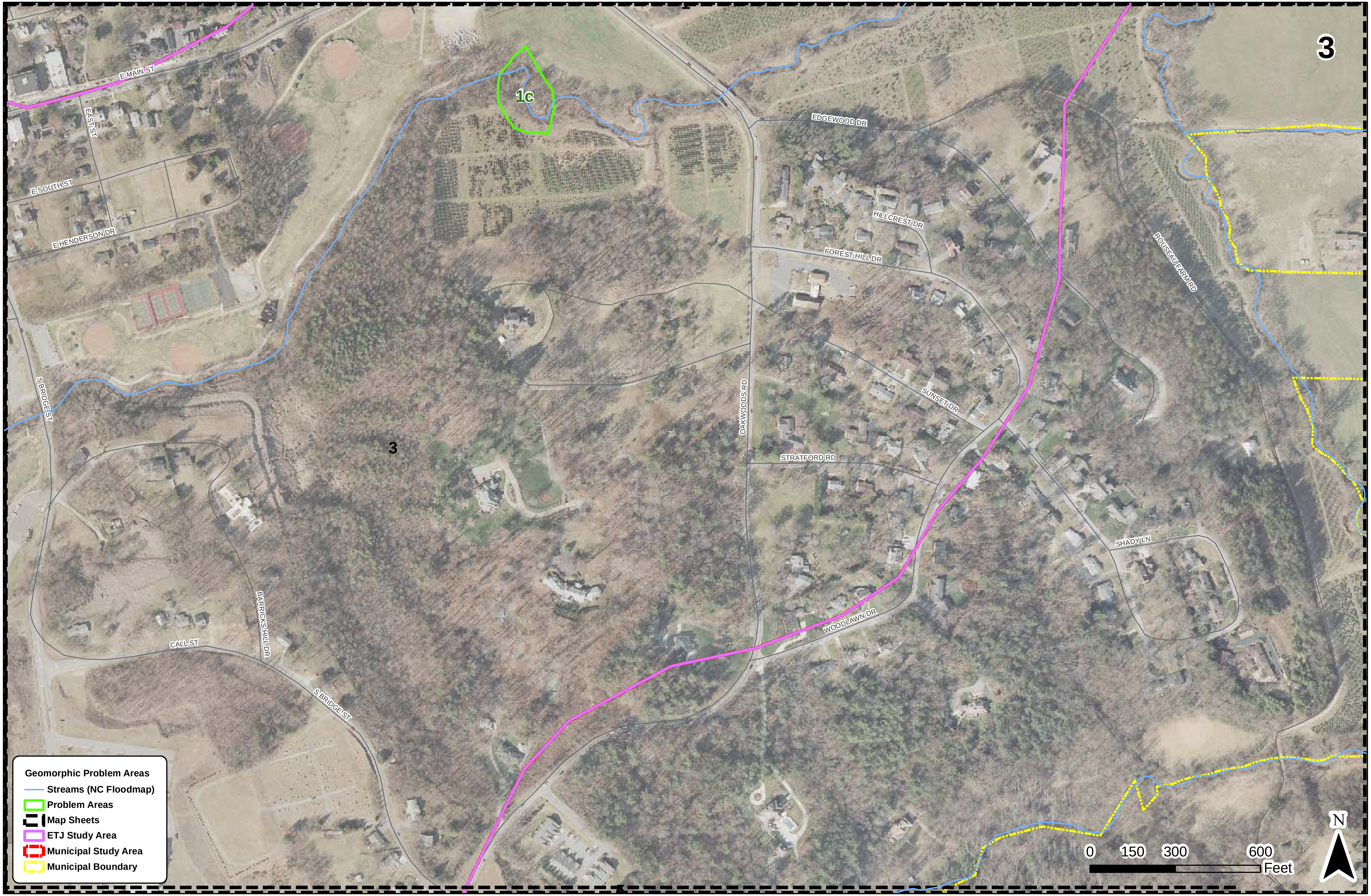
VALLEYVIEW AVE
WESTVIEW DR
GREENBRIAR LN
LINK ST
WOODLAND BLVD
W COWLES ST
E NORTH ST
BROAD ST
N BRIDGE ST
NORTH ST
E MAIN ST
N PINE ST
N WEST ST
W MAIN ST
E SOUTH ST
N SPRUCE ST
SOUTHWEST ST
S BRIDGE ST
N MORAVIAN ST
W SOUTH ST
W HENDERSON DR
N CHERRY ST
N BROOK ST
HILL AVE
CURTIS BRIDGE RD
RIVER ST
COLLEGE ST
WELBORN AVE
HIGHLAND ST
S SPRUCE ST
S CHERRY ST
FACTORY ST
SPRUCE ST
S FACTORY ST
S BROOK ST
CHURCH ST
WILKES ST
