BACK CREEK SITE
DETAILED STREAM AND WETLAND MITIGATION PLAN
MECKLENBURG COUNTY, NORTH CAROLINA

Prepared for:

North Carolina Department of Transportation
Raleigh, North Carolina

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January 2003

EXECUTIVE SUMMARY

The North Carolina Department of Transportation (NCDOT) is currently evaluating stream and wetland mitigation potential on property owned by three landowners: Daniel H. Fisher (Back Creek II Developers), Thelma C. Morgan, and Mecklenburg County Storm Water Services, collectively referred to as the Back Creek Site. The Back Creek Site is located approximately 5 miles northeast of the City of Charlotte in Mecklenburg County, North Carolina.

This document details stream restoration, as well as wetland enhancement/restoration procedures, on the Back Creek Site. An approximately 17.5-acre conservation easement, hereafter referred to as the Site, has been proposed for mitigation activities. The Site encompasses approximately 4117 linear feet of stream and 3.3 acres of jurisdictional wetlands. The Site watershed, consisting of approximately 4.1 square miles, is developing rapidly and is characterized by high-density residential development, commercial and industrial properties, and, to a lesser extent, mixed hardwood forest and agricultural land. Land use within the Site includes fallow pasture and various utilities corridors.

Under existing conditions, Back Creek is characterized by several distinct stream reaches: 1) the upstream reach has been dredged and straightened in support of adjacent sewer line installation and 2) the downstream reach retains its sinuous flow pattern. However, the majority of the channel has been degraded by rip-rap/boulders installed for bank stabilization. Natural vegetation within the floodplain has been removed in support of historic agricultural practices including grazing and hay production.

Restoration activities have been designed to restore historic stream and wetland functions which may have existed on-site prior to channel dredging/straightening, bank stabilization, and vegetation removal. Stream restoration includes floodplain grading and construction of approximately 4352 linear feet of meandering, E-type (highly sinuous) stream channel within the Site. Stream restoration is expected to include;

1) restoration of approximately 1390 linear feet of Back Creek on new location,
2) restoration of approximately 2135 linear feet of Back Creek in-place, and
3) restoration of approximately 827 linear feet of secondary tributary to Back Creek.

Wetland restoration/enhancement encompasses approximately 3.3 acres of floodplain underlain by hydric soils and includes removal of spoil castings from channel dredging/straightening activities and re-vegetation of the adjacent floodplain. An additional 0.5 acre of jurisdictional wetland may be created through the excavation of a shallow, open water/freshwater marsh complex adjacent to the restored stream channel.

Characteristic wetland soil features, groundwater wetland hydrology, and hydrophytic vegetation communities are expected to develop in areas adjacent to the constructed channel. The existing, degraded channel will be abandoned and backfilled. Subsequently, Site reforestation, including streamside and bottomland hardwood forest communities, has been included along the entire on-site stream and floodplain to further protect water quality and enhance opportunities for wildlife.

A Monitoring Plan has been prepared that entails a detailed analysis of stream geomorphology, wetland hydrology, and Site vegetation. Success of the project will be based on criteria set forth under each of the monitored parameters outlined in this document.

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BACK CREEK SITE
DETAILED STREAM AND WETLAND MITIGATION PLAN

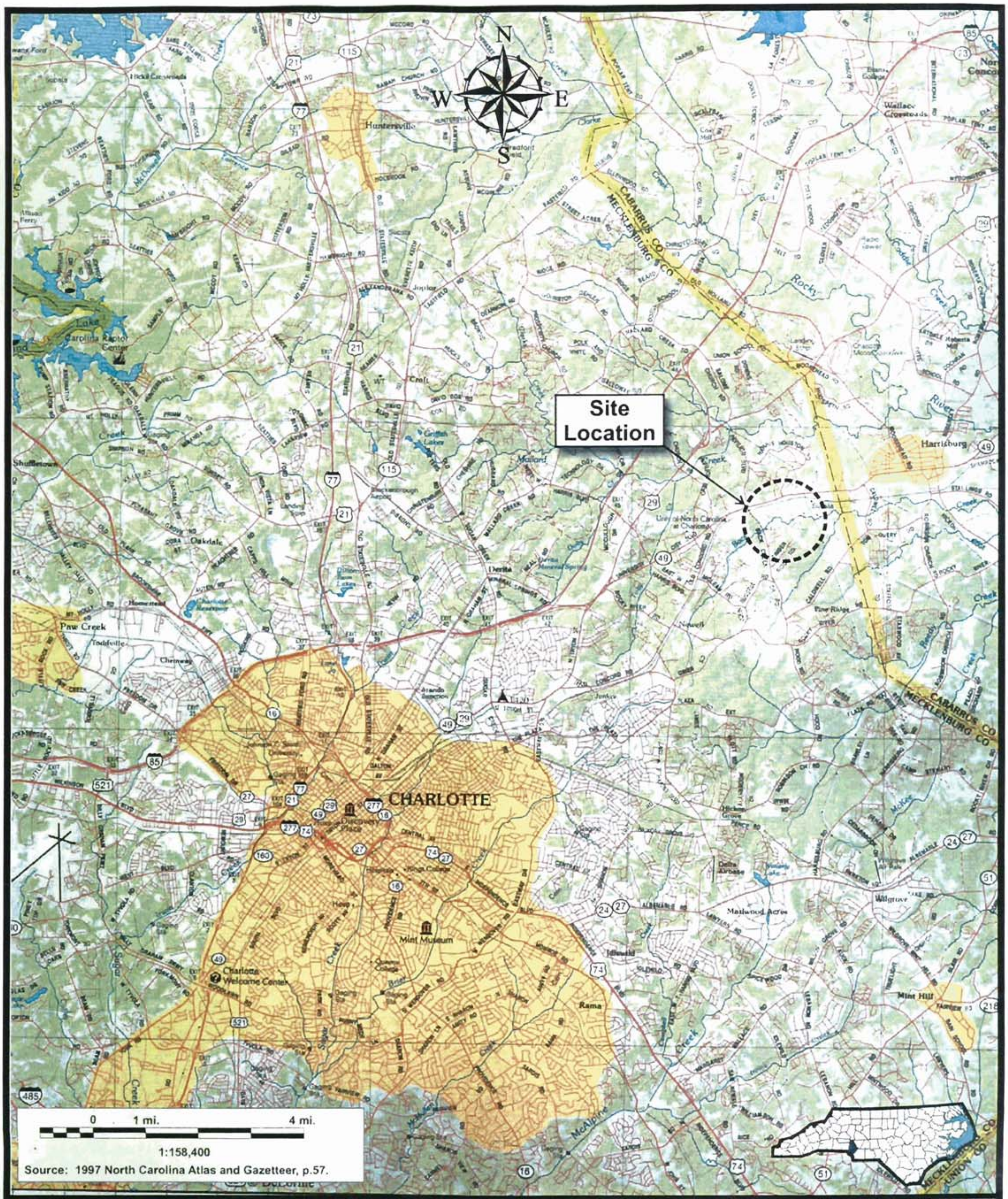
1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) is currently evaluating stream and wetland mitigation potential on property owned by three landowners: Daniel H. Fisher (Back Creek II Developers), Thelma C. Morgan, and Mecklenburg County Storm Water Services, collectively referred to as the Back Creek Site. The Back Creek Site is located approximately 5 miles northeast of the City of Charlotte, 0.25 mile south of the intersection of NC Highway 49 and Back Creek Church Road (SR 2827) (Figure 1).

Based on preliminary studies, it appears that approximately 17.5 acres of floodplain, open water, and adjacent floodplain slopes within the Back Creek Site may be placed under a conservation easement in order to conduct proposed mitigation activities. This 17.5-acre area will hereafter be referred to as the Site. The Site encompasses 3300 linear feet of Back Creek, approximately 817 linear feet of stream channel associated with two unnamed tributaries to Back Creek, and approximately 3.3 acres of jurisdictional wetland and/or hydric soil within the adjacent floodplain. Past Site land use, including livestock grazing, removal of riparian vegetation, as well as dredging and straightening of the upstream portion of Back Creek, appears to have resulted in degraded water quality, unstable channel characteristics (stream entrenchment, erosion, and bank collapse), and decreased wetland functionality.

The purpose of this study is to establish a detailed mitigation plan for stream restoration and wetland enhancement/restoration alternatives. The objectives of this study include the following.

- Classify the on-site streams based on fluvial geomorphic principles.
- Identify jurisdictional wetlands and/or hydric soils within the Site boundaries.
- Identify a suitable reference forest, stream, and wetland to model Site mitigation attributes.
- Develop a detailed plan of stream restoration and wetland enhancement/restoration activities within the proposed 17.5-acre conservation easement boundary.
- Establish success criteria and a method of monitoring the Site upon completion of mitigation construction.



EcoScience Corporation
Raleigh, North Carolina

SITE LOCATION
BACK CREEK MITIGATION SITE
Detailed Mitigation Planning
Mecklenburg County, North Carolina

Dwn. by:	MJR	FIGURE
Ckd by:	MJR	1
Date:	JAN 2003	
Project	02-113 04	

The goals of the restoration/enhancement efforts are as follows.

- Restore approximately 3525 linear feet of Back Creek including excavation of channel on new location (1390 linear feet) and restoration of channel in-place (2135 linear feet).
- Restore approximately 827 linear feet of secondary tributary to Back Creek.
- Restore approximately 1.5 acres of jurisdictional wetland, enhance approximately 1.8 acres of jurisdictional wetland, and create approximately 0.5 acres of open water/freshwater marsh adjacent to on-site channels.
- Reforest approximately 17.5 acres of floodprone area and adjacent upland slopes with native forest species.

This document represents a detailed mitigation plan summarizing activities proposed within the Site. The plan includes 1) descriptions of existing conditions, 2) reference stream and forest studies, 3) restoration/enhancement plans, and 4) Site monitoring and success criteria. Upon approval of this plan by regulatory agencies, engineering construction plans will be prepared and activities implemented as outlined. Proposed mitigation activities may be modified during the civil design stage due to constraints such as access issues, sediment-erosion control measures, drainage needs (floodway constraints), or other design considerations.

3.8 acres of existing wetland

2.0 METHODS

Natural resource information was obtained from available sources. U.S. Geological Survey (USGS) 7.5 minute topographic mapping (Harrisburg, NC), U.S. Fish and Wildlife Service (FWS) National Wetlands Inventory (NWI) mapping, Natural Resource Conservation Service (NRCS [formerly the Soil Conservation Service]) soils mapping for Mecklenburg County (NRCS 1980), historic aerial photography, and recent aerial photography were utilized to evaluate existing landscape, stream, and soil information prior to on-site inspection.

Reference stream geometry measurements have been used to orient channel reconstruction design. Reference stream and floodplain systems were identified and measured in the field to quantify stream geometry, substrate, and hydrodynamics. Stream characteristics and detailed mitigation plans were developed according to constructs outlined in Rosgen (1996), Dunne and Leopold (1978), Harrelson *et al.* (1994), Chang (1988), and North Carolina Wildlife Resources Commission (NCWRC) (1996). Stream pattern, dimension, and profile under stable environmental conditions were measured along reference (relatively undisturbed) stream reaches and applied to the degraded channel within the Site. Reconstructed stream channels and hydraulic geometry relationships have been designed to mimic stable channels identified and evaluated in the region.

North Carolina Natural Heritage Program (NHP) data bases were evaluated for the location of designated natural areas which may serve as reference sites for mitigation design. Characteristic and target natural community patterns were classified according to Schafale and Weakley's, *Classification of the Natural Communities of North Carolina* (1990).

Detailed field investigations were performed in November and December 2002, consisting of Site channel cross-sections, profile, and plan-view; valley cross-sections; detailed soil mapping; and mapping of on-site resources. Project scientists evaluated stream parameters to determine the stability of the existing channel. Hydrology, vegetation, and soil attributes were analyzed to determine the status of jurisdictional areas. Plant communities were delineated and described by structure and composition.

NRCS soil mapping was modified to identify hydric soil boundaries and to predict (target) biological diversity prior to human disturbances. NRCS soil map units were ground truthed by a licensed soil scientist to verify existing soil mapping units and to map inclusions.

Historical aerial photographs (1958, 1965, and 1993) were utilized to identify land use patterns and floodplain dynamics at the Site and in the watershed. Disturbances to streams and wetlands during watershed development were tracked, where feasible. However, none of these historical photographs exhibit riparian forest structure or historic stream pattern prior to significant disturbance. Recent (1999) aerial photography was evaluated to determine primary hydrologic features and to map relevant environmental features.

Information collected on-site and in reference ecosystems was compiled in a database and incorporated with field observations to evaluate the on-site stream under existing conditions. Subsequently, this mitigation plan was developed to facilitate restoration success and to provide stream and wetland mitigation for various NCDOT projects in the region.

3.0 EXISTING CONDITIONS

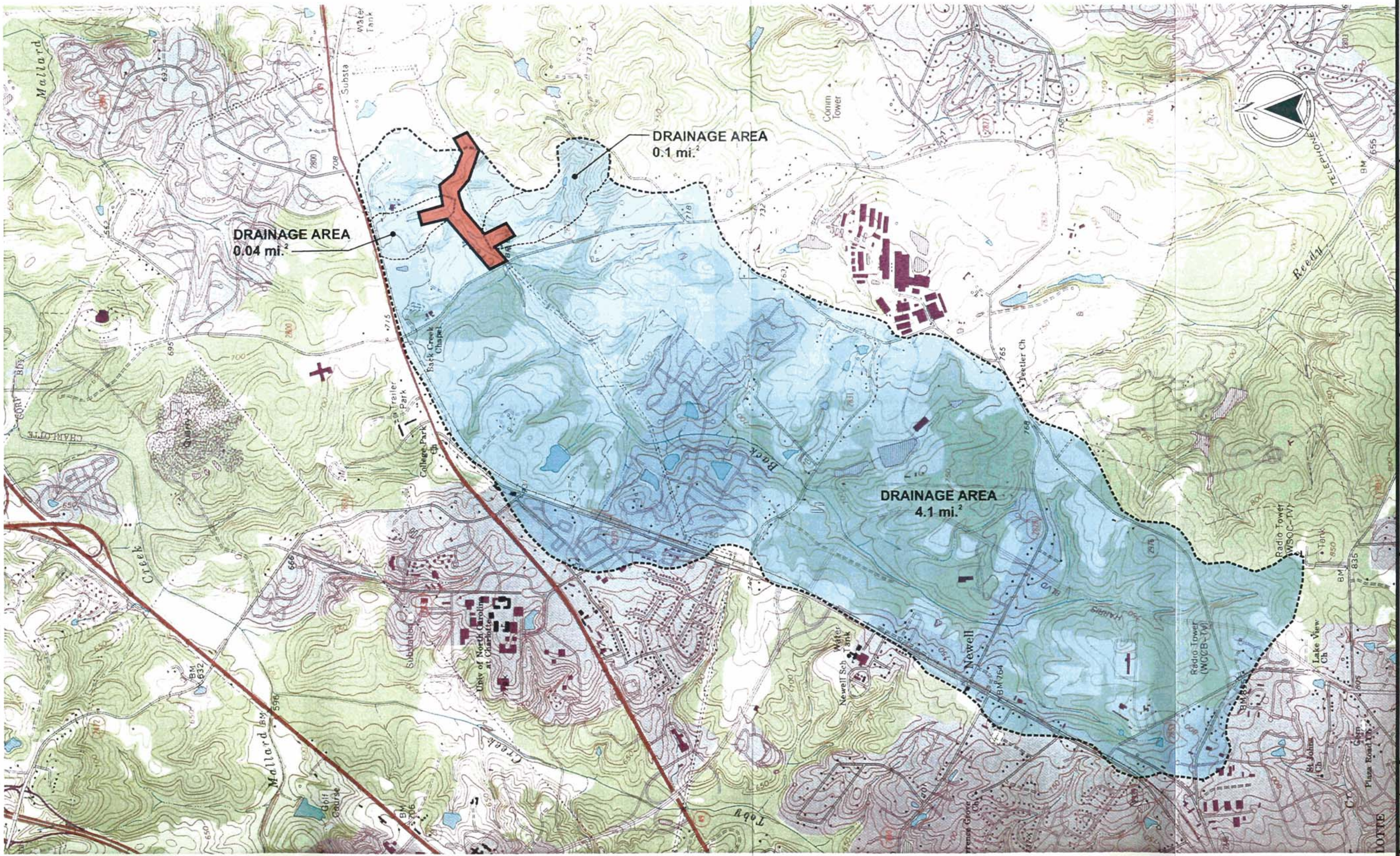
3.1 Physiography, Topography, and Land Use

The Site is located in the northeastern portion of Mecklenburg County, approximately 5 miles northeast of the City of Charlotte (Figure 1). This portion of the state is underlain by the intrusive rocks of the Charlotte Belt geologic formation within the Southern Outer Piedmont ecoregion of North Carolina (USGS Subbasin 03040105). This hydrophysiographic region is characterized by moderately dissected, irregular plains with moderately steep slopes and narrow floodplains (Griffith 2002) (Figure 2). This region is characterized by moderately high rainfall with precipitation averaging approximately 43 inches per year (NRCS 1980).

The Site encompasses a reach of a Back Creek, two unnamed tributaries to Back Creek, the adjacent associated floodplain, and wetland pockets located within the adjacent floodplain. Back Creek, a third-order stream, encompasses a drainage area of approximately 4.1 square miles. Back Creek flows in an easterly direction for approximately 3300 linear feet through the Site prior to its outfall at the eastern Site boundary. Back Creek flows through a relatively wide, flat (0.005 rise/run), alluvial valley (Valley Type VIII), with a floodprone area width measuring approximately 250 feet.

Within the Site boundaries, two smaller unnamed tributaries converge with Back Creek, one entering from the south and one from the north. These tributaries are significantly smaller than Back Creek, with a collective drainage area encompassing only 3 percent of the upstream Site drainage basin. These streams are characterized by relatively narrow, moderately steep (0.024 rise/run) valleys, which flatten and widen as they descend and converge with the larger Back Creek mainstem channel. As the valley flattens, alluvial fans (Valley Type III) form in the landscape, with floodprone area widths ranging from approximately 20 to 70 feet.

The upstream, Back Creek drainage basin is located in a rapidly developing region of Mecklenburg County. The upstream watershed is characterized by high-density residential development, commercial and industrial complexes, and, to a lesser extent, rural pasture and forest. Aerial photography from 1993 and 1999 indicate an increase in urban land use from approximately 1.4 square miles (33 percent of drainage area) to approximately 2.4 square miles (57 percent of drainage area) over the 6-year period (Figure 3 and Figure 4). Based on development adjacent to the Site and reconnaissance of the upstream drainage basin, these rapid-development trends appear to have continued to the present day.



Approx. Site Drainage Basin

Approx. Site Boundary

0 | 2000 ft. | 4000 ft.

1:24,000

Source: USGS 7.5 Minute Quadrangle (Harrisburg, N.C.)

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Client:

NCDOT

Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:

TOPOGRAPHY

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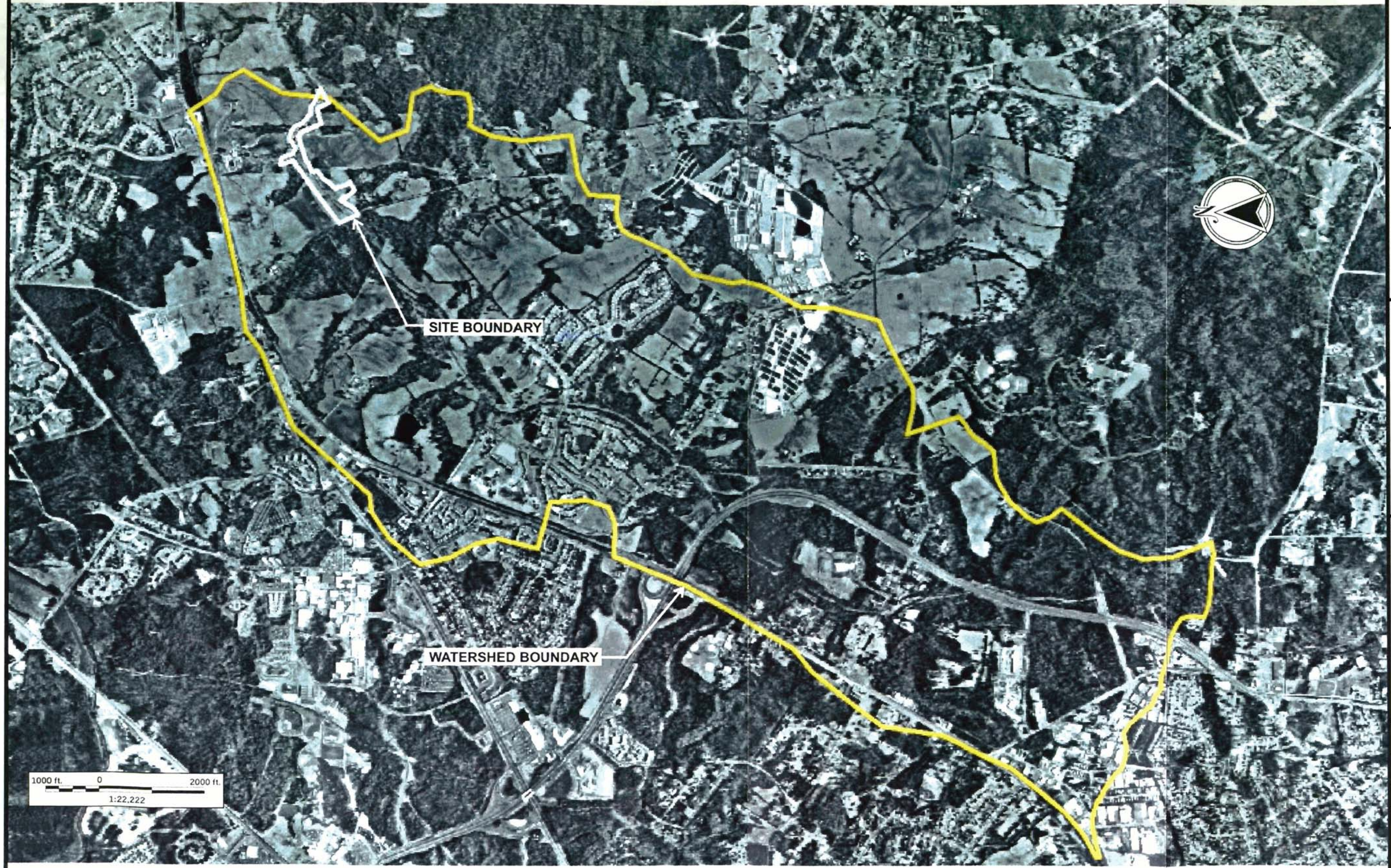
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE

2



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Client:

NCDOT

Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:

1993 BASIN-WIDE LAND USE

Dwn By: MAF	Date: JAN 2003
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FIGURE

3

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Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:

1999 BASIN-WIDE LAND USE

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE

4

Historically, the Site appears to have been utilized for livestock pasture and hay production. Currently, the Site is characterized by fallow, successional fields with a few stands of isolated hardwood forest. The farthest upstream fields are maintained through bush hogging and appear to support more grass species than adjacent successional fields (Figure 5). The maintained fields appear to be utilized by the Morgan family for hay production.

The Site is crossed by several utilities easements including a sewer line and high-tension-power lines (Figure 5). Back Creek appears to have been altered during sewer line construction, including dredging and straightening the upstream reach and stabilization of the entire reach through installation of rip-rap/boulders in the channel banks. The rip-rap/boulders are especially prevalent in reaches where the sewer line crosses, or abuts Back Creek.

Immediately adjacent to the Site, area pastureland has been converted to high-density residential development serviced by standard curb and gutter roads (Figure 5). Storm-water runoff is conveyed primarily through underground storm culverts which discharge into sediment basins or are piped directly into floodplain wetland depressions. In addition to residential development, construction of Interstate-485 is ongoing immediately north of the Site. Various culverts enter the Site from beneath the newly constructed roadway.

3.2 Soils

Site soils have been mapped by the NRCS (NRCS 1980) (Figure 6). On-site verification and ground-truthing of NRCS map units was conducted in the fall of 2002 by licensed soil scientists to refine soil map units and to locate inclusions and tax-adjunct areas. The portion of the Site most intensely surveyed includes low-lying floodplain areas. Systematic transects were established and sampled to ensure proper coverage. Soils were sampled for color, texture, consistency, and depth at each documented horizon.

Based on NRCS mapping, the Site floodplain is underlain predominantly by soils of the Monacan (*Fluvaquentic Eutrochrepts*) series, with side slopes characterized by soils of the Enon (*Ultic Hapludalfs*) and Wilkes (*Typic Hapludalfs*) series. However, Monacan soils are highly variable in the NRCS survey area and on-site soil profiles more closely resemble the Chewacla (*Fluvaquentic Dystrochrepts*) and Wehadkee (*Typic Fluvaquents*) associations of the neighboring Cabarrus County (2 miles east of the Site). Therefore, detailed soil mapping for the Site has been prepared based on landscape position, land use distinctions, and hydric verses non-hydric characteristics. As depicted in Figure 7, four revised soil map

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Project: BACK CREEK MITIGATION SITE

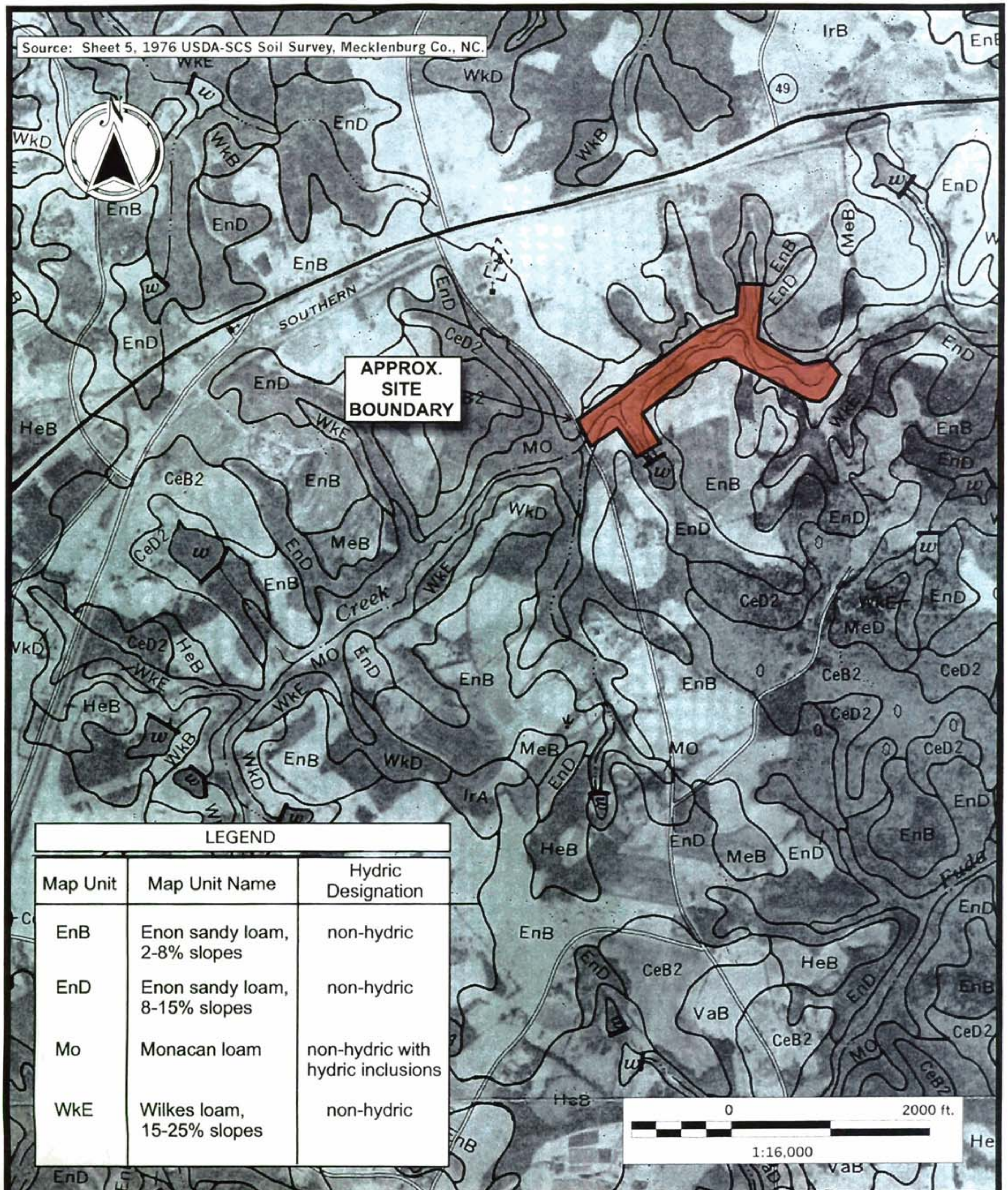
DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title: ON-SITE LAND USE

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE 5



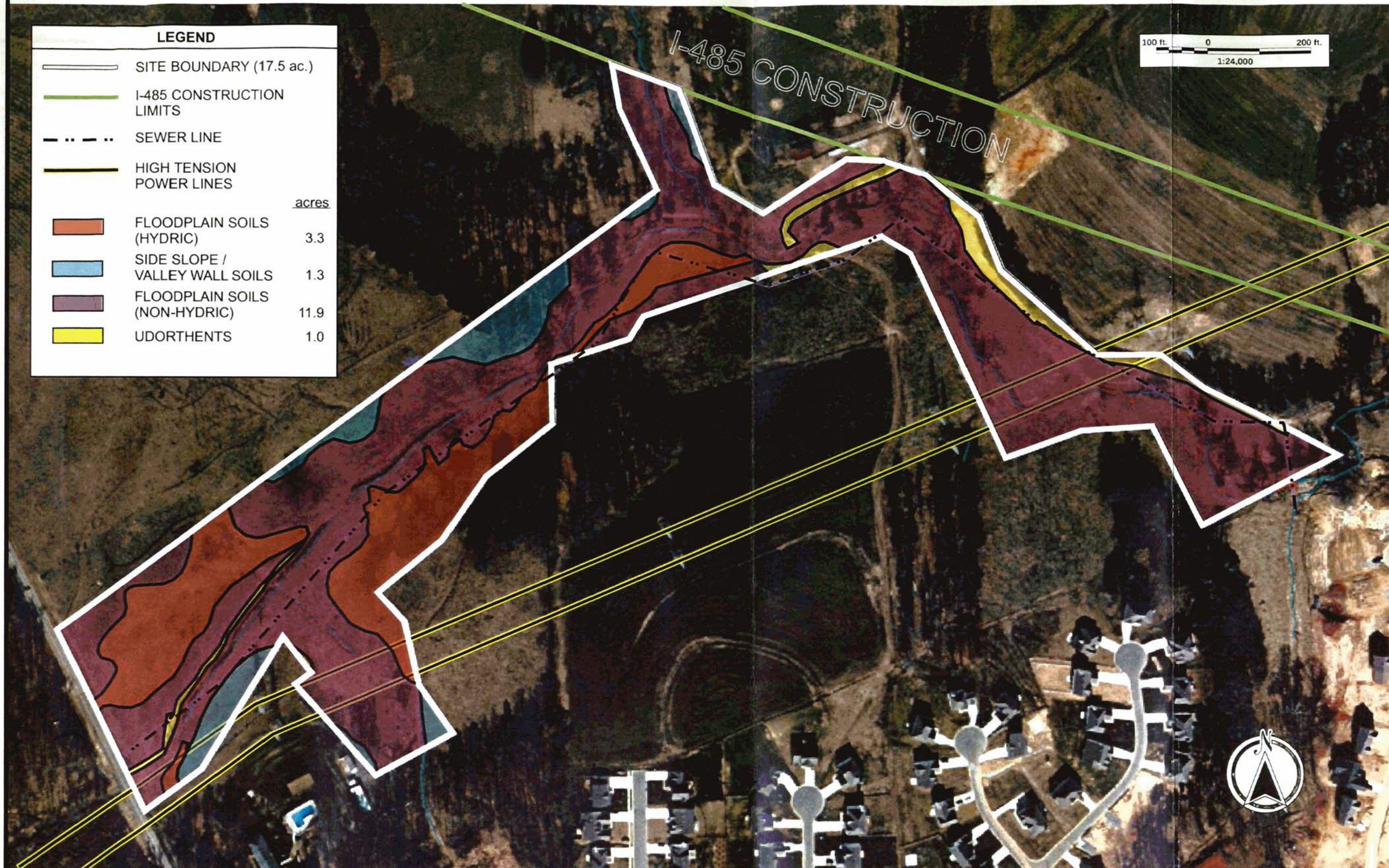
LEGEND		
Map Unit	Map Unit Name	Hydric Designation
EnB	Enon sandy loam, 2-8% slopes	non-hydric
EnD	Enon sandy loam, 8-15% slopes	non-hydric
Mo	Monacan loam	non-hydric with hydric inclusions
WkE	Wilkes loam, 15-25% slopes	non-hydric

EcoScience Corporation
Raleigh, North Carolina

NRCS SOIL MAPPING
BACK CREEK MITIGATION SITE
Detailed Mitigation Planning
Mecklenburg County, North Carolina

Dwn. by:	MJR
Ckd by:	MJR
Date:	JAN 2003
Project:	02-113.04

FIGURE 6



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Client:

NCDOT

Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:

MODIFIED SOIL UNITS

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE

7

units were identified: 1) udorthents, 2) floodplain soils (hydric), 3) floodplain soils (non-hydric), and 4) side slope/valley wall soils.

Udorthents

The Udorthents mapping unit consists of areas in which the natural soil profiles have been altered by earth-moving operations or other anthropogenic influences. Encompassing approximately 1.0 acre (6 percent) of the Site, this mapping unit includes spoil material deposited adjacent to Back Creek during dredging and straightening activities, fill slopes associated with residential construction, and agricultural roadways.

Floodplain Soils (Hydric)

Hydric soils are defined as "soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil layer" (SCS 1987). Based on NRCS mapping, hydric soils underlying the Site floodplain include soils of the Monacan series. However, detailed soil mapping indicates that vast expanses of the on-site floodplain exhibit characteristics of the hydric Wehadkee series.

Hydric soils occur in a narrow band along the upper reaches of the Site, encompassing approximately 3.3 acres (19 percent) of the Back Creek floodplain. On-site hydric soils are generally located in slight depressions within the floodplain and are characterized by dark brown to slightly gleyed loams and clay loams. In general, these areas appear to have been disturbed by utility easements and dredging/straightening of the upper reach of Back Creek. Based on preliminary studies, on-site hydric soils appear to be intermittently flooded from over-bank storm-water flows, upland runoff, groundwater migration into the Site, and, to a lesser extent, direct precipitation.

Floodplain Soils (Non-hydric)

Based on NRCS mapping, non-hydric soils underlying the Site floodplain are also mapped as Monacan loam. However, detailed soil mapping indicates that portions of the Site floodplain underlain by non-hydric soils exhibit characteristics of the Chewacla series.

Non-hydric soils occur adjacent to the entire on-site reach of Back Creek, encompassing approximately 11.9 acres (68 percent) of the Back Creek floodplain. Non-hydric floodplain soils are generally located in broad, nearly level portions of the Site and are characterized by yellowish brown loams and clay loams. These soils appear subject to frequent flooding; however, aerobic features in the soil profile may indicate that soil permeability is sufficient to maintain non-hydric characteristics of this portion of the floodplain.

Side Slope/Valley Wall Soils

Based on NRCS mapping, side slopes and valley walls adjacent to the Back Creek floodplain are mapped as Enon sandy loam and Wilkes loam. Detailed soil mapping confirmed these soils within the Site. Side slope/valley wall soils encompass approximately 1.3 acres (7 percent) of the Site, including slopes adjacent to the Back Creek floodplain. In general, Enon soils occur in portions of the Site where side slopes are less steep and Wilkes soils occurred in portions of the Site characterized by slopes steeper than 15 percent grade. Outside of the Site, these soil units have been disturbed by residential development.

3.3 Plant Communities

Distribution and composition of plant communities reflect landscape-level variations in topography, soils, hydrology, and past or present land use practices. Two plant communities have been identified on the Site: successional fields and hardwood forest (Figure 5).

Successional fields dominate the Site, accounting for approximately 90 percent of the Site area. This community is varied including fallow hay fields and wetland herbaceous assemblage. Hay fields are characterized by maintained, planted grasses such as alfalfa (*Medicago sativa*), fescue (*Festuca octiflora*), and bluegrass (*Poa pratensis*). Invasive species such as beggar ticks (*Bidens bipinnata*), broom sedge (*Andropogon virginicus*), blackberry (*Rubus* sp.), and dog fennel (*Eupatorium capillifolium*), with a few woody recruits including green ash (*Fraxinus pennsylvanica*), persimmon (*Diospyros virginiana*), and winged elm (*Ulmus alata*), occur throughout. Portions of fallow fields underlain by hydric soils are characterized by a hydrophytic species composition, including rushes (*Juncus* spp.), sedges (*Carex* spp.), smartweeds (*Polygonum* spp.), and beakrush (*Rhynchospora* sp.).

Hardwood forest occurs on the northern bank of Back Creek in the central portion of the Site. This community is characterized by more xeric, upland species such as white oak (*Quercus alba*), northern red oak (*Quercus rubrua*), and mockernut hickory (*Carya tomentosa*). As the slope descends towards the floodplain, this community grades towards a more mesic community with a canopy including willow oak (*Quercus phellos*), American sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), and black willow (*Salix nigra*). A few, mature, individual trees species are found in an approximately 15-foot wide riparian fringe adjacent to the Back Creek channel. This riparian fringe is characterized by river birch, black willow, American sycamore, rose (*Rosa* sp.), and Chinese privet (*Ligustrum sinense*).

3.4 Hydrology

Site hydrology is composed of surface water flows, groundwater migration into open water conveyances, and, to a lesser extent, precipitation. Surface water flows result primarily from upstream drainage basin catchment, discharge into upstream feeder tributaries, and surface water flows into and through the Site. No active seeps or springs have been identified within the Site boundaries.

3.4.1 Drainage Area

This hydrophysiographic region is considered characteristic of the Piedmont Physiographic Province, which extends throughout central portions of North Carolina. The region is characterized by dissected, irregular plains, with some low, rounded hills and ridges. Broad, gently sloping uplands are convex-concave interfluves with gentle side slopes of 6 percent or less. Moderately to steeply sloping areas with narrow, convex ridges are also common. In the Mecklenburg County area, precipitation averages 43 inches annually, distributed evenly throughout the year (NRCS 1980). The Site is located in USGS Hydrologic Unit #03040105 (USGS 1974).

The Site drainage area encompasses approximately 4.1 square miles at the downstream Site outfall. The drainage area, characterized by a mixture of rural and urban land use, appears to be rapidly converting from bottomland forest and agriculture towards high-density residential development and commercial/industrial complexes.

3.4.2 Discharge

Discharge estimates for the Site utilize an assumed definition of "bankfull" and the return interval associated with the bankfull discharge. For this study, the bankfull channel is defined as the channel dimensions designed to support the "channel forming" or "dominant" discharge (Gordon *et al.* 1992). Research indicates that a stable stream channel may support a return interval for bankfull discharge, or channel-forming discharge, of between 1 to 2 years (Gordon *et. al.* 1992, Dunne and Leopold 1978). The methods of Rosgen (1996) indicate calibration of bankfull dimensions based on a potential bankfull return interval of between 1.3 and 1.7 years for rural conditions.

Based on available regional curves, the bankfull discharge for Back Creek (4.1 square mile watershed) averages approximately 247 cubic feet per second (cfs) (Harman *et al.* 1999). In addition, the USGS regional regression equation indicates that the bankfull discharge for Back Creek averages approximately 270 cfs (USGS 2001).

To verify regional curves and USGS regression models, five gauged streams (Lithia Inn Branch, Mallard Creek, North Prong Clark Creek, Long Creek near Bessemer, and Long Creek near Paw Creek) were analyzed to determine a return interval for momentary peak discharges. Momentary peak discharges (return interval between 1.3 and 1.7 years) were calculated from the gauge data and plotted against the regional curve (Appendix A). Momentary peak discharges from analyzed stream gauges plotted above the predicted discharge from the regional curves for four of the five stream gauges. This may indicate that bankfull discharges at the Site are higher than predicted by regional curves.

Bankfull indicators in the field have also been utilized to predict bankfull discharge. The cross-sectional area associated with field indicators has been compared to regression equations that relate discharge to cross-sectional area in rural Piedmont streams. The average bankfull cross-sectional area in the channel has been estimated at approximately 56 square feet, suggesting a bankfull discharge of approximately 300 cfs. For this project, the stable "design" channel is assumed to support a bankfull discharge (1.3-year return interval) of between 250 and 300 cfs at the Site outfall under existing watershed conditions.

Velocity comparison of bankfull discharges were conducted through various measurements including R/D84, u/u*, mannings n by stream type, and direct measurement of bankfull flows. Velocity estimations that utilize channel dimension characteristics of depth, cross-sectional area, slope, and/or substrate (R/D84, u/u*, and mannings n by stream type) indicate that bankfull velocities may range between 3.8 and 4.6 feet per second. The continuity equation (cfs/cross sectional area) indicates that bankfull velocities may be approximately 4.3 feet/second. However, direct measurement of the channel immediately after a 1.6 to 1.8 inch rainfall event indicate bankfull velocities of approximately 2.5 feet per second. Measured velocities may be slightly lower that expected due to high channel roughness from rip-rap/boulder materials installed in channel banks by Mecklenburg County sewer-line utilities workers.

