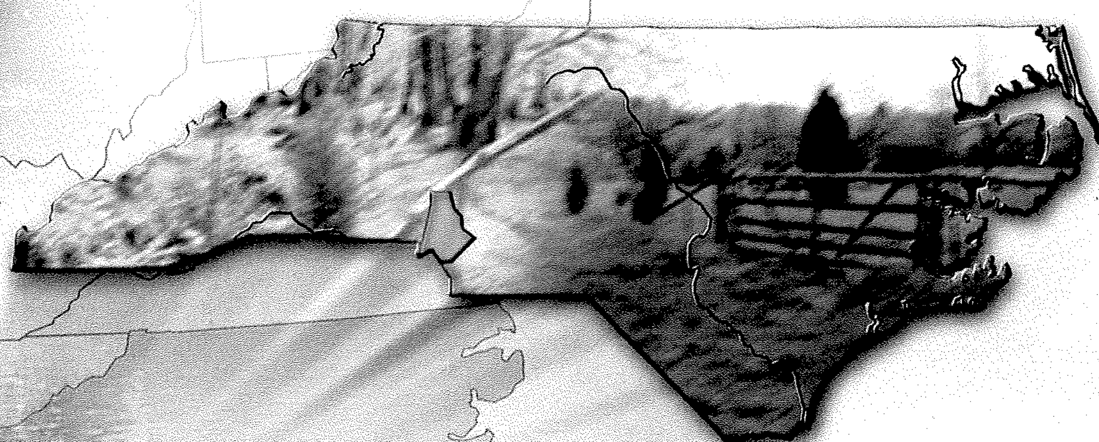
Restoration Report

Cato Farm Stream Restoration Project



Prepared for

North Carolina Wetlands Restoration Program

NC Wetlands Restoration Program

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July 2002

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Introduction

Project Description and Location

The Cato Farm Stream Restoration project will restore approximately 1790 linear feet of degraded stream to approximately 2295 linear feet of stream in two sections – a Rosgen Priority 1 Restoration Section(Rosgen E stream type) in the upper two-thirds of the project reach and a Transition Section connecting the Restoration Section back to the existing stream (Rosgen B stream type). In addition, the Rosgen E stream-type portion of the stream restoration will meander through a former wetland area of pasture that had been previously drained, re-hydrating the soils of the wetland. Figure 1 is an overview of the project.

The stream restoration site is at Cato Farm, located in northern Mecklenburg County, North Carolina, just east of the Town of Huntersville (see Figure 2). The existing stream is an unnamed tributary (UT) draining an area of 0.41 square miles into Clark's Creek in the Yadkin-Pee Dee River Basin (see Figure 3).

Project Goals and Objectives

The stream restoration project is designed to meet the following goals:

- Restore the stream to a stable form
- Restore the riparian zone adjacent to the stream
- Provide a crossing for cattle at one location along the project reach
- Provide fencing to prevent cattle from entering the riparian corridor (stream and adjacent overbank area)

Assessment and Design Methods

Overview

Any stream channel alteration should be designed using natural channel design principles. Design of restoration of degraded stream reaches first involves accurately diagnosing the current condition of a stream. Understanding of stream type, condition, and potential is essential to developing adequate restoration measures. This combination of assessment and design is often referred to as natural channel design. The following natural channel design methodology was employed for the Cato Farm Stream Restoration Project.

Natural Channel Design Methodology

Dave Rosgen has developed a natural channel design methodology that can be used in conjunction with his channel classification scheme to design stream restoration projects. Other approaches to stream restoration design also exist, though the focus of stream restoration in North Carolina has typically followed the Rosgen methodology. This section outlines the methodology described by Rosgen, modified for use at the Cato Farm site.

The first step in a stream restoration design is to study the stream and its watershed to understand the relationship between the stream and its drainage basin and determine the causes of stream degradation. Bankfull discharge and other flows should be determined for the watershed. Once sources of stream degradation are identified and bankfull discharge is determined, a plan for restoration can be formulated.

It is necessary to find a reference reach that has the same valley type, land type, and stream type as the design reach. A reference reach should be located in the immediate area or in the closest watershed in the same hydro-physiographic province. After an acceptable reference reach is selected, morphological characterization information should be compiled for the reference reach and the design reach to determine the relationships associated with the natural stable channel and existing morphology of the design reach.

A series of iterative calculations are performed, using data from the reference reach, to determine the appropriate stable cross-sectional, profile, and plan form dimensions of the design reach. When all channel dimensions have been calculated and checked, the proposed plan view over the existing channel with the appropriate bankfull width, pool width, meander wavelength, radius, belt width, etc. is laid out. The alignment should mimic natural variability to avoid a totally symmetrical layout for visual/natural appearance objectives.

Once the plan view has been sketched, the next step is to plot longitudinal profiles for both existing and proposed conditions. Stationing from longitudinal profile should be used to identify (name) cross-section locations and to implement the layout. The profile shows proposed depths and slopes of bed features (riffles, steps, and pools) as previously computed. In addition, cross-sections for existing and proposed conditions should be plotted using an overlay. Typical cross-sections for riffles, pools, steps, glides, and other features are plotted. The designer should check to ensure that dimensions are properly scaled, and that point bar slopes, entrenchment ratio, and side slope gradients are shown. Specific stabilization structures such as grade control structures, stream bank revetment, riparian vegetation, and other design features can now be added. These features should be shown on the plan, profile, and section views.

Detailed design drawings for the specific stabilizing features such as cross-vane for grade control and bank stabilization will be developed. These drawings, used for inserts into the design package, should show all dimensions and installation details.

Finally, the project will have a monitoring plan layout to ensure that the design implementation will be evaluated to:

- Ensure that stabilization structures are functioning properly.
- Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, and sediment transport and stream bank erosion rates.
- Determine biological response (food chains, standing crop, species diversity, etc.).
- Determine the extent to which the restoration objectives have been met.

Stream Classification

In 1985, Rosgen developed a stream classification system that categorizes essentially all types of channels based on measured morphological features, updated for broad applicability and communication among users. The Rosgen stream classification system uses bankfull stage as the basis for measuring the width/depth ratio and entrenchment ratio, two of the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures.

The Rosgen stream classification system includes several types (A, B, C, D, DA, E, F, and G) based on a hierarchical system (Rosgen, 1994, 1996). The first level distinguishes between single and multiple thread channels. Streams are then separated based on degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are evaluated to further subdivide the streams. Even more subtypes are then classified according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern. Figure 4a presents Rosgen's stream classification.

Bankfull Discharge

Natural channel design principles require that the proposed stream be designed with consideration of surface hydrology and runoff processes. Restored channels should be sized (width, depth, and cross-sectional area) for the bankfull discharge. Bankfull discharge is the discharge that fills the channel to the elevation where its floodplain begins. It is a frequently occurring flow of moderate magnitude. Nationally, data collected regarding bankfull discharge indicate a recurrence interval between 1 and 2 years (NC Stream Restoration Institute, 2001).

There are several field indicators of bankfull stage, an important determination used to subsequently determine bankfull discharge. Bankfull stage is the height of water, or stage, during bankfull flow. This may or may not be the top of the stream bank. If the stream has downcut due to changes in the watershed or streamside vegetation, the bankfull indicator may be a small bench or scour line on the stream bank. The top of the bank, which was formerly the floodplain, is called a "terrace" in this case. The most consistent bankfull indicator in North Carolina streams is the uppermost scour line (NC Stream Restoration Institute, 2001). Other bankfull indicators include the back of a point bar, the upper break in slope of the bank, and occasionally the top of the bank. Often, there is another prominent feature known as the "inner berm," also known as the "mean high water mark." This feature is usually identified as a scour line or small bench halfway between the low flow water surface and the bankfull stage.

Reference Reach

The reference reach is a channel segment that is stable—neither aggrading nor degrading—and is of the same morphological "type" as the channel under consideration for restoration. The reference reach is used to develop design criteria based on morphological relationships associated with the bankfull discharge stage. This reach should be used as the "blueprint" for the channel design (Rosgen, 1998). Data on channel characteristics in the form of dimensionless ratios are developed for each stream type. These ratios can then be applied to disturbed channel reaches for the purpose of designing restoration and stabilization projects (Rosgen, 1998).

Priorities of Stream Restoration

Though incised streams can occur naturally in certain landforms, they are often the product of urbanization. High, steep stream banks, poor or absent in-stream or riparian habitat, increased erosion and sedimentation, and low sinuosity are all characteristics of incised streams. Complete restoration of the stream, where the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is sometimes impractical due to encroachment into the abandoned floodplain terrace by homes, roadways, utilities, etc. A "priority system" for the restoration of incised streams, developed and used by Rosgen (1997) "considers a range of options based on numerous factors," providing the best level of stream restoration possible for the given setting. Figure 4b presents various restoration/stabilization options for incised channels within the framework of the Rosgen's "priority system." Generally:

- Priority 1 reconnects an incised stream with its abandoned floodplain (see item 'a' in Figure 4b)
- Priority 2 re-establishes a functional floodplain at the degraded stream's existing elevation or higher, but not at the original level (see items 'b' and 'c' in Figure 4b)
- Priority 3 converts the degraded channel to a new stream type without an active floodplain but containing a floodprone area (see items 'd' and 'e' in Figure 4b)
- Priority 4 stabilizes the channel in place (see item 'f' in Figure 4b)

Existing Conditions

Watershed

Overview

The UT that is the site of the proposed restoration is in the Clark's Creek watershed in northern Mecklenburg County, North Carolina. Clark's Creek drains toward the east, into the Yadkin-Pee Dee River Basin (see Figure 3).

Surface Water Classification

Surface Water Classifications are designations applied to surface water bodies, such as streams, rivers and lakes, which define the best uses to be protected within these waters (for example swimming, fishing, drinking water supply) and carry with them an associated set of water quality standards to protect those uses. Surface water classifications are one tool that state and federal agencies use to manage and protect all streams, rivers, lakes, and other surface waters in North Carolina. Classifications and their associated protection rules may be designed to protect water quality, fish and wildlife, the free flowing nature of a stream or river, or other special characteristics.

The waters of Clarks Creek are Class C waters. All surface waters in North Carolina waters must at least meet the standards for Class C (fishable / swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water (Water Supply Classes I through V). Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner. There are no restrictions on watershed development or types of discharges.

Soils

The soils of the project watershed are shown in Figure 8, from the USGS *Soil Survey of Mecklenburg County, North Carolina.* Monacan soils occur as long, narrow bands parallel to the streams and drainageways in the watershed. Soils of the Monacan series are deep, moderately well and somewhat poorly drained with moderate permeability. They formed in recent alluvial sediments of the Piedmont and Coastal Plain. Slopes are commonly less than 2 percent. In addition to soils of the Monacan series, Wilkes, Cecil, and Helena soils are found along and adjacent to the streams. Upland soils are predominantly Enon and Iredell. Table 1 provides brief descriptions of these soil types.

TABLE 1
Watershed Soil Types and Descriptions
Cato Farm Stream Restoration Project

Soil Name	Description
Cecil	The Cecil series consists of very deep, well drained moderately permeable soils on ridges and side slopes of the Piedmont uplands. They are deep to saprolite and very deep to bedrock. They formed in residuum weathered from felsic, igneous and high-grade metamorphic rocks of the Piedmont uplands. Slopes range from 0 to 25 percent. Well drained; medium to rapid runoff; medium internal drainage; moderate permeability. About half of the total acreage is in cultivation, with the remainder in pasture and forest. Common crops are small grains, corn, cotton, and tobacco
Enon	The Enon series consists of very deep, well drained, slowly permeable soils on ridgetops and side slopes in the Piedmont. They are moderately deep to saprolite and very deep to bedrock. They have formed in clayey residuum weathered from mafic or intermediate igneous and high-grade metamorphic rocks such as diorite, gabbro, diabase, or hornblende gneiss or schist. Slope ranges from 2 to 45 percent. Well drained; medium to rapid runoff; slow internal drainage; slow permeability. Cleared areas are used primarily for growing pasture, hay, corn, soybeans, and small grain. Forested areas have varying association of shortleaf, loblolly, and Virginia pine, eastern redcedar, white oak, northern and southern red oak, hickory, yellow-poplar, sweetgum, blackgum, dogwood, and holly.
Iredell	The Iredell series consists of moderately well drained, slowly permeable soils. These soils formed in material weathered from diabase, diorite, gabbro, and other rocks high in ferro-magnesium minerals. They are on uplands throughout the Piedmont. Slope is dominantly less than 6 percent but ranges up to 15 percent. Moderately well drained; medium runoff; very slow permeability. Most areas are used for growing cotton, small grain, hay, or pasture. Forested areas are dominantly in post and white oaks.
Helena	The Helena series consists of very deep, moderately well drained, slowly permeable soils that formed in residuum weathered from a mixture of felsic, intermediate, or mafic igneous or high-grade metamorphic rocks such as aplitic granite or granite gneiss that is cut by dykes of gabbro and diorite, or mixed with hornblende schist or hornblende gneiss. These soils are on broad ridges and toeslopes of the Piedmont uplands. Slope is dominantly between 2 to 10 percent but ranges from 0 to 15 percent. Moderately well drained; medium to rapid runoff; slow permeability. There is a perched water table in late winter and early spring. About two-thirds of this soil is used for crops and pasture. Common crops are tobacco, corn, soybeans, small grain, and vegetables. Less common are cotton and hay. The remaining acreage is in forests of mixed hardwood and pine. Native species include loblolly pine, shortleaf pine, Virginia pine, sweetgum, willow oak, red oak, white oak, yellow-poplar, and American elm. Understory species include sourwood, flowering dogwood, winged elm, eastern cedar, hophornbean, eastern redbud, and sassafras.
Monacan	Soils of the Monacan series are deep, moderately well and somewhat poorly drained with moderate permeability. They formed in recent alluvial sediments of the Piedmont and Coastal Plain. Slopes are commonly less than 2 percent. Moderately well and somewhat poorly drained; slow runoff; moderate permeability above the buried soil. Most areas of this soil are used for crops or pasture. Corn, soybeans, small grains and hay are the principal crops. The remainder is in woodland. Forests consist of mixed hardwoods and pines.
Wilkes	The Wilkes series consists of shallow, well drained soils with moderately slow permeability. They formed in residuum weathered from intermediate and mafic crystalline rocks on uplands in the Piedmont. Well drained; rapid runoff; medium to slow internal drainage; moderately slow permeability. About 80 percent of the soil is in trees and pasture. The dominant trees are shortleaf, loblolly, and Virginia pines, eastern red cedar, blackjack oak, and post oak. About 20 percent is cultivated to crops such as small grain, lespedeza, corn, and tobacco.

Land Use

The land use in Clark's Creek watershed is predominantly Woods/Brush, with scattered areas of Industrial and Residential (see Figure 5). The sub-basin that drains to the project site is Woods/Brush and > 2 acre Residential/Open Space. The land in the watershed is rapidly being developed and the rural character will likely be replaced by mostly single-family residential development if past development trends continue.

Restoration Site

Overview

The restoration site is an approximately 1790 linear foot long reach of stream on the agricultural property of William Cato and other members of the Cato family. The Cato property is currently a cattle farm. The restoration site is in a field actively being used to graze the cows.

Several activities in the vicinity of the stream have caused/are causing degradation to the stream and its riparian zone. First, the land has been cleared to provide open pasture for the cattle (see Photo 1). Secondly, the cows are not prevented from entering the stream (see Photo 2). Also, the stream channel appears to have been moved (straightened) from its original course (see Photo 3). Finally, at least three ditches have been graded to the stream for the purpose of drying out a marshy area adjacent to the stream (see Photo 4). These activities have created a straight, actively eroding and incising stream channel adjacent to a drying area of hydric soil which was once likely a wetland.

Stream Characterization (Existing)

The existing stream at the restoration site was surveyed and classified using Rosgen's Stream Classification (Rosgen, 1996). The survey was conducted in two parts. First, a geomorphological survey was performed following the guidelines in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (USFS, 1994). Following the geomorphological survey, full topographical survey of the site was performed. Figure 6 depicts the extent of the survey.

The existing channel is a Rosgen E stream type at its upper end. As the channel progresses downstream toward its confluence with Clark's Creek, it begins to incise, becoming a Rosgen G stream type. The entire channel reach is extremely straight.

Geomorphological Survey

Three areas within the limits of the project reach were surveyed and classified for the purpose of characterizing the existing conditions at the site. In addition, bankfull discharge was determined for each reach. These three areas — the upper Reach (UR), Middle Reach (MR), and Lower Reach (LR) -- are described in the following sections.

Upper Reach (UR)

The UR area at the Cato Farm site has the form and profile of a Rosgen E6 stream type (see Photo 5). The stream in this area is extremely straight however, therefore its pattern does not conform to the descriptions presented for the Rosgen E (Rosgen, 1996).

From Rosgen, 1996:

> *The E6 stream type is commonly seen as a riffle-pool system with the dominant bed material composed of silt and clay interspersed with organic materials. The streambanks are composed of materials similar to that of the bed and are typically stabilized with riparian or wetland vegetation that forms densely rooted sod mats. The E6 stream channels are very stable unless the streambanks are disturbed and significant changes in sediment supply and/or streamflow occur..*

Table 2 presents the summary geomorphologic data for this area. Detailed information for the UR area is presented in Appendix A.

TABLE 2
Geomorphologic Data for UR – Cato Farm
Stream Channel Classification Level II

Parameter			Value	Units
Bankfull Width (Wbkf)			7.7	Feet
Bankfull Mean Depth (d bkf)			0.7	Feet
Cross Sectional Area (Abkf)			5.7	Square feet
Width/Depth Ratio (w/d ratio)			10.4	
Bankfull Max. Depth (dmbkf)			1.9	Feet
Floodprone Area Width (Wfpa)			16.0	Feet
Entrenchment Ratio (ER)			2.1	
Channel Materials (Particle Size Index – d50)			silt	
D15	--	mm		
D34	--	mm		
D50	--	mm		
D84	0	mm		
D95	1	mm		
Water Surface Slope (s)			0.0098	Feet per foot
Channel Sinuosity (k)			1.0	
Rosgen Stream Type			**E6**	

Middle Reach (MR)

The MR area at the Cato Farm site is a Rosgen G5c stream type (see Photo 6). From Rosgen, 1996:

> *The G5 stream type is an entrenched, step-pool channel deeply incised in sandy materials. These "sandy gully" stream types transport great amounts of sediment due to the ease of particle detachment and fluvial entrainment. If the observed slope is less than 2% the reach is given a G5c designation. These stream types are very sensitive to disturbance and tend to make adverse channel adjustments to changes in flow regime and sediment supply from the watershed.*

Table 3 presents the summary geomorphologic data for the area. Detailed information for the MR area is presented in Appendix B.

TABLE 3
Geomorphologic Data for MR – Cato Farm
Stream Channel Classification Level II

Parameter			Value	Units
Bankfull Width (Wbkf)			5.2	Feet
Bankfull Mean Depth (d bkf)			1.65	Feet
Cross Sectional Area (Abkf)			8.6	Square feet
Width/Depth Ratio (w/d ratio)			3.2	
Bankfull Max. Depth (dmbkf)			2.0	Feet
Floodprone Area Width (Wfpa)			7.0	Feet
Entrenchment Ratio (ER)			1.3	
Channel Materials (Particle Size Index – d50)			0.5	mm
D15	--	mm		
D34	0.24	mm		
D50	0.5	mm		
D84	4.0	mm		
D95	10	mm		
Water Surface Slope (s)			0.0092	Feet per foot
Channel Sinuosity (k)			1.0	
Stream Type			**G5c**	

Lower Reach (LR)

The LR area at the Cato Farm site is also a Rosgen G5c stream type (see Photo 7). Table 4 presents the summary geomorphologic data for this area. Detailed information for the LR area is presented in Appendix C.

TABLE 4
Geomorphologic Data for LR – Cato Farm
Stream Channel Classification Level II

Parameter			Value	Units
Bankfull Width (Wbkf)			7.6	Feet
Bankfull Mean Depth (d bkf)			1.3	Feet
Cross Sectional Area (Abkf)			9.7	Square feet
Width/Depth Ratio (w/d ratio)			6.0	
Bankfull Max. Depth (dmbkf)			1.9	Feet
Floodprone Area Width (Wfpa)			11.0	Feet
Entrenchment Ratio (ER)			1.4	
Channel Materials (Particle Size Index – d50)			1.2	mm
D15	--	mm		
D34	0.58	mm		
D50	1.2	mm		
D84	9.0	mm		
D95	18	mm		
Water Surface Slope (s)			0.0154	Feet per foot
Channel Sinuosity (k)			1.1	
Stream Type			**G5c**	

Bankfull Discharge

In addition to describing the morphology of the existing channel at Cato Farm, the survey data collected was used to determine the bankfull discharge of the existing channel. The discharge was calculated and verified based on the Rural Piedmont Regional Curves (see Figure 7). Table 5 presents the bankfull discharges calculated in all three surveyed reaches of the existing channel.

TABLE 5
Cato Farm Bankfull Discharge

Reach	Drainage Area Square miles	Qbkf – Calculated cfs	Qbkf – Regional Curve[1] cfs		
			Mid	High	Low
Upper	0.31	42.1	38	12	120
Middle	0.36	65.8	45	15	140
Lower	0.41	82.1	50	17	150

1 – North Carolina Rural Regional Curve

The bankfull discharge will be used to calculate the design channel parameters for the stream restoration.

Soils

The soils at the project site can be seen in Figure 8, from the USGS *Soil Survey of Mecklenburg County, North Carolina*. The soils at the site are Monacan and Wilkes. The characteristics of these soils was described earlier in Table 1.

In addition to reviewing the County soil survey maps, a field investigation for the presence of hydric soils was conducted. Hydric soils were present at the site, on the west side of the stream (the right floodplain facing downstream at the existing channel). It appears, based on field observation, that the three drainage ditches cut from the area of hydric soils into the Cato Farm channel, have dried the floodplain out. The property owner in fact, described the area as formerly “very marshy” and difficult to maneuver farm equipment around in. Figure 9 depicts the limits of hydric soils as evaluated in the field and also shows the locations of the drainage ditches that have dried out this area. Appendix H is a technical memorandum regarding the wetland delineation.

Terrestrial Plant Community

The project site is located in a grazing field of an active dairy farm. The upper portion of the existing channel is in open field (see Photo 8). The field is comprised mostly of grasses – including tall fescue (*festuca arundinacea*), clover (*trifolium*), thistle (*carduus*), Queen Anne’s Lace (*daucus carota*). The channel itself is bordered by a narrow band of woody vegetation – including cedar (*juniperous*), mock orange (*Philedelphus*), privet (*Ligustrum*), sycamore (*platinus*), and alder (*alnus*). The grasses are kept short by the grazing cattle. The cattle also browse the woody vegetation along the stream banks (see Photo 9).

The middle and lower third of the existing channel reach is in a wooded area with a largely absent understory (see Photo 10). The woods are comprised of hardwoods, including sycamore, oak (*Quercus*), and poplar. The few shrubs are concentrated around the stream channel and include privet and mock orange. In addition, there are some herbaceous plants present in the floodplain terrace and along the stream, including wild geranium (*geranium*) and mayapples (*podophyllum*) (see Photo 11).

Wildlife

Wildlife observed at the project site during the survey included box turtle and frogs. Common Mecklenburg County wildlife that could be expected at the project site include gray squirrel, cottontail, fox, raccoon, opossum, bobwhite quail, mourning dove, numerous non-game birds, and deer (SCS, 1980).

Reference Reaches

Two reference reaches were necessary for use in designing the Cato Farm Stream Restoration – a low gradient, meandering stream type and a relatively high gradient stream type. Charlotte-Mecklenburg Storm Water Services (CMSWS) is in the process of surveying all the streams in Charlotte and Mecklenburg County in order to apply a Stream Restoration and Ranking Protocol (SRRP) to qualified stream reaches for the purpose of ranking and prioritizing future stream restoration projects in the County. Streams of reference quality have been identified as part of their process. A list of potential reference reaches was obtained from CMSWS and these as well as other stream reaches in the project vicinity were reviewed in the field to determine their suitability for use as design references for this project. While no reaches presented ideal examples of desired design parameters, two reaches, meeting the general criteria necessary were found and subsequently surveyed.

Coffey Creek

A high gradient stream reach was found on Coffey Creek in southern Mecklenburg County (see Figure 10). A reference reach survey, following the guidelines in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (USFS, 1994), was performed and the data is summarized in Table 6. The detailed data is presented in Appendix D.

The Coffey Creek reference reach is a Rosgen B4c stream type. It is moderately entrenched, with a series of steps and irregularly spaced scour pools. The stream bed is gravel dominated with large cobble and medium boulders controlling the grade (see Photo 12). The bankfull indicators were a change in slope on the stream bank corresponding to a change from predominantly herbaceous vegetation to woody vegetation (see Photo 13).

TABLE 6
Geomorphologic Data for Coffey Creek
Stream Channel Classification Level II

Parameter			Value	Units
Bankfull Width (Wbkf)			31.6	Feet
Bankfull Mean Depth (d bkf)			1.8	Feet
Cross Sectional Area (Abkf)			55.4	Square feet
Width/Depth Ratio (w/d ratio)			18	
Bankfull Max. Depth (dmbkf)			2.5	Feet
Floodprone Area Width (Wfpa)			46.0	Feet
Entrenchment Ratio (ER)			1.5	
Channel Materials (Particle Size Index – d50)			2.3	mm
D15	0.076	mm		
D34	1.05	mm		
D50	2.3	mm		
D84	142	mm		
D95	324	mm		
Water Surface Slope (s)			.0109	Feet per foot
Channel Sinuosity (k)			1.2	
Stream Type			**B4c**	

Unnamed Tributary (UT) – Park South Drive

A low gradient, meandering stream reach was found on unnamed tributary (UT) to Little Sugar Creek in southern Mecklenburg County (see Figure 11). A reference reach survey, following the guidelines in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (USFS, 1994) was performed and the data is summarized in Table 7. The detailed data is presented in Appendix E.

The UT reference reach is a Rosgen E5 stream type. It is a low width-to-depth ratio, glide-pool stream that is not entrenched. The stream bed is sand dominated (see Photo 14). The bankfull indicators were a change in slope on the stream bank (see Photo 15).

TABLE 7
Geomorphologic Data for UT – Park South Drive
Stream Channel Classification Level II

Parameter			Value	Units
Bankfull Width (Wbkf)			5.9	Feet
Bankfull Mean Depth (d bkf)			1.1	Feet
Cross Sectional Area (Abkf)			6.7	Square feet
Width/Depth Ratio (w/d ratio)			5.2	
Bankfull Max. Depth (dmbkf)			1.5	Feet
Floodprone Area Width (Wfpa)			29	Feet
Entrenchment Ratio (ER)			4.9	
Channel Materials (Particle Size Index – d50)			0.8	mm
D15	0.169	mm		
D34	0.50	mm		
D50	0.80	mm		
D84	8.0	mm		
D95	20	Mm		
Water Surface Slope (s)			0.0123	Feet per foot
Channel Sinuosity (k)			1.4	
Stream Type			**E5**	

Stream Channel Design

The general plan for restoration of the existing stream channel at Cato Farm includes the following elements:

- Stream Restoration - adjustment of the upper two-thirds of the stream reach into a Rosgen E stream type
- Stream Transition - adjustment of the lower one-third of the stream reach into a Rosgen B stream type
- Planting and preservation of the riparian zone

In addition, the following item is also included in the plans for Cato Farm Stream Restoration

- Providing for cattle crossing at one location along the restored stream reach

An overview of the Cato Farm Stream Restoration Project was presented earlier in Figure 1. A more detailed plan of the project is shown here in Figures 12 and 13. The dimension, pattern, and profile of the stream restoration were developed using dimensionless ratios derived from the measurements taken from the Rosgen B4c at Coffey Creek and the Rosgen E5 at the UT reference sites. The stable parameters at the reference reaches serve as the "blueprint" for the restoration design at Cato Farm. Table 8 presents the Stream Restoration section design, including reference reach measurements from the UT at Park South Drive, the dimensionless ratios developed from those measurement, and the subsequent design dimensions calculated for the project from the dimensionless ratios. Table 9 presents this same information for the Stream Transition section.

TABLE 8
Cato Farm Stream Restoration Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel		Proposed Reach	Reference Reach
	UR	MR	Restoration Reach	UT – Park South Drive
Variables				
1. Stream Type	E6	G5c		E5
2. Drainage Area (sq. mi.)	0.31	0.36	0.36	0.16
3. Bankfull Width (Wbkf) - feet	7.70	5.23	7.00	5.94
4. Bankfull Mean Depth (d bkf) - feet	0.74	1.65	1.33	1.13
5. Width/Depth Ratio (w/d ratio)	10.36	3.16	5.25	5.25
6. Cross Sectional Area (Abkf) - SF	5.72	8.63	8.60	6.72
7. Bankfull mean velocity (v bkf) - fps	7.37	7.62	7.65	7.06
8. Bankfull discharge (Q bkf) - cfs	42.15	65.75	65.80	47.43
9. Bankfull Max. Depth (d mbkf) - feet	1.87	2.00	1.76	1.49
10. Max. d riff/d bkf ratio	2.52	1.21	1.32	1.32
11. Low bank height to max. d bkf ratio	1.92	2.19	1.00	1.83
12. Floodprone Area Width (Wfpa) - feet	16.00	7.00	34.20	29.00
13. Entrenchment Ratio (ER)	2.08	1.34	4.89	4.89
14. Meander length (Lm) - feet	--	0.00	61.92 Range: 51.89-71.94	52.50 Range: 44-61
15. Ratio of meander length to bankfull width (Lm/W bkf)	---	---	8.85 Range: 7.41-10.28	8.85 Range: 7.41-10.28
16. Radius of curvature (Rc) - feet	0.00	0.00	18.26 Range: 13.09-27.72	15.48 Range: 11.10-23.50
17. Ratio of radius of curvature to bankfull width (Rc/W bkf)	---	---	2.61 Range: 1.87-3.96	2.61 Range: 1.87-3.96
18. Belt width (W blt) – feet	8.00	5.50	42.46	36.00
19. Meander width ration (W blt/W bkf)	1.04	1.05	6.07	6.07

TABLE 8
Cato Farm Stream Restoration Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel		Proposed Reach	Reference Reach
	UR	MR	Restoration Reach	UT – Park South Drive
20. Sinuosity (K = stream length/valley distance)	1.01	1.04	1.39	1.39
21. Valley slope – ft./ft.	0.01	0.01	0.01	0.02
22. Average slope (s avg = svalley/k) – ft.,/ft.	0.01	0.01	0.01	0.01
23. Pool slope (s pool) – ft./ft.	0.003 Range: 0-0.005	-0.04 Range: -0.01—0.06	-0.01 Range: -0.03-0.02	-0.01 Range: -0.03-0.02
24. Ratio of pool slope to average slope (s pool/s bkf)	0.26 Range: 0-0.51	-3.93 Range: -1.06—6.81	-0.87 Range: -4.18-2.95	-0.50 Range: -2.44-1.72
25. Maximum pool depth (d pool) – feet	1.89	2.84	2.75	2.33
26. Ratio of pool depth to average bankfull depth (d pool/d bkf)	2.54	1.72	2.06	2.06
27. Pool width (W pool) – feet	5.45	4.83	6.28	5.33
28. Ratio of pool width to bankfull width (W pool/W bkf)	0.71	0.92	0.90	0.90
29. Ratio of pool area to bankfull area (A pool/A bkf)	1.31	1.21	1.14	1.36
30. Pool-to-pool spacing – feet	25.00 Range: 17.5-32.5	35.60 Range: 35.2-35.9	23.59 Range: 16.51-31.84	20.00 Range: 14-27
31. Ratio of p-p spacing to bankfull width (p-p/Wbkf)	3.25 Range: 2.27-4.22	6.81 Range: 6.74-6.87	3.37 Range: 2.36-4.55	3.37 Range: 2.36-4.55

TABLE 8
Cato Farm Stream Restoration Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel		**Proposed Reach**	**Reference Reach**
	UR	MR	Restoration Reach	UT – Park South Drive
		Materials		
		Particle Size Distribution of Channel Material		
D16 – mm	--	--	--	0.17
D35 – mm	--	0.24	--	0.50
D50 – mm	--	0.51	--	0.82
D84 – mm	0.31	3.92	--	8.30
D95 – mm	1.12	9.80	--	19.95
		Particle Size Distribution of Bar Material		
D16 – mm	--	--	--	--
D35 – mm	--	--	--	--
D50 – mm	--	--	--	--
D84 – mm	--	--	--	--
D95 – mm	--	--	--	--
Largest size particle at the toe (lower third) of bar - mm	--	--	--	--
		Sediment Transport Validation (based on bankfull shear stress)		
Calculated value - lbs/ft^2			0.33	
Value from Shields Diagram - lbs/ft^2			0.32	
Critical dimensionless shear stress			0.03	
Minimum mean d bkf calculated using critical dimensionless shear stress equations			1.34	

TABLE 9
Cato Farm Stream Transition Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel	**Proposed Reach**	**Reference Reach**
	LR	Transition Reach	Coffey Creek
	Variables		
1. Stream Type	G5c		B4c
2. Drainage Area (sq. mi.)	0.41	0.41	4.04
3. Bankfull Width (Wbkf) - feet	7.64	13.50	31.57
4. Bankfull Mean Depth (d bkf) - feet	1.27	0.75	1.76
5. Width/Depth Ratio (w/d ratio)	5.99	17.99	17.99
6. Cross Sectional Area (Abkf) - SF	9.73	9.70	55.41
7. Bankfull mean velocity (v bkf) - fps	8.44	8.46	4.60
8. Bankfull discharge (Q bkf) - cfs	82.12	82.10	254.99
9. Bankfull Max. Depth (d mbkf) - feet	1.90	1.06	2.48
10. Max. d riff/d bkf ratio	1.49	1.41	1.41
11. Low bank height to max. d bkf ratio	3.21	4.05 Range: 1.65-6.41	1.33
12. Floodprone Area Width (Wfpa) - feet	11.00	19.67	46.00
13. Entrenchment Ratio (ER)	1.44	1.46	1.46
14. Meander length (Lm) - feet	0.00	341.23 Range: 319.43-363.04	798.00 Range: 747-849
15. Ratio of meander length to bankfull width (Lm/W bkf)	---	25.28 Range: 23.66-26.89	25.28 Range: 23.66-26.89
16. Radius of curvature (Rc) - feet	0.00	118.36 Range: 49.47-199.78	276.80 Range: 115.7-467.2

TABLE 9
Cato Farm Stream Transition Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel LR	**Proposed Reach** Transition Reach	**Reference Reach** Coffey Creek
17. Ratio of radius of curvature to bankfull width (Rc/W bkf)	---	8.77 Range: 3.66-14.8	8.77 Range: 3.66-14.8
18. Belt width (W blt) – feet	8.00	96.64	226.00
19. Meander width ration (W blt/W bkf)	1.05	7.16	7.16
20. Sinuosity (K = stream length/valley distance)	1.05	1.22	1.22
21. Valley slope – ft./ft.	0.02	0.02	0.01
22. Average slope (s avg = svalley/k) – ft.,/ft.	0.02	0.01	0.01
23. Pool slope (s pool) – ft./ft.	0.000 Range: -0.009-0.009	-0.004 Range: -0.01-0.003	0.00 Range:-0.01-0
24. Ratio of pool slope to average slope (s pool/s bkf)	0.00 Range: -0.58-0.57	-0.32 Range: -0.77-0.21	-0.39 Range: -0.92-0.26
25. Maximum pool depth (d pool) – feet	2.64	1.60	3.75
26. Ratio of pool depth to average bankfull depth (d pool/d bkf)	2.07	2.14	2.14
27. Pool width (W pool) – feet	8.86	14.16	33.12
28. Ratio of pool width to bankfull width (W pool/W bkf)	1.16	1.05	1.05
29. Ratio of pool area to bankfull area (A pool/A bkf)	1.71	15.75	1.29
30. Pool-to-pool spacing – feet	27.10 Range: 3.55-33.3	47.76 Range: 42.76-51.31	111.70 Range: 100-120
31. Ratio of p-p spacing to bankfull width (p-p/Wbkf)	3.55 Range: 2.74-4.36	3.54 Range: 3.17-3.80	3.54 Range: 3.17-3.8

TABLE 9
Cato Farm Stream Transition Design
Morphological Characteristics of the Existing and Proposed Channel with Reference Reach Data

	Existing Channel	Proposed Reach	Reference Reach
	LR	Transition Reach	Coffey Creek
Materials			
Particle Size Distribution of Channel Material			
D16 – mm	--		0.08
D35 – mm	0.58		1.05
D50 – mm	1.20		2.29
D84 – mm	8.64		141.68
D95 – mm	18.46		323.99
Particle Size Distribution of Bar Material			
D16 – mm	0.15		
D35 – mm	0.59		
D50 – mm	0.83		
D84 – mm	2.62		
D95 – mm	4.45		
Largest size particle at the toe (lower third) of bar - mm	18.00		
Sediment Transport Validation (based on bankfull shear stress)			
Calculated value - lbs/ft2		0.91	
Value from Shields Diagram - lbs/ft2		0.32	
Critical dimensionless shear stress		0.03	
Minimum mean d bkf calculated using critical dimensionless shear stress equations		1.34	

Restoration Techniques

Dimension

The existing channel dimension is unstable at spot locations throughout the project area due to trampling of the stream bed and banks by cattle. The degradation of the stream cross section at the lower portion of the existing stream is especially pronounced however. The stream banks in this section of channel are eroding along the entire length (see Photo 16). To address the erosion throughout the project, the stream cross-section (dimension) will be adjusted to mimic stable reference conditions.

Approximately the upper two-thirds of the stream (the Stream Restoration section) will remain/be converted to a Rosgen E stream type. A comparison of the Upper Reach (UR) and Middle Reach (MR) existing channel dimensions with those proposed is presented in Table 10. Typical cross-sections for the Stream Restoration section are shown in Figure 14.

TABLE 10
Cross Section Dimensions
Stream Restoration - Upper Two-Thirds of Project Reach

Parameter	Existing		Proposed
	Upper Reach	Middle Reach	
Bankfull Width, ft.	7.7	5.2	7
Mean Bankfull Depth, ft.	0.7	1.7	1.33
Maximum Bankfull Depth, ft.	1.9	2.0	1.76
Cross Sectional Area, ft^2	5.7	8.6	9.34
Width of Floodprone Area, ft.	16	7.0	34
Entrenchment Ratio	2.1	1.3	4.89
Bank Height Ratio	1.9	2.2	1.0

Approximately the lower one-third of the stream will be used to transition from the Stream Restoration section back to the exist stream cross section at the Cato Farm tributary's confluence with Clarks Creek (the downstream project limits). This Stream Transition section will be a Rosgen B stream type. A comparison of the Lower Reach (LR) existing channel dimensions and those proposed is presented in Table 11. Typical cross-sections for the Stream Transition section are shown in Figure 15.

TABLE 11
Cross Section Dimensions
Stream Transition – Lower One-Third of Project Reach

Parameter	Existing	Proposed
Bankfull Width, ft.	7.6	13.5
Mean Bankfull Depth, ft.	1.3	0.75
Maximum Bankfull Depth, ft.	1.9	1.06
Cross Sectional Area, ft^2	9.7	10.13
Width of Floodprone Area, ft.	11	20
Entrenchment Ratio	1.4	1.46
Bank Height Ratio	3.2	4.0

Pattern

The existing channel through Cato Farm is extremely straight. Both the Restoration and Transition sections of the proposed project will increase the sinuosity of the stream. The pattern of each proposed section will be based on that of the reference reaches – the upper two thirds of the stream will increase in sinuosity from 1.0 to 1.4 and the lower one-third of the stream from 1.1 to 1.22. The pattern parameters for the proposed Restoration and Transition sections was presented earlier in Tables 8 and 9.

Profile/Bedform

The profile of the existing channel through Cato Farm is unstable. Channel incision is evident in localized spots in the upper end of the channel and increases in severity in the lower channel reach. In addition, there is very little diversity in the existing channel bedform – pools, riffles, glides, runs, etc. are nearly indistinguishable from each other. The Stream Restoration section of the project will include the construction a riffle-pool stream bed and the Stream Transition section will include the construction of a step-pool stream bed. The proposed profile of the project is shown in Figures 16 and 17. Table 12 compares the existing and proposed profile/bedform parameters.

TABLE 12
Profile/Bedform Dimensions
Cato Farm Stream Restoration Project

Parameter	Existing		Proposed
Restoration Section – Upper Two-Thirds of Project	**Upper**	**Middle**	
Average Channel Slope, ft./ft.	0.0098	0.0092	0.012
Valley slope, ft./ft.	0.0098	0.0096	0.0097
Pool slope, ft./ft.	--	--	0.0
Maximum pool depth, ft.	1.9	2.8	2.75
Pool width, ft.	5.5	4.8	6.28
Riffle Slope, ft./ft.	--	0.0103	0.033
Restoration Section – Lower One-Third of Project			
Average Channel Slope, ft./ft.	.0154		.011
Valley slope, ft./ft.	0.0160		0.0160
Pool slope, ft./ft.	--		0.0
Maximum pool depth, ft.	2.6		1.6
Pool width, ft.	8.9		14.16
Riffle Slope, ft./ft.	--		.019

Sediment Transport

An evaluation of sediment competence was performed to determine the ability of the proposed stream to transport the existing channel bedload. If the combination of depth and slope of the proposed channel is not great enough to move the stream's largest particle size, or if the slope-depth combination is too great, then the potential for aggradation or excessive scour exists.

Critical Dimensionless Shear Stress

Critical dimensionless shear stress should be computed to determine the force needed to mobilize and transport the largest particle size made available annually (during a bankfull event) to the channel.

For a ratio of $D_{50} / \hat{D}_{50}$ between 3.0 and 7.0:

$$\tau_{ci} = 0.0834(D_{50} / \hat{D}_{50})^{-0.872}$$

Where,

τ_{ci} = critical dimensionless shear stress

D_{50} = median diameter of pavement or bed material on riffle

$\hat{D}_{50}$ = median diameter of bar sample (sub-pavement)

For a ratio of $D_{50} / \hat{D}_{50}$ that is NOT between 3.0 and 7.0, calculate the ratio of D_i / D_{50}, where:

D_i = largest diameter of particle on bar.

D_{50} = median diameter of pavement or bed material on riffle

If the ratio of D_i / D_{50} is between 1.3 and 3.0, then:

$$\tau_{ci} = 0.0384(D_i / D_{50})^{-0.872}$$

The particle sizes are determined by sampling the bed material on the riffle (to obtain D_{50}) and excavating a core sample of bar material (to obtain $\hat{D}_{50}$ and D_i). The bar sample is obtained as a surrogate of the sub-pavement size distribution and also provides an interpretation of bedload at the bankfull stage. The largest particle on the bar - D_i - represents the largest size of sediment frequently made available to the channel. A sampling methodology suggested by Angela Jessup, NC-USDA, was employed to obtain the bar sample (see Appendix F). The Wolman Pebble-Count procedure was used to obtain the data for the riffle.

Entrainment Analysis

Once the critical shear stress has been determined, the depth and slope required to entrain the largest particle can be calculated using:

$$d_r = \frac{\gamma_s \tau_{ci} D_i}{s_e}$$

and

$$s_e = \frac{\gamma_s \tau_{ci} D_i}{d_r}$$

Where,

d_r = required bankfull mean depth

d_e = existing bankfull mean depth

γ_s = submerged specific weight of sediment = 1.65

s_r = required bankfull water surface slope

s_e = existing bankfull water surface slope

Bankfull Shear Stress

Finally, the sediment competence of the proposed design is double checked by calculating the bankfull shear stress:

$\tau = \gamma * Rs$

Where,

τ = bankfull shear stress

γ = Specific weight of water = 62.4 lbs./cubic foot

R = hydraulic radius of riffle cross section

S = average water surface slope

The calculated bankfull shear stress must be great enough to initiate movement of the largest particle, but not so large as to cause erosion.

Results

The following is a summary of the results of the sediment transport analysis for this project. Detailed calculations are included in Appendix F:

- The sediment sampling conducted at Cato Farm indicated that the largest particle available to the channel annually (D_i)is 18 mm. The $\hat{D}_{50}$ is 0.83 mm and the D_{50} is 2.7 mm.
- The critical dimensionless shear stress required to mobilize and transport D_i is 0.030.
- The minimum depth and slope required to entrain the largest particle is therefore 0.176 feet and 0.0018 ft./ft., respectively; parameters that are both met in the proposed design.
- The existing channel's bankfull shear stress is 1.34 lbs./ft^2. A comparison of this calculated bankfull shear stress with the Shield curve indicates that the calculated shear stress exceeds the required shear stress of 0.32 lbs./ft^2. This clearly indicates a possible cause for the excessive headcutting and erosion occurring in the existing channel.
- Finally, confirmation was made that the proposed Stream Restoration section (upper two-third's) and the Stream Transition section would not exceed the required bankfull shear stress and therefore could be expected to neither aggrade nor degrade.

