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NC ECOSYSTEM
ENHANCEMENT PROGRAM

EXECUTIVE SUMMARY OF RESTORATION PLAN

UNNAMED TRIBUTARY TO CROOKED CREEK

Franklin County, North Carolina

Project ID No. 040614801

Prepared for:

NCDENR-Ecosystem Enhancement Program

Raleigh, North Carolina

June

~~April~~ 2005

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Project Engineer

I HEREBY CERTIFY THAT THE REPORT CONTAINED HEREIN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION.

SIGNED, SEALED AND DATED THIS 1ST DAY OF JUNE 2005
R. KEVIN WILLIAMS, PE, PLS, CPESC

NORTH CAROLINA PROFESSIONAL SEAL 20253 ENGINEER R. KEVIN WILLIAMS

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EXECUTIVE SUMMARY

The Unnamed Tributary to Crooked Creek is located in Franklin County, North Carolina within a generally rural watershed. Prior land use practices and straightening have made the stream unstable through the project site. The restoration section for the Unnamed Tributary to Crooked Creek flows through abandoned farmland/pastureland where grass buffer exists along the majority of the stream with wooded areas along the remaining areas. Stream restoration and buffer restoration techniques will help improve the water quality of the stream by reducing erosion and runoff of pollution directly into the stream. Improvement of the water quality is needed since the receiving stream is listed as Nutrient Sensitive Water (NSW). Nutrient Sensitive Waters require limitations on nutrient outputs. Restoration of a degraded system leads also to improvements in the aquatic and terrestrial communities that depend upon it. The Unnamed Tributary to Crooked Creek project site provides opportunities for stream restoration and buffer restoration. The following table summarizes and footages and acreages for the site.

Area	Before	After
EEP Easement Area (acres)	37.95	37.95
Existing Wetland and Stream Area within EEP Easement (acres)	34.41	n/a
Wetland Area within Proposed Restoration Construction Limits (acres)	n/a	2.80
Stream Restoration (feet)	1920	2270
Buffer restoration (acres)	n/a	4.34

The project site consists of an existing channel that is generally an F5 but evolving towards a C5. Restoration of this channel to a C type stream will help improve biological integrity of the system, reduce energy of the stream, reduce erosion, and increase habitat. The existing buffer consists of grass along the majority of the channel areas with wooded areas along the remaining areas. Restoration of the riparian buffer along the stream will help to improve aquatic and terrestrial habitats.

The Unnamed Tributary to Crooked Creek project site provides an excellent opportunity for restoration of the stream and buffer. Restoring ecological functions at this site will:

1) Decrease floodwater levels;
2) Improve water quality;
3) Increase aquatic and terrestrial habitat and diversity;
4) Improve the biological integrity of the system;
5) Reduce the amount of sediment and pollutants entering the system;
6) Provide landscape continuity.

Overall, the project will provide a variety of habitats from open water to uplands. The project will greatly increase the future habitat and food sources for a variety of wildlife species. Restoration of the stream channel and buffer will help improve water quality in the Unnamed Tributary to Crooked Creek, Crooked Creek and thus the Tar River.

1.0 PROJECT SITE LOCATION

The Unnamed Tributary to Crooked Creek (UTCC) – Speas Property project is located in Franklin County, North Carolina, northwest of the intersection of NC Highway 98 and Secondary Road 1001 (Pearces Road) (Figure 1). The project study area includes the Unnamed Tributary to Crooked Creek and portions of three smaller tributaries located on the proposed Shartree sub-division development site. The project will focus on the Unnamed Tributary to Crooked Creek with minor work along on the other tributaries. The project will include the restoration of 2,270 linear feet of Unnamed Tributary to Crooked Creek.

The project study area was identified as a potential stream restoration opportunity by the North Carolina Department of Natural Resources (DENR) Ecosystem Enhancement Program (EEP) based on an evaluation by EEP staff.

Ko & Associates (Ko), teamed with Environmental Services, Inc. (ESI), was retained to provide planning, design, construction observation and post-construction documentation services for the restoration of Unnamed Tributary to Crooked Creek on the Speas property. This document summarizes the background investigation, constraints, analysis, fieldwork, and methodologies used in preparing the design.

1.1 Directions to Project Site

Directions to the project study area from Raleigh, North Carolina, are as follows:
U.S. Highway 64 East to North Carolina Highway 98.
NC 98 through the Town of Bunn to Secondary Road 1001.
Turn right on SR 1001.
Turn left into first driveway into Project Study Area.

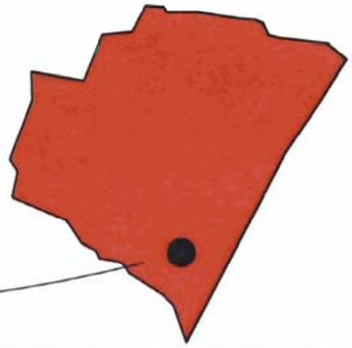
1.2 USGS hydrologic unit Code and NCDWQ River Basin Designation

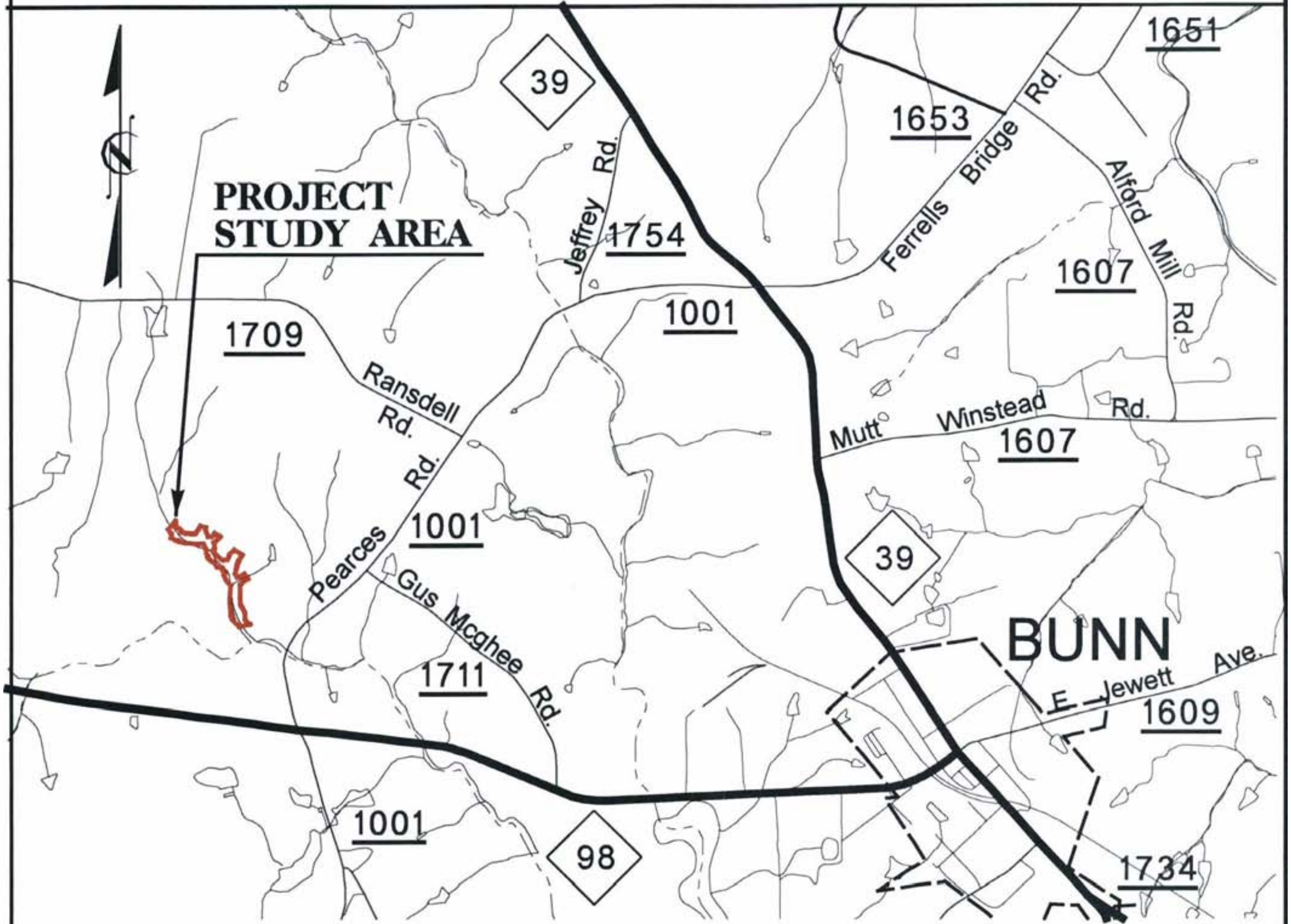
The Unnamed Tributary to Crooked Creek is located in Franklin County, North Carolina (Figure 1) within subbasin 03-03-01 of the Tar-Pamlico River Drainage Basin (DENR 2004) and is part of the USGS hydrologic unit UC 03020101 (USGS 1974). The channel reaches within the project study area are currently subject to the Tar-Pamlico Riparian Buffer Rules.

1.2.1 Tar-Pamlico Riparian Buffer Rules

The Tar-Pamlico Riparian Buffer rules place limits on what activities can take place within 50 feet of any water feature which is depicted as either a blue-line stream or open water feature on either the most recent version of the USGS 7.5-minute topographic quadrangle or the Natural Resource Conservation Service (NRCS) Soil Survey.

Franklin County North Carolina





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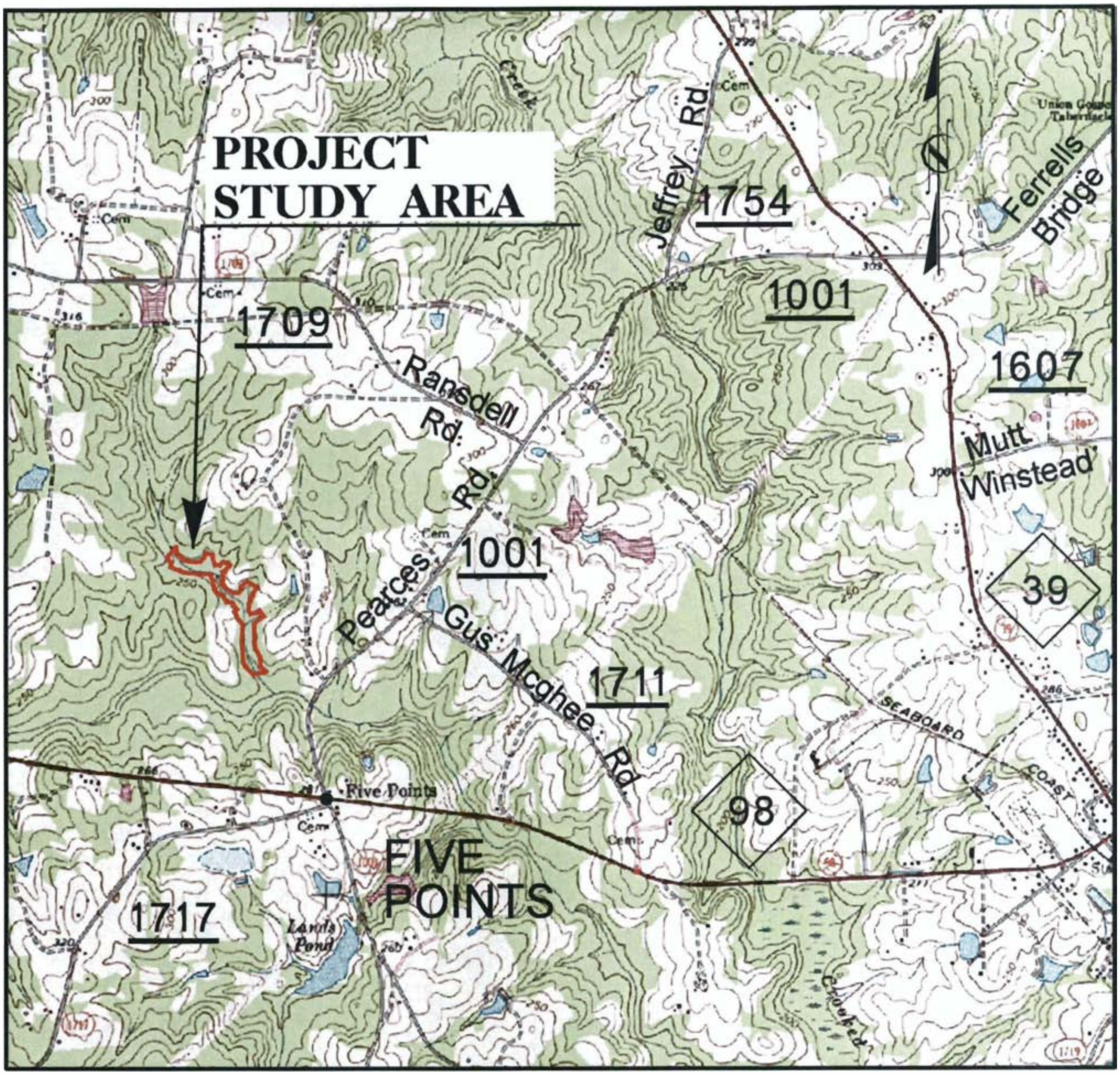
Vicinity Map