3.5 Stream Characterization

Stream characterization is intended to orient stream restoration based on a classification utilizing fluvial geomorphic principles (Rosgen 1996). This classification stratifies streams into comparable groups based on pattern, dimension, profile, and substrate characteristics. Primary components of the classification include degree of entrenchment, width/depth ratio, sinuosity, channel slope, and stream substrate composition. The stream classes characterizing existing reaches within the Site include E-type (low width to depth ratio) and C-type (moderate width to depth ratio) streams. Each stream type is modified by a number 1 through 6 (ex. E5), denoting a stream type which supports a substrate dominated by 1) bedrock, 2) boulders, 3) cobble, 4) gravel, 5) sand, or 6) silt/clay. Historically, the channel may have supported an E4/5 stream type typical of those found in the North Carolina Piedmont under similar watershed conditions.

3.5.1 Stream Geometry and Substrate

Stream geometry measurements under existing conditions are depicted in Figures 8 and 9 and summarized in Table 1. Back Creek is characterized by three distinct stream channel types: 1) upstream straightened (E-type), 2) downstream sinuous (C-type), and 3) downstream sinuous (E-type). Individual cross-section data and other morphological data (including a morphological measurement table) are included in Appendix B.

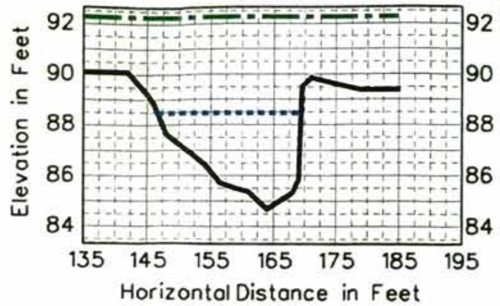
Upstream Straightened (E-type)

The upstream portion of the Site contains a dredged and straightened reach supporting characteristics of an E-type (low width to depth ratio) stream. E-type streams are characterized as slightly entrenched, riffle-pool channels exhibiting high sinuosity (>1.5). In North Carolina, E-type streams often occur in narrow to wide valleys with well-developed alluvial floodplains (Valley Type VIII). E-type streams typically exhibit a sequence of riffles and pools associated with a sinuous flow pattern. E-type channels are typically considered stable. However, these streams are sensitive to disturbance and may rapidly convert to other stream types.

The upstream channel has been dredged, straightened, and lined with rip-rap/boulders in support of adjacent sewer line utilities maintenance. The cross-sectional area of the channel is currently smaller than expected from regional curves and measurements of bankfull are currently 54 square feet, as compared to 56 square feet predicted by regional curves. In addition, the width/depth ratio measures 7, lower than is considered typical for streams of this size in the region. Channel cross-sectional area and width to depth ratio may have been diminished during dredging/straightening activities or the installation of rip-rap/boulders for bank stabilization. The channel is currently characterized by eroding banks as the channel attempts to enlarge to a stable cross-sectional area.

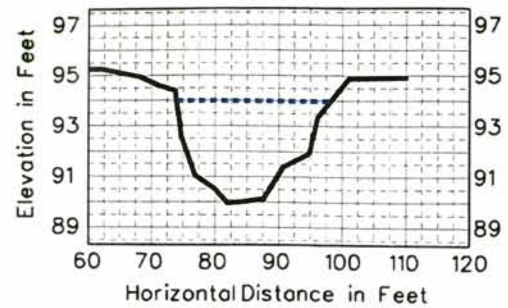
Straightening of the upstream channel has destroyed pattern variables such as beltwidth, meander length, pool-to-pool spacing, and radius of curvature. The channel is currently characterized by a sinuosity of 1.02 (thalweg distance/straight-line distance). Rip-rap/boulders appear to be inhibiting lateral channel extension and the formation of distinct, repetitive riffles and pools within the reach. Pattern variables are currently not within the modal concept for E-type channels in the region.

CROSS-SECTION 1
(Riffle)



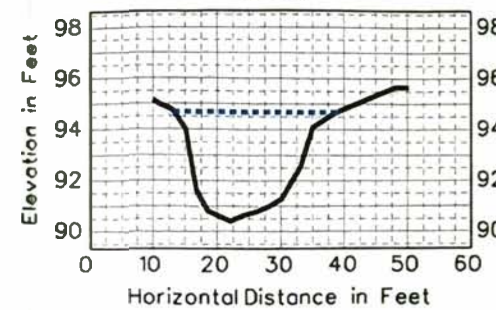
Bankfull Width: 22.7 ft.
Bankfull Maximum Depth: 3.8ft.
Bankfull Average Depth: 2.5 ft.
Bankfull Cross-sectional Area: 55.7 sq. ft..
Width of Flood Prone Area: 297 ft.±

CROSS-SECTION 4
(Pool)



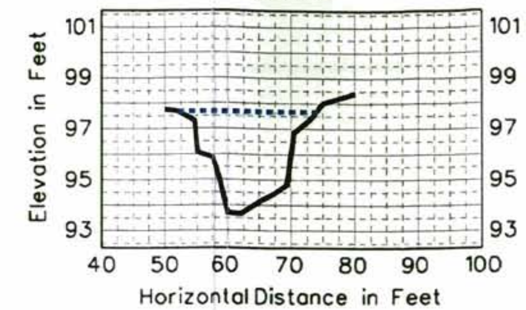
Bankfull Width: 24.5 ft.
Bankfull Maximum Depth: 4.1 ft.
Bankfull Average Depth: 2.8 ft.
Bankfull Cross-sectional Area: 69.2 sq. ft..

CROSS-SECTION 6
(Pool)



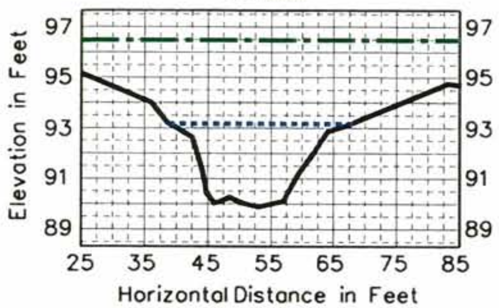
Bankfull Width: 26.5 ft.
Bankfull Maximum Depth: 4.3ft.
Bankfull Average Depth: 2.7 ft.
Bankfull Cross-sectional Area: 70.9 sq. ft..

CROSS-SECTION 7
(Riffle)



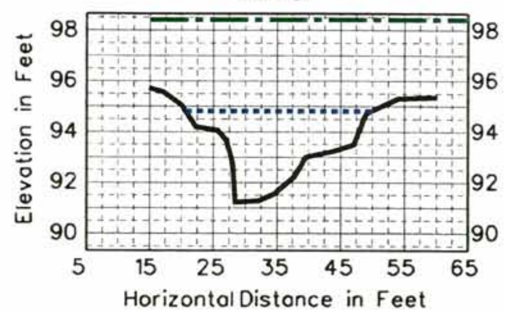
Bankfull Width: 21.9 ft.
Bankfull Maximum Depth: 4.0 ft.
Bankfull Average Depth: 2.2 ft.
Bankfull Cross-sectional Area: 48.7 sq. ft..
Width of Flood Prone Area: 290 ft.±

CROSS-SECTION 2
(Riffle)



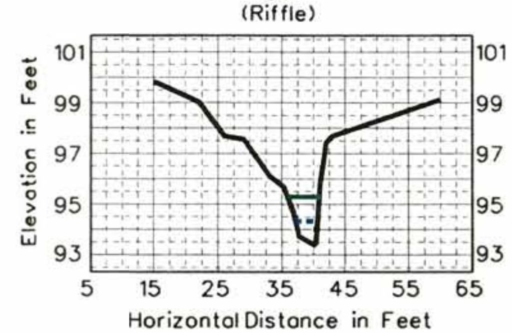
Bankfull Width: 29.5 ft.
Bankfull Maximum Depth: 3.3 ft.
Bankfull Average Depth: 1.9 ft.
Bankfull Cross-sectional Area: 55.7 sq. ft..
Width of Flood Prone Area: 114 ft.±

CROSS-SECTION 5
(Riffle)



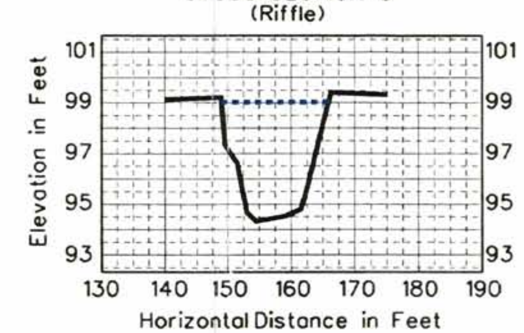
Bankfull Width: 29.5 ft.
Bankfull Maximum Depth: 3.6ft.
Bankfull Average Depth: 1.9ft.
Bankfull Cross-sectional Area: 56.1 sq. ft..
Width of Flood Prone Area: 293 ft.±

UT
(Riffle)



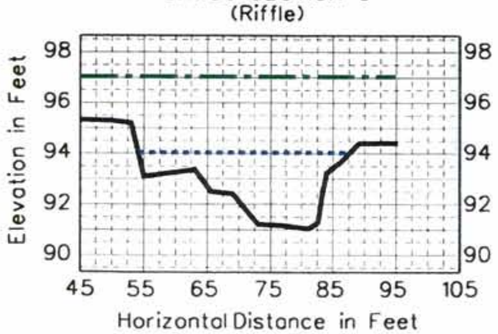
Bankfull Width: 3.5 ft.
Bankfull Maximum Depth: 1.0 ft.
Bankfull Average Depth: 0.7 ft.
Bankfull Cross-sectional Area: 2.5 sq. ft..
Width of Flood Prone Area: 5 ft.±

CROSS-SECTION 8
(Riffle)



Bankfull Width: 16.7 ft.
Bankfull Maximum Depth: 4.7 ft.
Bankfull Average Depth: 3.4 ft.
Bankfull Cross-sectional Area: 56.8 sq. ft..
Width of Flood Prone Area: 235 ft.±

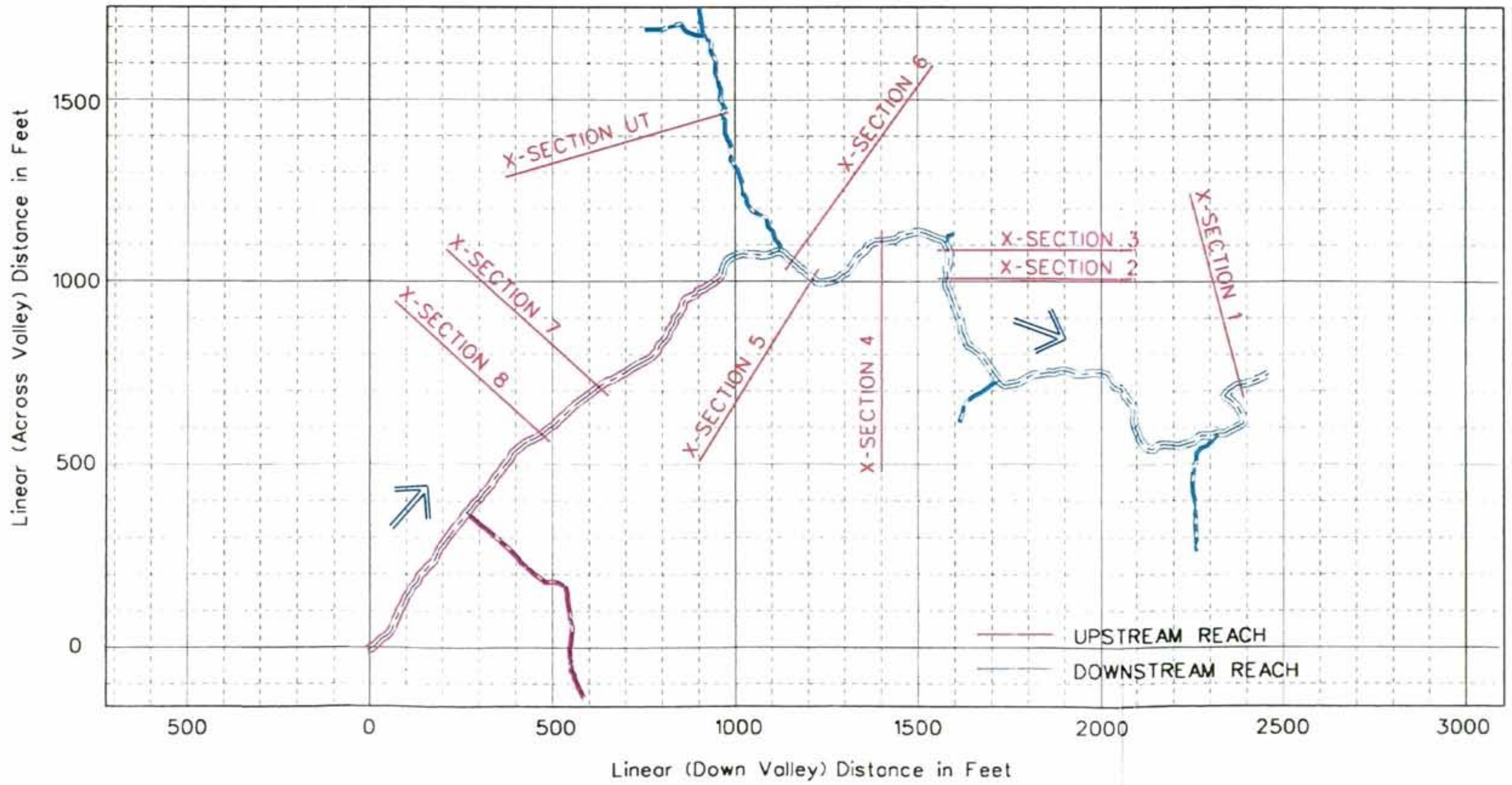
CROSS-SECTION 3
(Riffle)



Bankfull Width: 33.7 ft.
Bankfull Maximum Depth: 3.0 ft.
Bankfull Average Depth: 1.7 ft.
Bankfull Cross-sectional Area: 56.7 sq. ft..
Width of Flood Prone Area: 160 ft.±

NOTE:
All Cross-sections
Facing the Upstream Direction

EXISTING GRADE
BANKFULL ELEVATION
WIDTH OF PROPOSED FLOOD PRONE AREA



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NCDOT

Project:
BACK CREEK MITIGATION SITE

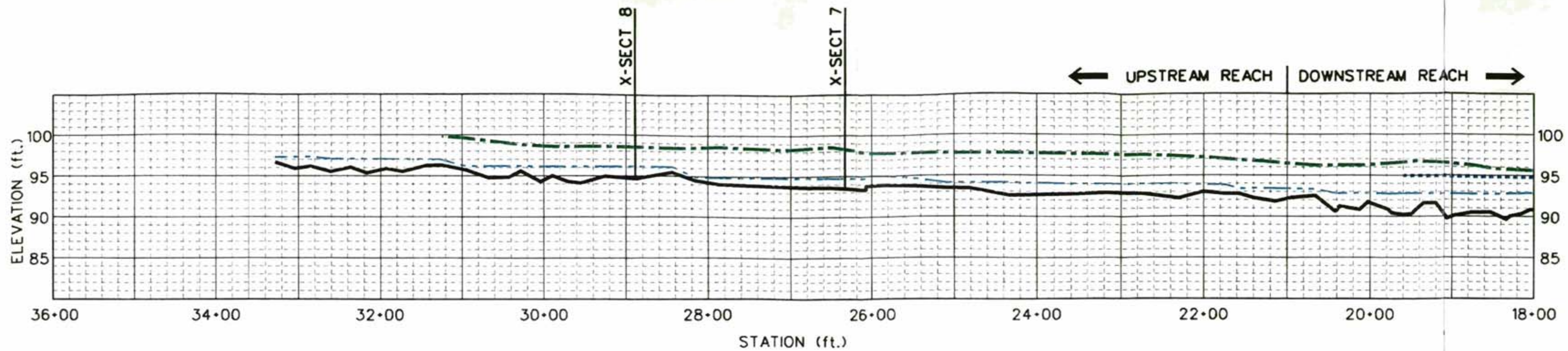
DETAILED MITIGATION PLANNING

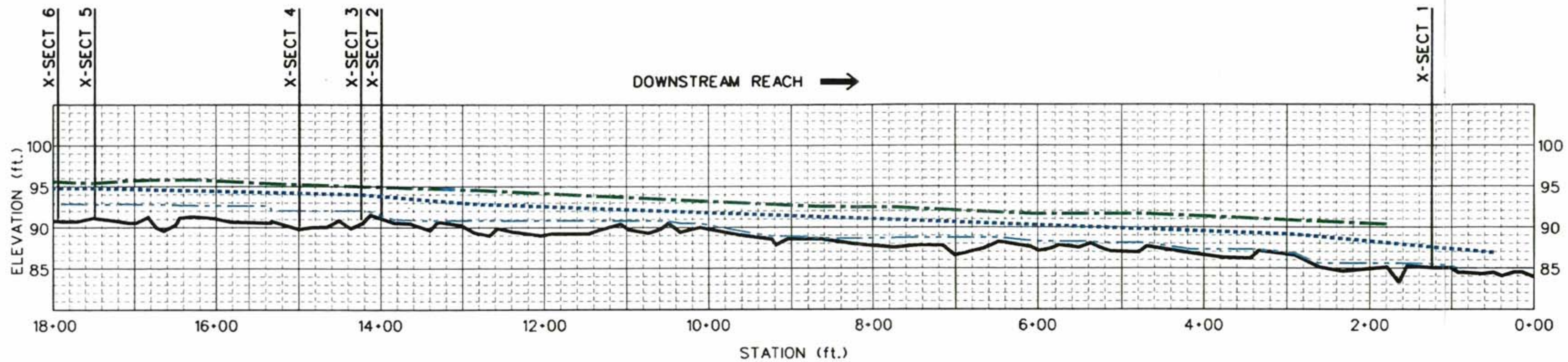
MECKLENBURG COUNTY, NORTH CAROLINA

Title:
EXISTING CROSS–SECTIONS AND PLAN VIEW

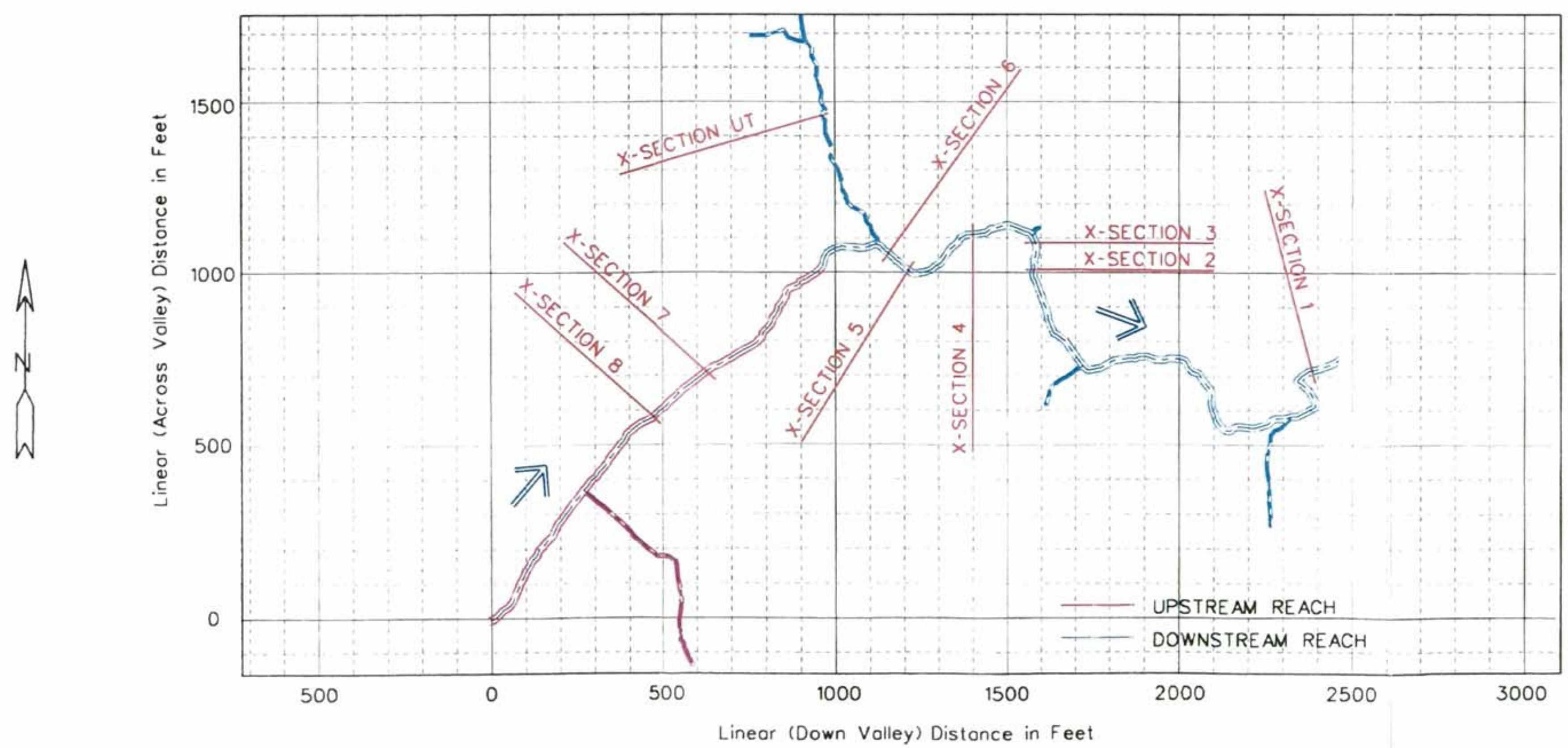
Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 02-113.04	

FIGURE
8





NOTE:
All Cross-sections
Facing the Upstream Direction



- EXISTING GRADE
- WATER SURFACE ELEVATION
- BANKFULL ELEVATION
- FLOOD PRONE AREA

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
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BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
EXISTING PROFILE AND PLAN VIEW

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: AS SHOWN
ESC Project No. 02-113.04	

FIGURE
9

TABLE 1
BACK CREEK STREAM RESTORATION SITE
Morphological Characteristics of Existing Channels

Variables	Exisiting Channel		
	Upstream Straightened	Downstream Sinuous (C)	Downstream Sinuous (E)
1 Stream Type	E5	C5	E4
2 Drainage Area (mi^2)	3.7-3.8	3.8-4.0	4.0-4.1
3 Bankfull Discharge (cfs)	250-300	250-300	250-300
Dimension Variables			
4 Bankfull Cross Sectional Area (A_{bkf})	54	56.2	55.7
5 Bankfull Width (W_{bkf})	Mean: 19.0 Range: 16.7-21.9	Mean: 32.2 Range: 29.5-36	Mean: 22.7 Range: --
6 Bankfull Mean Depth (D_{bkf})	Mean: 2.9 Range: 2.2-3.4	Mean: 1.8 Range: 1.6-1.9	Mean: 2.5 Range: --
7 Bankfull Maximum Depth (D_{max})	Mean: 4.4 Range: 4.0-4.7	Mean: 3.3 Range: 3.0-3.6	Mean: 3.8 Range: --
8 Pool Width (W_{pool})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 26.5 Range: 24.5-28.5	Mean: 26.5 Range: 24.5-28.5
9 Maximum Pool Depth (D_{pool})		Mean: 4.3 Range: 4.1-4.5	Mean: 4.3 Range: 4.1-4.5
10 Width of Floodprone Area (W_{fpa})	Mean: 253 Range: 290-235	Mean: 179 Range: 114-293	Mean: 297 Range: --
Dimension Ratios			
11 Entrenchment Ratio (W_{fpa}/W_{bkf})	Mean: 13.3 Range: 13-14	Mean: 6 Range: 4-10	Mean: 13 Range: --
12 Width/Depth Ratio W_{bkf}/D_{bkf}	Mean: 7 Range: 5-10	Mean: 19 Range: 16-23	Mean: 9 Range:
13 Max. D_{riff}/D_{bkf} Ratio	Mean: 1.6 Range: 1.4-1.8	Mean: 1.9 Range: 1.7-2.1	Mean: 1.5 Range:
14 Low Bank Height/ Max. D_{bkf} Ratio	Mean: 1.0 Range: 1.0-1.0	Mean: 1.2 Range: 1.1-1.5	Mean: 1.4 Range:
15 Pool Depth/Bankfull Mean Depth (D_{pool}/D_{bkf})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 1.5 Range: 1.4-1.6	Mean: 1.5 Range: 1.4-1.6
16 Pool width/Bankfull Width (W_{pool}/W_{bkf})		Mean: 0.8 Range: 0.8-0.9	Mean: 0.8 Range: 0.8-0.9
17 Pool Area/Bankfull Cross Sectional Area		Mean: 1.2 Range: --	Mean: 1.2 Range: --
Pattern Varialbles			
18 Pool to Pool Spacing (L_{p-p})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 180 Range: 59-351	Mean: 180 Range: 59-351
19 Meander Length (L_m)		Mean: 313 Range: 129-608	Mean: 313 Range: 129-608
20 Belt Width (W_{belt})		Mean: 95 Range: 41-199	Mean: 95 Range: 41-199
21 Radius of Curvature (R_c)		Mean: 67 Range: 23-135	Mean: 67 Range: 23-135
22 Sinuosity (Sin)	1.02	1.4	1.4

TABLE 1 Continued
BACK CREEK STREAM RESTORATION SITE
Morphological Characteristics of Existing, Reference, and Proposed Channels

Variables	Exisiting Channel		
	Upstream Straightened	Downstream Sinuous (C)	Downstream Sinuous (E)
Pattern Ratios			
23 Pool to Pool Spacing/ Bankfull Width (L_{p-p}/W_{bkf})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 5.6 Range: 1.8-10.9	Mean: 7.9 Range: 2.6-15.5
24 Meander Length/ Bankfull Width (L_m/W_{bkf})		Mean: 9.7 Range: 4.0-18.9	Mean: 13.8 Range: 5.7-26.8
25 Meander Width Ratio (W_{belt}/W_{bkf})		Mean: 3.0 Range: 1.3-6.2	Mean: 4.2 Range: 1.8-8.8
26 Radius of Curvature/ Bankfull Width (Rc/W_{bkf})		Mean: 2.1 Range: 0.7-4.2	Mean: 3.0 Range: 1.0-5.9
Profile Variables			
27 Average Water Surface Slope (S_{ave})	0.0037	0.0037	0.0037
28 Valley Slope (S_{valley})	0.0038	0.0052	0.0052
29 Riffle Slope (S_{riffle})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 0.0144 Range: 0-0.0507	Mean: 0.0144 Range: 0-0.0507
30 Pool Slope (S_{pool})		Mean: 0.0006 Range: 0-0.0035	Mean: 0.0006 Range: 0-0.0035
Profile Ratios			
31 Riffle Slope/ Water Surface Slope (S_{riffle}/S_{ave})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 3.3 Range: 0-11.8	Mean: 3.3 Range: 0-11.8
32 Pool Slope/Water Surface Slope (S_{pool}/S_{ave})		Mean: 0.14 Range: 0-0.8	Mean: 0.14 Range: 0-0.8
Materials			
D16	0.15	0.14	0.31
D35	0.39	0.28	2
D50	0.7	0.6	19.8
D84	10	32	55
D95	149	152	139

The average water surface slope for the upstream channel measures approximately 0.0037 (rise/run). Although this slope is within acceptable values of reference streams in the vicinity of the Site, water surface slopes at sewer line crossings have become over-steepened due to installation of rip-rap/boulders, pools have filled with sediment, and riffles have flattened (Figure 9). In general, the bed of the upstream channel is devoid of natural riffles and pools throughout much of its reach.

The channel is characterized by a D50 of approximately 0.7 millimeters, indicating a channel substrate dominated by sand-sized particles. Urbanization of the upstream watershed appears to have resulted in a shift of bedload from gravel to sand-sized particles. Investigations of Back Creek, upstream from the Site, indicate that until urbanization has achieved full build-out, sand may represent the primary material entering the Site.

Downstream Sinuous (C-type)

The central reach of the Site is characterized by a sinuous, over-widened and shallow channel, supporting characteristics of a C-type (moderate width to depth ratio) stream. C-type streams are characterized as slightly entrenched, riffle-pool channels exhibiting moderately high sinuosity (>1.2). In North Carolina, C-type streams often occur in narrow to wide valleys with well-developed alluvial floodplains (Valley Type VIII). C-type streams typically exhibit a sequence of riffles and pools associated with a sinuous flow pattern, with characteristic point bars within the active channel. C-type channels are typically considered stable. However, these streams can be significantly altered and rapidly destabilized by changes in bank stability, watershed condition, and/or flow regime.

The downstream, sinuous C-type channel is characterized by an oversized channel that has eroded its banks, resulting in a wide and shallow channel (width/depth ratio average 19 [ranging from 16 to 23]). Although C-type channels may be stable, the on-site reach appears to be characterized by extensive bank erosion, thereby enlarging the channel cross-sectional area. The existing channel measures approximately 91 square feet, ranging from 74 to 111 square feet. Regional curves predict a channel cross sectional area should measure 55.6 square feet for this reach. The oversized channel has resulted in channel incision, with bank-height ratios ranging from 1.1 to 1.5 (low bank height /bankfull maximum depth).

Pattern variables appear within the modal concept of C-type and E-type streams in the region. However, over-widening of the channel may affect pattern variables such as meander length, pool-to-pool spacing, radius of curvature, and sinuosity. The channel is currently characterized by a sinuosity of 1.4 (thalweg distance/straight-line distance), with pool-to-pool spacing averaging 180 feet (ranging from 59 to 351 feet), meander length averaging 313 feet (ranging from 129 to 608 feet), and beltwidth averaging 95 feet.

The average water surface slope for this downstream reach measures approximately 0.0037 (rise/run). The average riffle slope measures approximately 0.0144 (rise/run), ranging from 0 to 0.0507 (rise/run). The average riffle slope appears to be nearly four times the average water slope and the upper range of riffle slopes is more than 13 times the average water surface slope (Figure 9). Although average water surface slope appears to be characteristic of stable streams in the region, riffle slopes are significantly higher than indicative of reference streams in the vicinity of the Site.

Similar to the upstream straightened reach, this reach substrate is characterized by a D50 indicating a channel substrate dominated by sand size particles (0.6 millimeters). However, coarsening of the lower portion of this reach may indicate that 1) urbanization has occurred recently and sand substrate has not migrated completely through the reach or 2) stream power is not sufficient to move the load of sand through the reach.

Downstream Sinuous (E-type)

The downstream reach of the Site supports a sinuous, eroding channel, supporting characteristics of an E-type (low width/depth ratio) stream. E-type streams, as discussed above (Upstream Straightened, E-Type), are characteristic of wide, flat, alluvial floodplains in the region. E-type streams, although very stable, may be sensitive to upstream drainage basin changes and/or channel disturbance and may rapidly convert to other stream types.

The downstream sinuous E-type channel has been affected by sewer line maintenance, including straightening of several reaches and installation of rip-rap/boulders for bank stabilization. The channel appears to be downcutting into bed material, resulting in an incised and oversized channel. Typically, incised channels are expected to extend laterally, carving a new floodplain at the lower elevation; however, rip-rap/boulders may be hindering channel evolution. The channel is currently characterized by a cross-sectional area measuring 87 square feet (56 square feet predicted by the regional curves), with bankfull depths of 3.8 feet and resultant bank height ratios measuring approximately 1.4 (low bank height/bankfull maximum depth).

Pattern variables appear within the modal concept of C-type and E-type streams in the region. However, several portions of the channel have been altered in support of sewer line maintenance. Several reaches appear to have been straightened resulting in radius of curvatures ranging to a low of 23 feet (1.0 radius of curvature/bankfull width), pool-to-pool spacing ranging to a high of 351 feet (15.5 pool-to-pool spacing/bankfull width), and meander length ranging to a high of 608 feet (26.8 meander length/bankfull width). The channel is currently characterized by a sinuosity of 1.4 (thalweg distance/straight-line distance), which appears within the modal concept of stable streams in the region.

The average water surface slope for this downstream reach measures approximately 0.0037 (rise/run). The average riffle slope measures approximately 0.0144 (rise/run), ranging from 0 to 0.0507 (rise/run). The average riffle slope appears to be nearly four times the average water slope and the upper range of riffle slopes is more than 13 times the average water surface slope (Figure 9). Although average water surface slope appears to be characteristic of stable streams in the region, riffle slopes are significantly higher than indicative of reference streams in the vicinity of the Site.

The channel is characterized by a D50 of approximately 19.8 millimeters indicating a channel substrate dominated by coarse gravel. Sand sized particles from the upstream reach appear to have not migrated to this downstream reach, or have migrated to the downstream reach and have been transported through the Site outfall.

3.6 Stream Power, Shear Stress, and Stability Threshold

3.6.1 Stream Power

Stability of a stream refers to its ability to adjust itself to in-flowing water and sediment load. One form of instability occurs when a stream is unable to transport its sediment load, leading to the condition referred to as aggradation. Conversely, when the ability of the stream to transport sediment exceeds the availability of sediments entering a reach and/or stability thresholds for materials forming the channel boundary are exceeded, erosion or degradation occurs.

Stream power is the measure of a stream's capacity to move sediment over time. Stream power can be used to evaluate the longitudinal profile, channel pattern, bed form, and sediment transport of streams. Stream power may be measured over a stream reach (total stream power) or per unit of channel bed area. The total stream power equation is defined as:

$$\Omega = \rho g Q s$$

where Ω = total stream power (lb-ft/s^2), ρ = density of water, g = gravitational acceleration, Q = discharge (ft^3/sec), and s = energy slope (ft/ft). The specific weight of water (γ = 62.4 lb/ft^3) is equal to the product of water density and gravitational acceleration, ρg. A general evaluation of power for a particular reach can be calculated using bankfull discharge and water surface slope for the reach. As slopes become steeper and/or velocities increase, stream power increases and more energy is available for re-working channel materials. Straightening and clearing channels increases slope and velocity and thus stream power. Alterations to the stream channel may conversely decrease stream power. In particular, over widening of a channel will dissipate energy of flow over a larger area. This process will decrease stream power, allowing sediment to fall out of the water column, possibly leading to aggradation of the streambed.

The relationship between a channel and its floodplain is also important in determining stream power. Streams that remain within their banks at high flows tend to have higher stream power and relatively coarser bed materials. In comparison, streams that flood over their banks onto adjacent floodplains have lower stream power, transport finer sediments, and are more stable. Stream power assessments can be useful in evaluating sediment discharge within a stream and the deposition or erosion of sediments from the streambed.

3.6.2 Shear Stress

Shear stress, expressed as force per unit area, is a measure of the frictional force that flowing water exerts on a streambed. Shear stress and sediment entrainment are affected by sediment supply (size and amount), energy distribution within the channel, and frictional resistance of the streambed and bank on water within the channel. These variables ultimately determine the ability of a stream to efficiently transport bedload and suspended sediment.

For flow that is steady and uniform, the average boundary shear stress exerted by water on the bed is defined as follows:

$$\tau = \gamma R s$$

where τ = shear stress (lb/ft^2), γ = specific weight of water, R = hydraulic radius (ft), and s = the energy slope (ft/ft). Shear stress calculated in this way is a spatial average and does not necessarily provide a good estimate of bed shear at any particular point. Adjustments to account for local variability and instantaneous values higher than the mean value can be applied based on channel form and irregularity. For a straight channel, the maximum shear stress can be assumed from the following equation:

$$\tau_{max} = 1.5\tau$$

for sinuous channels, the maximum shear stress can be determined as a function of plan form characteristics:

$$\tau_{max} = 2.65\tau(R_c/W_{bkf})^{-0.5}$$

where R_c = radius of curvature (ft) and W_{bkf} = bankfull width (ft).

Shear stress represents a difficult variable to predict due to variability of channel slope, dimension, and pattern. Typically, as valley slope decreases channel depth and sinuosity increase to maintain adequate shear stress values for bedload transport. Channels that have higher shear stress values than required for bedload transport will scour bed and bank materials, resulting in channel degradation. Channels with lower shear stress values than needed for bedload transport will deposit sediment, resulting in channel aggradation.

The actual amount of work accomplished by a stream per unit of bed area depends on the available power divided by the resistance offered by the channel sediments, plan form, and vegetation. The stream power equation can thus be written as follows:

$$\omega = \rho g Q s = \tau v$$

where ω = stream power per unit of bed area (N/ft-sec, Joules/sec/ft^2), τ = shear stress, and v = average velocity (ft/sec). Similarly,

$$\omega = \Omega/W_{bkf}$$

where W_{bkf} = width of stream at bankfull (ft).

3.6.3 Stream Power and Shear Stress Methods and Results

Channel degradation or aggradation occurs when hydraulic forces exceed or do not approach the resisting forces in the channel. The amount of degradation or aggradation is a function of relative magnitude of these forces over time. The interaction of flow within the boundary of open channels is only imperfectly understood. Adequate analytical expressions describing this interaction have yet to be developed for conditions in natural channels. Thus, means of characterizing these processes rely heavily upon empirical formulas.

Traditional approaches for characterizing stability can be placed in one of two categories: 1) maximum permissible velocity and 2) tractive force, or stream power and shear stress. The former is advantageous in that velocity can be measured directly. Shear stress and stream power cannot be measured directly and must be computed from various flow parameters. However, stream power and shear stress are generally better measures of fluid force on the channel boundary than velocity.

Using the aforementioned equations, stream power and shear stress were estimated for 1) the existing on-site stream reach (taken at 3 cross-sections), 2) two reference streams (UT to Crane Creek and Reedy Creek), and 3) proposed on-site conditions. Important input values and output results (including stream power, shear stress, and per unit shear power and shear stress) are presented in Table 2.

Average stream velocity and discharge values were calculated for the existing on-site stream reach, reference streams, and proposed conditions. Stream roughness coefficients (n) were estimated using a modified version of Jarrett's (1985) weighted method for Cowan's (1956) roughness-component values and applied to Manning's equation (Manning 1981).

Table 2. Stream Power (Ω) and Shear Stress (τ) Values

	Discharge (ft^2/s)	Water surface Slope (ft/ft)	Total Stream Power (Ω)	Ω/W	Hydraulic Radius	Shear Stress	Velocity	τv	τ_{max}
Back Creek (Existing)									
Upstream Straightened	247	0.0037	57.03	3.00	2.18	0.50	4.6	2.3	0.75
Downstream Sinuous C-type	247	0.0037	57.03	1.77	1.57	0.36	4.4	1.6	0.67
Downstream Sinuous E-type	247	0.0037	57.03	2.51	2.01	0.46	4.4	2.0	0.72
Reference Streams									
UT to Crane Creek	117	0.0014	10.22	1.01	1.45	0.13	4.1	0.5	0.21
UT to Reedy Creek	17	0.0111	11.77	1.13	1.17	0.81	3.0	2.4	1.32
Proposed Conditions									
Upstream	247	0.0032	49.32	2.20	2.04	0.41	4.4	1.8	0.67
Downstream	247	0.0036	55.49	2.48	2.04	0.46	4.4	2.0	0.76
Total	247	0.0034	52.40	2.34	2.04	0.43	4.4	1.9	0.71

Calculations were performed on-site for the upstream straightened reach, the downstream sinuous, C-type (over-widened) reach, and the downstream sinuous, E-type reach. As would be expected, stream power and shear stress are lowest in the C-type (over-widened) reach (1.77 and 0.36, respectively) that is currently showing signs of aggradation. Conversely, stream power and shear stress are highest in the upstream straightened reach (3.0 and 0.5, respectively) were slopes have been steepened by dredging and straightening activities and the channel has been maintained at a low cross-sectional area and low width/depth ratio.

In order to maintain sediment transport functions of a stable stream system, the proposed channel should exhibit stream power and shear stress values between the aggrading and degrading on-site reaches of Back Creek. Results of the analysis indicate that the proposed channel is expected to maintain stream power values ranging from 2.2 to 2.48 and shear stress values ranging from 0.41 to 0.46. These values reside between values for unstable reaches measured for this study. Therefore, the design channel is expected to effectively transport sediment through the Site, resulting in stable channel characteristics.

3.7 Jurisdictional Wetlands

Jurisdictional wetland limits are defined using criteria set forth in the U.S. Army Corps of Engineers (COE) Wetlands Delineation Manual (DOA 1987). As stipulated in this manual, the presence of three clearly defined parameters (hydrophytic vegetation, hydric soils, and evidence of wetland hydrology) are required for a wetland jurisdictional determination.

Jurisdictional wetland limits were mapped in the field on 20 November 2002. Based on field assessment, jurisdictional wetlands exist as three individual pockets and occupy a total of 3.3 acres of the Site, as depicted in Figure 10.

Based on U.S. Fish and Wildlife Service, NWI mapping, on-site wetlands are classified as palustrine systems, with emergent vegetation that is persistently and/or temporarily flooded (PEM1A). Based on the N.C. Department of Environment, Health, and Natural Resources, *A Field Guide to North Carolina Wetlands* (DEHNR 1996), on-site wetlands are classified as Piedmont/Mountain Bottomland Hardwood Forest, which has been disturbed by land clearing.

On-site jurisdictional wetlands appear to be seasonally flooded by groundwater table fluctuations and over-bank surface water flows.