- The Stream Restoration section's bankfull shear stress was computed to be 0.33 lbs./ft^2, a value which approximates the required shear stress of 0.32 lbs./ft^2.
- The Stream Transition section's bankfull shear stress was computed to be 0.91 lbs./ ft^2, a value which exceeds the required shear stress. This excessive shear stress will be controlled in this channel section with the use of rock vanes for grade control and soil bioengineering stream bank stabilization for erosion control.

Flooding Analysis

A flooding analysis of the proposed stream restoration will be done in the final stages of project design, using HEC-RAS. The bankfull stage and the 100-year flood stage will be determined. Bankfull stage modeled by HEC-RAS will be compared to bankfull stage as designated in the design cross-sections. The 100-year flood stage will be identified on the final plans, although there are currently no structures or other facilities within the project limits that might be impacted by flooding.

In-Stream Structures

Cross vanes will be used to control the grade and create the step-pool bedform in the Stream Transition section of the project. Both log and rock vanes may be used. A typical rock vane is shown in Figures 18. These devices are placed low in the channel profile and are designed for pool formation below the structure. The structure is constructed to angle upstream, forcing the stream flow over the structure into the center of the channel away from the stream banks. This avoids the adverse effects of straight weirs, which create backwater problems, including flat slopes, and downstream-pointing weirs, which create bars and a scour hole that can de-stabilize the structure.

The objectives of the cross vane for the Cato Farm project are to:

- Create in-stream habitat – cover, holding water
- Remove stress from the near-bank region by directing flow to the center of the channel
- Provide grade control to prevent down cutting
- Increase sediment transport capacity

Vegetation

Overview

Vegetation is an important part of the proposed restoration design. Vegetation used for this project will:

- Provide engineering function by stabilizing the stream banks temporarily, then permanently
- Create habitat and a food source for wildlife in the riparian zone adjacent to the stream
- Encourage desirable in-stream habitat qualities such as:
  - Low water temperature from stream shading

- Available cover from overhanging shrubbery
- Food source from falling leaves

The vegetative components of this project include soil bioengineering stream bank stabilization, riparian buffer, and temporary seeding for erosion control.

Stream Bank and Riparian Area Re-Vegetation at Cato Farm

The stream banks and the adjacent riparian area of the proposed project will be planted with both woody and herbaceous vegetation as shown in Figures 19 and 20.. A buffer of woody and herbaceous species will be installed adjacent to both sides of the proposed stream throughout the project reach. Two soil bioengineering techniques are proposed for the stream banks of the project:

- The stream banks in the Stream Restoration section will be planted in native grasses stabilized with geotextiles
- The banks of the Stream Transition section will be soil bioengineered (live staked) with shrubs.

A schedule of plants for use on this project is shown in Table 13.

TABLE 13
Plant Schedule
Cato Farm Stream Restoration Project

COMMON NAME	BOTANICAL NAME	LIGHT	RATE or SPACING
	Native Grasses for Stream Banks and Buffers		
Indiangrass	*Sorghastrum*	Sun	4.5 lb/Ac.
Little Bluestem	*Andropogon scoparius*	Sun	3.5 lb/Ac.or 2' O.C.
Big Bluestem	*Andropogon gerardii*	Sun	6 lb/Ac.or 4' O.C.
"Shelter" Switchgrass	*Panicum virgatum*	Sun or light shade	3 -4 lb/Ac.or 3' O.C.
Tufted Hairgrass	*Deschampisa caespitosa*	Sun to light shade	3' O.C.
Maiden Gras	*Miscanthus*	Sun or light shade	4' O.C.
Fountain Grass	*Pennisetum*	Sun to light shade	4' O.C.
Mexican Feather Grass	*Stipa tenuissima*	Sun to light shade	3' O.C.

TABLE 13
Plant Schedule
Cato Farm Stream Restoration Project

COMMON NAME	BOTANICAL NAME	LIGHT	RATE or SPACING
Emergent Vegetation for Planting in Bankfull Region			
Soft Rush	*Juncus effusus*	Sun	18" O.C.
Rose Mallow	*Lavatera thuringiaca*	Sun	4' O.C.
Sweetflag	*Acorus calamus*	Sun to light shade	3' O.C.
Bushy Beardgrass	*Andropogon glomeratus*	Sun	18" O.C.
Tussock Sedge	*Carex stricta*	Sun to light shade	18" O.C.
Blue-flag Iris	*Iris virginica*	Sun to light shade	2' O.C.
Switchgrass	*Panicum virgatum*	Sun to light shade	3' O.C.
Wool-grass	*Scirpus cyperinus*	Sun	18" O.C.
Iron weed	*Vernonia noveboracensis*	Sun	2.5' O.C.
Woody Vegetation for Soil Bioengineering Stream Bank Stabilization			
Boxelder	*Acer Negundo*	Tree	Sun or part shade
Black Willow	*Salix Nigra*	Tree	Sun
Silky Dogwood	*Cornus Amomum*	Shrub	Sun or shade
Elderberry	*Sambueus Canadensis*	Shrub	Sun or light shade
Red Osier Dogwood	*Cornus Stolonifera*	Shrub	Sun or shade
River Birch	*Betula Nigra*	Tree	Partial Sun
Purple Osier Willow	*Salix Purpurea*	Shrub	Sun or light shade
Sycamore	*Plantanus occidentalis*	Tree	Sun
Button Bush	*Cephalanthus occidentalis*	Shrub	Sun or light shade
Trees for Buffer Planting			
River Birch	*Betula nigra*	Partial Sun	10' O.C.
Gray Birch	*Betula populfolia*	Partial Sun	10' O.C.
Eastern Red Cedar	*Juniperus virginiana*	Sun	10' O.C.
Black Gum	*Nyssa sylvatica*	Sun	20' O.C.
Sycamore	*Platanus accidentalis*	Sun	20' O.C.
Swamp White Oak	*Quercus bicolo*	Sun to partial sun	20' O.C.
Scarlet Oak	*Quercus coccinea*	Sun	20' O.C.
Pin Oak	*Quercus palustria*	Sun	20' O.C.
Willow Oak	*Quercus phellos*	Sun	20' O.C.

TABLE 13
Plant Schedule
Cato Farm Stream Restoration Project

COMMON NAME	BOTANICAL NAME	LIGHT	RATE or SPACING
Red Oak	*Quercus rubra*	Sun to partial sun	20' O.C.
	Shrubs for Buffer Planting		
Silky Dogwood	*Cornus Amomum*	Shrub	Sun or shade
Elderberry	*Sambueus Canadensis*	Shrub	Sun or light shade
Red Osier Dogwood	*Cornus Stolonifera*	Shrub	Sun or shade
Purple Osier Willow	*Salix Purpurea*	Shrub	Sun or light shade
Button Bush	*Cephalanthus occidentalis*	Shrub	Sun or light shade

Stream Bank Re-Vegetation - Soil Bioengineering

Introduction

Soil bioengineering is vegetation used alone or in conjunction with structural features (e.g., boulders, fiber rolls, geotextiles) to stabilize slopes, such as those of stream banks. Vegetation is the most channel desirable lining in most cases because of its dynamic and adaptive self-repairing qualities. Vegetative root systems stabilize channel banks through tensile reinforcement of the soil structure and resist sloughing due to saturation by mediating soil moisture through transpiration. Vegetation also has the advantage of filtering pollutants from runoff, improving fish and wildlife habitat. In most cases, vegetation is more aesthetically appropriate than more industrial hard stabilization measures.

Stream banks can be divided into four ranges when considering vegetation (see Figure 21).

1. Aquatic plant range that extends up to the low flow stage (LF)
2. Bank range that extends from the low flow stage to the bankfull stage (BF)
3. Lower riparian range or floodway that would be covered naturally with willows and shrubs (OF)
4. Upper riparian range or flood fringe areas that would be covered naturally with canopy-forming trees (FF)

Vegetative methods can be applied in all four ranges. Soil bioengineering methods are applicable primarily to the BF and the OF.

Conditions under which vegetation alone (i.e., vegetation not used in combination with a geotextiles or rip rap or as part of a soil bioengineering system) *may* not be acceptable, include but are not limited to the following:

1. Inability to employ a natural channel design principles because of lateral confinement that promotes flow conditions in excess of the maximum velocities and shear stress for

soil bioengineering systems or temporary erosion control measures used for vegetation is establishment

2. Lack of the regular maintenance necessary to prevent domination by noxious vegetation such as kudzu
3. Excessive shade
4. Excessive velocities

Vegetation used in combination with rip rap, geotextiles, rigid linings, and other engineered products almost always yields an acceptable channel lining if vegetation used alone does not.

Vegetation suitable for use in soil bioengineering must perform in certain ways (Larson and McGill):

- The plants must be able to tolerate inundation and adjust to variations in the depth duration, and frequency of inundation.
- The deep rooting capabilities of certain species provide greater structural stability. However, shallow rooting species, which spread rapidly laterally or form a dense mat, help resist scour and increase cohesion and protect against surfacewater runoff.
- Many suitable plants root easily from cuttings. This characteristic lowers the cost of vegetative stabilization compared with other techniques. Also the effectiveness of the roots increase over time. Therefore the capacity of the plants to establish themselves and quickly grow is important.
- Suitable plants are resistant to shear stress. Thin-stemmed, flexible woody species can lie down flat against the slope during high flows, reducing resistance to facilitate the conveyance of floodwaters. Yet they will spring back undamaged once the waters recede.
- Plants must be tolerant of sedimentation. Species that are sensitive to the depth at which they are planted will not adapt well to the ever-changing conditions on the stream bank.

The best source of plant material on any project is the project site itself. All public and private sites, which may contain desirable plant material, require permission from the property owner that may be difficult or impractical to obtain. Fortunately the number of commercial sources of dormant live cuttings, and in some cases ready-to-install live stakes, fascines, and other soil bioengineering systems, increases every year. The Natural Resources Conservation Service (NRCS) maintains a database of soil bioengineering plant materials (see Appendix 16B of the *NRCS Engineering Field Handbook,* Chapter 16, "Streambank and Shoreline Protection"). The Contractor may use other species upon approval. A list of commercial living material suppliers, additional plant species, and known local harvesting sites is available from the local NRCS, Agriculture Extension office, and/or CMSWS, in Mecklenburg County.

Soil Bioengineering Design

Procedures for designing open channels, with both vegetative and rip rap linings are found in Section 8.05 of the *North Carolina Erosion and Sediment Control Planning and Design Manual.* Tractive force in the watercourse channel that will be stabilized will be calculated in accordance with procedures explained in manual using the allowable shear stresses for soil bioengineering systems given in Table 14.

TABLE 14
Shear Stress Tolerance of Stream Bank Stabilization Measures
(After Schiechtl and Stern, 1994)

Material	Directly after Installation N/m^2	After 3-4 Growing Seasons N/m^2 (Unless Otherwise Noted)
Turf	10	100
Reed plantings	5	30
Reed fascine	30	60
Live fascine	60	80
Willow mattress	20	140
Willow sill	50	300
Hardwood plantings	20	120
Branchpacking	100	300
Joint planting	200	300
Class 2 rip rap	250	250
Concrete/block wall	600	600
Live stakes	20	120
Vegetated geogrid	115	300

Soil Bioengineering – Stream Restoration Section
Biodegradable geotextiles (coir-fiber fabrics) combined with native grass plugs will be used to stabilize the stream banks of the upper two-thirds of the project (see Figure 19). The proposed channel in this section is a Rosgen E stream type with relatively low shear stress. Plant species selected for use in this section are identified in Table 13 above.

Soil Bioengineering – Stream Transition Section
Live staking is proposed for stabilizing the stream banks of the lower one-third of the project (see Figure 20). The proposed channel in this section is a Rosgen B stream type, with a higher shear stress than in the Restoration Section upstream. Plant species selected for use in this section are identified in Table 13 above.

Construction Guidelines for Soil Bioengineering
Harvesting
Plant materials may be harvested from local sites or purchased from commercial nurseries. Only healthy, well-branched, and disease-free stock from species approved by the plan reviewer shall be acceptable. The harvesting sites should be left clean and tidy. Some harvesting activities may require permits from state or federal agencies.

Cutting

Equipment such as chain saws, bush axes, loppers, and pruners may be used for harvesting, provided that they are used in such a manner that they leave clean cuts. Live growing plant material at the harvesting site shall be handled with care to avoid bark stripping and splitting of stems. Cuts typically shall be made six to 12 inches (6″ to 12″) from the ground. Cuts shall be made flat or at a slight or blunt angle to ensure that the source sites will regenerate rapidly.

Binding

Twine or hoisting belts should be used to bind the live branch cuttings securely into bundles at the harvesting site for handling and for protection during transport. Live branch cuttings should be grouped in such a manner that they stay together when handled. Side branches and brushy limbs should be kept intact at this time and all growing tips should be placed in the same direction.

Fabrication

All live system preparation shall be done on the project site and should not be done at the harvesting or other remote staging sites. Preparation includes cutting of live stakes and trimming of branches or other activities required in installation.

Storage

Live cuttings or branches not installed on the day of arrival at the job site should be stored and protected. They may be stored in water or moist soil (healed-in) for a maximum of two days without refrigeration. Outside storage locations should be continually shaded and protected from the wind. Live cut materials should be protected from drying at all times. When the temperature reaches 50°F or above, on the day the material is harvested, the live cut branches should not be stored but rather installed on the day of harvesting. Live cut branches that have been fabricated into live stakes must be used on the day of fabrication and may not be stored.

Soil Bioengineering Installation Success Criteria

Although soil bioengineering uses living material and success is not as predictable as with manufactured products, performance requirements are specified. Only cut branches that are alive and healthy and properly installed at the time of final inspection will be accepted. Dead materials shall be replaced per the acceptance criteria in Table 15 for branch rooting (in percent) based on inspections after at least one growing season.

TABLE 15
Acceptance Criteria for Placing Dead Materials for Branch Rooting

Living System	Percent Living
Reed Rolls, Berms	100%
Fiber Rolls	100%
Willow Jetties	60%
Vegetated Gabions	60%
Live Stakes	100%
Joint Planting	100%
Live Fascine	40%
Vegetated Geogrid	60%
Brushmattress	60%

Riparian Buffer Re-Vegetation

Overview

Riparian buffers are natural or constructed, forested, low maintenance ecosystems adjacent to surface water bodies which serve as a filter for pollutant removal from overland storm water flow. Riparian buffers can be an important factor in attenuating the rate of runoff into streams, increasing infiltration and recharge to groundwater and surface-water bodies, reducing erosion of streams and riverbanks, improving aquatic habitat, reducing sedimentation pollution and soluble pollutants. Buffers are ideally vegetated with a combination of trees, shrubs, and herbaceous plants.

The aesthetic and recreational benefits of riparian forested buffers are many. In many localities, maintaining well-constructed, well-marked, and signed trails will build support for, and promote the preservation of, green ribbons of riparian forest in urban and suburban watersheds. Owners of commercial and institutional properties that front on urban drainages also can be encouraged to landscape the areas and add to riparian buffers.

Vegetated riparian buffers have a range of potential applications; therefore, design criteria must be considered with respect to specific performance goals. Important design factors include slope, hydrologic patterns, width, and structure of buffer. The optimum width for buffers will depend on the functions assigned to them (see Figure 22).

An accepted standard for riparian forest buffers is called the 3-zone buffer is illustrated in Figure 23. The width of each of the zones may vary depending upon the size of the stream and its topographic setting. However, 100 feet is sufficient in most small and medium-sized streams to incorporate the functions of the three zones.

- Zone 1 starts from the top of stream bank and typically is 15 feet wide, or wider. Vegetation in Zone 1 generally consists of trees and woody shrubs. Vegetation in the zone provides shade and detrital nutrients for aquatic organisms and stabilizes banks. Minimal disturbance is recommended for this area; however, vegetation structure must be maintained.

- Zone 2 typically is around 60 feet wide. The function of Zone 2 is to provide necessary contact time and material for buffering and filtering processes. Zone 2 cannot mitigate concentrated flow, therefore, for the buffer to be effective, only sheet or subsurface flow may reach this area. Vegetation in Zone 2 consists of trees and shrubs.
- Zone 3 typically is around 20 feet wide. The function of Zone 3 is to filter sediment, take up nutrients, and convert concentrated flow to sheet flow.

Although width generally increases the capacity of riparian forested buffers to improve water quality and provide habitat, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd *et al.*, 1987). An estimated minimum width of 30 feet is required for creating forest structure and riparian habitat. In developed areas where wide buffer areas may not be available, the following design principals should be used:

- Encourage sheet flow into the edge of the riparian forest buffer. Use BMPs such as filter strip to create sheet flow before the flow enters the riparian forested buffers.
- Width should be proportional to the watershed area and slope.
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and create habitat.
- In general, use native plants, which are preferable to horticultural varieties. In suburban and urban settings, riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat. However, planting designs must be dense enough to filter sediment and provide detrital nutrients for aquatic organisms.

Buffer Specifications and Methodology at Cato Farm

An area 75 feet wide will be preserved via a conservation easement for this project. A fence will installed along the easement boundary. The proposed channel will meander within the 75 foot wide easement; the top of the stream bank at the outside of a meander bend will be no closer than 28 feet from the easement boundary. Within the easement a vegetated buffer is proposed. The most upland section of the buffer will be a filter strip-type buffer (Zone 3) consisting of native grass plantings. This section of buffer will be 8 feet wide, measured between the fence and the stream. The farmer will be allowed to maintain this native grass strip free of woody vegetation to protect the fence from damage by trees which might cause a breach allowing the cattle access to the stream restoration, potentially damaging it. The section of buffer adjacent to the channel will be planted in trees, shrubs, and grasses (Zone 1 and 2) and will be a minimum of 20 feet wide (at the outside of a meander bend), increasing in width so that the total easement does not exceed 75 feet wide. Figure 24 depicts the proposed buffer. Plant species selected for use in this section are identified in Table 13 above. In addition, *Guidelines for Riparian Buffer Restoration*, 2001, has an extensive list of appropriate buffer plant species and is included as Appendix G with this report.

Design, monitoring, and maintenance specifications for the buffer include the following:

- Trees should be planted at a density sufficient to provide 320 trees per acre at maturity. To achieve this density, approximately 436 (10x10 feet spacing) to 681 (8x8 feet spacing) trees per acre should be planted initially. Shrubs should be planted at a density sufficient to provide 1,200 shrubs per acre. shrubs per acre based on various methods of spacing.

- Thinning of trees within the buffer is allowed provided that the minimum tree density requirement specified above is fulfilled and no tree larger than 2 inch caliper is removed except when dead or diseased.

- In the early stages of riparian buffer establishment, competition for nutrients by adjacent grasses and forbs will substantially inhibit seedling growth. Release from herbaceous competition has been demonstrated as the most cost-effective method to accelerate the growth of seedlings. The plan for buffer establishment must incorporate control of the herbaceous layer. Options for weed control include four to six inches of well-aged hardwood mulch, weed control fabrics, or pre-emergent herbicide. Typically, mowing to control weeds will be impractical based on the random distribution of plantings. Weed control should be continued for three years from the time of planting.

- Non-porous or impervious cover upstream of buffers should be minimized to ensure effective buffer operation. Direct flow of storm water through buffers such as in a ditch or storm water pipe should be prohibited. All storm water outfalls should end at the edge of the buffer with adequate dispersion encouraging sheet flow to allow biological processes to effectively remove pollutants. During the required five year monitoring period, the riparian buffer should be inspected for evidence of concentrated flow. If concentrated flow has begun to form, a level spreader or other best management practice should be installed to diffuse the flow before it enters the restored riparian buffer.

- Operation of land disturbing equipment within the buffer is prohibited. The pruning or thinning of vegetation should be performed by hand. Soils within the buffer should be left undisturbed.

- Maintenance of the stream bank stabilization is allowed if necessary, provided there is minimal buffer disturbance.

- Installation of pumps within the buffer for watering is allowed provided that the buffer is not disturbed during installation or operation and provided that all pumps operate off AC current. Gasoline engines are prohibited.

- Removal of natural leaf litter from the buffer is prohibited. Where this natural material is not present, organic mulch such as wood chips, tree bark and pine needles should be maintained at a minimum depth of 4 inches over the entire buffer.

- Fertilizers and herbicides should be used only on a very limited basis within the buffer. In some basins (Neuse and Tar-Pamlico) fertilizer application is allowed one time only, then the use of fertilizer is prohibited.

- In many cases, the most cost effective and successful size plant material is bare root seedlings. Some species such as the hickories do poorly as bare root seedlings and will be much more successful as containerized seedlings.

- Tree shelters should be used to accelerate growth and increase survivability of seedlings. In addition, management of competing vegetation after planting is easier, mowing and trimmer strikes are prevented, herbicides are isolated from trunk contact, and grazing by deer are restricted. The use of tree shelters may only be practical from an economic standpoint for more expensive seedlings of species difficult to establish, such as red oak. Reductions in maintenance costs and increased seedling vigor associated with tree shelters suggest that tree shelter plantings may be a more cost-effective approach than planting unprotected larger material.

- In urban or other high visibility areas, some specimen trees and shrubs should be incorporated into the planting plan.

- When planting the buffer with cuttings from approved woody vegetation species, rooted cuttings should be grown for a year from un-rooted cuttings. The cutting should be a minimum of 12 inches above the roots. The cuttings can be planted by putting the cuttings in holes dug to the depth of the roots. When dormant cuttings are harvested use only the previous season's growth. Live stakes should typically be approximately ¾ inch in diameter and three feet long, and dormant cuttings should be approximately ½ inch in diameter and two feet long. Rooted cuttings can be dug before the buds swell in the spring and stored at 40°F, unless they are to be planted immediately. Root systems should be protected from drying by treating the roots with a moisture-retaining gel immediately after they are dug up or when they arrive at the planting site.

- Seedlings should be at least one year old. Seedlings should be dug before the buds swell in the spring and stored at 40°F, unless they are to be planted immediately. The seedlings should be a minimum of 12 inches tall above the roots. The seedlings can be planted by putting the seedlings in a hole dug to the depth of the roots. Seedlings should be spaced two feet on-center in rows no more than two feet apart.

Temporary Seeding

Temporary seeding shall follow the guidelines specified in the *NC Erosion and Sedimentation Control Manual*. The seeding schedule for temporary stabilization is shown in Table 16.

TABLE 16
Seeding Schedule
Temporary Erosion Control

PERMANENT SPECIES				**WINTER**	**SPRING**	**SUMMER**	**FALL**
				Nov. 1 - Mar 15	**Mar 15 - May 15**	**May 15 - Aug 15**	**Aug 15 - Nov 1**
COMMON NAME	**BOTANICAL NAME**	**UNITS**	**QUANTITY**				
Redtop	*Agorstis alba*	lbs	25	X	X	X	X
Reed Canarygrass	*Phalans arundinaceae*	lbs	40	X	X	X	X
	TOTAL	**lbs**	**215**				
SOIL AMENDMENTS		**UNITS**	**QUANTITY**				
Agricultural Lime		lbs	4,000	X	X	X	X
Superphosphate		lbs	500	into seedbed at preparation			
10-10-10 Fertilizer		lbs	1,000	X	X	X	X
MULCH		**UNITS**	**QUANTITY**				
Small Grain Straw Mulch		lbs	3,000	X	X	X	X
STARTER SPECIES (nurse seed)		**UNITS**	**QUANTITY**				
Rye Grain	*Secale cereale*	lbs	40	X			
Common Millet		lbs	15			X	
German Millet		lbs	10			X	

All quantities shown are per acre

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FIGURES

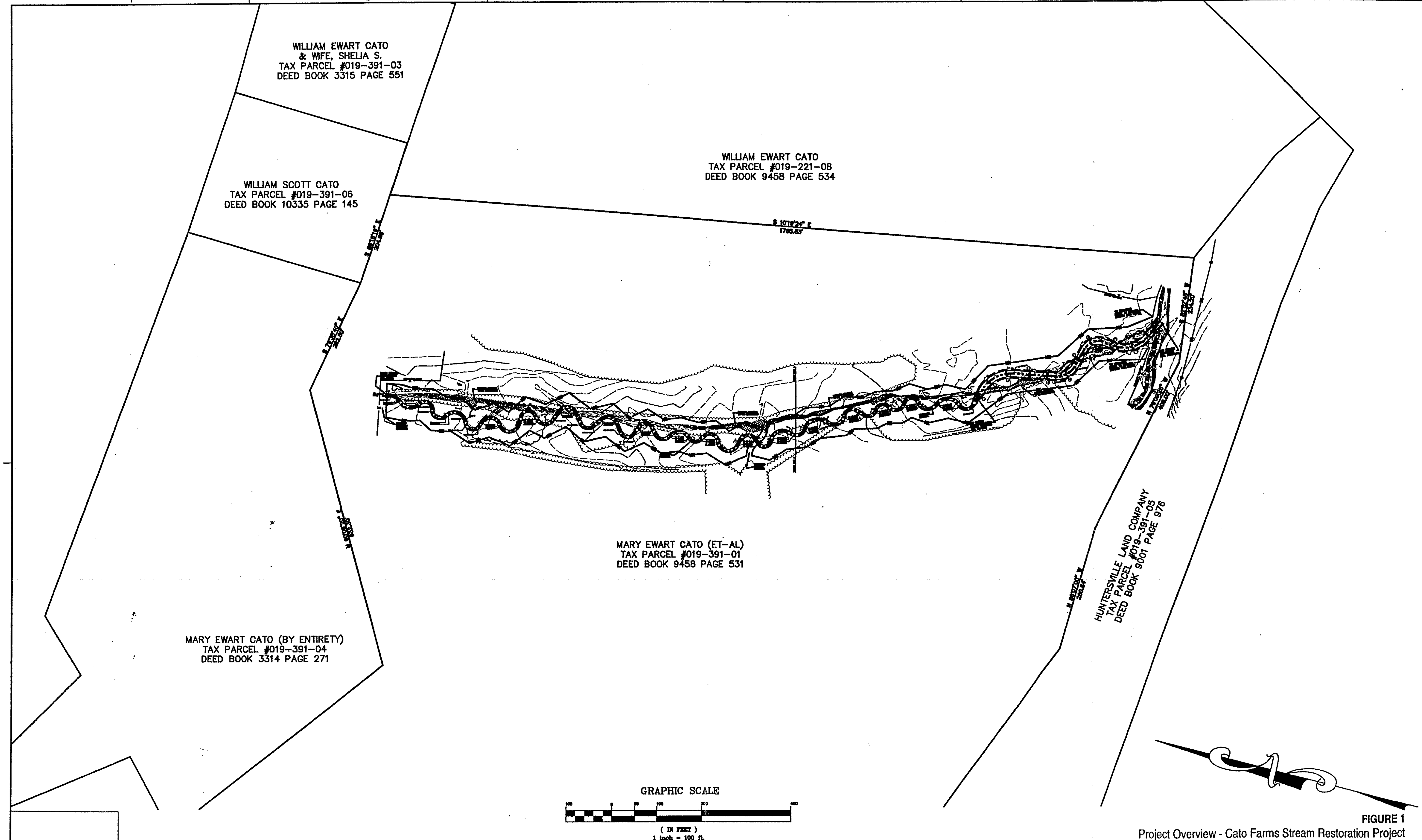

FIGURE 1

Project Overview - Cato Farms Stream Restoration Project

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DR	TDC					
CHK						
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STREAM RESTORATION PROJECT
PROJECT OVERVIEW

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DWG	CHM02
DATE	07/23/02
PROJ	171915

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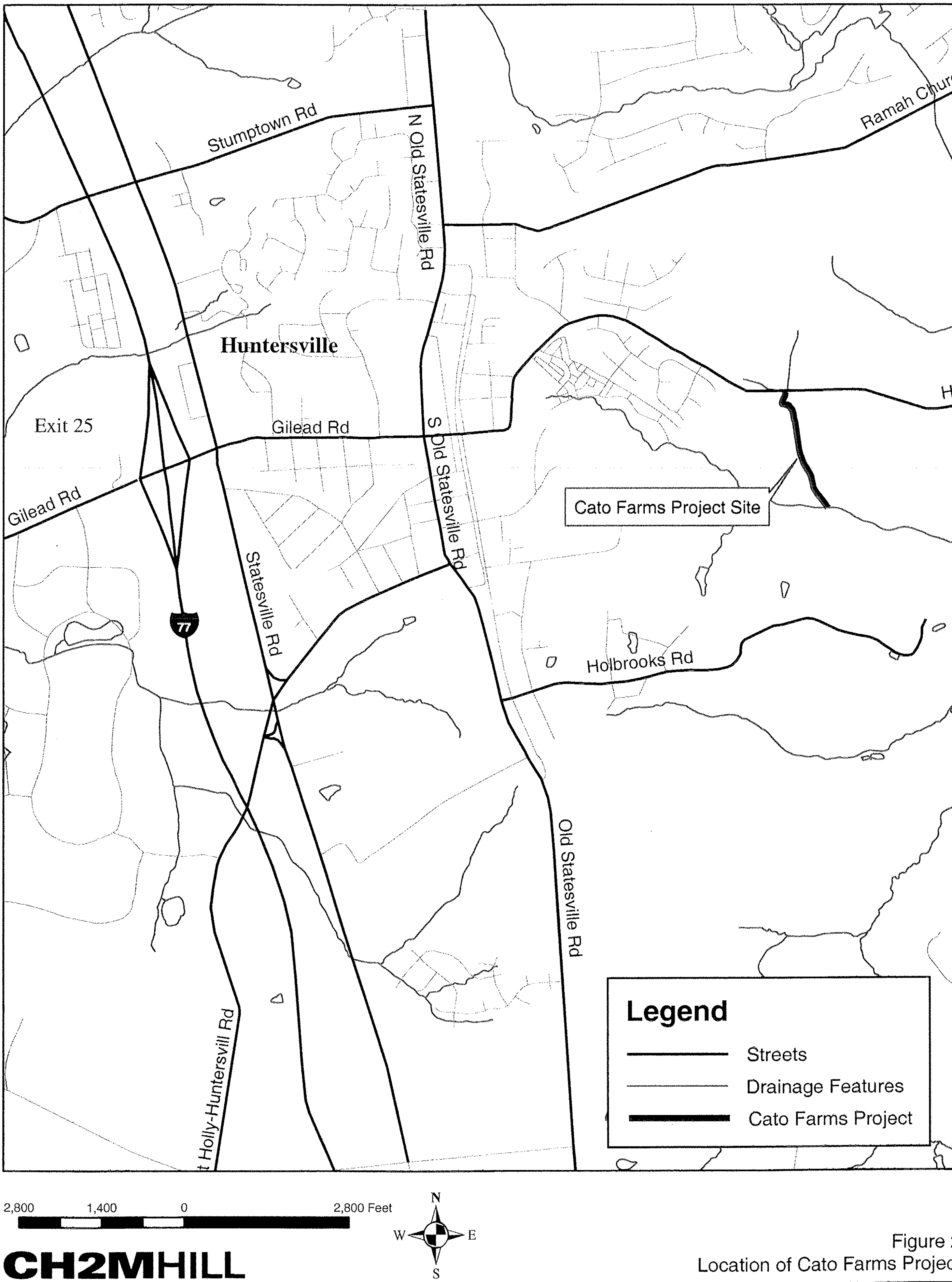

Figure 2
Location of Cato Farms Project

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P:NC DENR\171915\CADD&GIS\FIGURE 2

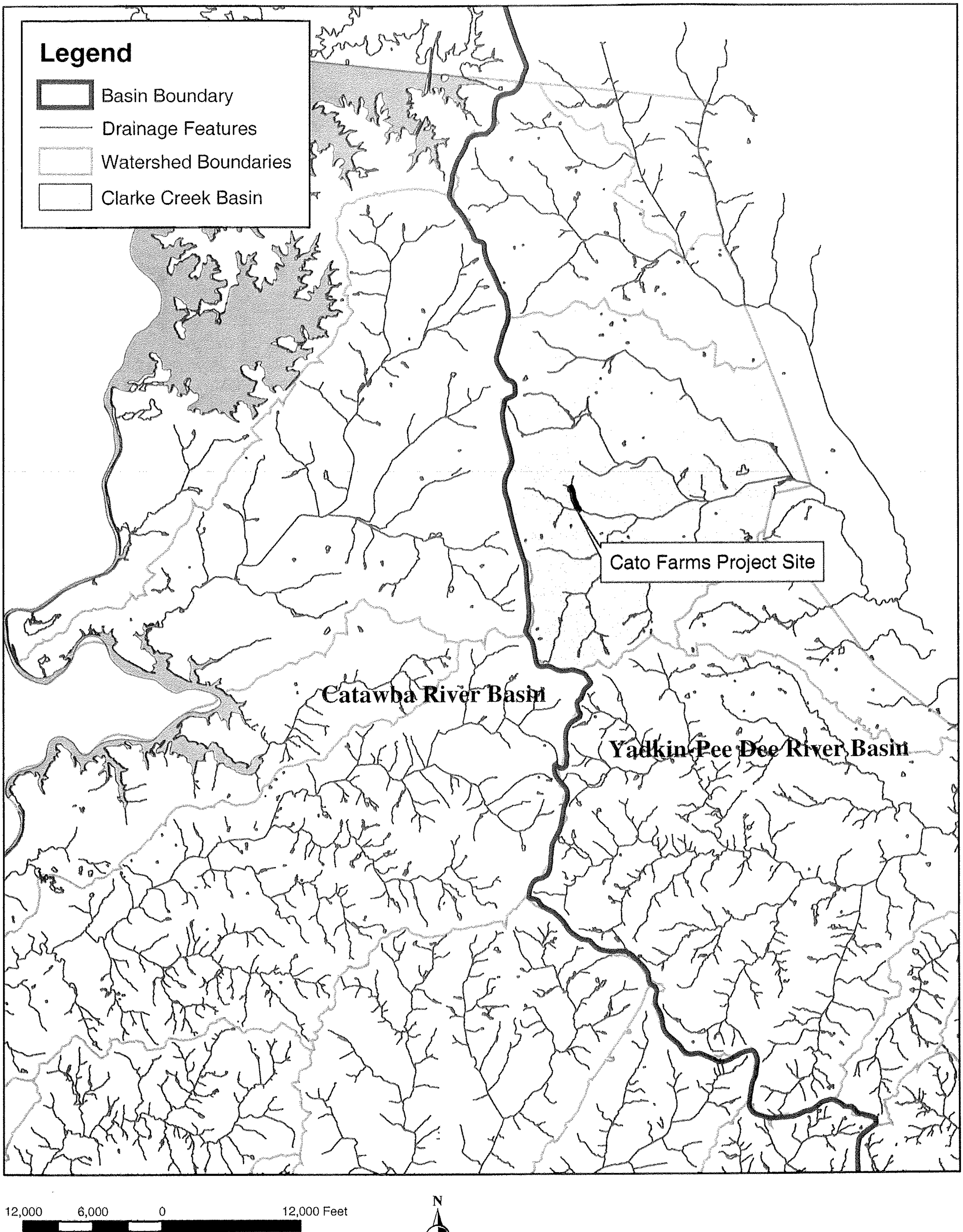

Figure 3
Clarke Creek Watershed

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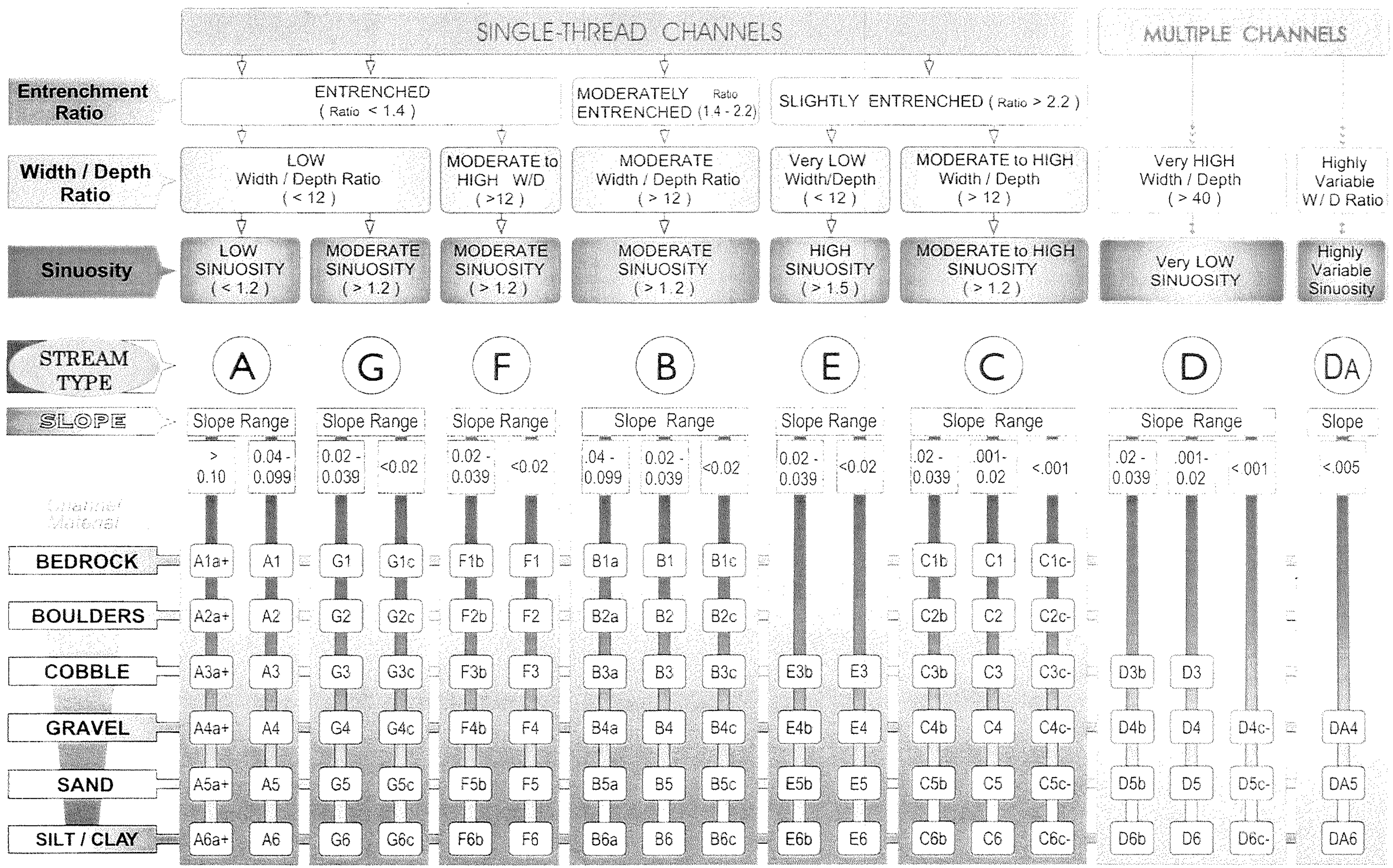
P:NC DENR\171915\CADD&GIS\FIGURE 3

The Key to the Rosgen Classification of Natural Rivers



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

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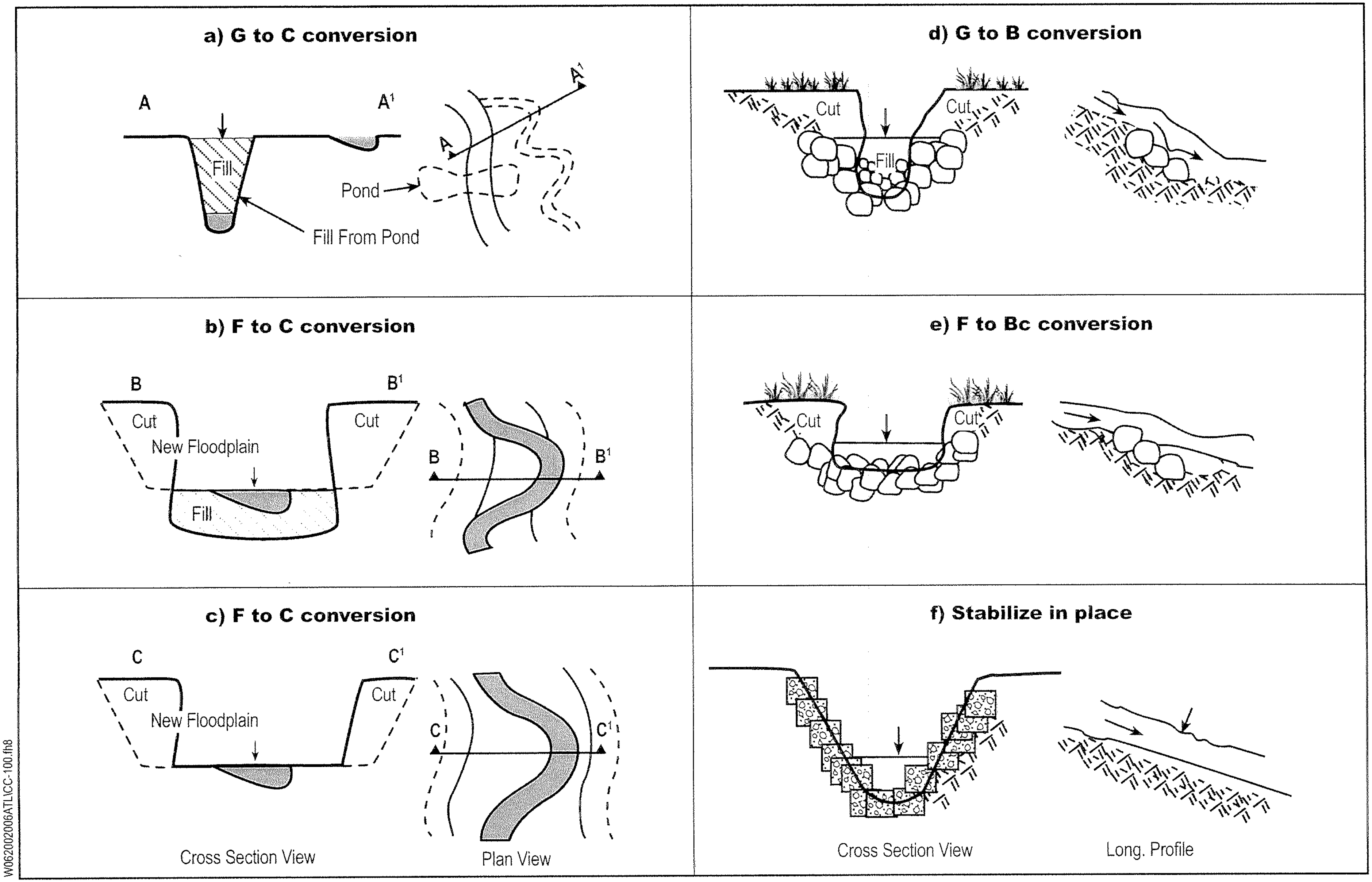
Figure 4a
Rosgen Stream Classification



Source: Rosgen, David L., "A Geomorphological Approach to Restoration of Incised Rivers," *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*, 1997

Figure 4b
Various Restoration/Stabilization Options for Incised Channels
Cato Farm Stream Restoration Project