S MORAVIAN ST
CORPORATION ST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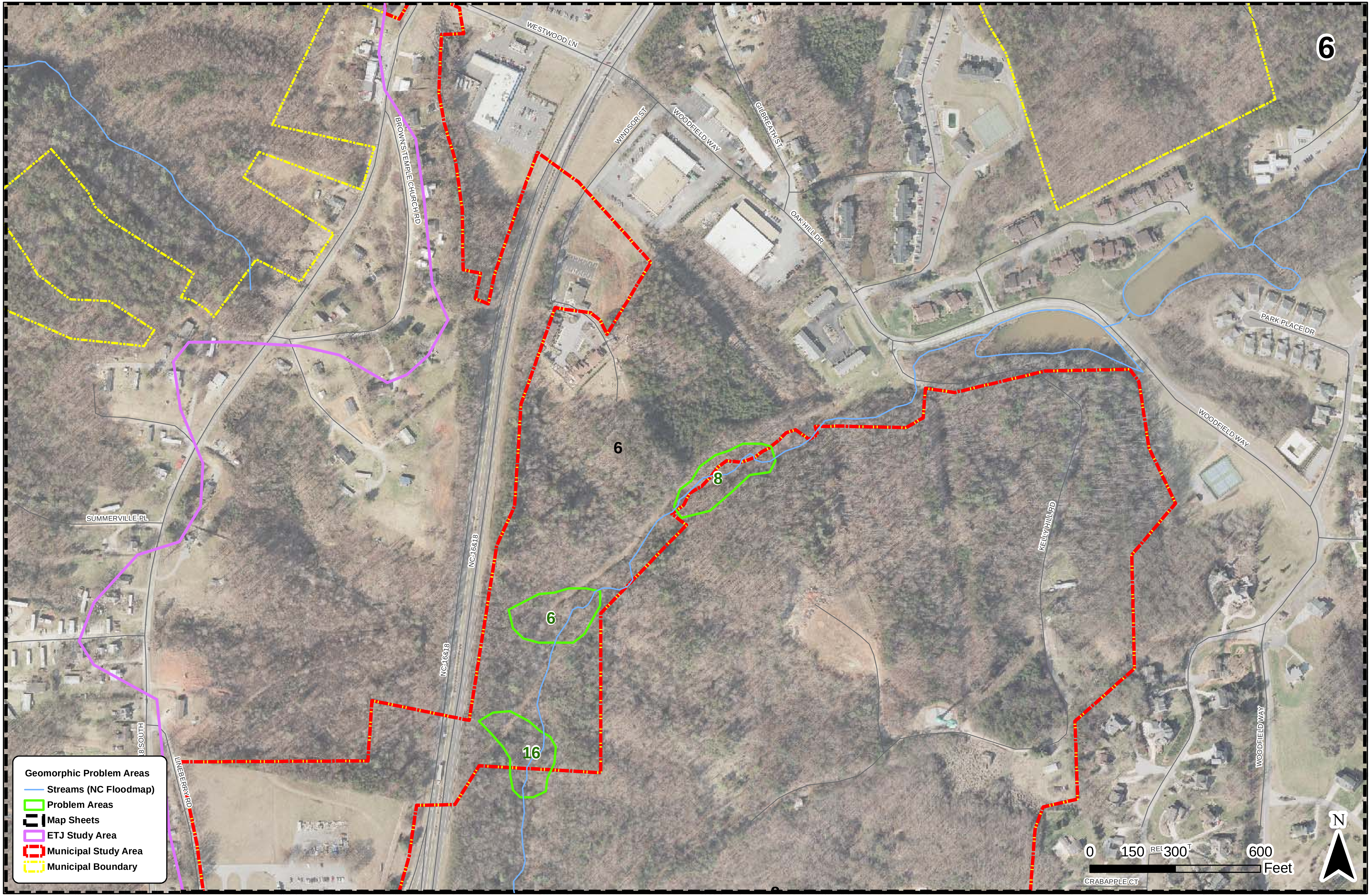
EAST ST
E SOUTH ST
E HENDERSON DR
S BRIDGE ST
EDGEWOOD DR
HILLCREST DR
FOREST HILL DR
ROUSEAU FARM RD
SUNSET DR
OAKWOODS RD
STRATFORD RD
SHADY LN
WOODLAWN DR
BARRICKS HILL DR
CALL ST
S BRIDGE ST
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0
150
300
600
Feet
N


4
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
N
9
20
4
WILKES ST