EcoScience Corporation
Raleigh, North Carolina 27605

Client:

NCDOT

Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:

JURISDICTIONAL WETLANDS

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE

10

Jurisdictional wetlands are located in poorly drained, depressional pockets, which retain surface water flows due to low permeability of the soil body. These areas are underlain by loamy to clayey soils which are gleyed in color with frequent modeling, potentially indicating a fluctuating water table. On-site floodplain soils appear to have been significantly disturbed by utility line installation and maintenance, dredging/straightening of on-site streams, and adjacent land development.

Historically, on-site wetlands may have supported mature hardwood forest, including swamp chestnut oak (*Quercus michauxii*), American elm (*Ulmus americana*), hackberry (*Celtus laevigata*), and green ash (Schafale and Weakley 1990). Jurisdictional areas are currently characterized by fallow fields dominated by rushes and sedges with other invasive herbs and a few woody recruits.

Disturbance to on-site jurisdictional wetlands include land clearing/vegetation removal, soil disturbance through installation of utilities easements, and hydrologic alterations such as dredging/straightening of streams. These disturbances may have collectively reduced the functionality of on-site jurisdictional wetlands. On-site impacts may have reduced hydrologic functions, biogeochemical functions, and plant and animal habitat interactions.

4.0 REFERENCE STUDIES

A fundamental concept of stream classification entails the development and application of regional reference curves to stream reconstruction and enhancement. Regional reference curves can be utilized to predict bankfull stream geometry, discharge, and other parameters in altered systems. Development of regional reference curves for North Carolina was initiated in 1995. The curves characterize a broad range of streams within the Piedmont physiographic province. Small watersheds or deviations in valley slope, land use, or geologic substrates may not be accurately described by the curves; therefore, verification of individual watersheds may be necessary. Reference sites have been utilized in conjunction with regional curves for detailed planning and characterization of this mitigation project.

In order to develop proposed geometric parameters for the on-site, degraded channel, three nearby streams were measured for reference. The primary reference reach for the on-site channel is located approximately 26 miles northeast from the Site, east of Salisbury (Unnamed Tributary to Crane Creek). Two additional reference streams were also measured in support of the project, including 1) a stream located approximately 5 miles south of the Site (Unnamed Tributary to Reedy Creek) and 2) a stream located approximately 19 miles northeast of the Site (Unnamed Tributary to Dutch Buffalo Creek) (Appendix C). These reference streams occur in the same USGS sub-basin as the Site (03040105) and are characterized by G-type and E-type channels. The G-type reference reach is not considered dimensionally stable; however, distinct bankfull variables were identifiable in the reach and pattern/profile characteristics appear to have not been degraded, allowing for limited assistance with channel design.

Table 3 provides a summary of the three reference streams utilized to establish reconstruction parameters. Data utilized to assemble Table 3 is provided in Appendix C. The table includes reference stream geometry measurements as well as ratios of geometry relative to bankfull width, bankfull depth, and bankfull slope. Because the stream channels at these sites could not be adequately viewed from available aerial photography, plan views were developed through the use of laser technology. Subsequently, channel cross-sections were measured at systematic locations and stream profiles were developed via laser level. Stream substrates were quantified through systematic pebble counts along the reference reaches. In-field measurements of channel geometry were also performed along stream wavelengths located outside of the plan view area.

TABLE 3
Reference Stream Geometery and Classification
Back Creek Mitigation Site

Variables	Exisiting Channel		
	UT to Dutch Buffalo Creek	UT to Reedy Creek	UT to Crane Creek
1 Stream Type	*G 5/6	E 4/5	E 4/5
2 Drainage Area (mi^2)	0.4	0.4	1.5
3 Bankfull Discharge (cfs)	46	46	85
Dimension Variables			
4 Bankfull Cross Sectional Area (A_{bkf})	Mean: 11.1 Range: 10.2 - 11.7	Mean: 15.5 Range: 11.8 - 17.1	Mean: 20.5 Range: 19.3 - 25.0
5 Bankfull Width (W_{bkf})	Mean: 10.0 Range: 9.7 - 11.5	Mean: 10.4 Range: 9.6 - 11.2	Mean: 10.1 Range: 9.5 - 11.9
6 Bankfull Mean Depth (D_{bkf})	Mean: 1.1 Range: 1.0 - 1.1	Mean: 1.4 Range: 1.2 - 1.6	Mean: 2.0 Range: 1.9-2.1
7 Bankfull Maximum Depth (D_{max})	Mean: 1.4 Range: 1.4 - 1.6	Mean: 2.2 Range: 1.8 - 2.2	Mean: 2.6 Range: 2.5 - 2.9
8 Pool Width (W_{pool})	Mean: 10.6 Range: 8.8 - 12.4	Mean: 14.2 Range: 13.7 - 14.7	Mean: 11.1 Range: 10.5 - 11.7
9 Maximum Pool Depth (D_{pool})	Mean: 2.1 Range: 2.0 - 2.2	Mean: 2.3 Range: 2.2 - 2.3	Mean: 2.9 Range: 2.8 - 3.0
10 Width of Floodprone Area (W_{fpa})	Mean: 17.5 Range: 16.0 - 18.5	Mean: 58 Range: 42 - 71	Mean: 237 Range: 232 - 345
Dimension Ratios			
11 Entrenchment Ratio (W_{fpa}/W_{bkf})	Mean: 1.8 Range: 1.4 - 1.9	Mean: 5.6 Range: 3.7 - 7.4	Mean: 25.0 Range: 20.0 - 34.5
12 Width/Depth Ratio W_{bkf}/D_{bkf})	Mean: 9 Range: 9 - 11	Mean: 7 Range: 6 - 8	Mean: 5 Range: 5 - 6
13 Max. D_{riff}/D_{bkf} Ratio	Mean: 1.4 Range: 1.3 - 1.5	Mean: 1.5 Range: 1.4 - 1.6	Mean: 1.3 Range: 1.2 - 1.4
14 Low Bank Height/ Max. D_{bkf} Ratio	Mean: 2.4 Range: 2.3 - 2.4	Mean: 1.0 Range: 1.0 - 1.2	Mean: 1.2 Range: 1.1 - 1.2
15 Pool Depth/Bankfull Mean Depth (D_{pool}/D_{bkf})	Mean: 1.9 Range: 1.8 - 2.0	Mean: 1.6 Range: 1.6 - 1.6	Mean: 1.5 Range: 1.4-1.5
16 Pool width/Bankfull Width (W_{pool}/W_{bkf})	Mean: 1.1 Range: 0.9 - 1.1	Mean: 1.4 Range:1.3 - 1.4	Mean: 1.1 Range: 1.0 - 1.2
Pattern Varialbles			
17 Pool to Pool Spacing (L_{p-p})	Mean: 55 Range: 34 - 90	Mean: 84 Range: 13 - 112	Mean: 53 Range: 26 - 114
18 Meander Length (L_m)	Mean: 80 Range: 58 - 111	Mean: 102 Range: 81 - 137	Mean: 73 Range: 61 - 115
19 Belt Width (W_{belt})	Mean: 52 Range: 42 - 60	Mean: 76 Range: 68 - 84	Mean: 86 Range: 74 - 101
20 Radius of Curvature (R_c)	Mean: 26.6 Range: 12.1 - 57	Mean: 27.6 Range: 17.1 - 42	Mean: 25.3 Range: 18.6 - 30.4
21 Sinuosity (Sin)	1.4	1.55	1.8

TABLE 3 Continued
Reference Stream Geometery and Classification
Back Creek Mitigation Site

Variables	Exisiting Channel		
	UT to Dutch Buffalo Creek	UT to Reedy Creek	UT to Crane Creek
Pattern Ratios			
22 Pool to Pool Spacing/ Bankfull Width (L_{p-p}/W_{bkf})	Mean: 5.5 Range: 3.4 - 9.0	Mean: 8.1 Range: 1.3 - 10.8	Mean: 5.2 Range: 2.6 - 11.3
23 Meander Length/ Bankfull Width (L_m/W_{bkf})	Mean: 8 Range: 5.8 - 11.1	Mean: 9.8 Range: 7.8 - 13.2	Mean: 7.2 Range: 6.0 - 11.4
24 Meander Width Ratio (W_{belt}/W_{bkf})	Mean: 5.2 Range: 4.2 - 6.0	Mean: 7.3 Range: 6.5 - 8.1	Mean: 8.5 Range: 7.4 - 10.0
25 Radius of Curvature/ Bankfull Width (Rc/W_{bkf})	Mean: 2.7 Range: 1.2 - 5.7	Mean: 2.7 Range: 1.6 - 4.0	Mean: 2.5 Range: 1.8 - 3.0
Profile Variables			
26 Average Water Surface Slope (S_{ave})	0.0062	0.0111	0.0014
27 Valley Slope (S_{valley})	0.0086	0.0172	0.0025
28 Riffle Slope (S_{riffle})	Mean: 0.0091 Range: 0.005 - 0.0159	Mean: 0.014 Range: 0.0105 - 0.0221	Mean: 0.0019 Range: 0.006 - 0.0033
29 Pool Slope (S_{pool})	Mean: 0.0019 Range: 0.0005 - 0.0052	Mean: 0.0069 Range: 0.0016 - 0.0182	Mean: 0.0004 Range: 0 - 0.0006
Profile Ratios			
30 Riffle Slope/ Water Surface Slope (S_{riffle}/S_{ave})	Mean: 1.5 Range: 0.8 - 2.6	Mean: 1.3 Range: 0.9 - 2.0	Mean: 1.4 Range: 0.4 - 2.4
31 Pool Slope/Water Surface Slope (S_{pool}/S_{ave})	Mean: 0.3 Range: 0.1 - 0.8	Mean: 0.6 Range: 0.1 - 1.6	Mean: 0.3 Range: 0 - 0.4
Materials			
D16	NA	0.1	NA
D35	0.18	0.29	0.44
D50	0.4	0.5	1.9
D84	13	12	12
D95	21	85	36

4.1 Reference Channel

Initially, reference streams in the region were visited and classified by stream type (Rosgen 1996). This classification stratifies streams into comparable groups based on geometric characteristics. Reference reaches identified in the vicinity were characterized primarily as E-type (highly sinuous) channels with sand or gravel substrate. E-type streams are slightly entrenched, highly sinuous (>1.5) channels which exhibit high meander width ratios (belt width/bankfull width). These streams exhibit a sequence of riffles and pools associated with a sinuous flow pattern.

Dimension

Data collected at UT to Crane Creek indicate a bankfull cross-sectional area ranging from 19.3 to 25.0 square feet, with bankfull widths of 9.5 to 11.9 feet, average depths of 1.9 to 2.1 feet, and width/depth ratios of 5 to 7 (Table 3). Regional curves predict that the stream should exhibit a bankfull cross-sectional area of approximately 28 square feet, slightly above the range displayed by the reach.

Field indicators measured at the UT to Reedy Creek indicate a bankfull cross-sectional area ranging from 11.8 to 17.1 square feet, including widths of 9.6 to 11.2 feet, average depths of 1.2 to 1.6 feet, and width/depth ratios of 6 to 8 (Table 3). Regional curves predict that the stream should exhibit a bankfull cross-sectional area of approximately 12 square feet, within the range displayed by the reach.

Pattern

In-field measurements of the UT to Crane Creek have yielded an average sinuosity of 1.8 (Table 3). Accompanying this sinuosity is a belt width which ranges between 74 and 101 feet, an average meander wavelength of 88 feet, and a radius of curvature ranging between 19 and 30 feet. Meander geometry values for this reference reach are acceptable for E-type streams in the region.

Based on field surveys, the UT to Reedy Creek demonstrates an average sinuosity of 1.55 (Table 3). This sinuosity supports a belt width which ranges between 68 and 84 feet, an average meander wavelength of 102 feet, and a radius of curvature ranging from 17 to 42 feet. Pattern values for this reference reach appear suitable for E-type streams in the vicinity.

Field surveys of the UT to Dutch Buffalo Creek indicate an average sinuosity of 1.4 (Table 3). Associated with this sinuosity is a belt width ranging from 42 to 60 feet, an average meander wavelength of 80 feet, and a radius of curvature ranging between 12 and 57 feet. Pattern values for this reference reach are acceptable for E-type streams in the Piedmont.

Profile

Based on elevational profile surveys, the reference reach at the UT to Reedy Creek is characterized by a relatively steep valley slope (0.017 rise/run); however, this was expected because this reach is located relatively far upstream, away from the influence of Reedy Creek and its associated floodplain. Typically, gradient decreases in a downstream direction as the watershed increases in size. This is evidenced by the valley slope of the UT to Crane Creek which is relatively flat (0.0025 rise/run). This reference reach was surveyed farther down valley, and the comparatively flat valley slope was anticipated. The valley slope on the reference portion of the UT to Dutch Buffalo Creek is moderately steep (0.0086 rise/run). However, this tributary flows through a progressively flattening valley. Pool slopes (S_{pool}) and riffle slopes (S_{riffle}) of all three reference reaches reside, on average, within the range indicative of stable stream systems.

4.2 Reference Forest Ecosystems

According to Mitigation Site Classification (MiST) guidelines (EPA 1990), Reference Forest Ecosystems (RFEs) must be established for mitigation sites. RFEs are forested areas on which to model restoration efforts of the mitigation site in relation to soils, hydrology, and vegetation. RFEs should be ecologically stable climax communities and should represent believed historical (pre-disturbance) conditions of the mitigation site. Quantitative data describing plant community composition and structure are collected at the RFEs and subsequently applied as reference data for design of the mitigation site planting scheme.

Three RFE areas were chosen to guide plant community restoration along the on-site channel. The RFEs are all found within the Southern Outer Piedmont Ecoregion, one southwest and two northeast of the Site. The RFEs support plant community, landform, and hydrological characteristics that restoration efforts will attempt to emulate. Circular, 0.1-acre plots were randomly established within the selected RFEs. Data collected within each plot include 1) tree, shrub, and herb species composition; 2) number of stems for each tree and shrub species; and 3) diameter at breast height (DBH) for each tree and shrub species. Field data (Tables 4A through 4C) indicate importance values (IV) of dominant tree species calculated based on relative density, dominance, and frequency of tree species composition (Smith 1980). Hydrology, surface topography, and habitat features were also evaluated.

Table 4A

Reference Forest Plot Summary
Bottomland Hardwood Forest (Canopy Species)
UT to Crane Creek Floodplain

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1] (%)	Relative Frequency (%)	Basal Area (ft^2 / acre)	Relative Basal Area (%)	Importance Value
Acer negundo	3	7.9	67	8.7	2.3	5.9	0.07
Acer rubrum	3	7.9	67	8.7	4.2	10.6	0.09
Carya ovata	5	13.2	67	8.7	2.5	6.3	0.09
Cary tomentosa	1	2.6	33	4.3	0.1	0.2	0.02
Fagus grandiflora	1	2.6	33	4.3	2.0	5.2	0.04
Fraxinus americana	1	2.6	33	4.3	1.3	3.3	0.03
Fraxinus pennsylvanica	6	15.8	100	13.0	3.5	8.8	0.13
Juniperus virginica	1	2.6	33	4.3	0.4	0.9	0.03
Liquidambar styraciflua	1	2.6	33	4.3	0.1	0.3	0.02
Liriodendron tulipifera	3	7.9	67	8.7	2.7	6.7	0.08
Nyssa sylvatica	1	2.6	33	4.3	0.1	0.2	0.02
Quercus falcata	1	2.6	33	4.3	2.9	7.3	0.05
Quercus michauxii	3	7.9	67	8.7	13.3	33.6	0.17
Quercus phellos	2	5.3	33	4.3	2.3	5.8	0.05
Ulmus americana	6	15.8	67	8.7	1.9	4.9	0.10
TOTALS	38	100	767	100	40	100	1

[1] Summary of three 0.1-acre plots

Table 4B

Reference Forest Plot Summary
Bottomland Hardwood Forest (Canopy Species)
UT to Reedy Creek Floodplain

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1] (%)	Relative Frequency (%)	Basal Area (ft^2 / acre)	Relative Basal Area (%)	Importance Value
Acer negundo	6	7.8	50	5.3	1.9	2.6	0.05
Acer rubrum	2	2.6	50	5.3	0.6	0.8	0.03
Carpinus caroliniana	7	9.1	50	5.3	1.2	1.7	0.05
Carya ovata	2	2.6	50	5.3	5.4	7.3	0.05
Celtis laevigata	6	7.8	50	5.3	3.1	4.2	0.06
Fagus grandiflora	2	2.6	50	5.3	6.5	8.8	0.06
Fraxinus pennsylvanica	1	1.3	25	2.6	0.4	0.5	0.01
Juglans nigra	4	5.2	75	7.9	5.2	7.0	0.07
Liquidambar styraciflua	7	9.1	75	7.9	6.6	8.9	0.09
Liriodendron tulipifera	5	6.5	75	7.9	15.9	21.5	0.12
Morus rubra	8	10.4	75	7.9	4.0	5.4	0.08
Nyssa sylvatica	3	3.9	75	7.9	3.0	4.0	0.05
Platanus occidentalis	2	2.6	25	2.6	6.5	8.8	0.05
Quercus alba	2	2.6	25	2.6	1.7	2.2	0.02
Quercus michauxii	1	1.3	25	2.6	0.5	0.7	0.02
Quercus phellos	1	1.3	25	2.6	1.6	2.2	0.02
Quercus rubra	7	9.1	50	5.3	7.2	9.8	0.08
Ulmus americana	11	14.3	100	10.5	3.0	4.0	0.10
TOTALS	77	100	950	100	74	100	1

[1] Summary of four 0.1-acre plots

TABLE 4C

Reference Forest Plot Summary
Bottomland Hardwood Forest (Canopy Species)
Rocky River at the Rocky River Golf Club

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1] (%)	Relative Frequency (%)	Basal Area (ft^2/acre)	Relative Basal Area (%)	Relative Importance (%)
Fraxinus pennsylvanica	62	42	10	26	57.8	51	0.39
Acer negundo	41	28	9	23	17.0	15	0.22
Ulmus americana	15	10	7	18	10.7	9	0.12
Quercus michauxii	6	4	1	3	11.8	10	0.06
Carpinus caroliniana	8	5	3	8	1.1	1	0.05
Quercus lyrata	4	3	3	8	5.1	4	0.05
Celtis laevigata	6	4	2	5	7.0	6	0.05
Platanus occidentalis	1	1	1	3	1.8	2	0.02
Ulmus alata	3	1	1	3	0.1	0	0.02
Fraxinus caroliniana	2	1	1	3	0.3	0	0.01
Ligustrum sinense	1	1	1	3	0.1	0	0.01
TOTALS	149	100	39	103	113	98	1

[1]Summary of ten - 0.1-acre plots

One of the northeastern RFEs is located in the floodplain of a UT to Crane Creek in Rowan County, North Carolina. Three 0.1-acre plots were established which best characterize expected steady-state forest composition. Forest vegetation was dominated by swamp chestnut oak (IV=0.17), green ash (IV=0.13), American elm (IV=0.10), and shagbark hickory (IV=0.09) (Table 4A). Portions of the canopy were also dominated by willow oak, boxelder (*Acer negundo*), tulip tree (*Liriodendron tulipifera*), black tupelo (*Nyssa sylvatica*), and red maple (*Acer rubrum*).

A second RFE is located southwest of the Site in the floodplain of Reedy Creek in Mecklenburg County, North Carolina. Within the RFE, vegetative sampling at four 0.1-acre plots indicate that forest tree vegetation was dominated by tulip tree (IV=0.12), American elm (IV=0.10), northern red oak (IV=0.08), and black walnut (*Juglans nigra*) (IV=0.07) (Table 4B). Other, less dominant tree species within the sample plots were green ash, boxelder, and American sycamore.

The third RFE is located northeast of the Site in the floodplain of the Rocky River in Cabarrus County, North Carolina. Ten 0.1-acre plots were established which best characterize expected steady-state forest composition. Forest vegetation was dominated by green ash (IV=0.39), boxelder (IV=0.22), American elm (IV=0.12), swamp chestnut oak (IV=0.06), ironwood (*Carpinus caroliniana*) (IV=0.05), overcup oak (*Querces lyrata*) (IV=0.05), and hackberry (IV=0.05) (Table 4C). Portions of the canopy were also dominated by winged elm, water ash (*Fraxinus caroliniana*), and Chinese Privet.

5.0 RESTORATION PLAN

The primary goals of this restoration plan include 1) construction of a stable, riffle-pool stream channel; 2) enhancement of water quality functions in the on-site, upstream, and downstream segments of the channel; 3) creation of a natural vegetation buffer along restored stream channels; 4) maximization of the area returned to historic wetland function; and 5) restoration of wildlife functions associated with a riparian corridor/stable stream.

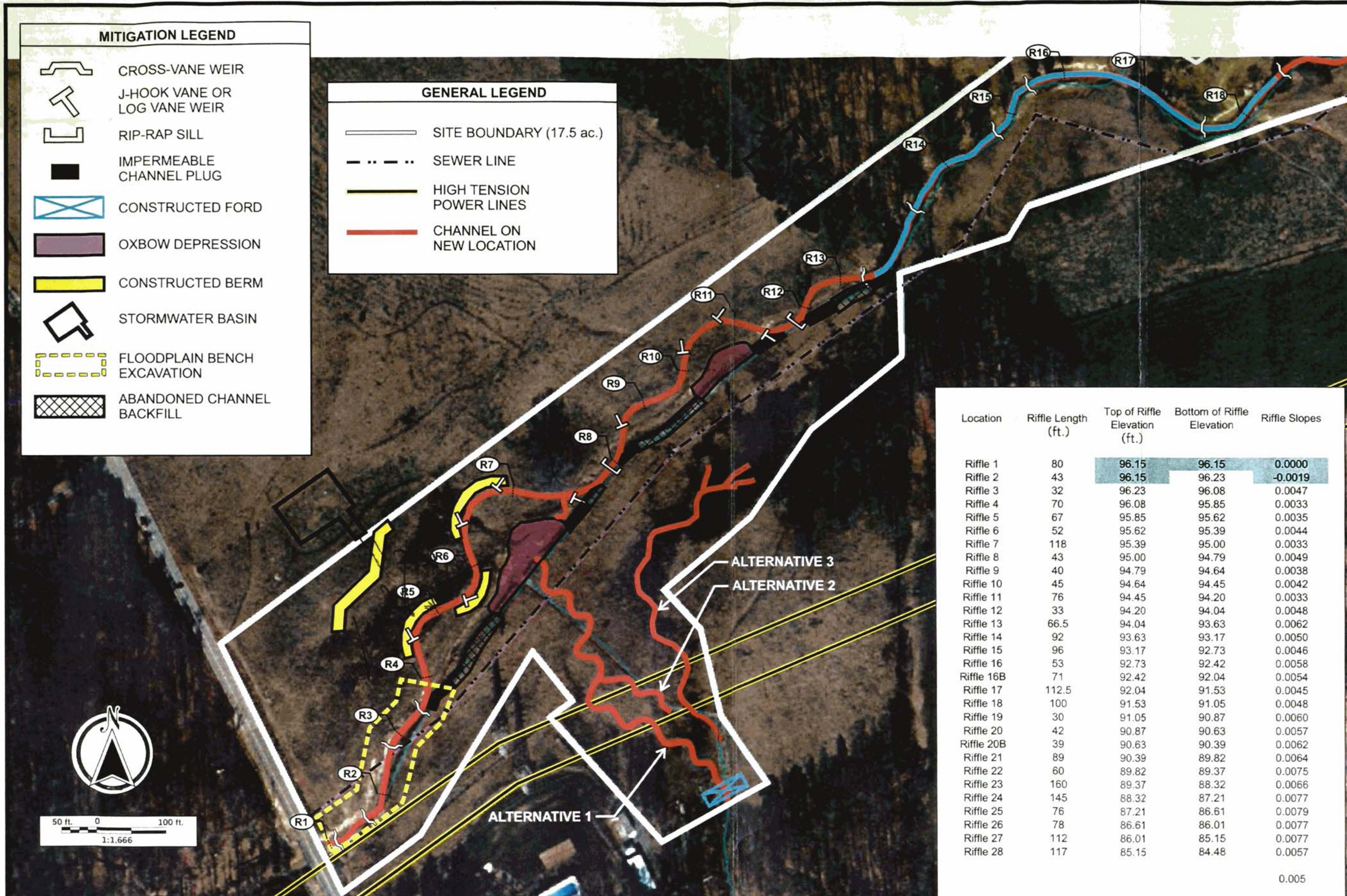
The complete mitigation plan is depicted in Figures 11A and 11B. The proposed mitigation plan is expected to restore approximately 3525 linear feet of Back Creek (1390 linear feet on new location and 2135 linear feet in-place), restore approximately 827 linear feet of secondary tributary adjacent to Back Creek, restore approximately 1.5 acres of jurisdictional wetland, enhance approximately 1.8 acres of jurisdictional wetland, and create approximately 0.5 acre of open water/freshwater marsh within the Site boundaries. Components of this plan may be modified based on construction or access constraints.

Primary activities proposed at the Site include 1) stream restoration, 2) wetland enhancement/restoration, 3) soil scarification, and 4) plant community restoration. Subsequently, a monitoring plan and contingency plan are outlined in Section 6 of this document.

5.1 Stream Restoration

This stream restoration effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography relative to reference conditions. This effort consists of 1) stream reconstruction on new location and 2) stream reconstruction in-place. Geometric attributes for the existing, degraded channel and the proposed, stable channel are listed in Table 5.

An erosion control plan and construction/transportation plan are expected to be developed during the next phase of this project. Erosion control will be performed locally throughout the Site and will be incorporated into construction sequencing. Exposed surficial soils at the Site are unconsolidated, alluvial sediments which do not re-vegetate rapidly after disturbance; therefore, seeding with appropriate grasses and immediate planting with disturbance-adapted shrubs will be employed following the earth-moving process. In addition, on-site root mats (seed banks) and vegetation will be stockpiled and redistributed after disturbance.



Location	Riffle Length (ft.)	Top of Riffle Elevation (ft.)	Bottom of Riffle Elevation	Riffle Slopes
Riffle 1	80	96.15	96.15	0.0000
Riffle 2	43	96.15	96.23	-0.0019
Riffle 3	32	96.23	96.08	0.0047
Riffle 4	70	96.08	95.85	0.0033
Riffle 5	67	95.85	95.62	0.0035
Riffle 6	52	95.62	95.39	0.0044
Riffle 7	118	95.39	95.00	0.0033
Riffle 8	43	95.00	94.79	0.0049
Riffle 9	40	94.79	94.64	0.0038
Riffle 10	45	94.64	94.45	0.0042
Riffle 11	76	94.45	94.20	0.0033
Riffle 12	33	94.20	94.04	0.0048
Riffle 13	66.5	94.04	93.63	0.0062
Riffle 14	92	93.63	93.17	0.0050
Riffle 15	96	93.17	92.73	0.0046
Riffle 16	53	92.73	92.42	0.0058
Riffle 16B	71	92.42	92.04	0.0054
Riffle 17	112.5	92.04	91.53	0.0045
Riffle 18	100	91.53	91.05	0.0048
Riffle 19	30	91.05	90.87	0.0060
Riffle 20	42	90.87	90.63	0.0057
Riffle 20B	39	90.63	90.39	0.0062
Riffle 21	89	90.39	89.82	0.0064
Riffle 22	60	89.82	89.37	0.0075
Riffle 23	160	89.37	88.32	0.0066
Riffle 24	145	88.32	87.21	0.0077
Riffle 25	76	87.21	86.61	0.0079
Riffle 26	78	86.61	86.01	0.0077
Riffle 27	112	86.01	85.15	0.0077
Riffle 28	117	85.15	84.48	0.0057
				0.005

(shaded) Riffle elevations and slope is equal to existing bed contours to avoid hydrologic trespass

EcoScience Corporation
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Client:
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BACK CREEK MITIGATION SITE

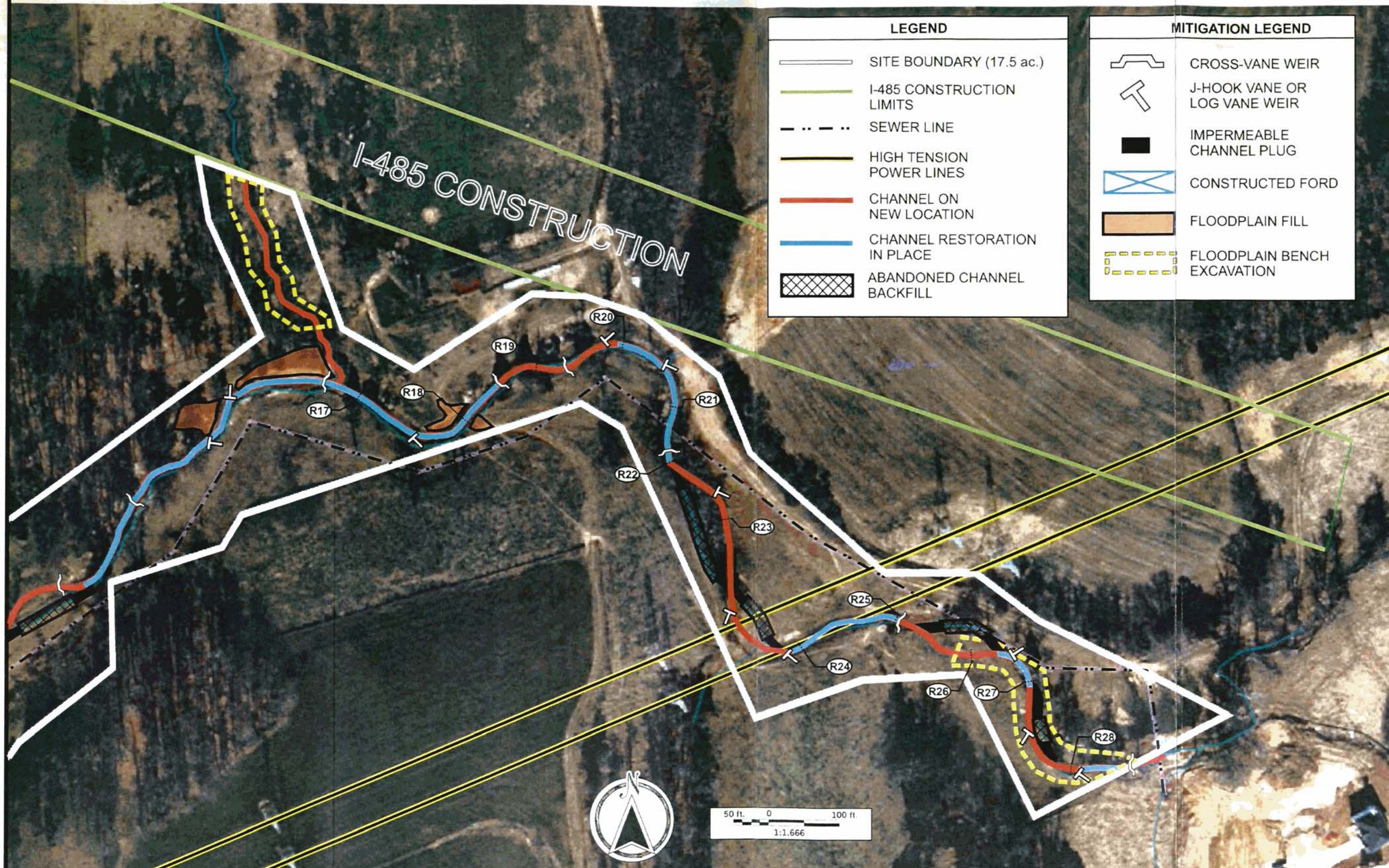
DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
MITIGATION PLAN

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE
11-A



NOTE:
FOR RIFFLE ELEVATIONS AND SLOPE, SEE TABLE. FIGURE 11-A.

EcoScience Corporation
Raleigh, North Carolina 27605

Client:
NCDOT

Project:
BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
MITIGATION PLAN

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE
11-B

TABLE 5
BACK CREEK STREAM RESTORATION SITE
Morphological Characteristics of Existing, Reference, and Proposed Channels

Variables	Exisiting Channel			Reference Reach	Proposed Reach
	Upstream Straightened	Downstream Sinuous (C)	Downstream Sinuous (E)	UT to Crane Creek	Back Creek
1 Stream Type	E5	C5	E4	E4/5	E4/5
2 Drainage Area (mi^2)	3.7-3.8	3.8-4.0	4.0-4.1	1.5	3.7-4.1
3 Bankfull Discharge (cfs)	250-300	250-300	250-300	85	250-300
Dimension Variables					
4 Bankfull Cross Sectional Area (A_{bkf})	54	56.2	55.7	20.5	56
5 Bankfull Width (W_{bkf})	Mean:. 19.0 Range: 16.7-21.9	Mean: 32.2 Range: 29.5-36	Mean: 22.7 Range: --	Mean: 10.1 Range: 9.5-11.9	Mean: 22.4 Range: 21.2-23.7
6 Bankfull Mean Depth (D_{bkf})	Mean: 2.9 Range: 2.2-3.4	Mean: 1.8 Range: 1.6-1.9	Mean: 2.5 Range: --	Mean: 2.0 Range: 1.9-2.1	Mean: 2.5 Range: 2.4-2.6
7 Bankfull Maximum Depth (D_{max})	Mean: 4.4 Range: 4.0-4.7	Mean: 3.3 Range: 3.0-3.6	Mean: 3.8 Range: --	Mean: 2.6 Range: 2.5-2.9	Mean: 3.3 Range: 2.8-3.8
8 Pool Width (W_{pool})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 26.5 Range: 24.5-28.5	Mean: 26.5 Range: 24.5-28.5	Mean: 11.1 Range: 10.5-11.7	Mean: 29.1 Range: 22.4-33.6
9 Maximum Pool Depth (D_{pool})		Mean: 4.3 Range: 4.1-4.5	Mean: 4.3 Range: 4.1-4.5	Mean: 2.9 Range: 2.8-3.0	Mean: 4.3 Range: 3.5-7.5
10 Width of Floodprone Area (W_{fpa})	Mean: 253 Range: 290-235	Mean: 179 Range: 114-293	Mean: 297 Range: --	Mean: 237 Range: 232-345	Mean: 230 Range: 114-297
Dimension Ratios					
11 Entrenchment Ratio (W_{fpa}/W_{bkf})	Mean: 13.3 Range: 13-14	Mean: 6 Range: 4-10	Mean: 13 Range: --	Mean: 25.0 Range: 20.0-34.5	Mean: 10.3 Range: 5.1-13.3
12 Width/Depth Ratio W_{bkf}/D_{bkf})	Mean: 7 Range: 5-10	Mean: 19 Range: 16-23	Mean: 9 Range:	Mean: 5 Range: 5-6	Mean: 9 Range: 8-10
13 Max. D_{riff}/D_{bkf} Ratio	Mean: 1.6 Range: 1.4-1.8	Mean: 1.9 Range: 1.7-2.1	Mean: 1.5 Range:	Mean: 1.3 Range: 1.3-1.5	Mean: 1.3 Range: 1.1-1.5
14 Low Bank Height/ Max. D_{bkf} Ratio	Mean: 1.0 Range: 1.0-1.0	Mean: 1.2 Range: 1.1-1.5	Mean: 1.4 Range:	Mean: 1.2 Range: 1.1-1.2	Mean: 1.0 Range: 1.0-1.2
15 Pool Depth/Bankfull Mean Depth (D_{pool}/D_{bkf})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 1.5 Range: 1.4-1.6	Mean: 1.5 Range: 1.4-1.6	Mean: 1.5 Range: --	Mean: 1.7 Range: 1.4-3.0
16 Pool width/Bankfull Width (W_{pool}/W_{bkf})		Mean: 0.8 Range: 0.8-0.9	Mean: 0.8 Range: 0.8-0.9	Mean: 1.1 Range: 1.0-1.2	Mean: 1.3 Range: 1.0-1.5
17 Pool Area/Bankfull Cross Sectional Area		Mean: 1.2 Range: --	Mean: 1.2 Range: --	Mean: 0.9 Range: --	Mean: 1.2 Range: 1.1-1.4
Pattern Varialbles					
18 Pool to Pool Spacing (L_{p-p})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 180 Range: 59-351	Mean: 180 Range: 59-351	Mean: 53 Range: 26-114	Mean: 126 Range: 60-210
19 Meander Length (L_m)		Mean: 313 Range: 129-608	Mean: 313 Range: 129-608	Mean: 73 Range: 61-115	Mean: 220 Range: 166-347
20 Belt Width (W_{belt})		Mean: 95 Range: 41-199	Mean: 95 Range: 41-199	Mean: 86.1 Range: 74.3-101.3	Mean: 57 Range: 25-140
21 Radius of Curvature (R_c)		Mean: 67 Range: 23-135	Mean: 67 Range: 23-135	Mean: 25.3 Range: 18.6-30.4	Mean: 58 Range: 43-100
22 Sinuosity (Sin)	1.02	1.4	1.4	1.8	1.5

TABLE 5 Continued
BACK CREEK STREAM RESTORATION SITE
Morphological Characteristics of Existing, Reference, and Proposed Channels

Variables	Exisiting Channel			Reference Reach	Proposed Reach
	Upstream Straightened	Downstream Sinuous (C)	Downstream Sinuous (E)	UT to Crane Creek	Back Creek
Pattern Ratios					
23 Pool to Pool Spacing/ Bankfull Width (L_{p-p}/W_{bkf})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 5.6 Range: 1.8-10.9	Mean: 7.9 Range: 2.6-15.5	Mean: 5.2 Range: 2.6-11.3	Mean: 5.6 Range: 2.7-9.4
24 Meander Length/ Bankfull Width (L_m/W_{bkf})		Mean: 9.7 Range: 4.0-18.9	Mean: 13.8 Range: 5.7-26.8	Mean: 7.2 Range: 6.0-11.4	Mean: 9.8 Range: 7.4-15.5
25 Meander Width Ratio (W_{belt}/W_{bkf})		Mean: 3.0 Range: 1.3-6.2	Mean: 4.2 Range: 1.8-8.8	Mean: 8.5 Range: 7.4-10.0	Mean: 2.5 Range: 1.1-6.3
26 Radius of Curvature/ Bankfull Width (Rc/W_{bkf})		Mean: 2.1 Range: 0.7-4.2	Mean: 3.0 Range: 1.0-5.9	Mean: 2.5 Range: 1.8-3.0	Mean: 2.6 Range: 2.0-4.5
Profile Variables					
27 Average Water Surface Slope (S_{ave})	0.0037	0.0037	0.0037	0.0014	0.0034
28 Valley Slope (S_{valley})	0.0038	0.0052	0.0052	0.0025	0.0051
29 Riffle Slope (S_{riffle})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 0.0144 Range: 0-0.0507	Mean: 0.0144 Range: 0-0.0507	Mean: 0.0019 Range: 0.0006-0.0033	Mean: 0.005 Range: 0.0033-0.0079
30 Pool Slope (S_{pool})		Mean: 0.0006 Range: 0-0.0035	Mean: 0.0006 Range: 0-0.0035	Mean: 0.0004 Range: 0.0000-0.0006	Mean: 0.0017 Range: 0-0.003
Profile Ratios					
31 Riffle Slope/ Water Surface Slope (S_{riffle}/S_{ave})	No distinctive repetitive pattern of riffles and pools due to straighting activities	Mean: 3.9 Range: 0-13.7	Mean: 3.9 Range: 0-13.7	Mean: 1.4 Range: 0.4-2.4	Mean: 1.5 Range: 1.0-2.3
32 Pool Slope/Water Surface Slope (S_{pool}/S_{ave})		Mean: 0.16 Range: 0-0.9	Mean: 0.16 Range: 0-0.9	Mean: 0.3 Range: 0.0-0.4	Mean: 0.5 Range: 0.1-0.9
Materials					
D16	0.15	0.14	0.31	NA	NA
D35	0.39	0.28	2	0.44	0.4
D50	0.7	0.6	19.8	1.9	2
D84	10	32	55	12	34
D95	149	152	139	36	140

A transportation plan, including the location of access routes and staging areas will be designed to avoid impacts to the existing wetland pockets and proposed design channel corridor. In addition, the transportation plan and all construction activities will minimize disturbance to existing vegetation and soils to the extent feasible. The number of transportation access points into the floodplain will be maximized to avoid traversing long distances through the Site interior.

5.1.1 Reconstruction on New Location

The upstream reach of the Site is characterized by an adjacent floodplain that is suitable for design channel excavation on new location. Primary activities designed to restore the channel on new location include 1) beltwidth preparation and grading, 2) floodplain bench excavation, 3) channel excavation, 4) installation of channel plugs, and 5) backfilling of the abandoned channel.

Beltwidth Preparation and Grading

The stream beltwidth corridor will be cleared to allow survey and equipment access. Care will be taken to avoid the removal of existing, deeply rooted vegetation within the beltwidth corridor which may provide design channel stability. Material excavated during grading will be stockpiled immediately adjacent to channel segments to be abandoned and backfilled. These segments will be backfilled after stream diversion is completed.

Spoil material may be placed to stabilize temporary access roads and to minimize compaction of the underlying floodplain. However, all spoil will be removed from floodplain surfaces upon completion of construction activities.

After preparation of the corridor, the design channel and updated profile survey will be developed and the location of each meander wavelength plotted and staked along the profile. Pool locations and relative frequency configurations may be modified in the field based on local variations in the floodplain profile.