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05	Figure: 1.0.1



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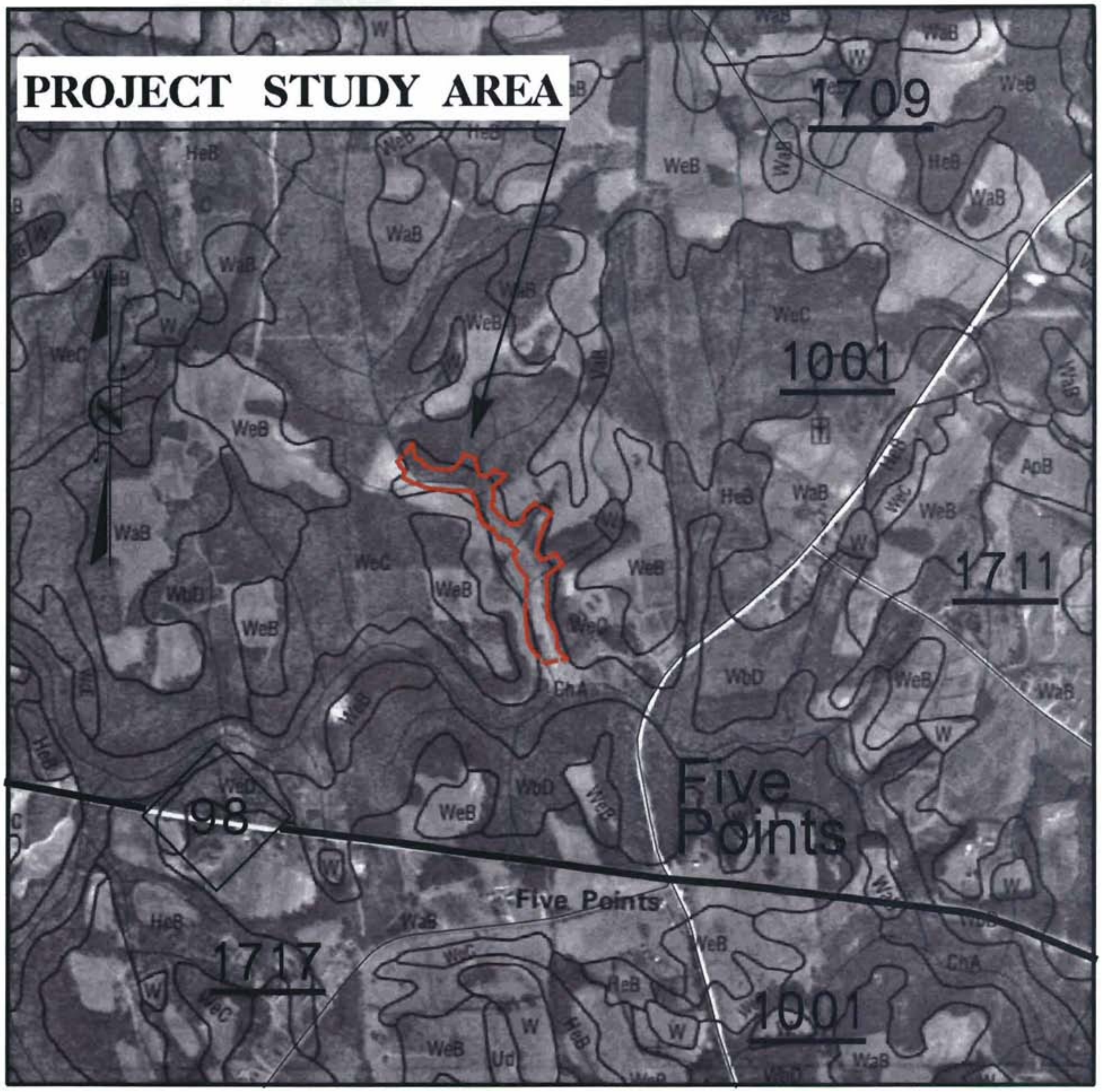
USGS Topographic Map

BUNN WEST

PHOTOREVISED 1973

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05	**Figure:** 1.0.2



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LEGEND	
Symbol	**Name**
ChA –	Chewacla and Wehadkee soil (0 to 3 percent slopes, freguently flooded)
WeC –	Wedowee sandy loam (6 to 10 percent slopes)

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Soil Survey Map

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05	Figure: 1.0.3

The Unnamed Tributary to Crooked Creek appears as a blue-line feature on the USGS 7.5-minute topographic quadrangle (Bunn West) and the Franklin County NRCS Soil Survey. The Tar-Pamlico Riparian Buffer Rules are applicable to the stream channels within the project site.

1.3 Project Vicinity Map

The project study area is located near the Community of Bunn, in Franklin County, North Carolina. The project vicinity is depicted on Figure 1.0.1.

2.0 PROJECT SITE STREAMS (EXISTING CONDITIONS)

2.1 Watershed Characterization

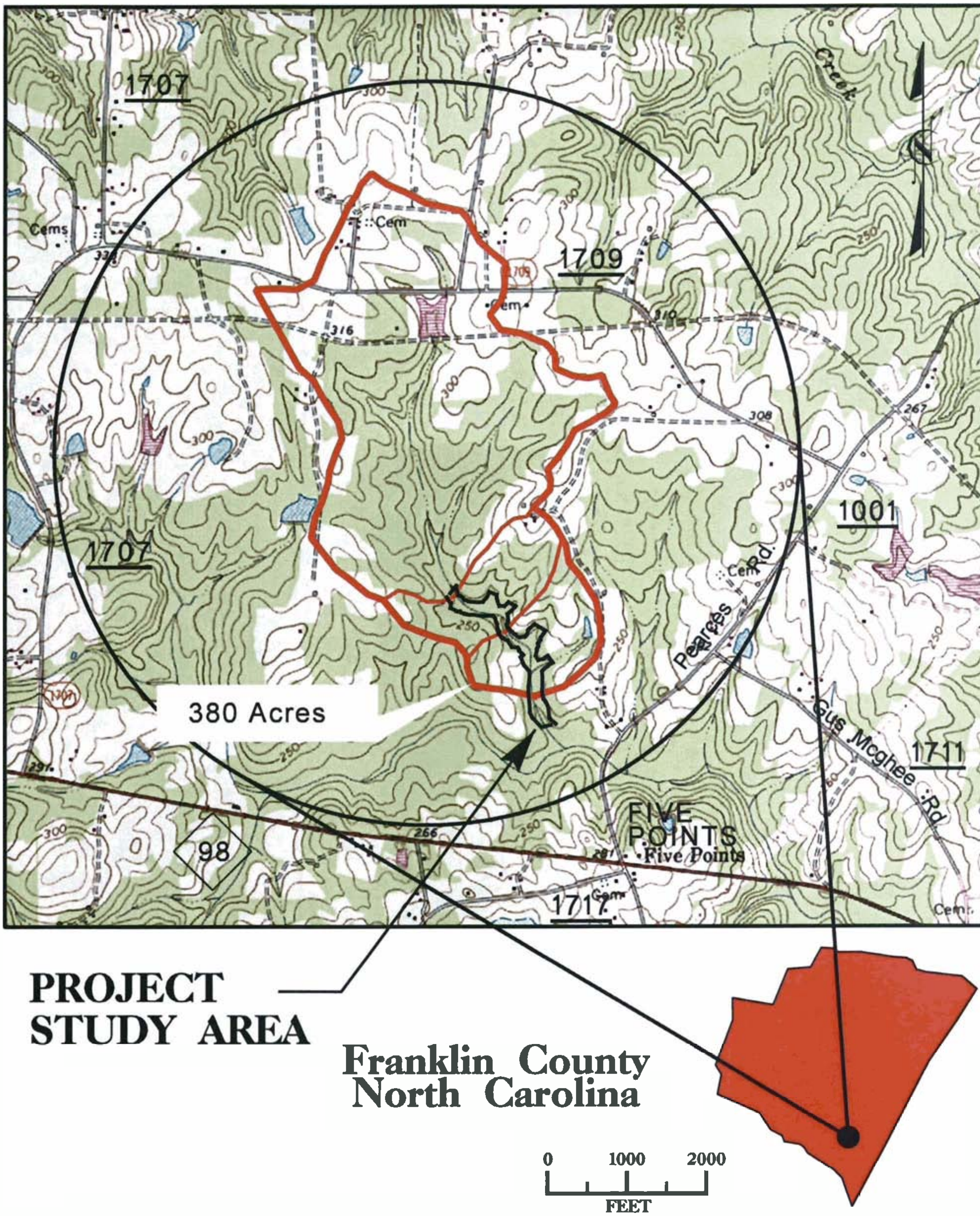
The watershed above Unnamed Tributary to Crooked Creek is approximately 380 acres in area. Elevations range from a topographic high of approximately 316 feet above mean sea level to a topographic low of 210 feet above mean sea level at the lower portion of the project study area (Figure 2.1.1). Current land use within the watershed is generally rural in nature, containing several small farms and private residences (Figure 2.1.2). Relief within the watershed is gently sloping.

Future land use within the watershed includes the development of at least one sub-division, the Shartree development, which is currently surrounding the areas immediately adjacent to Unnamed Tributary to Crooked Creek within the project study area.

The project study area was subjected to a jurisdictional delineation effort during the planning phase of the Shartree Subdivision design process. The delineation effort, which was accepted by the U.S. Army Corps of Engineers (COE), indicates the presence of stream channels and jurisdictional wetlands within the project study area.

The jurisdictional wetland areas within the project study area include forested wetlands along with shrub-scrub and herbaceous assemblages.

The majority of wetlands within the project study area affected by this project are the shrub-scrub and the herbaceous assemblages. Vegetation within the jurisdictional herbaceous assemblages includes soft rush (*Juncus effusus*), black willow (*Salix nigra*), and blackberry (*Rubus* sp.).



Watershed Topo Map

Stream Restoration Plans
UT–Crooked Creek Speas Property
Franklin County, North Carolina

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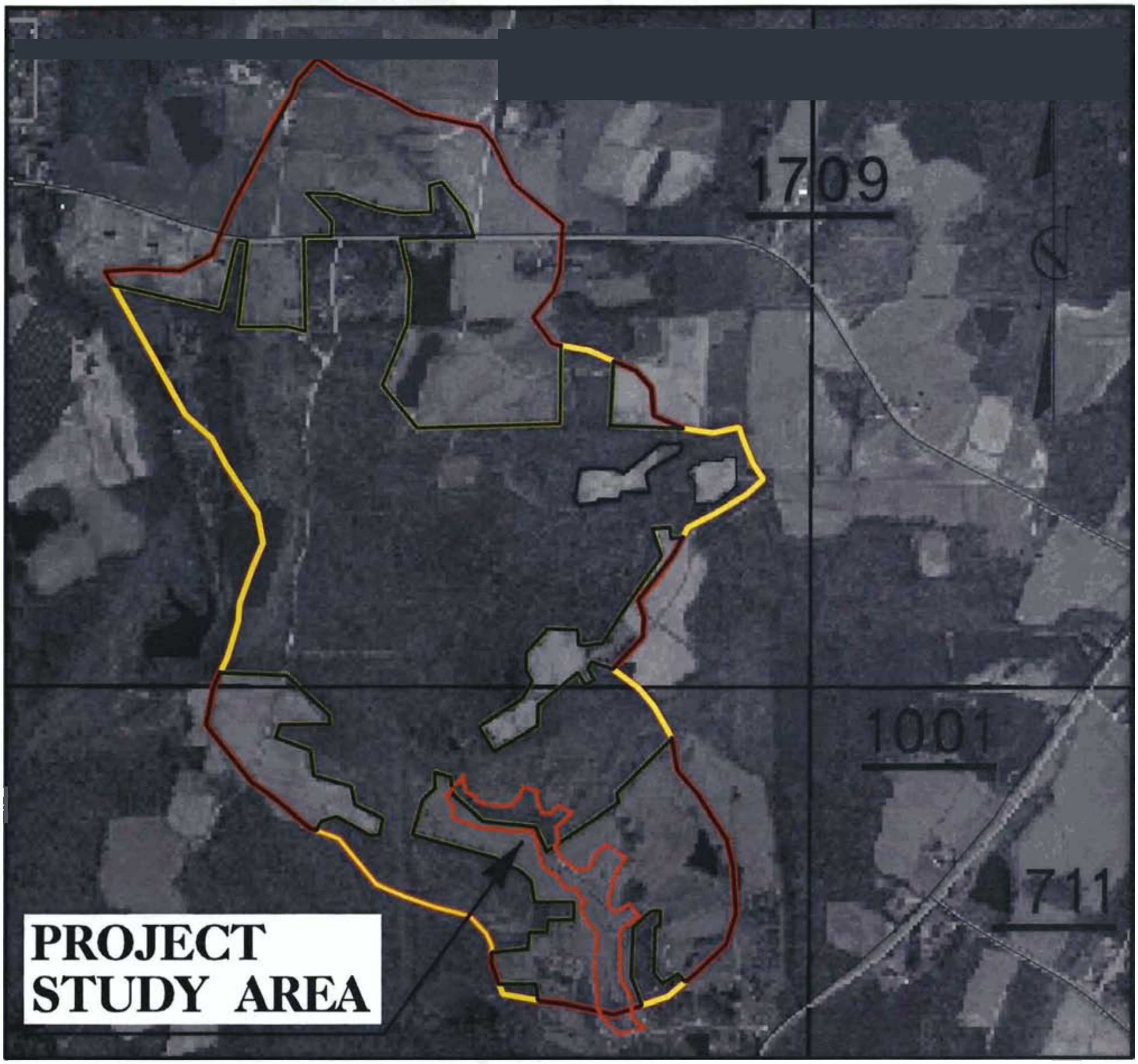
Date: 4/15/05	Figure: 2.1.1



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LEGEND

- PROJECT WATERSHED LIMITS
- FOREST
- AGRICULTURAL

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Land Use Map

Stream Restoration Plans
UT–Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05 **Figure:** 2.1.2

The State of North Carolina has classified all waters based on the present or expected best usage. Best Usage Classifications (BUC) and stream index numbers (SIN) follow *Classifications and Water Quality Standards* published for each river basin (DEM 1993), as updated through 2 October 2004. Generally, unnamed streams carry the same Best Usage Classification as its receiving water unless they are specifically denoted as having a separate Best Usage Classification.

Unnamed Tributary to Crooked Creek has not been assigned a separate stream index number. Its receiving water, Crooked Creek, from its source to the Tar River, has been assigned a stream index number of 28-30. Crooked Creek has been assigned a Best Usage Classification of **C NSW**. Class **C** waters are freshwaters protected for secondary recreation, fishing aquatic life (including propagation and survival), and wildlife. The supplemental classification, **NSW**, indicates Nutrient Sensitive Waters, which require limitations on nutrient outputs. Unnamed Tributary to Crooked Creek has not been assigned a separate Best Usage Classification, and therefore shares the Best Usage Classification of its receiving water.

2.2 Channel Classification

Information on stream morphology and classification from Applied River Morphology by Rosgen (1996) was used to evaluate and classify the stream. There are several pieces of data that were needed in order to classify the stream, which included: width-to-depth ratio, entrenchment ratio, slope, sinuosity, and dominant type of channel material. All five of the criteria are interrelated and were used to determine the current condition of the channel, classify the stream, and to aid in the design process.

Width-to-depth ratio is the ratio of the bankfull width to the mean depth of the bankfull channel. The width-to-depth ratio indicates the channel's ability to dissipate energy and transport sediment. The entrenchment ratio is the vertical containment of the stream and the degree to which the channel is incised in the valley floor. The entrenchment ratio indicates if the stream is able to access its floodplain. The flood-prone width divided by the bankfull width yields the entrenchment ratio. The slope is the change in water surface elevation per unit of stream length. The slope can be analyzed over the entire reach, to determine if the slope is stable within the existing channel material, or over sections, to determine the condition of pools and riffles. Sinuosity is the ratio of stream length to valley length. Extremely low sinuosity channels in the piedmont of North Carolina typically indicate a straightened channel. Channel bed and bank materials indicate the channel's resistance to hydraulic stress and ability to transport sediment (Rosgen, 1996). All five of the criteria are interrelated and were used to determine the current condition of the channel.

Elevation measurements for the longitudinal profile survey and pool and riffle cross-sections included, but were not limited to:

1) thalweg,
2) edge of water,
3) water surface,
4) bankfull,
5) top of low bank, and
6) terrace.

Measurements were also taken for the following:

1) bank slope,
2) width of flood prone area,
3) belt width,
4) valley length,
5) straight length,
6) pool-to-pool spacing, and
7) composition of channel materials.

These numbers helped to classify the stream and are used in the design process. Once the numbers are known a design will be proposed based on the geomorphic processes occurring with the channel. The survey also identified design constraints of the site (e.g., rock outcroppings, large trees, beaver dams and existing channels).

The stream is classified as a F5 evolving towards a C5 (Rosgen, 1996). The moderate entrenchment ratio, moderate to high width/depth ratio and low sinuosity signifies an "F" classification for the stream channel. The '5' classification means that the channel is mainly composed of sand.