CORPORATION ST
S BROOK ST
UNION ST
S MORAVIAN ST
RIDGE ST
US-421
S SPRUCE ST
JAMES ST
W PINE CIR
RUFFIN ST
S CHERRY ST
FLETCHER ST
KELLY ST
FRAZIER ST
NC-16&18
GILBREATH ST
SR#2516


5
OAKWOODS RD
WESTOVER DR
US-421
EDGEWOOD RD
US-421
BRUSHY MOUNTAIN RD
5
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0
150
300
600
Feet
N


6
WESTWOOD LN
WINDSOR ST
WOODFIELD WAY
GILBREATH ST
OAK HILL DR
BROWNS TEMPLE CHURCH RD
NC-16&18
SUMMERVILLE PL
PARK PLACE DR
WOODFIELD WAY
KELLY HILL RD
LINEBERRY RD
WOODFIELD WAY
CRABAPPLE CT
6
8
6
16
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
N


7
SR#2516
FOSTER ST
INDUSTRIAL PARK RD
BIRCH ST
5
17
7
15
BRUSHY MOUNTAIN RD
SLEEPY HOLLOW RD E
SLEEPY AVE WEST RD
FAIRVIEW CIR
OAKWOODS LN
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
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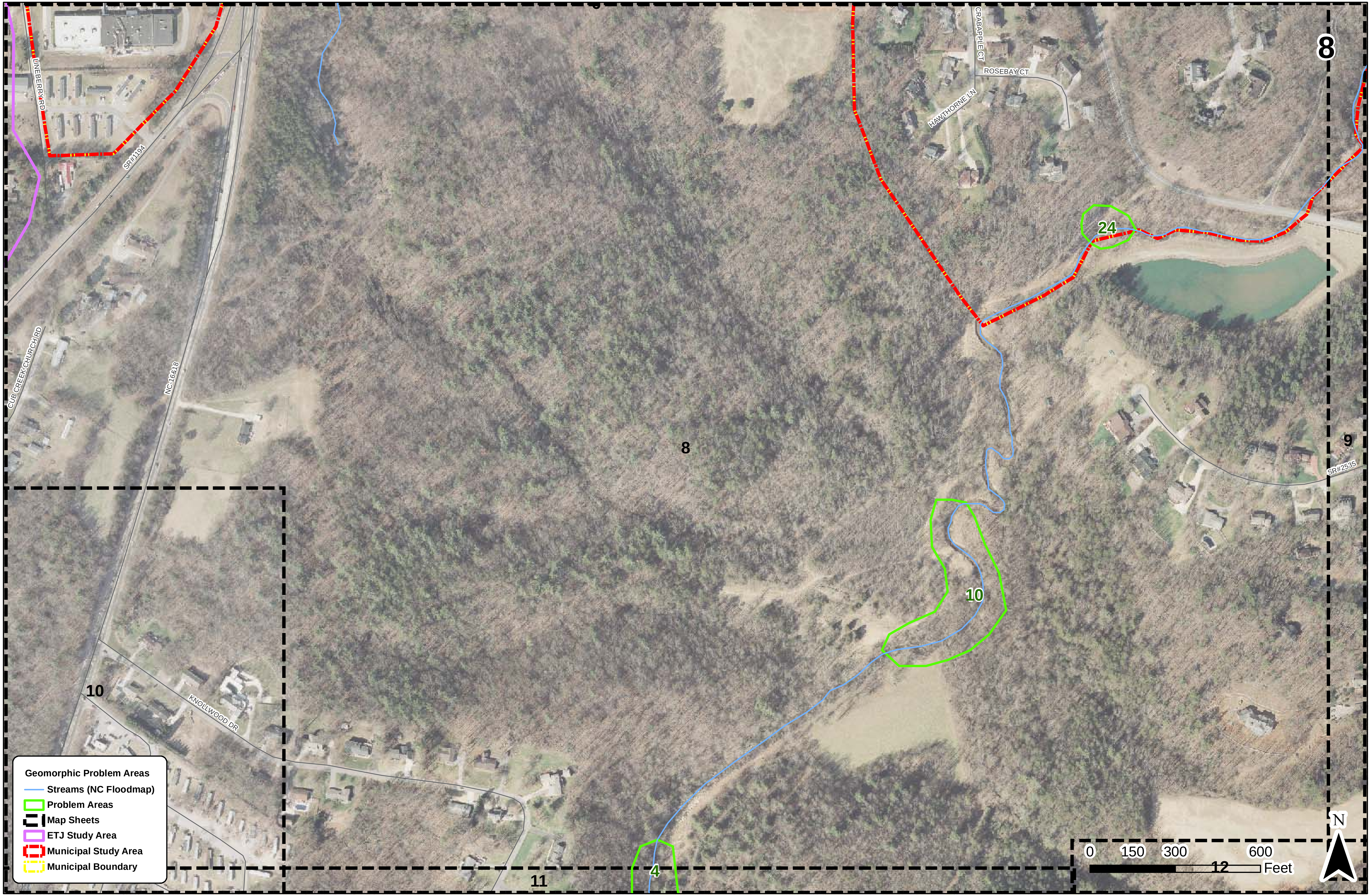
8
LINEBERRY RD
SR#1194
CRABAPPLE CT
ROSEBAY CT
HAWTHORNE LN
24