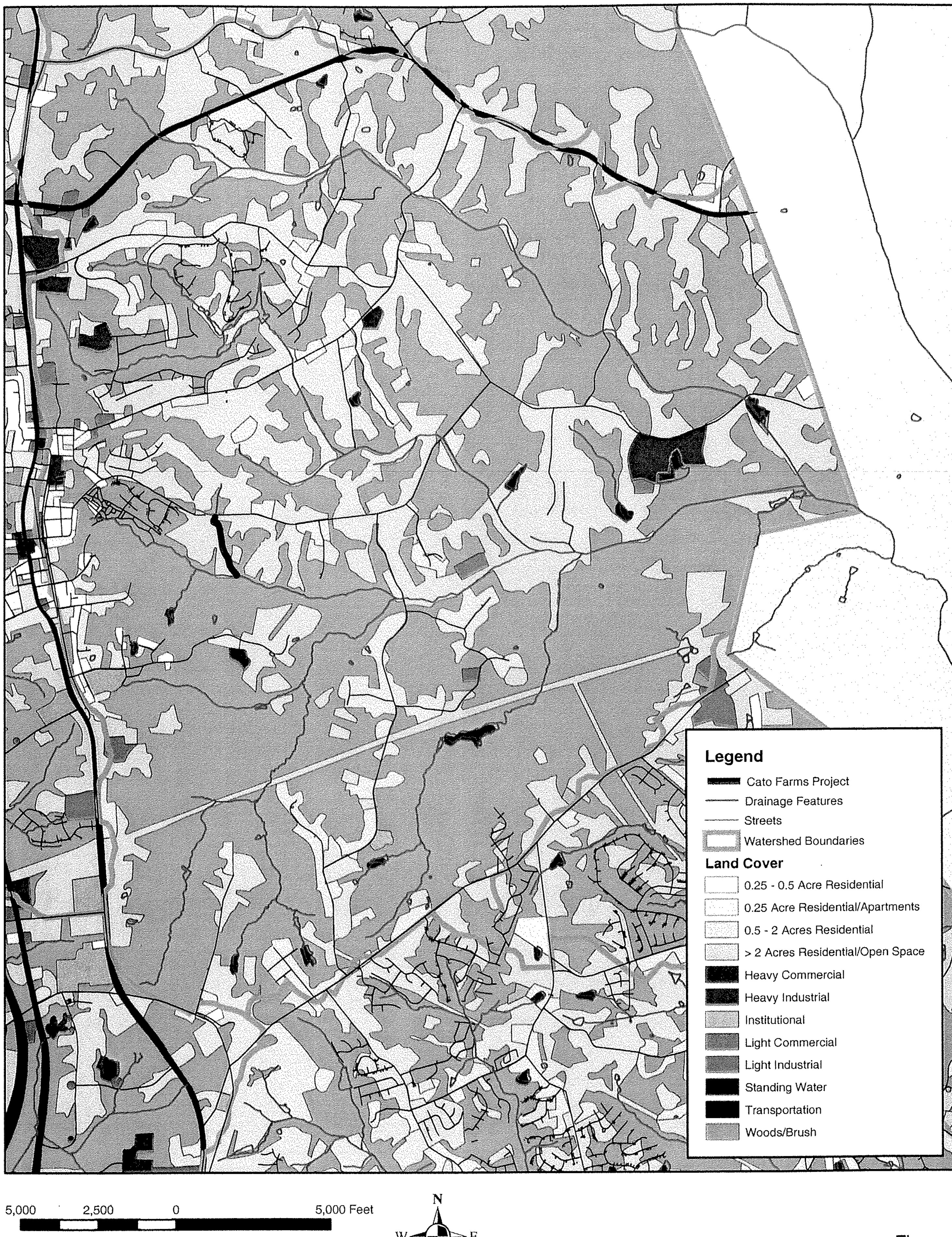


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Figure 5
Land Cover in Clarke Creek Watershed

P:NC DENR\171915\CADD&GIS\FIGURE 5

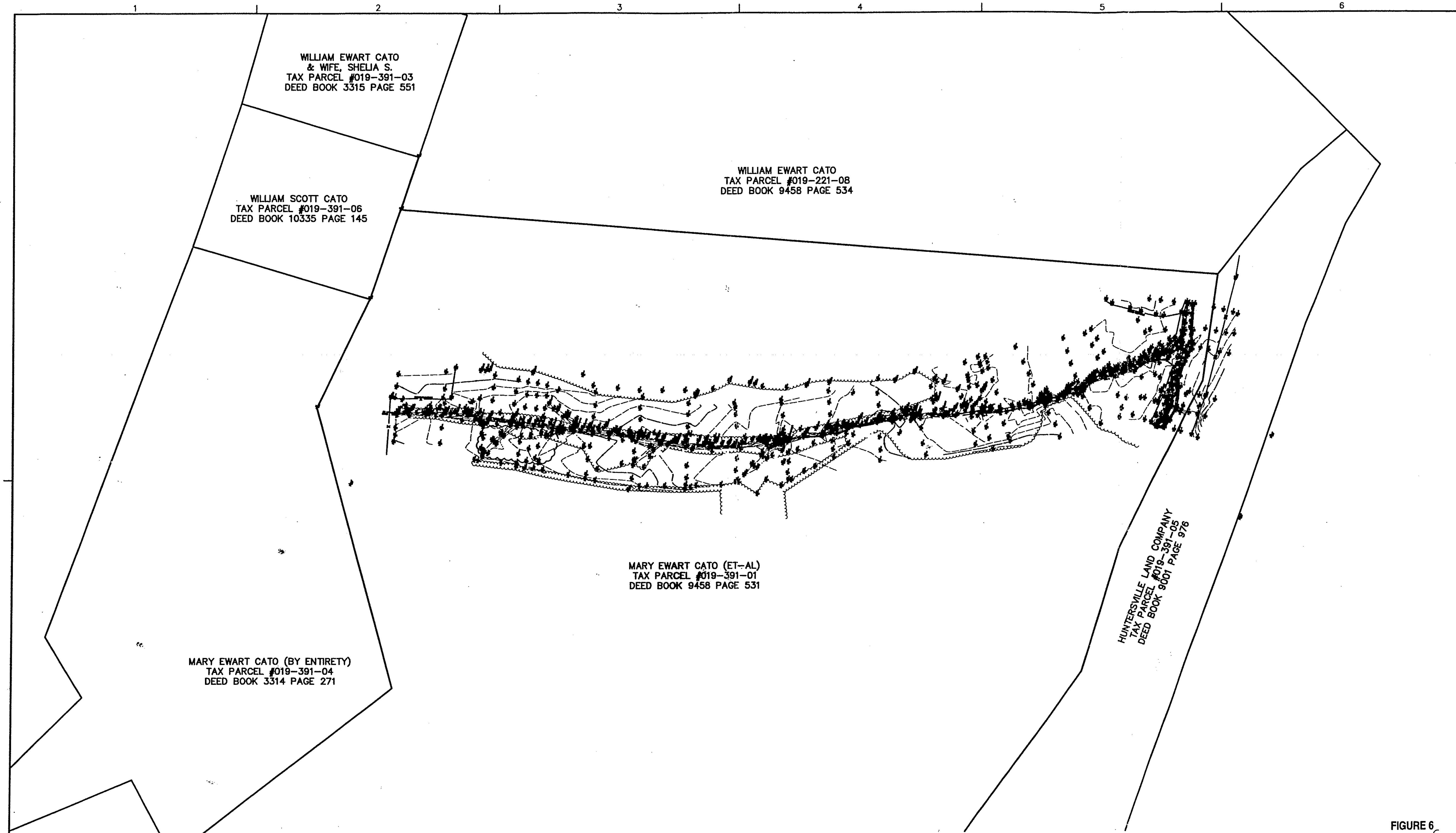

FIGURE 6
Existing Survey Base Map
Cato Farms Stream Restoration Project

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PROJECT OVERVIEW

SHEET	O-1
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DATE	06/14/02
PROJ	171915

PLOT DATE: 06/04/02

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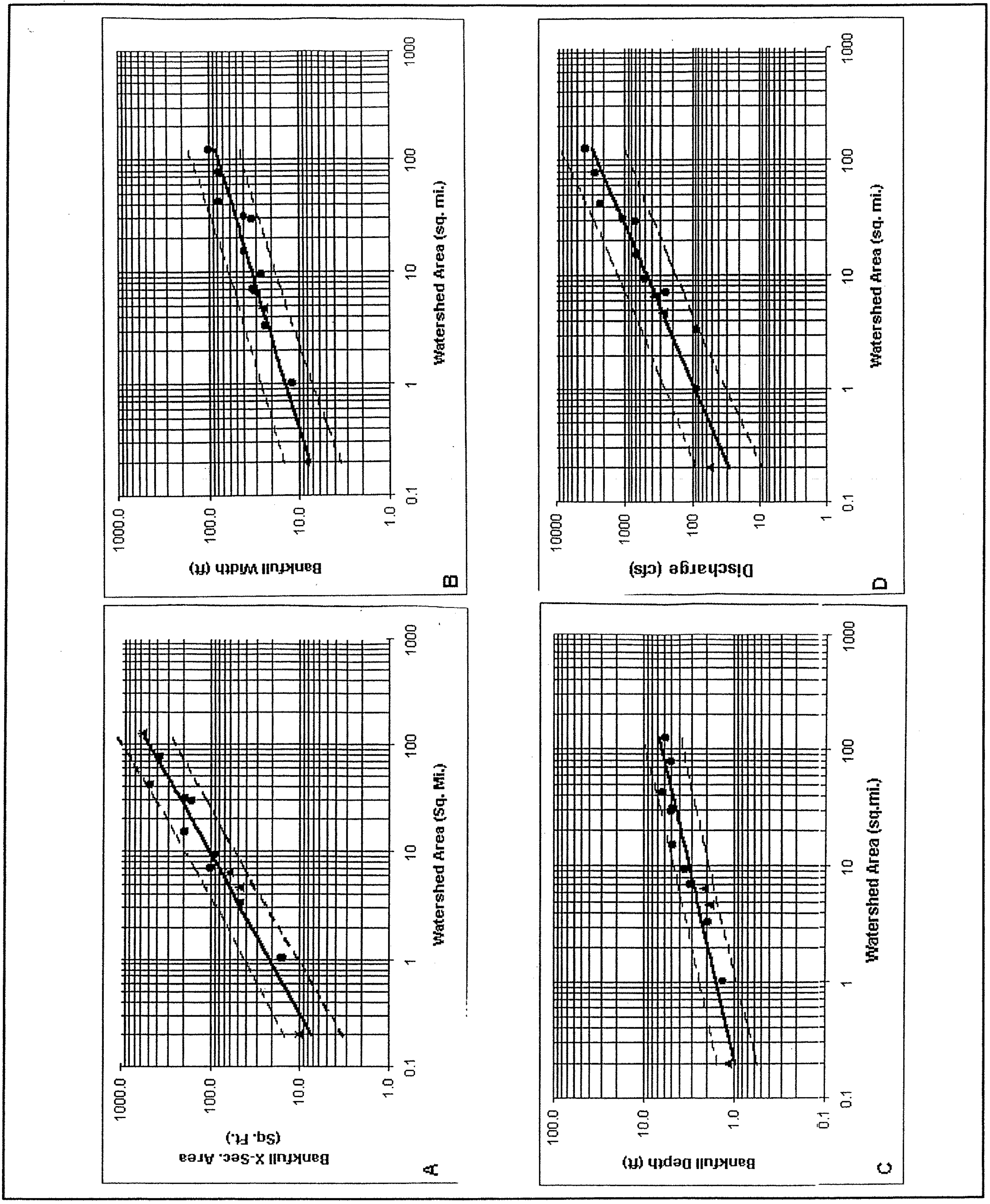

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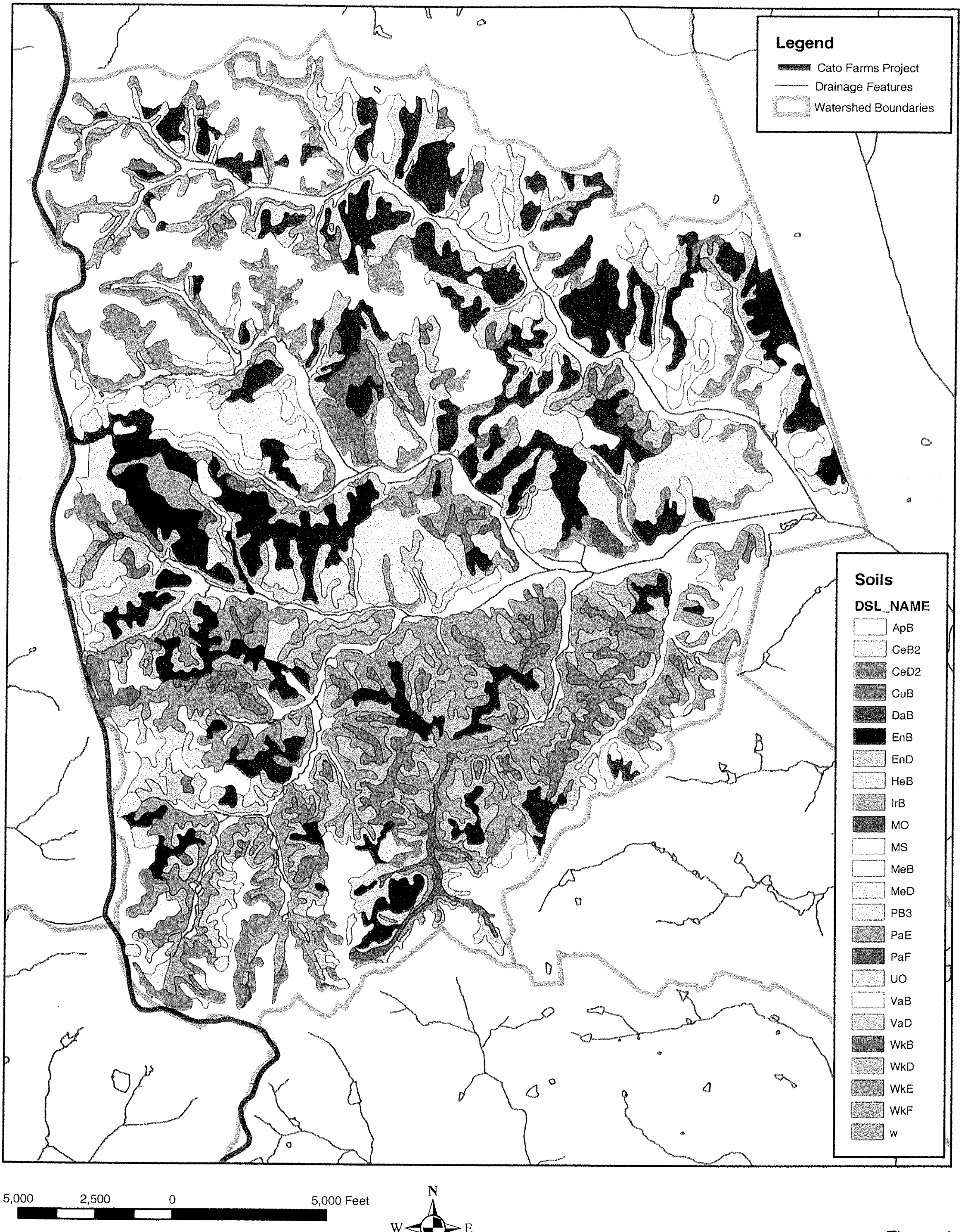
P:NC DENR\171915\CADD&GIS\FIGURE X

Figure 7
Regional Curves for Rural North Carolina Piedmont



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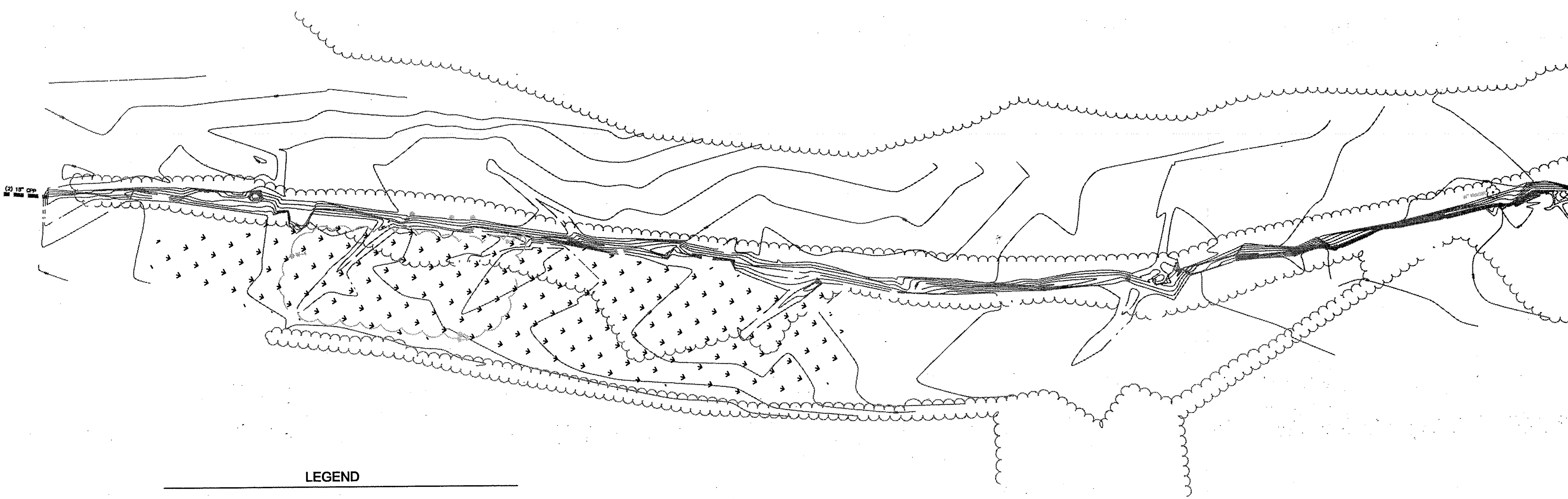
P:NC DENR\171915\CADD&GIS\FIGURE 8

Figure 8
Soils in Clarke Creek Watershed



LEGEND

FIELD IDENTIFIED HYDRIC SOILS AREAS

NOTE: NOT TO SCALE

FIGURE 9
Field Identified Hydric Soils
Cato Farms Stream Restoration Project

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DELINEATED WETLANDS

SHEET	
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DATE	06/14/02
PROJ	171915

PLOT DATE: 06/04/02

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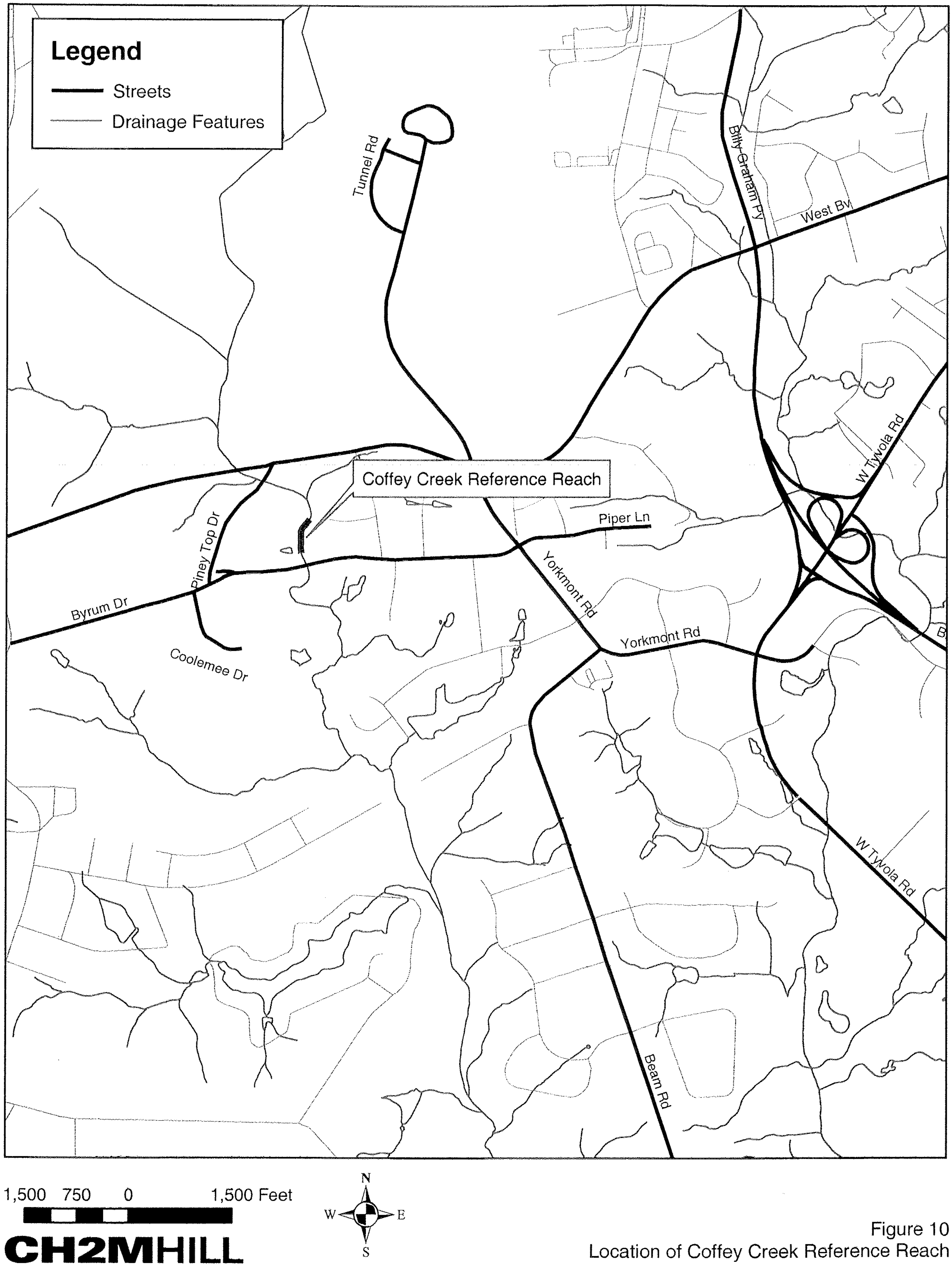

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Figure 10
Location of Coffey Creek Reference Reach

P:NC DENR\171915\CADD&GIS\FIGURE 10

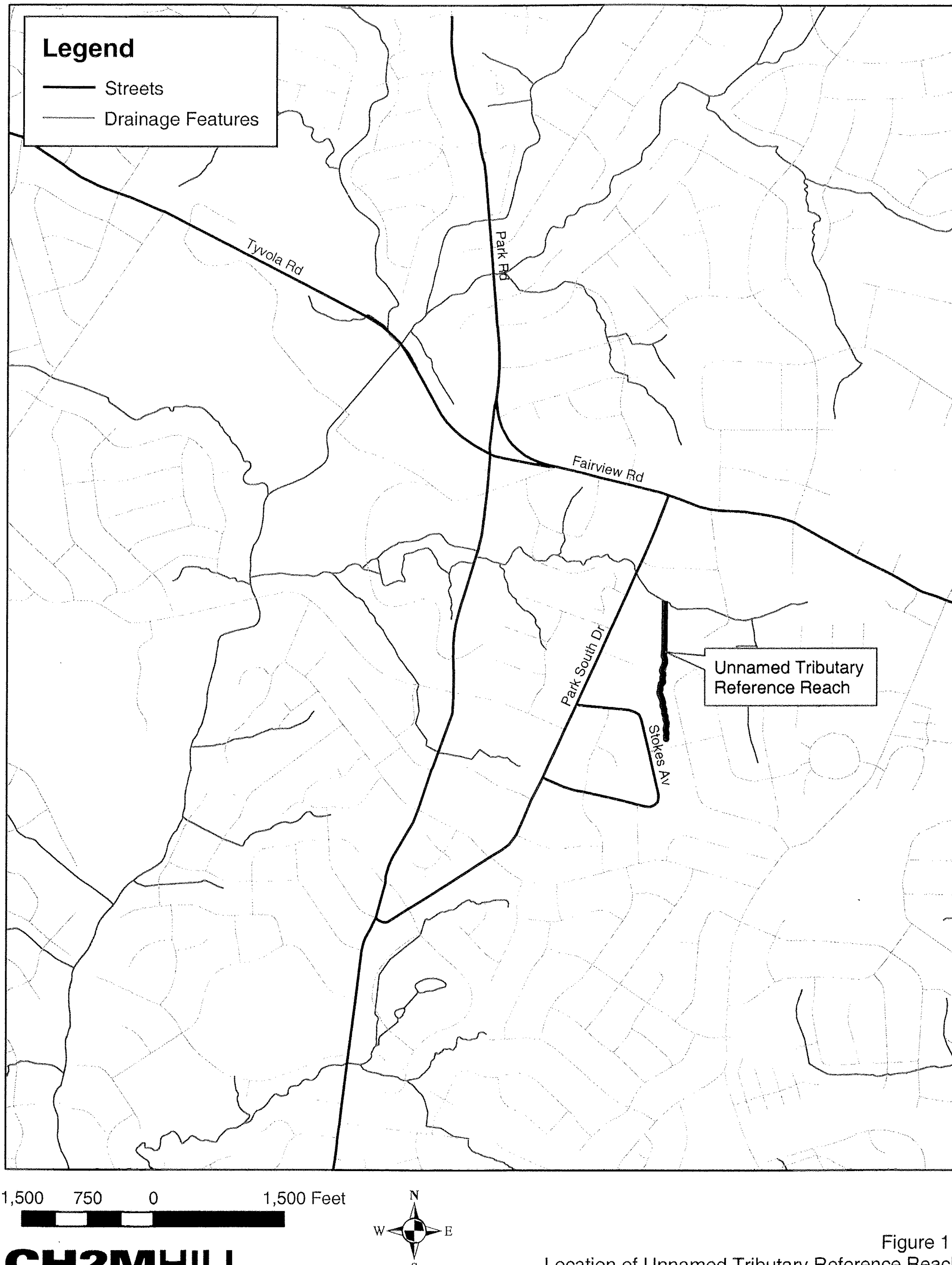

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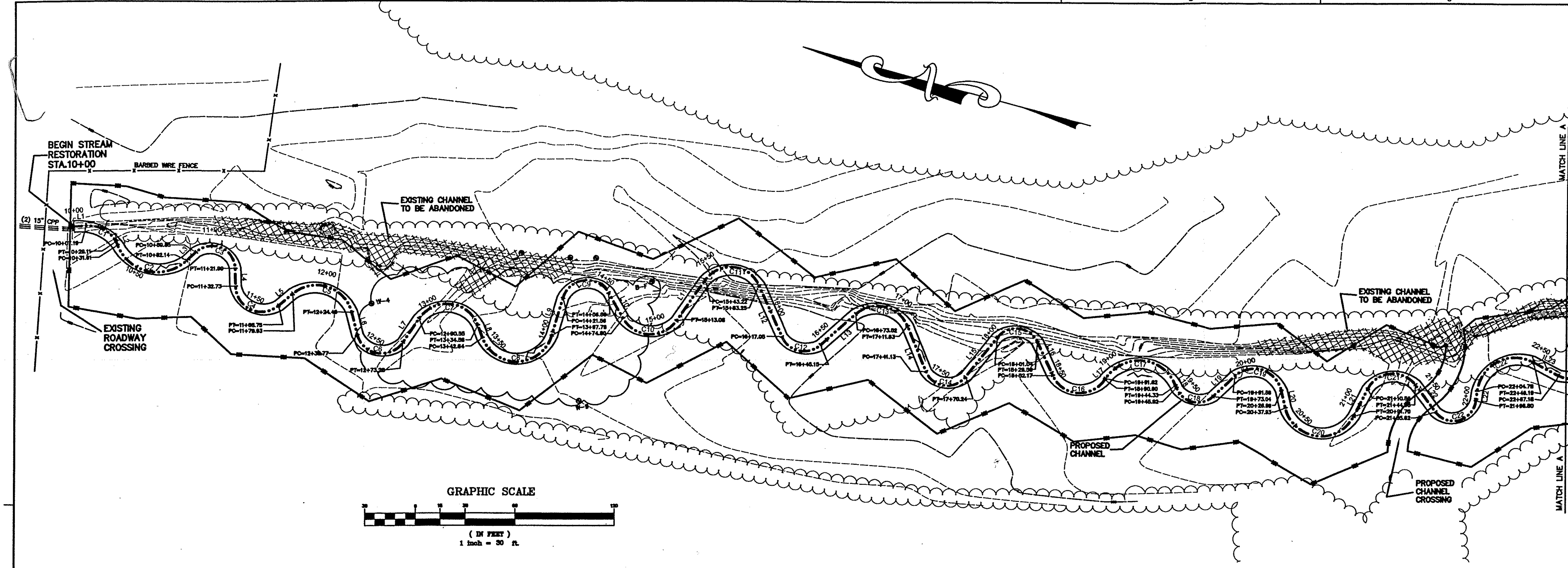
Figure 11
Location of Unnamed Tributary Reference Reach

P:NC DENR\171915\CADD&GIS\FIGURE 11



LINE TABLE		
LINE	LENGTH	BEARING
L1	7.19'	S 17°54'32" E
L2	2.50'	S 53°46'10" W
L3	7.81'	S 67°35'12" E
L4	10.73'	S 73°32'19" W
L5	11.17'	S 55°28'40" E
L6	14.31'	S 60°29'59" W
L7	17.27'	S 71°19'31" E
L8	8.08'	S 54°45'07" W
L9	23.78'	S 86°50'42" E
L10	18.10'	S 45°20'41" W
L11	30.14'	S 70°06'22" E
L12	33.80'	S 60°36'31" W
L13	28.37'	S 66°44'26" E
L14	29.50'	S 82°25'44" W
L15	30.79'	S 86°43'15" E
L16	22.57'	S 60°06'33" W
L17	1.02'	S 72°10'57" E
L18	1.60'	S 63°36'59" W
L19	18.54'	S 57°19'34" E
L20	10.94'	S 62°02'18" W
L21	18.89'	S 78°00'14" E
L22	20.66'	S 37°49'22" W
L23	5.99'	N 82°01'59" E
L24	18.00'	S 12°39'21" W
L25	3.32'	N 86°49'49" E
L26	23.67'	S 09°57'58" W
L27	4.41'	N 80°16'39" E
L28	26.85'	S 16°20'22" W
L29	5.99'	N 86°39'29" E
L30	13.92'	S 24°14'24" W
L31	8.62'	S 80°34'54" E
L32	11.91'	S 43°47'01" W
L33	2.80'	S 74°36'22" E
L34	15.45'	S 34°59'37" W
L35	43.72'	S 74°26'32" E
L36	93.51'	S 10°55'02" E
L37	38.98'	S 75°53'22" E
L38	27.57'	S 04°54'14" W
L39	45.25'	S 86°07'05" E

CURVE TABLE						
CURVE	RADIUS	LENGTH	TANGENT	CHORD BEARING	CHORD	DELTA
C1	20.00'	21.92'	12.21'	N 13°29'16" E	20.84'	62°47'38"
C2	26.00'	50.53'	38.06'	S 01°54'31" E	42.95'	111°21'22"
C3	14.00'	32.04'	30.81'	N 07°56'33" E	25.49'	131°07'31"
C4	16.00'	36.03'	33.56'	S 09°01'50" W	28.86'	129°00'58"
C5	22.00'	44.53'	35.19'	N 02°30'40" E	37.31'	115°56'36"
C6	15.00'	34.51'	33.56'	S 05°24'46" E	27.39'	131°49'30"
C7	20.00'	44.01'	38.32'	N 05°17'12" W	35.65'	126°04'36"
C8	22.00'	55.14'	66.91'	S 17°02'46" E	41.80'	143°36'49"
C9	15.00'	35.13'	35.50'	N 21°45'01" W	27.63'	134°11'23"
C10	19.00'	38.28'	30.06'	S 12°22'01" E	32.13'	115°27'03"
C11	19.00'	40.03'	33.39'	N 09°44'55" W	33.03'	120°42'53"
C12	15.00'	28.10'	20.40'	S 03°03'56" E	24.17'	107°20'56"
C13	20.00'	38.11'	28.13'	N 02°09'21" W	32.60'	109°10'10"
C14	14.00'	29.11'	23.84'	S 07°06'46" E	24.14'	119°08'59"
C15	14.00'	28.56'	22.78'	N 08°17'21" W	23.86'	116°51'46"
C16	18.00'	38.43'	32.89'	S 11°01'12" E	31.54'	122°19'30"
C17	24.00'	52.71'	46.93'	N 09°15'59" W	42.74'	125°49'56"
C18	14.00'	27.12'	20.36'	S 01°30'18" E	23.07'	110°58'33"
C19	17.00'	35.42'	29.07'	N 02°21'22" E	29.35'	119°21'53"
C20	22.00'	53.77'	60.51'	S 07°58'57" E	41.35'	140°02'33"
C21	17.00'	34.37'	27.11'	N 20°05'26" W	28.81'	115°49'35"
C22	14.00'	33.18'	34.47'	S 30°04'19" E	25.94'	135°47'22"
C23	23.00'	44.41'	33.23'	N 42°39'20" W	37.82'	110°37'22"
C24	17.00'	31.70'	22.90'	S 40°45'25" E	27.30'	106°49'32"
C25	26.00'	47.28'	33.36'	N 42°06'06" W	41.01'	104°06'09"
C26	20.00'	38.29'	28.40'	S 44°52'41" E	32.70'	109°41'19"
C27	15.00'	30.38'	24.03'	N 41°41'29" W	25.45'	116°03'43"
C28	15.00'	28.71'	21.30'	S 38°30'04" E	24.53'	109°40'53"
C29	14.00'	28.73'	23.11'	N 34°33'03" W	23.95'	117°34'56"
C30	18.00'	34.50'	25.82'	S 30°40'15" E	29.46'	109°49'16"
C31	15.00'	33.87'	31.72'	N 20°53'31" W	27.12'	129°22'45"
C32	22.00'	45.46'	36.90'	S 15°23'46" E	37.79'	118°23'13"
C33	26.00'	49.73'	36.85'	N 19°47'52" W	42.49'	109°34'59"
C34	15.00'	28.65'	21.20'	S 19°43'27" E	24.49'	109°26'09"
C35	72.00'	79.83'	44.56'	N 42°40'47" W	75.80'	63°31'30"
C36	50.00'	56.70'	31.84'	S 43°24'12" E	53.71'	64°58'20"
C37	35.00'	49.35'	29.76'	N 36°29'34" W	45.37'	80°47'36"
C38	64.00'	79.33'	45.67'	S 30°36'26" E	74.35'	71°01'16"

NOTES:

1. SEE SHEET D-1, DETAILS (1/D-1) AND (2/D-1) FOR TYPICAL CROSS-SECTION OF THE PROPOSED STREAM RESTORATION.

2. EXISTING CHANNEL TO BE ABANDONED SHALL BE FILLED IN ACCORDANCE WITH THE SPECIFICATIONS.

3. STREAM RESTORATION SHALL BE TO THE WEST SIDE OF THE EXISTING CHANNEL TO AVOID CONFLICT WITH A POTENTIAL FUTURE SANITARY SEWER LINE TO BE INSTALLED BY OTHERS.

4. STREAM FLOW SHALL BE MAINTAINED IN THE EXISTING CHANNEL WHILE THE PROPOSED CHANNEL IS BEING CONSTRUCTED. PROVISIONS SHALL BE MADE FOR PUMPING WATER OUT OF THE PROPOSED CHANNEL WHERE THE EXISTING AND PROPOSED CHANNELS OVERLAP.

5. PLANTING OF PROJECT SHALL BE IN ACCORDANCE WITH THE PLANTING PLAN SHOWN ON SHEET P-3 THROUGH P-4.

6. A CONSERVATION EASEMENT SHALL BE SECURED ABOUT THE CENTERLINE OF THE PROPOSED CHANNEL. THE EASEMENT SHALL BE 50' WIDE ON CENTER. THE PROPOSED EASEMENT WILL BE FENCED.

7. REFER TO SHEET O-1 FOR PROPOSED CONSTRUCTION EQUIPMENT STAGING AREA. (LIMITS TO BE FIELD VERIFIED WITH PROPERTY OWNER.)

LEGEND

- PROPERTY LINE
- THALWEG OF PROPOSED CHANNEL
- BANKFULL CHANNEL
- LIMITS OF FLOODPRONE AREA/TOP OF BANK
- EXISTING CONTOUR (5' MAJOR)
- EXISTING CONTOUR (1' MINOR)
- EXISTING FENCE LINE
- PROPOSED FENCE LINE AT LIMITS OF 75' EASEMENT
- EXISTING STORM PIPE
- SANITARY SEWER LINE
- (S) SANITARY SEWER MANHOLE
- TREE LINE
- TREE
- FILL EXISTING CHANNEL
- CROSS VANE
- DIRECTION OF FLOW
- B-F BANKFULL SURVEY SHOT
- W# WETLAND SURVEY SHOT

FIGURE 12

Plan Sheet #1 - Cato Farms Stream Restoration Project

PRELIMINARY

NOT FOR CONSTRUCTION

DSGN	SPB, SDC	SHEET	P-1
DR	TDC	DWG	CHM02
CHK		DATE	07/23/02
APVD		PROJ	171915

NO.	DATE	REVISION	BY	APVD

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 — 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

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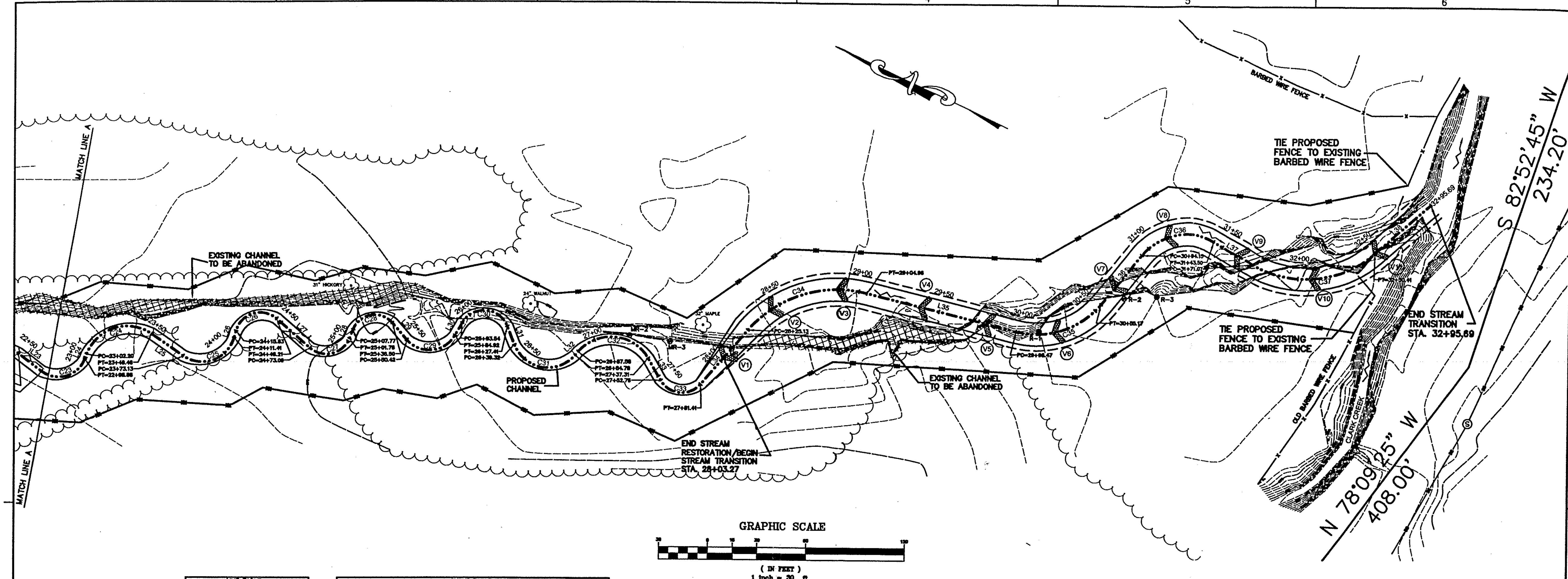
CHARLOTTE, N.C. 28217-1968
(704) 329-0072

CATO FARMS
STREAM RESTORATION PROJECT
PLAN - 10+00 TO 22+72.11

FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02_rev.dwg

PLOT DATE: 07/23/02



LINE TABLE		
LINE	LENGTH	BEARING
L1	7.19'	S 17°54'32" E
L2	2.50'	S 53°46'10" W
L3	7.81'	S 57°36'12" E
L4	10.73'	S 73°32'19" W
L5	11.17'	S 50°28'40" E
L6	14.31'	S 60°29'59" W
L7	17.27'	S 71°19'31" E
L8	8.06'	S 64°45'07" W
L9	23.78'	S 88°50'42" E
L10	18.10'	S 45°20'41" W
L11	30.14'	S 70°06'22" E
L12	33.80'	S 50°36'31" W
L13	28.37'	S 86°44'26" E
L14	29.50'	S 52°25'44" W
L15	30.79'	S 86°43'15" E
L16	22.57'	S 50°06'33" W
L17	1.02'	S 72°10'57" E
L18	1.60'	S 53°36'39" W
L19	18.54'	S 57°19'34" E
L20	10.94'	S 62°02'19" W
L21	18.89'	S 78°00'14" E
L22	20.86'	S 37°49'22" W
L23	8.99'	N 82°01'59" E
L24	18.00'	S 12°39'21" W
L25	3.32'	N 86°49'49" E
L26	23.67'	S 09°57'58" W
L27	4.41'	N 80°16'36" E
L28	26.85'	S 16°20'22" W
L29	8.99'	N 86°39'29" E
L30	13.92'	S 24°14'24" W
L31	8.62'	S 80°34'54" E
L32	11.91'	S 43°47'01" W
L33	2.80'	S 74°35'22" E
L34	16.45'	S 34°39'37" W
L35	43.72'	S 74°28'32" E
L36	93.81'	S 10°56'02" E
L37	38.96'	S 75°53'22" E
L38	27.57'	S 04°54'14" W
L39	46.26'	S 86°07'05" E

CURVE TABLE						
CURVE	RADIUS	LENGTH	TANGENT	CHORD BEARING	CHORD	DELTA
C1	20.00'	21.92'	12.21'	N 13°29'16" E	20.84'	62°47'36"
C2	26.00'	50.53'	38.06'	S 01°54'31" E	42.95'	111°21'22"
C3	14.00'	32.04'	30.81'	N 07°56'33" E	25.49'	131°07'31"
C4	16.00'	36.03'	33.56'	S 09°01'50" W	28.88'	129°00'58"
C5	22.00'	44.53'	35.19'	N 02°30'40" E	37.31'	115°58'36"
C6	15.00'	34.31'	33.55'	S 06°24'46" E	27.36'	131°49'30"
C7	20.00'	44.01'	38.32'	N 08°17'12" W	35.66'	126°04'36"
C8	22.00'	55.14'	66.91'	S 17°02'46" E	41.80'	143°35'49"
C9	15.00'	35.13'	35.80'	N 21°45'01" W	27.63'	134°11'23"
C10	19.00'	38.28'	30.06'	S 12°22'31" E	32.13'	115°27'03"
C11	19.00'	40.03'	33.39'	N 09°44'55" W	33.03'	120°42'53"
C12	15.00'	28.10'	20.40'	S 03°03'56" E	24.17'	107°20'56"
C13	20.00'	38.11'	28.13'	N 02°09'21" W	32.60'	109°10'10"
C14	14.00'	29.11'	23.84'	S 07°06'46" E	24.14'	119°06'59"
C15	14.00'	28.56'	22.78'	N 08°17'21" W	23.86'	116°51'48"
C16	18.00'	38.43'	32.89'	S 11°01'12" E	31.54'	122°19'30"
C17	24.00'	52.71'	46.83'	N 09°15'36" W	42.74'	125°49'56"
C18	14.00'	27.12'	20.36'	S 01°50'18" E	23.07'	110°58'33"
C19	17.00'	35.42'	29.07'	N 02°21'22" E	29.35'	119°21'53"
C20	22.00'	53.77'	60.51'	S 07°58'57" E	41.35'	140°02'33"
C21	17.00'	34.37'	27.11'	N 20°05'26" W	28.81'	115°49'36"
C22	14.00'	33.18'	34.47'	S 30°04'19" E	25.94'	135°47'22"
C23	23.00'	44.41'	33.23'	N 42°39'20" W	37.82'	110°37'22"
C24	17.00'	31.70'	22.90'	S 40°45'25" E	27.30'	106°49'32"
C25	26.00'	47.26'	33.36'	N 42°06'06" W	41.01'	104°06'09"
C26	20.00'	38.29'	28.40'	S 44°52'41" E	32.70'	109°41'19"
C27	15.00'	30.38'	24.03'	N 41°41'29" W	25.45'	116°03'43"
C28	15.00'	28.71'	21.30'	S 38°30'04" E	24.53'	109°40'53"
C29	14.00'	28.73'	23.11'	N 34°33'03" W	23.95'	117°34'55"
C30	18.00'	34.50'	25.62'	S 30°40'15" E	29.46'	109°49'15"
C31	15.00'	33.87'	31.72'	N 20°53'31" W	27.12'	129°22'45"
C32	22.00'	45.46'	38.90'	S 15°23'46" E	37.79'	118°23'13"
C33	26.00'	49.73'	36.85'	N 19°47'52" W	42.49'	109°34'59"
C34	15.00'	28.65'	21.20'	S 19°43'27" E	24.49'	109°26'09"
C35	72.00'	79.53'	44.56'	N 42°40'47" W	75.80'	63°31'30"
C36	60.00'	56.70'	31.84'	S 43°24'12" E	53.71'	54°08'20"
C37	35.00'	49.36'	29.78'	N 36°29'34" W	45.37'	80°47'36"
C38	64.00'	79.33'	45.67'	S 30°36'26" E	74.35'	71°01'18"

NOTES:

1. SEE SHEET D-1 AND D-2, DETAILS (1/D-1), (2/D-1), (1/D-2) AND (2/D-2) FOR TYPICAL CROSS-SECTION OF THE PROPOSED STREAM RESTORATION.

2. EXISTING CHANNEL TO BE ABANDONED SHALL BE FILLED IN ACCORDANCE WITH THE SPECIFICATIONS.

3. STREAM RESTORATION SHALL BE TO THE WEST SIDE OF THE EXISTING CHANNEL TO AVOID CONFLICT WITH A POTENTIAL FUTURE SANITARY SEWER LINE TO BE INSTALLED BY OTHERS.