Due to past straightening, the channel is much shorter than the natural condition. The slope of the streambed and the energy of the stream have been increased due to being straightened. The combination of maintenance practices and the increased energy due to past straightening activities has encouraged the stream to headcut and downcut to its current elevation, which is held by bedrock in several locations. Furthermore, the channel's riffle-pool sequence, which provides energy dissipation, has been eliminated. Table 4.2 presents the morphological characteristics data for the existing conditions along Unnamed Tributary to Crooked Creek and the existing channel survey data is in Appendix C.

2.3 Channel Morphology

One reach was surveyed for information on the existing conditions along Unnamed Tributary to Crooked Creek. The reach survey was preformed within the middle third of the affected reach, near the proposed roadway crossing of Shartree Farms Lane. The bankfull width for the survey reach was measured at 16.4 feet. The bankfull mean depth for the survey reach was measured at 0.81 feet. Based on these numbers, the width-to-depth ratio for the survey reach is 20.2. The bankfull cross-sectional area for the survey reach is 13.3 square feet (ft^2). Bankfull mean velocity for the survey reach is

4.3 feet per second (ft/s). The bankfull discharge for the survey reach is 56.6 cubic feet per second (cfs). The bankfull maximum depth for the survey reach is 1.91. The width of the flood-prone area for the survey reach is 24.8 feet. Additional morphological characteristics for Unnamed Tributary to Crooked Creek are presented in Table 4.2.

3.0 REFERENCE STREAMS

A reference reach provides natural channel design dimensions that are based on measured morphological relationships from stable channels. Criteria used to identify a potential reference reach include:

1) current land use,
2) drainage area,
3) stream order,
4) absence of man-made alterations or beaver dams,
5) stream classification, and
6) stream condition.

The upstream and downstream portions of Unnamed Tributary to Crooked Creek do not provide a stable dimension, pattern, and profile that can be used to design the proposed channel due to channel straightening and an unstable geometry. The upstream and downstream sections are currently under water due to damming by beavers. Reference streams had to be identified off-site in order to provide guidance in designing a stable stream with proper dimensions, patterns, and profiles based on bankfull stage (Rosgen, 2001). A search for suitable reference reaches for the design of the new channel was conducted based on the above-mentioned criteria. The stream identified as a potential reference reach that met the specified criteria is an UT to Marks Creek. This tributary lies within the Neuse River Basin in Wake County.

Once the site was identified, survey teams performed longitudinal profile and cross-sectional surveys. Elevation measurements for the longitudinal profile survey and pool and riffle cross-sections included, but were not limited to:

7) thalweg,
8) edge of water,
9) water surface,
10) bankfull,
11) top of low bank, and
12) terrace.

Measurements were also taken for the following:

8) bank slope,
9) width of flood prone area,
10) belt width,
11) valley length,

12) straight length,
13) pool-to-pool spacing, and
14) composition of channel materials.

The data gathered were used to form dimensionless ratios that will be used for the design along Unnamed Tributary to Crooked Creek. Restoration design uses reference reaches of stable channels and reference buffers within the same physiographic region for design parameters. The morphological characteristics of this reference reach are shown in Table 4.2.

3.1 Marks Creek South Reference

3.1.1 Stream Conditions

The UT to Marks Creek, which flows east into Marks Creek and then flows south into the Neuse River, is located approximately 2 miles east of the town of Knightdale. The stream is a second order stream with a watershed of 65 acres. This stream was surveyed on August 21, 2001.

The stream reach used for the survey totaled 106 feet. The survey included a longitudinal profile, cross-sections, bed material evaluation, buffer assessment, and system stability evaluation. The UT to Marks Creek reference reach was classified as a C5 stream type based upon the survey data. The reach is transporting its sediment supply without aggrading or degrading while maintaining its dimension, pattern, and profile. Bankfull width of the stream is approximately 11.1 and bankfull depth is approximately 0.7 feet. The reference reach has a sinuosity of 1.23 and a radius of curvature of 7-16 feet. The width-to-depth ratio of 15 is moderate and the entrenchment ratio of 5.3 is slightly entrenched as expected for a C type stream. The streambed material for Marks Creek South and Unnamed Tributary to Crooked Creek are dominated by sand. Photographs of Marks Creek South are presented in Exhibit 3.1. DWQ representatives inspected the site February 2002. The DWQ inspectors approved of the use of Marks Creek South as a reference reach.

3.1.2 EEP Functional Assessment

Benthic macroinvertebrates were collected at the site using the North Carolina Division of Water Quality's EPT sampling procedure. This type of collection is intended to quickly assess between-station differences in diversity and community composition. Four composite samples were taken at each site: 1 kick, 1 sweep, and 1 leaf pack collection along with visual inspections. Aquatic fauna observed in the channel during the field investigation included various odonates (dragonfly and damselfly nymphs), caddisflies, stoneflies, mayflies and crayfish.

Exhibit 3.1: Marks Creek South

4.0 PROJECT SITE RESTORATION PLAN

4.1 Restoration Project Goals and Objectives

The goal of this project is to provide a natural channel design approach to restoring the stream reach. The proposed adjustments to the dimension, pattern, and profile of the stream reach will be designed to increase long-term stability and create a more functional riparian system. The design will adjust the stream's geomorphic features, including dimension, pattern, and profile. The proposed adjustments will reflect the stable conditions and current geomorphic features of reference reach data. The proposed vegetated buffers are similar in composition to other natural riparian buffers commonly occurring within the physiographic region.

The design plan will establish an attached floodplain to the Unnamed Tributary to Crooked Creek reach. This feature will allow for more natural channel function, decreasing stream bank erosion, reduce channel stress during high flow events, improve aquatic habitat, and increase sediment removal.

4.1.1 Proposed Channel Classification

The main channel of the project will be designed as a C5 type channel. The restoration plan consists of a Priority 2 restoration (Rosgen, 1996). The restoration of hydraulic geometry and the establishment of a riparian buffer will contribute to water quality improvements within the watershed.

The stream channel's pattern, dimension and profile design is based upon morphological characteristics found in the reference reach. A conceptual design was developed using the ranges determined from the reference reach data. The proposed channel will be slightly entrenched with a moderate width/depth ratio and moderate sinuosity. The morphological characteristics of the reference reach and the proposed channel are shown in the table within Section 4.2.

The channel will be constructed as a C5 and the sand-dominated stream will have a meandering pattern within the constructed floodplain. The sinuous channel will allow for multiple riffle-pool sequences. The pools will dissipate the stream's energy while the riffles will allow stable elevation transitions. Figure 4.3.2 shows the proposed plan view for the restoration project and Figure 7.1 shows a typical cross-section.

The existing channel is currently incised, indicating the need for a Priority 2-type restoration. The design will include establishing a floodplain at the existing bankfull elevation or higher. The proposed bankfull channel will be raised slightly within the middle third of the project and then stepped down throughout the project through the use of rock cross vanes. The proposed profile of the stream will have a lower gradient than what currently exists, while cross vanes will gradually step down the stream in 0.5 foot increments. Figure 4.3.3 shows the proposed longitudinal profile for the restoration project.

A number of different structures and methods will be used to control grade and stabilize the channel. These structures and methods may include, but are not limited to: rock cross-vanes, rock vanes, rootwads, floodplain interceptors, matting, and planting materials. These structures provide grade control and bank stabilization, such that the proper dimension, pattern, and profile is maintained while providing various habitats for aquatic organisms. The structures provide a substrate for benthic macroinvertebrates to feed on, hide under, and attach to. They also provide shelter and create eddies for fish to rest and feed near. The majority of the materials for the structures will come from off site. Diagrams of these structures are located in Section 7.

4.1.1.1 Proposed Channel Structures

Rock Cross-Vanes and Rock Vanes will be utilized to direct the flow away from the banks and toward the center of the channel. Rootwads will be used for bank stabilization and to introduce woody material into the channel. Without this introduction it would be many years before the planted vegetation would be able to provide the stream with this habitat feature.

Rock Cross-Vanes - Rock cross-vanes direct the flow away from the streambanks into the middle of the channel. The structure creates a scour pool below, while maintaining the grade for the upstream portion. These structures will also provide a stable drop in the stream profile throughout the Site. Boulders are used to build these structures and filter fabric and smaller rock will be used to further strengthen it by solidifying gaps between the boulders.

Rock Vanes - The rock vane directs the flow away from the streambank and into the center of the channel. The rock vane structure creates a scour pool immediately downstream which provides a habitat feature. Boulders are used to build these structures and will be used throughout the Site on the outside meander bend.

Rootwads - Rootwads will be utilized for streambank protection, habitat for fish, habitat for terrestrial insects, cover and introduction of woody material into the stream. Rootwads act as a deflection device to the stream's flow. The roots buffer the streambank and aid in turning the stream's erosive forces away from the streambank.

Floodplain Interceptor - Floodplain interceptors will provide water on the floodplain with a stabilized access point to flow back into the channel. The floodplain interceptors shall be placed in low swale type areas on the floodplain where floodwater is expected to re-enter the stream channel.

Matting and Planting - Matting, live staking, and vegetation planting will be utilized to stabilize the project. Matting will provide immediate protection to the streambanks while the plantings develop a root mass and aid in protecting against shear stress. Vegetation transplanting will not be used on the Site due to the lack of existing appropriate plant materials. The plantings will develop into mature trees that will be capable of providing the stream with shade and wildlife habitat. The streambed and point bars of the stream channel will not be matted or planted.

4.1.2 Target Wetland Communities

The restored floodplain area will be revegetated with woody material to promote stability and nutrient removal and herbaceous material to promote sediment removal. Exact species composition and stem quantities will be dependant on availability at the time of planting. Planting will be targeted for the first winter after the completion of construction.

Tree species targeted for planting within the restored floodplain will include tulip poplar (*Liriodendron tulipifera*), black willow *(Salix nigra*), river birch (*Betula nigra*), and swamp chestnut oak (*Quercus michauxii*). Herbaceous species within this community will include soft rush (*Juncus effusus*).

Portions of the revegetated communities will be non-jurisdictional. Vegetation within these areas include white oak (*Quercus alba*), willow oak (*Quercus phellos*), short leaf pine (*Pinus* echinata), and American beech (*Fagus grandifolia*). Flowering dogwood (*Cornus florida*) will be interspersed throughout this community.

4.2 Morphological Table

ITEM	Existing Conditions	Proposed Conditions	Reference Reach
LOCATION	UT to Crooked Creek	UT to Crooked Creek	South Unnamed Trib. to Marks Creek
STREAM TYPE	F5	C5	C5
DRAINAGE AREA, Ac - Sq Mi	341.00 Ac - 0.53 Sq Mi	380.00 Ac - 0.59 Sq Mi	65.02 Ac - 0.10 Sq Mi
BANKFULL WIDTH (W_{bkf}), ft	16.4 ft	15.0 ft	11.1 ft
BANKFULL MEAN DEPTH (d_{bkf}), ft	0.81 ft	1.15 ft	0.72 ft
WIDTH/DEPTH RATIO (W_{bkf}/d_{bkf})	20.2	13.0	15.4
BANKFULL X-SECTION AREA (A_{bkf}), ft^2	13.3 ft^2	17.3 ft^2	8.0 ft^2
BANKFULL MEAN VELOCITY, fps	4.3 fps	3.9 fps	2.1 fps
BANKFULL DISCHARGE, cfs	56.6 cfs	61.2 cfs	17.2 cfs
BANKFULL MAX DEPTH (d_{max}), ft	1.91 ft	1.50 ft	1.80 ft
WIDTH Flood-Prone Area (W_{fpa}), ft	24.8 ft	67.5 69.0 ft	59.1 ft
ENTRENCHMENT RATIO (ER)	1.5	4.5 - 4.6	5.3
MEANDER LENGTH (Lm), ft	6 - 29 ft	45.0 - 135.0 ft	19.7 - 42.0 ft
RATIO OF Lm TO W_{bkf}	1.05	3.0 - 9.0	1.8 - 3.8
RADIUS OF CURVATURE, ft	4 - 7 ft	30.0 - 45.0 ft	6.6 - 15.8 ft
RATIO OF Rc TO W_{bkf}	0.33	2.0 - 3.0	0.6 - 1.0
BELT WIDTH, ft	7.9 ft	31.5 - 63.0 ft	37.7 ft
MEANDER WIDTH RATIO	0.48	2.1 - 4.2	3.4 -
SINUOSITY (K)	1.01	1.22	1.23
VALLEY SLOPE, ft/ft	0.0070 ft/ft	0.0083 ft/ft	0.0178 ft/ft
AVERAGE SLOPE (S), ft/ft	0.0071 ft/ft	0.0039 ft/ft	0.0164 ft/ft
POOL SLOPE, ft/ft	N/A	0.0014 ft/ft	0.0000 ft/ft
RATIO OF POOL SLOPE TO AVERAGE SLOPE	N/A	0.4	0.0 - 0.1
MAX POOL DEPTH, ft	2.50 ft	2.88 ft	2.78 ft
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	3.1	2.5	3.9
POOL WIDTH, ft	19.3	19.50 ft	11.47 ft
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.2	1.30	1.03
POOL TO POOL SPACING, ft	6 - 31 ft	36.0 - 82.5 ft	4.9 - 47.3 ft
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	0.4 - 1.9	2.4 - 5.5	0.4 - 4.3

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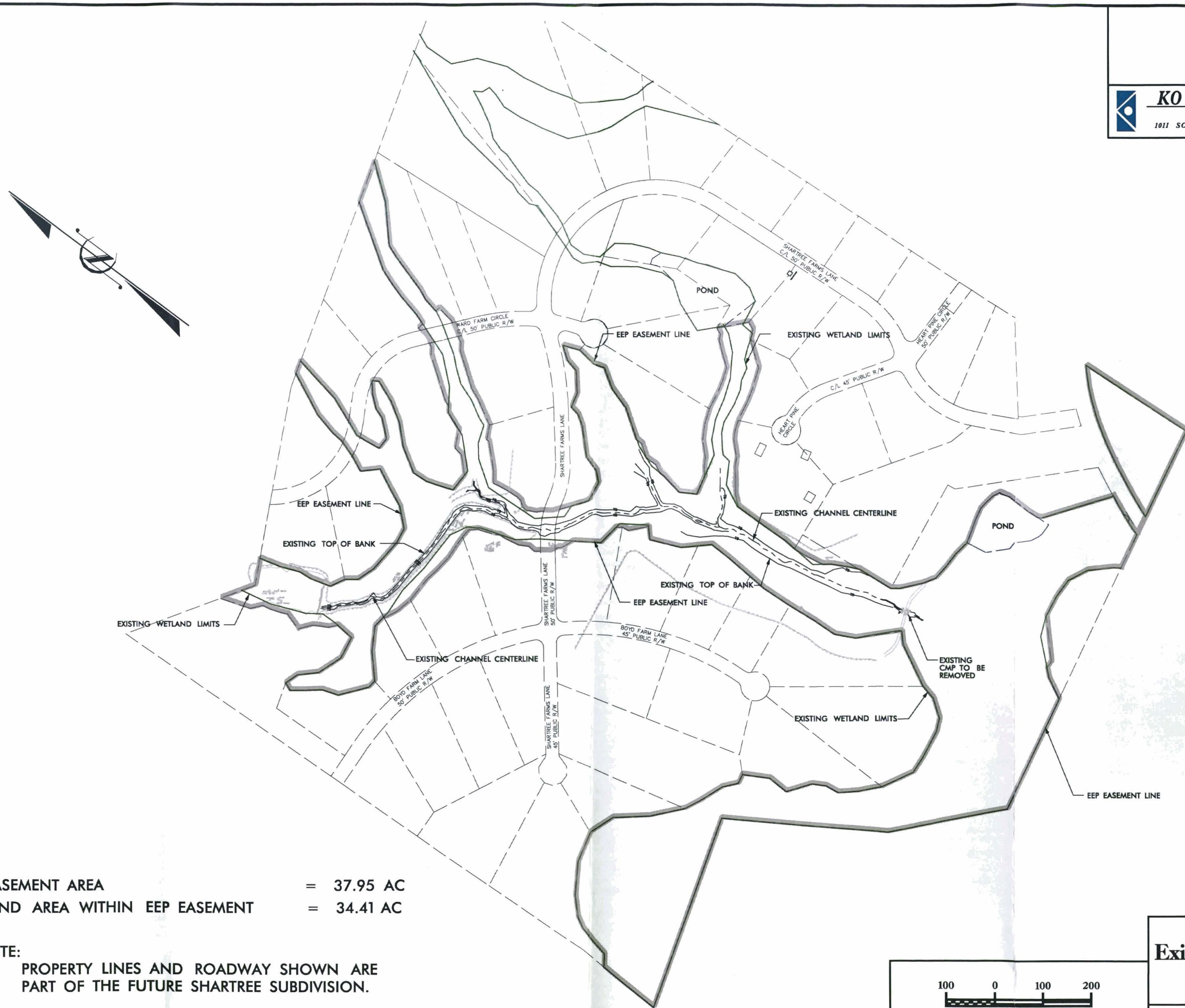

EEP EASEMENT AREA = 37.95 AC
WETLAND AREA WITHIN EEP EASEMENT = 34.41 AC

NOTE:
PROPERTY LINES AND ROADWAY SHOWN ARE PART OF THE FUTURE SHARTREE SUBDIVISION.