CUB CREEK CHURCH RD
NC-16&18
8
9
SR#2535
10
10
KNOLLWOOD DR
4
11
12
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0
150
300
600
Feet
N


9
13
18
7
8
9
12
13
SR#2556
FOREST DR
CLUBHOUSE RD
SR#2535
SR#2508
SANDWEDGE RD
JESSIE REINS RD
BRUSHY MOUNTAIN RD
BRUSHY AVE
OAKHILL LN
COUNTRY OAKS LN
COUNTRY CLUB HILLS LN
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
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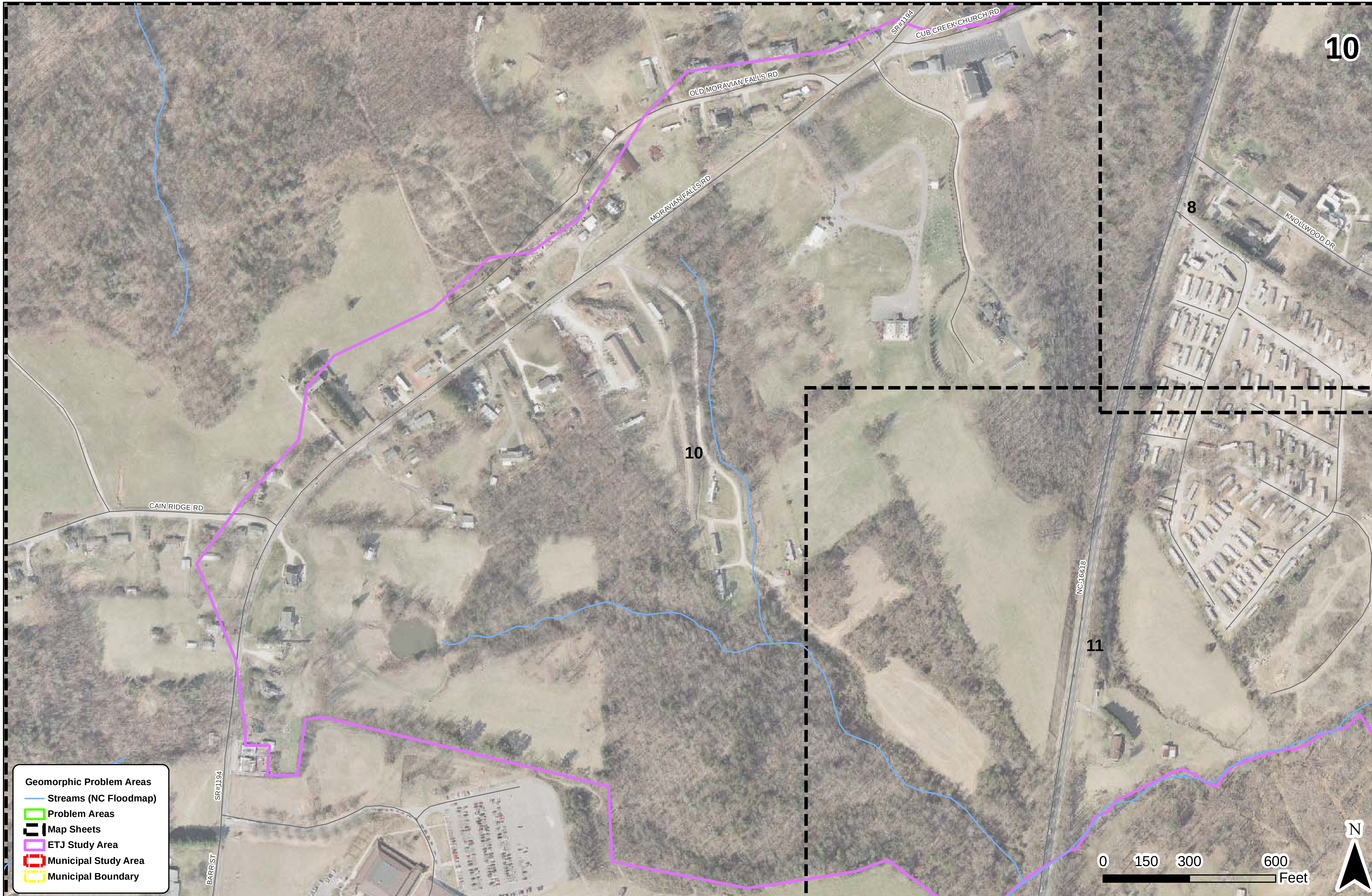