Floodplain Bench Excavation

The creation of a bankfull, floodplain bench is expected to 1) remove the eroding material and collapsing banks, 2) promote overbank flooding during bankfull flood events, 3) reduce the erosive potential of flood waters, and 4) increase the width of the active floodplain. Bankfull benches may be created by excavating the adjacent floodplain to bankfull elevations or filling eroded/abandoned channel areas with suitable material. After excavation, or filling of the bench, a relatively level floodplain surface is expected to be stabilized with suitable erosion control measures. Planting of the bench with native floodplain vegetation is expected to reduce erosion of bench sediments, reduce flow velocities in flood waters, filter pollutants, and provide wildlife habitat.

Channel Excavation

The channel will be constructed within the range of values depicted in Table 5. The cross-sectional area will average 56 square feet, with a bankfull width measuring approximately 22.4 feet, and an average bankfull depth measuring approximately 2.5 feet (Figure 12).

Figures 11A and 11B provide a plan form and riffle elevations, lengths, and slopes for the constructed channel. Elevations depicted for the top of each riffle are equivalent to the previous bottom of riffle, allowing for a flat water surface in all pools under normal flow conditions. A conceptual view of the proposed profile and plan view of the constructed channel is depicted in Figure 13.

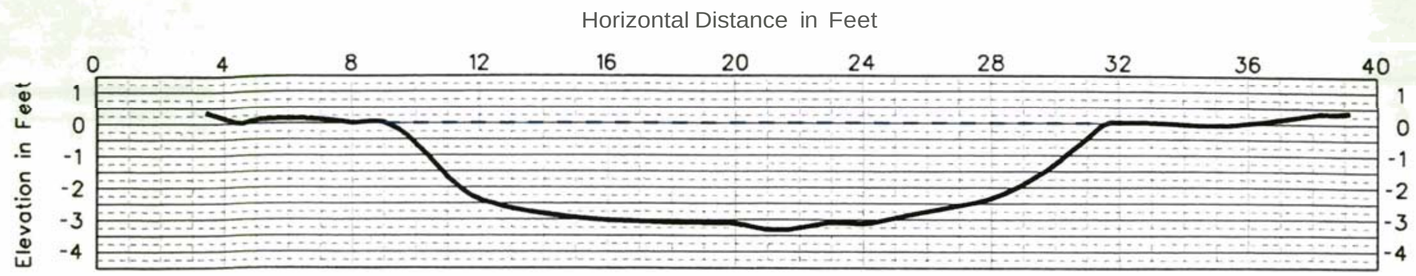
The stream banks and local belt width area of constructed channels will be immediately planted with shrub and herbaceous vegetation. Shrubs such as tag alder (*Ulnus serrulata*) and black willow may be removed from the banks of the abandoned channel or stockpiled during clearing and replaced into the stream construction area. Deposition of shrub and woody debris into and/or overhanging the constructed channel is encouraged. Root mats may also be selectively removed from adjacent areas and placed as erosion control features on channel banks.

Particular attention will be directed toward providing vegetative cover and root growth along the outer bends of each stream meander. Live willow stake revetments will be constructed as conceptually depicted in Figure 14. Available root mats or biodegradable, erosion-control matting may be embedded into the break-in-slope to promote more rapid development of an overhanging bank. Willow stakes will be purchased and/or collected on-site and inserted through the root/erosion mat into the underlying soil.

Channel Plugs

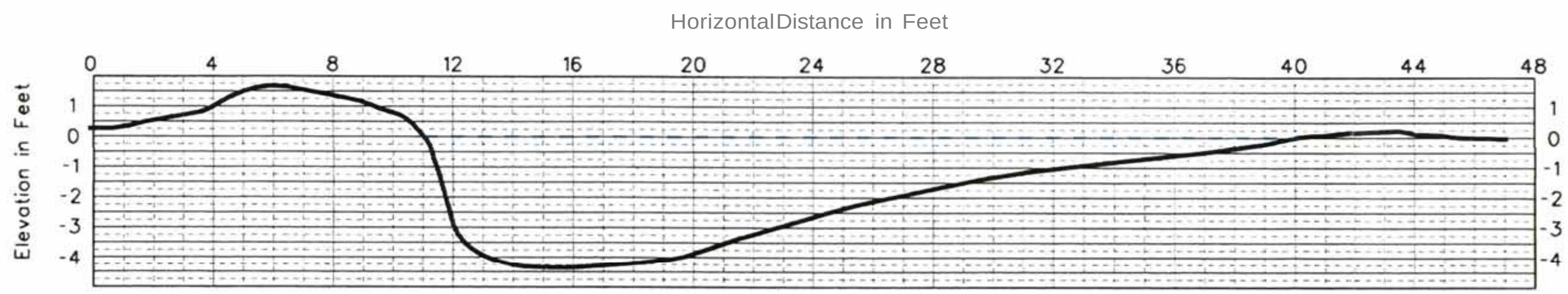
Impermeable plugs will be installed along abandoned channel segments at locations identified in Figures 11A and 11B. The plugs will consist of low-permeability materials or hardened structures designed to be of sufficient strength to withstand the erosive energy of surface flow events across the Site. Dense clays may be imported from off-site or existing material, compacted within the channel, may be suitable for plug construction. The plug will be sufficiently wide and deep to form an imbedded overlap in the existing banks and channel bed.

The plug situated at the upstream terminus of the design channel, located below the stream diversion point, may sustain high-energy flows.



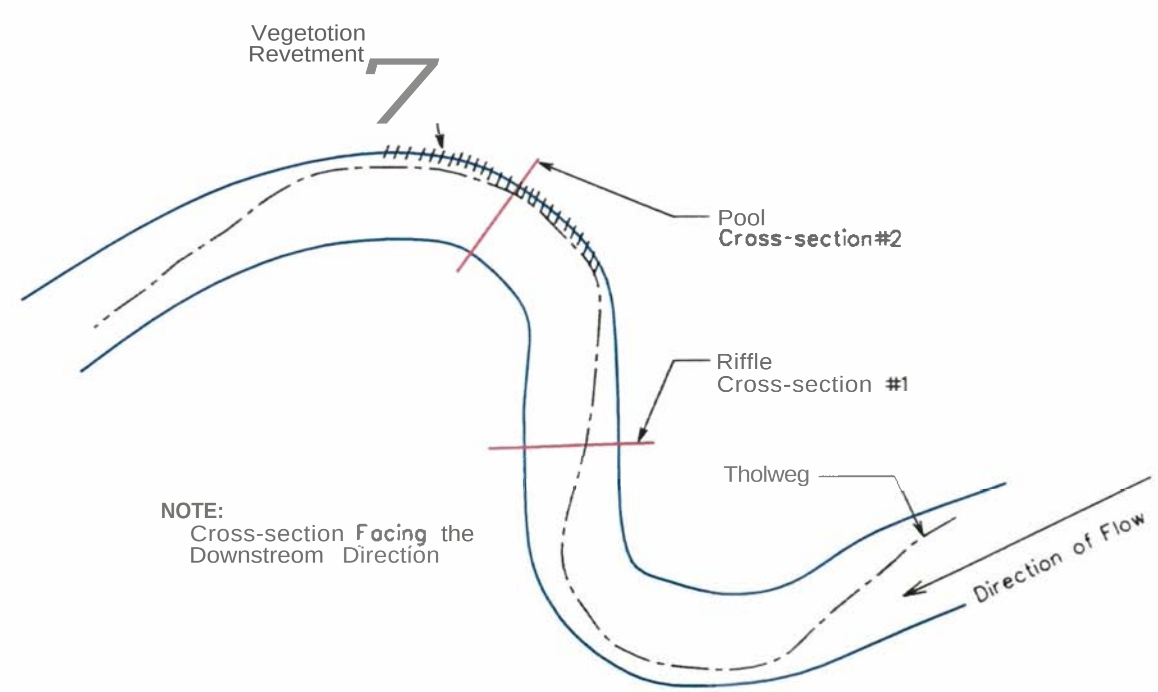
Cross-section 1 Riffle

Bankfull Cross-sectional **Area:** 56 **ft.sq.**
Bankfull Width: **22.7'**
Bankfull Average Depth: 2.5'
Bankfull Maximum Depth: **3.3'**



Cross-section 2 Pool

Bankfull Cross-sectional Area: 67.4 ft.sq.
Bankfull Width: 29.1'
Bankfull Average Depth: **2.3'**
Bankfull Maximum Depth: **4.3'**



NOTE:
Cross-section Facing the Downstream Direction

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **BACK CREEK MITIGATION SITE**

DETAILED MITIGATION STUDIES

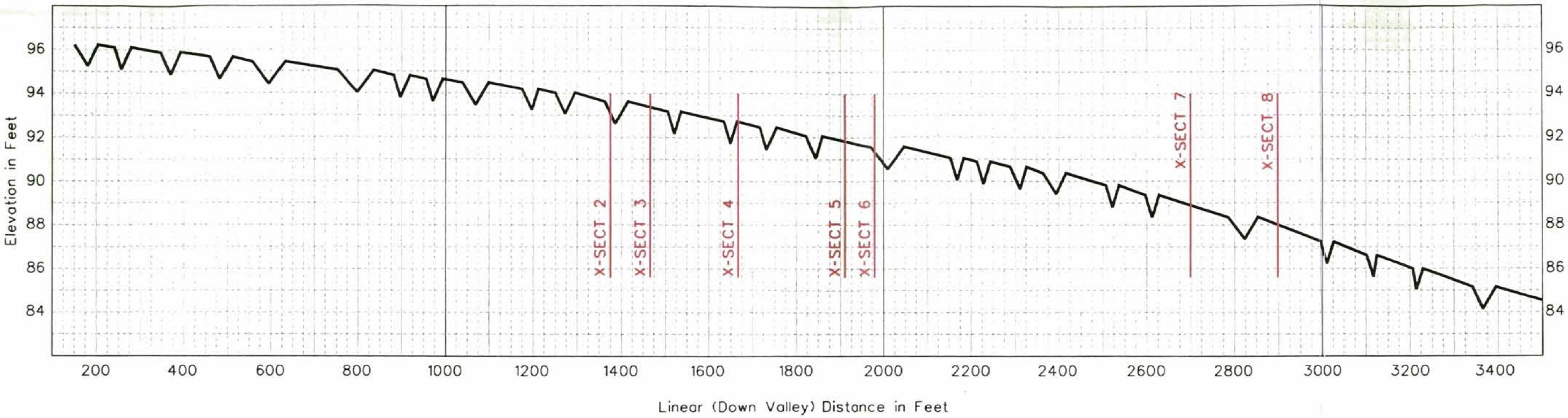
MECKLENBURG COUNTY, NORTH CAROLINA

Title: **PROPOSED CROSS-SECTIONS**

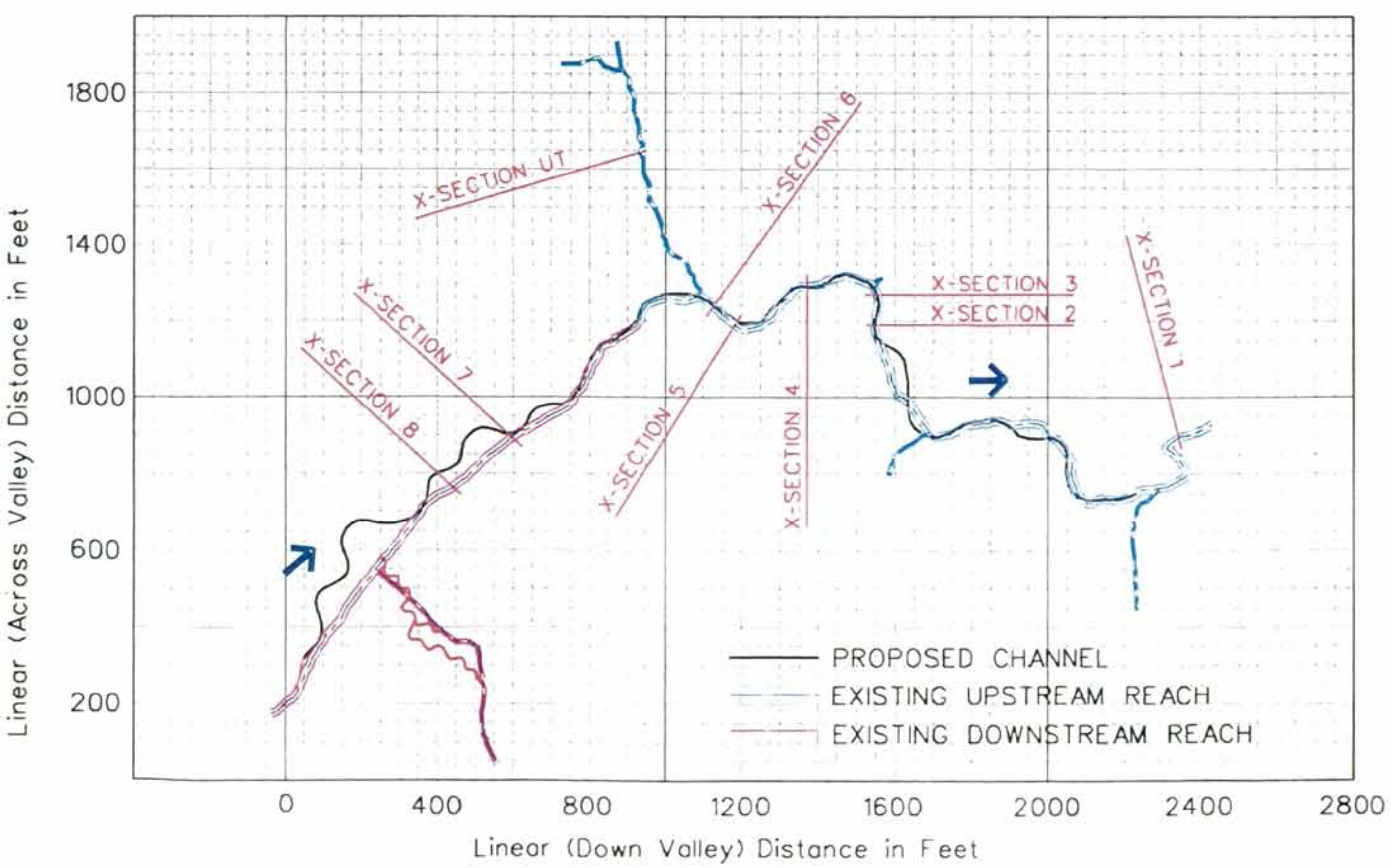
Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 02-113.04	

FIGURE **12**

PROFILE



PLAN VIEW



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Project:
BACK CREEK MITIGATION SITE

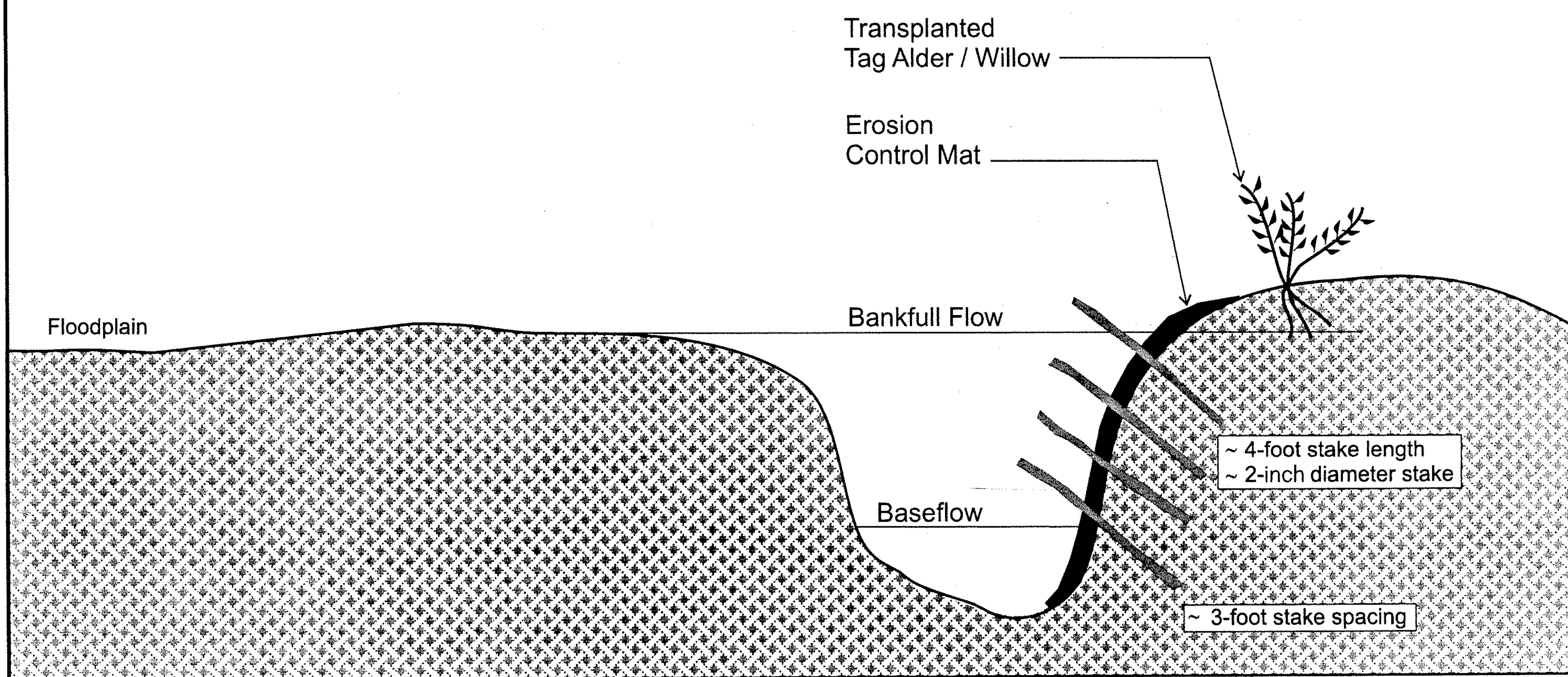
DETAILED MITIGATION STUDIES

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
PROPOSED PROFILE AND PLAN VIEW

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 02-113.04	

FIGURE
13



Not To Scale

EcoScience Corporation

Live Willow Stake Embankment with Erosion Control Matting
BACK CREEK MITIGATION SITE
DETAILED MITIGATION PLANNING
Mecklenburg County, North Carolina

Figure:	14
Project:	02-113.04
Date:	JAN 2003

Therefore, a hardened structure or additional armoring (Section 5.1.1.1) may be considered at this location.

Channel Backfilling

After impermeable plugs are installed, the abandoned channel will be back-filled. Backfilling will be performed primarily by pushing stockpiled materials into the channel. The channel will be filled to the extent that on-site material is available and compacted to maximize microtopographic variability, including ruts, ephemeral pools, and hummocks in the vicinity of the backfilled channel.

A deficit of fill material for channel back-fill may occur. If so, a series of closed, linear depressions may be left along confined channel segments. Additional fill material for critical areas may be obtained by excavating shallow depressions along the banks of these planned, open-channel segments. These excavated areas will represent closed linear, elliptical, or oval depressions. In essence, the channel may be converted to a sequence of shallow, ephemeral pools adjacent to effectively plugged and back-filled channel sections. These pools would be expected to stabilize and fill with organic material over time. Vegetation debris (root mats, top soils, shrubs, woody debris, *etc.*) will be redistributed across the backfill area upon completion.

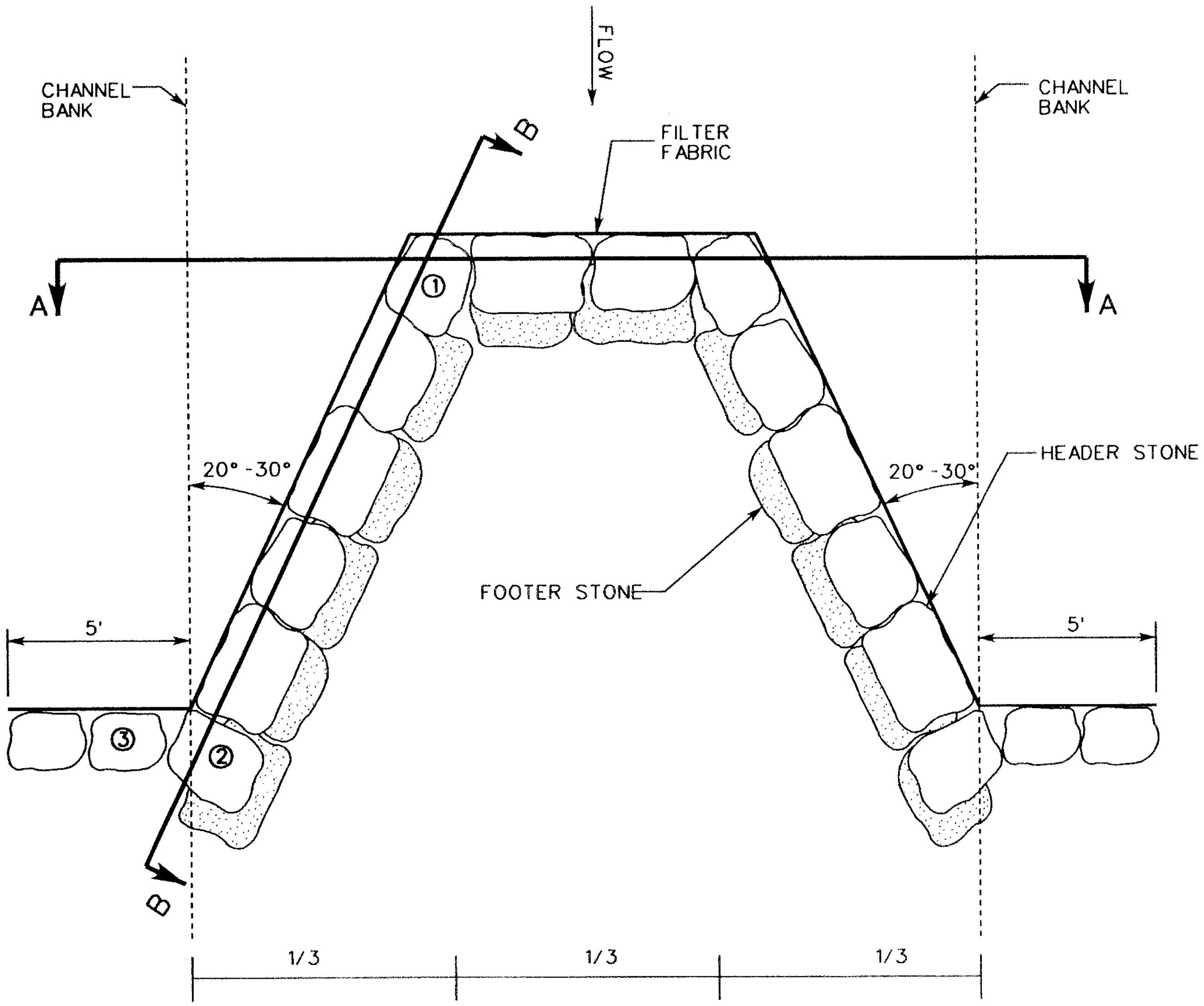
5.1.1.1 In-Stream Structures

Stream restoration under natural stream design techniques normally involves the use of in-stream structures for bank stabilization, grade control, and habitat improvement. Primary activities designed to achieve these objectives may include the installation of 1) cross-vane weirs, 2) J-hook and/or log vanes, 3) stone/rip-rap sills, and 4) root wads.

Cross-vane Weirs

Cross-vane weirs may be installed at locations as depicted in Figures 11A and 11B. The purpose of the vane is to 1) sustain bank stability, 2) direct high velocity flows during bankfull events toward the center of the channel, 3) maintain average pool depth throughout the reach, 4) preserve water surface elevations and reconnect the adjacent floodplain to flooding dynamics from the stream, and 5) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.

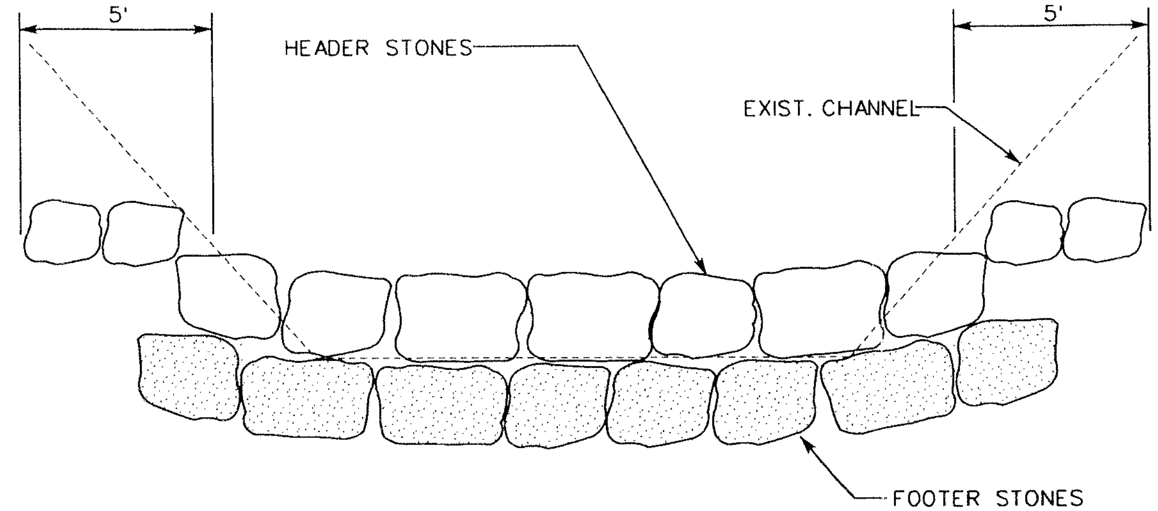
Cross-vane weirs will be constructed as conceptually depicted in Figure 15. The structure will be constructed of boulders approximately 30 inches in minimum width. Cross-vane weir construction will be initiated by imbedding footer rocks into the stream bed for stability and to prevent undercutting of the structure. Header rocks will then be placed atop the



PLAN VIEW

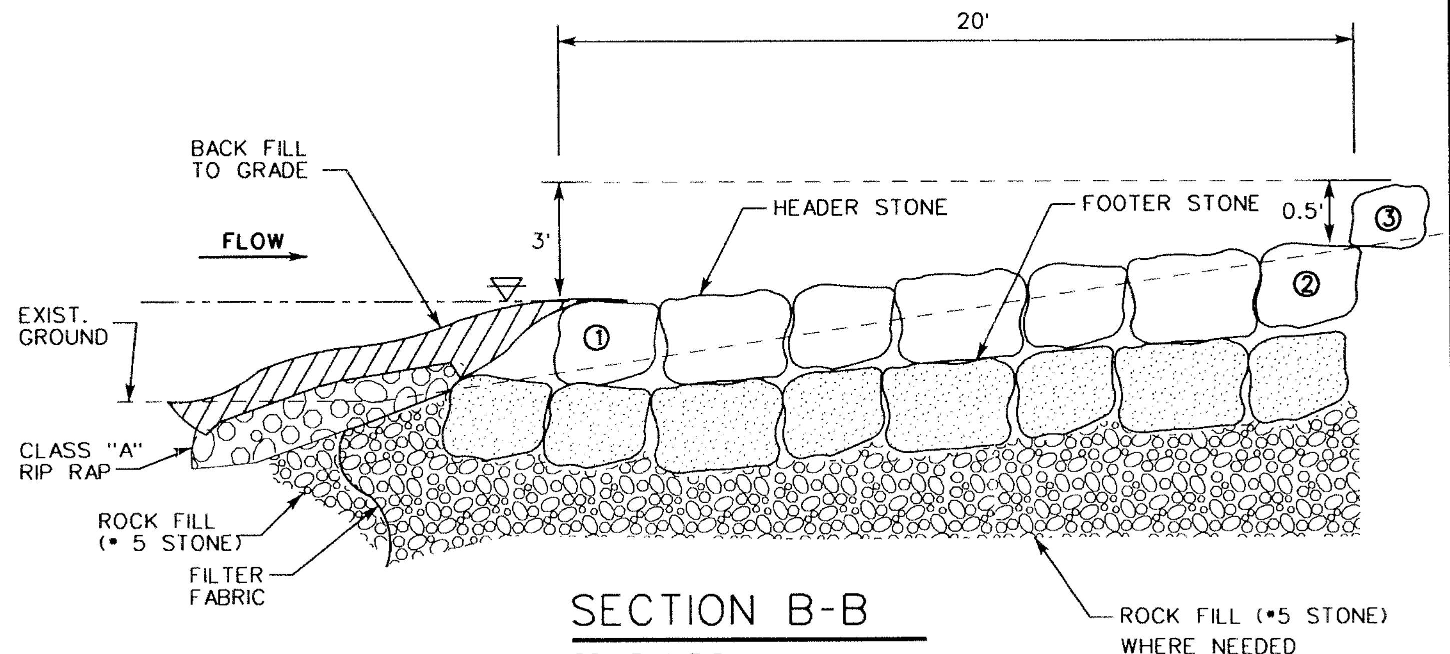
SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER



SECTION A-A

SCALE: N.T.S.



SECTION B-B

SCALE: N.T.S.

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NCDOT

Project:
BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
TYPICAL CROSS–VANE WEIR

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown

ESC Project No.: 02-113.04

FIGURE
15

footer rocks at the design elevation. Footer and header rocks create an arm that slopes from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. The cross-vane arms at both banks will be tied into the bank with a sill to eliminate the possibility of water diverting around the structure. Once the header and footer stones are in place, filter fabric will be buried into a trench excavated around the upstream side of the vane arms. The filter fabric is then draped over the header rocks to force water over the vane. The upstream side of the structure can then be backfilled with suitable material to the elevation of the header stones. Approximately 13 of these structures are anticipated at appropriate locations to maintain bank stability and surface-water elevations along the reach. The approximate location of each structure is depicted in Figures 11A and 11B. Modifications to the location and elevation of each structure may be necessary during construction activities.

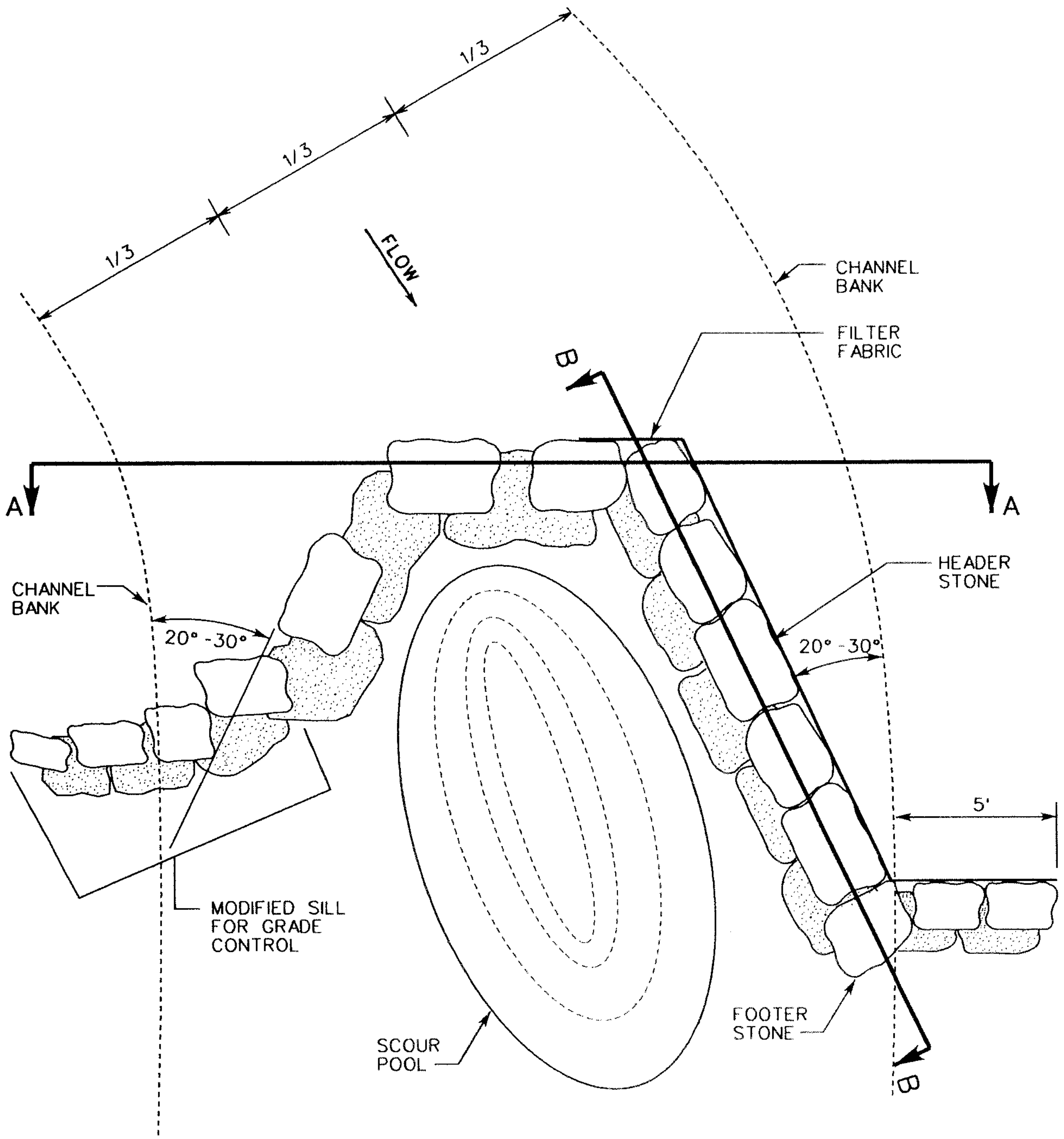
J-hook/log vanes

J-hook or log vane weirs may be installed at locations depicted in Figures 11A and 11B. The primary purpose of these vanes is to direct high-velocity flows during bankfull events towards the center of the channel. J-hook vanes will be constructed using the same type and size of rock used to construct cross-vane weirs (Figure 16). Log vanes will be constructed utilizing large tree trunks harvested from the Site or imported from off-site. The tree stem harvested for a log-vane arm must be long enough to be imbedded into the stream channel and extend several feet into the floodplain (Figure 17). A trench will be dug into the stream channel that is deep enough for the head of the log to be at or below the channel invert. The trench is then extended into the floodplain and the log is set into the trench such that the log arm is below the floodplain elevation. If the log is not of sufficient size to completely block stream flow (gaps occur between the log and channel bed) then a footer log or stone footers will be installed beneath the header log. Boulders will then be situated at the base of the log and at the head of the log to hold the log in place.

Similar to a cross vane, the arm of the J-hook vane and the log vane (which forms an arm) must slope from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. Once these vanes are in place, filter fabric is toed into a trench on the upstream side of the vane and draped over the structure to force water over the vane. The upstream side of the structure is then backfilled with suitable material.

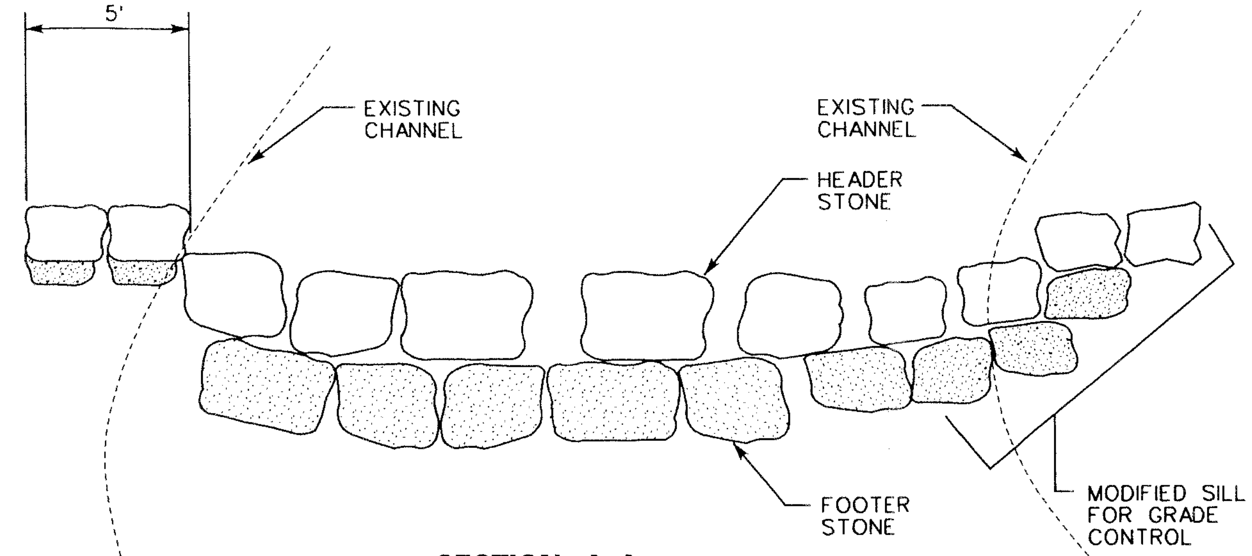
Stone/Rip-Rap Sills

Stone/rip-rap sills may be installed at various locations within the channel to fix the elevation of riffle heads, protect against headcut migration up



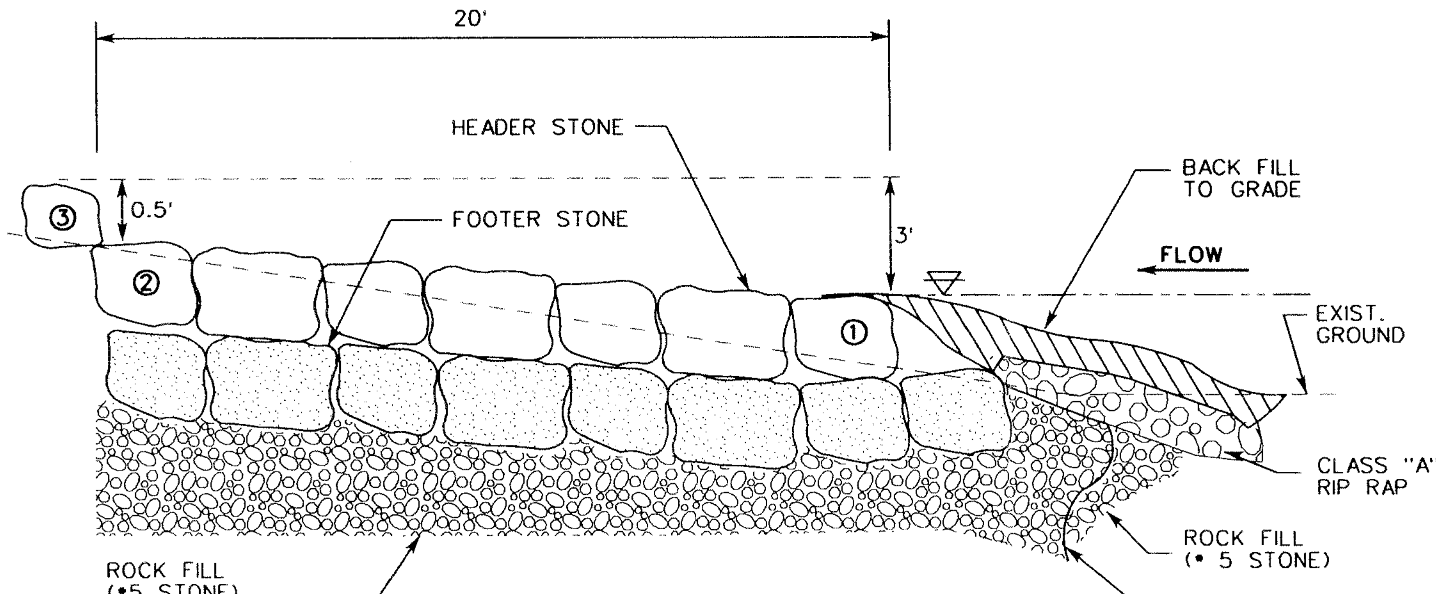
PLAN VIEW

SCALE: N.T.S.



SECTION A–A

SCALE: N.T.S.