100 0 100 200
SCALE

EEP Easement & Existing Wetland Limits

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05 | Figure: 4.3.1

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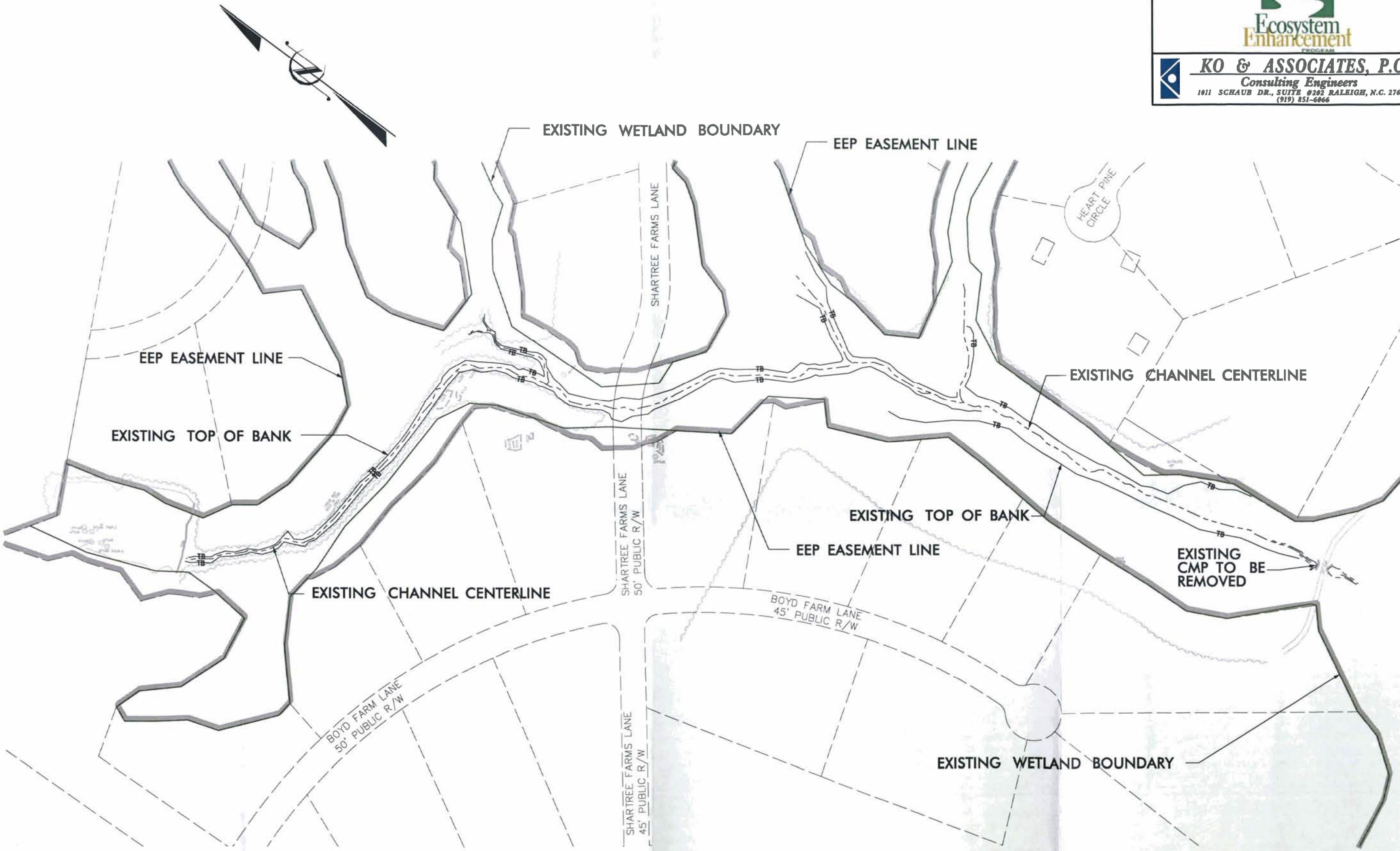


NOTE:
1.) PROPERTY LINES AND ROADWAY SHOWN ARE PART OF THE FUTURE SHARTREE SUBDIVISION.
2.) SEE FIGURE 4.3.1 FOR COMPLETE EEP EASEMENT AND WETLAND LIMITS.

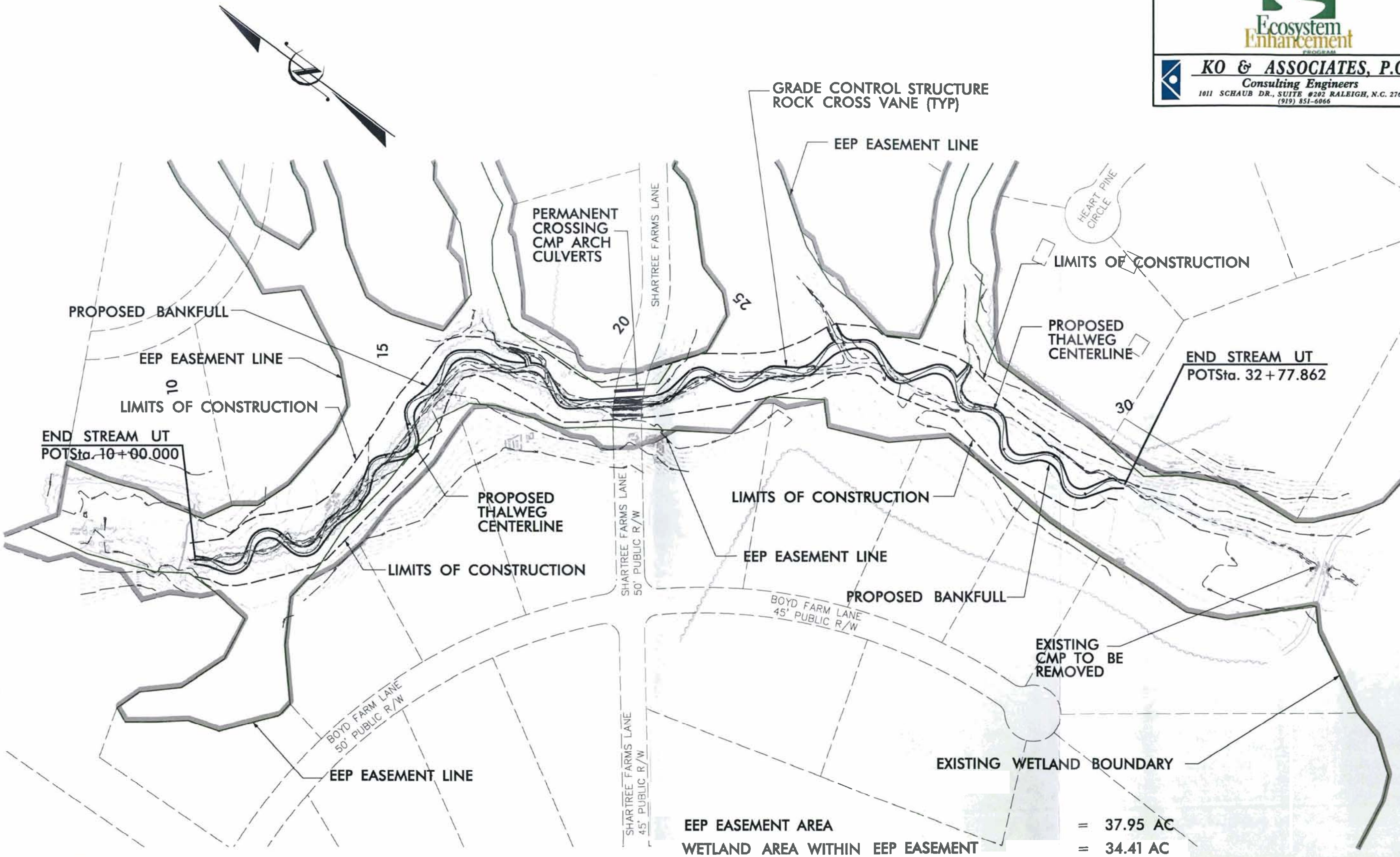
EEP EASEMENT AREA = 37.95 AC
WETLAND AREA WITHIN EEP EASEMENT = 34.41 AC

50 0 50 100
SCALE

Existing Channel Conditions

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05 Figure: 4.3.2



EEP EASEMENT AREA	=	37.95 AC
WETLAND AREA WITHIN EEP EASEMENT	=	34.41 AC
WETLAND AREA WITHIN CONSTRUCTION LIMITS	=	3.60 AC

NOTE:

1.) PROPERTY LINES AND ROADWAY SHOWN ARE PART OF THE FUTURE SHARTREE SUBDIVISION.
2.) SEE FIGURE 4.3.1 FOR COMPLETE EEP EASEMENT AND WETLAND LIMITS.

SCALE: 50 0 50 100

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Proposed Channel Alignment

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Franklin County, North Carolina

Date: 4/15/05 Figure: 4.3.3

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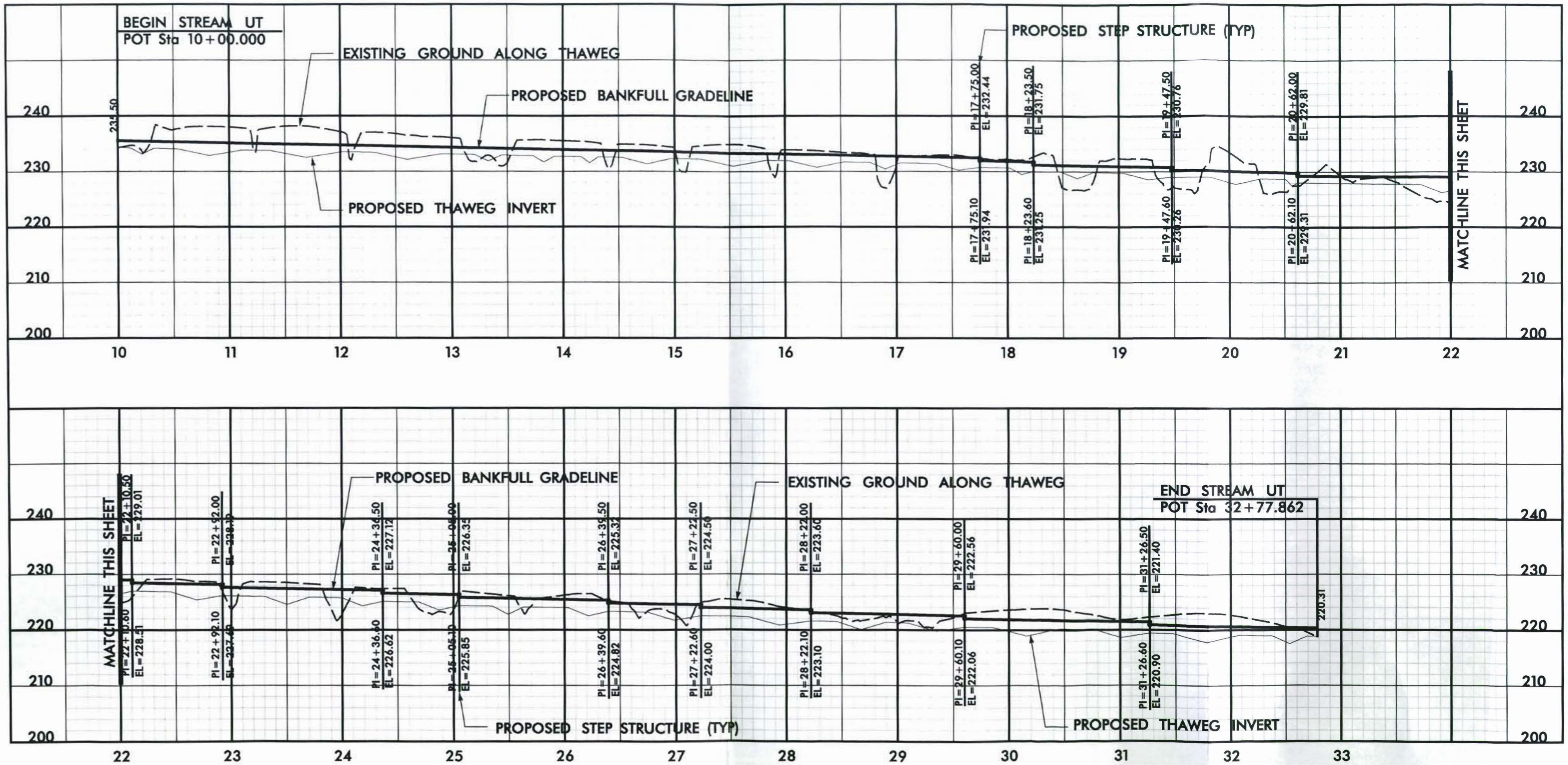


10	0	10	20

VERTICAL SCALE

50	0	50	100

HORIZONTAL SCALE

NOTE: GRADE BETWEEN DROP STRUCTURES = 0.3947%

Longitudinal Profile

Stream Restoration Plans
UT-Crooked Creek Speas Property
Franklin County, North Carolina

Date: 4/15/05 | Figure: 4.3.4

4.4 Sediment Transport Analysis

4.4.1 Methodology

The data contained within the existing conditions was obtained from a reach within an affected section of the stream located within the middle section of the project area. The affected reach was visually classified in the field as a type F5 channel, data was collected along the affected section.