4. STREAM FLOW SHALL BE MAINTAINED IN THE EXISTING CHANNEL WHILE THE PROPOSED CHANNEL IS BEING CONSTRUCTED. PROVISIONS SHALL BE MADE FOR PUMPING WATER OUT OF THE PROPOSED CHANNEL WHERE THE EXISTING AND PROPOSED CHANNELS OVERLAP.

5. PLANTING OF PROJECT SHALL BE IN ACCORDANCE WITH THE PLANTING PLAN SHOWN ON SHEET P-3 THROUGH P-4.

6. A CONSERVATION EASEMENT SHALL BE SECURED ABOUT THE CENTERLINE OF THE PROPOSED CHANNEL. THE EASEMENT SHALL BE 50' WIDE ON CENTER.

7. CROSS VANE SHALL BE PLACED IN ACCORDANCE WITH THE CROSS VANE TABLE AND DETAIL (1/D-3).

CROSS VANE TABLE	
V1	28+03
V2	28+44.08
V3	28+88
V4	29+34
V5	29+79
V6	30+22
V7	30+68
V8	31+13
V9	31+60
V10	32.08
V11	32+51

LEGEND

- PROPERTY LINE
- THALWEG OF PROPOSED CHANNEL
- BANKFULL CHANNEL
- LIMITS OF FLOODPRONE AREA/TOP OF BANK
- EXISTING CONTOUR (5' MAJOR)
- EXISTING CONTOUR (1' MINOR)
- EXISTING FENCE LINE
- PROPOSED FENCE LINE AT LIMITS OF 75' EASEMENT
- EXISTING STORM PIPE
- SANITARY SEWER LINE
- SANITARY SEWER MANHOLE
- TREE LINE
- TREE
- FILL EXISTING CHANNEL
- CROSS VANE
- DIRECTION OF FLOW
- B-F BANKFULL SURVEY SHOT
- W# WETLAND SURVEY SHOT

FIGURE 13

Plan Sheet #2 - Cato Farms Stream Restoration Project

PRELIMINARY

NOT FOR CONSTRUCTION

DSGN	SPB, SDC
DR	TDC
CHK	
APVD	

NO.	DATE	REVISION	BY	APVD

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

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CATO FARMS

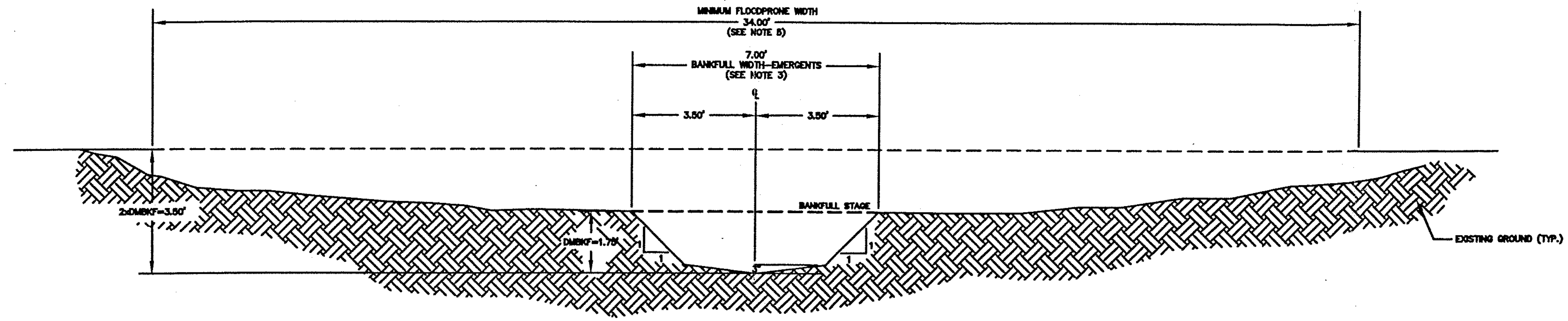
STREAM RESTORATION PROJECT

PLAN - 22+72.11 TO 32+95.69

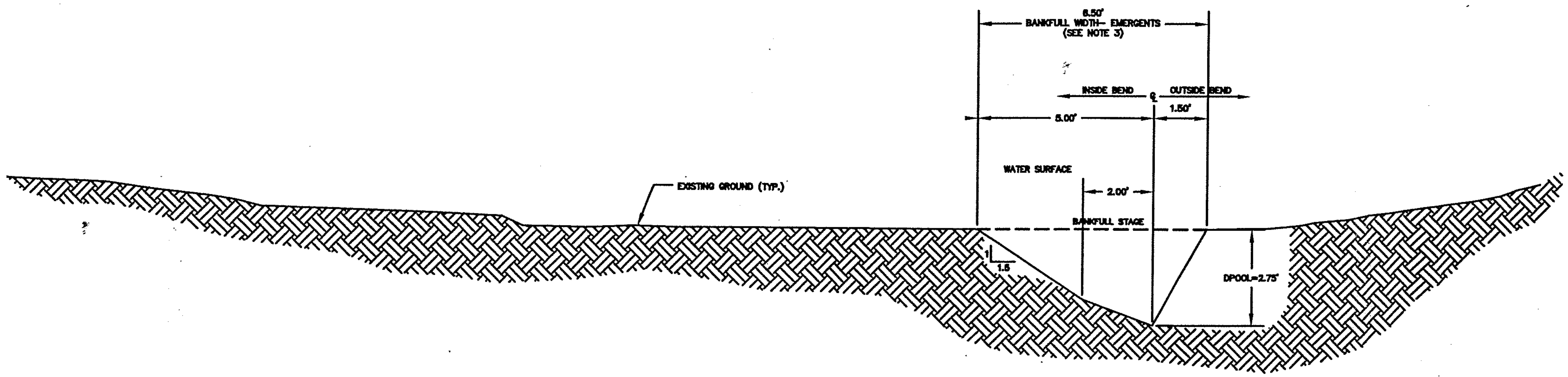
SHEET	P-2
DWG	CHM02
DATE	07/23/02
PROJ	171915

FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02_rev.dwg

PLOT DATE: 07/23/02



(1/D-1) STREAM RESTORATION (STA. 10+00 TO STA. 28+03.27) TYPICAL RIFFLE CROSS-SECTION
NTS



(2/D-1) STREAM RESTORATION (STA. 10+00 TO STA. 28+03.27) TYPICAL POOL (BEND) CROSS-SECTION
NTS

CROSS SECTION NOTES:

1. ALL TYPICAL SECTIONS ARE VIEWED FACING DOWNSTREAM.

2. REVERSE TYPICAL SECTION (2/D-1) AS NEEDED DEPENDING ON THE DIRECTION OF THE BEND IN THE STREAM – 2:1 SLOPE SHALL BE USED ON THE OUTSIDE STREAMBANK IN A BEND (MEANDER) AND 12:1 SLOPE SHALL BE USED ON THE INSIDE STREAMBANK IN A BEND (MEANDER).

3. TYPICAL SECTION VERTICAL CONTROL SHALL BE ABOUT THE THALWEG POINT PER THE PROFILE SHOWN ON SHEET PR–1 AND PR–2.

4. SEE STREAM SCHEMATIC, (1/D-3) FOR LOCATIONS OF POOLS/RIFFLES IN THE PLAN VIEW. TYPICAL SECTIONS (1/D-1) AND (2/D-1) SHALL BE APPLIED IN ACCORDANCE WITH THE STREAM SCHEMATIC.

5. FLOODPRONE AREA SHALL BE NO LESS THAN 34 FEET. IF LOCALIZED TOPOGRAPHIC FEATURES ALONG THE STREAM RESTORATION REACH CREATE A FLOODPRONE AREA LESS THAN 34 FEET WIDE, THAN ADDTIONAL GRADING SHALL BE REQUIRED.

FIGURE 14
Stream Restoration Typical Cross Sections
Cato Farms Stream Restoration Project

PRELIMINARY
NOT FOR CONSTRUCTION

DSGN	SPB, SDC					
DR	TDC					
CHK						
APVD		NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
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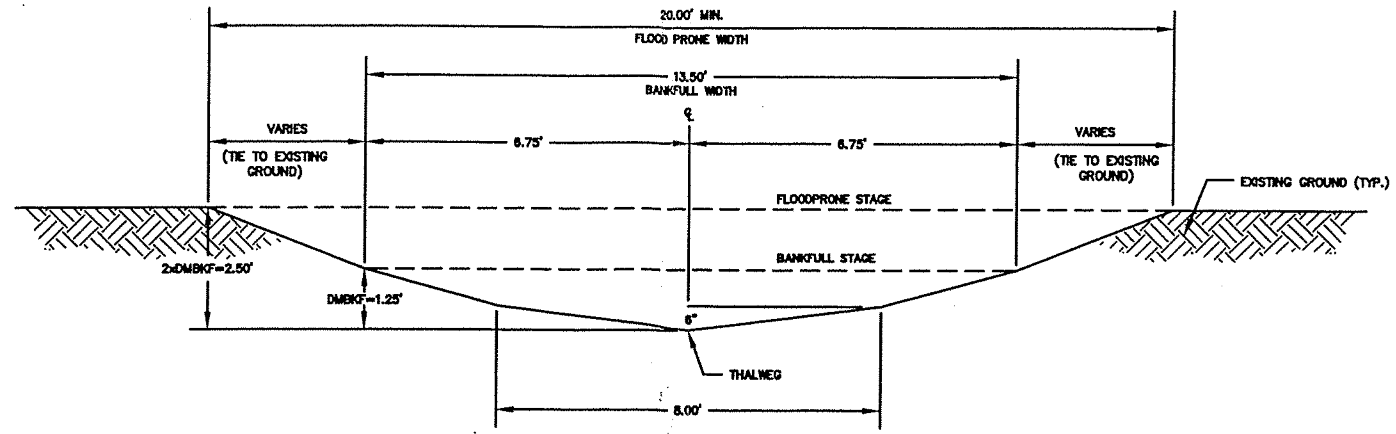
(704) 329-0072

CATO FARMS
STREAM RESTORATION PROJECT
DETAILS

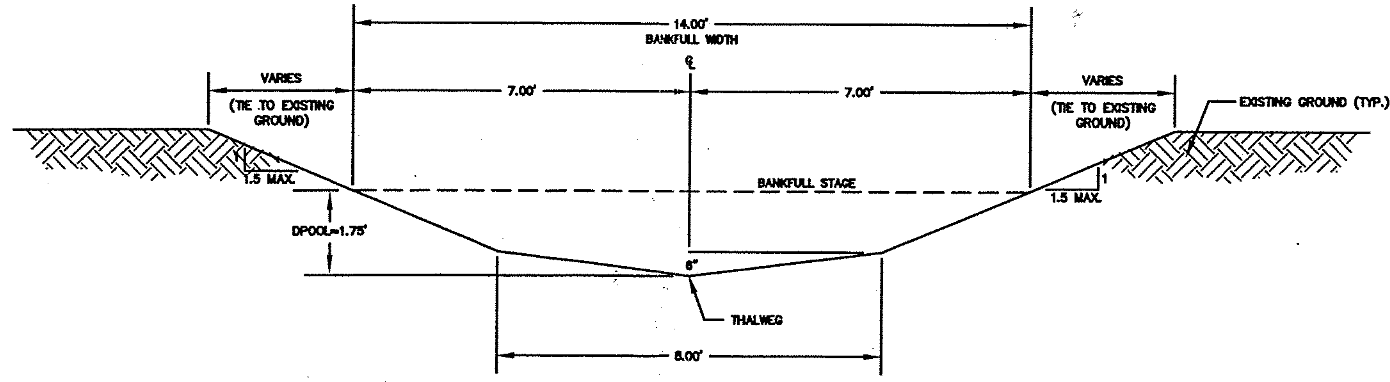
SHEET	D-1
DWG	CHM02
DATE	07/23/02
PROJ	171915

FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02_rev.dwg

PLOT DATE: 07/23/02



1 D-2 STREAM TRANSITION TYPICAL VANE CROSS-SECTION
NTS



2 D-2 STREAM TRANSITION TYPICAL POOL CROSS-SECTION
NTS

CROSS SECTION NOTES:

1. ALL TYPICAL SECTIONS ARE VIEWED FACING DOWNSTREAM.
2. REFER TO PLAN SHEET P-2 FOR LOCATION OF VANES.
3. TYPICAL SECTION VERTICAL CONTROL SHALL BE ABOUT THE THALWEG POINT PER THE PROFILE SHOWN ON SHEET PR-1 AND PR-2.
4. SEE STREAM SCHEMATIC, (1/P-3) FOR LOCATIONS OF POOLS /RIFFLES IN THE PLAN VIEW. TYPICAL SECTIONS (1/D-2) AND (2/D-2) SHALL BE APPLIED IN ACCORDANCE WITH THE STREAM SCHEMATIC.

FIGURE 15
Stream Transition Typical Cross Sections
Cato Farms Stream Restoration Project

PRELIMINARY
NOT FOR CONSTRUCTION

DSGN	SPB, SDC					
DR	TDC					
CHK						
APVD		NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 — 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

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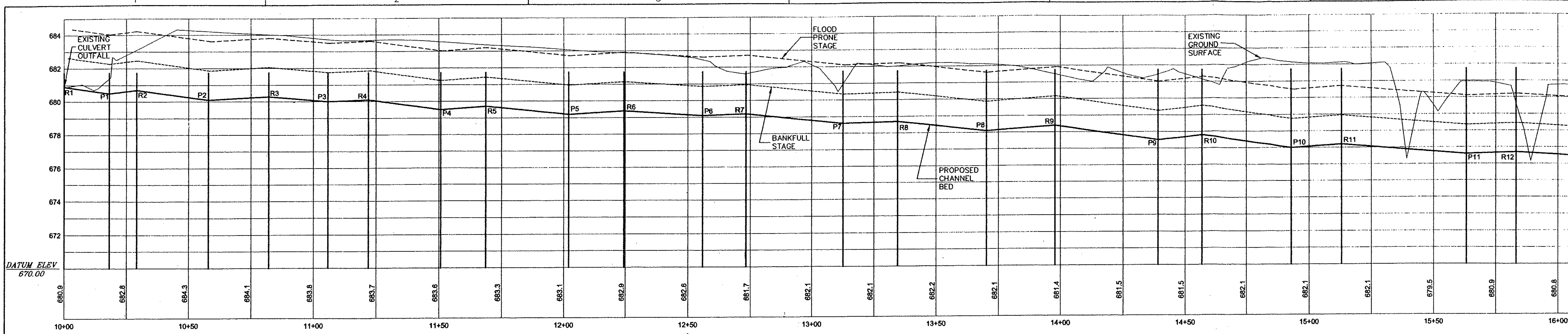
CATO FARMS
STREAM RESTORATION PROJECT
DETAILS

SHEET	D-2
DWG	CHM02
DATE	07/23/02
PROJ	171915

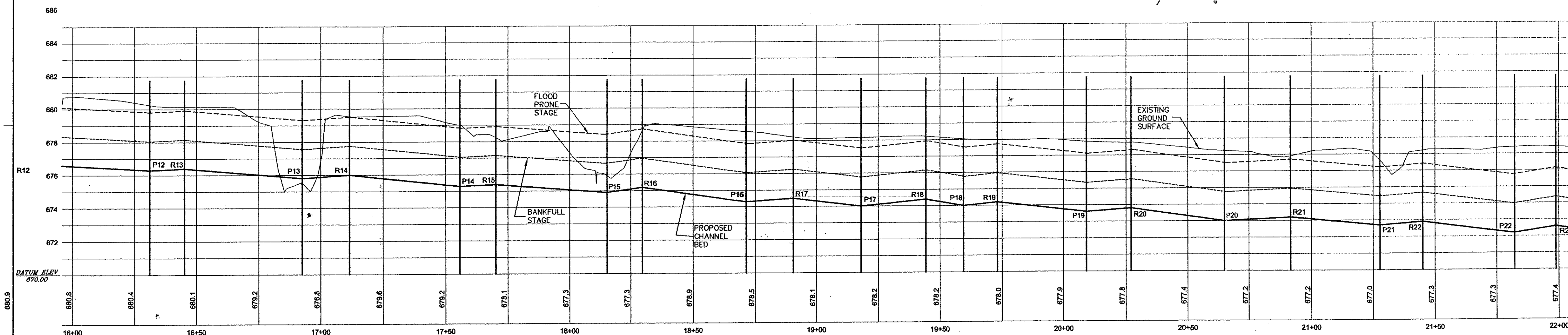
PLOT DATE: 07/23/02

FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02_rev.dwg



STREAMLINE RELOCATION PROFILE-E

SCALE: 1" = 20' (HORIZ.), 1" = 3' (VERT.)



STREAMLINE RELOCATION PROFILE-E

SCALE: 1" = 20' (HORIZ.), 1" = 3' (VERT.)

PROFILE DATA TABLE

Feature #	Bed Feature	Station	Elevation	Slope	Notes
R 1	Riffle	1000	680.90	2.20%	
P 1	Pool	1018.15	680.50	-1.80%	
R 2	Riffle	1029.11	680.70	2.07%	
P 2	Pool	1057.88	680.10	-0.80%	
R 3	Riffle	1082.14	680.30	1.23%	
P 3	Pool	1105.87	680.00	-0.60%	
R 4	Riffle	1121.99	680.10	2.10%	
P 4	Pool	1150.75	679.50	-1.10%	
R 5	Riffle	1168.75	679.70	1.47%	
P 5	Pool	1202.2	679.20	-0.90%	
R 6	Riffle	1224.46	679.40	0.95%	
P 6	Pool	1256.03	679.10	-0.55%	
R 7	Riffle	1273.28	679.20	1.52%	
P 7	Pool	1312.56	678.60	-0.45%	

PROFILE DATA TABLE

R 8	Riffle	1334.56	678.70	1.69%	
P 8	Pool	1370.21	678.10	-1.10%	
R 9	Riffle	1397.78	678.40	2.17%	
P 9	Pool	1439.12	677.50	-1.70%	
R 10	Riffle	1456.69	677.80	2.20%	
P 10	Pool	1493	677.00	-0.97%	
R 11	Riffle	1513.08	677.20	1.20%	
P 11	Pool	1563.24	676.60	-0.50%	
R 12	Riffle	1583.25	676.70	0.83%	
P 12	Pool	1631.1	676.30	-0.70%	
R 13	Riffle	1645.15	676.40	1.27%	
P 13	Pool	1692.58	675.80	-1.05%	
R 14	Riffle	1711.63	676.00	1.58%	
P 14	Pool	1755.68	675.30	-0.70%	
R 15	Riffle	1770.24	675.40	1.12%	
P 15	Pool	1815.32	674.90	-2.10%	
R 16	Riffle	1829.59	675.20	2.15%	
P 16	Pool	1871.38	674.30	-1.05%	

PROFILE DATA TABLE

R 17	Riffle	1890.6	674.50	1.82%	
P 17	Pool	1917.98	674.00	-1.50%	
R 18	Riffle	1944.33	674.40	2.60%	
P 18	Pool	1959.48	674.00	-1.45%	
R 19	Riffle	1973.04	674.20	1.65%	
P 19	Pool	2009.29	673.60	-1.10%	
R 20	Riffle	2026.99	673.80	2.10%	
P 20	Pool	2064.82	673.00	-0.75%	
R 21	Riffle	2091.7	673.20	1.40%	
P 21	Pool	2127.78	672.70	-1.20%	
R 22	Riffle	2144.96	672.90	1.90%	
P 22	Pool	2182.21	672.20	-2.45%	
R 23	Riffle	2198.8	672.60	2.15%	
P 23	Pool	2226.98	672.00	-0.90%	

PRELIMINARY

NOT FOR CONSTRUCTION

FIGURE 16

Profile Sheet #1 - Cato Farms Stream Restoration Project

DSGN	SPB, SDC
DR	TDC
CHK	
APVD	

NO. | DATE | REVISION | BY | APVD

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

THE SURVEY COMPANY, INC.
4105-B STUART ANDREW BLVD
CHARLOTTE, NC 28217
(704) 561-9970 (704) 561-9972 FAX
EMAIL: surveyco@bellsouth.net

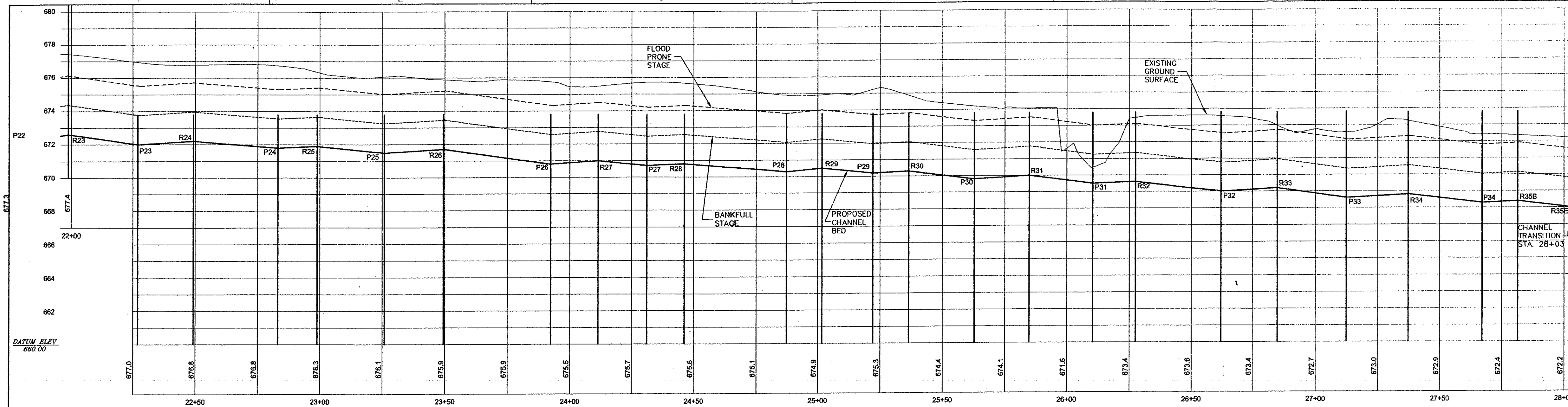
CH2MHILL
CH2M HILL, INC.
4824 PARKWAY PLAZA BOULEVARD
SUITE 200
CHARLOTTE, N.C. 28217-1968
(704) 329-0072

CATO FARMS
STREAM RESTORATION PROJECT
STREAM PROFILE

SHEET	PR-1
DWG	CHM02
DATE	06/14/02
PROJ	171915

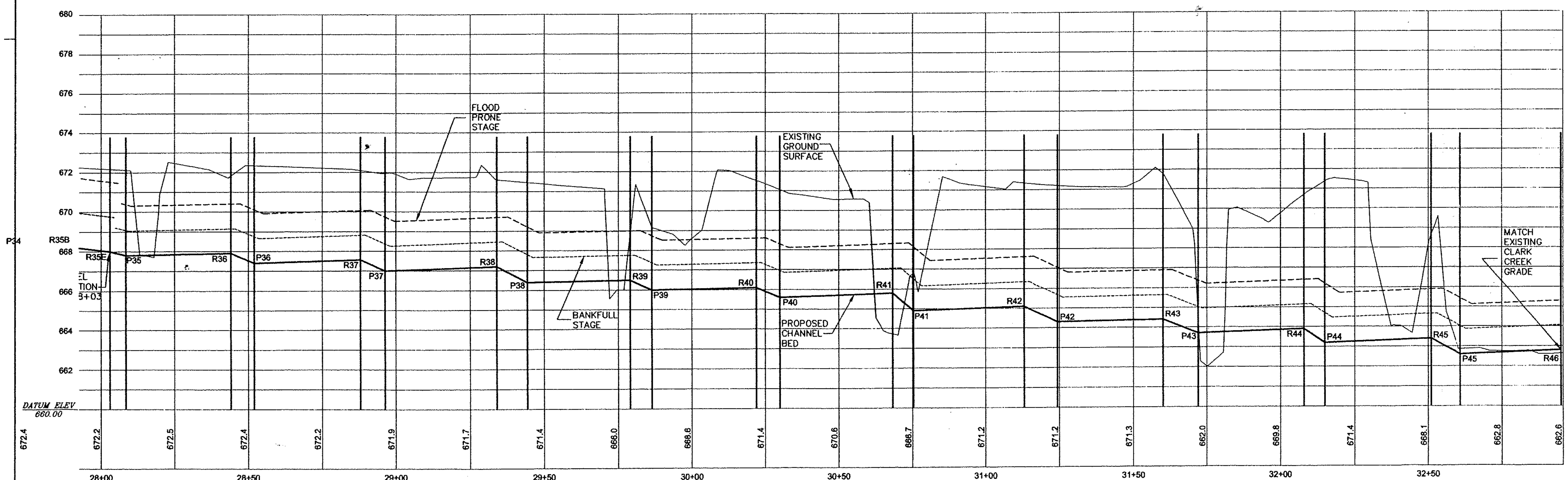
FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02.dwg

PLOT DATE: 06/13/02



STREAMLINE RELOCATION PROFILE-E

SCALE: 1" = 20' (HORIZ.), 1" = 3' (VERT.)



STREAMLINE RELOCATION PROFILE-B

SCALE: 1" = 20' (HORIZ.), 1" = 3' (VERT.)

PROFILE DATA TABLE

Feature #	Bed Feature	Station	Elevation	Slope	Notes
R 23	Riffle	2198.8	672.60	2.15%	
P 23	Pool	2226.98	672.00	-0.90%	
R 24	Riffle	2249.19	672.20	1.17%	
P 24	Pool	2283.03	671.80	-0.60%	
R 25	Riffle	2298.88	671.90	1.47%	
P 25	Pool	2325.83	671.50	-0.85%	
R 26	Riffle	2349.46	671.70	2.10%	
P 26	Pool	2392.28	670.80	-1.05%	
R 27	Riffle	2411.41	671.00	1.55%	
P 27	Pool	2431.02	670.70	-0.70%	
R 28	Riffle	2446.21	670.80	1.22%	
P 28	Pool	2487.42	670.30	-1.35%	
R 29	Riffle	2501.78	670.50	1.45%	
P 29	Pool	2522.14	670.20	-0.70%	
R 30	Riffle	2536.5	670.30	1.60%	
P 30	Pool	2567.67	669.80	-1.15%	
R 31	Riffle	2584.92	670.00	1.95%	
P 31	Pool	2610.48	669.50	-0.60%	
R 32	Riffle	2627.41	669.60	1.75%	
P 32	Pool	2662.05	669.00	-0.90%	
R 33	Riffle	2684.78	669.20	2.17%	
P 33	Pool	2712.44	668.60	-0.80%	
R 34	Riffle	2737.31	668.80	1.68%	
P 34	Pool	2767.08	668.30	-0.70%	
R 35	Riffle	2781.41	668.40	1.85%	
R 35	Riffle End	2803	668.00	3.70%	Transition Point
P 35	Pool	2808.41	667.80	-0.55%	
R 36	Riffle/Run	2844.08	667.90	6.33%	
P 36	Pool	2852.00	667.40	-0.55%	
R 37	Riffle/Run	2888	667.56	7.21%	
P 37	Pool	2896.33	667.00	-0.53%	
R 38	Riffle/Run	2934	667.20	7.77%	
P 38	Pool	2944.33	666.40	-0.31%	
R 39	Riffle/Run	2979	666.50	6.85%	
P 39	Pool	2986.33	666.00	-0.27%	
R 40	Riffle/Run	3022	666.10	6.20%	
P 40	Pool	3030.00	665.60	-0.53%	
R 41	Riffle/Run	3068	665.80	12.22%	
P 41	Pool	3075.33	664.90	-0.53%	
R 42	Riffle/Run	3113	665.10	7.06%	
P 42	Pool	3124.33	664.30	-0.27%	
R 43	Riffle/Run	3160	664.40	5.83%	
P 43	Pool	3172.00	663.70	-0.56%	
R 44	Riffle/Run	3208	663.90	9.96%	
P 44	Pool	3215.00	663.20	-0.56%	
R 45	Riffle/Run	3251	663.40	8.01%	
P 45	Pool	3261.00	662.60	-0.29%	
R 46	Riffle	3295	662.81	1.10%	

FIGURE 17

Profile Sheet #2 - Cato Farms Stream Restoration Project

PRELIMINARY

NOT FOR CONSTRUCTION

DSGN	SPB, SDC
DR	TDC
CHK	
APVD	

NO. | DATE | REVISION | BY | APVD

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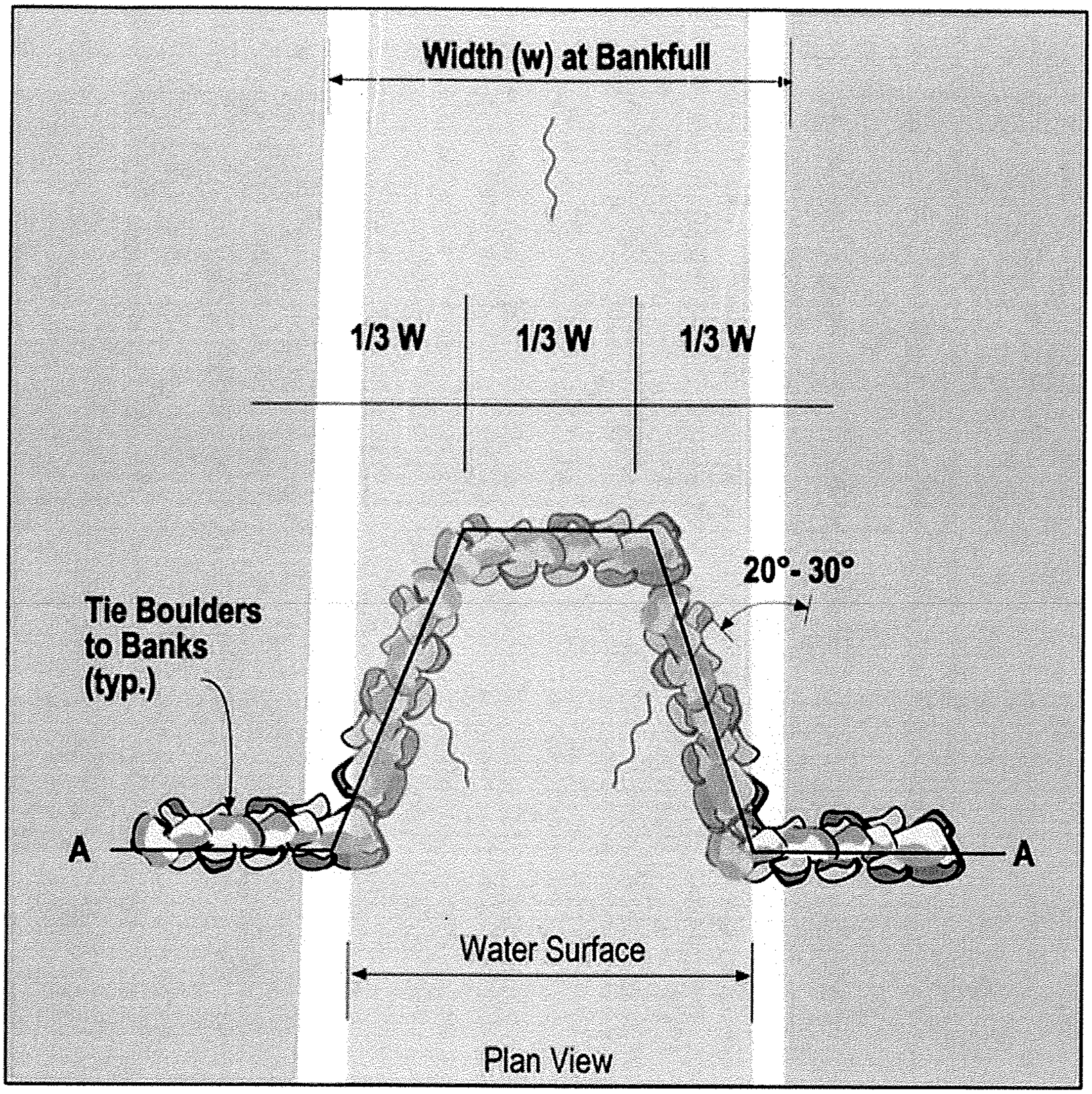
CHARLOTTE, N.C. 28217-1968
(704) 329-0072

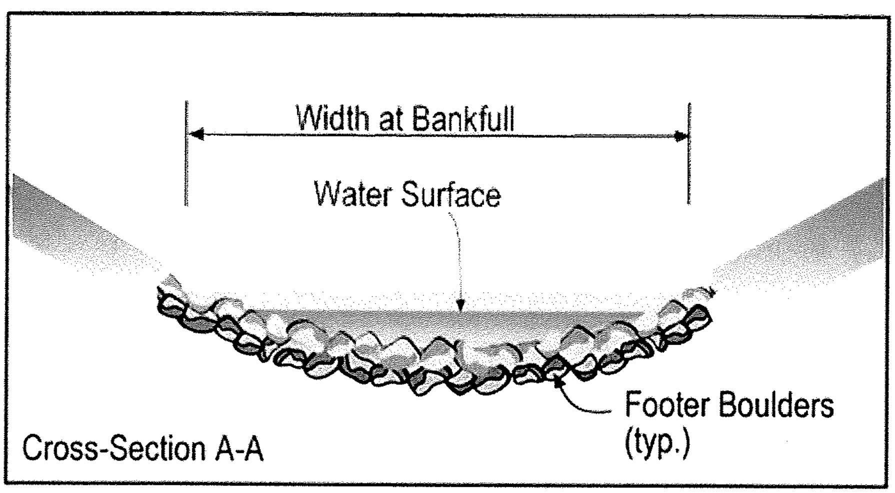
CATO FARMS
STREAM RESTORATION PROJECT
STREAM PROFILE

SHEET	PR-2
DWG	CHM02
DATE	06/14/02
PROJ	171915

FILENAME: P:\Land Projects\CHM02 Cato Farm\dwg\CHM02.dwg

PLOT DATE: 06/13/02





Not to Scale

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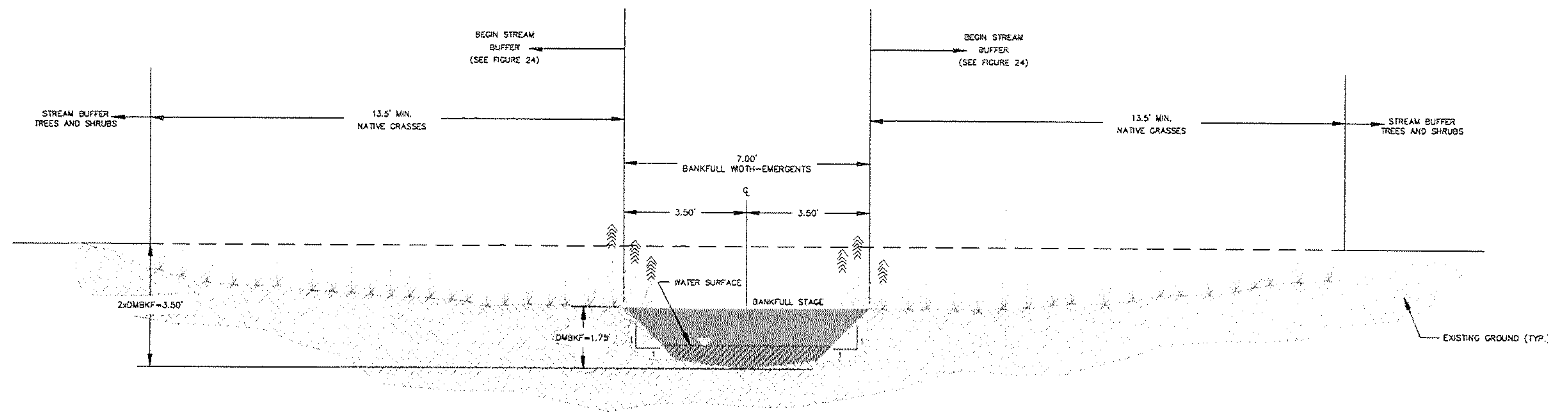
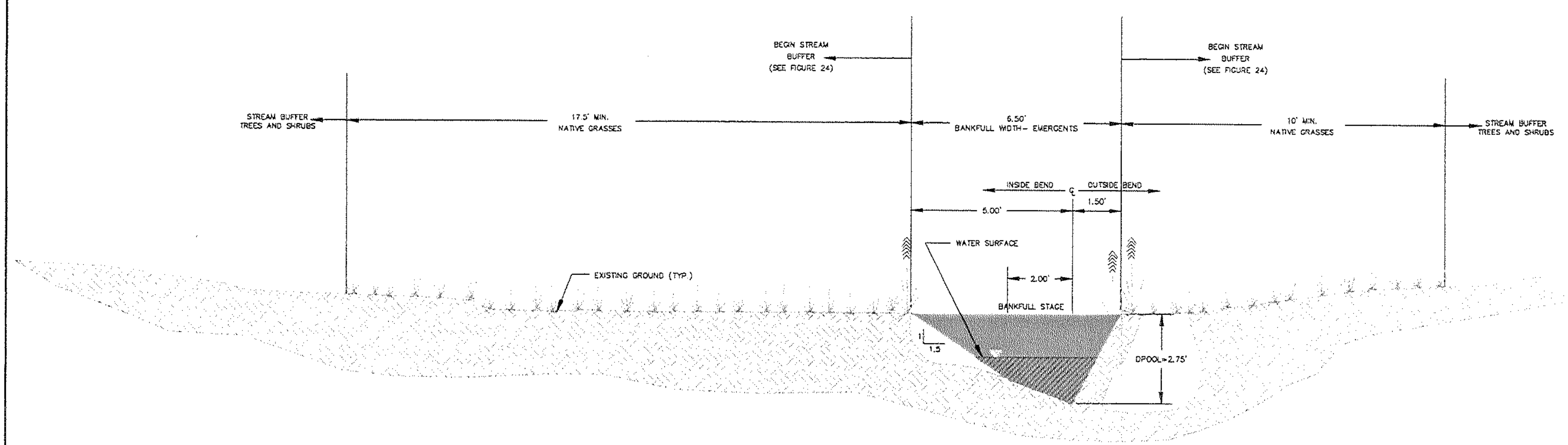
Figure 18
Rock Vane for Stream Transition Section



STREAM RESTORATION (STA. 10+00 TO STA. 28+03.27) TYPICAL RIFFLE CROSS-SECTION - PLANTING PLAN
NTS



STREAM RESTORATION (STA. 10+00 TO STA. 28+03.27) TYPICAL POOL (BEND) CROSS-SECTION - PLANTING PLAN
NTS

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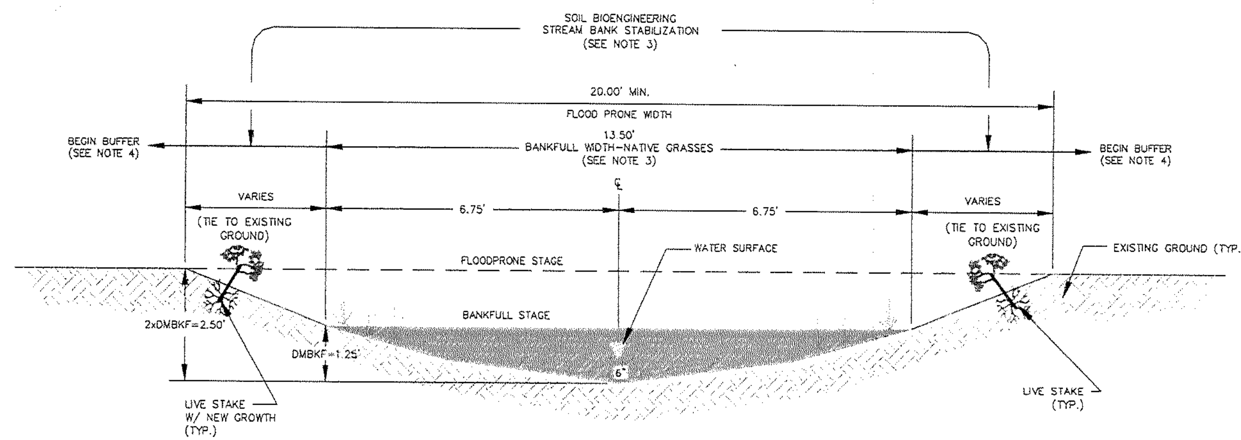
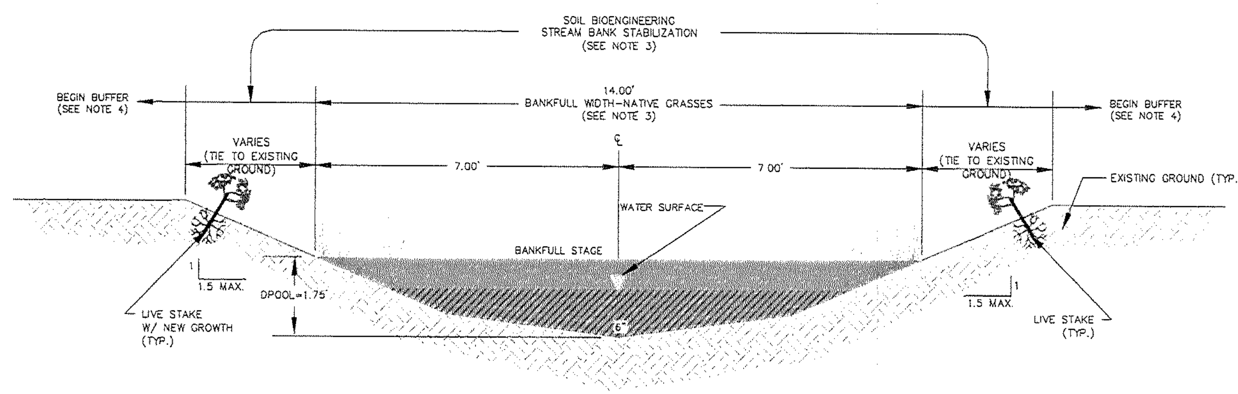
Figure19
Planting Plan for Stream Restoration Section



1 D-5 STREAM TRANSITION TYPICAL VANE CROSS-SECTION–PLANTING PLAN
NTS



2 D-5 STREAM TRANSITION TYPICAL POOL CROSS-SECTION–PLANTING PLAN
NTS

CH2MHILL

Figure 20
Planting Plan for Stream Transition Section

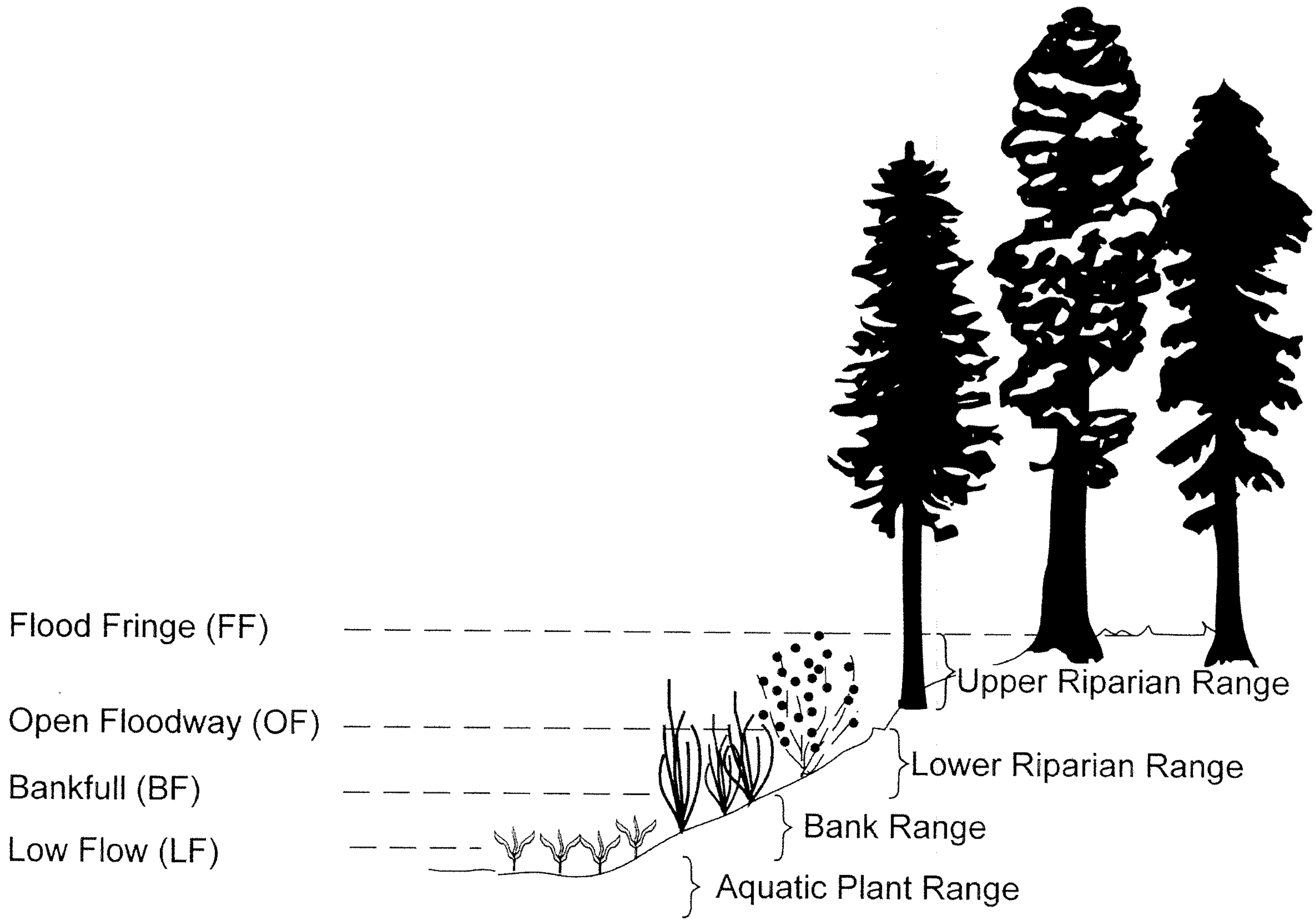


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FIGURE 21
Stream Bank Vegetative Ranges
(Adapted from Stormwater Management Manual for the Puget Sound Basin, February 1992)