SECTION B–B

SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER

EcoScience Corporation

Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **BACK CREEK MITIGATION SITE**

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title: **TYPICAL J–HOOK VANE**

Dwn By: MAF	Date: JAN 2003
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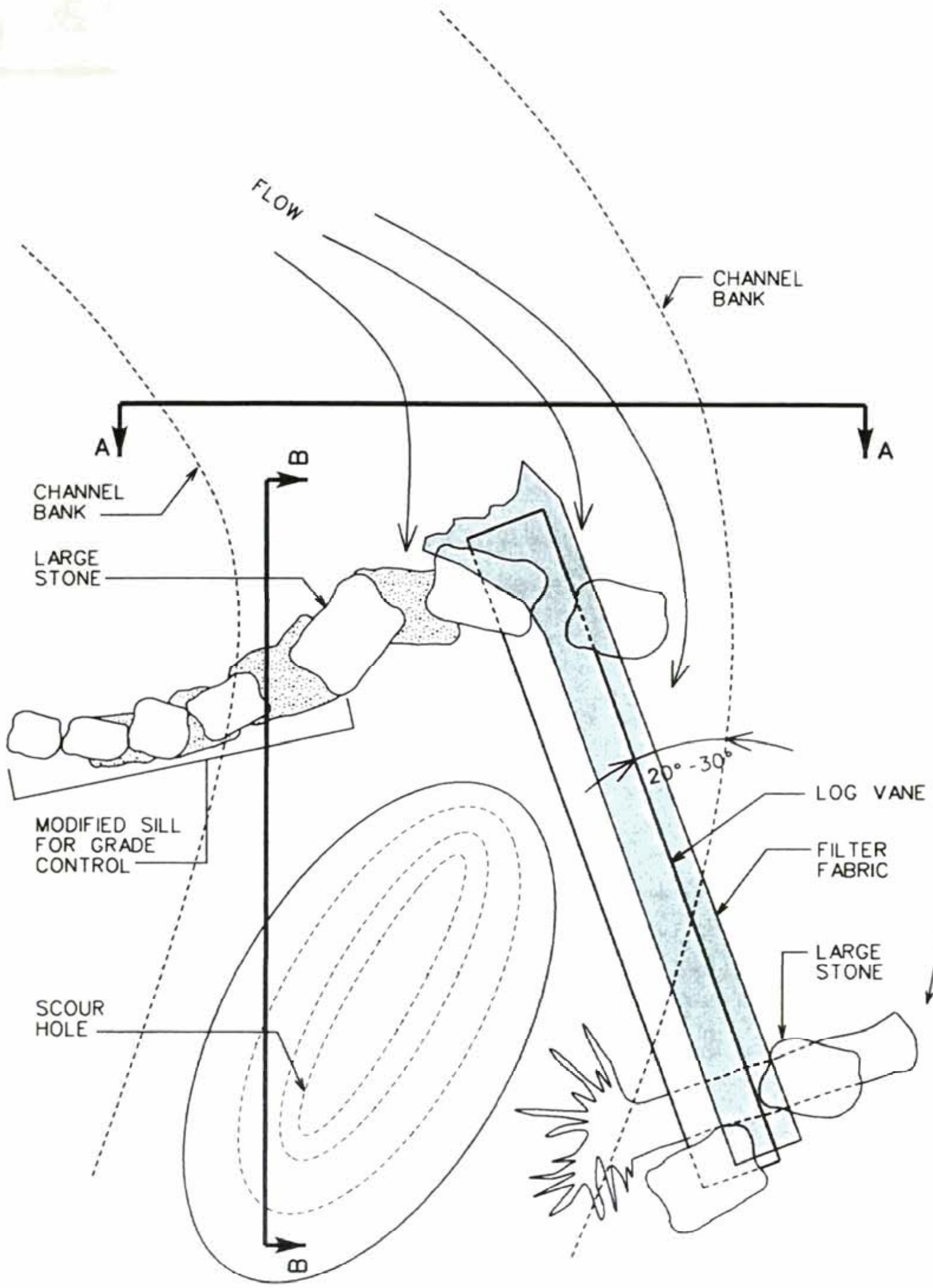
FIGURE

16

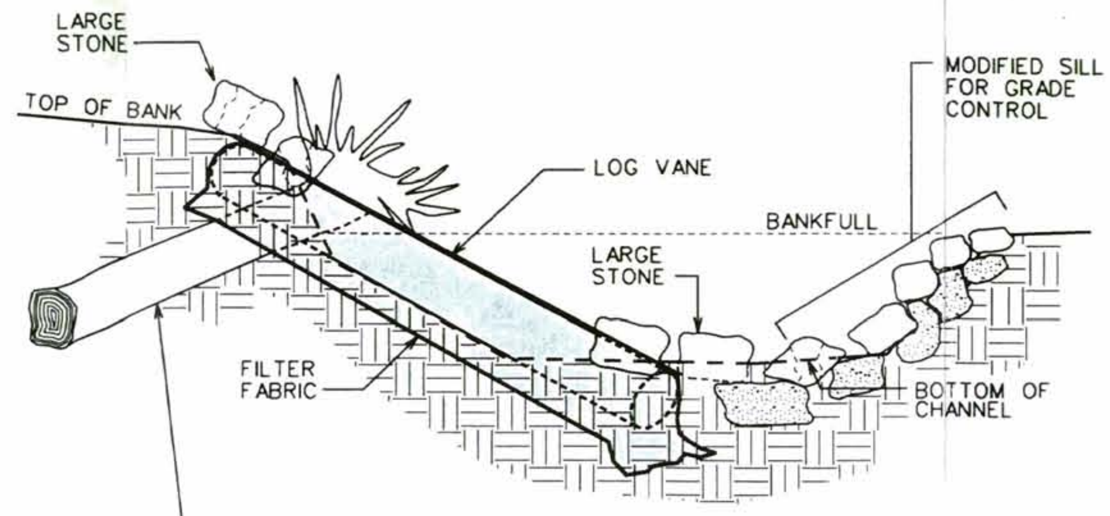


PLAN VIEW

SCALE: N.T.S.

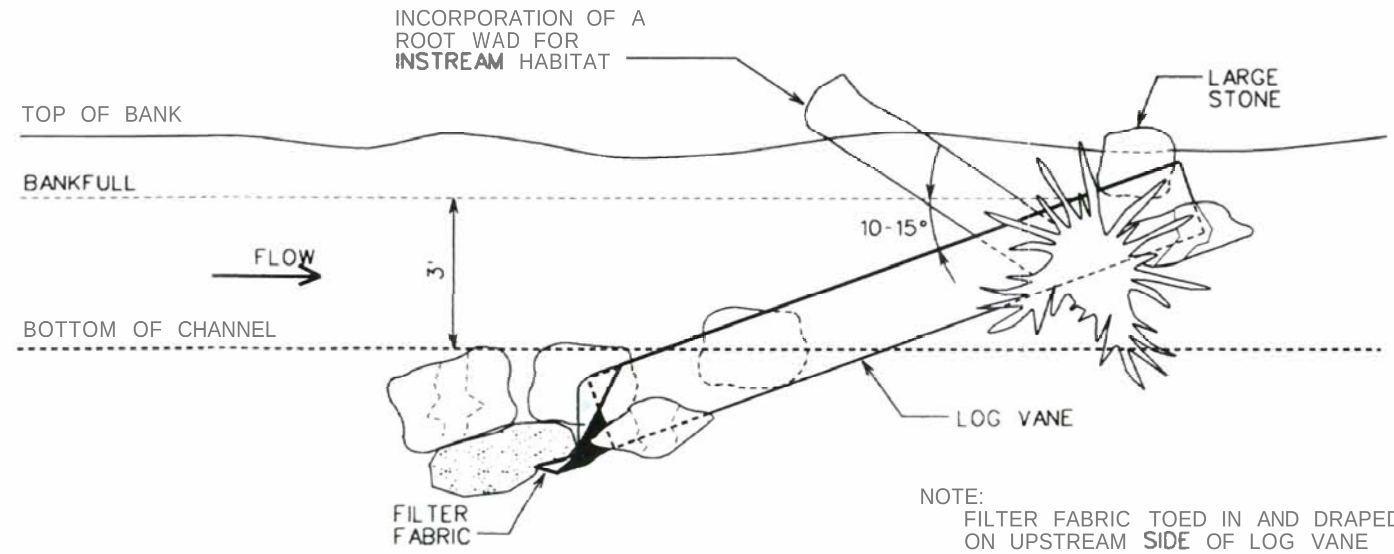
NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.

INCORPORATION OF A ROOT WAD FOR INSTREAM HABITAT



CROSS-SECTION A-A

SCALE: N.T.S.



NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.

PROFILE B-B

SCALE: N.T.S.

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: NCDOT

Project: BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title: TYPICAL LOG VANE WEIR

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown

ESC Project No.: 02-113.04

FIGURE 17

the channel, and provide for grade control at sensitive areas such as new location channel and abandoned channel tie-in points. Stone/rip-rap sills may be constructed of rip-rap and/or small boulders which are unsuitable for cross vane and j-hook vane construction.

Sill construction will be initiated by excavating a trench across the channel. Boulders and rip-rap will be piled into the trench to the final elevation of the riffle head. The stone should be piled to conform to channel dimension upstream and downstream of the sill, forming a saddle shaped structure that ties into floodplain elevation. Once the stone has been installed, filter fabric will be toed into a trench on the upstream side of the structure and draped over the top of the stones. After filter fabric is in place the structure can be backfilled with suitable material to the elevation of the sill.

Root-Wad Installation

Root wads may be installed in conjunction with log vanes and/or J-hook vanes to provide diverse in-stream habitat including shade, detritus, and bank overhang. As there are few mature trees on-site, root wads are expected to be imported from off-site. The imported root wads must have approximately 10 to 15 feet of bole left intact. The bole may be utilized as footer for a vane arm and/or will be used to anchor the root wad in the bank. If backfilling is necessary behind the root wad, this area will be stabilized with suitable erosion control measures. Planting with native floodplain vegetation is expected to reduce erosion of bank sediments, reduce flow velocities in flood waters, filter pollutants, and provide wildlife habitat.

5.1.2 Reconstruction In-Place

The reach of Back Creek expected to be reconstructed in-place includes downstream reaches of the mainstem tributary where the channel retains a sinuous flow pattern. The main objective of restoration in this reach is to raise the channel invert to within approximately 3.3 feet of the floodplain surface and to reduce channel size to approximately 56 square feet. Primary activities designed to achieve these objectives may include 1) installation of cross-vane and log-vane weirs and 2) creation of a bankfull bench.

In-stream Structures

In-stream structures including cross-vane and log-vane weirs may be installed in the channel. These structures are conceptually depicted in Figures 15 and 17 and are described in section 5.1.1.1 of this report. The purpose of these vanes is to 1) direct high velocity flows during bankfull events toward the center of the channel, 2) increase the average pool depth throughout the reach, 3) provide diverse in-stream habitat including shade and detritus, and 4) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.

Bankfull Bench Creation

Reaches of Back Creek proposed to be restored in-place through bankfull bench excavation include the downstream tie-in at the project outfall (Figure 11B). Bench excavation in this location will maintain stable bank-height ratios and proposed bankfull cross-sectional areas in the vicinity of the restored channel tie-in point with off-site bed elevations. After excavation of the bench, the new floodplain surface is expected to be stabilized and planted with native floodplain vegetation.

5.1.3 Secondary Tributary Bank Sloping/Bench Excavation

Two secondary tributaries to Back Creek enter the Site; one enters the Site from the south, at the upper extent of the project, and a second enters the Site from the north midway through the project reach. Both tributaries are characterized by smaller drainage basins measuring approximately 0.1 square mile and 0.04 square mile, respectively. Various mitigation scenarios exist for these channels and are discusses below.

5.1.3.1 Upstream Tributary (Through the Morgan Property)

Several alternatives are proposed for mitigation of this upstream tributary. This tributary has been straightened, entrenched, and approximately one third of the channel has been lined with rip-rap. Based on regional curves and data collected on-site, the proposed cross-sectional area will average 4.5 square feet, with a bankfull width of 5.6 feet, and an average bankfull depth of 0.8 feet. Four mitigation options are proposed for this secondary tributary: 1) no action, 2) reconstruction of stream channel from the property line, 3) reconstruction of stream channel from the rip-rap terminus, and 4) re-direction of channel into the wetland enhancement area.

Regardless of the preferred mitigation alternative, landowner constraints may necessitate the installation of a channel ford to allow access to portions of the property isolated by the conservation easement and/or stream restoration activities. The location of the proposed channel ford is depicted on Figure 11A, and may be subject to change dependant upon comment from landowners and/or construction constraints. The ford is expected to consist of a shallow depression in the stream banks where vehicular crossings can be made. The ford shall be constructed of hydraulically stable rip-rap or suitable rock and should be large enough to handle the weight of anticipated vehicular traffic.

No Action

Actions designed to restore the secondary tributary may be expected to hydraulically impact the existing property owner. Three alternatives described below are designed to reduce potential for both on-site and off-site impacts. However, if off-site impacts appear to be unavoidable with these three alternatives, a no-action alternative is recommended for the secondary tributary. No action is expected to represent a preservation-based mitigation effort. Planting of the stream banks may be recommended to reduce bank degradation and sedimentation of adjacent and downstream reaches. In addition, continued communication with the upstream landowner is recommended.

Channel Reconstruction from Property Line (Alternative 1)

This alternative calls for the excavation of approximately 583 linear feet of channel from the southern property line to the tie-in point with Back Creek. The rip-rap section of the existing channel may be removed and utilized for ford construction at the location depicted in Figure 11A. The existing channel will be plugged and backfilled as necessary. After excavation of the channel, stream banks and local belt width areas will be immediately planted with shrub and herbaceous vegetation. The primary purpose of this alternative is to restore stream and water quality function to as much of this tributary as possible without adversely affecting adjacent property owners.

Channel Reconstruction from Rip-Rap Terminus (Alternative 2)

This alternative calls for the excavation of approximately 500 linear feet of channel from the rip-rap terminus to the tie-in point with Back Creek. Floodplain excavation may occur along portions of the existing rip-rap section to reduce flooding during major precipitation events. The remaining channel will be plugged and backfilled as needed. After excavation of the channel, stream banks and local belt width areas will be immediately planted with shrub and herbaceous vegetation. The primary purpose of this alternative is to restore stream and water quality function to as much of this tributary as possible without adversely affecting land use of the current property owner.

Channel Re-direction into Jurisdictional Wetlands (Alternative 3)

This alternative involves the redirection of the channel from the rip-rap channel towards wetland enhancement areas along the southeastern bank of Back Creek. Additional excavation along the proposed channel may be required to maintain the necessary slope for the release of water into enhancement areas. The primary purpose of this alternative is to 1) reduce flooding concerns of the existing property owner, 2) increase the area and function of on-site wetlands, and 3) provide habitat for a variety of wildlife and plant species.

5.1.3.2 Central Tributary

Several alternatives are proposed for mitigation of this centrally located tributary. This tributary has been severely entrenched (bank height ratio of 1.7) due to upstream and downstream land use activities. Based on regional curves and data collected on-site, the proposed cross-sectional area should average 2.4 square feet, with a bankfull width of 3.9 feet, and an average bankfull depth of 0.6 foot. Four possible mitigation options are proposed for this secondary tributary: 1) no action, 2) bank sloping, 3) floodplain bench excavation, and 4) the introduction of structures to stabilize the channel.

No Action

Actions designed to restore this tributary may impact the Interstate 540 (I-540) roadway project and/or the properties adjacent to I-540. Alternatives described below are designed to reduce potential for both on-site and off-site impacts. However, if off-site impacts appear to be unavoidable with these alternatives, a no-action alternative is recommended for the tributary. No action is expected to represent a preservation-based mitigation effort. Planting of the stream banks may be recommended to reduce bank degradation and sedimentation of adjacent and downstream reaches.

I-485

Bank Sloping (Alternative 1)

This alternative calls for the enhancement of approximately 244 linear feet of channel from the I-540 right-of-way to the convergence with Back Creek. The objective of bank sloping is to remove the eroding material and collapsing banks. After excavation, the slopes will exhibit a gentle gradient (minimum 3:1 slope) prior to tie in with the existing land surface. Shrubs and vegetation that develop dense root mats will be inserted through the short-term erosion control materials. The bank sloping effort will be locally adjusted to maximize the use of knick points (geologic control features) and existing deep rooted vegetation.

Floodplain Bench Excavation (Alternative 2)

This alternative calls for the restoration of approximately 244 linear feet of channel from the I-540 right-of-way to the convergence with Back Creek. Floodplain bench excavation is proposed for the full length of the channel. The objective of bench excavation is to 1) remove the eroding material and collapsing banks, 2) enlarge the bankfull channel width, and 3) increase the width of the flood-prone area and reintroduce floodplain function such as a reduction of flow velocities in flood waters, filter pollutants, and provide wildlife habitat.

In-stream Structures

In-stream structures including cross-vane and log-vane weirs may be installed in the channel. These structures are conceptually depicted in

Figures 15 through 17 and are described in section 5.1.1.1 of this report. The purpose of these vanes in this channel is to 1) direct high velocity flows during bankfull events toward the center of the channel, 2) provide diverse in-stream habitat including shade and detritus, and 3) modify energy distributions through increases in channel roughness and local energy slopes during peak flows. In-stream structures may be incorporated into alternatives 1 and 2 to reduce hazards of headcut and/or bank failure.

5.2 Wetland Enhancement/Restoration

Alternatives for wetland restoration are designed to restore a fully functioning wetland system which will provide surface water storage, nutrient cycling, removal of imported elements and compounds, and will create a variety and abundance of wildlife habitat. Mitigation activities are expected to restore approximately 1.5 acres of jurisdictional wetland, enhance approximately 1.8 acres of jurisdictional wetland, and create approximately 0.5 acre of open water/freshwater marsh within the Site.

Portions of the Site underlain by hydric soil have been impacted by ditching of a natural stream, channel incision, vegetative clearing, earth movement associated with the dredging/straightening of Back Creek, and/or utilities installation. Wetland mitigation options should focus on 1) the re-establishment of historic water table elevations, 2) excavation and grading of elevated spoil and sediment embankments, 3) reestablishing hydrophytic vegetation, and 4) reconstructing stream corridors.

Re-establishment of Historic Groundwater Elevations

The existing channel depth in the upstream reach of Back Creek measures 4.4 feet, while the depth for the proposed channel in the upstream reach is 3.3 feet. Similar projects conducted in this region of the state utilized DRAINMOD simulations in Chewacla/Wehadkee soils to determine groundwater influence on wetland hydroperiod around streams that were encised. According to these simulations, by raising the water surface elevation by 1.1 feet the zone of influence may be reduced by approximately 20-25 feet in a pasture/open field setting. Additionally, by re-planting these areas the zone of influence may be reduced by approximately 40-45 feet, based on forested conditions (Appendix D). Based on these results an increase in the water table elevation may re-establish historic elevations and possibly re-hydrate approximately 1.0 acre of relict wetland adjacent to the channel.

Excavation and Grading of Elevated Spoil and Sediment Embankments

Some areas adjacent to the existing channel have experienced both natural and unnatural sediment deposition. Spoil piles were likely cast adjacent to the channel during dredging/straightening of the upstream reach. Major flood events may have also deposited additional sediment adjacent to stream banks from upstream construction activities. The removal of these spoil materials as well as sediment deposition adjacent to the channel may restore approximately 0.5 acre of historic wetland.

Hydrophytic Vegetation
On-site wetland areas have endured significant disturbance from land use activities such as land clearing, utilities installation and maintenance, grazing, hay production, and other anthropogenic maintenance. Wetland areas may be re-vegetated with native vegetation typical of wetland communities in the region. Emphasis should focus on developing a diverse plant assemblage. Sections 5.4 (Plant Community Restoration) and 5.4.1 (Planting Plan) provide detailed information concerning community species associations. Re-vegetation of portions of the Site underlain by hydric soils is expected to enhance the entire 3.3 acres of on-site jurisdictional wetland.

Reconstructing Stream Corridors
This stream restoration plan involves the reconstruction of both Back Creek and its associated tributaries. The existing channels will be backfilled so that the water table will be restored to relict conditions. However, some portions of the existing Back Creek channel will remain open for the creation of wetland 'oxbow lake' like features. These features will be plugged on each side of the open channel and will function as open water systems. They are expected to provide habitat for a variety of wildlife as well as create approximately 0.5 acre of open water/freshwater marsh within the Site.

5.3 Floodplain Soil Scarification

Microtopography and differential drainage rates within localized floodplain areas represent important components of floodplain functions. Reference forests in the region exhibit complex surface microtopography. Small concavities, swales, exposed root systems, seasonal pools, oxbows, and hummocks associated with vegetative growth and hydrological patterns are scattered throughout these systems. As discussed in the stream reconstruction section, efforts to advance the development of characteristic surface microtopography will be implemented.

In areas where soil surfaces have been compacted, ripping or scarification will be performed. Mixing of vegetation debris in surface soils and tip mounds will also promote future complexity across the landscape. After construction, the soil surface should exhibit complex microtopography ranging to 1 foot in vertical asymmetry across local reaches of the landscape. Subsequently, community restoration will be initiated on complex floodplain surfaces.

5.4 Plant Community Restoration

Restoration of floodplain forest and stream-side habitat allows for development and expansion of characteristic species across the landscape. Ecotonal changes between community types contribute to diversity and provide secondary benefits, such as enhanced feeding and nesting opportunities for mammals, birds, amphibians, and other wildlife.

RFE data, on-site observations, and community descriptions from *Classification of the Natural Communities of North Carolina* (Schafale and Weakley 1990) were used to develop the primary plant community associations that will be promoted during community restoration activities. These community associations include 1) Piedmont/Mountain floodplain forest, 2) stream-side assemblage, 3) riverine bottomland hardwood forest, and 4) slope forest (Figure 18). Figure 19 identifies the location, based on elevation and position relative to the restored stream, of each target community to be planted. Planting elements within each map unit are listed below.

Piedmont/Mountain Floodplain Forest

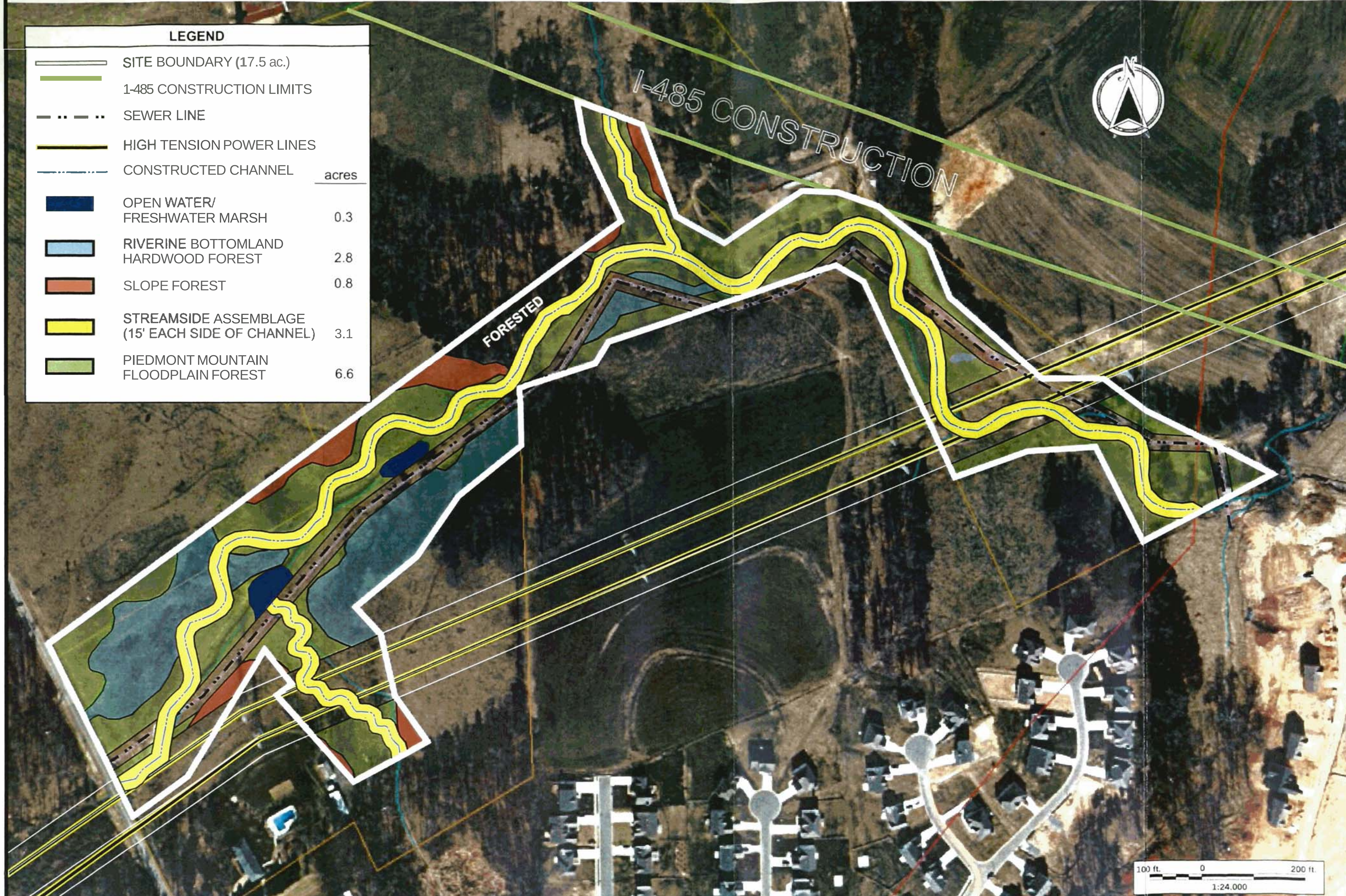
1. Hackberry (*Celtis laevigita*)
2. Green Ash (*Fraxinus pennsylvanica*)
3. Swamp Chestnut Oak (*Quercus michauxii*)
4. American Elm (*Ulmus americana*)
5. Shagbark Hickory (*Carya ovata*)
6. American Sycamore (*Platanus occidentalis*)
7. Willow Oak (*Quercus phellos*)
8. Black Gum (*Nyssa sylvatica*)
9. Black Walnut (*Juglans nigra*)

Stream-Side Forest Assemblage

1. Black Willow (*Salix nigra*)
2. Box Elder (*Acer negundo*)
3. Ironwood (*Carpinus caroliniana*)
4. River Birch (*Betula nigra*)
5. American Sycamore (*Platanus occidentalis*)
6. Swamp Dogwood (*Cornus amomum*)

Stream-Side Shrub Assemblage

1. Tag Alder (*Alnus serrulata*)
2. Buttonbush (*Cephalanthus occidentalis*)
3. Elderberry (*Sambucus canadensis*)



EcoScience Corporation

Raleigh, North Carolina 27605

Client: Alt. 2

NCDOT

25 ft. utility

Project:

BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

PLANTING PLAN

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE

18

COMMUNITY ASSEMBLAGE	SLOPE FOREST	STREAMSIDE ASSEMBLAGE	PIEDMONT/ MOUNTAIN FLOODPLAIN FOREST	RIVERINE BOTTOMLAND HARDWOOD FOREST
CANOPY VEGETATION	Mockernut Hickory American Beech White Oak Southern Red Oak Northern Red Oak Willow Oak Black Cherry	**Streamside Forest** Black Willow Box Elder Ironwood River Birch American Sycamore Swamp Dogwood **Streamside Shrub** Tag Alder Buttonbush Elderberry Arrow-wood Viburnum Possumhaw Viburnum Bankers Dwarf Willow Black Willow	Hackberry Green Ash Swamp Chestnut Oak American Elm Shagbark Hickory American Sycamore Willow Oak Black Gum Black Walnut	Swamp Chestnut Oak Cherrybark Oak Green Ash American Elm Willow Oak Yellow Poplar Water Oak Sugar Berry
LAND FORM	Floodplain Slopes	Stream Banks and Adjacent Flood Plain	Floodplain	Floodplain Flats

EcoScience Corporation

Raleigh, North Carolina 27605

Client: NCDOT

Project: BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title: CONCEPTUAL MODEL OF TARGET COMMUNITY PATTERNS

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE 19

4. Arrow-wood Viburnum (*Viburnum dentatum*)
5. Possumhaw Viburnum (*Viburnum nudum*)
6. Bankers Dwarf Willow (*Salix cotteli*)
7. Black Willow (*Salix nigra*)

Riverine Bottomland Hardwood Forest

1. Swamp Chestnut Oak (*Quercus michauxii*)
2. Cherrybark Oak (*Quercus pagoda*)
3. Green Ash (*Fraxinus pennsylvanica*)
4. American Elm (*Ulmus americana*)
5. Willow Oak (*Quercus phellos*)
6. Yellow Poplar (*Liriodendron tulipifera*)
7. Water Oak (*Quercus nigra*)
8. Sugar Berry (*Symplocos tinctoria*)

Slope Forest

1. Mockernut Hickory (*Carya tomentosa*)
2. American Beech (*Fagus grandifolia*)
3. White Oak (*Quercus alba*)
4. Southern Red Oak (*Quercus falcata*)
5. Northern Red Oak (*Quercus rubra*)
6. Willow Oak (*Quercus phellos*)
7. Black Cherry (*Prunus serotina*)

The stream-side trees and shrubs include species with high value for sediment stabilization, rapid growth rate, and the ability to withstand hydraulic forces associated with bankfull flow and overbank flood events. Stream-side trees and shrubs will be planted within 10 to 15 feet of the channel throughout the meander belt width. Shrub elements will be planted along the banks of the reconstructed stream, concentrated along outer bends.

Piedmont/Mountain floodplain forests are targeted for non-hydric soils located in outer portions of the floodplain. Riverine bottomland hardwood species will be planted in portions of the Site underlain by hydric soils. Species common along slope forests will be planted on slopes adjacent to the floodplain.

Certain opportunistic species which may dominate the early successional forests have been excluded from community restoration efforts. Opportunistic species consist primarily of red maple, tulip tree, and sweetgum. These species should also be considered important components of bottomland forests where species diversity has not been jeopardized.

The following planting plan is the blueprint for community restoration. The anticipated results stated in the Success Criteria (Section 6.6) are expected to reflect potential vegetative conditions achieved after steady-state conditions prevail over time.

5.4.1 Planting Plan

The purpose of a planting plan is to re-establish vegetative community patterns across the landscape. The plan consists of 1) acquisition of available plant species, 2) implementation of proposed Site preparation, and 3) planting of selected species.

Species selected for planting will be dependent upon availability of local seedling sources. Advance notification to nurseries (1 year) will facilitate availability of various non-commercial elements.

Bare-root seedlings of tree species will be planted within specified map areas at a density of 435 stems per acre on 10-foot centers. Table 6 depicts the total number of stems and species distribution within each vegetation association. Planting will be performed between December 1 and March 15 to allow plants to stabilize during the dormant period and set root during the spring season. A total of 7136 diagnostic tree and shrub seedlings will be planted during restoration (Table 6).

TABLE 6
Planting Plan
Back Creek Mitigation Site

Vegetation Association (Planting Area)	Riverine Bottomland Hardwood Forest	Stream-Side Assemblage		Slope Forest	Piedmont/ Mountain Floodplain Forest	TOTAL
		Forest	Shrub			
Area (acres)	2.8	3.1		0.8	6.6	17.2
SPECIES	# planted[1] (% total)[2]	# planted (% total)	# planted (% total)	# planted (% total)	# planted (% total)	# planted
Green Ash	243 (20)				431 (15)	674
Swamp Chestnut Oak	243 (20)				287 (10)	530
American Elm	243 (20)				287 (10)	530
Cherrybark Oak	122 (10)					122
Willow Oak	122 (10)				287 (10)	409
Water Oak	122 (10)					122
Sugarberry	122 (10)					122
Black Willow		202 (15)	337 (25)			539
Box Elder		270 (20)				270
Ironwood		135 (10)				135
River Birch		135 (10)				135
American Sycamore		337 (25)			431 (15)	768
Swamp Dogwood		270 (20)				270
Tag Alder			270 (20)			270
Elderberry			135 (10)			135
Arrow-wood Viburnum			135 (10)			135
Possumhaw Viburnum			135 (10)			135
Bankers Dwarf Willow			337 (25)			337
Mockernut Hickory				70 (20)		70
American Beech				70 (20)		70
White Oak				70 (20)		70
Southern Red Oak				70 (20)		70
Black Cherry				70 (20)		70
Hackberry					287 (10)	287
Shagbark Hickory					287 (10)	287
Black Gum					287 (10)	287
Black Walnut					287 (10)	287
TOTAL	1217	1349	1349	350	2871	7136

[1] Planting densities comprise 435 trees and/or shrubs per acre within each specified planting area.

[2] Some non-commercial elements may not be locally available at the time of planting. The stem count for unavailable species should be distributed among other target elements based on the percent (%) distribution. One year of advance notice to forest nurseries will promote availability of some non-commercial elements. However, reproductive failure in the nursery may occur.

[3] Scientific names for each species, required for nursery inventory, are listed in the mitigation plan.

6.0 MONITORING PLAN

Monitoring of Site restoration efforts will be performed until success criteria are fulfilled. Monitoring is proposed for the stream channel, as well as wetland components of hydrology and vegetation.

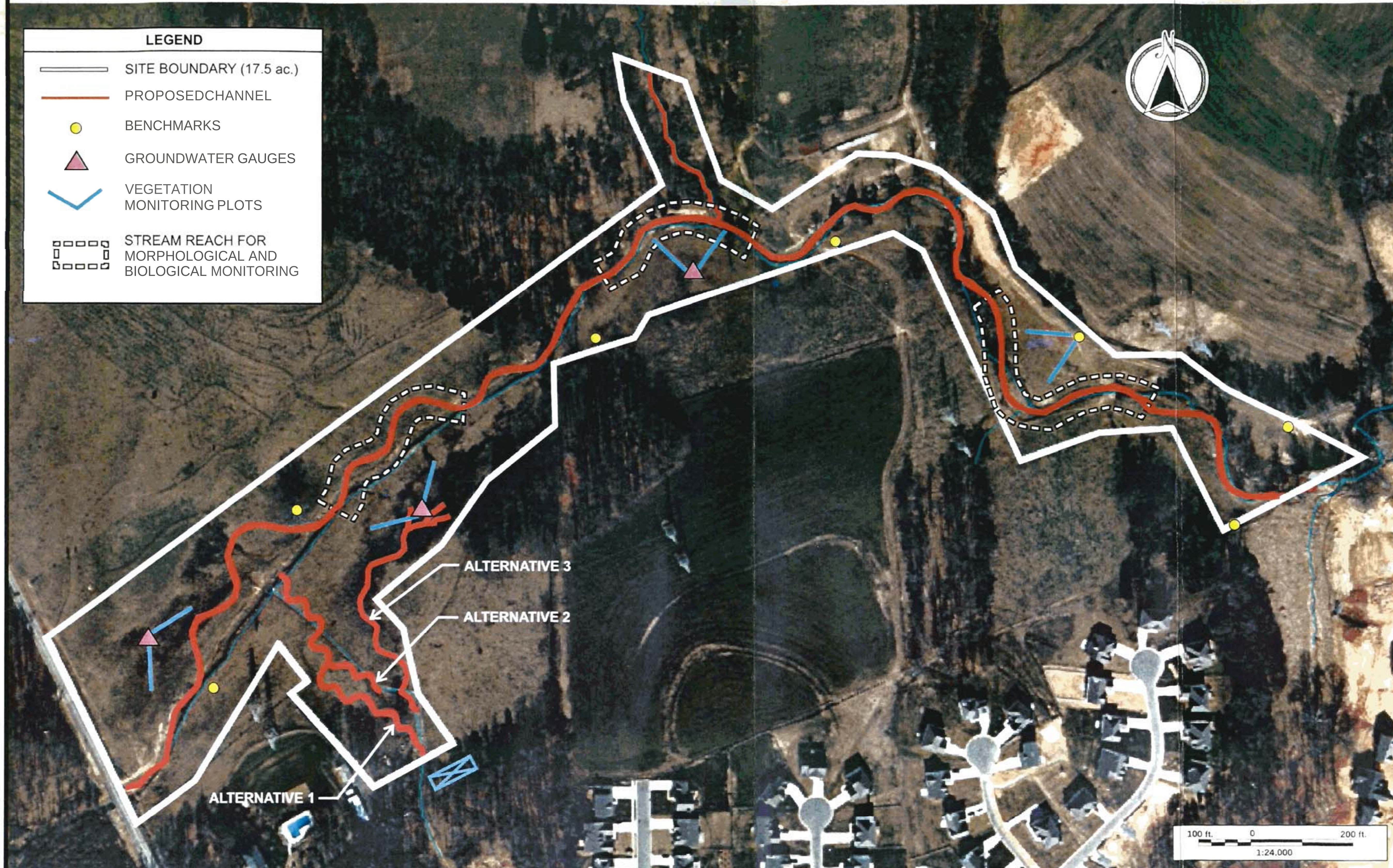
6.1 Stream Monitoring

Three stream reaches are proposed to be monitored for geometric and biological activity as depicted in Figure 20. Each stream reach will extend for a minimum of 300 feet along the restored channel. Annual fall monitoring will include development of a channel plan view, channel cross-sections on riffles and pools, pebble counts, and a water surface profile of the channel. The data will be presented in graphic and tabular format. Data to be presented will include 1) cross-sectional area, 2) bankfull width, 3) average depth, 4) maximum depth, 5) width/depth ratio, 6) meander wavelength, 7) belt width, 8) water surface slope, 9) sinuosity, and 10) stream substrate composition. The stream will subsequently be classified according to stream geometry and substrate (Rosgen 1996). Significant changes in channel morphology will be tracked and reported by comparing data in each successive monitoring year. A photographic record that will include pre-construction and post-construction pictures has been initiated.

6.2 Stream Success Criteria

Success criteria for stream restoration will include 1) successful classification of the reach as a functioning stream system (Rosgen 1996), 2) channel stability indicative of a stable stream system, and 3) development of diagnostic biological communities over time.

The channel configuration will be measured on an annual basis in order to track changes in channel geometry, profile, or substrate. These data will be utilized to determine the success in restoring stream channel stability. Specifically, the width/depth ratio should characterize an E-type and/or a borderline E-type/C-type channel ($\leq$ 15), bank height-ratios must characterize a stable or moderately unstable channel ($\leq$ 1.3), and changes in cross-sectional area and channel width must indicate less than 0.5 foot of bed and/or bank erosion per year along the monitoring reach. In addition, abandoned channel reaches or shoot cutoffs must not occur and sinuosity values must remain greater than 1.35 (thalweg distance/straight-line distance). The field indicator of bankfull will be described in each monitoring year and indicated on a representative channel cross-section figure. If the stream channel is down-cutting or



EcoScience Corporation
Raleigh, North Carolina 27605

Client:
NCDOT

Project:
BACK CREEK MITIGATION SITE

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title:
MONITORING PLAN

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown
ESC Project No.: 02-113.04	

FIGURE
20

the channel width is enlarging due to bank erosion, additional bank or slope stabilization methods may be employed.

The stream must maintain shear stress values to adequately transport sediment through the Site. Pebble counts will be conducted annually to determine D50 and D84 values within the restored stream. Pebble counts would be expected to indicate a general coarsening of materials on the riffles throughout the monitoring period. Substrate will be considered successful if the channel is characterized by a substrate consisting of sand/fine gravel (D50 greater than 0.5-2 millimeters).

Visual assessment of in-stream structures will be conducted to determine if failure has occurred. Failure of a structure may be indicated by collapse of the structure, undermining of the structure, abandonment of the channel around the structure, and/or stream flow beneath the structure.

6.3 Hydrology Monitoring

While hydrological modifications are being performed on the Site, surficial monitoring wells will be designed and placed in accordance with specifications in the COE's *Installing Monitoring Wells/Piezometers in Wetlands* (WRP Technical Note HY-IA-3.1, August 1993). Monitoring wells will be set to a depth immediately above the top of the clay subsurface layer (range: 24 to 40 inches below the surface).

Two monitoring wells will be placed immediately adjacent to vegetation sampling plots to provide representative coverage within each of the identified mitigation design units (Figure 20). Hydrological sampling will be performed throughout the growing season at intervals necessary to satisfy the hydrology success criteria within each design unit (EPA 1990).

6.4 Hydrology Success Criteria

Target hydrological characteristics include saturation or inundation for at least 12.5 percent of the growing season at lower landscape positions, during average climatic conditions. Upper landscape reaches may exhibit surface saturation/inundation between 5 percent and 12.5 percent of the growing season based on groundwater gauge data. These 5-12.5 percent areas are expected to support hydrophytic vegetation. If wetland parameters are marginal as indicated by vegetation and hydrology monitoring, a jurisdictional determination will be performed in these areas.

Hydrological contingency will require consultation with hydrologists and regulatory agencies if wetland hydrology enhancement is not achieved.

Floodplain surface modification, including construction of ephemeral pools, represents a likely mechanism to increase the floodplain area that supports jurisdictional wetlands. Recommendations for contingency to establish wetland hydrology will be implemented and monitored until Hydrology Success Criteria are achieved.

6.5 Vegetation Monitoring

Restoration monitoring procedures for vegetation are designed in accordance with EPA guidelines enumerated in Mitigation Site Type (MiST) documentation (EPA 1990) and COE Compensatory Hardwood Mitigation Guidelines (DOA 1993). A general discussion of the restoration monitoring program is provided. A photographic record of plant growth should be included in each annual monitoring report.

After planting has been completed in winter or early spring, an initial evaluation will be performed to verify planting methods and to determine initial species composition and density. Supplemental planting and additional Site modifications will be implemented, if necessary.

During the first year, vegetation will receive cursory, visual evaluation on a periodic basis to ascertain the degree of overtopping of planted elements by nuisance species. Subsequently, quantitative sampling of vegetation will be performed between September 1 and October 30 after each growing season until the vegetation success criterion is achieved.

During quantitative vegetation sampling in early fall of the first year, approximately four sample plots will be randomly placed within the Site. Sample-plot distributions are expected to resemble locations depicted in Figure 20; however, best professional judgment may be necessary to establish vegetative monitoring plots upon completion of construction activities. In each sample plot, vegetation parameters to be monitored include species composition and species density. Visual observations of the percent cover of shrub and herbaceous species will also be recorded.

6.6 Vegetation Success Criteria

Success criteria have been established to verify that the vegetation component supports community elements necessary for floodplain forest development. Success criteria are dependent upon the density and growth of characteristic forest species. Additional success criteria are dependent upon density and growth of "Character Tree Species." Character Tree Species include planted species along with species identified through visual inventory of an approved reference (relatively undisturbed) bottomland forest community used to orient the project design. All canopy tree species planted and identified in the reference forest will be utilized to define "Character Tree Species" as termed in the success criteria.