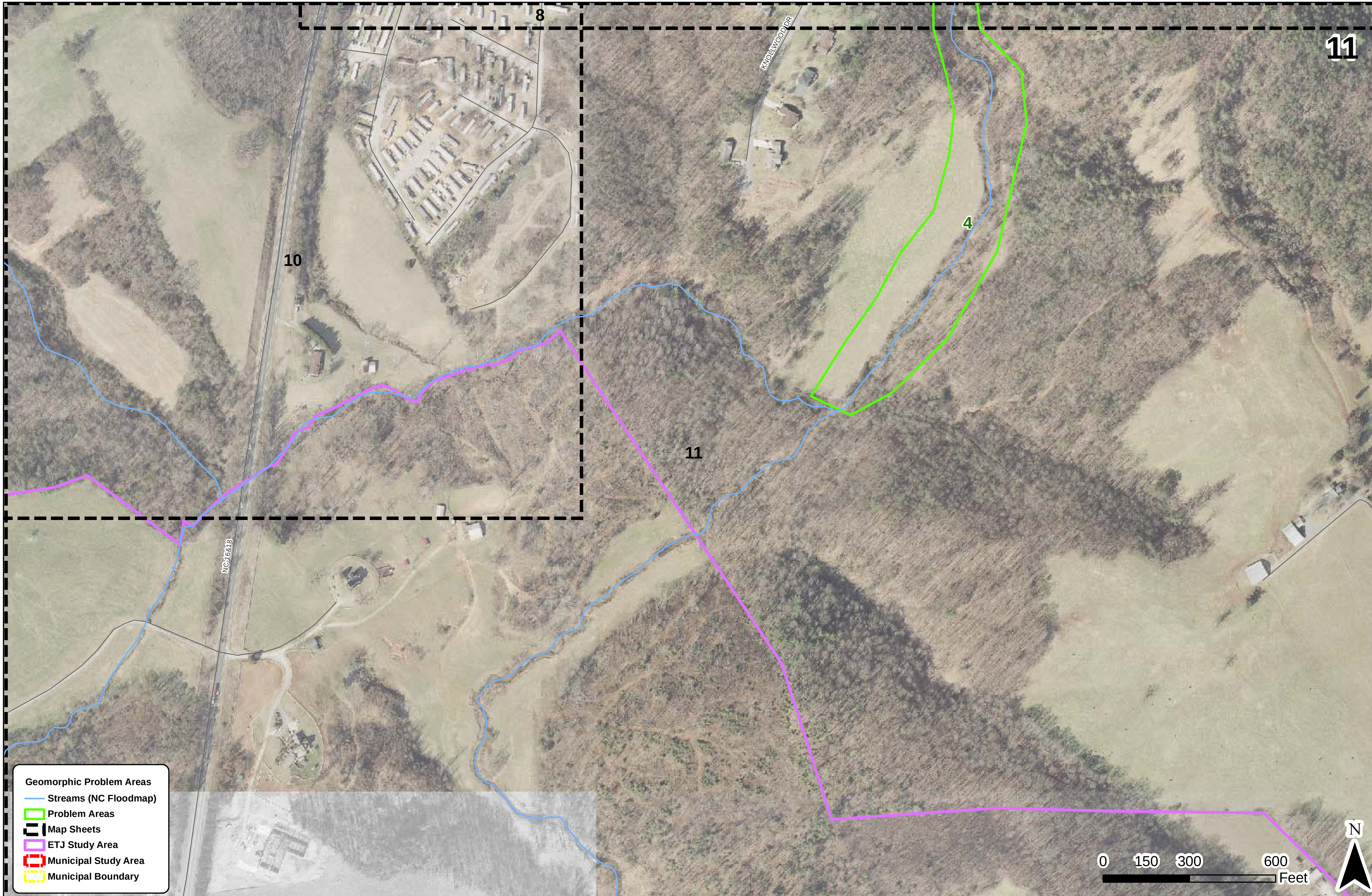
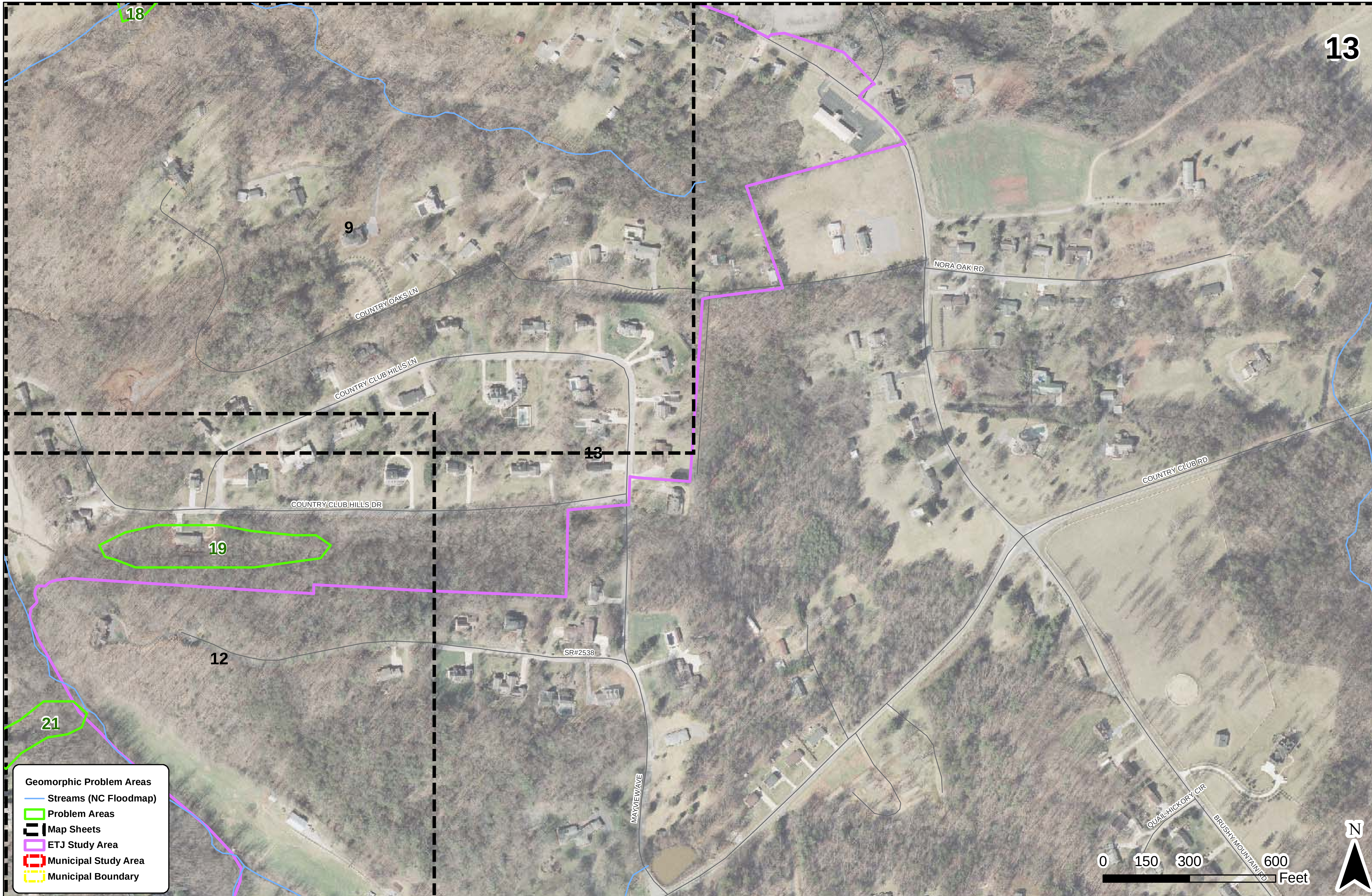


10
OLD MORAVIAN FALLS RD
MORAVIAN FALLS RD
CUB CREEK CHURCH RD
SR#1194
CAIN RIDGE RD
KNOLLWOOD DR
NC-16&18
BARR ST
8
10
11
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
N



11
8
10
11
4
KNOLLWOOD DR
NC-16&18
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0
150
300
600
Feet
N

8
7
9
12
COUNTRY CLUB HILLS LN
COUNTRY CLUB HILLS DR
19
CLUBHOUSE RD
SR#2538
13
21
SR#2469
3
12
SR#2560
12
S OAKWOODS TRCE
11
FAIRWAY LN
PARTRIDGE LN
COUNTRY CLUB RD
SR#2526
14
COUNTRY CLUB RD
SR#2527
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
N


13
18
9
19
12
21
13
COUNTRY OAKS LN
COUNTRY CLUB HILLS LN
COUNTRY CLUB HILLS DR
NORA OAK RD
COUNTRY CLUB RD
SR#2538
MAYVIEW AVE
QUAIL HICKORY CIR
BRUSHY MOUNTAIN RD
Geomorphic Problem Areas
Streams (NC Floodmap)
Problem Areas
Map Sheets
ETJ Study Area
Municipal Study Area
Municipal Boundary
0 150 300 600
Feet
N