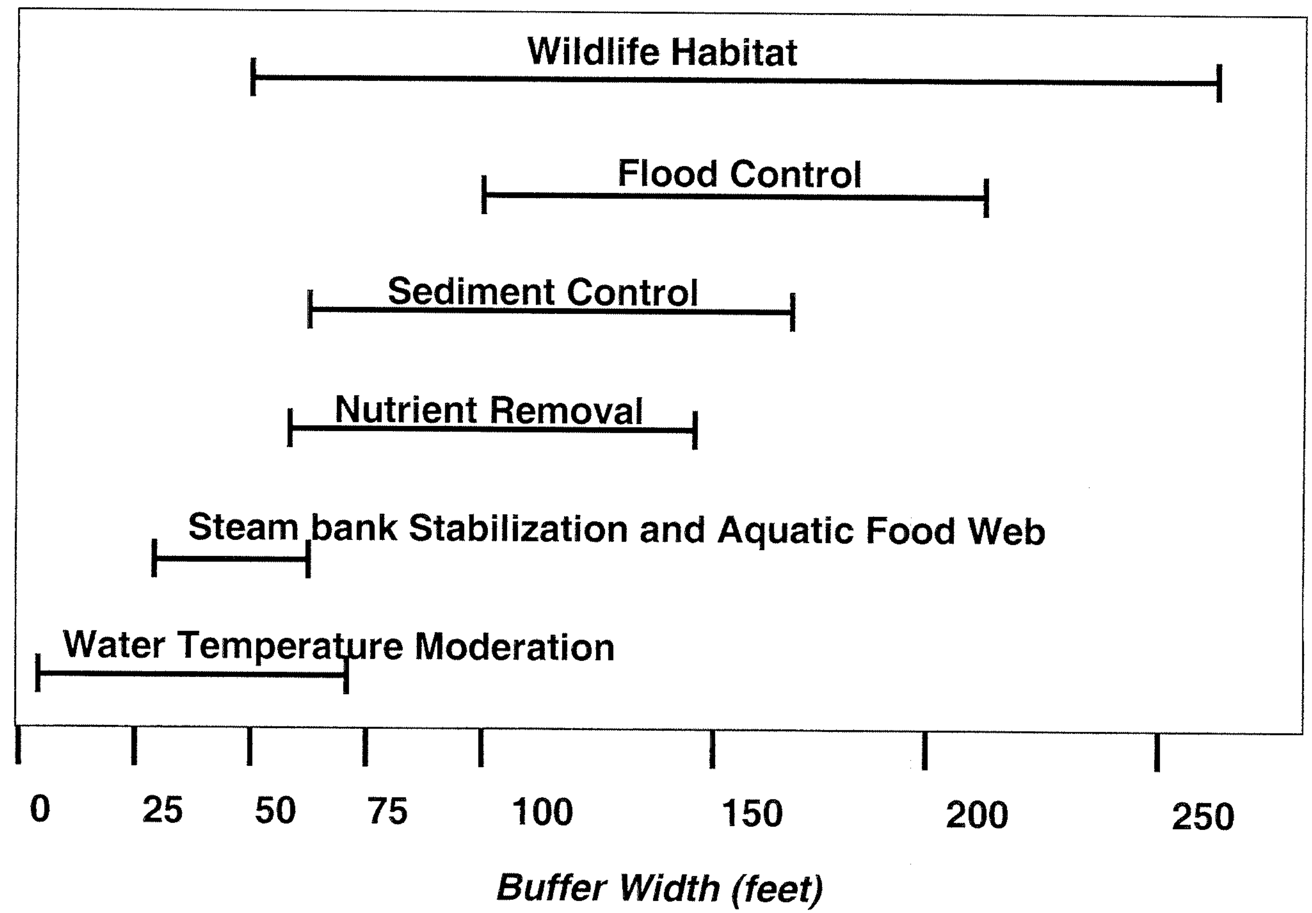

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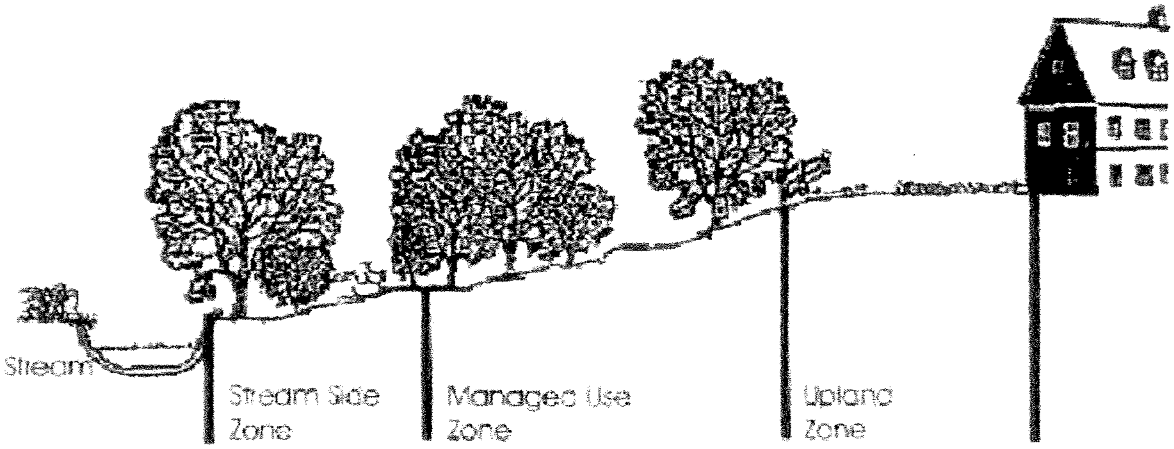
FIGURE 22
Range of minimum width for meeting specific buffer objectives
(Palone and Todd, draft)



Buffer function, vegetation and use vary according to the different buffer zones as described in the following table.

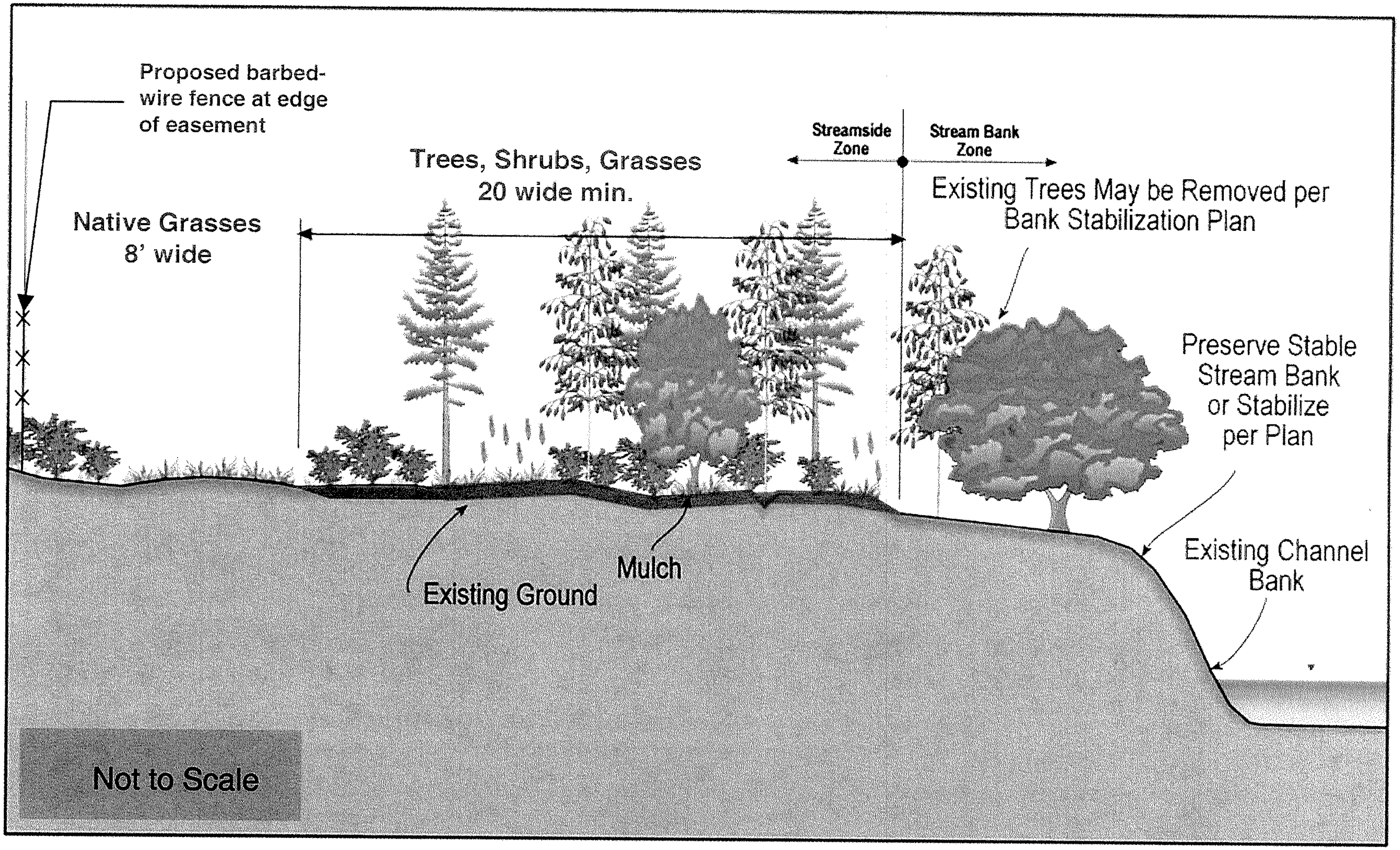
Characteristics	Stream Side Zone	Managed Use Zone	Upland Zone
Function	Protect the integrity of the ecosystems	Provide distance between upland development and the stream side zone	Prevent encroachment and filter runoff
Vegetative Targets [1]	**Undisturbed (no cutting or clearing allowed)** - If existing tree density is inadequate, reforestation is encouraged	**Limited clearing** - Existing tree density must be retained to a minimum of 8 healthy trees of a minimum 6 inch caliper per 1000 square feet - If existing tree density is inadequate, reforestation is encouraged	**Grass** or other herbaceous ground cover allowed - Forest is encouraged
Uses [2]	**Very restricted** - Permitted uses limited to: flood control structures and bank stabilization as well as installation of utilities and road crossings with stabilization of disturbed areas as specified in Section 12.806.2	**Restricted** - Permitted uses limited to: all uses allowed in the Stream Side Zone, as well as storm water best management practices (BMPs), bike paths, and greenway trails (not to exceed 10 feet in width)	**Restricted** - Permitted uses limited to: all uses allowed in the Stream Side and Managed Use Zones, as well as grading for lawns, gardens, and gazebos and storage buildings (non-commercial and not to exceed 150 square ft)

Footnotes:

(1) Re-vegetation of disturbed buffers is required as specified in the Charlotte-Mecklenburg Land Development Standards Manual when such disturbances result in the failure of the buffer system to comply with the vegetative targets specified above. The manual also contains recommended tree densities for each zone for voluntary reforestation efforts.

(2) Fill material can not be brought into the buffer. Grading is allowed only in the Upland Zone. Commercial buildings or occupied structures are not allowed in the buffer. Permitted uses within the buffer zones should be coordinated to ensure minimal disturbance of the buffer system. For example, if it is necessary to install utilities within the buffer, every attempt should be made to build greenway trails so they follow the cleared areas ir

Figure 23
Three-Zone Buffer
from SWIM Stream Buffer Implementation Guidelines, MCDEP, 2000



Note:

The proposed channel shall meander within a 75 foot wide conservation easement. Buffer shall be a minimum of 28 feet wide at the outside of a stream meander bend.

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Figure 24
Stream Buffer
Cato Farms Stream Restoration Project

PHOTOGRAPHS

Photo 1. Land has been cleared adjacent to stream to provide pasture

Photo 2. Cattle are not prevented from entering stream

Photo 3. Evidence of old stream bed exist in the floodplain adjacent to the channel indicating the channel has been realigned

Photo 4. Swales like the one in the center of this photograph were constructed to drain the pasture

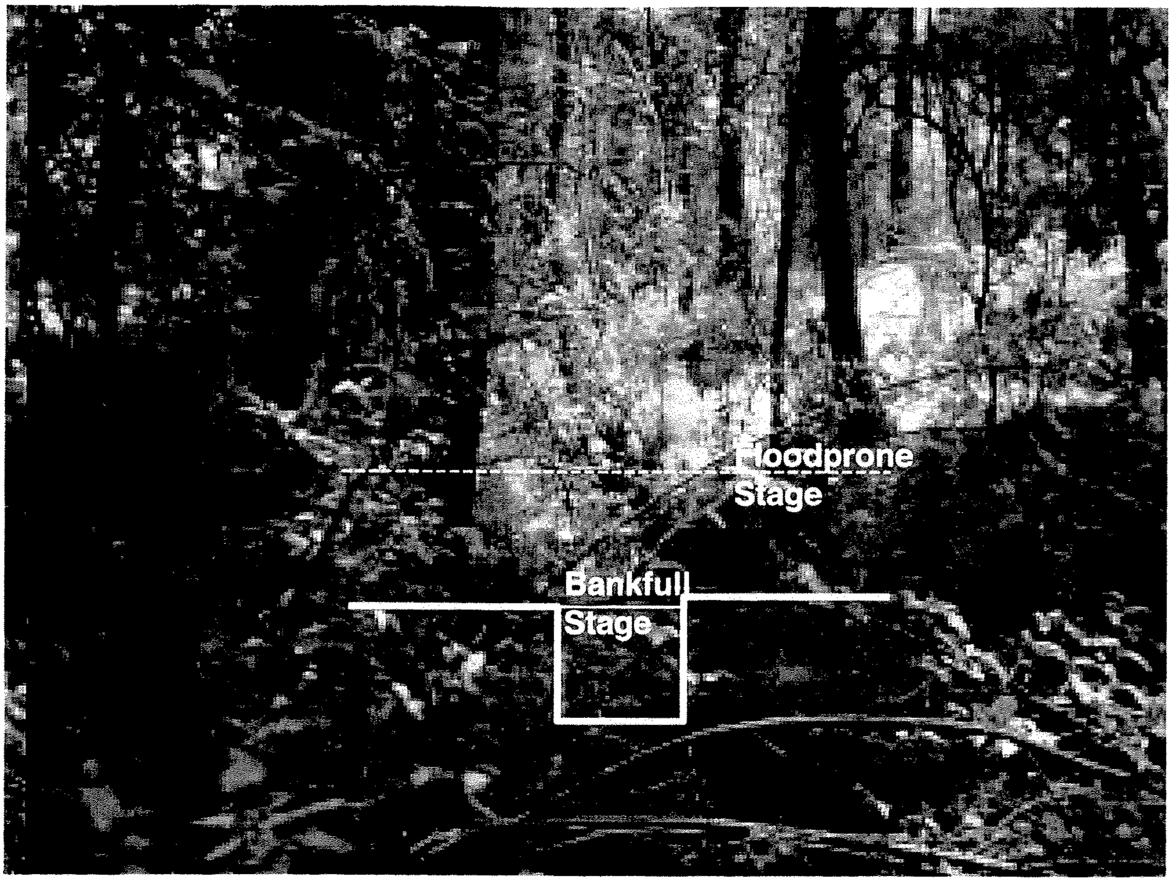


Photo 5. The Upper Reach at Cato Farm is a Rosgen E5 stream type

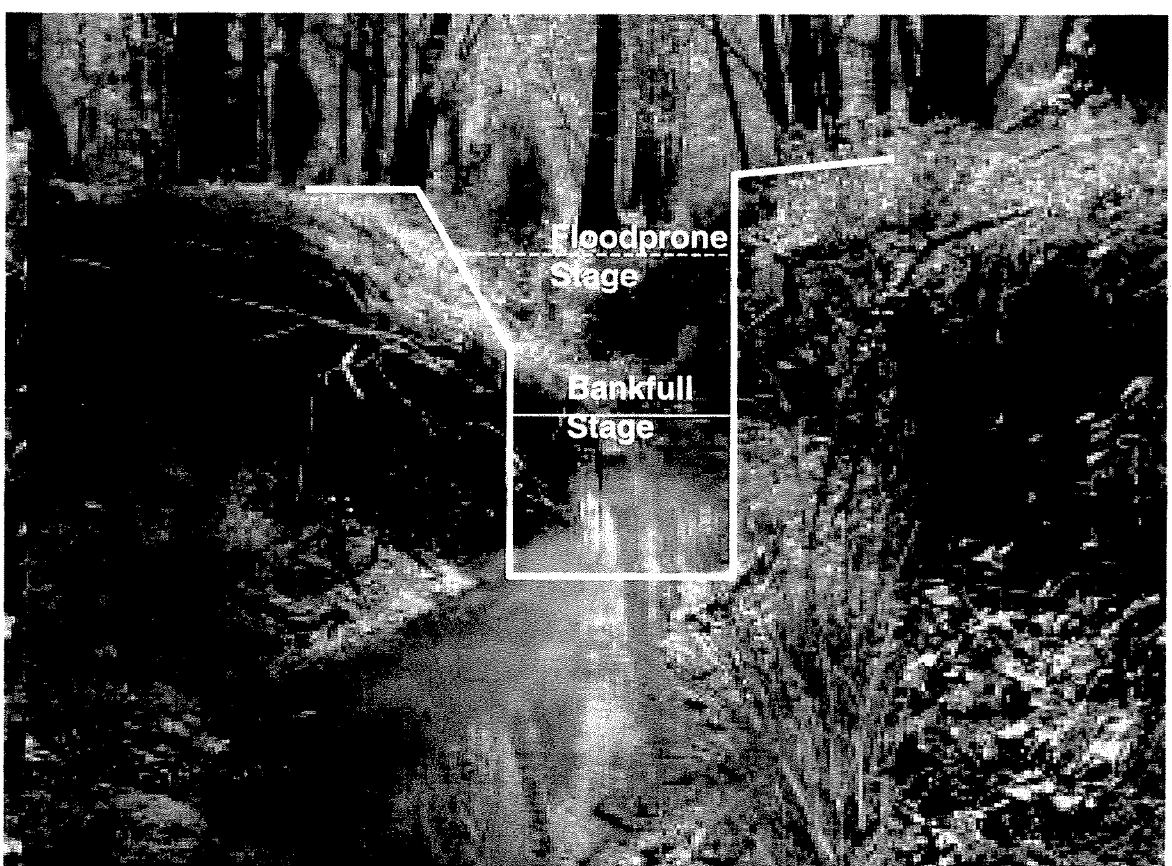


Photo 6. The Middle Reach at Cato Farm is a Rosgen G5c stream type

Photo 7. The Lower Reach at Cato Farm is a Rosgen G5c stream type

Photo 8. The upstream portion af the project area is in open field

Photo 9. Cows browse woody vegetation along stream banks

Photo 10. Understory is largely absent from riparian zone at the downstream end of the Cato Farm project site

Photo 11. Mayapples in the floodplain at Cato Farm

Photo 12. Coffey Creek Rosgen B5c stream type reference reach

Photo 13. Change in slope on the stream bank indicates the bankfull stage

Photo 14. The UT - Park South Drive reference reach has sand dominated bed material

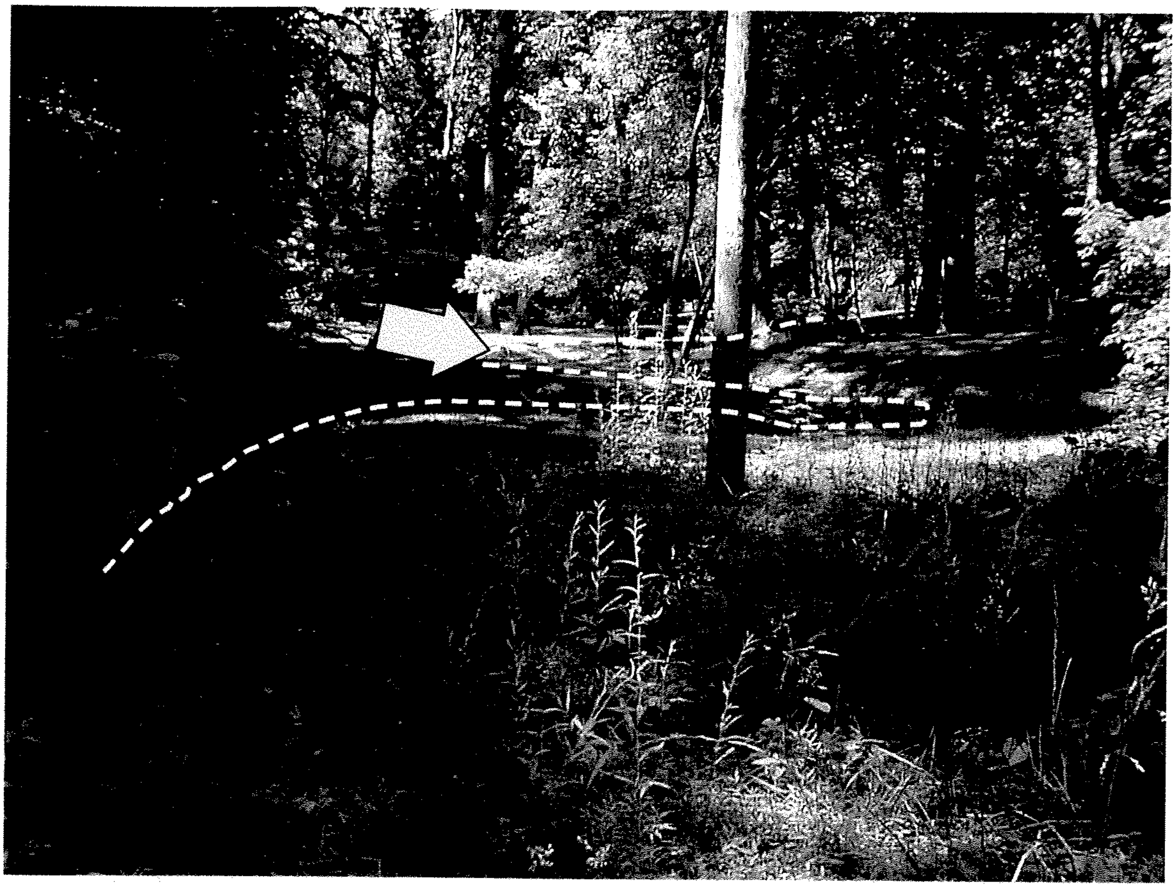
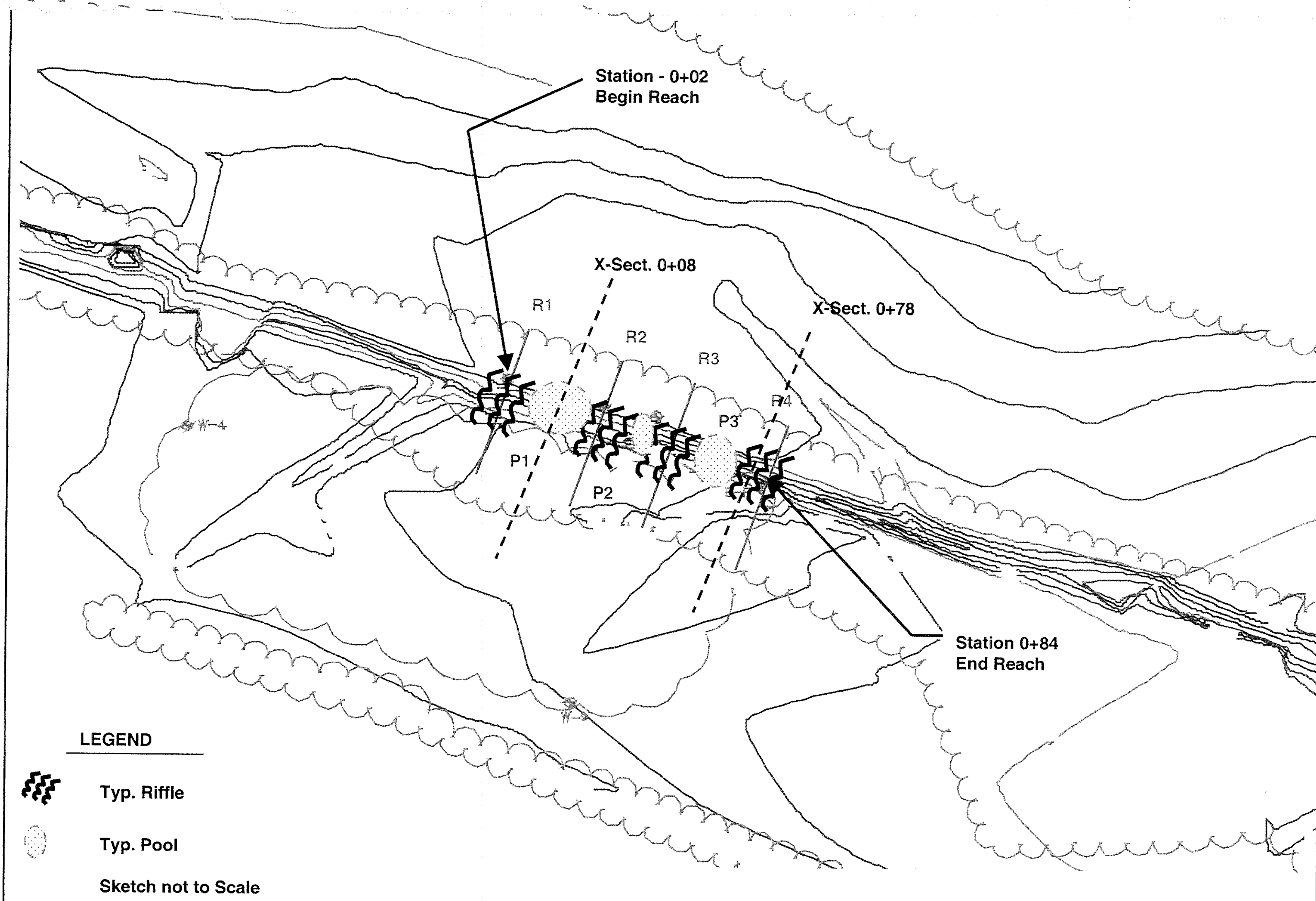


Photo 15. Bankfull indicator at the top of the stream bank at UT - Park South Drive reference reach

Photo 16. Stream bank erosion is pronounced at the Lower Reach at Cato Farm

APPENDICES

APPENDIX A



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Cato Farms Upper Reach
Cato Farms Restoration Project

Reference Reach

Hints

Stream:	Cato Farms Trib to Clark Creek- Upper Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	
Longitude:	
County:	Mecklenburg
Date:	April 18, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	E6
Drainage Area (sq mi):	0.31
Notes:	This is the farthest upstream of three surveyed reaches.

Dimension

		typical	min	max
Size:	x-area bankfull	5.7	---	---
	width bankfull	7.7	---	---
	mean depth	0.7	---	---
Ratios:	Width/Depth Ratio	10.4	---	---
	Entrenchment Ratio	2.1	---	---
	Riffle Max Depth Ratio	2.5	---	---
	Pool Area Ratio	1.3	---	---
	Pool Width Ratio	0.7	---	---
	Pool Max Depth Ratio	2.5	---	---
	Bank Height Ratio	1.9		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	---	---	---
	Glide Width Ratio	---	---	---
	Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	42.1	42.1	42.1
velocity (ft/sec)	7.4	5.6	---
shear stress @ max depth (lbs/ft sq)	1.14	1.15	---
shear stress (lbs/ft sq)	0.32	0.60	---
shear velocity (ft/sec)	0.41	0.56	---
unit stream power (lbs/ft/sec)	3.342	3.342	3.34
relative roughness	727.1	1340.6	---
friction factor u/u*	18.1	10.1	---
threshold grain size @ max depth (mm)	93.8	95.8	---
threshold grain size (mm)	19	38	---

Pattern

	typical	min	max
Sinuosity	1.0		
Meander Width Ratio	1.0	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	0.978	---	---
measured valley slope (%)	0.870	---	---
valley slope (%)	0.984		
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	0.3	---	0.5
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	3.2	2.3	4.2

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	#N/A	#N/A	#N/A	0.0	0.0	---
D35	#N/A	#N/A	#N/A	0	0	---
D50	#N/A	#N/A	#N/A	0	0	---
D84	0.3	0	0	0	0	---
D95	1.1	2	1	0	0	---
Largest Bar						0
% Silt/Clay	59%	54%	65%	---	---	---
% Sand	39%	43%	35%	---	---	---
% Gravel	2%	4%	0%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	

Reference Reach

Stream:	Cato Farms Trib to Clark Creek- Upper Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 18, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	E6
Drainage Area (sq mi):	0.31

Pattern

	typical	min	max
bankfull width (ft)	7.69784		
meander length (ft)			
belt width (ft)	8		
amplitude (ft)			
radius (ft)			
arc angle (degrees)			
straight length (ft)			
stream length	610		
valley length	605		
Sinuosity	1.01		
Meander Width Ratio	1.0	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---

Profile

	typical	min	max
bankfull width (ft)	7.69784		
pool-pool spacing (ft)	25	17.5	32.5
riffle length (ft)			
pool length (ft)	5.5	3	8
run length (ft)			
glide length (ft)			
channel slope (%)	0.978		
riffle slope (%)			
pool slope (%)	0.25	0	0.5
run slope (%)			
glide slope (%)			
measured valley slope (%)	0.87		
valley slope (%)	1.0		
Riffle Length Ratio	---	---	---
Pool Length Ratio	0.7	0.4	1.0
Run Length Ratio	---	---	---
Glide Length Ratio	---	---	---
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	0.3	---	0.5
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	3.2	2.3	4.2

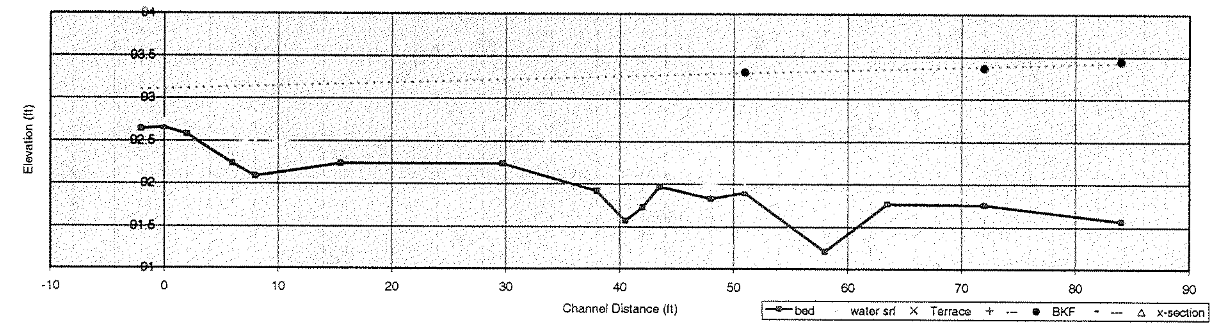
Slope Calculator

	station	elevation	% slope	note
point 1	0	92.65		
point 2	29.7	92.23	1.414	bed
point 1	29.7	92.23		
point 2	43.5	91.96	1.957	bed
point 1	43.5	91.96		
point 2	84	91.56	0.988	bed
point 1	0	92.72		
point 2	29.7	92.73	-0.034	wse
point 1	29.7	92.73		
point 2	84	91.65	1.989	wse
point 1				
point 2			---	
point 1				
point 2			---	

Avg. Bed 1.453

Avg. WSE 0.978

Slope Profile



98.69 Elevation BM

notes	cross section	station	BS	HI	FS TP	FS bed	depth water	FS BKF	FS Terrace	FS	FS	AZ azimuth	ELEV bed	ELEV water srf	ELEV BKF	ELEV Terrace	ELEV ---	ELEV ---
			2.21	98.9														
R4		84		98.9		7.34	0.09	5.46					91.56	91.65	93.44			
		72		98.9		7.15	0.12	5.54					91.75	91.87	93.36			
		63.5		98.9		7.14	0.14						91.76	91.9				
		58		98.9		7.7	0.72						91.2	91.92				
		51		98.9		7.01	0.07	5.59					91.89	91.96	93.31			
		48		98.9		7.08							91.82					
R3		43.5		98.9		6.94							91.96					
		42		98.9		7.18							91.72					
		40.5		98.9		7.34	0.54						91.56	92.1				
		38		98.9		6.99							91.91					
R2		29.7		98.9		6.67	0.5						92.23	92.73				
		15.5		98.9		6.67							92.23					
		8		98.9		6.82	0.39						92.08	92.47				
		6		98.9		6.67							92.23					
		2		98.9		6.33							92.57					
R1		0		98.9		6.25	0.07						92.65	92.72				
		-2		98.9		6.27							92.63					
				98.9														
				98.9														
				98.9														
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Reference Reach

Hints

Stream:	Cato Farms Trib to Clark Creek- Upper Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 18, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	E6
Drainage Area (sq mi):	0.31

Dimension

		typical	min	max
Riffle:	x-area bankfull	5.7		
	width bankfull	7.7		
	hydraulic radius	0.5		
	max depth	1.9		
	bank ht	3.6		
	width flood prone area	16.0		
	mean depth	0.74		
Pool:	x-area pool	7.5		
	width pool	5.5		
	hydraulic radius	1.0		
	max depth pool	1.9		
	bank ht	3.6		
Run:	x-area run			
	width run			
	hydraulic radius			
	max depth run			
	bank ht			
Glide:	x-area glide			
	width glide			
	max depth glide			

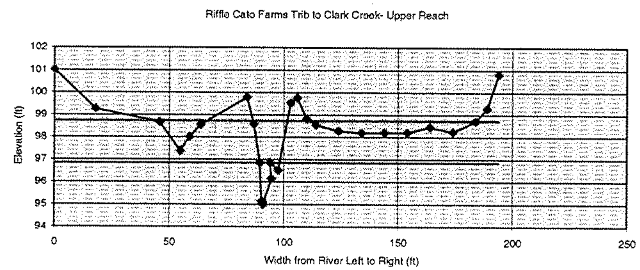
Dimensionless Ratios:

	typical	min	max
Width/Depth Ratio	10.4		
Entrenchment Ratio	2.1		
Riffle Max Depth Ratio	2.5	---	---
Pool Area Ratio	1.3	---	---
Pool Width Ratio	0.7	---	---
Pool Max Depth Ratio	2.5	---	---
Bank Height Ratio	1.9		
Run Area Ratio	---	---	---
Run Width Ratio	---	---	---
Run Max Depth Ratio	---	---	---
Glide Area Ratio	---	---	---
Glide Width Ratio	---	---	---
Glide Max Depth Ratio	---	---	---

Hydraulics:

	riffle	pool	run
channel slope (%)	0.978		
discharge rate, Q (cfs)	42.1		
velocity (ft/sec)	7.4	5.6	---
shear stress @ max depth (lbs/ft sq)	1.141	1.153	---
shear stress (lbs/ft sq)	0.321	0.600	---
shear velocity (ft/sec)	0.407	0.557	---
stream power (lbs/sec)	25.7	25.7	25.7
unit stream power (lbs/ft/sec)	3.342	3.342	3.342
relative roughness	727.1	1340.6	---
friction factor u/u*	18.1	10.1	---
threshold grain size @ max depth (mm)	94	96	---
threshold grain size (mm)	18.7	37.6	---

Cross Section



section: Riffle
Cato Farms Trib to Clark Creek- Upper Reach
Clark Creek

description:

height of instrument (ft): 105.14

notes	omit pt.	distance (ft)	FS (ft)	elevation
terrace	☐	0	4.13	101.01
	☐	18	5.87	99.27
swale	☐	46	6.48	98.66
FL	☐	55	7.78	97.36
	☐	59	7.13	98.01
Top Swale	☐	64	6.59	98.55
FP	☐	84	5.36	99.78
L TB	☐	87	6.57	98.57
L BKF	☐	89.7	8.29	96.85
L TOE	☐	90.3	10.02	95.12
WS	☑	91	10.05	95.09
THAL	☐	91	10.16	94.98
L TOE	☐	94.7	9	96.14
R BKF	☐	94	8.28	96.86
Bottom Be	☐	97.6	8.62	96.52
Top Berm	☐	103	5.62	99.52
Top Berm	☐	108	5.38	99.76
FP	☐	110	6.33	98.81
FP	☐	114	6.6	98.54
FP	☐	124	6.87	98.27
FP	☐	134	6.95	98.19
FP	☐	144	6.94	98.2
FP	☐	154	6.94	98.2
FP	☐	164	6.69	98.45
FP	☐	174	6.91	98.23
Toe Terrac	☐	184	6.44	98.7
Terrace	☐	189	5.86	99.28
terrace	☐	194	4.33	100.81

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8.29	6.57	16.0	0.978	0.013
96.85	98.57			

dimensions			
5.7	x-section area	0.7	d mean
7.7	width	10.9	wet P
1.9	d max	0.5	hyd radi
3.6	bank ht	10.4	w/d ratio
16.0	W flood prone area	2.1	ent ratio

hydraulics	
7.4	velocity (ft/sec)
42.1	discharge rate, Q (cfs)
0.32	shear stress ((lbs/ft sq)
0.41	shear velocity (ft/sec)
3.342	unit stream power (lbs/ft/sec)
2.27	Froude number
18.1	friction factor u/u*
18.7	threshold grain size (mm)

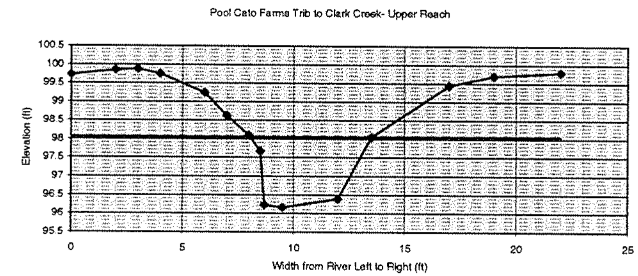
check from channel material			
0	measured D84 (mm)		
727.1	relative roughness	19.1	fric. factor
0.012	Manning's n from channel material		

check from channel material (R/D84) - Limerinos			
514.0568	R/D84 (ft/ft)	18.282763	u/u*
0.01	Manning's n from channel material		

u/u* = friction factor

check from Shear Velocity	
7.43388	u - velocity
0.013	Manning's n from Shear Velocity

Cross Section



section: Pool
Cato Farms Trib to Clark Creek- Upper Reach
Clark Creek

description:

height of instrument (ft): 104.59

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☐	0	4.87	99.72
	☐	2	4.74	99.85
	☐	3	4.71	99.88
	☐	4	4.84	99.75
	☐	6	5.35	99.24
	☐	7	5.97	98.62
	☐	8	6.5	98.09
	☐	8.5	6.92	97.67
	☐	8.7	8.36	96.23
	☐	9.5	8.43	96.16
	☐	12	8.2	96.39
	☐	13.5	6.54	98.05
	☐	17	5.15	99.44
	☐	19	4.9	99.69
	☐	22	4.8	99.79

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.54	4.84		0.978	
98.05	99.75			

dimensions			
7.5	x-section area	1.4	d mean
5.5	width	7.6	wet P
1.9	d max	1.0	hyd radi
3.6	bank ht		

hydraulics	
0.60	shear stress ((lbs/ft sq)
0.56	shear velocity (ft/sec)
37.6	threshold grain size (mm)

Reference Reach

Reference Reach	Hints
Stream:	Cato Farms Trib to Clark Creek- Upper Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 18, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	E6
Drainage Area (sq mi):	0.31

Channel Materials

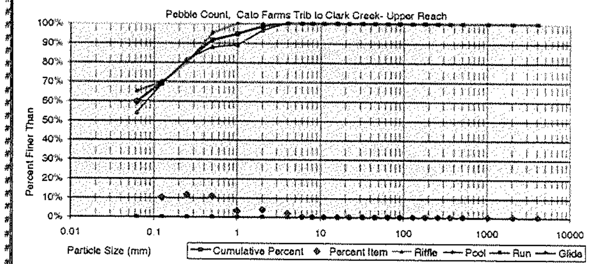
	total	riffle	pool	run	glide	bar sample
D16	#N/A	#N/A	#N/A	0.000	0.000	---
D35	#N/A	#N/A	#N/A	0.00	0.00	---
D50	#N/A	#N/A	#N/A	0.0	0.0	---
D84	0	0	0	0	0	---
D95	1	2	1	0	0	---
Largest of Bar Sample						
% Silt/Clay	59%	54%	65%	---	---	---
% Sand	39%	43%	35%	---	---	---
% Gravel	2%	4%	0%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	

Weighted Pebble Count

Percent Riffle: 50 Percent Run:
Percent Pool: 50 Percent Glide:

Material	Size Range (mm)		Total #
silt/clay	0	0.062	59.4
very fine sand	0.062	0.13	10.0
fine sand	0.13	0.25	11.3
medium sand	0.25	0.5	10.6
coarse sand	0.5	1	3.1
very coarse sand	1	2	3.8
very fine gravel	2	4	1.9
fine gravel	4	6	0.0
fine gravel	6	8	0.0
medium gravel	8	11	0.0
medium gravel	11	16	0.0
coarse gravel	16	22	0.0
coarse gravel	22	32	0.0
very coarse gravel	32	45	0.0
very coarse gravel	45	64	0.0
small cobble	64	90	0.0
medium cobble	90	128	0.0
large cobble	128	180	0.0
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			0.0
		Weighted Count	100
		True Total Particle Count	100

Pebble Count
Cato Farms Trib to Clark Creek- Upper Reach
Clark Creek
Near Huntersville, NC
Note: D84 appears to be about 0.3 mm

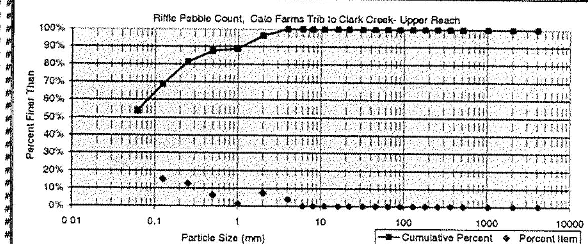


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	#N/A	#N/A	0	1	59%	39%	2%	0%	0%	0%

Riffle Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	43
very fine sand	0.062	0.13	12
fine sand	0.13	0.25	10
medium sand	0.25	0.5	5
coarse sand	0.5	1	1
very coarse sand	1	2	6
very fine gravel	2	4	3
fine gravel	4	6	
fine gravel	6	8	
medium gravel	8	11	
medium gravel	11	16	
coarse gravel	16	22	
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			
		Total Particle Count	80

Riffle Pebble Count,
Cato Farms Trib to Clark Creek- Upper Reach
Clark Creek
Near Huntersville, NC
Note:

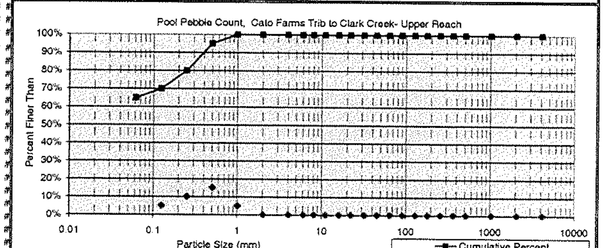


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	#N/A	#N/A	0	2	54%	43%	4%	0%	0%	0%

Pool Pebble Count

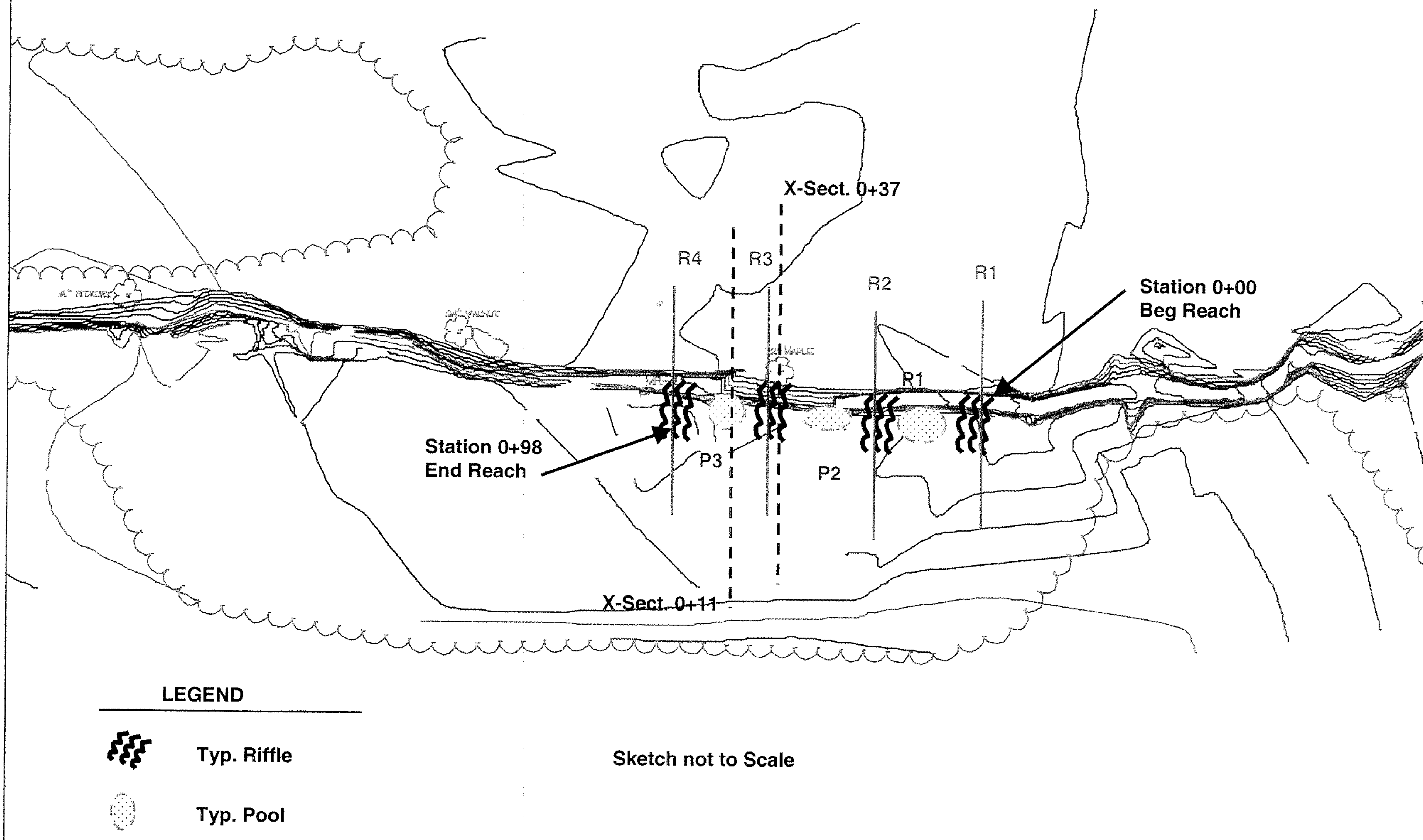
Material	Size Range (mm)		Count
silt/clay	0	0.062	13
very fine sand	0.062	0.13	1
fine sand	0.13	0.25	2
medium sand	0.25	0.5	3
coarse sand	0.5	1	1
very coarse sand	1	2	
very fine gravel	2	4	
fine gravel	4	6	
fine gravel	6	8	
medium gravel	8	11	
medium gravel	11	16	
coarse gravel	16	22	
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			
		Total Particle Count	20

Pool Pebble Count,
Cato Farms Trib to Clark Creek- Upper Reach
Clark Creek
Near Huntersville, NC
Note:



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	#N/A	#N/A	0	1	65%	35%	0%	0%	0%	0%

APPENDIX B



CH2MHILL

Cato Farms Middle Reach
Cato Farms Restoration Project

Reference Reach

Hints

Stream:	Cato Farms Trib to Clark Creek- Middle Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	
Longitude:	
County:	Mecklenburg
Date:	April 18-19, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	G5c
Drainage Area (sq mi):	0.36
Notes:	This is the middle reach of three reaches surveyed.