An average density of 320 stems per acre of Character Tree Species must be surviving in the first three monitoring years. Subsequently, 290 Character Tree Species per acre must be surviving in year 4, and 260 Character Tree Species per acre in year 5. Planted species must represent a minimum of 30 percent of the required stem per acre total (96 stems/acre). Each naturally recruited Character Tree Species may represent up to 10 percent of the required stem per acre total. In essence, seven naturally recruited Character Tree Species may represent a maximum of 70 percent of the required stem/acre total. Additional stems of naturally recruited species above the 10 percent - 70 percent thresholds are discarded from the statistical analysis. The remaining 30 percent is reserved for planted Character Tree Species (oaks, etc.) as a seed source for species maintenance during mid-successional phases of forest development.

If vegetation success criteria are not achieved based on average density calculations from combined plots over the entire restoration area, supplemental planting may be performed with tree species approved by regulatory agencies. Supplemental planting will be performed as needed until achievement of vegetation success criteria.

No quantitative sampling requirements are proposed for herb assemblages as part of the vegetation success criteria. Development of floodplain forests over several decades will dictate the success in migration and establishment of desired understory and groundcover populations. Visual estimates of the percent cover of herbaceous species and photographic evidence will be reported for information purposes.

6.7 Contingency

In the event that stream success criteria are not fulfilled, a mechanism for contingency will be implemented. Stream contingency may include, but may not be limited to 1) structure repair and/or installation, 2) repair of dimension, pattern, and/or profile variables, and 3) bank stabilization. The method of contingency is expected to be dependent upon stream variables not in compliance with success criteria. Primary concerns, which may jeopardize stream success include 1) structure failure, 2) headcut migration through the Site, and/or 3) bank erosion.

Structure Failure – In the event that on-site structures are compromised, the affected structure may be repaired, maintained, or replaced. Once the structure is repaired or replaced, it must function to stabilize adjacent stream banks and/or maintain grade control within the channel.

Structures which remain intact, but exhibit flow around, beneath, or through the header/footer stones may be repaired by excavating a trench on the upstream side of the structure and re-installing filter fabric in front of the header and footer stones. Structures which have been compromised, resulting in shifting or collapse of, header/footer stones should be removed and replaced with a structure suitable for on-site flows.

Headcut Migration Through the Site – In the event that a headcut occurs within the Site (identified visually or through on-site measurements [i.e. bank height ratios exceeding 1.4]), provisions for impeding headcut migration and repairing damage caused by the headcut may be implemented. Headcut migration may be impeded through the installation of in-stream grade control structures (rip-rap sill and/or cross-vane weir) and/or restoring stream geometry variables until channel stability is achieved. Channel repairs to stream geometry may include channel backfill with coarse material and stabilizing the material with erosion control matting, vegetative transplants, and/or willow stakes.

Bank Erosion – In the event that severe bank erosion occurs at the Site, resulting in width/depth ratios that exceed a value of 15, contingency measures to reduce bank erosion and width/depth ratio may occur. Bank erosion contingency may include the installation of cross-vane weirs and/or bank stabilization measures. If the resultant bank erosion induces shoot cutoffs or channel abandonment, a channel may be excavated which will reduce shear stress to stable values.

7.0 FINAL DISPENSATION OF THE PROPERTY

NCDOT will maintain the Site conservation easement until all mitigation activities are completed and the Site is determined to be successful. All landowners are expected to retain ownership of their respective parcels. The conservation easement is expected to be transferred perpetually with property upon sale of the properties. Covenants and/or restrictions on the deed will be included that will ensure adequate management and protection of the Site in perpetuity.

8.0 REFERENCES

Chang, Howard H. 1988. Fluvial Processes in River Engineering. John Wiley & Sons.

Cowan, W.L. 1956. Estimating Hydraulic Roughness Coefficients. Agricultural Engineering, 37, 473-475.

Department of the Army (DOA). 1993 (unpublished). Corps of Engineers Wilmington District. Compensatory Hardwood Mitigation Guidelines (12/8/93).

Department of the Army (DOA). 1987. Corps of Engineers Wetland Delineation Manual. Tech. Rpt. Y-87-1, Waterways Experiment Station, COE, Vicksburg, Mississippi.

Department of Environment, Health and Natural Resources (DEHNR). 1996. A Field Guide to North Carolina Wetlands. Tech. Rpt. No. 96-01. North Carolina Division of Environmental Management, Water Quality Section, Raleigh, North Carolina

Dunne, D. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company. N.Y.

Environmental Protection Agency (EPA). 1990. Mitigation Site Type Classification (MiST). EPA Workshop, August 13-15, 1989. EPA Region IV and Hardwood Research Cooperative, NCSU, Raleigh, North Carolina.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology: an Introduction for Ecologists. John Wiley & Sons, Ltd. West Sussex, England.

Griffith, G.E. 2002. Ecoregions of North and South Carolina. Reston Virginia. U.S. Geological Society (map scale 1:1,500,000).

Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.A. O'Hara, A. Jessup, and R. Everhart. 1999. Bankfull Hydraulic Geometry Relationships for North Carolina Streams. N.C. State University, Raleigh, North Carolina.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. Gen. Tech. Rep. RM-245. USDA Forest Service. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Jarret, R.D. 1985 Determination of Roughness Coefficients for Streams in Colorado. USGS Water Resources Investigations Report 85-4004, Lakewood, Colorado.

Manning, R. 1981. On the Flow of Water in Open Channels and Pipes. Transactions of the Institution of Civil Engineers of Ireland. 20, 161-20.

Natural Resources Conservation Service (NRCS). 1980. Soil Survey of Mecklenburg County, North Carolina. United States Department of Agriculture.

North Carolina Wildlife Resources Commission (NCWRC). 1996. Draft Guidelines for Stream Relocation and Restoration in North Carolina. Raleigh, North Carolina.

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

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina: Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, N.C. Department of Environment, Health, and Natural Resources. Raleigh, North Carolina.

Smith, R. L. 1980. Ecology and Field Biology, Third Edition. Harper and Row, New York. 835 pp.

Soil Conservation Service (SCS). 1987. Hydric Soils of the United States. In cooperation with the National Committee for Hydric soils. United States Department of Agriculture.

United States Geological Survey (USGS). 1974. Hydrologic Unit Map - 1974. State of North Carolina.

United States Geological Survey (USGS) 2001. Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina – Revised. USGS Water-Resources Investigations Report 01-4207. Raleigh, North Carolina.

APPENDIX A
STREAM GAUGE DATA

PEAK STREAM FLOW

Mallard Creek near Charlotte, NC

USGS Station # 02124130

Drainage Area 20.70 square miles

Rank	Water Year	Discharge (cfs)	Exceedence Probability	Exceedence Probability %	Return Interval (years)
1	1962	4500	0.053	5.3	19.00
2	1955	3060	0.105	10.5	9.50
3	1971	2900	0.158	15.8	6.33
4	1959	2410	0.211	21.1	4.75
5	1954	2100	0.263	26.3	3.80
6	1965	1970	0.316	31.6	3.17
7	1966	1900	0.368	36.8	2.71
8	1967	1680	0.421	42.1	2.38
9	1958	1650	0.474	47.4	2.11
10	1956	1600	0.526	52.6	1.90
11	1968	1520	0.579	57.9	1.73
12	1964	1470	0.632	63.2	1.58
13	1960	1360	0.684	68.4	1.46
14	1969	1300	0.737	73.7	1.36
15	1963	1180	0.789	78.9	1.27
16	1957	1170	0.842	84.2	1.19
17	1961	890	0.895	89.5	1.12
18	1970	870	0.947	94.7	1.06

bankfull (ranks 12–15)

Regional Curves indicate:

A lower discharge than USGS Guage Data

$y = 89.039\,(20.70)^{.7223} = 794.5$ cfs

PEAK STREAM FLOW

North Prong Clark Creek near Huntersville, NC

USGS Station # 02124060

Drainage Area 3.61 square miles

Rank	Water Year	Discharge (cfs)	Exceedence Probability	Exceedence Probability %	Return Interval (years)
1	1959	2450	0.048	4.8	21
2	1954	1780	0.095	9.5	10.5
3	1964	1670	0.143	14.3	7
4	1966	1420	0.190	19.0	5.25
5	1962	1110	0.238	23.8	4.2
6	1973	970	0.286	28.6	3.5
7	1963	785	0.333	33.3	3
8	1958	660	0.381	38.1	2.63
9	1955	640	0.429	42.9	2.33
10	1965	500	0.476	47.6	2.1
11	1967	480	0.524	52.4	1.91
12	1960	430	0.571	57.1	1.75
13	1961	415	0.619	61.9	1.62
14	1956	390	0.667	66.7	1.50
15	1957	318	0.714	71.4	1.40
16	1971	305	0.762	76.2	1.31
17	1968	295	0.810	81.0	1.24
18	1972	290	0.857	85.7	1.17
19	1969	228	0.905	90.5	1.11
20	1970	203	0.952	95.2	1.05

Bank full (ranks 14–16)

Regional Curves indicate:

A lower discharge than the USGS gauge data.

$y = 89.039(3.61)^{0.7223} =$ 225.04 cfs

PEAK STREAM FLOW

Lithia Inn Branch near Lincolnton NC

USGS Station # 02143310

Drainage Area 1.01 square mile

Rank	Water Year	Discharge (cfs)	Exceedence Probability	Exceedence Probability %	Return Interval (years)
1	1960	722	0.071	7.1	14.00
2	1965	580	0.143	14.3	7.00
3	1956	565	0.214	21.4	4.67
4	1962	525	0.286	28.6	3.50
5	1958	396	0.357	35.7	2.80
6	1961	315	0.429	42.9	2.33
7	1954	145	0.500	50.0	2.00
8	1964	138	0.571	57.1	1.75
9	1966	128	0.643	64.3	1.56
10	1955	115	0.714	71.4	1.40
11	1959	93	0.786	78.6	1.27
12	1967	80	0.857	85.7	1.17
13	1957	70	0.929	92.9	1.08

Bankfull (ranks 9–11)

Regional Curves indicate:

A discharge within the range as indicated by USGS gauge data

$y = 89.039\,(1.01)^{.7223} = \underline{89.7\ \text{cfs}}$

PEAK STREAM FLOW

Long Creek near Paw Creek, NC

USGS Station # 02142900

Drainage Area 16.40 square miles

Rank	Water Year	Discharge (cfs)	Exceedence Probability	Exceedence Probability %	Return Interval (years)
1	1982	4300	0.028	2.8	36.00
2	1975	3720	0.056	5.6	18.00
3	1977	3480	0.083	8.3	12.00
4	1986	2790	0.111	11.1	9.00
5	1973	2250	0.139	13.9	7.20
6	1984	1890	0.167	16.7	6.00
7	1987	1760	0.194	19.4	5.14
8	1983	1650	0.222	22.2	4.50
9	1978	1550	0.250	25.0	4.00
10	1993	1550	0.278	27.8	3.60
11	1991	1480	0.306	30.6	3.27
12	2001	1400	0.333	33.3	3.00
13	1985	1390	0.361	36.1	2.77
14	2000	1370	0.389	38.9	2.57
15	1979	1360	0.417	41.7	2.40
16	1992	1360	0.444	44.4	2.25
17	1967	1350	0.472	47.2	2.12
18	1989	1320	0.500	50.0	2.00
19	1994	1280	0.528	52.8	1.89
20	1966	1260	0.556	55.6	1.80
21	1998	1220	0.583	58.3	1.71
22	1974	1180	0.611	61.1	1.64
23	1976	1180	0.639	63.9	1.57
24	1990	1160	0.667	66.7	1.50
25	1995	1140	0.694	69.4	1.44
26	1996	1020	0.722	72.2	1.38
27	1971	972	0.750	75.0	1.33
28	1988	954	0.778	77.8	1.29
29	1969	874	0.806	80.6	1.24
30	1968	830	0.833	83.3	1.20
31	1980	814	0.861	86.1	1.16
32	1999	797	0.889	88.9	1.13
33	1972	774	0.917	91.7	1.09
34	1970	543	0.944	94.4	1.06
35	1981	530	0.972	97.2	1.03

ankfull

Regional Curves indicate:

A much lower discharge than the USGS gauge data

$y = 89.039(16.40)^{.7223} = \underline{671.5 \text{ cfs}}$

PEAK STREAM FLOW

Long Creek near Bessemer, NC

USGS Station # 02144000

Drainage Area 31.80 square miles

Rank	Water Year	Discharge (cfs)	Exceedence Probability	Exceedence Probability %	Return Interval (years)
1	1972	6500	0.023	2.3	44.00
2	1958	5290	0.045	4.5	22.00
3	1978	4930	0.068	6.8	14.67
4	1977	3890	0.091	9.1	11.00
5	1985	2920	0.114	11.4	8.80
6	1965	2680	0.136	13.6	7.33
7	1963	2620	0.159	15.9	6.29
8	1984	2460	0.182	18.2	5.50
9	1979	2410	0.205	20.5	4.89
10	1987	2230	0.227	22.7	4.40
11	1961	2120	0.250	25.0	4.00
12	1973	2110	0.273	27.3	3.67
13	1990	1870	0.295	29.5	3.38
14	1971	1830	0.318	31.8	3.14
15	1960	1660	0.341	34.1	2.93
16	1964	1650	0.364	36.4	2.75
17	1991	1500	0.386	38.6	2.59
18	1962	1430	0.409	40.9	2.44
19	1975	1390	0.432	43.2	2.32
20	1976	1330	0.455	45.5	2.20
21	1995	1300	0.477	47.7	2.10
22	1966	1240	0.500	50.0	2.00
23	1982	1230	0.523	52.3	1.91
24	1959	1180	0.545	54.5	1.83
25	1974	1160	0.568	56.8	1.76
26	1968	1140	0.591	59.1	1.69
27	1955	1040	0.614	61.4	1.63
28	1993	1040	0.636	63.6	1.57
29	1956	1020	0.659	65.9	1.52
30	1967	1010	0.682	68.2	1.47
31	1996	1010	0.705	70.5	1.42
32	1994	993	0.727	72.7	1.38
33	1980	990	0.750	75.0	1.33
34	1983	982	0.773	77.3	1.29
35	1954	980	0.795	79.5	1.26
36	1981	932	0.818	81.8	1.22
37	1989	850	0.841	84.1	1.19
38	1969	837	0.864	86.4	1.16
39	1986	824	0.886	88.6	1.13
40	1970	774	0.909	90.9	1.10
41	1957	722	0.932	93.2	1.07
42	1992	533	0.955	95.5	1.05
43	1988	384	0.977	97.7	1.02

Bankfull (ranks 29–34)

Regional Curves indicate:

A discharge slightly above the USGS gauge data

$$y = 89.039\,(31.80)^{.5223} = 1083.4 \text{ cfs}$$

APPENDIX B
EXISTING STREAM DATA

Back Creek Existing Conditions

Dimension

Down Stream Sinuous (Riffles)

X-Section	Area Bkf	Area Existing	Width Bkf	Depth Average	Depth Max	W/D Ratio	FPA	ENT	Low Bank Height	Bank Height Ratio	Stream Type
1	52.5	87.4	22.5	2.3	3.7	10	297	13.2	5.2	1.4	E
2	52.2	110.9	27.5	1.9	3.2	14	114	4.1	4.9	1.5	C
3	52.3	97.2	33	1.6	2.9	21	160	4.8	3.3	1.1	C
A (2)	53	81	35	1.5	3.4	23	236	7	4.1	1.2	C
5	51.8	74	28	1.8	3.5	15	293	10.5	4.1	1.2	C
Mean	52.3	90.8	30.9	1.7	3.3	18.3	200.8	6.6	4.1	1.3	

Up-Stream Strait (Riffles)

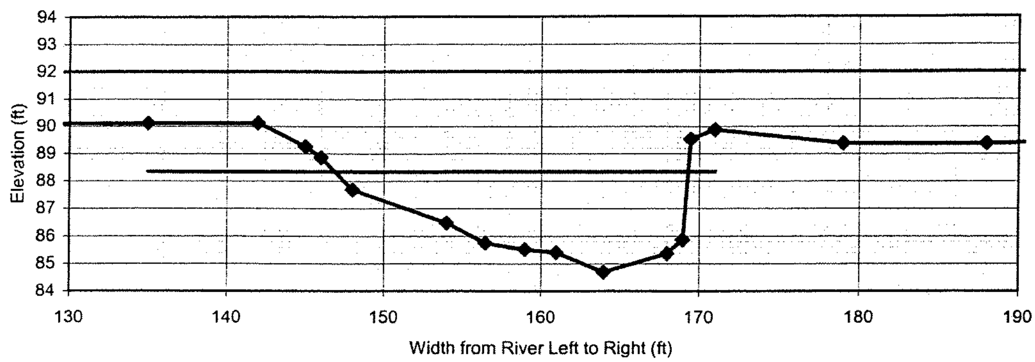
X-Section	Area Bkf	Area Existing	Width Bkf	Depth Average	Depth Max	W/D Ratio	FPA	ENT	Low Bank Height	Bank Height Ratio	Stream Type
7	48.7	48.7	21.9	2.2	4	10	290	13.2	4	1	E
B (3)	52	61	18	2.9	4.3	6	211	12	4.7	1.1	E
8	51.8	63.1	16.3	3.2	4.4	5	235	14.4	4.8	1.1	E
Mean	50.8	57.6	18.7	2.8	4.2	7.0	245.3	13.2	4.5	1.1	

Down Stream Sinuous (Pools)

X-Section	Area Bkf	Area Existing	Width Bkf	Depth Average	Depth Max	Low Bank Height	Bank Height Ratio
4	66.8	91.4	24.1	2.8	4	4.9	1.2
6	69.3	101.9	26.3	2.6	4.4	5.3	1.2
Mean	68.1	96.7	25.2	2.7	4.2	5.1	1.2

Cross Section

Cross Section 1 Riffle 128



section:	Cross Section 1
	Riffle

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description:	
height of instrument (ft):	95.86

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	10	2.88	92.98
	☑	28	2.57	93.29
	☑	98	5.78	90.08
	☐	135	5.76	90.1
	☐	142	5.75	90.11
	☐	145	6.61	89.25
	☐	146	7.01	88.85
	☐	148	8.19	87.67
	☐	154	9.39	86.47
	☐	156.5	10.12	85.74
	☐	159	10.35	85.51
	☐	161	10.47	85.39
	☐	164	11.18	84.68
	☐	168	10.51	85.35
	☐	169	10.01	85.85
	☐	169.5	6.34	89.52
	☐	171	5.99	89.87
	☑	179	6.49	89.37
	☑	188	6.49	89.37
	☑	223	6.05	89.81
	☑	234	7.05	88.81
	☑	244	6.23	89.63
	☑	355	3.61	92.25
	☐			
	☐			
	☐			
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	☐			
	☐			
	☐			

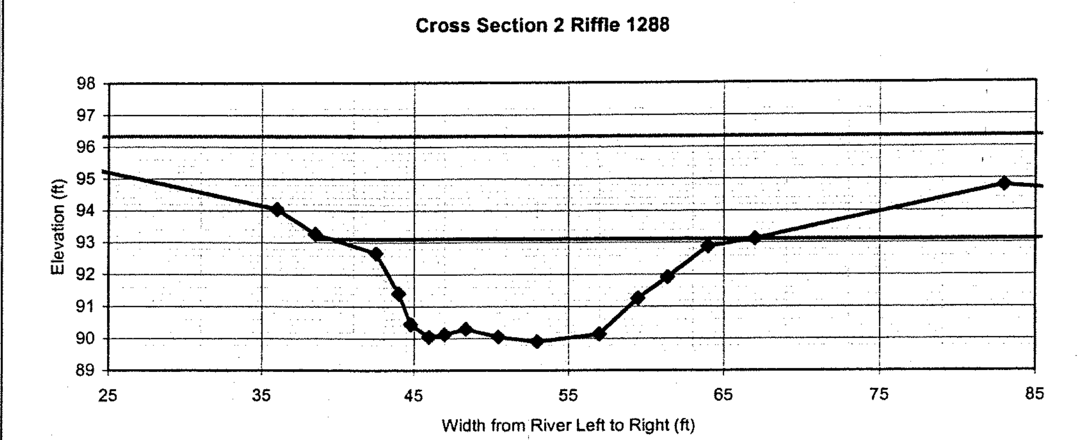
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.52	5.99	297.0	0.43	0.033
88.34	89.87			

dimensions			
52.5	x-section area	2.3	d mean
22.5	width	25.3	wet P
3.7	d max	2.1	hyd radi
5.2	bank ht	9.6	w/d ratio
297.0	W flood prone area	13.2	ent ratio

hydraulics	
4.8	velocity (ft/sec)
252.3	discharge rate, Q (cfs)
0.56	shear stress ((lbs/ft sq)
0.54	shear velocity (ft/sec)
3.012	unit stream power (lbs/ft/sec)
0.31	Froude number
9.0	friction factor u/u*
34.5	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: **Cross Section 2**
Riffle

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description:
height of instrument (ft): **99.86**

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	2.49	97.37
	☑	20	4.14	95.72
	☑	36	5.83	94.03
	☐	38.5	6.6	93.26
	☐	42.5	7.2	92.66
	☐	44	8.46	91.4
	☐	44.8	9.42	90.44
	☐	46	9.82	90.04
	☐	47	9.74	90.12
	☐	48.4	9.58	90.28
	☐	50.5	9.82	90.04
	☐	53	9.97	89.89
	☐	57	9.73	90.13
	☐	59.5	8.61	91.25
	☐	61.4	7.95	91.91
	☐	64	6.99	92.87
	☐	67	6.75	93.11
	☐	83	5.09	94.77
	☐	88	5.29	94.57
	☐	103	5	94.86
	☑	130	3.7	96.16
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

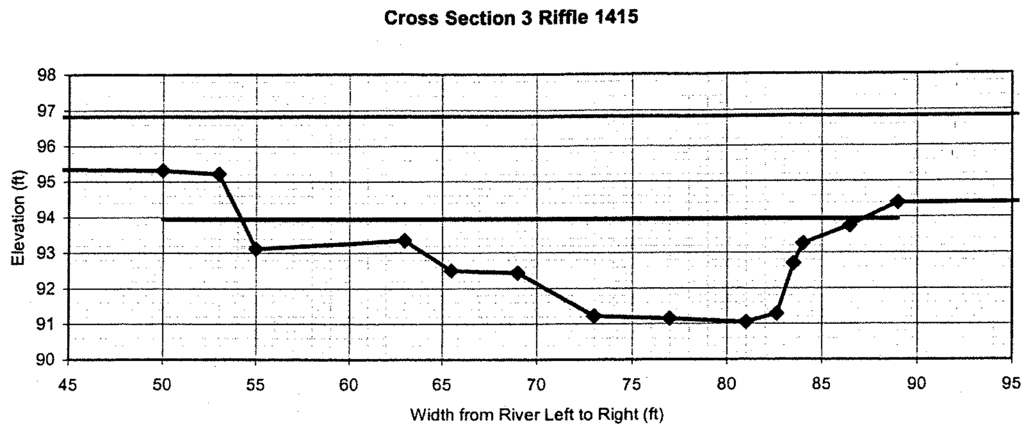
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.75	5.09	114.0	0.43	0.033
93.11	94.77			

dimensions			
52.2	x-section area	1.9	d mean
27.5	width	29.1	wet P
3.2	d max	1.8	hyd radi
4.9	bank ht	14.5	w/d ratio
114.0	W flood prone area	4.1	ent ratio

hydraulics	
4.4	velocity (ft/sec)
228.0	discharge rate, Q (cfs)
0.48	shear stress ((lbs/ft sq)
0.50	shear velocity (ft/sec)
2.224	unit stream power (lbs/ft/sec)
0.31	Froude number
8.8	friction factor u/u*
29.5	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: **Cross Section 3**

Riffle

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description:

height of instrument (ft): 100.98

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	5.41	95.57
	☑	34	5.57	95.41
	☐	50	5.67	95.31
	☐	53	5.77	95.21
	☐	55	7.87	93.11
	☐	63	7.63	93.35
	☐	65.5	8.5	92.48
	☐	69	8.56	92.42
	☐	73	9.77	91.21
	☐	77	9.84	91.14
	☐	81	9.94	91.04
	☐	82.6	9.71	91.27
	☐	83.5	8.3	92.68
	☐	84	7.74	93.24
	☐	86.5	7.24	93.74
	☐	89	6.6	94.38
	☑	98	6.57	94.41
	☑	108	5.95	95.03
	☑	115	5.28	95.7
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

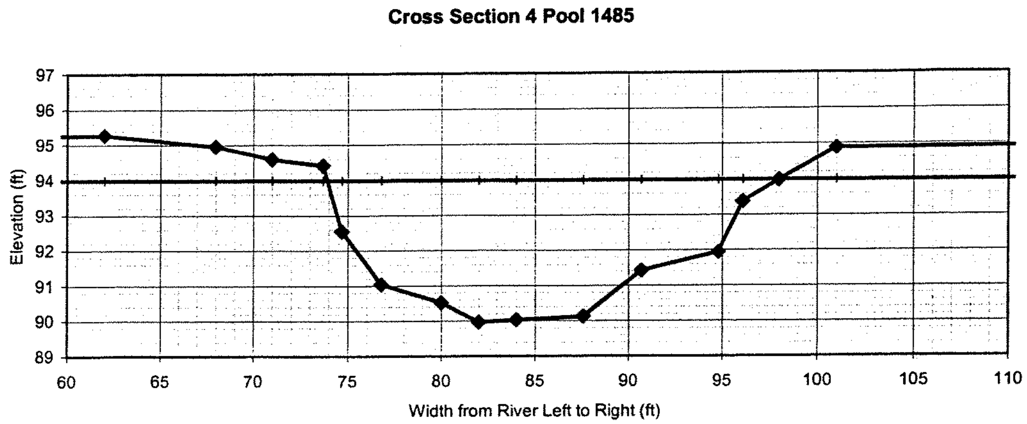
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.05	6.6	160.0	0.43	0.033
93.93	94.38			

dimensions			
52.3	x-section area	1.6	d mean
33.0	width	34.8	wet P
2.9	d max	1.5	hyd radi
3.3	bank ht	20.8	w/d ratio
160.0	W flood prone area	4.8	ent ratio

hydraulics	
3.9	velocity (ft/sec)
202.8	discharge rate, Q (cfs)
0.40	shear stress ((lbs/ft sq)
0.46	shear velocity (ft/sec)
1.648	unit stream power (lbs/ft/sec)
0.29	Froude number
8.5	friction factor u/u*
24.2	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: **Cross Section 4**

Pool

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description:

height of instrument (ft): **100.98**

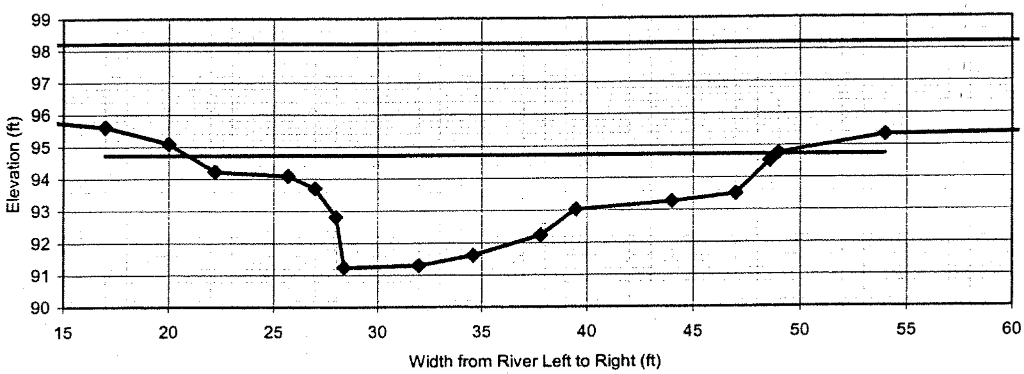
notes	omit pt.	distance (ft)	FS (ft)	elevation
	☐	0	5.41	95.57
	☐	32	5.91	95.07
	☐	62	5.71	95.27
	☐	68	6.03	94.95
	☐	71	6.39	94.59
	☐	73.7	6.57	94.41
	☐	74.7	8.44	92.54
	☐	76.8	9.95	91.03
	☐	80	10.47	90.51
	☐	82	11.02	89.96
	☐	84	10.96	90.02
	☐	87.6	10.86	90.12
	☐	90.7	9.57	91.41
	☐	94.8	9.05	91.93
	☐	96.1	7.62	93.36
	☐	98	7.02	93.96
	☐	101	6.11	94.87
	☐	122	6.03	94.95
	☐	139	5.35	95.63
	☐	146	4.47	96.51
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank		channel slope (%)	
7	6.11		0.43	
93.98	94.87			

dimensions			
66.8	x-section area	2.8	d mean
24.1	width	26.6	wet P
4.0	d max	2.5	hyd radi
4.9	bank ht		

hydraulics	
0.67	shear stress ((lbs/ft sq)
0.59	shear velocity (ft/sec)
42.6	threshold grain size (mm)

Cross Section



section:	Cross Section 5
	Riffle --- ---
description:	
height of instrument (ft):	101.52

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	3	4.53	96.99
	☑	9	5.4	96.12
	☐	17	5.92	95.6
	☐	20	6.44	95.08
	☐	22.2	7.3	94.22
	☐	25.7	7.44	94.08
	☐	27	7.83	93.69
	☐	28	8.72	92.8
	☐	28.4	10.29	91.23
	☐	32	10.23	91.29
	☐	34.6	9.92	91.6
	☐	37.8	9.29	92.23
	☐	39.5	8.5	93.02
	☐	44	8.26	93.26
	☐	47	8.03	93.49
	☐	48.6	7.01	94.51
	☐	49	6.77	94.75
	☐	54	6.2	95.32
	☑	78	5.96	95.56
	☑	123	5.84	95.68
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

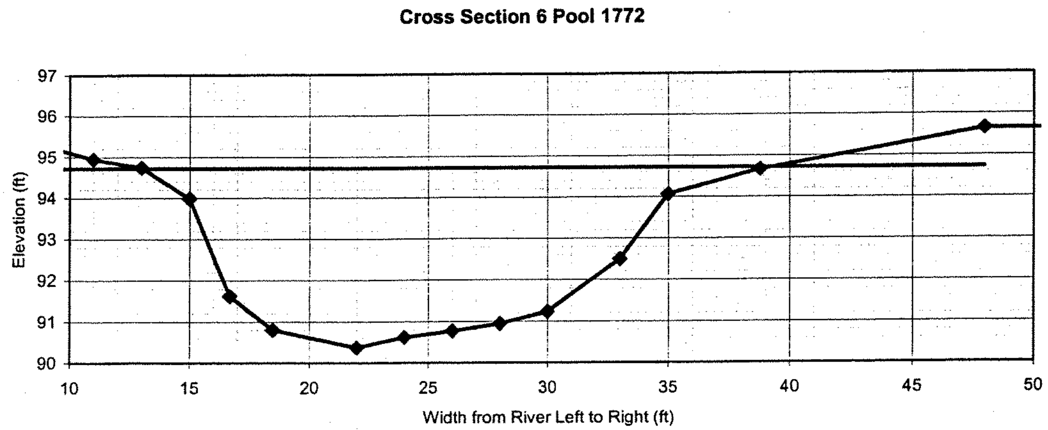
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.8	6.2	293.0	0.43	0.033
94.72	95.32			

dimensions			
51.8	x-section area	1.8	d mean
28.0	width	30.4	wet P
3.5	d max	1.7	hyd radi
4.1	bank ht	15.2	w/d ratio
293.0	W flood prone area	10.5	ent ratio

hydraulics	
4.2	velocity (ft/sec)
218.4	discharge rate, Q (cfs)
0.46	shear stress ((lbs/ft sq)
0.49	shear velocity (ft/sec)
2.090	unit stream power (lbs/ft/sec)
0.30	Froude number
8.7	friction factor u/u*
27.8	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: Cross Section 6

Pool

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description:

height of instrument (ft): 101.52

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	3	4.92	96.6
		7	5.94	95.58
		11	6.58	94.94
		13	6.79	94.73
		15	7.54	93.98
		16.7	9.9	91.62
		18.5	10.73	90.79
		22	11.16	90.36
		24	10.91	90.61
		26	10.76	90.76
		28	10.58	90.94
		30	10.3	91.22
		33	9.03	92.49
		35	7.47	94.05
		38.8	6.86	94.66
		48	5.88	95.64
	✓	73	5.97	95.55
	✓	128	5.84	95.68

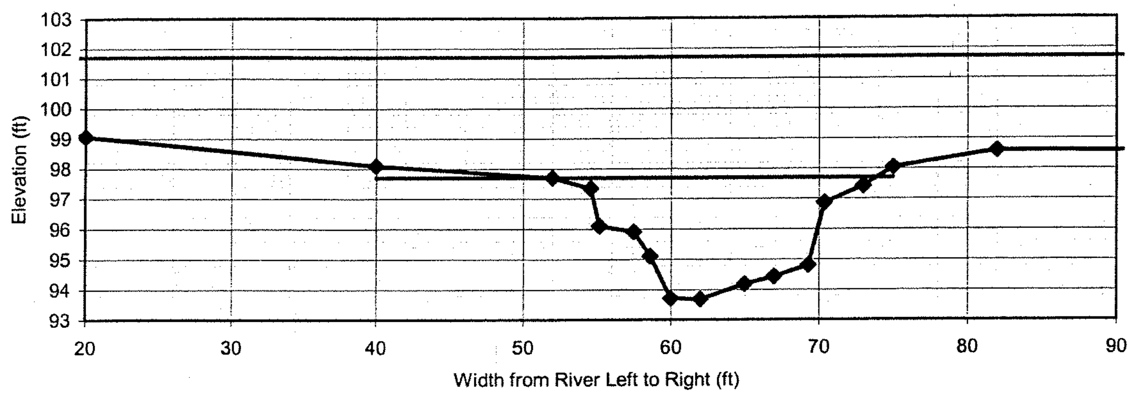
FS bankfull	FS top of bank		channel slope (%)
6.8	5.88		0.43
94.72	95.64		

dimensions			
69.3	x-section area	2.6	d mean
26.3	width	28.8	wet P
4.4	d max	2.4	hyd radi
5.3	bank ht		

hydraulics	
0.65	shear stress ((lbs/ft sq)
0.58	shear velocity (ft/sec)
40.8	threshold grain size (mm)

Cross Section

Cross Section 7 Riffle 2610



section: **Cross Section 7**

Riffle

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description:

height of instrument (ft): 104.07

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	0	3.18	100.89
	✓	20	5.02	99.05
		40	5.99	98.08
		52	6.38	97.69
		54.6	6.74	97.33
		55.2	7.97	96.1
		57.5	8.17	95.9
		58.6	8.97	95.1
		60	10.37	93.7
		62	10.39	93.68
		65	9.89	94.18
		67	9.65	94.42
		69.3	9.27	94.8
		70.4	7.21	96.86
		73	6.66	97.41
		75	6.04	98.03
	✓	82	5.49	98.58
	✓	168	5.65	98.42
	✓	190	5.58	98.49

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.38	6.38	290.0		
97.69	97.69			

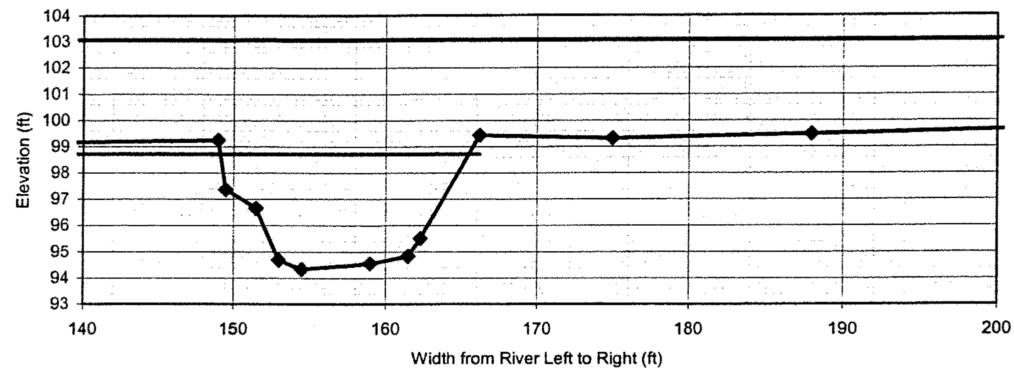
dimensions			
48.7	x-section area	2.2	d mean
21.9	width	25.0	wet P
4.0	d max	2.0	hyd radi
4.0	bank ht	9.8	w/d ratio
290.0	W flood prone area	13.2	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
89.5	relative roughness	14.0	fric. factor
0.000	Manning's n from channel material		

Cross Section

Cross Section 8 Riffle 2888



section:	Cross Section 8
	Riffle --- ---
description:	
height of instrument (ft):	105.21

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	1	4.73	100.48
	☑	35	5.55	99.66
	☑	54	5.58	99.63
	☑	63	5.85	99.36
	☑	88	7.03	98.18
	☑	103	7.59	97.62
	☑	112	6.93	98.28
	☑	127	5.8	99.41
	☐	135	5.45	99.76
	☐	139	6.06	99.15
	☐	149	5.97	99.24
	☐	149.5	7.85	97.36
	☐	151.5	8.56	96.65
	☐	153	10.54	94.67
	☐	154.5	10.88	94.33
	☐	159	10.67	94.54
	☐	161.5	10.39	94.82
	☐	162.3	9.72	95.49
	☐	166.2	5.78	99.43
	☑	175	5.9	99.31
	☑	188	5.73	99.48
	☑	235	5.11	100.1
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

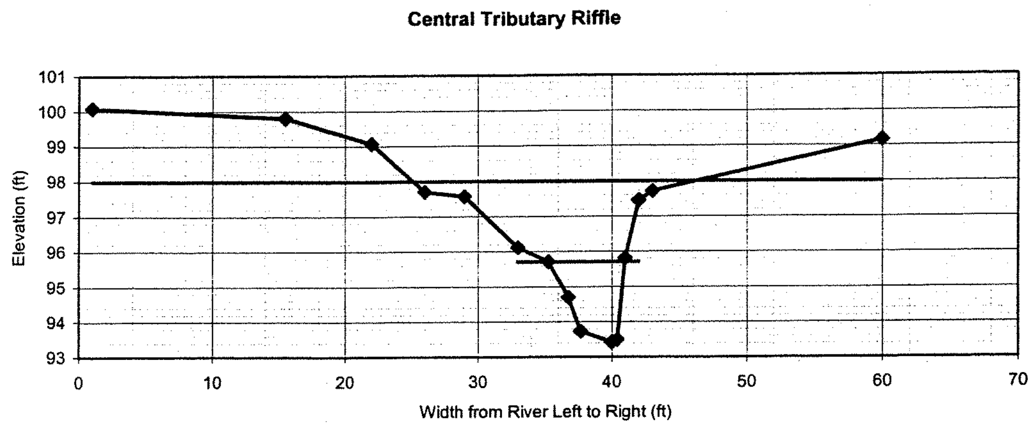
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.5	6.06	235.0		
98.71	99.15			

dimensions			
51.8	x-section area	3.2	d mean
16.3	width	20.1	wet P
4.4	d max	2.6	hyd radi
4.8	bank ht	5.2	w/d ratio
235.0	W flood prone area	14.4	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
127.5	relative roughness	14.8	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	Unnamed Tributary
	Riffle --- ---
description:	Riffle
height of instrument (ft):	104.36

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	1	4.28	100.08
	✓	15.5	4.57	99.79
	✓	22	5.3	99.06
	✓	26	6.67	97.69
	✓	29	6.8	97.56
		33	8.25	96.11
		35.3	8.66	95.7
		36.8	9.67	94.69
		37.7	10.64	93.72
		40	10.95	93.41
		40.4	10.88	93.48
		41	8.56	95.8
		42	6.92	97.44
	✓	43	6.66	97.7
	✓	60	5.22	99.14

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8.66	6.92	21.0		
95.7	97.44			

dimensions			
8.6	x-section area	1.5	d mean
5.7	width	8.2	wet P
2.3	d max	1.0	hyd radi
4.0	bank ht	3.8	w/d ratio
21.0	W flood prone area	3.7	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

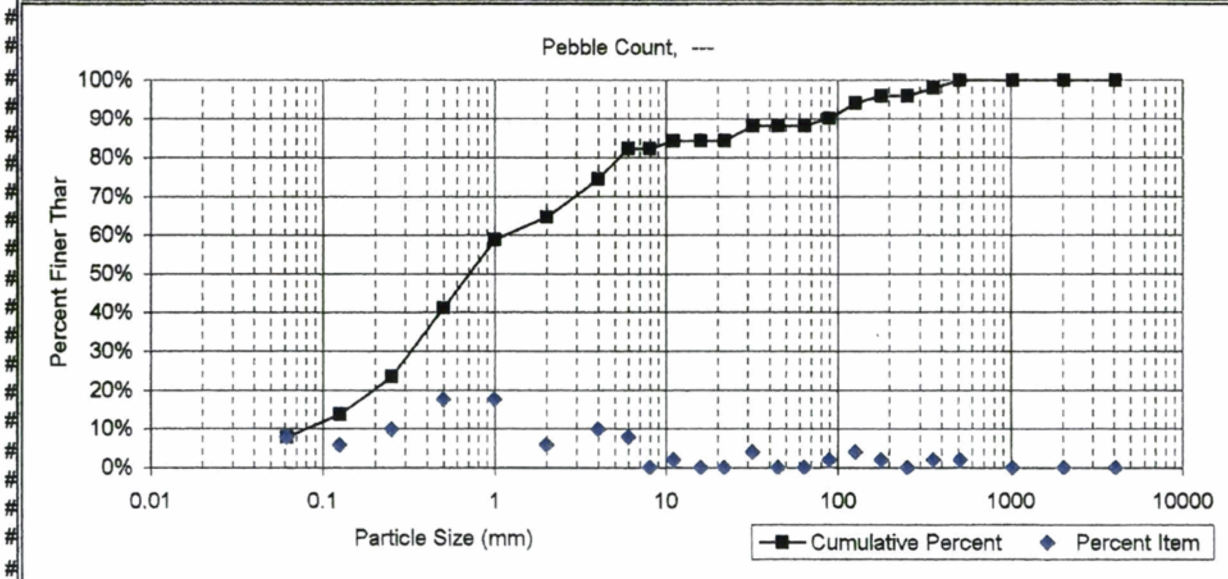
check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Pebble Count