This stream has been determined as having a sand bed material and entrainment calculations are not appropriate for sediment transport in sand bed systems. Determination and evaluation of the stream power is an acceptable approach in regards to sediment transport in sand bed material streams. The affected section has been classified as a F type stream; it is entrenched and has a high width to depth ratio. When converting a channel from a type F to C, the design approach is to reduce the stream power to minimize degradation. The proposed design has reduced the unit stream power from 1.53 to 1.00 (lbs/ft/s) and the shear stress from 1.96 to 0.25 (lbs/sq ft). The largest size particle recorded during the pebble count was 14mm. Using Rosgen's version of Shields Curve the shear stress to initiate movement of a 14mm particle can be as low as 0.15 (lbs/sq ft).

Therefore, the proposed type C stream will be a stable channel because the reduction of unit stream power and shear stress should hinder the existing scour/bed cutting and maintaining the shear stress above the minimum needed to initiate movement of the largest particle should avoid aggradation.

4.4.2 Calculations and Discussion

The data contained within the existing conditions was obtained from a reach within an affected section of the stream located within the middle section of the project area. The affected reach was visually classified in the field as a type F5 channel, data was collected along the affected section.

This stream has been determined as having a sand bed material and entrainment calculations are not appropriate for sediment transport in sand bed systems. Determination and evaluation of the stream power is an acceptable approach in regards to sediment transport in sand bed material streams. The affected section has been classified as an F type stream; it is entrenched and has a high width to depth ratio. When converting a channel from a type F to C, the design approach is to reduce the stream power to minimize degradation. The proposed design has reduced the unit stream power from 1.53 to 1.00 (lbs/ft/s) and the shear stress from 1.96 to 0.25 (lbs/sq ft). The largest size particle recorded during the pebble count was 14mm. Using

Rosgen's version of Shields Curve the shear stress to initiate movement of a 14mm particle can be as low as 0.15 (lbs/sq ft).

4.5 HEC-RAS

Given that the project involves modifications to a stream channel, it is important to analyze the effect of these changes on flood elevations. Floodwater elevations were analyzed using HEC-RAS. HEC-RAS is a software package designed to perform one-dimensional, steady flow, analysis of water surface profiles for a network of natural and constructed channels.

HEC-RAS uses two equations, energy and/or momentum, depending upon the water surface profile. The model is based on the energy equation. The energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is used in situations where the water surface profile rapidly varies, such as hydraulic jumps and stream junctions. The 100-year discharges were taken from the FEMA Flood Study.

Backwater analysis was performed for the existing and proposed conditions for both bankfull and 100-year discharges. In addition to steady flow data, Geometric data is also required to run HEC-RAS. Geometric data consists of establishing the connectivity of the river system, which includes: cross-section data, reach lengths, energy loss coefficients (friction losses, contraction, and expansion losses), and stream junction information.

4.5.1 Bankfull Discharge Analysis

The methodology used to evaluate the hydrologic analysis required the evaluation of the existing stream's bankfull elevation and corresponding bankfull area. In degraded systems bankfull indicators are often not present or are unreliable due to maintenance practices and the stream's degrading processes. The existing bankfull elevations and bankfull cross-sectional areas were determined by evaluating the North Carolina Piedmont Discharge Curve (Harman et al 1999).

Hydrologic Engineering Center's River Analysis System (HEC-RAS Version 3.1.2) was used to evaluate how the discharge flows within the proposed channel geometry. This evaluation verifies that the proposed plan, dimension, and profile would adequately carry the discharge at the bankfull stage, the point where water begins to overflow onto the floodplain (USACE 2001).

The discharge analysis required the evaluation of the existing stream's watershed area, bankfull area and corresponding bankfull discharge. Discharge rates for the bankfull event used in the design of this project were calculated using the piedmont regional curve.

$$Q_{bkf} = 89.04x^{0.72}; (R^2 = 0.97)$$ (Harman et al, 1999).

The bankfull discharge for the Project is approximately 61 ft^3/s. The existing bankfull velocity is approximately 4.27 ft/s. The proposed design will reduce the velocity to 3.89 ft/s and the proposed geometry, pattern and profile will reduce the shear stress and stream power from the existing condition. The existing and proposed geometries were evaluated at the bankfull discharge rates, using HEC-RAS. A HEC-RAS evaluation of the design's discharge was utilized to determine if the bankfull discharge is carried in the proposed channel's geometry. This evaluation verifies that the proposed plan, dimension, and profile would adequately carry the discharge at the bankfull stage, the point where water begins to overflow onto the floodplain.

4.5.2 No-Rise

The HEC-RAS model was used to evaluate the effect of the design on flood elevations and to ensure that the project would not increase flooding. HEC-RAS is a step-backwater software program designed to perform one-dimensional, steady flow, hydraulic calculations for water surface profiles of channels. For the study reach, 93 geometric cross-sections were modeled along the length of the existing and proposed channels. Two models, one for existing conditions and one for proposed conditions, were developed and executed to determine the water surface elevations for both the bankfull and 100-year events. The bankfull discharge is 61 cubic feet per second (cfs) and the 100-year discharge was calculated to be 500 cfs along the reach. The proposed channel adequately carries the bankfull stage. The analysis indicates that the proposed channel geometry will not increase the 100-year flood elevations within the project area. In fact, the analysis indicates that the water surface elevation will be reduced by 2.3 feet at the uptream end of the project for the 100-year flow. The bankfull analysis indicates that there will be a decrease in water surface for the middle third of the stream project. It is within this middle third where the proposed channel invert will be raised to compensate for the downcutting that has occurred in the past. However, the bankfull discharge is kept within the proposed channel for the entire reach. The results are summarized in a comparison table, which is provided in Appendix C.

4.5.3 Hydrologic Trespass

Hydrologic trespass includes any issue which may affect hydrology outside of the property boundaries on which the project is located. These issues were reviewed for this project. The beaver impoundment located at the upstream end of the project study area was an area of potential hydrologic trespass. Any modifications to the beaver impoundment could affect hydrology upstream of the impoundment, by either lowering or raising the water level. All other on-site modifications would not affect off-site hydrology.

4.6 Hydrologic Modifications

The jurisdictional wetland areas located within the project study area are slated for hydrologic and vegetative enhancement.

4.6.1 Narrative of Modifications

The wetlands currently existing within the project study area are generally herbaceous and shrub-scrub communities, lacking any overhead canopy structure. Vegetative enhancement of these areas will include planting of tree species within these areas, as outlined in Section 4.1.2. The deep rooted tree community will provide greater soil stability, as well as shade for the stream channel and hard and soft mast for wildlife.

Hydrologic modifications to the jurisdictional wetland areas will include re-attaching the channel to its floodplain, enhancing overbank flooding.

4.7 Soil Restoration

Soil grading will be a necessary part of the construction phase of this project. Topsoil, as a viable growing medium, is generally limited to the upper portions of the soil profile. As part of the construction phase of this project, soils within the project study area will be subjected to restorative activities.

4.7.1 Topsoil Stockpiling

During construction activities, existing topsoil will be stockpiled for future use. After grading activities have taken place, stockpiled soil will be placed to ensure that a viable growing medium is present within the restored area.

4.7.2 Soil Amendments

Existing soils will be tested by the contractor to determine the need of additional soil amendments beyond those typically proposed within the Erosion and Sedimentation Plan.

4.7.3 Scarification

Scarification of the soil surfaces will be conducted to enhance micro topographic relief and increase surface water storage and infiltration. Scarification will be conducted to a depth of 18 inches below the soil surface in a cross hatched pattern.

4.8 Natural Plant Community Restoration

To ensure the long term stability of the vegetative communities within the project study area, only native species will be used to revegetate the area.

4.8.1 List of Vegetation By Zone

Vegetation to be restored within the project study area is described in Section 4.1.2. Two zones are proposed and can be described as follows. The first zone includes the riparian wetland/floodplain areas. Tree species targeted for this area include tulip poplar, river birch, swamp chestnut oak, and black willow. Herbaceous species targeted for this zone include soft rush. The second zone includes the upland buffer, beyond the riparian zone. Tree species within this area include white oak, willow oak, short leaf pine, and American beech. Flowering dogwood will be interspersed throughout this community.

5.0 PERFORMANCE CRITERIA AND MONITORING PLAN

The restoration success criteria, and any required remediation actions, will be generally based on Appendix II of the "Stream Mitigation Guidelines (April 2003).

5.1 Streams

Permanent cross section locations will be established within the restored channel, two in riffles and two in pools. Survey of the longitudinal profile will be conducted. This information will be used to verify channel stability.

Permanent photo-reference points will be established to give visual documentation of success over time. This documentation will be used to determine the extent of any aggradation/degradation of the stream channel, bank erosion, and formation of any in-stream bars.

At the request of EEP, macrobenthos monitoring will not be undertaken within this channel.

5.2 Vegetation

Three permanent vegetation plots will be established within the vegetation restoration area. Yearly monitoring will be conducted. Success of live stakes will require a 70% survival rates, averaging 260 stems per acre at the end of year 5.

6.0 REFERENCES

[DWQ] Division of Water Quality. 2004. Tar-Pamlico River Basinwide Water Quality Plan. N.C. Department of Environment and Natural Resources, Raleigh. 222 pp. + appendices.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press, Chapel Hill. 1183 pp.

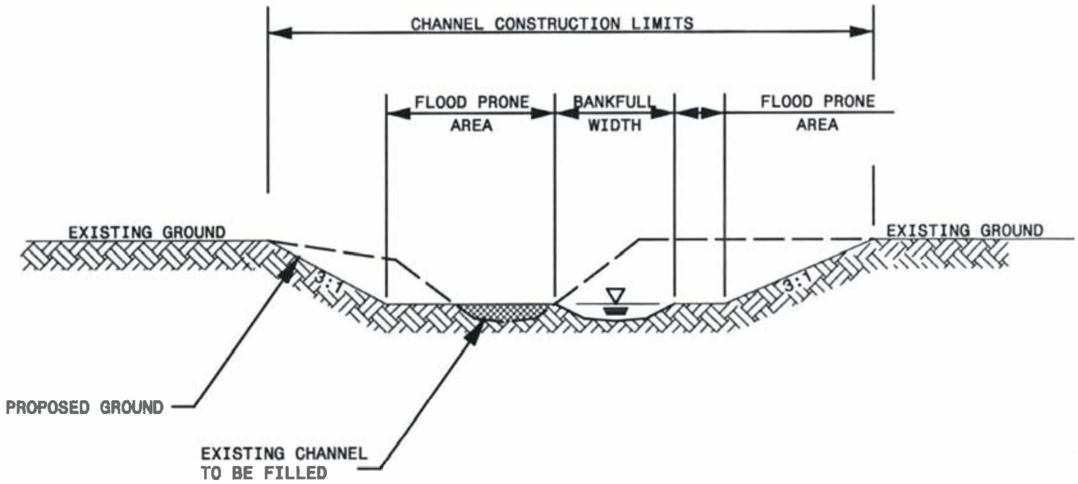
Rosgen, D. 1996. Applied River Morphology. Printed Media Companies. Minneapolis, Mn. 364 pp.

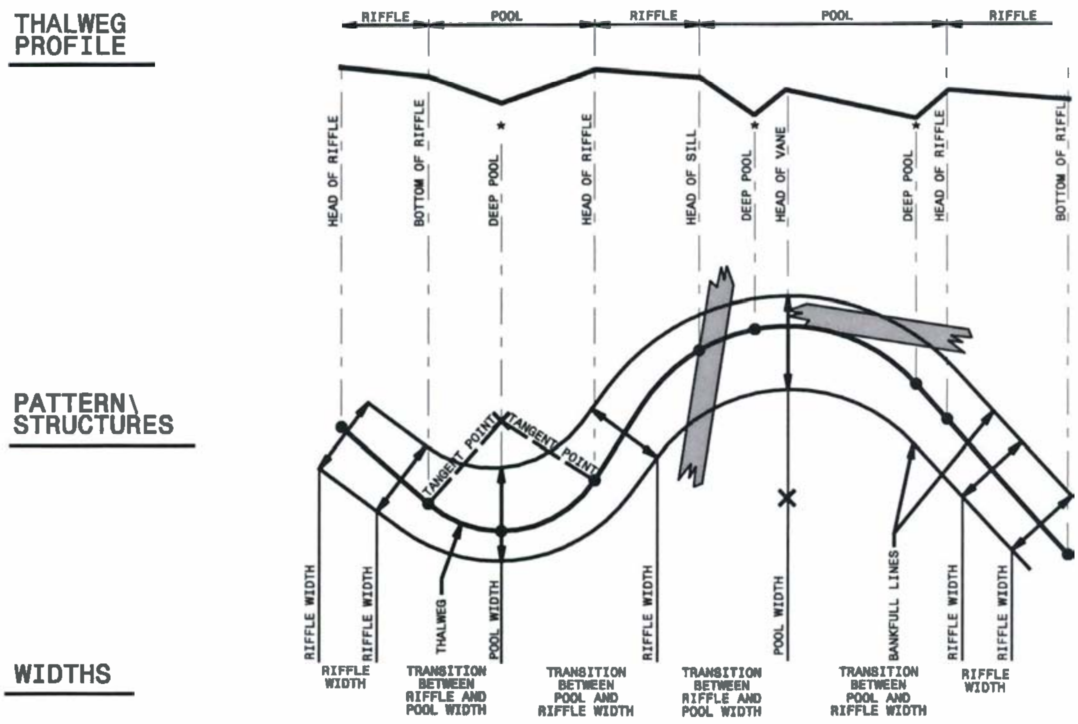
[USDA] U.S. Department of Agriculture. Unpublished. Soil Survey of Franklin County, North Carolina. U.S. Department of Agriculture.

[USGS] U.S. Geological Survey. 1968. Bunn West, NC, 7.5-Minute Topographic Quadrangle

[USGS] U.S. Geological Survey. 1974. Hydrologic Unit Map.

U.S. Army Corps of Engineers, 2003. Stream Mitigation Guidelines. 26 pp. + appendices.