Dimension

		typical	min	max
Size:	x-area bankful	8.6	---	---
	width bankful	5.2	---	---
	mean depth	1.7	---	---
Ratios:	Width/Depth Ratio	3.2	---	---
	Entrenchment Ratio	1.3	---	---
	Riffle Max Depth Ratio	1.2	---	---
	Pool Area Ratio	1.2	---	---
	Pool Width Ratio	0.9	---	---
	Pool Max Depth Ratio	1.7	---	---
	Bank Height Ratio	2.2		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	---	---	---
	Glide Width Ratio	---	---	---
	Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	65.8	65.8	65.8
velocity (ft/sec)	7.6	6.3	---
shear stress @ max depth (lbs/ft sq)	1.15	1.63	---
shear stress (lbs/ft sq)	0.63	0.61	---
shear velocity (ft/sec)	0.57	0.56	---
unit stream power (lbs/ft/sec)	7.208	7.208	7.21
relative roughness	128.4	168.5	---
friction factor u/u*	13.3	11.2	---
threshold grain size @ max depth (mm)	94.5	187.3	---
threshold grain size (mm)	40	38	---

Pattern

	typical	min	max
Sinuosity	1.0		
Meander Width Ratio	1.1	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	0.918	0.1	1.4
measured valley slope (%)	0.860	---	---
valley slope (%)	0.956		
Riffle Slope Ratio	1.1	0.1	1.7
Pool Slope Ratio	-3.9	-1.1	-6.8
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	6.8	6.7	6.9

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	#N/A	#N/A	0.189	0.0	0.0	---
D35	0.24	0.14	0.56	0	0	---
D50	0.5	0.2	0.8	0	0	---
D84	3.9	2	8	0	0	---
D95	9.8	6	11	0	0	---
Largest Bar						0
% Silt/Clay	21%	31%	10%	---	---	---
% Sand	51%	51%	50%	---	---	---
% Gravel	29%	18%	40%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	

Reference Reach

Stream:	Cato Farms Trib to Clark Creek- Middle Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 18-19, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	G5c
Drainage Area (sq mi):	0.36

Pattern

	typical	min	max
bankfull width (ft)	5.225662		
meander length (ft)			
belt width (ft)	5.5		
amplitude (ft)			
radius (ft)			
arc angle (degrees)			
straight length (ft)			
stream length	449		
valley length	431		
Sinuosity	1.04		
Meander Width Ratio	1.1	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---

Profile

	typical	min	max
bankfull width (ft)	5.225662		
pool-pool spacing (ft)	35.6	35.2	35.9
riffle length (ft)	9.95	6.6	13.3
pool length (ft)	6.85	2.4	11.3
run length (ft)			
glide length (ft)			
channel slope (%)	0.918	0.114	1.4
riffle slope (%)	1.03	0.114	1.57
pool slope (%)	-3.61	-0.97	-6.25
run slope (%)			
glide slope (%)			
measured valley slope (%)	0.86		
valley slope (%)	1.0		
Riffle Length Ratio	1.9	1.3	2.5
Pool Length Ratio	1.3	0.5	2.2
Run Length Ratio	---	---	---
Glide Length Ratio	---	---	---
Riffle Slope Ratio	1.1	0.1	1.7
Pool Slope Ratio	-3.9	-1.1	-6.8
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	6.8	6.7	6.9

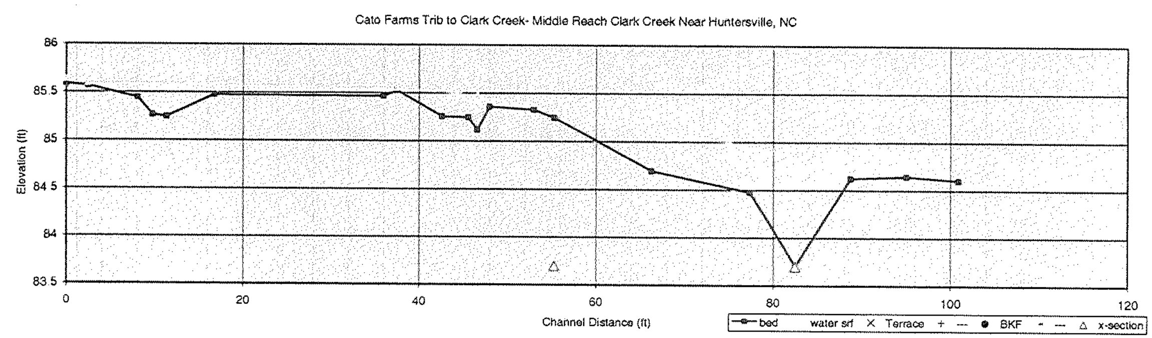
Slope Calculator

	station	elevation	% slope	note
point 1	2.5	85.56		
point 2	37.5	85.52	0.114	Bed
point 1	37.5	85.52		
point 2	55.3	85.24	1.573	Bed
point 1	55.3	85.24		
point 2	100.9	84.6	1.404	Bed
point 1	2.5	85.59		
point 2	37.5	85.55	0.114	WSE
point 1	37.5	85.55		
point 2	55.3	85.33	1.236	WSE
point 1	55.3	85.33		
point 2	100.9	84.69	1.404	WSE
point 1				
point 2			---	

Bed Avg 1.030

WSE Avg 0.918

Slope Profile



96.69 :Elevation BM

notes	cross section	station	BS	HI	FS TP	FS bed	depth water	FS BKF	FS Terrace	FS	FS	AZ azimuth	ELEV bed	ELEV water srf	ELEV BKF	ELEV Terrace	ELEV ---	ELEV ---
				96.69														
H Riffle		0		96.69		11.11	0.05						85.58	85.63				
M Riffle		2.5		96.69		11.13	0.03						85.56	85.59				
H Run		8.1		96.69		11.25							85.44					
H Pool		9.8		96.69		11.43							85.26					
M Pool		11.4		96.69		11.45	0.35						85.24	85.59				
H Glide		16.8		96.69		11.22							85.47					
H Riffle		36		96.69		11.23							85.46					
M Riffle		37.5		96.69		11.17	0.03						85.52	85.55				
H Glide		42.6		96.69		11.44							85.25					
H Pool		45.6		96.69		11.45							85.24					
M Pool		46.6		96.69		11.58	0.37						85.11	85.48				
H Glide		48		96.69		11.34							85.35					
H Riffle		53		96.69		11.37							85.32					
M Riffle	Riffle	55.3		96.69		11.45	0.09						85.24	85.33				
H Glide		68.3		96.69		12							84.69					
H Pool		77.4		96.69		12.22							84.47					
M Pool	Pool	82.5		96.69		12.99	1.17						83.7	84.87				
H Glide		88.7		96.69		12.07							84.62					
H Riffle		95		96.69		12.05							84.64					
M Riffle		100.9		96.69		12.09	0.09						84.6	84.69				

Reference Reach

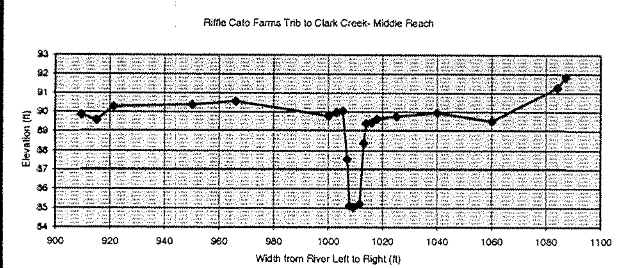
Stream:	Cato Farms Trib to Clark Creek- Middle Reach
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 18-19, 2002
Observers:	Paige Baker, Sean Collins, Jeff Keaton
Channel Type:	G5
Drainage Area (sq mi):	0.36

Dimension		typical	min	max
Riffle:	x-area bankfull	8.6		
	width bankfull	5.2		
	hydraulic radius	1.1		
	max depth	2.0		
	bank ht	4.4		
	width flood prone area	7.0		
	mean depth	1.65		
Pool:	x-area pool	10.5		
	width pool	4.8		
	hydraulic radius	1.1		
	max depth pool	2.8		
	bank ht	5.5		
Run:	x-area run			
	width run			
	hydraulic radius			
	max depth run			
	bank ht			
Glide:	x-area glide			
	width glide			
	max depth glide			

Dimensionless Ratios:	typical	min	max
Width/Depth Ratio	3.2		
Entrenchment Ratio	1.3		
Riffle Max Depth Ratio	1.2	---	---
Pool Area Ratio	1.2	---	---
Pool Width Ratio	0.9	---	---
Pool Max Depth Ratio	1.7	---	---
Bank Height Ratio	2.2		
Run Area Ratio	---	---	---
Run Width Ratio	---	---	---
Run Max Depth Ratio	---	---	---
Glide Area Ratio	---	---	---
Glide Width Ratio	---	---	---
Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
channel slope (%)	0.918		
discharge rate, Q (cfs)	65.8		
velocity (ft/sec)	7.6	6.3	---
shear stress @ max depth (lbs/ft sq)	1.146	1.627	---
shear stress (lbs/ft sq)	0.634	0.607	---
shear velocity (ft/sec)	0.572	0.560	---
stream power (lbs/sec)	37.7	37.7	37.7
unit stream power (lbs/ft/sec)	7.208	7.208	7.208
relative roughness	128.4	168.5	---
friction factor u/u*	13.3	11.2	---
threshold grain size @ max depth (mm)	95	~~187~~	---
threshold grain size (mm)	39.9	38.0	---

Cross Section



section:
Riffle
Cato Farms Trib to Clark Creek- Middle Reach
Clark Creek

description:

height of instrument (ft): 96.69

notes	omit pt.	distance (ft)	FS (ft)	elevation
	■	909.4	6.83	89.86
bottom byp	■	915	7.13	89.56
TB bypass	■	921.2	6.41	90.28
	■	950	6.32	90.37
	■	966	6.15	90.54
	■	1000	6.91	89.78
	■	1003	6.71	89.98
ltop	■	1005.4	6.65	90.04
bnk	■	1007	9.16	87.53
LTOE	■	1007.8	11.59	85.1
THAL	■	1009.2	11.68	85.01
RTOE	■	1011.6	11.49	85.2
	■	1013	8.31	88.38
RTB	■	1014	7.3	89.39
	■	1016	7.25	89.44
	■	1018	7.06	89.63
	■	1025	6.92	89.77
	■	1040	6.73	89.96
	■	1060	7.18	89.51
	■	1084	5.41	91.28
	■	1087	4.86	91.83

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
9.68	7.3	7.0	0.918	0.02
87.01	89.39			

dimensions			
8.6	x-section area	1.7	d mean
5.2	width	7.8	wet P
2.0	d max	1.1	hyd radi
4.4	bank ht	3.2	w/d ratio
7.0	W flood prone area	1.3	ent ratio

hydraulics	
7.6	velocity (ft/sec)
65.8	discharge rate, Q (cfs)
0.63	shear stress ((lbs/ft sq)
0.57	shear velocity (ft/sec)
7.208	unit stream power (lbs/ft/sec)
1.09	Froude number
13.3	friction factor u/u*
39.9	threshold grain size (mm)

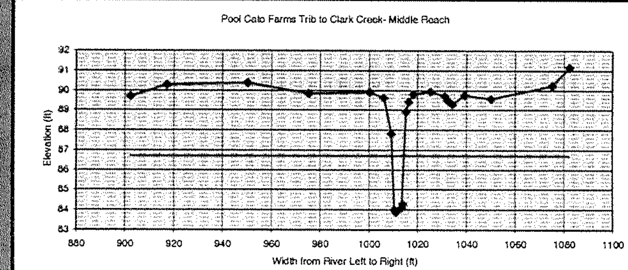
check from channel material (D/D84) - Limerinos			
4	measured D84 (mm)		
128.4	relative roughness	14.8	fric. factor
0.018	Manning's n from channel material		

check from channel material (R/D84) - Limerinos			
86.013642	R/D84 (ft/ft)	13.857034	u/u*
0.019	Manning's n from channel materia		

u/u* = friction factor

check from Shear Velocity	
7.9217823	u - velocity
0.019	Manning's n from Shear Velocity

Cross Section



section:
Pool
Cato Farms Trib to Clark Creek- Middle Reach
Clark Creek

description:

height of instrument (ft): 96.69

notes	omit pt.	distance (ft)	FS (ft)	elevation
	■	902	7.01	89.68
	■	917	6.42	90.27
	■	950	6.32	90.37
	■	975	6.86	89.83
	■	1000	6.79	89.9
LTB	■	1005.9	7.09	89.6
	■	1009	8.9	87.79
T TOE	■	1010.2	12.7	83.99
	■	1010.9	12.84	83.85
THAL	■	1013.8	12.41	84.28
	■	1013.2	12.6	84.09
	■	1015	7.8	88.89
	■	1016	7.3	89.39
	■	1018	6.91	89.78
	■	1025	6.76	89.93
	■	1031	7.01	89.68
	■	1032	7.21	89.48
	■	1034	7.42	89.27
	■	1039	6.96	89.73
	■	1050	7.14	89.55
	■	1075	6.47	90.22
	■	1082	5.55	91.14

FS bankfull	FS top of bank		channel slope (%)	
10	7.3		0.918	
86.69	89.39			

dimensions			
10.5	x-section area	2.2	d mean
4.8	width	9.9	wet P
2.8	d max	1.1	hyd radi
5.5	bank ht		

hydraulics	
0.61	shear stress ((lbs/ft sq)
0.56	shear velocity (ft/sec)
38.0	threshold grain size (mm)

Reference Reach

Reference Reach						Hints
Stream:	Cato Farms Trib to Clark Creek- Middle Reach					
Watershed:	Clark Creek					
Location:	Near Huntersville, NC					
Latitude:	---					
Longitude:	---					
County:	Mecklenburg					
Date:	April 18-19, 2002					
Observers:	Paige Baker, Sean Collins, Jeff Keaton					
Channel Type:	G5c					
Drainage Area (sq mi):	0.36					

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	#N/A	#N/A	0.189	0.000	0.000	---
D35	0.24	0.14	0.56	0.00	0.00	---
D50	0.5	0.2	0.8	0.0	0.0	---
D84	4	2	8	0	0	---
D95	10	6	11	0	0	---
Largest of Bar Sample						
% Silt/Clay	21%	31%	10%	---	---	---
% Sand	51%	51%	50%	---	---	---
% Gravel	29%	18%	40%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	

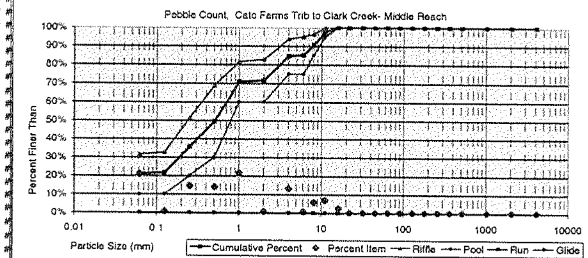
Weighted Pebble Count

Percent Riffle:	50	Percent Run:	
Percent Pool:	50	Percent Glide:	

Material	Size Range (mm)		Total #
silt/clay	0	0.062	20.6
very fine sand	0.062	0.13	0.6
fine sand	0.13	0.25	14.4
medium sand	0.25	0.5	13.8
coarse sand	0.5	1	21.3
very coarse sand	1	2	0.6
very fine gravel	2	4	13.1
fine gravel	4	6	0.6
fine gravel	6	8	5.6
medium gravel	8	11	6.9
medium gravel	11	16	2.5
coarse gravel	16	22	0.0
coarse gravel	22	32	0.0
very coarse gravel	32	45	0.0
very coarse gravel	45	64	0.0
small cobble	64	90	0.0
medium cobble	90	128	0.0
large cobble	128	180	0.0
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			0.0
		Weighted Count:	100
		True Total Particle Count:	100

Pebble Count

Cato Farms Trib to Clark Creek- Middle Reach
Clark Creek
Near Huntersville, NC
Note:



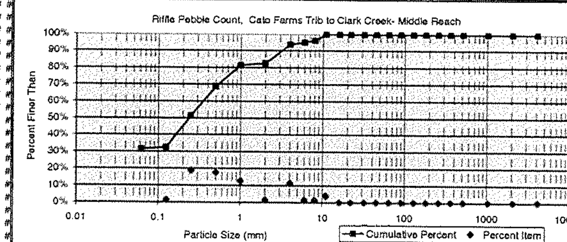
Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	0.24	0.5	4	10	21%	51%	29%	0%	0%	0%

Riffle Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	25
very fine sand	0.062	0.13	1
fine sand	0.13	0.25	15
medium sand	0.25	0.5	14
coarse sand	0.5	1	10
very coarse sand	1	2	1
very fine gravel	2	4	9
fine gravel	4	6	1
fine gravel	6	8	1
medium gravel	8	11	3
medium gravel	11	16	
coarse gravel	16	22	
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			
		Total Particle Count:	80

Riffle Pebble Count

Cato Farms Trib to Clark Creek- Middle Reach
Clark Creek
Near Huntersville, NC
Note:



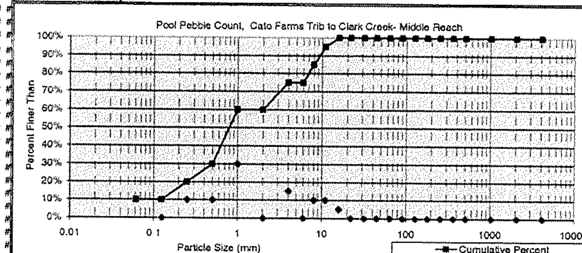
Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	0.14	0.2	2	6	31%	51%	18%	0%	0%	0%

Pool Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	2
very fine sand	0.062	0.13	
fine sand	0.13	0.25	2
medium sand	0.25	0.5	2
coarse sand	0.5	1	6
very coarse sand	1	2	
very fine gravel	2	4	3
fine gravel	4	6	
fine gravel	6	8	2
medium gravel	8	11	2
medium gravel	11	16	1
coarse gravel	16	22	
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			
		Total Particle Count:	20

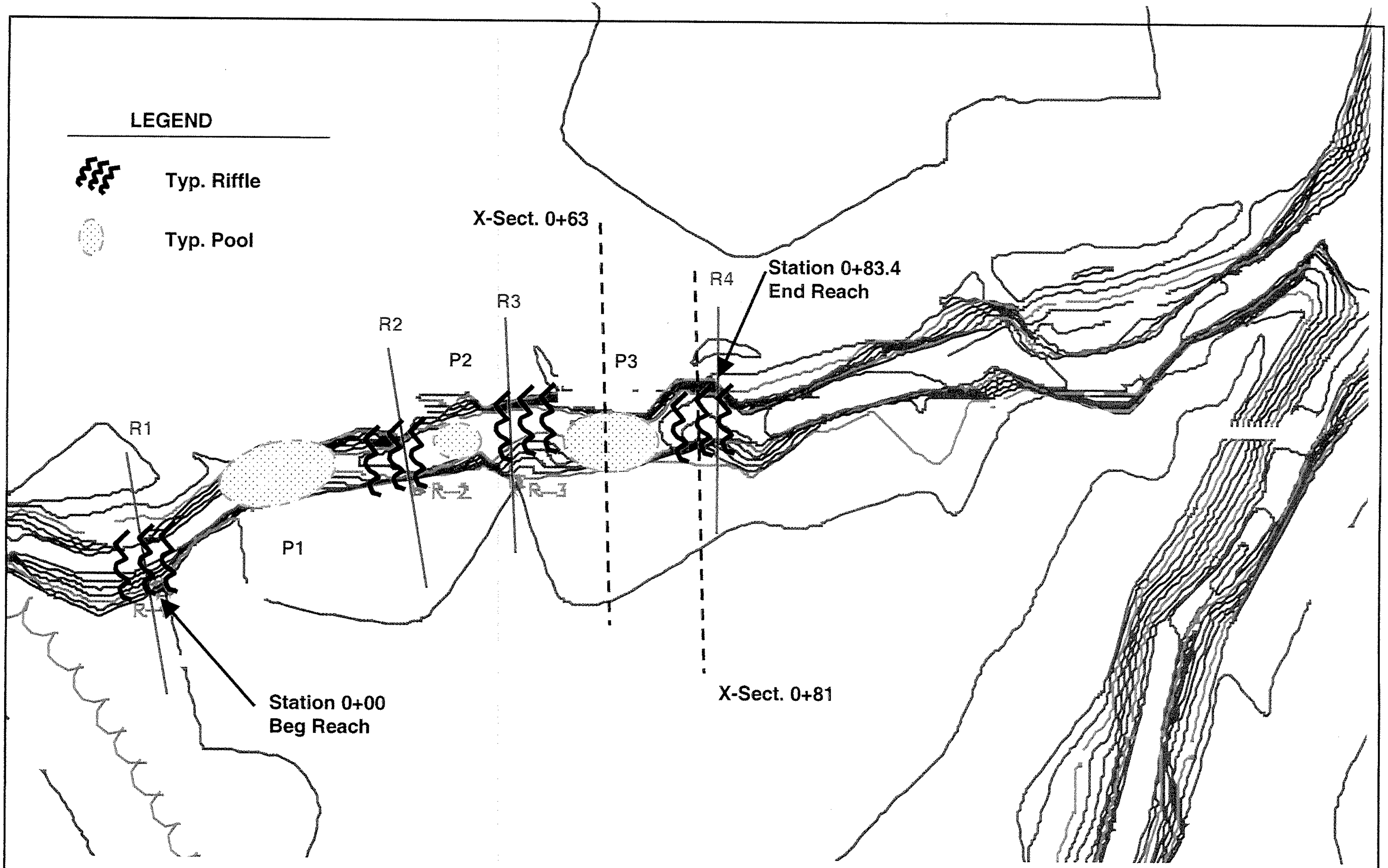
Pool Pebble Count

Cato Farms Trib to Clark Creek- Middle Reach
Clark Creek
Near Huntersville, NC
Note:



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.189	0.56	0.8	8	11	10%	50%	40%	0%	0%	0%

APPENDIX C



Sketch not to Scale

CH2MHILL

Cato Farms Lower Reach
Cato Farms Restoration Project

Reference Reach

Hints

Stream:	Cato Farms Tributary Lower Reach
Watershed:	Clark Creek, Yadkin
Location:	Huntersville, NC
Latitude:	
Longitude:	
County:	Mecklenburg
Date:	April 24, 2002
Observers:	Jeff Keaton, Vicki Jones
Channel Type:	G5c
Drainage Area (sq mi):	0.41
Notes:	

Dimension

		typical	min	max
Size:	x-area bankful	9.7	---	---
	width bankful	7.6	---	---
	mean depth	1.3	---	---
Ratios:	Width/Depth Ratio	6.0	---	---
	Entrenchment Ratio	1.4	---	---
	Riffle Max Depth Ratio	1.5	---	---
	Pool Area Ratio	1.7	---	---
	Pool Width Ratio	1.2	---	---
	Pool Max Depth Ratio	2.1	---	---
	Bank Height Ratio	3.2		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	---	---	---
	Glide Width Ratio	---	---	---
	Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	82.1	82.1	82.1
velocity (ft/sec)	8.4	4.9	---
shear stress @ max depth (lbs/ft sq)	1.83	2.54	---
shear stress (lbs/ft sq)	1.04	1.41	---
shear velocity (ft/sec)	0.73	0.85	---
unit stream power (lbs/ft/sec)	10.334	10.334	10.33
relative roughness	44.9	66.3	---
friction factor u/u*	11.5	5.8	---
threshold grain size @ max depth (mm)	234.5	445.4	---
threshold grain size (mm)	78	#N/A	---

Pattern

	typical	min	max
Sinuosity	1.1		
Meander Width Ratio	1.0	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	1.540	1.1	2.0
measured valley slope (%)	0.560	---	---
valley slope (%)	1.622		
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	0.0	-0.6	0.6
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	3.5	2.7	4.4

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	#N/A	0.065	#N/A	0.0	0.0	---
D35	0.58	0.70	0.52	0	0	---
D50	1.2	2.7	0.9	0	0	---
D84	8.6	11	4	0	0	---
D95	18.5	22	16	0	0	---
Largest Bar						0
% Silt/Clay	18%	15%	21%	---	---	---
% Sand	39%	25%	54%	---	---	---
% Gravel	39%	54%	23%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	5%	7%	3%	---	---	

Reference Reach

Hints

Stream:	Cato Farms Tributary Lower Reach
Watershed:	Clark Creek, Yadkin
Location:	Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 24, 2002
Observers:	Jeff Keaton, Vicki Jones
Channel Type:	G5c
Drainage Area (sq mi):	0.41

Pattern

	typical	min	max
bankfull width (ft)	7.636364		
meander length (ft)			
belt width (ft)	8		
amplitude (ft)			
radius (ft)			
arc angle (degrees)			
straight length (ft)			
stream length	879.3		
valley length	835		
Sinuosity	1.05		
Meander Width Ratio	1.0	---	---
Amplitude Ratio	---	---	---
Meander Length Ratio	---	---	---
Straight Length Ratio	---	---	---
Radius Ratio	---	---	---

Profile

	typical	min	max
bankfull width (ft)	7.636364		
pool-pool spacing (ft)	27.1	20.9	33.3
riffle length (ft)	6.3	4.8	7.8
pool length (ft)	9.6	4.4	14.8
run length (ft)			
glide length (ft)			
channel slope (%)	1.54	1.079	1.954
riffle slope (%)			
pool slope (%)	-0.0009	-0.897	0.878
run slope (%)			
glide slope (%)			
measured valley slope (%)	0.56		
valley slope (%)	1.6		
Riffle Length Ratio	0.8	0.6	1.0
Pool Length Ratio	1.3	0.6	1.9
Run Length Ratio	---	---	---
Glide Length Ratio	---	---	---
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	0.0	-0.6	0.6
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	3.5	2.7	4.4

Slope Calculator

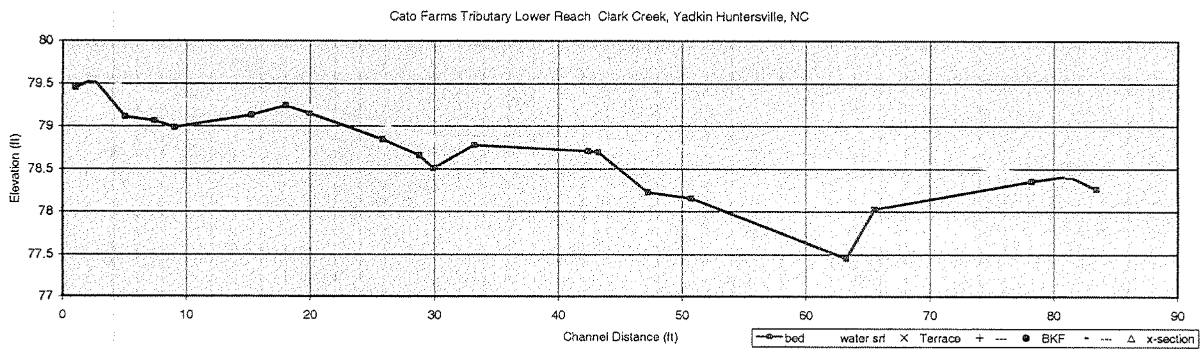
Hints

	station	elevation	% slope	note
point 1	2.5	79.54		
point 2	19.9	79.15	2.241	Bed
point 1	19.9	79.15		
point 2	43.2	78.69	1.974	Bed
point 1	43.2	78.69		
point 2	81.2	78.41	0.737	Bed
point 1	2.5	79.57		
point 2	19.9	79.23	1.954	WSE
point 1	19.9	79.23		
point 2	43.2	78.86	1.588	WSE
point 1	43.2	78.86		
point 2	81.2	78.45	1.079	WSE
point 1				
point 2			---	

Avg Bed 1.65

Avg WSE 1.54

Slope Profile



90.29 :Elevation BM

notes	cross section	station	BS	HI	FS TP	FS bed	depth water	FS BKF	FS Terrace	FS	FS	AZ azimuth	ELEV bed	ELEV water srf	ELEV BKF	ELEV Terrace	ELEV ---	ELEV ---
H Riffle		1	2.93	93.22		13.77							79.45					
M Riffle		2.5		93.22		13.68	0.03						79.54	79.57				
H Run		5		93.22		14.11							79.11					
H Pool		7.4		93.22		14.16							79.06					
M Pool		9		93.22		14.24	0.35						78.98	79.33				
H Glide		15.2		93.22		14.09							79.13					
H Riffle		18		93.22		13.98							79.24					
M Riffle		19.9		93.22		14.07	0.08						79.15	79.23				
H Run		25.8		93.22		14.38							78.84					
H Pool		28.8		93.22		14.57							78.65					
M Pool		29.9		93.22		14.72	0.37						78.5	78.87				
H Glide		33.2		93.22		14.45							78.77					
H Riffle		42.4		93.22		14.52							78.7					
M Riffle		43.2		93.22		14.53	0.17						78.69	78.86				
H Run		47.2		93.22		15							78.22					
H Pool		50.7		93.22		15.07							78.15					
M Pool		63.2		93.22		15.77	1.15						77.45	78.6				
H Glide		65.5		93.22		15.2							78.02					
H Riffle		78.2		93.22		14.87							78.35					
M Riffle		81.2		93.22		14.81	0.04						78.41	78.45				
B Riffle		83.4		93.22		14.96							78.26					
				93.22														
				93.22														
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Reference Reach

Hints

Stream:	Cato Farms Tributary Lower Reach
Watershed:	Clark Creek, Yadkin
Location:	Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 24, 2002
Observers:	Jeff Keaton, Vicki Jones
Channel Type:	G5c
Drainage Area (sq mi):	0.41

Dimension

		typical	min	max
Riffle:	x-area bankfull	9.7		
	width bankfull	7.6		
	hydraulic radius	1.1		
	max depth	1.9		
	bank ht	6.1		
	width flood prone area	11.0		
	mean depth	1.27		
Pool:	x-area pool	16.7		
	width pool	8.9		
	hydraulic radius	1.5		
	max depth pool	2.6		
	bank ht	7.5		
Run:	x-area run			
	width run			
	hydraulic radius			
	max depth run			
	bank ht			
Glide:	x-area glide			
	width glide			
	max depth glide			

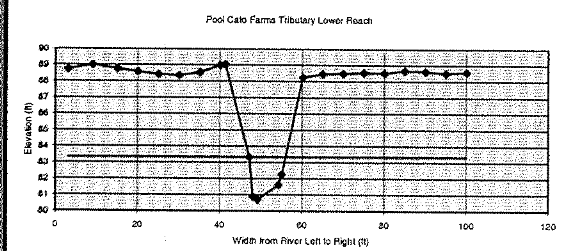
Dimensionless Ratios

	typical	min	max
Width/Depth Ratio	6.0		
Entrenchment Ratio	1.4		
Riffle Max Depth Ratio	1.5	---	---
Pool Area Ratio	1.7	---	---
Pool Width Ratio	1.2	---	---
Pool Max Depth Ratio	2.1	---	---
Bank Height Ratio	3.2		
Run Area Ratio	---	---	---
Run Width Ratio	---	---	---
Run Max Depth Ratio	---	---	---
Glide Area Ratio	---	---	---
Glide Width Ratio	---	---	---
Glide Max Depth Ratio	---	---	---

Hydraulics

	riffle	pool	run
channel slope (%)	1.540		
discharge rate, Q (cfs)	82.1		
velocity (ft/sec)	8.4	4.9	---
shear stress @ max depth (lbs/ft sq)	1.826	2.537	---
shear stress (lbs/ft sq)	1.038	1.407	---
shear velocity (ft/sec)	0.732	0.852	---
stream power (lbs/sec)	78.9	78.9	78.9
unit stream power (lbs/ft/sec)	10.334	10.334	10.334
relative roughness	44.9	66.3	---
friction factor u/u*	11.5	5.8	---
threshold grain size @ max depth (mm)	236	445	---
threshold grain size (mm)	77.9	#N/A	---

Cross Section



section: Pool

Cato Farms Tributary Lower Reach

Clark Creek, Yadkin

description:

height of instrument (ft): 93.22

notes	omit pt.	distance (ft)	FS (ft)	elevation
FP		3	4.5	88.72
FP		9	4.24	88.98
FP		15	4.47	88.75
FP		20	4.65	88.57
FP		25	4.81	88.41
FP		30	4.88	88.34
FP		35	4.71	88.51
FP		40	4.26	88.96
LTB		41.2	4.2	89.02
		47.1	9.9	83.32
LTOE		48	12.34	80.88
Thalweg		49.1	12.54	80.68
WSE		54.2	11.61	81.61
Right Toe		55.05	10.97	82.25
RTB		60.1	5	88.22
FP		65	4.78	88.44
FP		70	4.76	88.46
FP		75	4.71	88.51
FP		80	4.72	88.5
FP		85	4.58	88.64
FP		90	4.62	88.6
FP		95	4.72	88.5
FP		100	4.66	88.56

FS bankfull	FS top of bank		channel slope (%)	
9.9	5		1.54	
83.32	88.22			

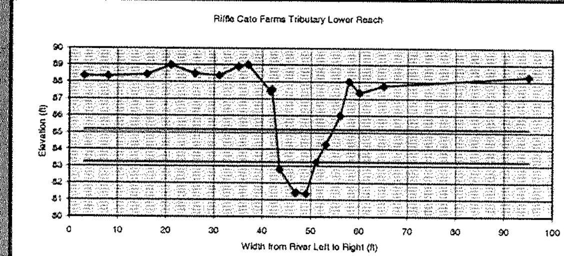
dimensions

16.7	x-section area	1.9	d mean
8.9	width	11.4	wet P
2.6	d max	1.5	hyd radi
7.5	bank ht		

hydraulics

1.41	shear stress ((lbs/ft sq)
0.85	shear velocity (ft/sec)
444.2	threshold grain size (mm

Cross Section



section: Riffle

Cato Farms Tributary Lower Reach

Clark Creek, Yadkin

description:

height of instrument (ft): 93.22

notes	omit pt.	distance (ft)	FS (ft)	elevation
FP		3	4.9	88.32
FP		8	4.91	88.31
FP		16	4.82	88.4
FP		21	4.27	88.95
FP		26	4.77	88.45
FP		31	4.88	88.34
FP		35	4.33	88.89
FP		37	4.24	88.98
LTB		41.6	5.8	87.42
		42	5.7	87.52
LTOE		43.5	10.43	82.79
THAL		46.6	11.84	81.38
Waters Ed		47	11.79	81.43
		49	11.9	81.32
		51	10	83.22
		53	8.97	84.25
		56	7.25	85.97
RTB		57.6	5.22	88
FP		60	5.9	87.32
FP		65	5.5	87.72
FP		95	4.96	88.26

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
10	5.8	11.0	1.54	0.023
83.22	87.42			

dimensions

9.7	x-section area	1.3	d mean
7.6	width	9.0	wet P
1.9	d max	1.1	hyd radi
6.1	bank ht	6.0	w/d ratio
11.0	W flood prone area	1.4	ent ratio

hydraulics

8.4	velocity (ft/sec)
82.1	discharge rate, Q (cfs)
1.04	shear stress ((lbs/ft sq)
0.73	shear velocity (ft/sec)
10.334	unit stream power (lbs/ft/sec)
1.74	Froude number
11.5	friction factor u/u*
77.9	threshold grain size (mm

check from channel materia

9	measured D84 (mm)		
44.9	relative roughness	12.3	fric. factor
0.022	Manning's n from channel materia		

check from channel material (R/D84) - Limerinos

38.10895	R/D84 (ft/ft)	11.841854	u/u*
0.022	Manning's n from channel materia		

u/u* = friction factor

check from Shear Velocit

8.661854	u - velocity
0.022	Manning's n from Shear Velocit

Reference Reach

Hints

Stream:	Cato Farms Tributary Lower Reach
Watershed:	Clark Creek, Yadkin
Location:	Huntersville, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	April 24, 2002
Observers:	Jeff Keaton, Vicki Jones
Channel Type:	G5c
Drainage Area (sq mi):	0.41

Channel Materials

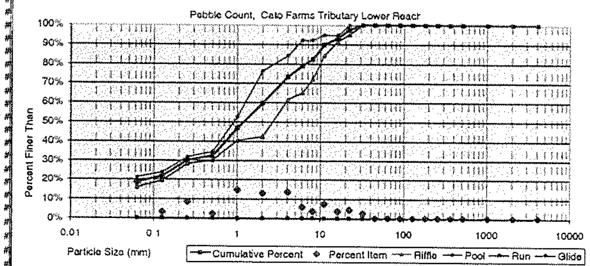
	total	riffle	pool	run	glide	bar sample
D16	#N/A	0.065	#N/A	0.000	0.000	---
D35	0.58	0.70	0.52	0.00	0.00	---
D50	1.2	2.7	0.9	0.0	0.0	---
D84	9	11	4	0	0	---
D95	18	22	16	0	0	---
Largest of Bar Sample						
% Silt/Clay	18%	15%	21%	---	---	---
% Sand	39%	25%	54%	---	---	---
% Gravel	39%	54%	23%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	5%	7%	3%	---	---	

Weighted Pebble Count

Percent Riffle: 50 | Percent Run:
Percent Pool: 50 | Percent Glide:

Material	Size Range (mm)		Total #
silt/clay	0	0.062	17.6
very fine sand	0.062	0.13	2.9
fine sand	0.13	0.25	7.9
medium sand	0.25	0.5	2.1
coarse sand	0.5	1	13.9
very coarse sand	1	2	12.4
very fine gravel	2	4	12.9
fine gravel	4	6	5.5
fine gravel	6	8	3.3
medium gravel	8	11	7.0
medium gravel	11	16	3.3
coarse gravel	16	22	4.2
coarse gravel	22	32	2.5
very coarse gravel	32	45	0.0
very coarse gravel	45	64	0.0
small cobble	64	90	0.0
medium cobble	90	128	0.0
large cobble	128	180	0.0
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			4.6
Weighted Count:			100
True Total Particle Count:			100

Pebble Count,
Cato Farms Tributary Lower Reach
Clark Creek, Yadkin
Huntersville, NC
Note

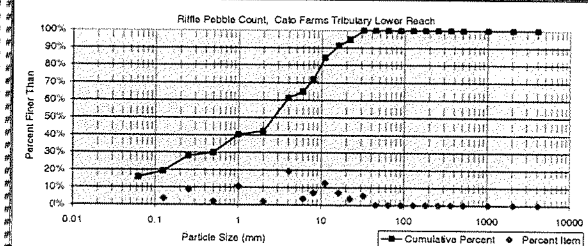


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	0.58	1.2	9	18	18%	39%	39%	0%	0%	5%

Riffle Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	9
very fine sand	0.062	0.13	2
fine sand	0.13	0.25	5
medium sand	0.25	0.5	1
coarse sand	0.5	1	6
very coarse sand	1	2	1
very fine gravel	2	4	11
fine gravel	4	6	2
fine gravel	6	8	4
medium gravel	8	11	7
medium gravel	11	16	4
coarse gravel	16	22	2
coarse gravel	22	32	3
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			4
Total Particle Count:			61

Riffle Pebble Count,
Cato Farms Tributary Lower Reach
Clark Creek, Yadkin
Huntersville, NC
Note

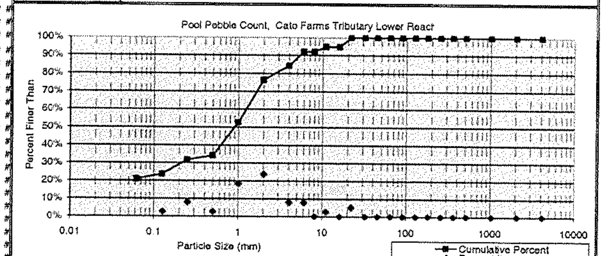


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.065	0.70	2.7	11	22	15%	25%	54%	0%	0%	7%

Pool Pebble Count

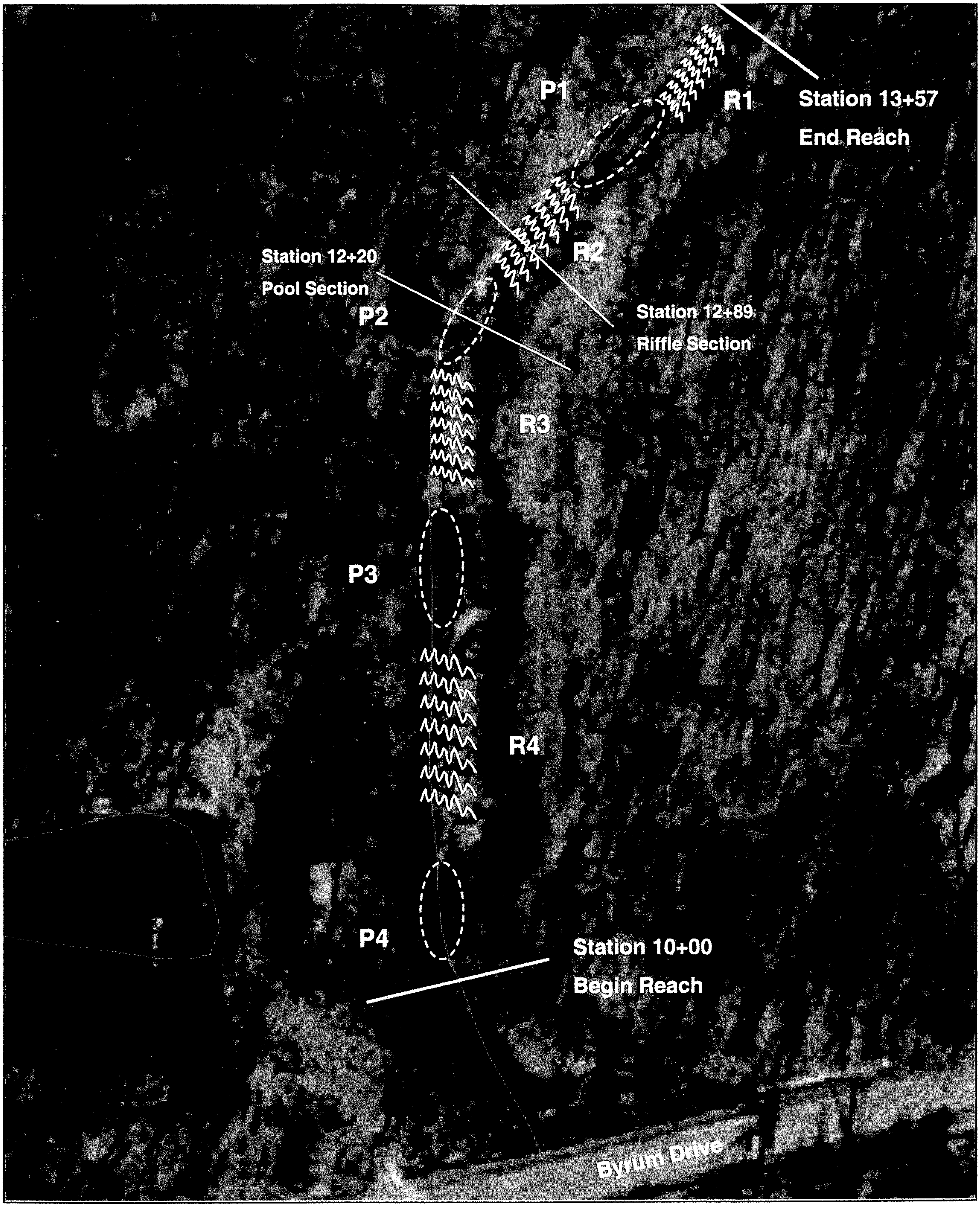
Material	Size Range (mm)		Count
silt/clay	0	0.062	8
very fine sand	0.062	0.13	1
fine sand	0.13	0.25	3
medium sand	0.25	0.5	1
coarse sand	0.5	1	7
very coarse sand	1	2	9
very fine gravel	2	4	3
fine gravel	4	6	3
fine gravel	6	8	
medium gravel	8	11	1
medium gravel	11	16	
coarse gravel	16	22	2
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			1
Total Particle Count:			39

Pool Pebble Count
Cato Farms Tributary Lower Reach
Clark Creek, Yadkin
Huntersville, NC
Note



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	0.52	0.9	4	16	21%	54%	23%	0%	0%	3%

APPENDIX D



75 37.5 0 75 Feet

CH2MHILL

Coffey Creek Reference Reach Sketch

Cato Farms Stream Restoration Project

P:\NC DENR\171915\CADD&GIS\Coffey Creek Figure

Reference Reach

Hints

Stream:	Coffey Creek
Watershed:	Catawba
Location:	Charlotte, NC
Latitude:	
Longitude:	
County:	Mecklenburg, County
Date:	May 9, 2002
Observers:	JK,SDC
Channel Type:	B4c
Drainage Area (sq mi):	4.04
Notes:	Site located 200' upstream of Byrum Drive Culvert. Culvert is 30' dia arch plate with natural bottom. Site is located near Charlotte Airport.