Material	Size Range (mm)		Count	
silt/clay	0	0.062	**4**	# #
very fine sand	0.062	0.13	**3**	# #
fine sand	0.13	0.25	**5**	# #
medium sand	0.25	0.5	**9**	# #
coarse sand	0.5	1	**9**	# #
very coarse sand	1	2	**3**	# #
very fine gravel	2	4	**5**	# #
fine gravel	4	6	**4**	# #
fine gravel	6	8		# #
medium gravel	8	11	**1**	# #
medium gravel	11	16		# #
coarse gravel	16	22		# #
coarse gravel	22	32	**2**	# #
very coarse gravel	32	45		# #
very coarse gravel	45	64		# #
small cobble	64	90	**1**	# #
medium cobble	90	128	**2**	# #
large cobble	128	180	**1**	# #
very large cobble	180	256		# #
small boulder	256	362	**1**	# #
small boulder	362	512	**1**	# #
medium boulder	512	1024		# #
large boulder	1024	2048		# #
very large boulder	2048	4096		# #
bedrock			**1**	#
	Total Particle Count:		52	

Pebble Count,

Note:	**Upstream Straightened Reach**



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
0.147	0.39	0.7	10	149	8%	56%	23%	8%	4%	2%

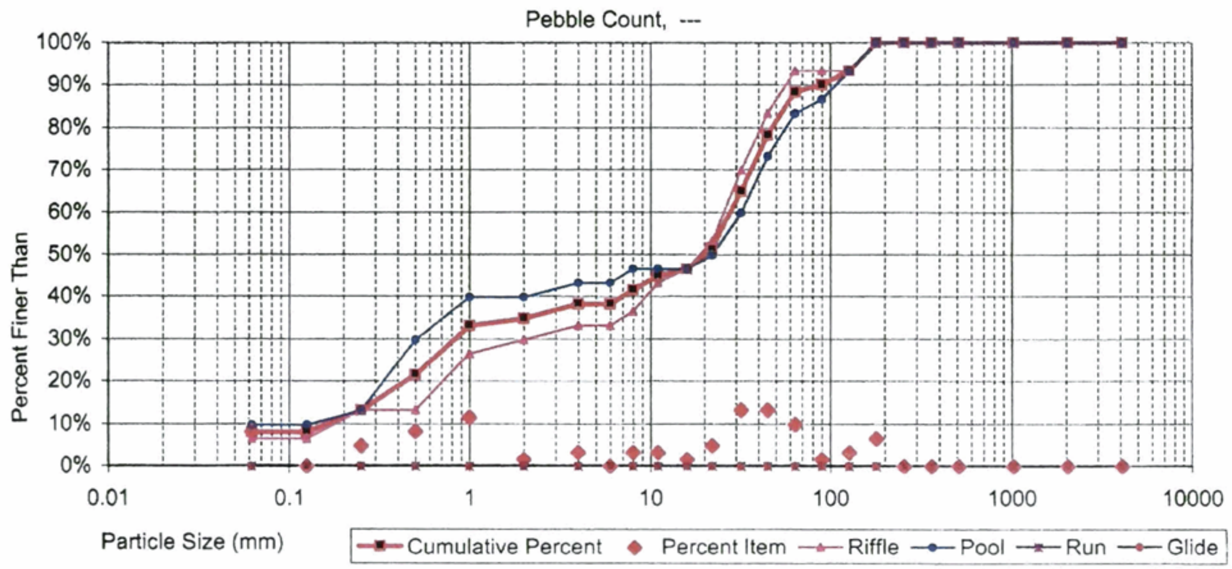
Weighted Pebble Count

Percent Riffle:	50	Percent Run:	0
Percent Pool:	50	Percent Glide:	0

Pebble Count,

Note: **Downstream Sinuous E-type Stream**

Material	Size Range (mm)		Total #		
silt/clay	0	0.062	8.3	#	#
very fine sand	0.062	0.13	0.0	#	#
fine sand	0.13	0.25	5.0	#	#
medium sand	0.25	0.5	8.3	#	#
coarse sand	0.5	1	11.7	#	#
very coarse sand	1	2	1.7	#	#
very fine gravel	2	4	3.3	#	#
fine gravel	4	6	0.0	#	#
fine gravel	6	8	3.3	#	#
medium gravel	8	11	3.3	#	#
medium gravel	11	16	1.7	#	#
coarse gravel	16	22	5.0	#	#
coarse gravel	22	32	13.3	#	#
very coarse gravel	32	45	13.3	#	#
very coarse gravel	45	64	10.0	#	#
small cobble	64	90	1.7	#	#
medium cobble	90	128	3.3	#	#
large cobble	128	180	6.7	#	#
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:	60		



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.312	2.00	19.8	55	139

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
8%	27%	53%	12%	0%	0%

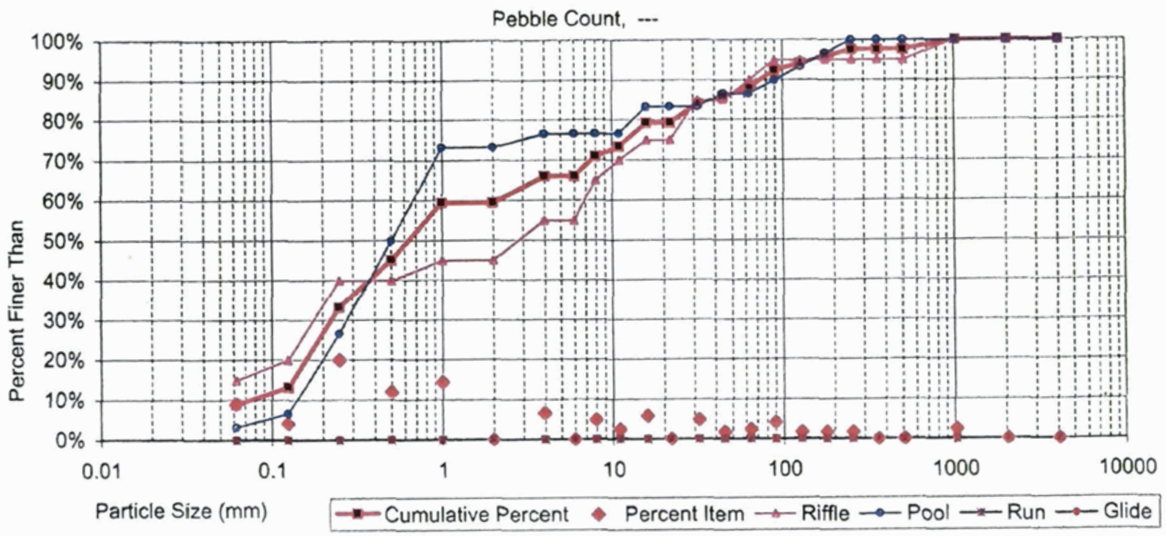
Weighted Pebble Count

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

Pebble Count,

Note: **Downstream Sinuous C-type Stream**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	8.8	# #
very fine sand	0.062	0.13	4.0	# #
fine sand	0.13	0.25	19.5	# #
medium sand	0.25	0.5	11.7	# #
coarse sand	0.5	1	14.0	# #
very coarse sand	1	2	0.0	# #
very fine gravel	2	4	6.4	# #
fine gravel	4	6	0.0	# #
fine gravel	6	8	4.8	# #
medium gravel	8	11	2.4	# #
medium gravel	11	16	5.7	# #
coarse gravel	16	22	0.0	# #
coarse gravel	22	32	4.8	# #
very coarse gravel	32	45	1.7	# #
very coarse gravel	45	64	2.4	# #
small cobble	64	90	4.0	# #
medium cobble	90	128	1.7	# #
large cobble	128	180	1.7	# #
very large cobble	180	256	1.7	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	2.4	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			2.4	#
		Weighted Count:	100	
		True Total Particle Count:	51	



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.138	0.28	0.6	32	152

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
9%	49%	28%	9%	2%	2%

Existing Pattern

Back Creek Mitigation Plan
Stream Plan View All measurments in feet

Downstream Sinuous Reach

Pool (from)	Pool Spacing	Belt Width	Radius of Curvature	Meander Wavelength	Bankfull Width Estimate
3	164			281	
4	129	41	57	176	
5	59		55	293	
6	281	59	48	562	
7	316		67	304	
8	105	123	67	608	
9	351		71		
10	287	199	23	433	
11	222		106	293	
12	140	117	43	246	
13	105		128	129	
14	94	76	36	176	
15	129		39	257	
16	140	47	135		
Average	180	95	67	313	
Low	59	41	23	129	
High	351	199	135	608	

Sinuousity for the downstream reach is **1.41**

Upstream Straightened Reach

Upstream reach has no distinctive repetitive pattern of riffles and pools due to straighting activities. Pattern data other then sinuousity was not recorded. Sinuousity for the upstream reach is **1.02**

Existing Profile

Date: November 4 and 5, 2002

Bed Elevation	Water Surface Elevation	Bankfull Elevation	Floodplain Elevation	Feature	Site Stationing	
81.58	81.94			Invert of Center C	-501	
80.49	81.93			Scour hole at cul\	-489	
82.13	82.13			run	-447	
82.53	82.76			br	-438	
82.10	82.86			mr	-421	
82.18	82.83	85.15		mr	-388	
82.84	83.35			tr	-379	
81.73	83.43			p1	-348	
82.68	83.43	85.66		run	-331	
82.93	83.42			br1	-313	
82.13	83.44			p2	-288	
82.38	83.43			run	-264	
82.84	83.43			tr1	-250	
82.53	83.43			p2b	-242	
82.83	83.42		88.79	run	-223	
83.42	83.53			br2	-218	
82.89	83.54	85.50		mr2	-172	
82.38	83.55			mid riffle scour pc	-146	
82.19	83.55	85.52		mid riffle scour pc	-122	
82.99	83.55			bottom of run (rip	-115	
84.65	84.97			top of run (rip rap	-87	
83.57	84.97			p3	-77	
84.21	84.97	89.97		run3	-53	
84.57	84.97			run/glide apex	-34	
83.79	84.97			p3b	-23	
84.48	84.97			br3	-17	
83.90	84.96			p4	0	0
84.46	84.97			br4	15	15
84.47	84.97			mr/tr	25	25
84.00	84.98			p5	38	38
84.41	84.97	86.90		run5	49	49
84.27	84.96			p5b	63	63
84.45	84.97			run	85	85
84.42	84.98			run	94	94
85.01	85.33			br5	104	104
85.00	85.50	87.62		mid riffle @ Cros:	128	128
85.24	85.59			tr5	155	155
83.20	85.58			p6	166	166
85.06	85.59		90.36	run6	177	177
84.80	85.59			mr6	209	209
84.61	85.60			p7	230	230
85.11	85.61			run7	260	260
86.53	86.83	89.12		br7	289	289
87.15	87.27			tr7	333	333
86.19	87.29			p8	344	344
86.30	87.28			run8	380	380
86.81	87.30			br8	417	417
87.64	88.14		91.64	tr8	471	471
86.89	88.14			p9	480	480
87.05	88.14			run	515	515

87.57	88.12			run	528	528
88.00	88.30			br9	538	538
87.50	88.24			mr9	553	553
87.83	88.31			tr9	577	577
87.39	88.31			glide	588	588
87.13	88.31			p10	599	599
87.61	88.35	90.36	91.66	br10 near adj trib	612	612
88.25	88.75			tr10	651	651
87.40	88.75			glide	670	670
86.54	88.75		92.00	p11	700	700
87.76	88.74			run	717	717
87.81	88.74			run	744	744
87.50	88.70		92.45	run	774	774
87.96	88.68			br11	829	829
88.53	88.72		92.54	mr11	867	867
88.57	88.90			tr11	907	907
87.80	88.91			p12	919	919
88.47	88.90			br12	926	926
89.01	89.53			mr12 @ sewer lin	965	965
90.00	90.50			tr12	1010	1010
89.67	90.52			glide 13	1027	1027
89.39	90.51			p13	1035	1035
90.50	90.79			br 13	1051	1051
89.78	90.81			tie in stream @ c	1059	1059
89.31	90.83			p14	1077	1077
89.71	90.81			run	1101	1101
90.40	90.83			br14	1108	1108
89.99	90.84			glide	1123	1123
89.55	90.84			glide14	1138	1138
89.25	90.84			glide	1148	1148
89.21	90.85			glide	1191	1191
88.98	90.86			p15	1204	1204
89.42	90.83			run	1238	1238
89.87	90.86			run glide apex	1258	1258
88.97	90.89			p16	1270	1270
89.41	90.87	92.94	94.62	run	1288	1288
90.24	90.89			br16	1304	1304
90.67	90.87			tr16	1332	1332
89.68	90.89			p17	1340	1340
90.47	90.92			run	1364	1364
90.56	90.99			br17	1386	1386
91.50	91.99			tr17	1415	1415
90.53	92.01			glide	1425	1425
89.89	92.01	93.56		p18	1437	1437
90.80	92.02			run/glide apex	1452	1452
90.05	92.03			p18b	1467	1467
90.00	92.04			p18b	1485	1485
89.78	92.04			p18b	1502	1502
90.77	92.09		95.38	br18	1536	1536
90.51	92.68			br18	1536	1536
90.68	92.68	94.94		mr18	1581	1581
91.07	92.72	93.46		mr	1601	1601
91.23	92.68		95.84	mr	1622	1622
91.29	92.72			secondary trib tie	1630	1630
91.13	92.74			glide	1644	1644
90.27	92.79			glide	1652	1652
89.54	92.80			convergence riffle	1664	1664
89.97	92.81		95.84	convergence riffle	1677	1677
91.22	92.84			top of convergenc	1687	1687
90.57	92.84			glide19	1697	1697
90.53	92.85		95.75	p20	1709	1709

90.75	92.84			br20	1722	1722
91.15	92.84	93.74	95.39	x-sec 5 riffle 20	1751	1751
90.71	92.86			p21 x-sec	1772	1772
90.70	92.85			run	1791	1791
90.80	92.85		95.60	oxbow low bank	1804	1804
90.33	92.83			glide	1814	1814
90.05	92.84		95.70	glide 21	1828	1828
89.63	92.78			p22	1837	1837
90.51	92.79		95.96	run	1852	1852
90.43	92.79		96.31	atypical riffle	1878	1878
90.07	92.78			glide	1897	1897
89.71	92.78			p23	1906	1906
91.59	92.77		96.60	br23	1924	1924
91.61	92.83			tr23	1936	1936
90.74	92.80		96.72	glide23	1944	1944
90.31	92.81			p24	1949	1949
90.16	92.80	93.91		p24	1962	1962
90.37	92.78			p24	1974	1974
90.89	92.78			br24	1981	1981
91.72	92.85		96.33	tr24	2004	2004
90.82	92.85			p25	2016	2016
91.21	92.84			run glide apex	2036	2036
90.53	92.83		95.13	scour pool 25b	2045	2045
92.52	93.34		96.24	tr25	2065	2065
92.23	93.41			fence/property lin	2097	2097
91.83	93.40			p26	2117	2117
92.21	93.44			run	2142	2142.00
92.77	93.42			br26	2159	2159.00
92.73	93.84			potential tie-in pt	2172	2172.00
92.96	93.95		97.25	tr26	2205	2205.00
92.20	94.00			p27	2234	2234.00
92.80	94.02		97.65		2274	2274.00
92.92	94.04			br27	2312	2312.00
92.72	94.06		97.74	mr	2366	2366.00
92.51	94.16		97.81	p28	2434	2434.00
93.39	94.13		97.80	br28	2484	2484.00
93.46	94.16			mr	2514	2514.00
93.73	94.80		98.00	mr	2558	2558.00
93.88	95.02			tr28	2587	2587.00
93.75	95.05		97.88	p29	2610	2610.00
93.32	94.71			X-sec-7	2610	2610.00
93.58	94.73		98.56		2652	2652.00
93.63	94.84			TR29	2682	2682.00
93.78	94.83		98.31		2710	2710.00
93.89	94.88				2739	2739.00
94.02	94.90		98.62	BB	2789	2789.00
94.47	94.92				2818	2818.00
95.45	96.13		98.48	Ditch Tie in C	2845	2845.00
94.63	96.17			X-sec 8	2888	2888.00
94.91	96.15		98.64		2931	2931.00
94.10	96.15			PA	2956	2956.00
94.26	96.15				2973	2973.00
94.99	96.17		98.57	TR B	2993	2993.00
94.24	96.16			PB	3004	3004.00
95.58	96.19		98.83		3029	3029.00
94.81	96.21			C	3047	3047.00
94.73	96.22				3071	3071.00
95.71	96.25		99.65	Bottom of Steep F	3098	3098.00
96.30	97.01		99.90	Top of Steep R/R	3129	3129.00
96.23	97.04		100.50	Sewerline Crossii	3147	3147.00
95.54	97.07		100.42	D	3175	3175.00

95.87	97.05	100.48		3197	3197.00
95.35	97.08	100.39	E	3219	3219.00
96.02	97.10	100.80	F	3237	3237.00
95.51	97.09		BR G	3261	3261.00
96.15	97.34	101.16	TR G	3289	3289.00
95.90	97.35		Fence	3306	3306.00
96.65	97.31		Bridge	3332	3332.00

UT to Back Creek on Morgan Property

95.58			Mainstem tie in
95.97	96.03		
95.74	96.13	99.07	
97.36	97.51		
98.60	98.83		X
99.82	99.95	99.86	
99.22	99.95	100.89	Y Channel width =2.6
99.90	100.08		
98.37	100.08		scour pool
99.29	100.08		bottom of headcut
101.17	101.24	102.32	top of headcut
100.99	101.54		
102.12	102.22	103.39	
101.14	102.23		scour pool below Rip-rap
102.22	102.22	103.48	bottom of rip rap
102.96	103.45	103.58	
104.12	104.14		
104.19	104.44	104.39	at bend
105.32	105.42	104.97	fence corner
106.61	106.83	106.70	
107.74	107.74		fence at prop line

UT to Back Creek on BC Developers Property

90.97	92.26		confluence of Back Ceek
92.51	92.65		
92.19	92.73		small pool
92.60	93.00		
92.64	93.02		
92.49	93.03		Pool
92.97	93.04		BR
92.79	93.13		TR
92.68	93.17		Pool
92.95	93.15	95.83	BR
93.41	93.67		TR
93.01	93.69	97.15	Pool
93.67	93.76		BR
94.40	94.50	98.83	TR
93.38	94.52		Scour pool below bedrock (grade control
93.97	94.51		Base of nickpoint
96.10	96.15	99.99	Top of nickpoint
95.96	96.16		
97.42	97.64		approximately 2 feet past fence line
97.55	97.98		stormwater outfall (36 inch culvert)

Site: Back Creek prop Downstream Sinuous Facet Slopes

Personnel: Grant, Adam

Station (feet)	Water Surface Elevation	Feature		Riffles	Pools
0	81.94	Invert of Center Culvert			
12	81.93	Scour hole at culvert			
54	82.13	run			0.0035
63	82.76	br			
80	82.86	mr			
113	82.83	mr			
122	83.35	tr		0.0100	
153	83.43	p1			
170	83.43	run			0.0017
188	83.42	br1			
213	83.44	p2			
237	83.43	run			
251	83.43	tr1			
259	83.43	p2b			
278	83.42	run			0.0000
283	83.53	br2			
329	83.54	mr2			
355	83.55	mid riffle scour pool			
379	83.55	mid riffle scour pool			
386	83.55	bottom of run (rip-rap over)			0.0002
414	84.97	top of run (rip rap over)		0.0507	
424	84.97	p3			
448	84.97	run3			0.0000
467	84.97	run/glide apex			
478	84.97	p3b			
484	84.97	br3			
501	84.96	p4			
516	84.97	br4			
526	84.97	mr/tr		0.0000	
539	84.98	p5			
550	84.97	run5			
564	84.96	p5b			
586	84.97	run			
595	84.98	run			
605	85.33	br5			
629	85.50	mid riffle @ Cross Section 1			
656	85.59	tr5		0.0051	
667	85.58	p6			
678	85.59	run6			0.0000
710	85.59	mr6			
731	85.60	p7	skipped about 3 pools		
761	85.61	run7			
790	86.83	br7	ideal riffle		
834	87.27	tr7	ideal riffle	0.0100	
845	87.29	p8			
881	87.28	run8			
918	87.30	br8			0.0001
972	88.14	tr8		0.0156	
981	88.14	p9			
1016	88.14	run			
1029	88.12	run			0.0000
1039	88.30	br9			
1054	88.24	mr9			
1078	88.31	tr9			
1089	88.31	glide			
1100	88.31	p10			
1113	88.35	br10 near adj trib			0.0017
1152	88.75	tr10		0.0103	
1171	88.75	glide			
1201	88.75	p11			
1218	88.74	run			0.0000
1245	88.74	run			
1275	88.70	run			
1330	88.68	br11			
1368	88.72	mr11			
1408	88.90	tr11		0.0028	
1420	88.91	p12			
1427	88.90	br12			0.0000
1466	89.53	mr12 @ sewer line			

1511	90.50	tr12	0.0190		
1528	90.52	glide 13			
1536	90.51	p13			
1552	90.79	br 13			
1560	90.81	tie in stream @ culvert			
1578	90.83	p14			
1602	90.81	run		0.0000	
1609	90.83	br14			
1624	90.84	glide			
1639	90.84	glide14			
1649	90.84	glide			
1692	90.85	glide			
1705	90.86	p15			
1739	90.83	run			
1759	90.86	run glide apex		0.0002	
1771	90.89	p16			
1789	90.87	run		0.0003	
1805	90.89	br16			
1833	90.87	tr16	[redacted]		Value changed from negative to zero for statistical analysis
1841	90.89	p17			
1865	90.92	run		0.0016	
1887	90.99	br17			
1916	91.99	tr17	0.0345		
1926	92.01	glide			
1938	92.01	p18			
1953	92.02	run/glide apex		0.0008	
1968	92.03	p18b			
1986	92.04	p18b			
2003	92.04	p18b			
2037	**92.68**	**br18**			
2082	92.68	mr18			
2102	92.72	mr18			
2123	92.68	mr18			
2131	92.72	TR	[redacted]		Not used in slope calculations due to high water
2145	92.74	Glide			
2153	92.79	Glide			
2165	92.80	convergence riffle			
2178	92.81	convergence riffle			
2188	92.84	top of convergence riffle			
2198	92.84	glide19			
2210	92.85	p20			
2223	92.84	br20			
2252	92.84	x-sec 5 riffle 20			
2273	92.86	p21 x-sec			
2292	92.85	run			
2305	92.85	br 21 oxbow low bank			
2315	92.83	Glide			
2329	92.84	glide 21			
2338	92.78	p22			
2353	92.79	run			
2379	92.79	atypical riffle			
2398	92.78	Glide			
2407	92.78	p23			
2425	92.77	br23			
2437	92.83	TR 23	[redacted]		
2445	92.80	glide 23			
2450	92.81	p24			
2463	92.80	p24			
2475	92.78	P24		[redacted]	
2482	92.78	br24			
2505	92.85	tr24	[redacted]		
2517	92.85	p25 bed rock			
2537	92.84	run glide apex			
2546	92.83	scour pool 25b			
2566	93.34	tr25			
2598	93.41	fence/property line			
		ave	0.0144	0.0006	
		min	0.0000	0.0000	
		max	0.0507	0.0035	
		standev	0.0156	0.0010	

Velocity Comparison Form

Class

Date 11/22/02 Team Adam, Grant

Stream Back Creek Location X-section 2 (downstream, sinuous C-Type)

Input Variables			Output Variables		
Bankfull Cross Sectional Area (A_{BKF})	55.7	ft^2	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	1.9	ft
Bankfull Width (W_{BKF})	29.5	ft	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	33.3	ft
D84	32	mm	D84 (mm/304.8)	0.105	ft
Bankfull Slope	0.0037	ft/ft	Hydraulic Radius (R) (A_{BKF}/WP)	1.67	ft
Gravity	32.13	ft/s^2	R/D84 (use D84 in FEET)	15.93	ft/ft

R/D84, u/u*, Mannings n		
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book:p233)	10	ft/s/ ft/s
Mannings n: (Reference Reach Field Book: p189, River Field Book:p236)	0.028	$ft^{1/6}$
Velocity: from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$	4.6	ft/s

u/u*=2.83+5.7logR/D84		
u*: $u^*=(gRS)^{0.5}$	0.45	ft/s
Velocity: u=u*(2.83+5.7logR/D84)	4.4	ft/s

Mannings n by Stream Type		
Stream Type	C5	
Mannings n: (Reference Reach Field Book: p187, River Field Book:p237)	0.034	$ft^{1/6}$
Velocity: from Manning's equation $u=1.49R^{2/3}S^{1/2}/n$	3.8	ft/s

For Larger Streams

Continuity Equation		
Q_{BKF} (cfs) from regional curve or stream gage calibration	238	cfs
Velocity (u=Q/A or from stream gage hydraulic geometry)	4.3	ft/s

Shear stress

The shear stress or tractive force results from the tangential pull of flowing water on the stream bed and banks, and is expressed in pounds per square foot or n/m^2. The energy expended on the wetted perimeter of the stream increases proportionally with the energy slope and water depth.

Existing Conditions Upstream Straightened

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress (pounds/sq ft)	w (stream power per unit bed area)	Rc	Max shear stress (2.65t(Rc/Wbkf))
54	2.9	19	24.8	2.18	0.0037	62.4	4.6	0.503	2.313	135	0.500

Existing Conditions Downstream Sinuous C-type

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w		
56.2	1.8	32.2	35.8	1.57	0.0037	62.4	4.4	0.362	1.595	67	0.666

Existing Conditions Downstream Sinuous E-type

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w		
55.7	2.5	22.7	27.7	2.01	0.0037	62.4	4.4	0.464	2.043	67	0.716

UT to Crane Creek Reference

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress (lbs/sq. ft)	w (stream power per unit bed area)	Rc	Max shear stress (2.65t(Rc/Wbkf))
20.5	2	10.1	14.10	1.45	0.0014	62.4	4.1	0.127	0.521	NA	0.75*

Reedy Creek Reference

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w		
15.5	1.4	10.4	13.20	1.17	0.0111	62.4	3	0.813	2.440	27.6	1.323

Proposed Conditions Upstream

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w	Rc	Max shear stress (2.65t(Rc/Wbkf))
56	2.5	22.4	27.4	2.04	0.0032	62.4	4.4	0.408	1.796	58	0.672

Proposed Conditions Downstream

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w		
56	2.5	22.4	27.4	2.04	0.0036	62.4	4.4	0.459	2.020	58	0.756

Proposed Conditions Total

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w		
56	2.5	22.4	27.4	2.04	0.0034	62.4	4.4	0.434	1.908	58	0.714

* (1.5*shear stress) for straightened channels

Change in slope

Proposed Conditions Back Creek

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w
56	2.5	22.4	27.4	2.04	0.0017	62.4	4.4	0.217	0.954
56	2.5	22.4	27.4	2.04	0.0018	62.4	4.4	0.230	1.010
56	2.5	22.4	27.4	2.04	0.0019	62.4	4.4	0.242	1.066
56	2.5	22.4	27.4	2.04	0.002	62.4	4.4	0.255	1.122
56	2.5	22.4	27.4	2.04	0.0021	62.4	4.4	0.268	1.178
56	2.5	22.4	27.4	2.04	0.0024	62.4	4.4	0.306	1.347
56	2.5	22.4	27.4	2.04	0.0026	62.4	4.4	0.332	1.459
56	2.5	22.4	27.4	2.04	0.0028	62.4	4.4	0.357	1.571
56	2.5	22.4	27.4	2.04	0.003	62.4	4.4	0.383	1.683
56	2.5	22.4	27.4	2.04	0.0032	62.4	4.4	0.408	1.796
56	2.5	22.4	27.4	2.04	0.0034	62.4	4.4	0.434	1.908
56	2.5	22.4	27.4	2.04	0.0036	62.4	4.4	0.459	2.020
56	2.5	22.4	27.4	2.04	0.0038	62.4	4.4	0.485	2.132
56	2.5	22.4	27.4	2.04	0.004	62.4	4.4	0.510	2.245
56	2.5	22.4	27.4	2.04	0.0044	62.4	4.4	0.561	2.469
56	2.5	22.4	27.4	2.04	0.0052	62.4	4.4	0.663	2.918
56	2.5	22.4	27.4	2.04	0.0056	62.4	4.4	0.714	3.142
56	2.5	22.4	27.4	2.04	0.006	62.4	4.4	0.765	3.367
56	2.5	22.4	27.4	2.04	0.0065	62.4	4.4	0.829	3.647
56	2.5	22.4	27.4	2.04	0.007	62.4	4.4	0.893	3.928
56	2.5	22.4	27.4	2.04	0.0079	62.4	4.4	1.008	4.433

Change in depth/width

Proposed Conditions Whitelace B

Area	Depth	Width	WP	Hyd. Rad.	Slope	Specific weight of Water	average bankfull velocity	Shear Stress	w
56	1.5	37.3	40.33	1.39	0.0034	62.4	4.4	0.295	1.296
56	1.6	35.0	38.20	1.47	0.0034	62.4	4.4	0.311	1.368
56	1.7	32.9	36.34	1.54	0.0034	62.4	4.4	0.327	1.438
56	1.8	31.1	34.71	1.61	0.0034	62.4	4.4	0.342	1.506
56	1.9	29.5	33.27	1.68	0.0034	62.4	4.4	0.357	1.571
56	2	28.0	32.00	1.75	0.0034	62.4	4.4	0.371	1.634
56	2.1	26.7	30.87	1.81	0.0034	62.4	4.4	0.385	1.694
56	2.2	25.5	29.85	1.88	0.0034	62.4	4.4	0.398	1.751
56	2.3	24.3	28.95	1.93	0.0034	62.4	4.4	0.410	1.806
56	2.4	23.3	28.13	1.99	0.0034	62.4	4.4	0.422	1.858
56	2.5	22.4	27.40	2.04	0.0034	62.4	4.4	0.434	1.908
56	2.6	21.5	26.74	2.09	0.0034	62.4	4.4	0.444	1.955
56	2.7	20.7	26.14	2.14	0.0034	62.4	4.4	0.454	2.000
56	2.8	20.0	25.60	2.19	0.0034	62.4	4.4	0.464	2.042
56	2.9	19.3	25.11	2.23	0.0034	62.4	4.4	0.473	2.082
56	3	18.7	24.67	2.27	0.0034	62.4	4.4	0.482	2.119
56	3.1	18.1	24.26	2.31	0.0034	62.4	4.4	0.490	2.154
56	3.2	17.5	23.90	2.34	0.0034	62.4	4.4	0.497	2.187
56	3.3	17.0	23.57	2.38	0.0034	62.4	4.4	0.504	2.218
56	3.4	16.5	23.27	2.41	0.0034	62.4	4.4	0.511	2.246
56	3.5	16.0	23.00	2.43	0.0034	62.4	4.4	0.517	2.273

Stream Power

The rate of doing work, or a measure of the energy available for moving rock, sediment particles, or woody or other debris in the stream channel, as determined by discharge, water surface slope, and the specific weight of water

w=specific (per unit) stream power (Joules/second/sq. ft)

Existing Conditions Upstream Straightened

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0037	19	57.03	3.00

Existing Conditions Downstream Sinuous C-type

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0037	32.2	57.03	1.77

Existing Conditions Downstream Sinuous E-type

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0037	22.7	57.03	2.51

UT to Crane Creek Reference

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	117	0.0014	10.1	10.22	1.01

Reedy Creek Reference

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	17	0.0111	10.4	11.77	1.13

Proposed Conditions Upstream

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0032	22.4	49.32	2.20

Proposed Conditions Downstream

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0036	22.4	55.49	2.48

Proposed Conditions Total

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247	0.0034	22.4	52.40	2.34

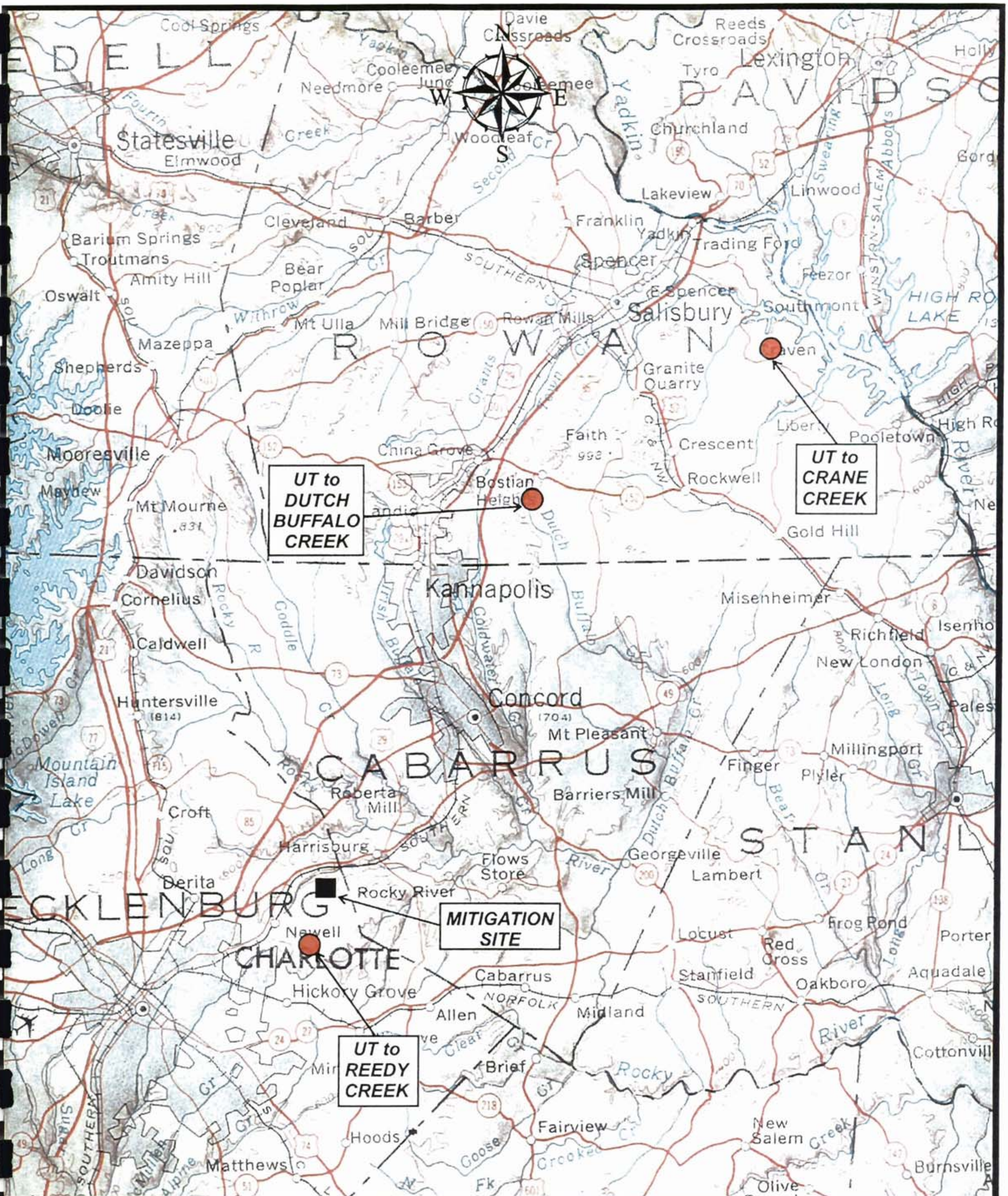
Proposed Conditions Back Creek

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247.0	0.002	22.4	30.83	1.38
62.4	247.0	0.0024	22.4	36.99	1.65
62.4	247.0	0.0026	22.4	40.07	1.79
62.4	247.0	0.0028	22.4	43.16	1.93
62.4	247.0	0.003	22.4	46.24	2.06
62.4	247.0	0.0032	22.4	49.32	2.20
62.4	247.0	0.0034	22.4	52.40	2.34
62.4	247.0	0.0036	22.4	55.49	2.48
62.4	247.0	0.0038	22.4	58.57	2.61
62.4	247.0	0.004	22.4	61.65	2.75
62.4	247.0	0.0044	22.4	67.82	3.03
62.4	247.0	0.0048	22.4	73.98	3.30
62.4	247.0	0.005	22.4	77.06	3.44
62.4	247.0	0.0052	22.4	80.15	3.58
62.4	247.0	0.0058	22.4	89.39	3.99
62.4	247.0	0.006	22.4	92.48	4.13
62.4	247.0	0.0065	22.4	100.18	4.47

Proposed Conditions Back Creek

Density of Water	Discharge	Slope	Channel Width	total stream power	w=W/W
62.4	247.0	0.0034	19.5	52.40	2.69
62.4	247.0	0.0034	20	52.40	2.62
62.4	247.0	0.0034	20.5	52.40	2.56
62.4	247.0	0.0034	21	52.40	2.50
62.4	247.0	0.0034	21.5	52.40	2.44
62.4	247.0	0.0034	21.8	52.40	2.40
62.4	247.0	0.0034	22	52.40	2.38
62.4	247.0	0.0034	22.2	52.40	2.36
62.4	247.0	0.0034	22.4	52.40	2.34
62.4	247.0	0.0034	22.6	52.40	2.32
62.4	247.0	0.0034	23	52.40	2.28
62.4	247.0	0.0034	23.4	52.40	2.24
62.4	247.0	0.0034	23.8	52.40	2.20
62.4	247.0	0.0034	24.2	52.40	2.17
62.4	247.0	0.0034	24.6	52.40	2.13
62.4	247.0	0.0034	25.2	52.40	2.08
62.4	247.0	0.0034	26	52.40	2.02

APPENDIX C
REFERENCE STREAM DATA

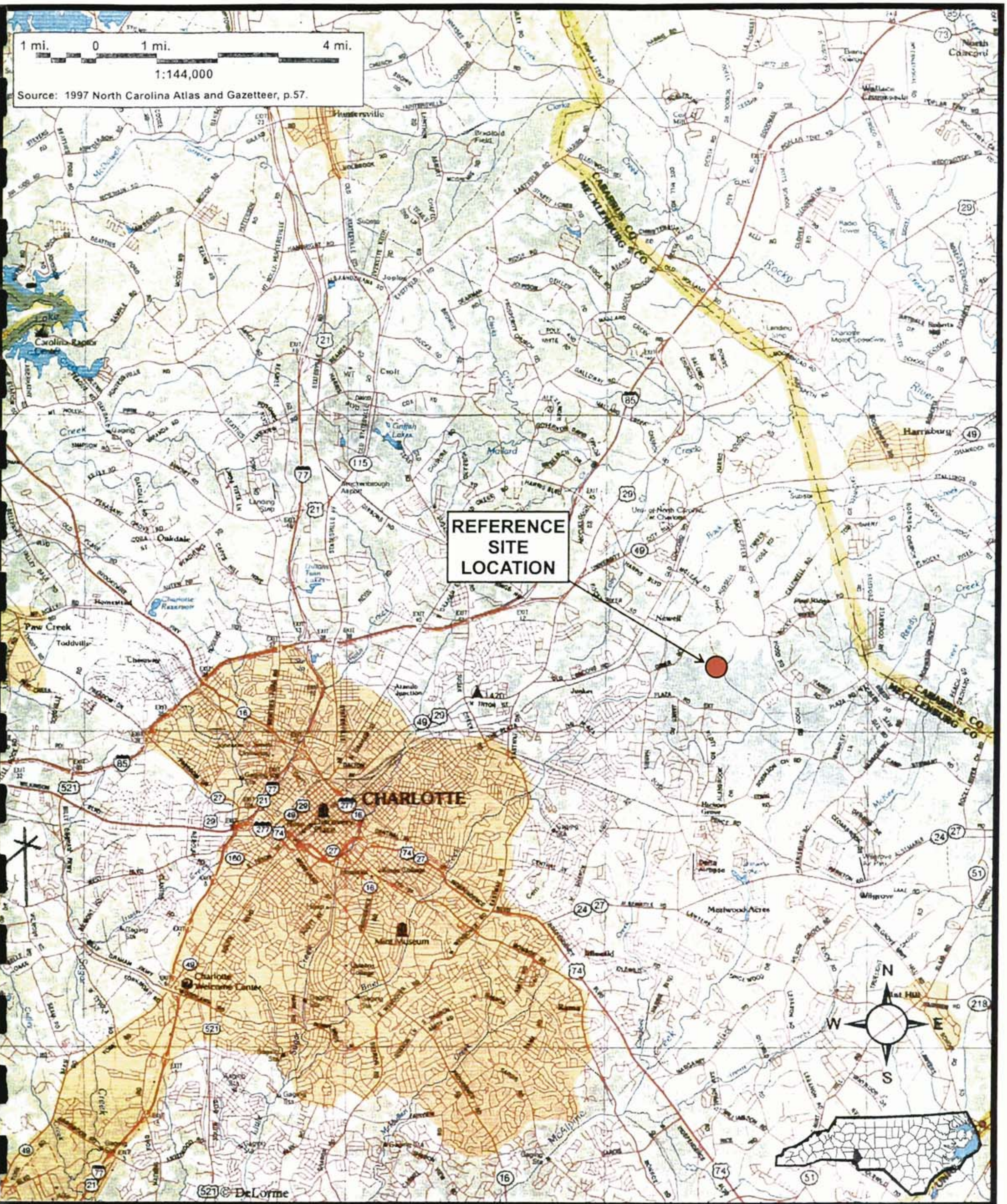


EcoScience Corporation
Raleigh, North Carolina

REFERENCE SITE LOCATIONS
Back Creek Mitigation Site
DETAILED MITIGATION STUDIES
Mecklenburg County, North Carolina