* NOTE: REFER TO PROFILE, SHEETS -- AND -- FOR DEEP POOL LOCATIONS

SCALE: Not To Scale

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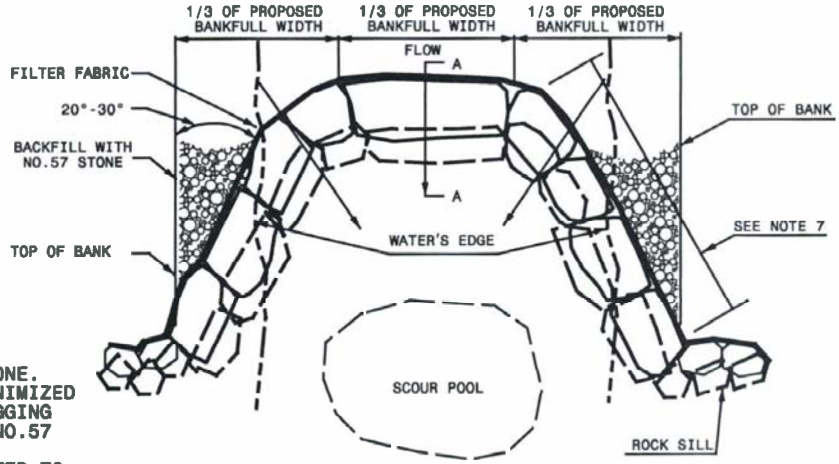
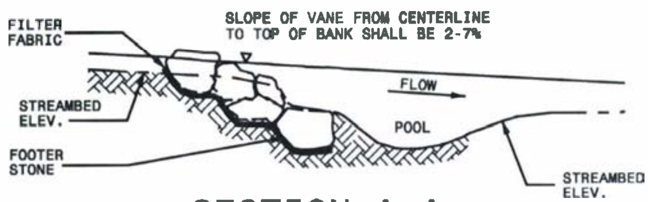
Date:	4/15/05	**Figure:**	7.1

ROCK CROSS VANE



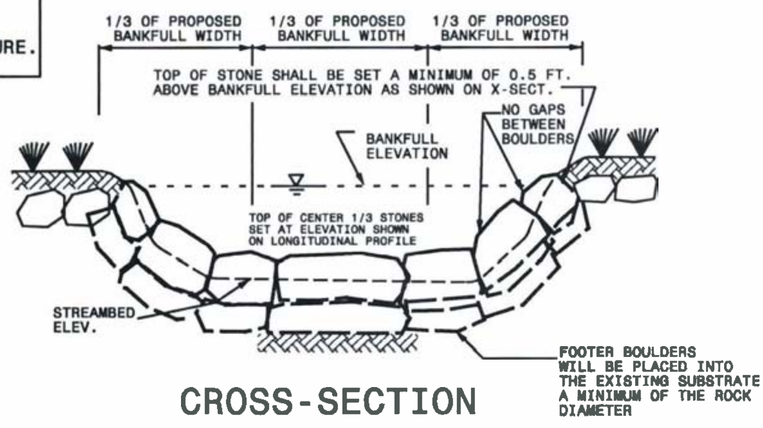
NOTES:

1. ALL STONES ARE TO BE STRUCTURE STONE.
2. GAPS BETWEEN BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER, PLUGGING WITH STRUCTURE STONE CLASS A AND NO.57 AND LINING WITH FILTER FABRIC.
3. DIMENSIONS AND SLOPES MAYBE ADJUSTED TO FIT BY THE ENGINEER.
4. A DOUBLE FOOTER BOULDER SHALL BE UTILIZED IN SAND BED MATERIAL.
5. CONTRACTOR WILL BE REQUIRED TO FIT BOULDERS TIGHTLY.
6. FOOTER BOULDERS AND VANE BOULDERS SHALL BE NATIVE STONE OR SHOT ROCK, CUBICAL OR RECTANGULAR IN NATURE.
7. SLOPE OF VANE FROM CENTERLINE TO TOP OF BANK SHALL BE 2-7%.



SECTION A-A

FILTER FABRIC SHALL BE PLACED ON THE UPSTREAM SIDE OF THE STRUCTURE TO PREVENT WASHOUT OF SEDIMENT THROUGH BOULDER GAPS. FILTER FABRIC SHALL EXTEND FROM THE BOTTOM OF THE FOOTER BOULDER TO THE FINISHED GRADE ELEVATION AND SHALL BE PLACED THE ENTIRE LENGTH OF STRUCTURE.



CROSS-SECTION

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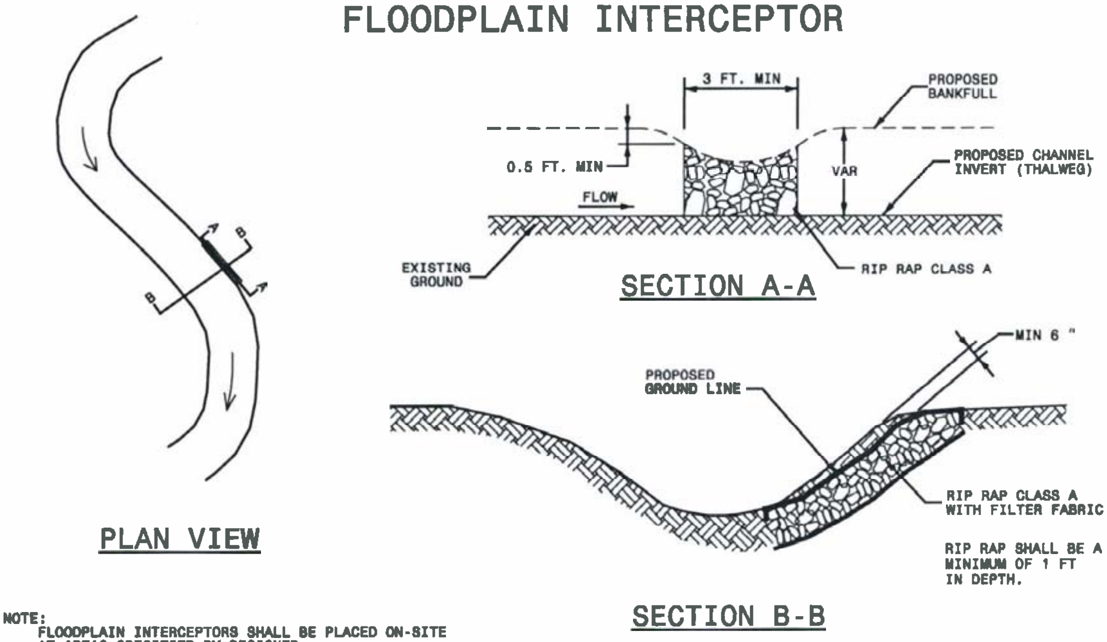
Stream Restoration Plans
UT–Crooked Creek Speas Property
Franklin County, North Carolina

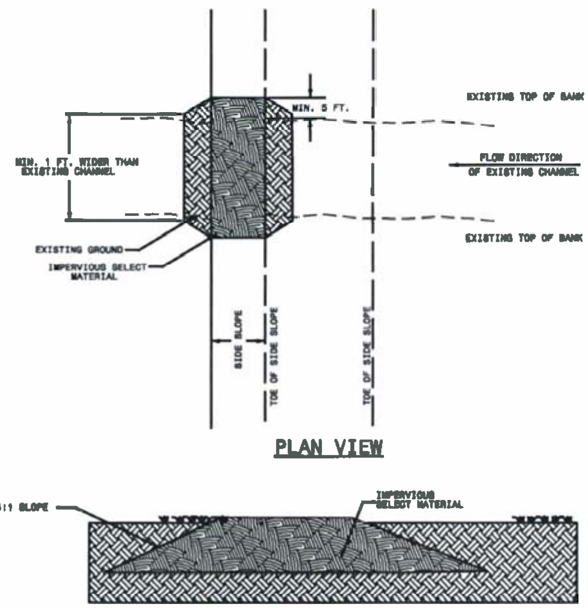
Date: 4/15/05	**Figure:** 7.2

FLOODPLAIN INTERCEPTOR



NOTE:
FLOODPLAIN INTERCEPTORS SHALL BE PLACED ON-SITE AT AREAS SPECIFIED BY DESIGNER.

IMPERVIOUS DITCH PLUG



CROSS-SECTION

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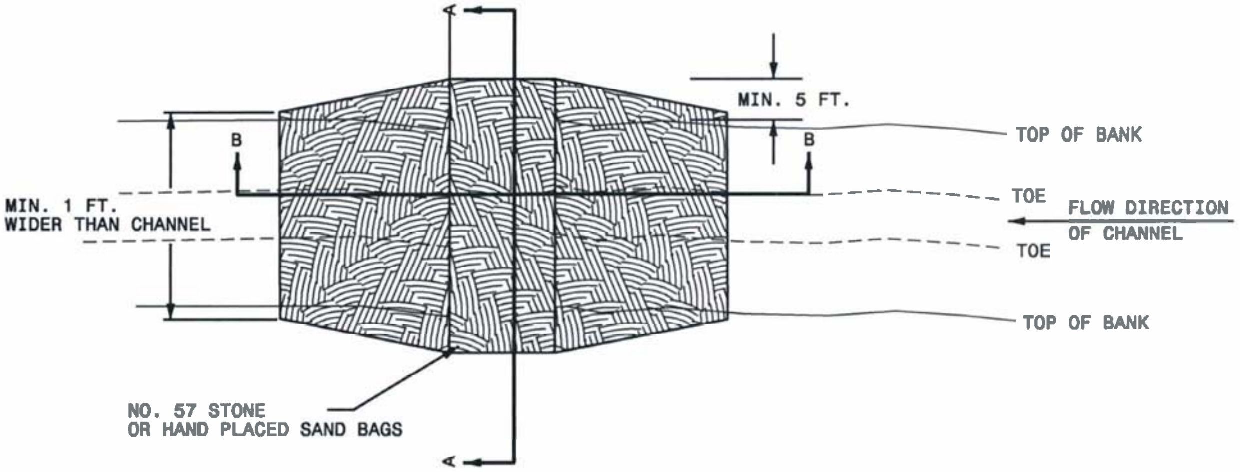
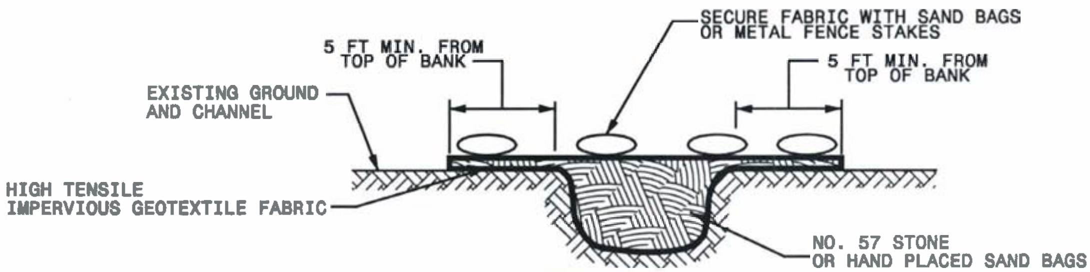
Date: 4/15/05	Figure: 7.3

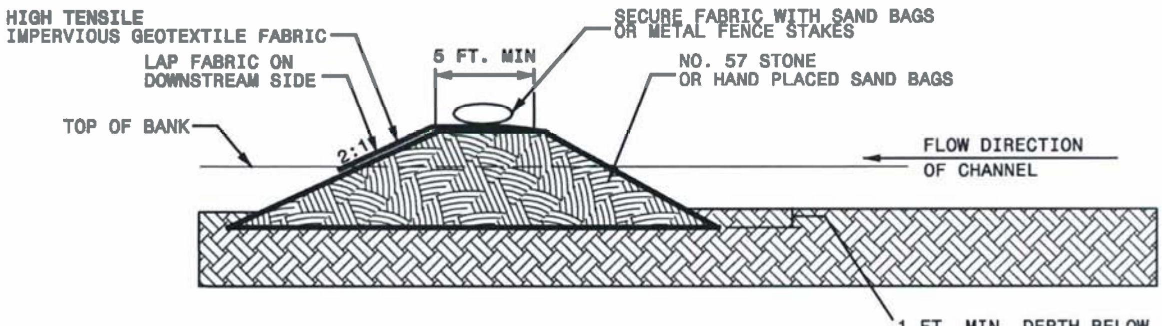
TEMPORARY IMPERVIOUS STREAM CHANNEL PLUG



PLAN VIEW



SECTION A-A



SECTION B-B

SCALE: Not To Scale

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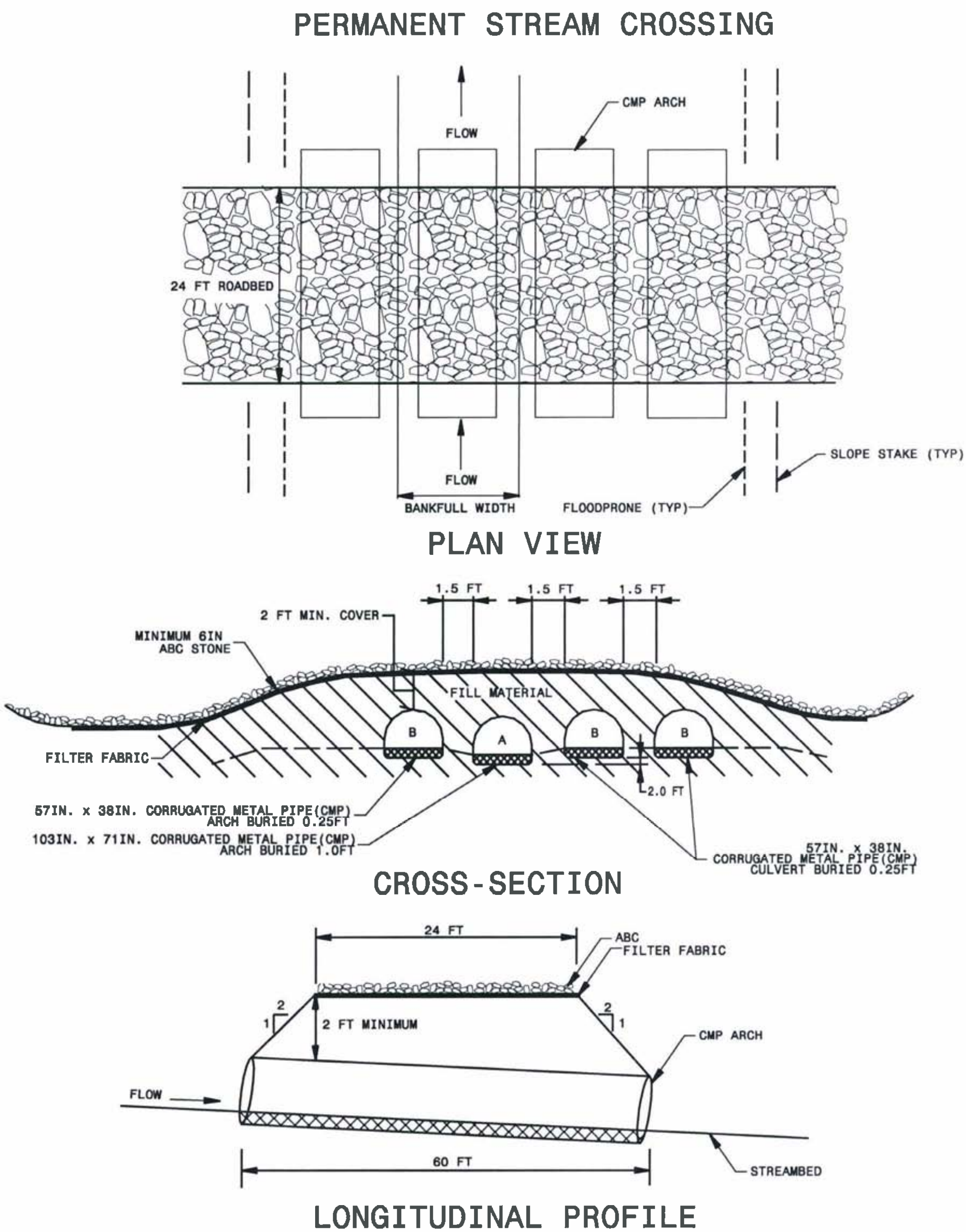
Date: 4/15/05	Figure: 7.4



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Franklin County, North Carolina

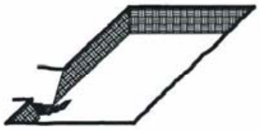
Date: 4/15/05	Figure: 7.5

PLANTING DETAILS

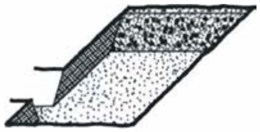
SEEDLING / LINER BAREROOT PLANTING DETAIL

HEALING IN

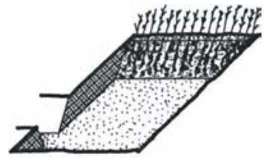
1. Locate a healing-in site in a shady, well protected area.
2. Excavate a flat bottom trench 12IN. deep and provide drainage.