Dimension

		typical	min	max
Size:	x-area bankfull	55.4	---	---
	width bankfull	31.6	---	---
	mean depth	1.8	---	---
Ratios:	Width/Depth Ratio	18.0	---	---
	Entrenchment Ratio	1.5	---	---
	Riffle Max Depth Ratio	1.4	---	---
	Pool Area Ratio	1.3	---	---
	Pool Width Ratio	1.0	---	---
	Pool Max Depth Ratio	2.1	---	---
	Bank Height Ratio	1.3		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	---	---	---
	Glide Width Ratio	---	---	---
	Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	255.0	255.0	255.0
velocity (ft/sec)	4.6	3.6	---
shear stress @ max depth (lbs/ft sq)	1.69	2.55	---
shear stress (lbs/ft sq)	1.16	1.40	---
shear velocity (ft/sec)	0.77	0.85	---
unit stream power (lbs/ft/sec)	5.494	5.494	5.49
relative roughness	3.8	4.6	---
friction factor u/u*	6.0	4.2	---
threshold grain size @ max depth (mm)	201.0	450.1	---
threshold grain size (mm)	96	#N/A	---

Pattern

	typical	min	max
Sinuosity	1.2		
Meander Width Ratio	7.2	---	---
Amplitude Ratio	5.7	4.5	6.8
Meander Length Ratio	25.3	23.7	26.9
Straight Length Ratio	---	---	---
Radius Ratio	8.8	3.7	14.8
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	1.090	0.9	1.3
measured valley slope (%)	1.100	---	---
valley slope (%)	1.335		
Riffle Slope Ratio	1.8	1.0	2.6
Pool Slope Ratio	-0.4	-0.9	0.3
Run Slope Ratio	12.0	3.8	24.8
Glide Slope Ratio	-1.3	-0.8	-27.2
Pool Spacing Ratio	3.5	3.2	3.8

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	0.076	#N/A	0.080	0.0	0.0	---
D35	1.05	2.45	0.55	0	0	---
D50	2.3	20.3	1.3	0	0	---
D84	141.7	257	119	0	0	---
D95	324.0	325	323	0	0	---
Largest Bar						0
% Silt/Clay	11%	15%	8%	---	---	---
% Sand	29%	14%	42%	---	---	---
% Gravel	21%	33%	12%	---	---	---
% Cobble	8%	11%	5%	---	---	---
% Boulder	13%	14%	12%	---	---	---
% Bedrock	17%	13%	21%	---	---	

Reference Reach

Stream:	Coffey Creek
Watershed:	Catawba
Location:	Charlotte, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg, County
Date:	May 9, 2002
Observers:	JK,SDC
Channel Type:	B4c
Drainage Area (sq mi):	4 04

Pattern

	typical	min	max
bankfull width (ft)	31 57064		
meander length (ft)	798	747	849
belt width (ft)	226		
amplitude (ft)	179	142	216
radius (ft)	276.8	115.7	467.2
arc angle (degrees)			
straight length (ft)			
stream length	1240.7		
valley length	1013		
Sinuosity	1.22		
Meander Width Ratio	7.2	---	---
Amplitude Ratio	5 7	4 5	6.8
Meander Length Ratio	25.3	23.7	26.9
Straight Length Ratio	---	---	---
Radius Ratio	8.8	3.7	14.8

Profile

	typical	min	max
bankfull width (ft)	31 57064		
pool-pool spacing (ft)	111.7	100	120
riffle length (ft)	44	33	60
pool length (ft)	49.1	39	61
run length (ft)	10.6	4.8	17
glide length (ft)	7	3	13
channel slope (%)	1.09	0.92	1.25
riffle slope (%)	1.93	1.1	2.79
pool slope (%)	-0.42	-1	0.28
run slope (%)	13.1	4.1	27
glide slope (%)	-1.47	-0.85	-29.7
measured valley slope (%)	1.1		
valley slope (%)	1.3		
Riffle Length Ratio	1.4	1.0	1.9
Pool Length Ratio	1.6	1.2	1.9
Run Length Ratio	0.3	0.2	0.5
Glide Length Ratio	0.2	0.1	0.4
Riffle Slope Ratio	1.8	1.0	2.6
Pool Slope Ratio	-0.4	-0.9	0.3
Run Slope Ratio	12.0	3.8	24.8
Glide Slope Ratio	-1.3	-0.8	-27.2
Pool Spacing Ratio	3.5	3.2	3.8

Slope Calculator

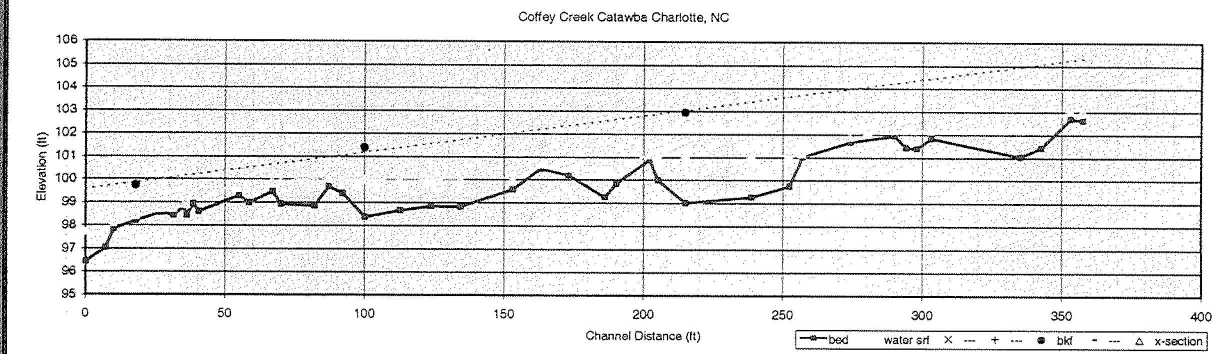
	station	elevation	% slope	note
point 1	1290	102.18		
point 2	1202	101.08	-1.250	WSE
point 1	1202	101.08		
point 2	1087	100.02	-0.922	WSE
point 1				
point 2			---	
point 1				
point 2			---	
point 1				
point 2			---	
point 1				
point 2			---	
point 1				
point 2			---	

Avg WSE 1.08667

Radius Calculator

	Coffey Creek Catawba Charlotte, NC				
cord	430	623	226		
mid ord	125	119	91		
outside bank radius	247 4	467 2	115.7	---	---

Slope Profile



100 :Elevation BM

notes	cross section	distance	station	BS	HI	FS TP	FS bed	depth water	FS bkf	FS	FS	FS	AZ azimuth	ELEV bed	ELEV water srf	ELEV bkf	ELEV —	ELEV —	ELEV —
				6.35	106.35														
p4 mid		0	0		106.35		9.94	1.33						96.41	97.74				
		7.1	7.1		106.35		9.34	0.72						97 01	97.73				
p4 beg		2.9	10		106.35		8.52	0.25						97.83	98.08				
		8	18		106.35		8.16	0.2	6.62					98.19	98.39	99.73			
r4 end		9	27		106.35		7.82	0.18						98.53	98.71				
		4.5	31.5		106.35		7.92	0.27						98.43	98 7				
		3.5	35		106.35		7.57	0.1						98.78	98.88				
		1.3	36.3		106.35		7.93	0.45						98.42	98.87				
		2.3	38.6		106.35		7.44	0.42						98.91	99.33				
		1.9	40.5		106.35		7.77	0.68						98.58	99.26				
		14.5	55		106.35		7.09	0.51						99.26	99.77				
		3.5	58.5		106.35		7.39	0.86						98.96	99.82				
		8.5	67		106.35		6.91	0.48						99.44	99 92				
		3	70		106.35		7.45	1.02						98.9	99.92				
		12	82		106.35		7.52	1.21						98.83	100.04				
r4 beg		5	87		106.35		6.68	0.35						99.67	100.02				
p3 end		5	92		106.35		6.97	0.62						99.38	100				
p3 mid		8	100		106.35		8	1.65	4.98					98.35	100	101.37			
TP1			0		106.35	6.17													
			0	7.04	107.22										#N/A	#N/A	#N/A	#N/A	#N/A
		12.5	112.5		107.22		8.58	1.4						98.64	100.04				
		11.3	123.8		107.22		8.4	1.2						98.82	100.02				
		10.4	134.2		107.22		8.42	1.24						98.8	100.04				
p3 beg		18.8	153		107.22		7.67	0.49						99.55	100.04				
r3 end		10	163		107.22		6.76	0.2						100.46	100.66				
		10	173		107.22		7.05	0.5						100.17	100.67				
		13	186		107.22		8	1.35						99.22	100 57				
		4	190		107.22		7.4	0.84						99.82	100.66				
TP2			0		107.22	6.23													
			0	9.61	110.6										#N/A	#N/A	#N/A	#N/A	#N/A
r3 beg		12	202		110.6		9.73	0.21						100.87	101.08				
p2 end		3	205		110.6		10.62	1.15						99.98	101.13				
p2 mid		10	215		110.6		11.62	2.15	7.67					98.98	101.13	102 93			
		23.5	238.5		110.6		11.37	1.89						99.23	101.12				
p2 beg		13.7	252.2		110.6		10.87	1.38						99 73	101.11				
r2 end		4.8	257		110.6		9.59	0.14						101.01	101 15				
		17	274		110.6		8.94	0.22						101.66	101 88				
r2-beg		16	290		110.6		8.67	0.25						101.93	102 18				
		4	294		110.6		9.19	0.78						101.41	102 19				
		4	298		110.6		9.22	0.82						101.38	102 2				
p1 end		5	303		110.6		8.78	0.35						101.82	102.17				
p1 mid		32	335		110.6		9.58	1.25						101.02	102.27				
p1 beg		7.5	342.5		110.6		9.18	0.8						101.42	102.22				
r1 end		10.5	353		110.6		7.92	0.4						102.68	103.08				
		4.5	357.5		110.6		8	0.43						102 6	103.03				
			0		110.6														
			0		110.6														
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			0		110.6														
			0		110.6														

Reference Reach

Hints

Stream:	Coffey Creek
Watershed:	Catawba
Location:	Charlotte, NC
Latitude:	---
Longitude:	---
County:	Mecklenburg, County
Date:	May 9, 2002
Observers:	JK,SDC
Channel Type:	B4c
Drainage Area (sq mi):	4.04

Dimension

		typical	min	max
Riffle:	x-area bankfull	55.4		
	width bankfull	31.6		
	hydraulic radius	1.7		
	max depth	2.5		
	bank ht	3.3		
	width flood prone area	46.0		
	mean depth	1.76		
Pool:	x-area pool	71.4		
	width pool	33.1		
	hydraulic radius	2.1		
	max depth pool	3.8		
	bank ht	7.2		
Run:	x-area run			
	width run			
	hydraulic radius			
	max depth run			
	bank ht			
Glide:	x-area glide			
	width glide			
	max depth glide			

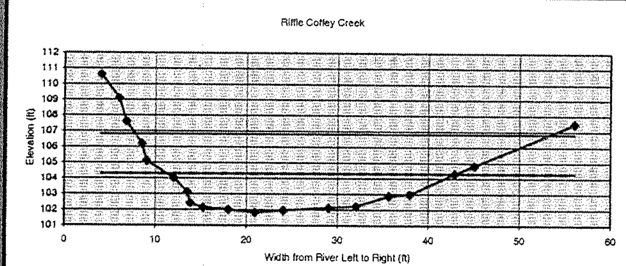
Dimensionless Ratios:

	typical	min	max
Width/Depth Ratio	18.0		
Entrenchment Ratio	1.5		
Riffle Max Depth Ratio	1.4	---	---
Pool Area Ratio	1.3	---	---
Pool Width Ratio	1.0	---	---
Pool Max Depth Ratio	2.1	---	---
Bank Height Ratio	1.3		
Run Area Ratio	---	---	---
Run Width Ratio	---	---	---
Run Max Depth Ratio	---	---	---
Glide Area Ratio	---	---	---
Glide Width Ratio	---	---	---
Glide Max Depth Ratio	---	---	---

Hydraulics:

	riffle	pool	run
channel slope (%)	1.090		
discharge rate, Q (cfs)	255.0		
velocity (ft/sec)	4.6	3.6	---
shear stress @ max depth (lbs/ft sq)	1.687	2.551	---
shear stress (lbs/ft sq)	1.156	1.397	---
shear velocity (ft/sec)	0.772	0.849	---
stream power (lbs/sec)	173.4	173.4	173.4
unit stream power (lbs/ft/sec)	5.494	5.494	5.494
relative roughness	3.8	4.6	---
friction factor u/u*	6.0	4.2	---
threshold grain size @ max depth (mm)	~~204~~	~~459~~	---
threshold grain size (mm)	96.1	#N/A	---

Cross Section



section:	Riffle
	Riffle
	Coffey Creek
	Catawba
description:	X-1 @ Sta. 2+89
height of instrument (ft):	110.60

notes	omit pt.	distance (ft)	FS (ft)	elevation
	■	4	0	110.6
	■	6	1.51	109.09
	■	6.8	3.01	107.59
	■	8.5	4.41	106.19
	■	9	5.51	105.09
	■	12	6.6	104
	■	13.5	7.5	103.1
	■	13.8	8.2	102.4
	■	15.2	8.48	102.12
	■	18	8.61	101.99
	■	20.9	8.8	101.8
	■	24	8.65	101.95
	■	29	8.5	102.1
	■	32	8.41	102.19
	■	35.6	7.73	102.87
	■	37.9	7.63	102.97
	■	42.8	6.32	104.28
	■	45	5.8	104.8
	■	56	3.13	107.47

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.32	5.51	46.0	1.09	0.048
104.28	105.09			

dimensions

55.4	x-section area	1.8	d mean
31.6	width	32.6	wet P
2.5	d max	1.7	hyd radi
3.3	bank ht	18.0	w/d ratio
46.0	W flood prone area	1.5	ent ratio

hydraulics

4.6	velocity (ft/sec)
255.0	discharge rate, Q (cfs)
1.16	shear stress ((lbs/ft sq)
0.77	shear velocity (ft/sec)
5.494	unit stream power (lbs/ft/sec)
0.37	Froude number
6.0	friction factor u/u*
96.1	threshold grain size (mm)

check from channel material

142	measured D84 (mm)		
3.8	relative roughness	6.1	fric. factor
0.047	Manning's n from channel material		

check from channel material (R/D84) - Limerinos

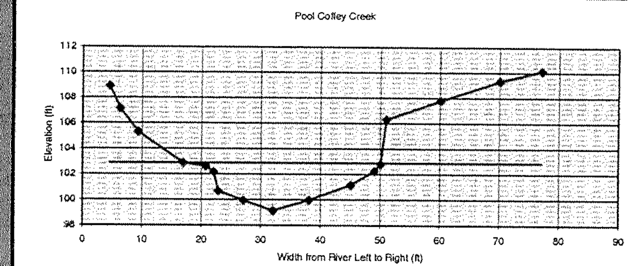
3.6551833	R/D84 (ft/ft)	6.0385822	u/u*
0.048	Manning's n from channel materia		

u/u* = friction factor

check from Shear Velocity

4.66091	u - velocity
0.048	Manning's n from Shear Velocit

Cross Section



section:	
	Pool
	Coffey Creek
	Catawba
description:	X-2 @ Sta. 2+20
height of instrument (ft):	115.56

notes	omit pt.	distance (ft)	FS (ft)	elevation
	■	4.5	6.64	108.92
	■	6.3	8.45	107.11
	■	9.3	10.26	105.3
	■	16.9	12.69	102.87
	■	20.8	12.95	102.61
	■	22	13.42	102.14
	■	22.8	14.9	100.66
	■	27	15.63	99.93
	■	32	16.44	99.12
	■	38	15.61	99.95
	■	45	14.43	101.13
	■	49	13.34	102.22
	■	50	12.77	102.79
	■	51	9.27	106.29
	■	60	7.82	107.74
	■	70	6.24	109.32
	■	77	5.47	110.09

FS bankfull	FS top of bank		channel slope (%)	
12.69	9.27		1.09	
102.87	106.29			

dimensions

71.4	x-section area	2.2	d mean
33.1	width	34.7	wet P
3.8	d max	2.1	hyd radi
7.2	bank ht		

hydraulics

1.40	shear stress ((lbs/ft sq)
0.85	shear velocity (ft/sec)
~~139.2~~	threshold grain size (mm)

Reference Reach — Hints

Stream	Coffey Creek
Watershed	Catawba
Location	Charlotte, NC
Latitude	---
Longitude	---
County	Mecklenburg, County
Date	May 9, 2002
Observers	JK,SDC
Channel Type	B4c
Drainage Area (sq mi)	4.04

Channel Materials

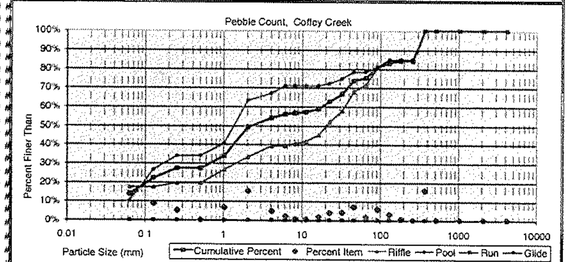
	total	riffle	pool	run	glide	bar sample
D16	0.076	#N/A	0.080	0.000	0.000	---
D35	1.05	2.45	0.55	0.00	0.00	---
D50	2.3	20.3	1.3	0.0	0.0	---
D84	142	257	119	0	0	---
D95	324	325	323	0	0	---
Largest of Bar Sample						
% Silt/Clay	11%	15%	8%	---	---	---
% Sand	29%	14%	42%	---	---	---
% Gravel	21%	33%	12%	---	---	---
% Cobble	8%	11%	5%	---	---	---
% Boulder	13%	14%	12%	---	---	---
% Bedrock	17%	13%	21%	---	---	---

Weighted Pebble Count

Percent Riffle: 45 — Percent Run:
Percent Pool: 55 — Percent Glide:

Pebble Count,
Coffey Creek
Catawba
Charlotte, NC
Note:

Material	Size Range (mm)		Total #
silt/clay	0	0.062	11.2
very fine sand	0.062	0.13	7.2
fine sand	0.13	0.25	4.2
medium sand	0.25	0.5	0.0
coarse sand	0.5	1	5.5
very coarse sand	1	2	12.6
very fine gravel	2	4	3.9
fine gravel	4	6	1.7
fine gravel	6	8	0.5
medium gravel	8	11	0.5
medium gravel	11	16	1.4
coarse gravel	16	22	3.3
coarse gravel	22	32	3.4
very coarse gravel	32	45	5.7
very coarse gravel	45	64	1.4
small cobble	64	90	4.7
medium cobble	90	128	2.6
large cobble	128	180	0.5
very large cobble	180	256	0.0
small boulder	256	362	12.9
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			17.4
		Weighted Count:	100
		True Total Particle Count:	200

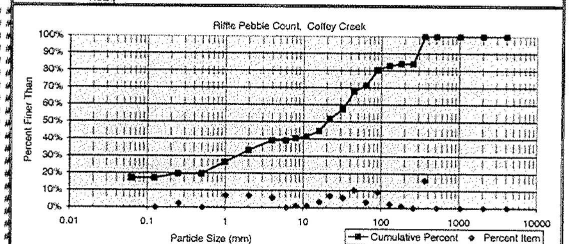


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.076	1.05	2.3	142	324	11%	29%	21%	8%	13%	17%

Riffle Pebble Count

Riffle Pebble Count,
Coffey Creek
Catawba
Charlotte, NC
Note:

Material	Size Range (mm)		Count
silt/clay	0	0.062	15
very fine sand	0.062	0.13	0
fine sand	0.13	0.25	2
medium sand	0.25	0.5	0
coarse sand	0.5	1	6
very coarse sand	1	2	6
very fine gravel	2	4	5
fine gravel	4	6	0
fine gravel	6	8	1
medium gravel	8	11	1
medium gravel	11	16	3
coarse gravel	16	22	6
coarse gravel	22	32	5
very coarse gravel	32	45	9
very coarse gravel	45	64	3
small cobble	64	90	8
medium cobble	90	128	2
large cobble	128	180	1
very large cobble	180	256	0
small boulder	256	362	14
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			13
		Total Particle Count:	100

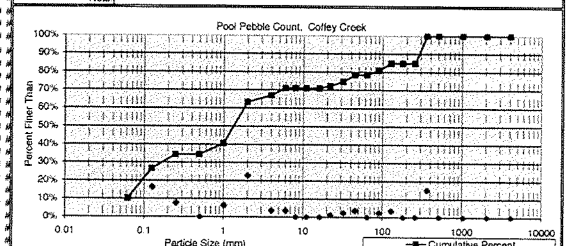


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	2.45	20.3	257	325	15%	14%	33%	11%	14%	13%

Pool Pebble Count

Pool Pebble Count,
Coffey Creek
Catawba
Charlotte, NC
Note:

Material	Size Range (mm)		Count
silt/clay	0	0.062	8
very fine sand	0.062	0.13	13
fine sand	0.13	0.25	6
medium sand	0.25	0.5	0
coarse sand	0.5	1	5
very coarse sand	1	2	18
very fine gravel	2	4	3
fine gravel	4	6	3
fine gravel	6	8	0
medium gravel	8	11	0
medium gravel	11	16	0
coarse gravel	16	22	1
coarse gravel	22	32	2
very coarse gravel	32	45	3
very coarse gravel	45	64	0
small cobble	64	90	2
medium cobble	90	128	3
large cobble	128	180	0
very large cobble	180	256	0
small boulder	256	362	12
small boulder	362	512	0
medium boulder	512	1024	0
large boulder	1024	2048	0
very large boulder	2048	4096	0
bedrock			21
		Total Particle Count:	100

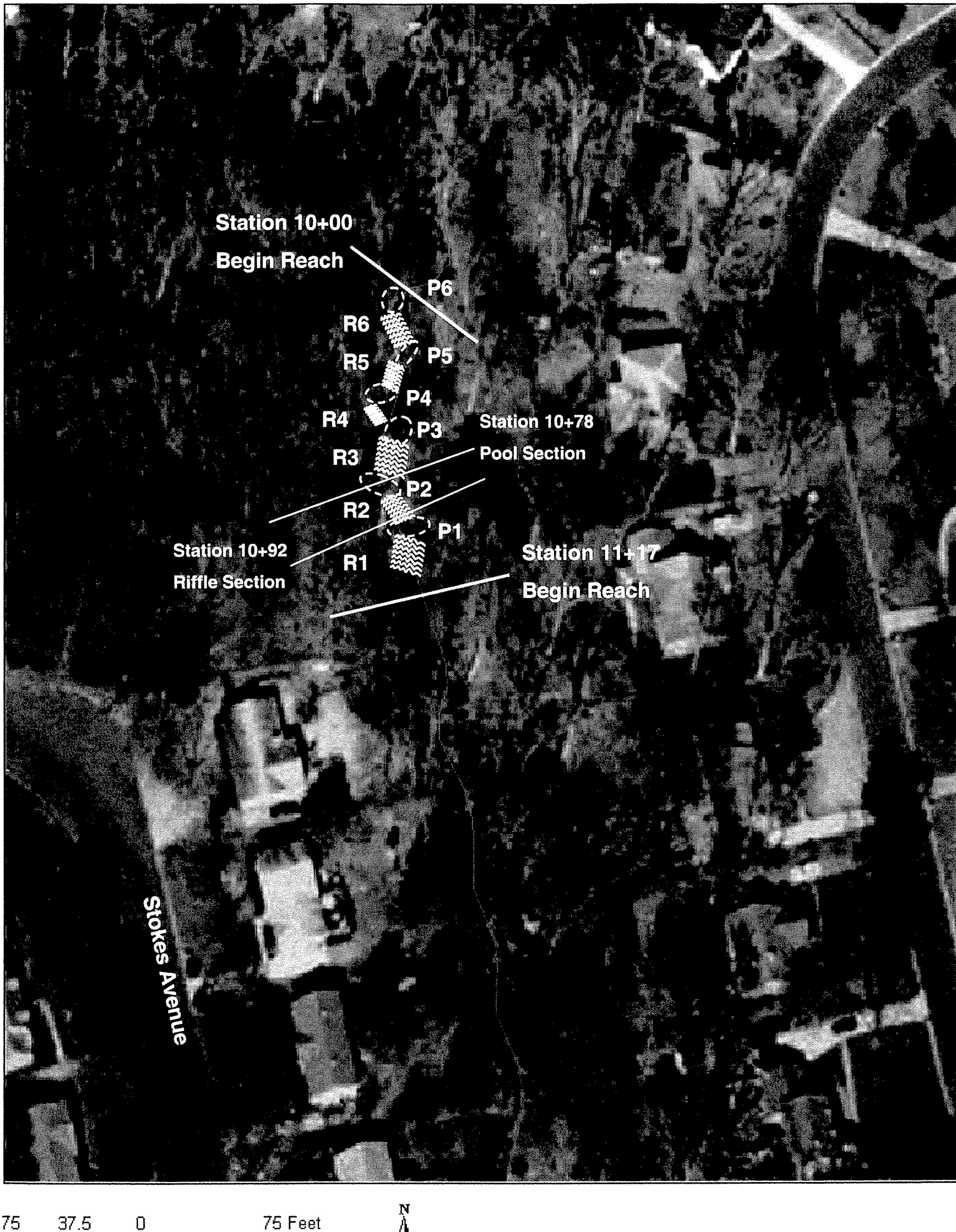


Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.080	0.55	1.3	119	323	8%	42%	12%	5%	12%	21%

Run Pebble Count

Run Pebble Count,

APPENDIX E



CH2MHILL

UT - Park South Drive Reference Reach Sketch
Cato Farms Stream Restoration Project

Reference Reach

Hints

Stream:	Reference E
Watershed:	
Location:	Off of Park South Drive
Latitude:	
Longitude:	
County:	Mecklenburg
Date:	May 23, 2002
Observers:	SDC, VLJ
Channel Type:	E5
Drainage Area (sq mi):	0.16
Notes:	Field Book 010 page 84-97

Dimension

		typical	min	max
Size:	x-area bankfull	6.7	---	---
	width bankful	5.9	---	---
	mean depth	1.1	---	---
Ratios:	Width/Depth Ratio	5.2	---	---
	Entrenchment Ratio	4.9	---	---
	Riffle Max Depth Ratio	1.3	---	---
	Pool Area Ratio	1.4	---	---
	Pool Width Ratio	0.9	---	---
	Pool Max Depth Ratio	2.1	---	---
	Bank Height Ratio	1.8		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	---	---	---
	Glide Width Ratio	---	---	---
	Glide Max Depth Ratio	---	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	47.4	47.4	47.4
velocity (ft/sec)	7.1	5.2	---
shear stress @ max depth (lbs/ft sq)	1.14	1.79	---
shear stress (lbs/ft sq)	0.70	0.84	---
shear velocity (ft/sec)	0.60	0.66	---
unit stream power (lbs/ft/sec)	6.133	6.133	6.13
relative roughness	41.6	62.9	---
friction factor u/u*	11.7	7.9	---
threshold grain size @ max depth (mm)	94.2	225.2	---
threshold grain size (mm)	45	52	---

Pattern

	typical	min	max
Sinuosity	1.4		
Meander Width Ratio	6.1	---	---
Amplitude Ratio	3.2	1.9	5.2
Meander Length Ratio	8.8	7.4	10.3
Straight Length Ratio	---	---	---
Radius Ratio	2.6	1.9	4.0
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	1.230	0.0	2.6
measured valley slope (%)	2.220	---	---
valley slope (%)	1.714		
Riffle Slope Ratio	2.7	-0.1	4.0
Pool Slope Ratio	-0.5	-2.4	1.7
Run Slope Ratio	2.5	1.1	4.6
Glide Slope Ratio	4.1	1.6	6.5
Pool Spacing Ratio	3.4	2.4	4.5

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	0.169	0.287	0.130	0.0	0.0	---
D35	0.50	1.12	0.28	0	0	---
D50	0.8	1.6	0.5	0	0	---
D84	8.3	9	3	0	0	---
D95	19.9	27	18	0	0	---
Largest Bar						0
% Silt/Clay	0%	0%	0%	---	---	---
% Sand	71%	60%	83%	---	---	---
% Gravel	29%	40%	18%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	

Reference Reach

Hints

Stream:	Reference E
Watershed:	---
Location:	Off of Park South Drive
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	May 23, 2002
Observers:	SDC, VLJ
Channel Type:	E5
Drainage Area (sq mi):	0.16

Pattern

	typical	min	max
bankfull width (ft)	5.935294		
meander length (ft)	52.5	44	61
belt width (ft)	36		
amplitude (ft)	19	11	31
radius (ft)	15.48	11.1	23.5
arc angle (degrees)			
straight length (ft)			
stream length	255		
valley length	183		
Sinuosity	1.39		
Meander Width Ratio	6.1	---	---
Amplitude Ratio	3.2	1.9	5.2
Meander Length Ratio	8.8	7.4	10.3
Straight Length Ratio	---	---	---
Radius Ratio	2.6	1.9	4.0

Profile

	typical	min	max
bankfull width (ft)	5.935294		
pool-pool spacing (ft)	20	14	27
riffle length (ft)	6.67	3	10
pool length (ft)	10.8	8	14
run length (ft)	4.33	3	5
glide length (ft)	2.5	2	3
channel slope (%)	1.23	0.048	2.58
riffle slope (%)	3.34	-0.125	4.88
pool slope (%)	-0.621	-3	2.12
run slope (%)	3.09	1.4	5.67
glide slope (%)	5	2	8
measured valley slope (%)	2.22		
valley slope (%)	1.7		
Riffle Length Ratio	1.1	0.5	1.7
Pool Length Ratio	1.8	1.3	2.4
Run Length Ratio	0.7	0.5	0.8
Glide Length Ratio	0.4	0.3	0.5
Riffle Slope Ratio	2.7	-0.1	4.0
Pool Slope Ratio	-0.5	-2.4	1.7
Run Slope Ratio	2.5	1.1	4.6
Glide Slope Ratio	4.1	1.6	6.5
Pool Spacing Ratio	3.4	2.4	4.5

Slope Calculator

Hints

	station	elevation	% slope	note
point 1	117	97.18		
point 2	94	96.97	-0.913	Bed
point 1	94	96.97		
point 2	75	96.48	-2.579	Bed
point 1	75	96.48		
point 2	54	96.47	-0.048	Bed
point 1	54	96.47		
point 2	32	96.2	-1.227	Bed
point 1	32	96.2		
point 2	13	95.94	-1.368	Bed
point 1				
point 2			---	
point 1				
point 2			---	

Avg Bed 1.227061

Radius Calculator

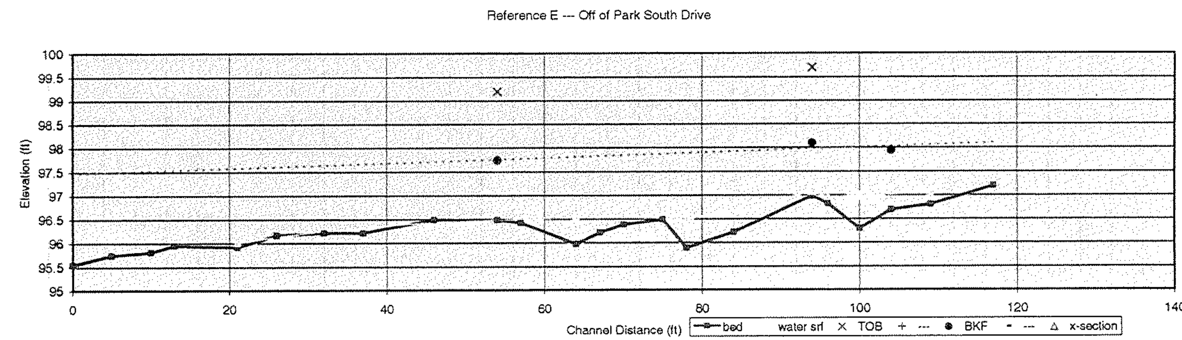
Hints

Reference E

Off of Park South Drive

cord	20	32	20	46	17
mid ord	16.9	26.5	22	18.5	18.3
outside bank radius	11.4	18.1	13.3	23.5	11.1

Slope Profile



100 :Elevation BM

notes	cross section	distance	station	BS	HI	FS TP	FS bed	depth water	FS BKF	FS TOB
				5.75	105.75					
			0		105.75					
p6 mid		0	0		105.75		10.22			
p6 beg		5	5		105.75		10.02			
r6 end		5	10		105.75		9.95			
p5 end / r6 beg		3	13		105.75		9.81			
p5 mid		8	21		105.75		9.84	0.1		
R5 end/P5beg		5	26		105.75		9.6			
p4 end / R5 beg		6	32		105.75		9.55			
p4 mid		5	37		105.75		9.55	0.15		
r4 end/ p4 beg		9	46		105.75		9.27			
r4 beg		8	54		105.75		9.28		8.01	6.56
p3 end		3	57		105.75		9.34			
p3 mid		7	64		105.75		9.79	0.58		
p3 beg		3	67		105.75		9.55	0.39		
r3 end		3	70		105.75		9.38			
p2 end / r3 beg		5	75		105.75		9.27			
P2 mid		3	78		105.75		9.87	0.6		
r2 end / p2 beg		6	84		105.75		9.54			
r2 beg		10	94		105.75		8.78	0.1	7.65	6.06
p1 end		2	96		105.75		8.94	0.15		
p1 mid		4	100		105.75		9.47	0.72		
p1 beg		4	104		105.75		9.07		7.81	
R1 end		5	109		105.75		8.96	0.24		
R1 beg		8	117		105.75		8.57			
			0		105.75					
			0		105.75					
			0		105.75					
			0		105.75					
			0		105.75					
			0		105.75					
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			0		105.75					
			0		105.75					

notes	FS	FS	AZ azimuth	ELEV bed	ELEV water srf	ELEV BKF	ELEV TOB	ELEV ---	ELEV ---
p6 mid				95.53					
p6 beg				95.73					
r6 end				95.8					
p5 end / r6 beg				95.94					
p5 mid				95.91	96.01				
R5 end/P5beg				96.15					
p4 end / R5 beg				96.2					
p4 mid				96.2	96.35				
r4 end/ p4 beg				96.48					
r4 beg				96.47		97.74	99.19		
p3 end				96.41					
p3 mid				95.96	96.54				
p3 beg				96.2	96.59				
r3 end				96.37					
p2 end / r3 beg				96.48					
P2 mid				95.88	96.48				
r2 end / p2 beg				96.21					
r2 beg				96.97	97.07	98.1	99.69		
p1 end				96.81	96.96				
p1 mid				96.28	97				
p1 beg				96.68		97.94			
R1 end				96.79	97.03				
R1 beg				97.18					

Reference Reach

Hints

Stream:	Reference E
Watershed:	---
Location:	Off of Park South Drive
Latitude:	---
Longitude:	---
County:	Mecklenburg
Date:	May 23, 2002
Observers:	SDC, VLJ
Channel Type:	E5
Drainage Area (sq mi):	0.16

Dimension

		typical	min	max
Riffle:	x-area bankfull	6.7		
	width bankfull	5.9		
	hydraulic radius	0.9		
	max depth	1.5		
	bank ht	2.7		
	width flood prone area	29.0		
	mean depth	1.13		
Pool:	x-area pool	9.1		
	width pool	5.3		
	hydraulic radius	1.1		
	max depth pool	2.3		
	bank ht	2.8		
Run:	x-area run			
	width run			
	hydraulic radius			
	max depth run			
	bank ht			
Glide:	x-area glide			
	width glide			
	max depth glide			

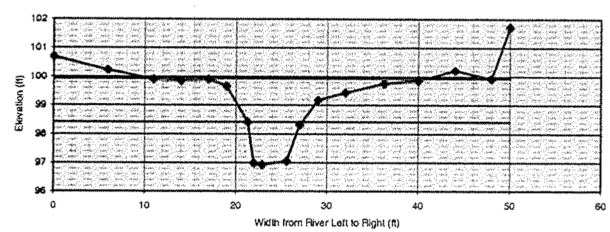
Dimensionless Ratios:

	typical	min	max
Width/Depth Ratio	5.2		
Entrenchment Ratio	4.9		
Riffle Max Depth Ratio	1.3	---	---
Pool Area Ratio	1.4	---	---
Pool Width Ratio	0.9	---	---
Pool Max Depth Ratio	2.1	---	---
Bank Height Ratio	1.8		
Run Area Ratio	---	---	---
Run Width Ratio	---	---	---
Run Max Depth Ratio	---	---	---
Glide Area Ratio	---	---	---
Glide Width Ratio	---	---	---
Glide Max Depth Ratio	---	---	---

Hydraulics:

	riffle	pool	run
channel slope (%)	1.230		
discharge rate, Q (cfs)	47.4		
velocity (ft/sec)	7.1	5.2	---
shear stress @ max depth (lbs/ft sq)	1.144	1.788	---
shear stress (lbs/ft sq)	0.702	0.840	---
shear velocity (ft/sec)	0.602	0.658	---
stream power (lbs/sec)	36.4	36.4	36.4
unit stream power (lbs/ft/sec)	6.133	6.133	6.133
relative roughness	41.6	62.9	---
friction factor u/u*	11.7	7.9	---
threshold grain size @ max depth (mm)	94	226	---
threshold grain size (mm)	44.7	51.5	---

Cross Section



section: Riffle
Reference E
---

description: X-R1, Sta. 0+92.5 long. Profile

height of instrument (ft): 105.75

notes	omit pt.	distance (ft)	FS (ft)	elevation
		0	5.05	100.7
		6	5.52	100.23
		11	5.86	99.89
		14	5.91	99.84
		17	5.85	99.9
TOB		19	6.09	99.66
BKF		21.3	7.33	98.42
Toe		22	8.76	96.99
Thalweg		22.9	8.82	96.93
Toe		25.6	8.7	97.05
Bkf		27	7.43	98.32
TOB		29	6.58	99.17
		32	6.31	99.44
		38.3	6	99.75
		40	5.9	99.85
		44	5.54	100.21
		48	5.83	99.92
		50	4.04	101.71

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.33	6.09	29.0	1.23	0.022
98.42	99.66			

dimensions			
6.7	x-section area	1.1	d mean
5.9	width	7.3	wet P
1.5	d max	0.9	hyd radi
2.7	bank ht	5.2	w/d ratio
29.0	W flood prone area	4.9	ent ratio

hydraulics	
7.1	velocity (ft/sec)
47.4	discharge rate, Q (cfs)
0.70	shear stress ((lbs/ft sq)
0.60	shear velocity (ft/sec)
6.133	unit stream power (lbs/ft/sec)
1.37	Froude number
11.7	friction factor u/u*
44.7	threshold grain size (mm)

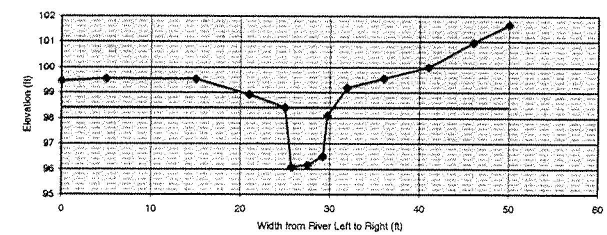
check from channel material			
8	measured D84 (mm)		
41.6	relative roughness	12.1	fric. factor
0.021	Manning's n from channel material		

check from channel material (R/D84) - Limerinos			
33.604116	R/D84 (ft/ft)	11.530437	u/u*
0.022	Manning's n from channel materia		

u/u* = friction factor

check from Shear Velocity	
6.9368234	u - velocity
0.022	Manning's n from Shear Velocit

Cross Section



section: Pool
Reference E
---

description: X-P1, Sta. 0+78 long. Profile

height of instrument (ft): 105.75

notes	omit pt.	distance (ft)	FS (ft)	elevation
		0	6.3	99.45
		5	6.22	99.53
		15	6.23	99.52
TOB		21	6.84	98.91
bkf		25	7.35	98.4
Toe		25.7	9.68	96.07
		27.5	9.6	96.15
Toe		29.2	9.26	96.49
bkf		29.7	7.66	98.09
tob		31.9	6.57	99.18
		36	6.2	99.55
		41	5.75	100
		46	4.79	100.96
		50	4.1	101.65

FS bankfull	FS top of bank		channel slope (%)	
7.35	6.84		1.15	
98.4	98.91			

dimensions			
9.1	x-section area	1.7	d mean
5.3	width	8.3	wet P
2.3	d max	1.1	hyd radi
2.8	bank ht		

hydraulics	
0.78	shear stress ((lbs/ft sq)
0.64	shear velocity (ft/sec)
50.6	threshold grain size (mm)