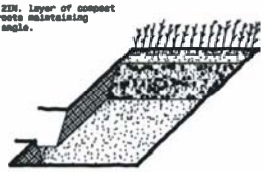
3. Backfill the trench with 2IN. of compost. Place a 2IN. layer compost at a sloping angle at one end of the trench.



4. Place a single layer of plants against the sloping end so that the root collar is at ground level.



5. Place a 2IN. layer of compost over the roots maintaining a sloping angle.



6. Repeat layers of plants and compost as necessary and water thoroughly.

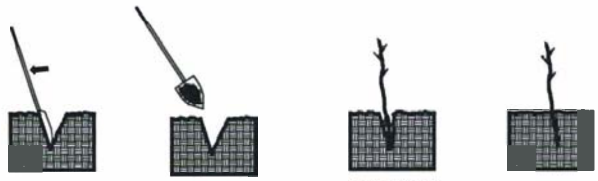
TREE REFORESTATION SHALL BE PLANTED 13' ON CENTER, RANDOM SPACING, AVERAGING 8' ON CENTER, APPROXIMATELY 260 PLANTS PER ACRE.

PLANTING NOTES:

PLANTING BAG
During planting, seedlings shall be kept in a moist canvas bag or similar container to prevent the root systems from drying.

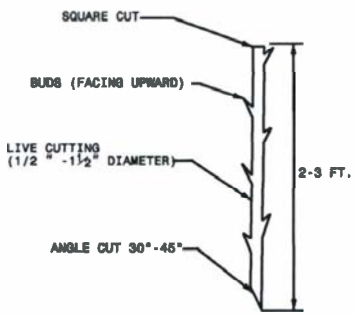
ROOT PRUNING
All seedlings shall be root pruned, if necessary, so that no roots extend more than 24inches (24IN.) below the root collar.

PLANTING METHOD USING A SHOVEL

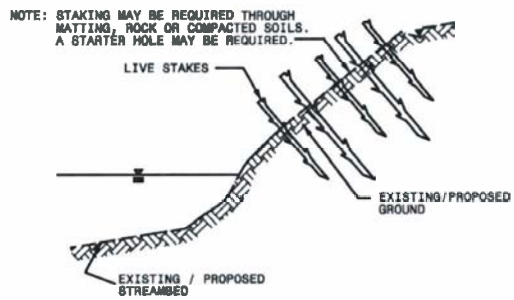


1. Dig hole with shovel
2. Remove soil from hole with shovel. Hole shall not be made by compacting soil away from the hole.
3. Remove shovel and place seedling at correct depth.
4. Fill hole with soil. Tamp soil to remove air pockets. Water Thoroughly.

LIVE STAKE DETAIL



LIVE STAKE



NOTE:
1. LIVE STAKES SHALL BE EVENLY SPACED 4 FT. APART.
2. LIVE STAKES SHALL BE DRIVEN UNTIL APPROXIMATELY ¾ OF LIVE STAKE IS WITHIN GROUND.
3. IF STARTER HOLE IS NEEDED, MINIMIZE AIR POCKET.
4. UTILIZE ALL ON SITE TRANSPLANT MATERIALS MADE AVAILABLE BY THE OWNER. ONCE SOURCE OF TRANSPLANT MATERIAL HAS BEEN HARVESTED, THEN UTILIZE LIVE STAKING.

BANK STABILIZATION WITH LIVE STAKES

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Date:	4/15/05	Figure:	7.6

FIGURES

APPENDICES

APPENDIX A
RESTORATION SITE PHOTOGRAPHS

Existing Channel Looking Upstream Near Downstream Limits of Project

Existing Overbank Area in Middle Section of Project

Existing Channel Along Upper Section of Project

Existing Channel Along Upper Section of Project

Existing Channel Along Upper Section of Project

Existing Channel Along Upper Section of Project

Existing Channel Looking Downstream at the Top of Beaver Dam

Pond Created by Beaver Dam at Upstream Limits of Project

APPENDIX B
EXISTING CHANNEL DATA

Existing Data

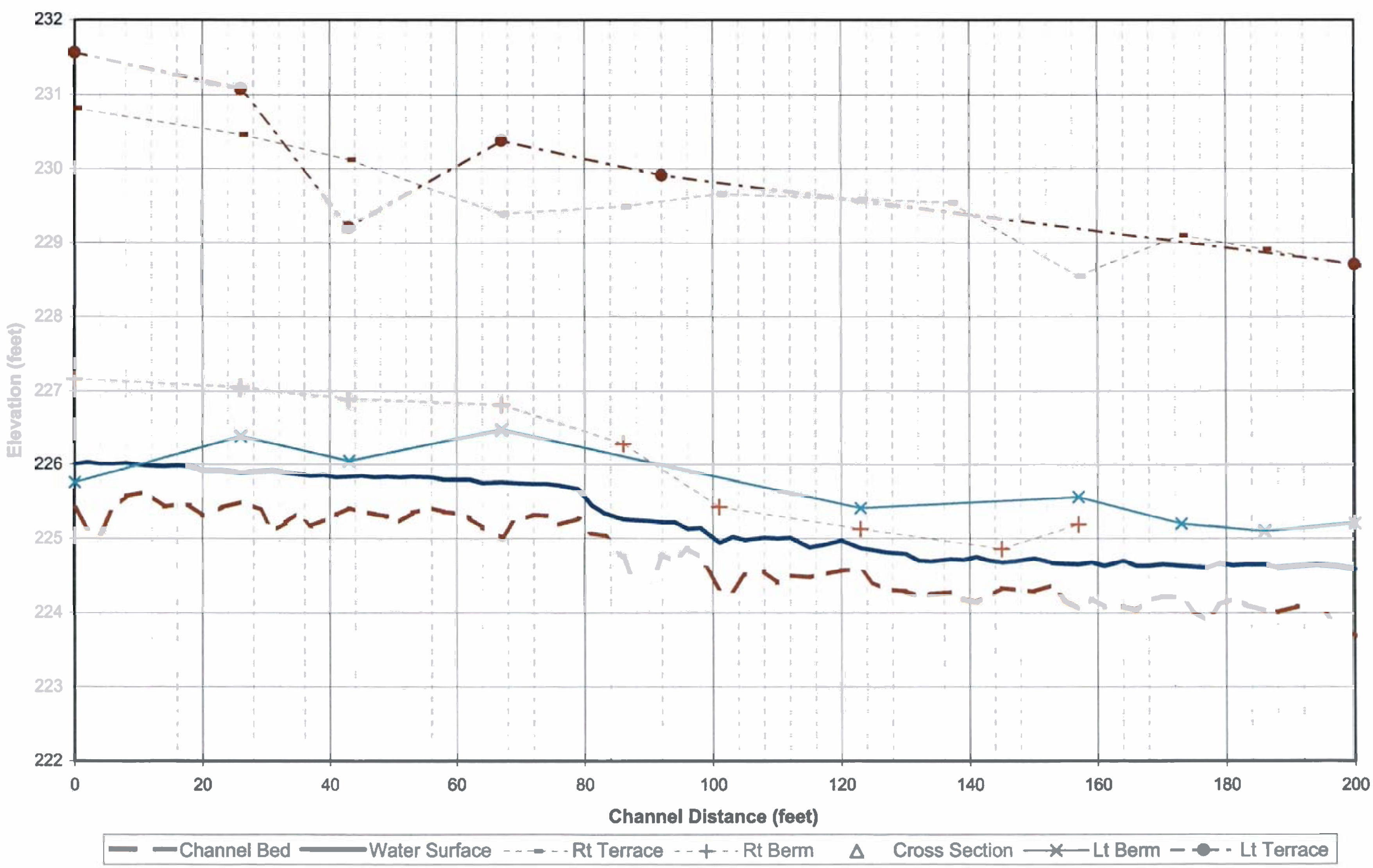
Basin:	Tar River	Channel Slope:	0.71 %
Reach:	UT TO CROOKED CREEK	Stream Length:	200 ft
Observers:	RKW, WHT, TJC	Valley Length:	197.4 ft
Channel Type:	F5	Sinousity:	1.01
Drainage Area (sq mi):	0.5328	Meander Length:	NA ft
		Belt Width:	7.9 ft
		Radius of Curvature:	NA ft

Longitudinal Data

Station	Elevation Streambed	Elevation Water Surface	Top of Rt Berm	Top of Rt Bank	Top of Lt Berm	Top of Lt Bank
0	225.41	226.01	227.16	230.81	225.76	231.56
2	225.14	226.03				
4	225.07	226.01				
6	225.41	226.01				
8	225.57	226.02				
11	225.63	225.99				
14	225.43	225.98				
16	225.46	225.99				
18	225.45	225.98				
20	225.31	225.92				
23	225.42	225.92				
26	225.49	225.89	227.05	230.46	226.38	231.07
29	225.39	225.91				
31	225.10	225.92				
33	225.21	225.89				
35	225.35	225.87				
37	225.17	225.85				
39	225.25	225.86				
41	225.32	225.83				
43	225.41	225.84	226.89	230.12	226.05	229.21
45	225.36	225.85				
47	225.33	225.83				
49	225.30	225.84				
51	225.23	225.83				
53	225.35	225.84				
56	225.41	225.83				
58	225.36	225.80				
60	225.34	225.80				
62	225.28	225.80				
64	225.15	225.75				
67	225.01	225.76	226.81	229.39	226.47	230.38
69	225.24	225.75				
72	225.32	225.74				
74	225.31	225.74				
76	225.19	225.72				
79	225.27	225.67				
81	225.07	225.45				
83	225.04	225.34				
86	224.76	225.26	226.28	229.49		
88	224.33	225.25				
90	224.29	225.24				
92	224.78	225.22				229.91
94	224.69	225.22				
96	224.87	225.13				
98	224.75	225.14				

Station	Elevation Streambed	Elevation Water Surface	Top of Rt Berm	Top of Rt Bank	Top of Lt Berm	Top of Lt Bank
98	224.75	225.14				
101	224.33	224.94	225.43	229.66		
103	224.30	225.02				
105	224.51	224.98				
108	224.56	225.01				
110	224.40	225.00				
112	224.50	225.01				
115	224.48	224.88				
117	224.51	224.91				
120	224.57	224.97				
123	224.58	224.87	225.13	229.59	225.41	
125	224.40	224.84				
127	224.31	224.81				
130	224.29	224.79				
132	224.22	224.70				
134	224.25	224.69				
137	224.27	224.72		229.54		
139	224.18	224.71				
141	224.14	224.75				
143	224.22	224.70				
145	224.33	224.68	224.86			
147	224.31	224.69				
150	224.28	224.73				
153	224.37	224.67				
155	224.16	224.66				
157	224.05	224.65	225.19	228.55	225.56	
159	224.19	224.68				
161	224.08	224.63				
164	224.08	224.70				
166	224.03	224.63				
168	224.17	224.63				
170	224.22	224.65				
173	224.21	224.63		229.10	225.20	
175	224.02	224.62				
177	223.89	224.61				
179	224.12	224.67				
181	224.19	224.64				
183	224.11	224.65				
186	224.03	224.65		228.91	225.10	
188	224.01	224.61				
191	224.08	224.63				
194	224.15	224.65				
197	223.83	224.63				
200	223.69	224.59		228.69	225.21	228.71

UT to Crooked Creek Existing Longitudinal Profile



Existing Data

Basin:	Tar River
Reach:	UT TO CROOKED CREEK
Observers:	RKW, WHT, TJC
Channel Type:	F5
Drainage Area (sq mi):	0.5328

Riffle Cross-Sectional Data

Station	Elevation
0	229.93
5.1	229.59
8.3	229.3
11.3	226.78
13.3	226.24
19	225.87
20.6	225.53
22.3	224.94
23	224.66
23.3	224.57
24	224.56
24.2	224.52
25.1	224.61
25.2	224.98
25.7	225.27
27.1	225.65
28.2	226.21
29.5	226.59
31.5	226.84
32.6	228.24
33.1	229.75
44.7	230.21

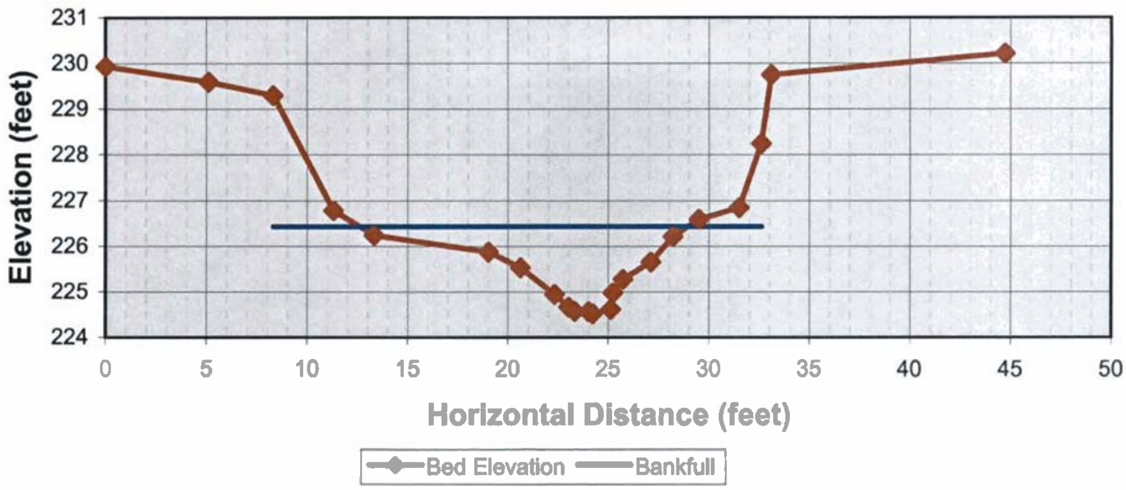
Bankfull Area	13.3 sq.ft
Bankfull Width	16.4 ft
Max depth	1.9 ft
Mean depth	0.8 ft
Width/Depth Ratio	20.2
Flood Prone Width	24.8 ft
Entrenchment Ratio	1.5