Reference Reach						Hints
Stream:	Reference E					
Watershed:	---					
Location:	Off of Park South Drive					
Latitude:	---					
Longitude:	---					
County:	Mecklenburg					
Date:	May 23, 2002					
Observers:	SDC, VLJ					
Channel Type:	E5					
Drainage Area (sq mi):	0.16					

Channel Materials	total	riffle	pool	run	glide	bar sample
D16	0.169	0.287	0.130	0.000	0.000	---
D35	0.50	1.12	0.28	0.00	0.00	---
D50	0.8	1.6	0.5	0.0	0.0	---
D84	8	9	3	0	0	---
D95	20	27	18	0	0	---
Largest of Bar Sample						
% Silt/Clay	0%	0%	0%	---	---	---
% Sand	71%	60%	83%	---	---	---
% Gravel	29%	40%	18%	---	---	---
% Cobble	0%	0%	0%	---	---	---
% Boulder	0%	0%	0%	---	---	---
% Bedrock	0%	0%	0%	---	---	---

Weighted Pebble Count

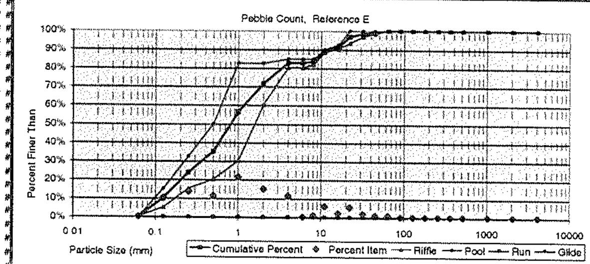
Percent Riffle:	50	Percent Run:	
Percent Pool:	50	Percent Glide:	

Material	Size Range (mm)		Total #
silt/clay	0	0.062	0.0
very fine sand	0.062	0.13	10.0
fine sand	0.13	0.25	13.8
medium sand	0.25	0.5	11.3
coarse sand	0.5	1	21.3
very coarse sand	1	2	15.0
very fine gravel	2	4	11.3
fine gravel	4	6	0.0
fine gravel	6	8	0.8
medium gravel	8	11	5.8
medium gravel	11	16	2.1
coarse gravel	16	22	5.4
coarse gravel	22	32	1.7
very coarse gravel	32	45	0.8
very coarse gravel	45	64	0.8
small cobble	64	90	0.0
medium cobble	90	128	0.0
large cobble	128	180	0.0
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			0.0
		Weighted Count:	100
		True Total Particle Count:	100

Pebble Count

	Reference E

	Off of Park South Drive
Note:	



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.169	0.50	0.8	8	20	0%	71%	29%	0%	0%	0%

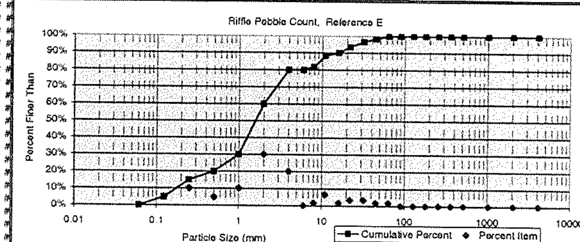
Riffle Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	0
very fine sand	0.062	0.13	3
fine sand	0.13	0.25	6
medium sand	0.25	0.5	3
coarse sand	0.5	1	6
very coarse sand	1	2	18
very fine gravel	2	4	12
fine gravel	4	6	0
fine gravel	6	8	1
medium gravel	8	11	4
medium gravel	11	16	1
coarse gravel	16	22	2
coarse gravel	22	32	2
very coarse gravel	32	45	1
very coarse gravel	45	64	1
small cobble	64	90	0
medium cobble	90	128	0
large cobble	128	180	0
very large cobble	180	256	0
small boulder	256	362	0
small boulder	362	512	0
medium boulder	512	1024	0
large boulder	1024	2048	0
very large boulder	2048	4096	0
bedrock			0
		Total Particle Count:	60

Riffle Pebble Count,

	Reference E

	Off of Park South Drive
Note:	



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.287	1.12	1.6	9	27	0%	60%	40%	0%	0%	0%

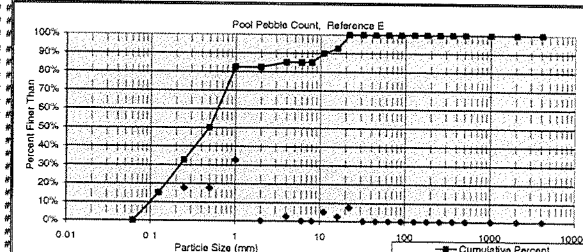
Pool Pebble Count

Material	Size Range (mm)		Count
silt/clay	0	0.062	0
very fine sand	0.062	0.13	6
fine sand	0.13	0.25	7
medium sand	0.25	0.5	7
coarse sand	0.5	1	13
very coarse sand	1	2	0
very fine gravel	2	4	1
fine gravel	4	6	0
fine gravel	6	8	0
medium gravel	8	11	2
medium gravel	11	16	1
coarse gravel	16	22	3
coarse gravel	22	32	
very coarse gravel	32	45	
very coarse gravel	45	64	
small cobble	64	90	
medium cobble	90	128	
large cobble	128	180	
very large cobble	180	256	
small boulder	256	362	
small boulder	362	512	
medium boulder	512	1024	
large boulder	1024	2048	
very large boulder	2048	4096	
bedrock			
		Total Particle Count:	40

Pool Pebble Count,

	Reference E

	Off of Park South Drive
Note:	



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.130	0.28	0.5	3	18	0%	83%	18%	0%	0%	0%

APPENDIX F

Reference Reach

Hints

Stream:	Cato Farms Trib to Clark Creek
Watershed:	Clark Creek
Location:	Near Huntersville, NC
Latitude:	
Longitude:	
County:	Mecklenburg
Date:	April 18, 2002
Observers:	Paige Baker, Sean Collins, Phil Sacco
Two Largest Particles:	(1) 18mm / 15g , (2) 19mm / 11g
Drainage Area (sq mi):	0.41
Notes:	This data for is the Shear Stress and Sediment Entrainment Analysis

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	---	---	---	---	---	0.2
D35	---	---	---	---	---	1
D50	---	---	---	---	---	1
D84	---	---	---	---	---	3
D95	---	---	---	---	---	4
Largest Bar						0
% Silt/Clay	---	---	---	---	---	13%
% Sand	---	---	---	---	---	65%
% Gravel	---	---	---	---	---	22%
% Cobble	---	---	---	---	---	---
% Boulder	---	---	---	---	---	---
% Bedrock	---	---	---	---	---	

Reference Reach

Reference Reach		Hints
Stream:	Cato Farms Trib to Clark Creek	
Watershed:	Clark Creek	
Location:	Near Huntersville, NC	
Latitude:	---	
Longitude:	---	
County:	Mecklenburg	
Date:	April 18, 2002	
Observers:	Paige Baker, Sean Collins, Phil Sacco	
Channel Type:	(1) 18mm / 15g , (2) 19mm / 11g	
Drainage Area (sq mi):	0.41	

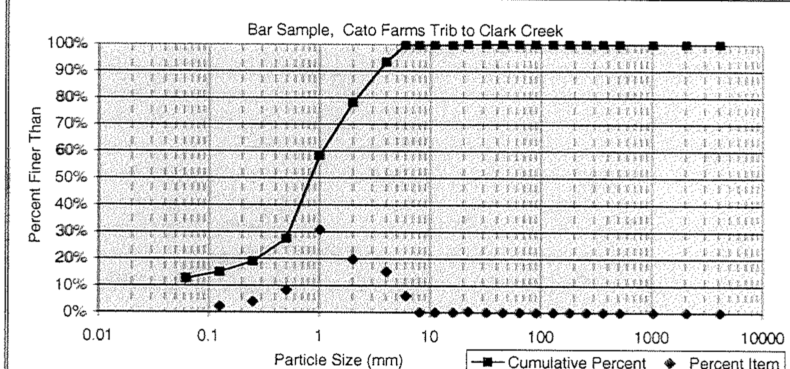
Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	0.000	---	---	---	---	0.150
D35	0.00	---	---	---	---	0.59
D50	0.0	---	---	---	---	0.8
D84	0	---	---	---	---	3
D95	0	---	---	---	---	4
Largest of Bar Sample						
% Silt/Clay	---	---	---	---	---	13%
% Sand	---	---	---	---	---	65%
% Gravel	---	---	---	---	---	22%
% Cobble	---	---	---	---	---	---
% Boulder	---	---	---	---	---	---
% Bedrock	---	---	---	---	---	

Bar Sample

Material	Size Range (mm)		Weight		
silt/clay	0	0.062	1004	13%	13%
very fine sand	0.062	0.13	175	2%	15%
fine sand	0.13	0.25	315	4%	19%
medium sand	0.25	0.5	670	8%	27%
coarse sand	0.5	1	2429	31%	58%
very coarse sand	1	2	1567	20%	78%
very fine gravel	2	4	1204	15%	93%
fine gravel	4	6	500	6%	100%
fine gravel	6	8		0%	100%
medium gravel	8	11		0%	100%
medium gravel	11	16		0%	100%
coarse gravel	16	22	26	0%	100%
coarse gravel	22	32		0%	100%
very coarse gravel	32	45		0%	100%
very coarse gravel	45	64		0%	100%
small cobble	64	90		0%	100%
medium cobble	90	128		0%	100%
large cobble	128	180		0%	100%
very large cobble	180	256		0%	100%
small boulder	256	362		0%	100%
small boulder	362	512		0%	100%
medium boulder	512	1024		0%	100%
large boulder	1024	2048		0%	100%
very large boulder	2048	4096		0%	100%
	Total Particle Weight:		7890		

Bar Sample,	
	Cato Farms Trib to Clark Creek
	Clark Creek
	Near Huntersville, NC
Note:	



Size percent less than (mm)					Percent by substrate type				
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder
0.150	0.59	0.8	3	4	13%	65%	22%	0%	0%

#1	#2	D100
18	19	22

Step 1. Field Data Collection

Step 2. **Particle Size - Class Indices**

D16	D35	D50	D84	D95	D100	#1	#2	silt/clay	sand	gravel	cobble	boulder
0.15	0.59	0.83	2.62	4.45	22.00	18.00	19.00	13%	65%	22%	0%	0%

Step 3. **Average Bankfull Slope**

BM	90.29							# Records	3
Notes	Sta	BS	HI	FS	Depth	Bed El	WSE	PT to PT Slope	Avg Slope (ft/ft)
		2.93	93.22						
Mid Riffle	2.5		93.22	13.68	0.03	79.54	79.57		
Mid Riffle	19.9		93.22	14.07	0.08	79.15	79.23	0.022	
Mid Riffle	43.2		93.22	14.53	0.17	78.69	78.86	0.020	
Mid Riffle	81.2		93.22	14.81	0.04	78.41	78.45	0.007	
									0.0165

Step 4. **Critical Dimensionless Shear Stress**

Stress required to mobilize and transport the largest particle from the bar sample

Step A) Calculate the ratio D50/D50^

Where:
- D50 = median diameter of the riffle bed (from the 100 count pebble count in the riffle or pavement sample)
- D50^ = median diameter of the bar sample (or subpavement sample)

D50 =	2.70	mm	ratio =	3.25
D50^ =	0.83	mm		

the ratio D50 / D50^ is between the values of 3.0 and 7.0 then calculate the critical dimensionless sheer stress using Equation 1

~~Tci = 0.0834 (D50 / D50^)~~ ^ -0.872 — Equation 1

Tci = 0.030

Step B) If the ration of D50 /D50^ is not between the values of 3.0 and 7.0 then calculate the ratio of Di / D50

Where:
- Di = Largest particle from the bar sample (or subpavement sample)
- D50 = median diameter of the riffle bed (from the 100 count pebble count in the riffle or pavement sample)

Di =	18.00	mm	Largest	or	Di =	22.00	mm	D100
D50 =	1.20	mm	ratio =	15.0	Largest	18.3	D100	

the ratio of Di / D50 is between the value of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

Tci = 0.0384 (Di/D50)^ -0.887 — Equation 2

Tci =	N/A	Largest	Tci =	N/A	D100

Step 5. **Entrainment**

Calculate the min. mean bankfull depth required for entrainment of the largest particle in the bar sample (or subpavement sample) and the bankfull water surface slope required for entrainment of the largest particle

Step A) **dr= (1.65*(Tci)*Di) / Se** — **Equation 3**

Step B) **Sr= (1.65 *(Tci) * Di) / de** — **Equation 4**

Where:
- dr (ft) = Required bankfull mean depth
- de (ft) = Existing bankfull mean depth
- 1.65 = Sediment density (submerged specific weight) = Density of sediment (2.65) - density of water (1.00)
- Tci = Critical Dimensionless Shear Stress
- Di (ft) = Largest particle from bar sample (or subpavement sample
- Sr (ft/ft) = Required bankfull water surface slope
- Se (ft/ft) = Existing bankfull water surface slope

Di (ft) =	0.0591	ft
Tci =	0.030	
Se =	0.0165	ft/ft
dr =	**0.176207**	**ft**
de (ft) =	1.6	**ft**
Sr =	**0.001818**	**ft/ft**

Step 6.	Check - Calculate bankfull shear stress							
	T=yRS						Equation 5	
	Where:	T =	Bankfull shear stress, lbs/ft^2					
		y=	specific weight of water = 62.4 lbs/ ft^3					
		R =	Hydraulic radius of riffle cross section, ft					
		S =	Average water surface slope ft/ft					
		y=	62.4	lbs/ft^3				
		R =	1.3	ft				
		S =	0.0165	ft/ft				
		T =	**1.34**	**lbs/ft^2**				

Step 7. Largest Particle = 18.00 mm
Shields curve (T) shear stress to move largest particle = 0.32 lbs/sqft.
Refer to RED book page 190 for Shields curve to confirm that slope will provide shear stress great enough to move largest Particle

Existing

Reach 1		
Design	E	
y=	62.4	lbs/ft^3
R =	0.748	ft
S =	0.0069	ft/ft
T =	**0.320**	**lbs/ft^2**

Min. Shear Stress Required to Maintain Sedement Transport

Proposed

Reach 1		
Design	E	
y=	62.4	lbs/ft^3
R =	0.748	ft
S =	0.00714	ft/ft
T =	**0.333**	**lbs/ft^2**

Calculated Shear Stress based on Proposed Channel Dimensions

Existing

Reach 2		
Design	B	
y=	62.4	lbs/ft^3
R =	1.33	ft
S =	0.0039	ft/ft
T =	**0.320**	**lbs/ft^2**

Min. Shear Stress Required to Maintain Sedement Transport

Proposed

Reach 2		
Design	B	
y=	62.4	lbs/ft^3
R =	1.33	ft
S =	0.01096	ft/ft
T =	**0.910**	**lbs/ft^2**

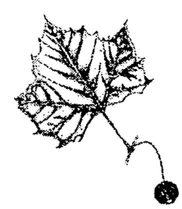
Calculated Shear Stress based on Proposed Channel Dimensions

APPENDIX G

Guidelines for Riparian Buffer Restoration

Department of Environment and Natural Resources
Division of Water Quality
Wetlands Restoration Program
Raleigh, NC
January 2001





Purpose of these Guidelines

Riparian buffers have been identified as a valuable tool for protection of water quality when properly designed and established in the appropriate landscape setting. For this reason, the goal of the North Carolina Wetlands Restoration Program (NCWRP) is to implement projects to restore riparian buffers that have the greatest value for reducing pollutants in our surface waters as well as provide important aquatic and wildlife habitat. The purpose of these guidelines is to provide the technical information necessary for the successful planning and establishment of riparian buffers. The guidelines are intended for use by private consultants in developing restoration plans for the NCWRP but should also have utility for private landowners as well as local governments involved in the restoration of riparian buffers.

Criteria for Priority Riparian Buffer Restoration Projects

A number of factors determine the success of particular riparian buffer restoration projects. In addition to the physical characteristics of the site, issues such as land costs, land ownership, and logistical constraints must be taken into consideration. The following physical characteristics are intended to provide general guidance when identifying sites and are not intended to exclude sites that may have merit based on other criteria.

- Woody vegetation absent or sparse (less than 100 stems per acre that are $\geq$ 5 inches diameter at breast height) measured within 50 feet of intermittent and perennial streams, lakes, ponds, and shorelines.
- Adjacent to headwater streams or those streams defined as first, second, or third order.
- Project length greater than 1,000 feet (for projects implemented by the NCWRP).
- Ditches, gullies, or evidence of concentrated flow within 50 feet of intermittent and perennial streams, lakes, ponds, and estuaries.
- Adjacent source of nitrogen including cropland, pasture, golf course, residential development, ball fields, etc.
- Water table depth within three to four feet of surface as determined by characteristics of soil cores.

Components of a Riparian Buffer Restoration/Enhancement Plan

Site Assessment

The riparian area to be restored should be evaluated with respect to these factors that control the viability of riparian plants:

- Soil moisture
- Soil pH
- Soil texture
- Seasonal high water table depth
- Flooding potential
- Aspect, topography, and microtopographic relief

Site Preparation

The restoration/enhancement plan should address these items regarding preparation of the site for planting:

- Plow or rip site to improve compacted soil and/or eliminate areas where channelized flow has developed.
- Control of sod-forming grasses such as fescue and Kentucky bluegrass that will compete with plantings for nutrients.
- Control of invasive, exotic plants that would hinder the re-establishment of woody vegetation. Proposals for pesticide use should always be reviewed by the North Carolina Division of Water Quality staff to insure compliance with the Neuse and Tar-Pamlico Riparian Buffer Rules.

Common Invasive Exotic Plants in North Carolina

Ailanthus altissima (Tree-of-Heaven)
Albizia julibrissin (Mimosa)
Elaeagnus umbellata (Autumn Olive)
Hedera helix (English Ivy)
Lespedeza cuneata (Korean or Sericea Lespedeza)
Ligustrum sinense (Chinese Privet)
Lonisera japonica (Japanese Honeysuckle)
Microstegium vimineum (Japanese Grass)
Paulownia tomentosa (Princess Tree)
Pueraria lobata (Kudzu)
Rosa multiflora (Multiflora Rose)
Wisteria sinensis (Chinese Wisteria)

- Stabilize areas of bare soil. Refer to the following list for species of grasses/sedge appropriate for soil stabilization. The majority of these species are by necessity not native to North Carolina. At present, there are only a few species of native grasses useful for erosion control that are commercially available. Please note that fescue grasses should not be used for soil stabilization. Fescue grasses, particularly tall fescue, are competitive and will inhibit the eventual re-establishment of native species.

Agrostis alba (Redtop)

Found in fields, pastures, roadsides, and other disturbed places throughout North Carolina, this native warm season grass should be used sparingly for erosion control and soil stabilization.

Carex stricta (Sedge)

This sedge occurs naturally in marshes and low meadows throughout the mountains and northern piedmont and coastal plain of North Carolina. This species has utility in a mix for soil stabilization in moist areas.

Dactylis glomerata (Orchardgrass)

This perennial, cool season bunchgrass is a good alternative to fescue because it is less competitive and allows native herbs to colonize the site.

Hordeum spp. (Barley)

A number of species of barley can be used for soil stabilization. Barley is a cool season, annual grass that when moisture is available will germinate in the fall, stay green during the winter, and then die in the spring as competition for warm season plants increases.

Panicum clandestinum (Deer Tongue)

This native, perennial, warm season bunchgrass can be used in moist low woods primarily in the piedmont and mountains.

Panicum spp. (Panic Grasses)

A number of species of panic grasses can be used for soil stabilization depending on the moisture regime and soils of the site.

Panicum virgatum (Switchgrass)

This native, perennial, warm season bunchgrass can tolerate a wide range of moisture regimes. It can be used along streams, in wet or dry woods, brackish and freshwater marshes, sloughs, swales, and low pinelands primarily in the eastern piedmont and coastal plain.

Pennisetum glaucum (Brown Top or Pearl Millet)

This fast-growing, robust, annual grass exhibits good drought tolerance which makes this species an important warm season option for soil stabilization.

Phalaris arundinacea (Reed Canarygrass)

A native to North Carolina, this perennial cool season grass is used for the stabilization of pond shorelines, drainage ditches, and streambanks in the mountains and western piedmont. It is established by planting freshly cut stem slips or rhizome fragments. Please note that this species is aggressive and forms large monotypic stands that displace other species. It should only be used if no other species are available.

Secale cereale (Winter Rye or Rye Grain)

Winter rye is a cold-hardy annual grass that will germinate and grow at low temperatures. By maturing early, it offers less competition during the late spring, a critical time in the establishment of perennial species. Winter rye germinates quickly and is tolerant of poor soils.

Sorghum bicolor (Sudangrass)

Only the small-stemmed varieties of this annual warm season grass should be used. Sudangrass is useful for temporary seeding, and it is adapted to soils relatively high in clay content. Seed for common Sudangrass is not always available, but other small-stemmed types may be used, such as the hybrid Trudan. The coarse-stemmed Sorghum-Sudangrass hybrids are not appropriate for erosion control.

Suppliers of Grass Seed*

Ernst Conservation Seeds
9006 Mercer Pike
Meadville, PA 16335
814-336-2404
800-873-3321

Lofts Seed Company, Inc.
P.O. Box 26223
Winston-Salem, NC 27114-6223
800-543-7333

Mellow Marsh Farm
205 Anolis Road
Pittsboro, NC 27312
919-542-3532

Southern Tier Consulting, Inc.
2701-A Route 305
P.O. Box 30
West Clarksville, NY 14786
800-848-7614

*North Carolina suppliers are preferred.

Species Diversity and Composition

The most effective riparian buffers have trees and shrubs to provide perennial root systems and long-term nutrient storage. The design of a riparian buffer can be modified to fit the landscape and the landowner's needs, for example, by replacing shrubs with more trees, substituting some of the trees with shrubs, or incorporating a grass zone. In any scenario, the width of the woody vegetation should be at least 30 feet directly adjacent to the streambank/shoreline.

Choose 10-12 species of native trees and/or shrubs appropriate for site based on site assessment and reference conditions. In addition, please note that this list is alphabetical and does not take into account the assemblages of plants found in nature. The inventory of plants found on the reference site can help determine an appropriate assemblage for the restoration site. In addition, the North Carolina Natural Heritage Program's *Classification of the Natural Communities of North Carolina: Third Approximation* is a valuable reference on natural assemblages of plants (Shafele, Michael P. and Alan S. Weakley, 1990).

Typically, there should be at least three or four understory trees for every canopy tree to provide structural diversity similar to mature forests. Where shrub species are incorporated into the planting plan, they should be distributed more densely at outer edge of riparian buffer to reduce light penetration and recolonization by invasive exotic species. Refer to Table 1 for a list of native tree and shrub species appropriate for use in riparian buffers.

Table 1. Master List of Native Plants

Native Regions		Light Requirements		Moisture Requirements	
M=	Mountains	S=	Shade	L=	Low Moisture
P=	Piedmont	P=	Partial Sun	M=	Moderate Moisture
C=	Coastal Plain	F=	Full Sun	H=	High Moisture
				A=	Aquatic

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Medium to Large Trees											
Acer barbatum	Southern sugar maple		X	X	X	X			X		
Acer saccharinum	silver maple		X		X	X	X		X		
Acer saccharum	sugar maple	X				X	X		X		
Betula alleghaniensis	yellow birch	X			X	X			X		
Betula lenta	cherry birch, sweet birch	X			X	X			X		
Betula nigra	river birch	X	X	X		X	X		X	X	
Carya aquatica	water hickory			X		X	X			X	
Carya cordiformis	bitternut hickory	X	X	X	X	X	X		X	X	
Carya glabra	pignut hickory	X	X	X	X	X	X	X	X		

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Carya ovata	shagbark hickory	X	X	X	X	X	X		X		
Carya tomentosa	mockernut hickory	X	X	X	X	X	X	X	X		
Celtis laevigata	sugarberry, hackberry		X	X	X	X			X		
Chamaecyparis thyoides	Atlantic white cedar			X		X	X		X	X	
Cladrastis kentuckea	yellowwood	X			X	X			X		
Diospyros virginiana	persimmon	X	X	X	X	X	X	X	X		
Fagus grandifolia	American beech	X	X	X	X	X			X		
Fraxinus americana	white ash	X	X	X	X	X			X		
Fraxinus pennsylvanica	green ash	X	X	X	X	X			X	X	
Fraxinus profunda	pumpkin ash, red ash		X	X		X				X	
Juglans nigra	black walnut	X	X	X	X	X			X		
Liriodendron tulipifera	tulip poplar, yellow poplar	X	X	X	X	X	X		X		
Magnolia acuminata	cucumber magnolia	X	X		X	X			X		
Magnolia fraseri	Fraser magnolia	X				X			X		
Nyssa aquatica	water tupelo			X	X	X	X			X	X
Nyssa sylvatica	black gum	X	X	X	X	X	X	X	X		
Nyssa sylvatica var. biflora	swamp black gum			X	X	X	X			X	
Oxydendrum arboreum	sourwood	X	X	X		X	X	X	X		
Picea rubens	red spruce	X			X	X	X		X		
Pinus echinata	shortleaf pine	X	X	X		X	X	X			
Pinus palustris	longleaf pine		X	X			X	X	X		
Pinus rigida	pitch pine	X					X	X			
Pinus serotina	pond pine			X			X		X	X	
Pinus strobus	white pine	X	X			X	X		X		
Platanus occidentalis	sycamore	X	X	X		X	X		X	X	
Populus deltoides	eastern cottonwood		X	X			X			X	
Populus heterophylla	swamp cottonwood			X		X	X			X	
Prunus serotina	black cherry	X	X	X	X	X	X	X	X		
Quercus alba	white oak	X	X	X		X	X	X	X		
Quercus bicolor	swamp white oak		X		X	X				X	
Quercus coccinea	scarlet oak	X	X		X	X		X			
Quercus falcata	Southern red oak	X	X	X	X	X		X	X		
Quercus pagoda	cherrybark oak		X	X	X	X			X	X	
Quercus laurifolia	laurel oak			X	X	X	X		X	X	
Quercus lyrata	overcup oak		X	X	X	X				X	
Quercus margaretta	sand post oak			X		X	X	X			
Quercus marilandica	black jack oak	X	X	X	X	X		X			
Quercus michauxii	swamp chestnut oak		X	X	X	X	X		X	X	
Quercus nigra	water oak		X	X	X	X	X	X	X		
Quercus phellos	willow oak		X	X	X	X	X		X	X	
Quercus prinus	chestnut oak	X	X		X	X		X			
Quercus rubra	Northern red oak	X	X		X	X		X	X		
Quercus shumardii	shumard oak		X	X	X	X			X	X	
Quercus stellata	post oak	X	X	X	X	X		X			
Quercus velutina	black oak	X	X	X	X	X		X			
Quercus virginiana	live oak			X		X	X	X			
Robinia pseudoacacia	black locust	X	X	X		X	X		X		
Taxodium ascendens	pond-cypress			X		X	X				X
Taxodium distichum	bald-cypress			X		X	X				X

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Tilia americana var. heterophylla	basswood	X	X		X	X			X		
Tsuga canadensis	Eastern hemlock	X	X		X	X	X		X		
Tsuga caroliniana	Carolina hemlock	X	X			X	X	X			
Ulmus alata	winged elm		X	X	X	X	X	X	X		
Ulmus americana	American elm	X	X	X	X	X			X		
Small Trees											
Amelanchier arborea	downy serviceberry, shadbush	X	X	X	X	X			X		
Amelanchier canadensis	Canada serviceberry			X			X		X	X	
Amelanchier laevis	smooth serviceberry	X				X	X	X	X		
Asimina triloba	pawpaw	X	X	X	X	X			X		
Carpinus caroliniana	ironwood, American hornbeam	X	X	X	X	X			X	X	
Cercis canadensis	eastern redbud	X	X	X	X	X			X		
Chionanthus virginicus	white fringetree, old man's beard	X	X	X		X	X		X		
Cornus alternifolia	alternate-leaf dogwood	X			X	X			X		
Cornus florida	flowering dogwood	X	X	X	X	X		X	X		
Crateagus crus-galli	cockspur hawthorn	X	X	X		X	X	X	X		
Crateagus flabellata	fanleaf hawthorn	X	X			X			X		
Crateagus flava	October haw	X	X	X		X	X		X		
Cyrilla racemiflora	titi			X		X	X		X	X	
Fraxinus caroliniana	water ash			X	X	X				X	
Gordonia lasianthus	loblolly bay			X	X	X	X		X	X	
Halesia tetraptera (H. carolina)	common silverbell	X	X		X	X			X		
Ilex opaca	American holly	X	X	X	X	X		X	X	X	
Juniperus virginiana	Eastern red cedar	X	X	X		X	X	X	X		
Magnolia tripetala	umbrella tree	X	X		X				X		
Magnolia virginiana	sweetbay magnolia		X	X	X	X	X		X	X	
Morus rubra	red mulberry	X	X	X	X	X			X		
Osmanthus americana	wild olive, devilwood			X	X	X			X		
Ostrya virginiana	Eastern hop-hornbeam	X	X		X	X			X		
Persea borbonia	red bay			X	X	X	X	X	X		
Persea palustris	swamp bay			X	X	X	X		X	X	
Pinus pungens	table mountain pine	X					X	X			
Prunus americana	American wild plum	X	X			X			X		
Prunus caroliniana	Carolina laurel-cherry			X		X	X	X	X		
Quercus incana	bluejack oak			X		X	X	X			
Quercus laevis	turkey oak			X		X	X	X			
Rhus glabra	smooth sumac	X	X				X	X	X		
Rhus hirta (Rhus typhina)	staghorn sumac	X					X	X			
Salix caroliniana	swamp willow	X	X	X		X	X		X	X	
Salix nigra	black willow	X	X	X		X	X		X	X	
Sassafras albidum	sassafras	X	X	X		X	X	X	X		
Staphylea trifolia	bladdernut		X		X				X	X	
Symplocos tinctoria	horse-sugar, sweetleaf	X	X	X	X	X		X	X		
Ulmus rubra	slippery elm	X	X		X	X			X		
Shrubs											
Aesculus sylvatica	painted buckeye	X	X		X	X			X		
*Alnus serrulata**	common alder	X	X	X	X	X	X			X	X

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Aronia arbutifolia	red chokeberry	X	X	X	X	X			X	X	
Baccharis halimifolia	silverling		X	X			X	X	X	X	
Callicarpa americana	American beautyberry		X	X	X	X	X		X		
Calycanthus floridus	sweet-shrub	X	X		X	X			X		
Castanea pumila	Allegheny chinkapin	X	X	X	X	X	X	X			
Ceanothus americanus	New Jersey tea	X	X	X		X	X	X			
Cephalanthus occidentalis	buttonbush	X	X	X		X	X				X
Clethra acuminata	mountain sweet pepperbush	X			X	X			X		
Clethra alnifolia	sweet pepperbush			X	X	X			X	X	
Comptonia peregrina	sweet fern	X	X			X	X				
Cornus amomum	silky dogwood	X	X	X	X	X				X	X
Cornus stricta	swamp dogwood			X	X	X				X	
Corylus americana	American hazel, hazelnut	X	X		X	X			X		
Euonymus americanus	hearts-a-bustin', strawberry bush	X	X	X	X	X		X	X		
Fothergilla gardenii	witch-alder			X		X			X	X	
Gaylussacia frondosa	dangleberry			X	X	X	X		X	X	
Hamamelis virginiana	witch hazel	X	X	X	X	X		X	X		
Hydrangea arborescens	wild hydrangea	X	X		X	X			X		
Ilex coriacea	gallberry			X	X	X			X	X	
Ilex decidua	deciduous holly, possumhaw		X	X	X	X			X		
Ilex glabra	inkberry			X	X	X	X		X	X	
Ilex verticillata	winterberry	X	X	X	X	X	X		X	X	
Ilex vomitoria	yaupon holly			X	X	X	X	X			
Itea virginica	Virginia willow		X	X	X	X				X	
Kalmia angustifolia var. caroliniana	lamb-kill, sheep-kill			X		X	X		X	X	
Kalmia latifolia	mountain laurel	X	X		X	X		X	X		
Leucothoe axillaris	coastal dog-hobble			X	X	X			X		
Leucothoe fontanesiana	dog-hobble	X	X		X				X		
Leucothoe racemosa	fetterbush		X	X	X	X			X	X	
Lindera benzoin	spicebush	X	X		X				X		
Lyonia ligustrina	northern maleberry	X	X	X		X			X	X	
Lyonia lucida	shining fetterbush			X	X	X			X		
*Myrica cerifera**	Southern wax-myrtle		X	X	X	X	X	X	X	X	
*Myrica cerifera var. pumila**	dwarf Southern wax-myrtle			X		X	X	X	X		
*Myrica heterophylla**	bayberry, evergreen bayberry			X	X	X			X		
Pieris floribunda	evergreen mountain fetterbush	X					X	X	X		
Rhododendron atlanticum	dwarf azalea			X		X			X		
Rhododendron calendulaceum	flame azalea	X			X	X			X		
Rhododendron catawbiense	Catawba rhododendron	X	X		X	X	X	X	X		
Rhododendron maximum	rosebay rhododendron	X	X		X	X		X	X		
Rhododendron periclymenoides	pinxter flower, wild azalea	X	X	X	X	X			X		
Rhododendron viscosum	swamp azalea	X		X		X	X		X	X	
Rhus copallina	winged sumac	X	X	X		X	X	X	X		
Rosa carolina	pasture rose, Carolina rose	X	X	X		X	X	X	X		
Rosa palustris	swamp rose	X	X	X		X	X				X
Rubus allegheniensis	Alleghany blackberry	X	X				X	X			
Rubus cuneifolius	blackberry		X	X		X	X	X	X		
Rubus odoratus	purple flowering raspberry	X				X			X		
Salix humilis	prairie willow	X	X				X	X			

Scientific Name	Common Name	Region			Light			Moisture			
		M	P	C	S	P	F	L	M	H	A
Salix sericea	silky willow	X	X	X		X	X				X
Sambucus canadensis	common elderberry	X	X	X			X		X	X	
Spiraea alba	narrow-leaved meadowsweet	X					X		X		
Spiraea latifolia	broad-leaved meadowsweet	X					X		X		
Spiraea tomentosa	meadowsweet	X	X	X		X	X			X	
Stewartia malacodendron	silky camellia			X	X	X			X		
Stewartia ovata	mountain camellia	X	X		X	X			X		
Styrax grandifolia	bigleaf snowbell		X	X	X	X			X		
Vaccinium arboreum	sparkleberry		X	X	X	X		X	X		
Vaccinium corymbosum	highbush blueberry	X	X	X	X	X	X	X	X	X	
Vaccinium crassifolium	creeping blueberry			X		X			X		
Vaccinium elliottii	mayberry			X	X				X		
Vaccinium stamineum	deerberry, gooseberry	X	X	X	X	X		X			
Vaccinium pallidum	lowbush blueberry	X	X		X	X		X			
Viburnum acerifolium	maple-leaf viburnum	X	X		X	X		X	X		
Viburnum dentatum	Southern arrowwood viburnum	X	X	X	X	X	X		X		
Viburnum nudum	possumhaw viburnum	X	X	X	X	X				X	
Viburnum prunifolium	blackhaw viburnum	X	X	X	X	X			X		
Viburnum rafinesquianum	downy arrowwood		X		X	X			X		
Viburnum rufidulum	rusty blackhaw		X	X	X	X		X			
Xanthorhiza simplicissima	yellowroot	X	X	X	X			X	X		

* These species fix nitrogen and should not be used for riparian restoration adjacent to Nutrient Sensitive Waters.

Where grasses are incorporated into the planting plan on the outside of the buffer strip, only native grasses should be used. Native grasses produce a much more extensive and deep root system than commonly used non-native grasses such as fescue.

Common Native Grasses

Andropogon gerardii (Big Bluestem)
Andropogon virginicus (Broomsedge)
Arundinaria gigantea (Giant Cane)
Eragrostis spectabilis (Purple Love Grass)
Panicum anceps (Beaked Panicum)
Panicum clandestinum (Deertongue)
Panicum hemitomon (Maidencane)
Panicum virgatum (Switchgrass)
Schizachyrium scoparium (Little Bluestem)
Sorghastrum nutans (Indiangrass)
Tridens flavus (Purple-Top)
Tripsacum dactyloides (Gama Grass)

Planting Density

Trees should be planted at a density sufficient to provide 320 trees per acre at maturity. To achieve this density, approximately 436 (10x10 feet spacing) to 681 (8x8 feet spacing) trees per acre should be planted initially. Shrubs should be planted at a density sufficient to provide 1,200 shrubs per acre. Refer to Table 2 for the number of trees and shrubs per acre based on various methods of spacing.

Table 2. Number of Trees/Shrubs per Acre by Various Methods of Spacing

Spacing (feet)	Trees/Shrubs (number)
2x2	10,890
3x3	4,840
4x4	2,722
5x5	1,742
6x6	1,210
7x7	889
8x8	681
9x9	538
10x10	436
11x11	360
12x12	302
13x13	258

Plant Size

In many cases, the most cost effective and successful size plant material is bare root seedlings. Some species such as the hickories do poorly as bare root seedlings and will be much more successful as containerized seedlings. In either case, tree shelters should be used to accelerate growth and increase survivability of seedlings. In addition, management of competing vegetation after planting is easier, mowing and weed wacker strikes are prevented, herbicides are isolated from trunk contact, and grazing by deer are restricted. The use of tree shelters may only be practical from an economic standpoint for more expensive seedlings of species difficult to establish, such as red oak. Reductions in maintenance costs and increased seedling vigor associated with tree shelters suggest that tree shelter plantings may be a more cost-effective approach than planting unprotected larger material. In urban or other high visibility areas, some specimen trees and shrubs should be incorporated into the planting plan for projects implemented by the NCWRP.

When live stakes or dormant cuttings are incorporated in a planting plan, choose only the previous season's growth. Live stakes should typically be approximately ¾ inch in diameter and three feet long, and dormant cuttings should be approximately ½ inch in diameter and two feet long.

Supplier of Tree Shelters:
Treessentials Company
2371 Waters Drive
Mendota Heights, MN 55120-1163
800-248-8239

Suppliers of Native Plant Material

Local nurseries are the best option in acquiring plants that will be successful. Plants grown from seeds or cuttings collected close to the restoration area will be the most likely to survive and reproduce. The following is a list of nurseries that supply native plant material. This list is not considered exhaustive or an endorsement by the NCWRP but merely a source of potential vendors of native plants.

Carolina Greenery
375 Carthage Road
West End, NC 27376-8731
910-947-3150

Cedar Point Nursery and Garden Center
100 Commercial Court
Swansboro, NC 28584
252-393-6880

Coastal Plain Conservation Nursery
3067 Conners Drive
Edenton, NC 27932
252-482-5707

Cure Nursery
880 Buteo Road
Pittsboro, NC 27312
919-542-6186

Denton's Nursery
3535 NC 42 West
Wilson, NC 27893
252-237-0022

Fern Valley Farms
1624 Fern Valley Road
Yadkinville, NC 27055
336-463-2412

Hoffman Nursery
5520 Bahama Road
Rougemont, NC 27572
919-479-6620

Laurel Springs Nursery
401 Regal Street
Hendersonville, NC 28792
828-692-4012
888-823-4622

McLamb Nursery, Inc.
640 Greenleaf Road
Angier, NC 27501-9801
919-894-3709
800-900-3709

Mellow Marsh Farm
205 Anolis Road
Pittsboro, NC 27312
919-542-3532

NC Division of Forest Resources
Claridge Nursery
762 Claridge Nursery Road
Goldsboro, NC 27530
919-731-7988

NC Division of Forest Resources
Edwards Nursery
701 Sanford Drive
Morganton, NC 28655
828-438-6270

NC Division of Forest Resources
Linville Nursery
6321 Linville Falls Highway
Newland, NC 28657
828-733-5236

Niche Gardens
1111 Dawson Road
Chapel Hill, NC 27516
919-967-0078

Taylor's Nursery, Inc.
3705 New Bern Avenue
Raleigh, NC 27610
919-231-6161

Wa Ya Nursery & Tree Farm
11199 Canada Road
Tuckasegee, NC 28783
828-293-5720

We-Du Nurseries
Rt. 5, Box 724
Marion, NC 28752
828-738-8300

Woodlander's, Inc.
1128 Colleton Ave.
Aiken, SC 29801
803-648-7522

For more information about suppliers of native plants contact:

'Native Plant Sources'
North Carolina Botanical Garden
University of North Carolina at Chapel Hill
CB 3375, Totten Center
Chapel Hill, NC 27599-3375
919-962-0522

Planting Layout

The planting plan should indicate that trees and shrubs will be planted in a random pattern. For inexperienced planting crews, pre-labeled flagged wires can be used to mark the random location of plantings. These flags can also be color coded for each particular species. Various colors of spray paint can also be used to differentiate species.

Planting Practices

When planting seedlings, it is helpful to mark the plants with colored flagging to make them easier to locate during maintenance tasks. The flagging can also be color-coded to mark plants that have died for replacement at a later date. Tree protectors are also helpful for locating plants.

Tree seedlings should be kept moist and should not be exposed for extended periods of time. A correctly planted tree should have the following general characteristics:

- Planted so that the root collar is slightly below the soil surface.
- Have the main roots nearly straight or spread out.
- Have soil firm around the roots.
- Have the tree in an upright postion and have it nearly even with the general ground level, not sunk in a hole or raised on a mound.

Please note that the Neuse and Tar-Pamlico Riparian Buffer Rules allow for a one time fertilizer application to establish newly planted vegetation. Ongoing fertilizer application is prohibited by these rules.

Riparian Buffer Maintenance

Control of Grasses and Forbs

In the early stages of riparian buffer establishment, competition for nutrients by adjacent grasses and forbs will substantially inhibit seedling growth. Release from herbaceous competition has been demonstrated as the most cost-effective method to accelerate the growth of seedlings. The plan for buffer establishment must incorporate control of the herbaceous layer. Options for weed control include four to six inches of well-aged hardwood mulch, weed control fabrics, or pre-emergent herbicide. Typically, mowing to control weeds will be impractical based on the random distribution of plantings. Weed control should be continued for three years from the time of planting.

Areas of Concentrated Flow

During the required five year monitoring period, the riparian buffer should be inspected for evidence of concentrated flow. If concentrated flow has begun to form, a level spreader or other best management practice should be installed to diffuse the flow before it enters the restored riparian buffer.

Prepared by Cherri L. Smith, North Carolina Wetlands Restoration Program. Illustrations by Karen M. Lynch and design by Marcia Nye.

N.C. Wetlands Restoration Program
NCDENR DWQ

APPENDIX H

Wetland Restoration Potential at the Cato Farm Site

PREPARED FOR: NCWRP

PREPARED BY: CH2M HILL

COPIES: Paige Baker

DATE: June 13, 2002

On April 19, 2002, a field survey of the Cato Farms site was conducted to identify disturbed (cleared, drained, etc) wetland(s), if any, for potential restoration as part of the County Wetland Restoration Plan. The Cato Farms site is an active pasture, and much of the natural vegetation was removed and replaced with grasses for grazing. The site is drained by a tributary to Clark Creek.

Prior to the field survey, the County soil survey report was reviewed for hydric soils. No hydric soils were listed in the County. The Monacan soil series was identified by the NRCS occurring in the floodplain and boarding the tributary and was described as somewhat poorly drained. Hydric inclusion may occur in this poorly drained soil.

In addition to reviewing the County soil survey maps, a field investigation for the presence of the wetland parameters (hydric soils, hydrologic indicators, and hydrophytic vegetation) was conducted throughout the site. Indicators of Hydric soils, an altered hydrology, and a few falculative hydrophytic plant species were identified in the floodplain on the west side of the stream (the right floodplain facing downstream at the existing channel). The soil conditions consisting of a low chroma matrix (Munsel 5Y/5/1) and bright mottles (Munsel 10YR/5/5) in the upper 10 inches confirmed the presence of hydric soils.

A predominance of oxidized root channels in the upper 12 inches and saturated soil conditions within 8 inches of the surface near the headwaters of the tributary confirmed that a wetland hydrology occurred but has been disturbed. Because saturated conditions (a hydrologic indicator) were not found to be present within all of the hydric soils area delineated, it appears that the three drainage ditches observed in the field, crossed through the area of hydric soils and into the Cato Farms tributary, lowered the water table, and drained the floodplain. Furthermore, the downstream section of the tributary crossing the site is deeply incised (6 to 8 feet deep), which effectively lowered the water table to those depths, contributing to additional wetland drainage. The property owner in fact, described the area as formerly "very marshy" and difficult to maneuver farm equipment around in. Figure 9 depicts the limits of hydric soils as evaluated in the field and also shows the locations of the drainage ditches that have dried out this area.

Restoring the hydrology, by filling the crosscut ditches, and planting wetland species would restore wetlands to a portion of the area with hydric soils. Additional wetland area could be restored provided the streambed in the deeply incised tributary was elevated to increase the ground water level so the upper soil horizons would be saturated during most of the growing season.