Pool

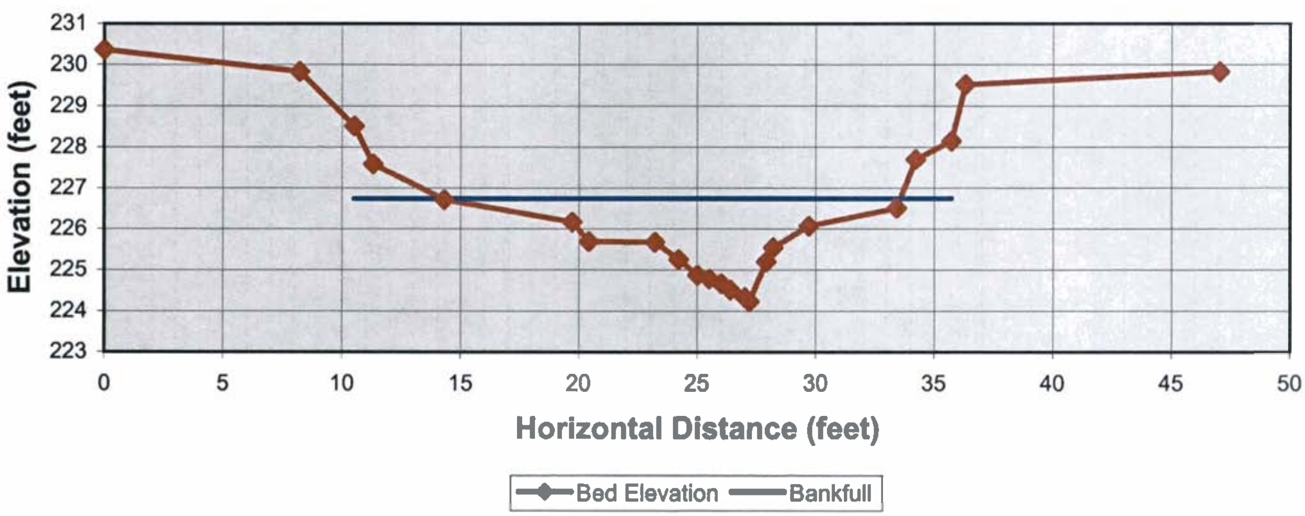
Station	Elevation
0	230.36
8.2	229.83
10.5	228.51
11.3	227.59
14.3	226.71
19.7	226.16
20.4	225.69
23.2	225.67
24.2	225.25
25	224.87
25.5	224.78
26	224.67
26.4	224.51
27	224.33
27.2	224.23
27.9	225.2
28.2	225.54
29.7	226.06
33.4	226.5
34.2	227.7
35.7	228.14
36.3	229.51
47	229.82

Bankfull Area	17.3 sq.ft
Bankfull Width	19.3 ft
Max depth	2.5 ft
Mean depth	0.9 ft

UT to Crooked Creek Existing Riffle Cross-Section



UT to Crooked Creek Existing Pool Cross-Section



APPENDIX C
HEC-RAS DATA

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
1000.01	Bankfull	63.1	221.02	220.22	-0.8
1000.01	100 Yr	500	223.1	222.17	-0.93
1025.52	Bankfull	63.1	221.2	220.46	-0.74
1025.52	100 Yr	500	223.35	222.78	-0.57
1034.15	Bankfull	63.1	221.37	220.67	-0.7
1034.15	100 Yr	500	223.4	223.08	-0.32
1057.17	Bankfull	63.1	221.49	220.55	-0.94
1057.17	100 Yr	500	223.86	222.97	-0.89
1097.9	Bankfull	63.1	221.51	220.82	-0.69
1097.9	100 Yr	500	224.07	223.32	-0.75
1133.82	Bankfull	63.1	222.07	220.66	-1.41
1133.82	100 Yr	500	224.3	223.28	-1.02
1147.24	Bankfull	63.1	222.19	220.86	-1.33
1147.24	100 Yr	500	224.35	223.31	-1.04
1149.35	Bankfull	63.1	222.19	220.8	-1.39
1149.35	100 Yr	500	224.35	223.13	-1.22
1162.93	Bankfull	63.1	222.1	221.16	-0.94
1162.93	100 Yr	500	224.25	223.54	-0.71
1193.55	Bankfull	63.1	222.22	221.27	-0.95
1193.55	100 Yr	500	224.44	223.25	-1.19
1222.13	Bankfull	63.1	222.33	221.76	-0.57
1222.13	100 Yr	500	224.6	224.01	-0.59
1257.39	Bankfull	63.1	222.59	221.57	-1.02
1257.39	100 Yr	500	225.11	223.94	-1.17
1278.25	Bankfull	63.1	222.72	221.91	-0.81
1278.25	100 Yr	500	225.15	224.16	-0.99
1280.35	Bankfull	63.1	222.67	221.85	-0.82
1280.35	100 Yr	500	225.17	223.89	-1.28
1300.64	Bankfull	63.1	222.79	222.18	-0.61
1300.64	100 Yr	500	225.19	224.56	-0.63
1336.37	Bankfull	63.1	223	222.32	-0.68
1336.37	100 Yr	500	225.37	224.4	-0.97

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
1364.57	Bankfull	63.1	222.96	222.81	-0.15
1364.57	100 Yr	500	225.33	224.87	-0.46
1395.12	Bankfull	63.1	223.25	222.64	-0.61
1395.12	100 Yr	500	225.56	224.66	-0.9
1418.21	Bankfull	63.1		223.02	223.02
1418.21	100 Yr	500		225.38	225.38
1440.51	Bankfull	63.1	223.34	222.83	-0.51
1440.51	100 Yr	500	225.79	225.3	-0.49
1455.75	Bankfull	63.1	223.44	223.08	-0.36
1455.75	100 Yr	500	225.8	225.34	-0.46
1457.35	Bankfull	63.1	223.43	223.01	-0.42
1457.35	100 Yr	500	225.78	225.13	-0.65
1484.81	Bankfull	63.1	223.53	223.38	-0.15
1484.81	100 Yr	500	225.57	225.59	0.02
1526.94	Bankfull	63.1	223.68	223.55	-0.13
1526.94	100 Yr	500	226.12	225.6	-0.52
1540.75	Bankfull	63.1	223.75	223.89	0.14
1540.75	100 Yr	500	226.14	225.94	-0.2
1542.35	Bankfull	63.1	223.75	223.82	0.07
1542.35	100 Yr	500	226.07	225.96	-0.11
1562.51	Bankfull	63.1	223.79	224.19	0.4
1562.51	100 Yr	500	226.29	226.45	0.16
1599.66	Bankfull	63.1	223.88	224.32	0.44
1599.66	100 Yr	500	226.78	226.35	-0.43
1627.5	Bankfull	63.1	224	224.81	0.81
1627.5	100 Yr	500	227.07	226.79	-0.28
1654.78	Bankfull	63.1	224.4	224.63	0.23
1654.78	100 Yr	500	227.12	226.53	-0.59
1680.26	Bankfull	63.1	224.51	225.02	0.51
1680.26	100 Yr	500	226.99	227.19	0.2
1711.26	Bankfull	63.1	224.72	224.85	0.13
1711.26	100 Yr	500	227.76	227.17	-0.59

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
1730.75	Bankfull	63.1	224.45	225.12	0.67
1730.75	100 Yr	500	227.79	227.41	-0.38
1732.35	Bankfull	63.1	224.67	225.06	0.39
1732.35	100 Yr	500	227.79	227.3	-0.49
1739	Bankfull	63.1	224.79	225.38	0.59
1739	100 Yr	500	227.81	227.68	-0.13
1768.08	Bankfull	63.1	225.05	225.46	0.41
1768.08	100 Yr	500	227.74	227.52	-0.22
1789.75	Bankfull	63.1	225.16	225.88	0.72
1789.75	100 Yr	500	227.86	226.55	-1.31
1791.35	Bankfull	63.1	225.18	225.82	0.64
1791.35	100 Yr	500	227.88	227.68	-0.2
1802.9	Bankfull	63.1	225.15	226.12	0.97
1802.9	100 Yr	500	227.78	228.05	0.27
1842.57	Bankfull	63.1	225.16	226.25	1.09
1842.57	100 Yr	500	227.8	228.03	0.23
1868.75	Bankfull	63.1	225.27	226.7	1.43
1868.75	100 Yr	500	227.9	228.33	0.43
1870.35	Bankfull	63.1	225.27	226.65	1.38
1870.35	100 Yr	500	227.91	228.39	0.48
1883.32	Bankfull	63.1	225.29	226.93	1.64
1883.32	100 Yr	500	227.97	228.75	0.78
1924.14	Bankfull	63.1	225.38	227.06	1.68
1924.14	100 Yr	500	228.54	228.85	0.31
1963.78	Bankfull	63.1	225.17	227.57	2.4
1963.78	100 Yr	500	227.21	229.21	2
2012.69	Bankfull	63.1	225.72	227.39	1.67
2012.69	100 Yr	500	229.28	229.51	0.23
2048.75	Bankfull	63.1	226.25	227.92	1.67
2048.75	100 Yr	500	229.44	229.66	0.22
2050.35	Bankfull	63.1	226.26	227.86	1.6
2050.35	100 Yr	500	229.44	229.87	0.43

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
2065.89	Bankfull	63.1	226.35	228.14	1.79
2065.89	100 Yr	500	229.51	230.29	0.78
2101.75	Bankfull	63.1	226.54	228.24	1.7
2101.75	100 Yr	500	229.6	229.41	-0.19
2121.75	Bankfull	63.1	226.8	228.65	1.85
2121.75	100 Yr	500	230.21	232.14	1.93
2123.35	Bankfull	63.1	226.81	228.59	1.78
2123.35	100 Yr	500	230.22	232.13	1.91
2130.29	Bankfull	63.1	226.8	228.88	2.08
2130.29	100 Yr	500	230.12	232.13	2.01
2160.92	Bankfull	63.1	226.91	228.97	2.06
2160.92	100 Yr	500	230.34	232.04	1.7
2191		Culvert			
2221.28	Bankfull	63.1	227.64	229.85	2.21
2221.28	100 Yr	500	230.18	234.29	4.11
2257.2	Bankfull	63.1	227.91	229.92	2.01
2257.2	100 Yr	500	230.37	234.3	3.93
2277.19	Bankfull	63.1	228.06	229.89	1.83
2277.19	100 Yr	500	231.42	234.3	2.88
2292.75	Bankfull	63.1	228.07	229.92	1.85
2292.75	100 Yr	500	231.42	234.3	2.88
2294.35	Bankfull	63.1	228.09	229.82	1.73
2294.35	100 Yr	500	231.44	234.29	2.85
2309.5	Bankfull	63.1	228.09	230.04	1.95
2309.5	100 Yr	500	231.22	234.3	3.08
2350.67	Bankfull	63.1	228.26	230.16	1.9
2350.67	100 Yr	500	232.02	234.27	2.25
2374.75	Bankfull	63.1	228.21	230.58	2.37
2374.75	100 Yr	500	231.91	234.29	2.38
2376.35	Bankfull	63.1	228.22	230.46	2.24
2376.35	100 Yr	500	231.76	234.28	2.52
2393.03	Bankfull	63.1	228.35	230.79	2.44
2393.03	100 Yr	500	231.95	234.34	2.39

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
2430.96	Bankfull	63.1	228.44	230.94	2.5
2430.96	100 Yr	500	232.28	234.33	2.05
2458.81	Bankfull	63.1	228.31	231.41	3.1
2458.81	100 Yr	500	231.64	234.42	2.78
2487.16	Bankfull	63.1	228.93	231.28	2.35
2487.16	100 Yr	500	232.72	234.43	1.71
2505.75	Bankfull	63.1	228.99	231.51	2.52
2505.75	100 Yr	500	233.27	234.44	1.17
2507.32	Bankfull	63.1	229.01	231.42	2.41
2507.32	100 Yr	500	233.32	234.42	1.1
2512.43	Bankfull	63.1	229.03	231.7	2.67
2512.43	100 Yr	500	233.33	234.48	1.15
2537.56	Bankfull	63.1	229.13	231.85	2.72
2537.56	100 Yr	500	233.34	234.39	1.05
2557.75	Bankfull	63.1	229.14	232.27	3.13
2557.75	100 Yr	500	233.25	234.47	1.22
2559.35	Bankfull	63.1	229.12	232.15	3.03
2559.35	100 Yr	500	233.2	234.33	1.13
2573.24	Bankfull	63.1	229.12	232.47	3.35
2573.24	100 Yr	500	233.1	234.56	1.46
2604.38	Bankfull	63.1	229.25	232.71	3.46
2604.38	100 Yr	500	233.64	234.46	0.82
2632.74	Bankfull	63.1	229.39	233.07	3.68
2632.74	100 Yr	500	233.41	234.97	1.56
2661.31	Bankfull	63.1	228.89	232.91	4.02
2661.31	100 Yr	500	233.85	234.77	0.92
2694.51	Bankfull	63.1	230.41	233.3	2.89
2694.51	100 Yr	500	233.12	235.49	2.37
2764.88	Bankfull	63.1	231.34	233.34	2
2764.88	100 Yr	500	235.37	235.61	0.24
2811.96	Bankfull	63.1	231.67	233.4	1.73
2811.96	100 Yr	500	235.81	235.5	-0.31

UT CROOKED CREEK HEC-RAS ANALYSIS

River Station	Storm	Discharge (cfs)	Existing WSEL (ft)	Proposed WSEL (ft)	Backwater (ft)
2858.56	Bankfull	63.1	232.22	233.9	1.68
2858.56	100 Yr	500	236.1	236.04	-0.06
2947.15	Bankfull	63.1	233.12	233.97	0.85
2947.15	100 Yr	500	236.41	236.21	-0.2
3000.4	Bankfull	63.1	233.7	234.11	0.41
3000.4	100 Yr	500	237.75	236.07	-1.68
3035.88	Bankfull	63.1	232.96	234.6	1.64
3035.88	100 Yr	500	237.44	236.63	-0.81
3074.26	Bankfull	63.1	234.53	234.44	-0.09
3074.26	100 Yr	500	238.14	236.57	-1.57
3116.99	Bankfull	63.1	235.33	234.89	-0.44
3116.99	100 Yr	500	238.8	237.09	-1.71
3142.92	Bankfull	63.1	235.23	234.7	-0.53
3142.92	100 Yr	500	238.87	236.94	-1.93
3179.63	Bankfull	63.1	235.42	235.14	-0.28
3179.63	100 Yr	500	239.37	237.49	-1.88
3219.27	Bankfull	63.1	235.52	234.98	-0.54
3219.27	100 Yr	500	239.66	237.42	-2.24
3262.98	Bankfull	63.1	235.34	235.46	0.12
3262.98	100 Yr	500	239.6	237.74	-1.86
3300.06	Bankfull	63.1	236.24	235.29	-0.95
3300.06	100 Yr	500	240.14	237.67	-2.47
3316.53	Bankfull	63.1	236.36	235.72	-0.64
3316.53	100 Yr	500	240.09	237.94	-2.15
3352.35	Bankfull	63.1	236.65	235.6	-1.05
3352.35	100 Yr	500	240.02	237.69	-2.33