Dwn. by:	MAF
Ckd by:	WGL
Date:	DEC 2002
Project:	02-113.04

APPENDIX B
Figure 1

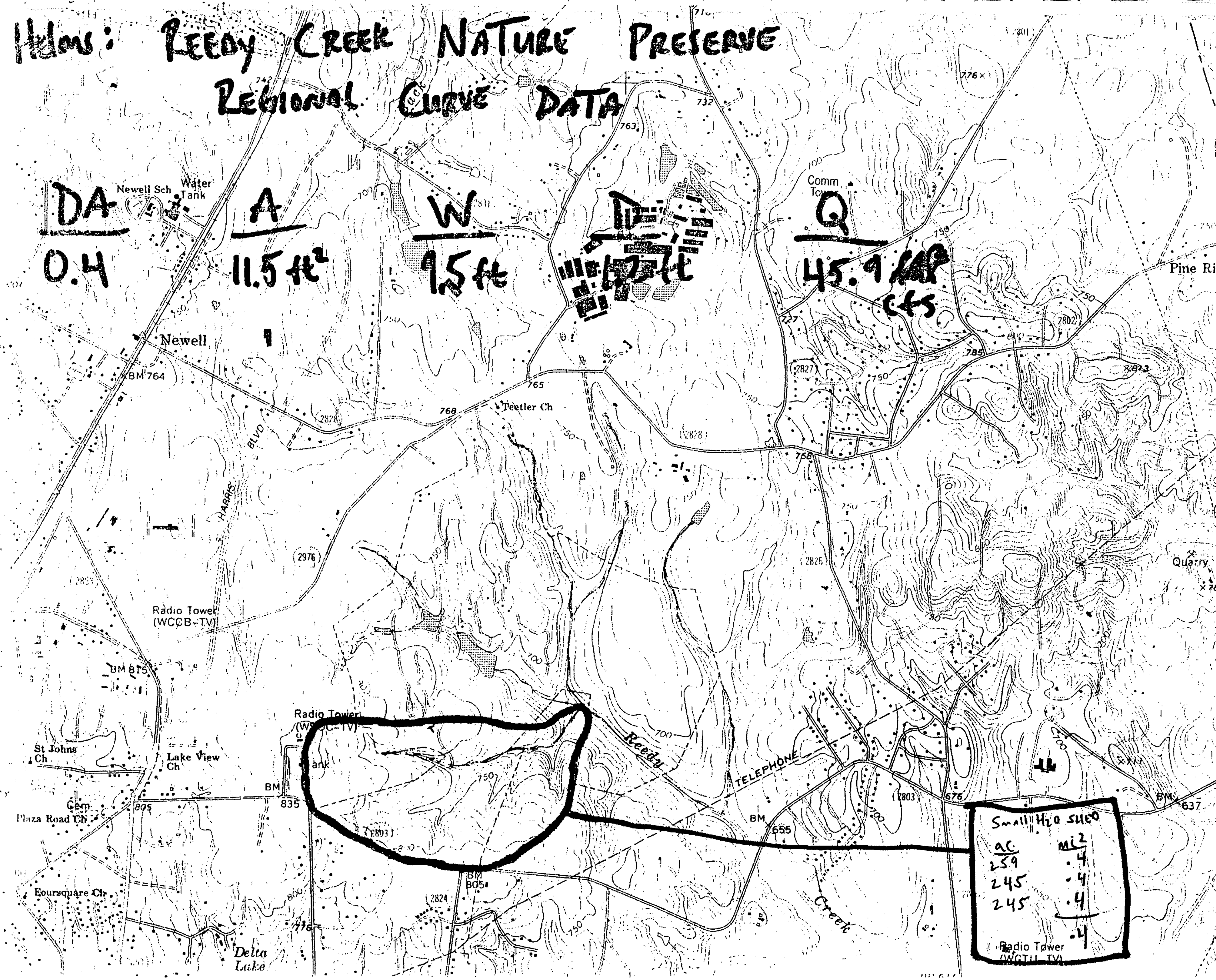


EcoScience Corporation
Raleigh, North Carolina

UT to REEDY CREEK
Reference Site
Mecklenburg County, North Carolina

Dwn. by:	MAF	APPENDIX B	
Ckd by:	WGL		
Date:	DEC 2002	Figure	
Project:	02-113.04	2A	

Helms: Reedy Creek Nature Preserve
Regional Curve Data



Helms! Reedy Creek Nature Park

Reference Dimension

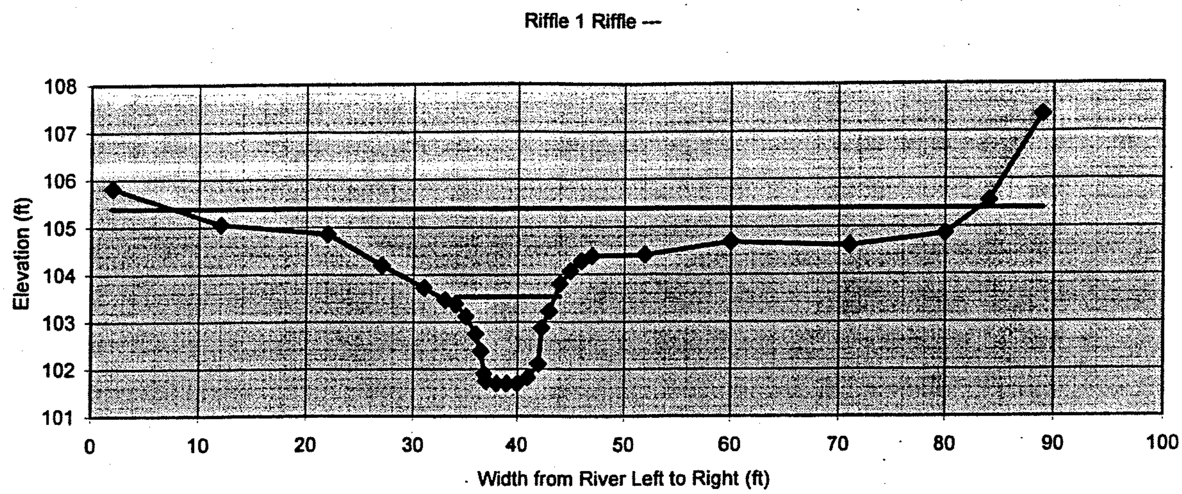
Riffles

X Sect #	A Bkfl	W Bkfl	D Ave	D max	W/D	FPA	Ent. Ratio	LBH	BHR	Dmax/Dave	Stream Type
1	11.8	9.6	1.2	1.8	8	70.5	7.4	1.8	1.0	1.5	E
2	17.1	10.4	1.6	2.2	6	58	5.6	2.6	1.2	1.4	E
3	15.5	11.2	1.4	2.2	8	42	3.7	2.0	1.0	1.6	E
Ave	14.8	10.4	1.4	2.1	7	56.8	5.6	2.1	1.1	1.4	
Median	15.5	10.4	1.4	2.2	8	58	5.6	2.0	1.0	1.4	

Pools

X-Sect	A	W	D ave	D max	LBH	BHR
2	17.1	14.7	1.2	2.3	2.3	1.0
4	18.8	13.7	1.4	2.2	2.3	1.0
Ave	18.0	14.2	1.3	2.3	2.3	1.0

Cross Section



section:	Riffle 1
	Riffle --- ---
description:	Reedy Creek
height of instrument (ft):	110.44

notes	omit pt	distance (ft)	FS (ft)	elevation
	☑	2	4.62	105.82
	☑	12	5.38	105.06
	☑	22	5.58	104.86
	☑	27	6.24	104.2
	☑	31	6.71	103.73
	☑	33	6.97	103.47
	☐	34	7.06	103.38
	☐	35	7.32	103.12
	☐	36	7.69	102.75
	☐	36.5	8.06	102.38
	☐	36.8	8.54	101.9
	☐	37	8.69	101.75
	☐	38	8.74	101.7
	☐	39	8.74	101.7
	☐	40	8.75	101.69
	☐	41	8.62	101.82
	☐	42	8.33	102.11
	☐	42.3	7.57	102.87
	☐	43	7.22	103.22
	☐	44	6.64	103.8
	☑	45	6.37	104.07
	☑	46	6.17	104.27
	☑	47	6.06	104.38
	☑	52	6.03	104.41
	☑	60	5.75	104.69
	☑	71	5.83	104.61
	☑	80	5.58	104.86
	☑	84	4.9	105.54
	☑	89	3.08	107.36

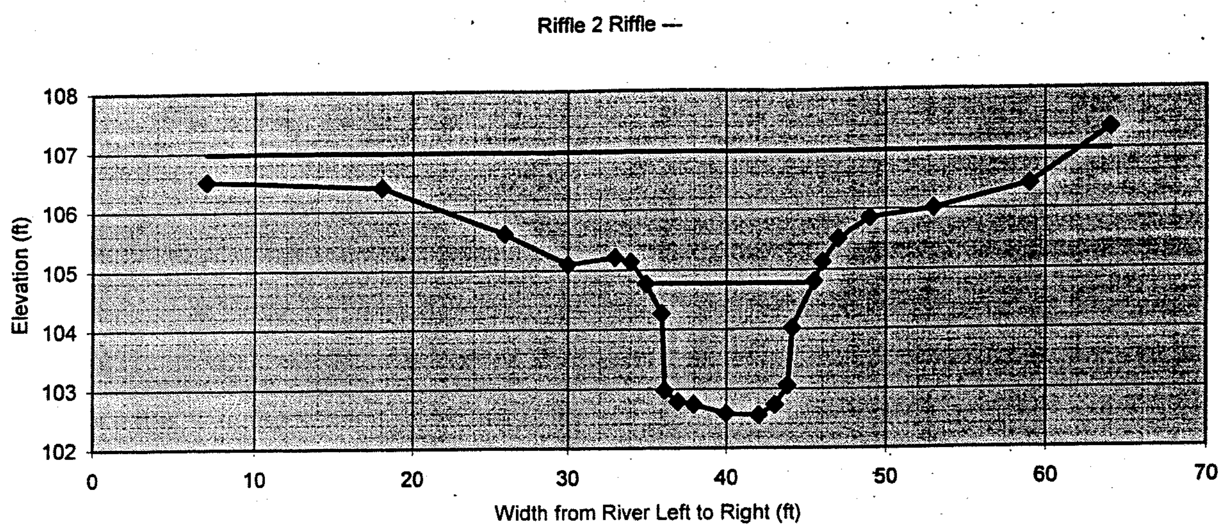
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.9	6.9	70.5		
103.54	103.54			

dimensions			
11.8	x-section area	1.2	d mean
9.6	width	10.8	wet P
1.8	d max	1.1	hyd radi
1.9	bank ht	7.8	w/d ratio
70.5	W flood prone area	7.4	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
12	measured D84 (mm)		
30.2	relative roughness	11.3	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	Riffle 2
	Riffle — —
description:	
height of instrument (ft):	111.72

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	7	5.2	106.52
	☑	18	5.32	106.4
	☑	26	6.1	105.62
	☑	30	6.62	105.1
	☑	33	6.51	105.21
	☑	34	6.59	105.13
	☐	35	6.95	104.77
	☐	36	7.45	104.27
	☐	36.2	8.74	102.98
	☐	37	8.93	102.79
	☐	38	8.98	102.74
	☐	40	9.13	102.59
	☐	42	9.16	102.56
	☐	43	8.99	102.73
	☐	43.8	8.67	103.05
	☐	44.1	7.7	104.02
	☐	45.5	6.92	104.8
	☑	46	6.6	105.12
	☑	47	6.21	105.51
	☑	49	5.86	105.86
	☑	53	5.71	106.01
	☑	59	5.31	106.41
	☑	64	4.38	107.34
	☐			
	☐			
	☐			

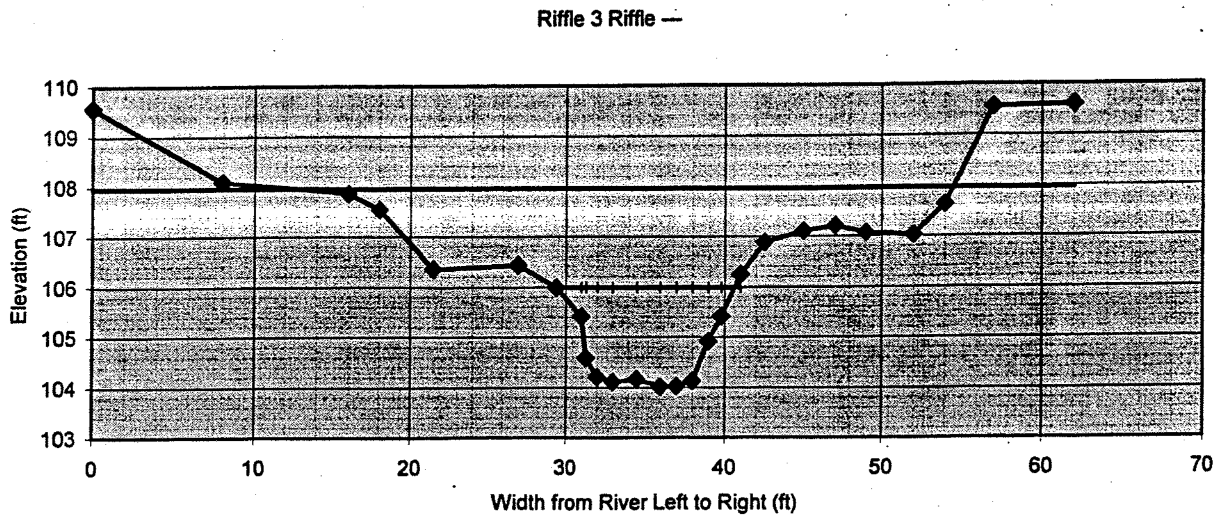
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's n
6.95	6.59	58.0		
104.77	105.13			

dimensions			
17.1	x-section area	1.6	d mean
10.4	width	12.7	wet P
2.2	d max	1.3	hyd radi
2.6	bank ht	6.4	w/d ratio
58.0	W flood prone area	5.6	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
12	measured D84 (mm)		
40.2	relative roughness	12.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	Riffle 3
	Riffle --- ---
description:	
height of instrument (ft):	112.42

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	0	2.85	109.57
	✓	8	4.32	108.1
	✓	16	4.55	107.87
	✓	18	4.87	107.55
	✓	21.5	6.06	106.36
	✓	27	5.98	106.44
		29.4	6.43	105.99
		31	7.01	105.41
		31.3	7.83	104.59
		32	8.21	104.21
		33	8.3	104.12
		34.5	8.25	104.17
		36	8.4	104.02
		37	8.39	104.03
		38	8.29	104.13
		39	7.5	104.92
		39.8	7	105.42
		41	6.17	106.25
	✓	42.5	5.53	106.89
	✓	45	5.31	107.11
	✓	47	5.21	107.21
	✓	49	5.35	107.07
	✓	52	5.39	107.03
	✓	54	4.79	107.63
	✓	57	2.86	109.56
	✓	62	2.82	109.6

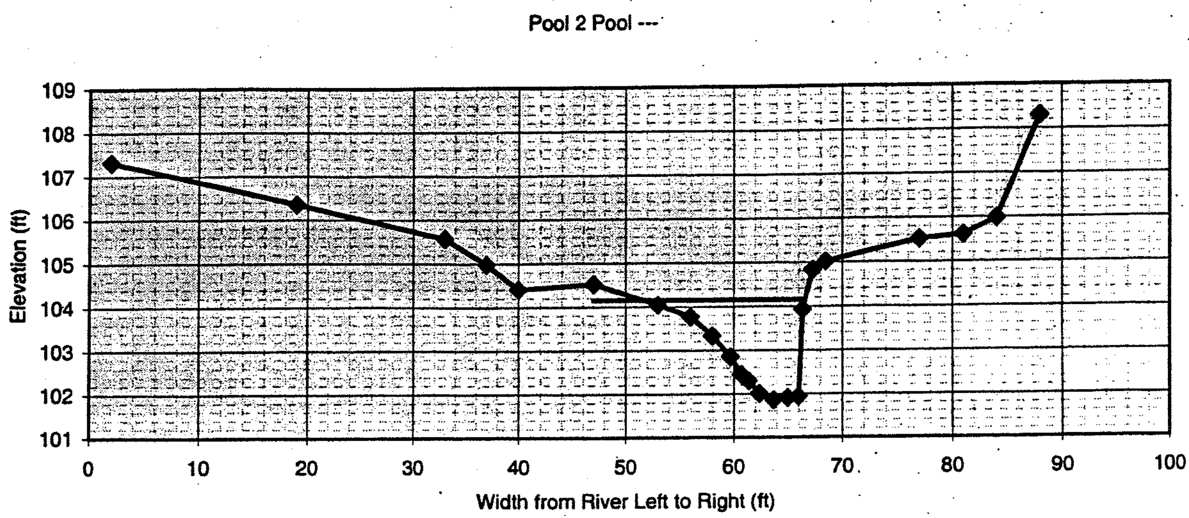
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.43	6.43	42.0	0.0029	0.034
105.99	105.99			

dimensions			
15.5	x-section area	1.4	d mean
11.2	width	12.6	wet P
2.0	d max	1.2	hyd radi
2.0	bank ht	8.1	w/d ratio
42.0	W flood prone area	3.7	ent ratio

hydraulics	
0.3	velocity (ft/sec)
4.2	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.03	shear velocity (ft/sec)
0.001	unit stream power (lbs/ft/sec)
0.00	Froude number
8.0	friction factor u/u*
0.1	threshold grain size (mm)

check from channel material			
12	measured D84 (mm)		
34.0	relative roughness	11.6	fric. factor
0.024	Manning's n from channel material		

Cross Section



section:	Pool 2
	Pool --- ---
description:	
height of instrument (ft):	111.05

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	2	3.73	107.32
	✓	19	4.69	106.36
	✓	33	5.48	105.57
	✓	37	6.07	104.98
	✓	40	6.64	104.41
		47	6.53	104.52
		53	7	104.05
		56	7.28	103.77
		58	7.72	103.33
		59.7	8.2	102.85
		60.7	8.6	102.45
		61.4	8.75	102.3
		62.4	9.04	102.01
		63.7	9.19	101.86
		65	9.14	101.91
		66	9.11	101.94
		66.4	7.12	103.93
	✓	67.3	6.22	104.83
	✓	68.5	6.03	105.02
	✓	77	5.53	105.52
	✓	81	5.44	105.61
	✓	84	5.07	105.98
	✓	88	2.75	108.3

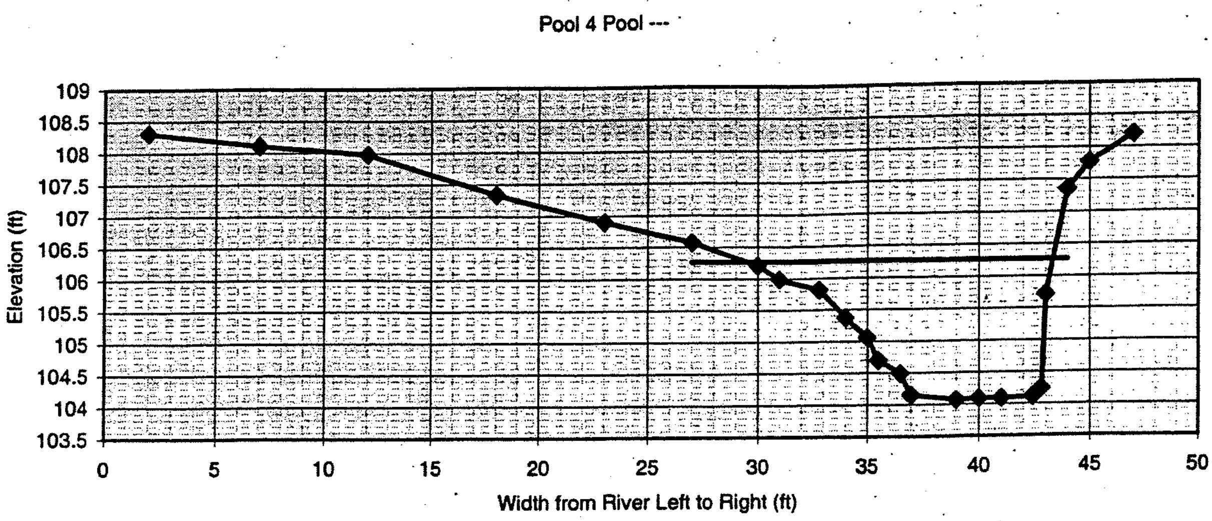
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
~~6.9~~	6.9			
104.15	104.15			

dimensions			
17.1	x-section area	1.2	d mean
14.7	width	16.6	wet P
2.3	d max	1.0	hyd radi
2.3	bank ht	~~12.6~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
~~12~~	measured D84 (mm)		
~~28.6~~	relative roughness	~~11.1~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section



section:	Pool 4
	Pool

	---
description:	
height of instrument (ft):	113.51

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	2	5.2	108.31
	✓	7	5.4	108.11
	✓	12	5.53	107.98
	✓	18	6.17	107.34
	✓	23	6.61	106.9
		27	6.94	106.57
		30	7.3	106.21
		31	7.52	105.99
		32.8	7.69	105.82
		34	8.14	105.37
		35	8.45	105.06
		35.5	8.81	104.7
		36.5	9.02	104.49
		37	9.36	104.15
		39	9.44	104.07
		40	9.42	104.09
		41	9.42	104.09
		42.4	9.4	104.11
		42.8	9.27	104.24
		43	7.79	105.72
		44	6.16	107.35
	✓	45	5.74	107.77
	✓	47	5.31	108.2

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
~~7.25~~	6.16			
106.26	107.35			

dimensions

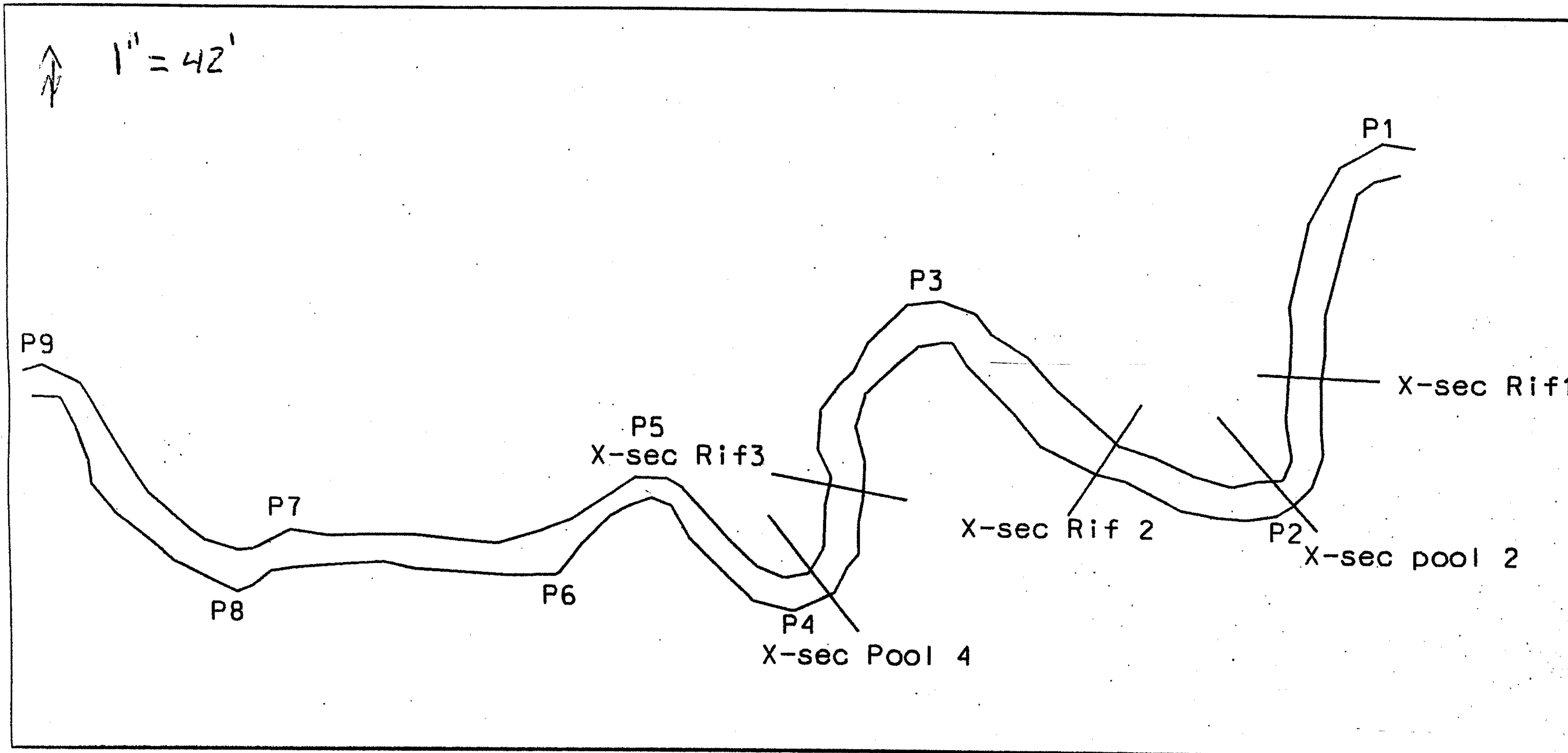
18.8	x-section area	1.4	d mean
13.7	width	15.8	wet P
2.2	d max	1.2	hyd radi
3.3	bank ht	~~10.0~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics

~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

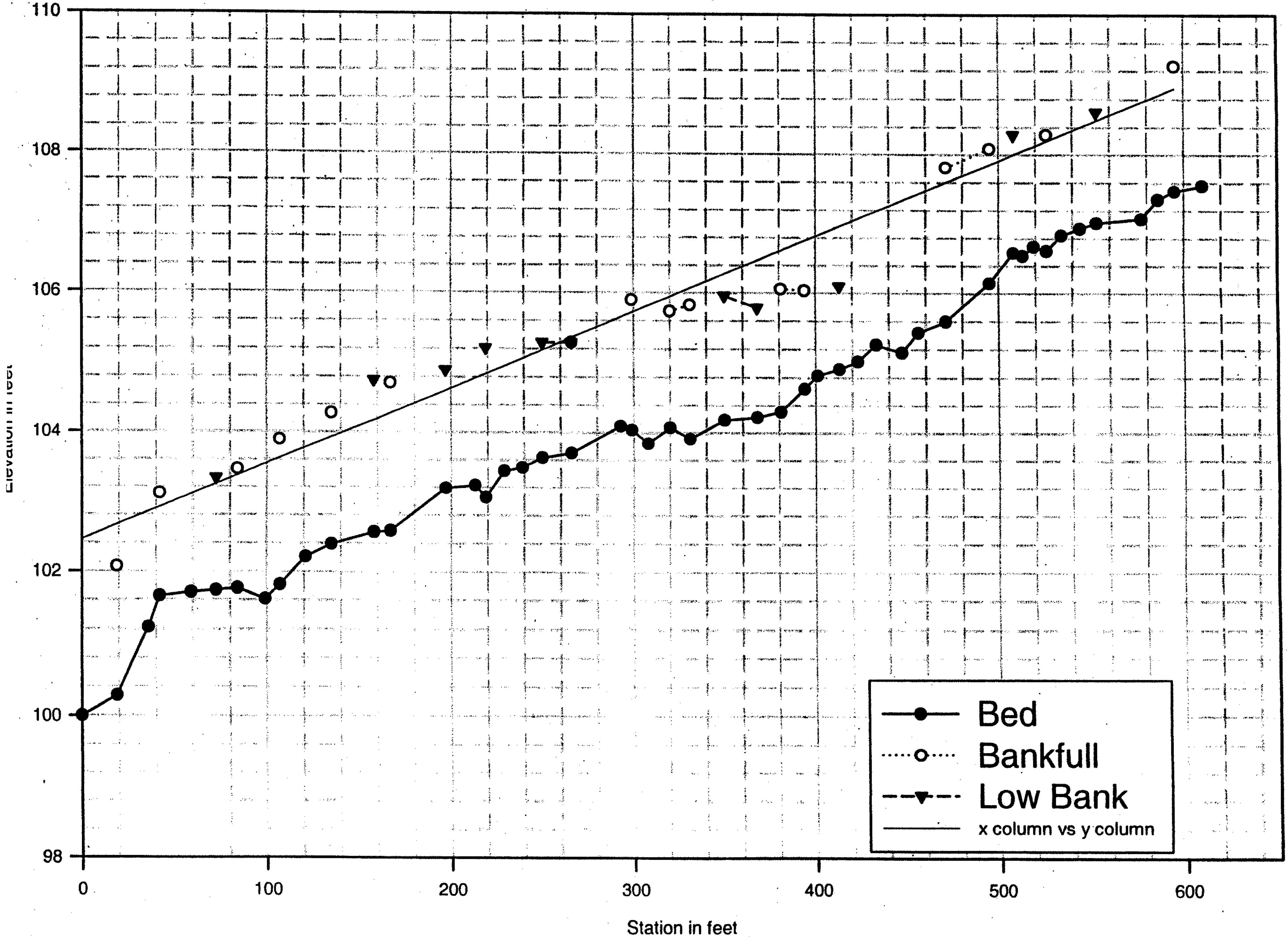
check from channel material

~~12~~	measured D84 (mm)		
~~33.7~~	relative roughness	~~11.5~~	fric. factor
~~0.000~~	Manning's n from channel material		



...\gps\reference\reedref.dgn Sep. 11, 2002 08:59:13

Reedy Creek Nature Park
Reference Stream
Profile



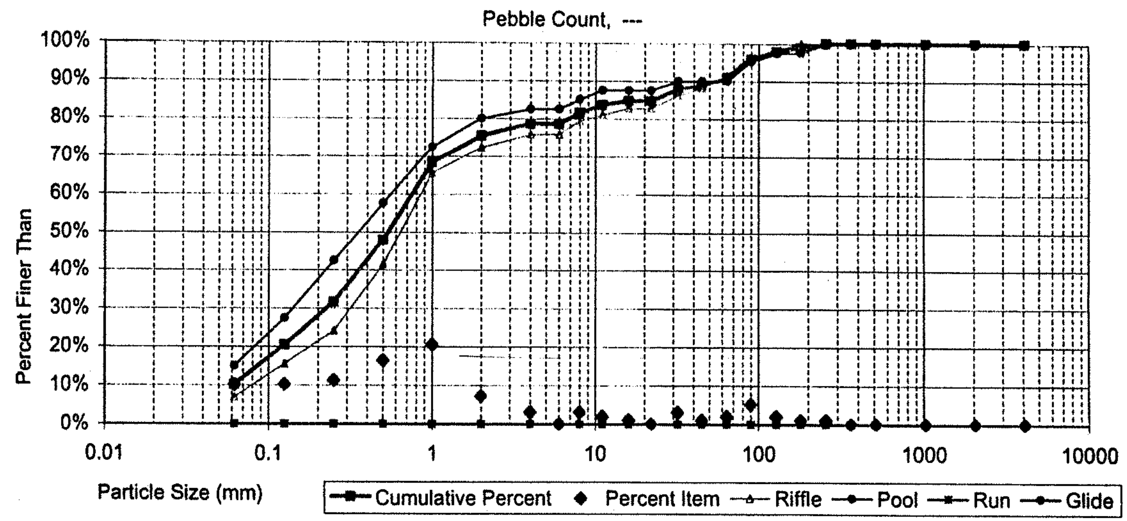
Weighted Pebble Count

Percent Riffle:	60	Percent Run:	0
Percent Pool:	40	Percent Glide:	0

Pebble Count,

Note: **Reedy Creek Composite Pebble Count**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	10.0	# #
very fine sand	0.062	0.13	10.0	# #
fine sand	0.13	0.25	11.0	# #
medium sand	0.25	0.5	16.0	# #
coarse sand	0.5	1	20.0	# #
very coarse sand	1	2	7.0	# #
very fine gravel	2	4	3.0	# #
fine gravel	4	6	0.0	# #
fine gravel	6	8	3.0	# #
medium gravel	8	11	2.0	# #
medium gravel	11	16	1.0	# #
coarse gravel	16	22	0.0	# #
coarse gravel	22	32	3.0	# #
very coarse gravel	32	45	1.0	# #
very coarse gravel	45	64	2.0	# #
small cobble	64	90	5.0	# #
medium cobble	90	128	2.0	# #
large cobble	128	180	1.0	# #
very large cobble	180	256	1.0	# #
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			2.0	#
Weighted Count:			100	
True 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
0.092	0.29	0.5	12	85	10%	64%	15%	9%	0%	2%

EcoScience Corporation
Raleigh, North Carolina

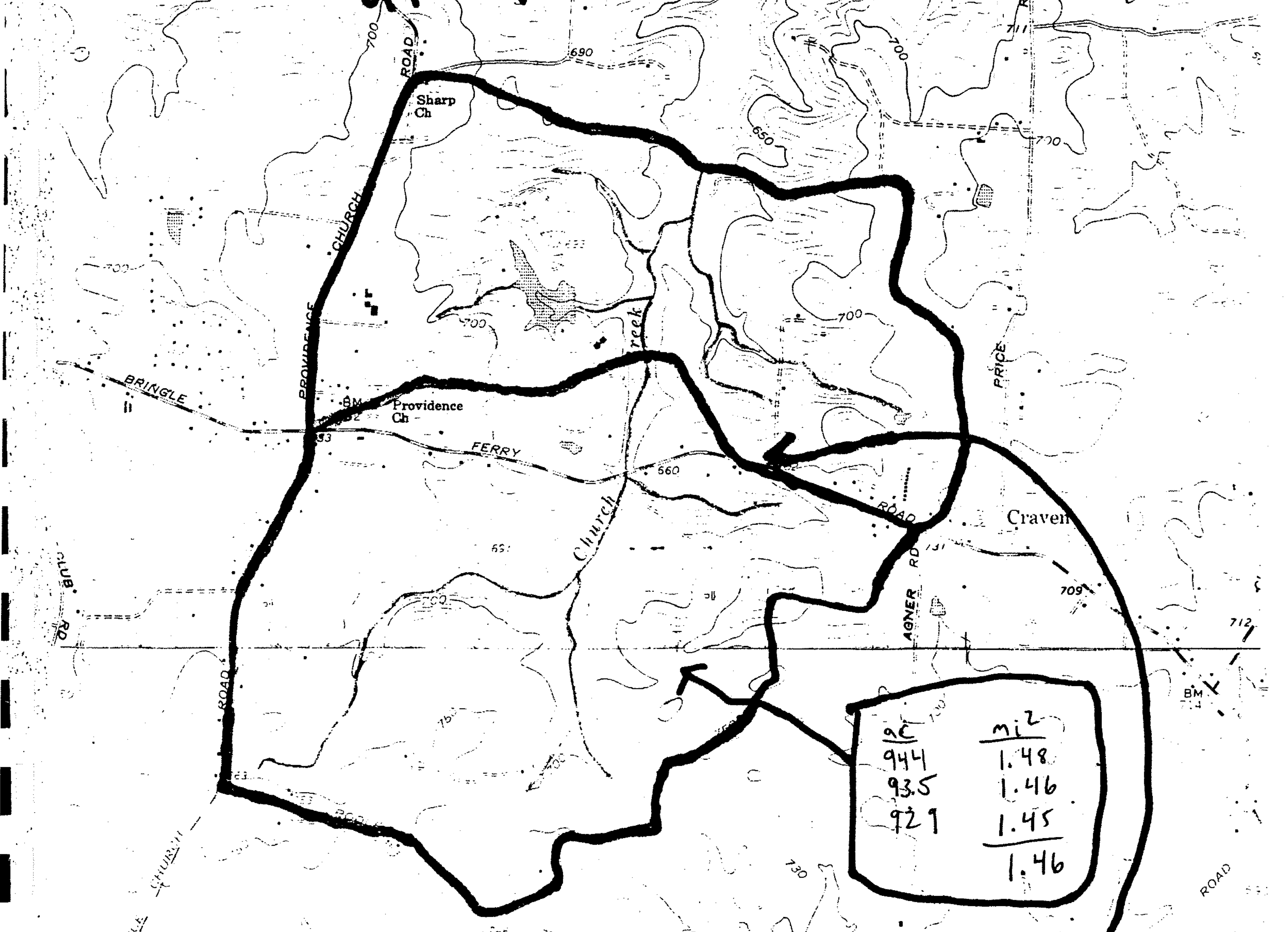
UT to CRANE CREEK
Reference Site
Rowan County, North Carolina

Dwn. by:	MAF
Ckd by:	WGL
Date:	DEC 2002
Project:	02-113.04

APPENDIX B

Figure 2B

DAN NICHOLAS PARK – Helms Reference
Regional Curve Data
UT to Crane Creek



DA	A	W	D	Q
1.5	28.2 ft²	16.0 ft	1.8 ft	119 cfs
2.5	39.8 ft²	19.5 ft	2.0 ft	173 cfs
1.46	27.7	15.8 ft	1.8	117 cfs

ac	mi²
1621	2.53
1624	2.54
1623	2.54
	2.5

HELMS: DAN NICHOLAS PARK (UT TO ...

REFERENCE DIMENSION

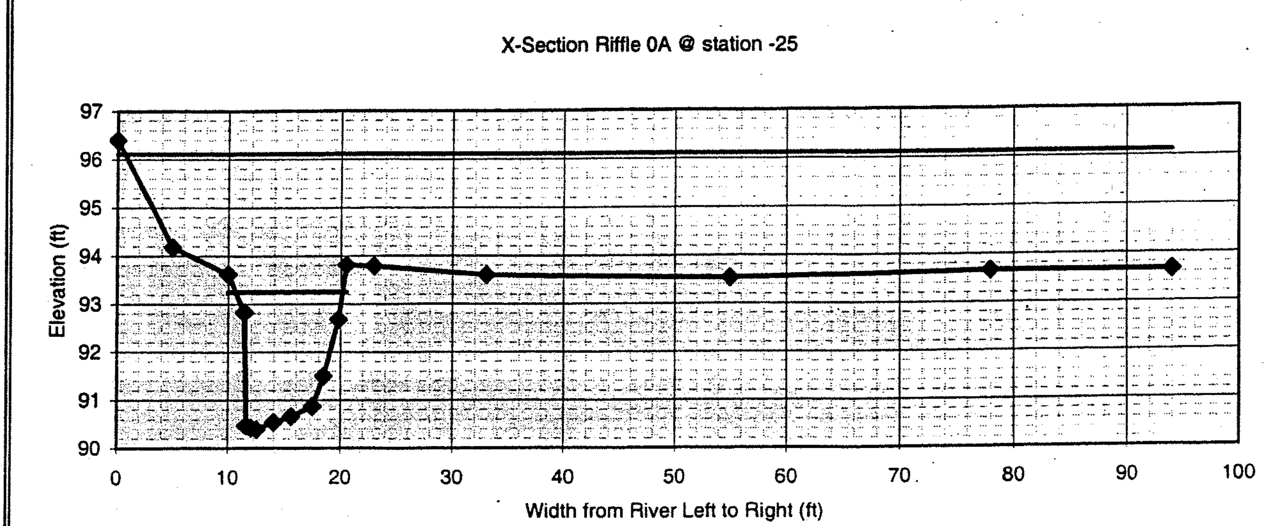
RIFFLES

X SECT #	A BKFL	W BKFL	DAVE	DMAX	W/D	FPA	ENT RATIO	LOW BANK HEIGHT	BANK HEIGHT RATIO	DMAX/DAVE	STREAM TYPE
A	19.8	9.5	2.1	2.9	4.5	237	25.0	3.2	1.1	1.4	E
B	25.0	11.9	2.1	2.6	5.7	237	20.0	3.1	1.2	1.2	E
3	20.5	10.1	2.0	2.5	5.1	232	23.0	2.9	1.2	1.3	E
7	19.3	10.0	1.9	2.5	5.3	345	34.5	3.1	1.2	1.3	E
E	21.2	10.4	2.0	2.6	5.2	263	25.6	3.1	1.2	1.3	
DIAN	20.5	10.1	2.0	2.6	5.1	237	25.0	3.1	1.2	1.3	E
E	19.3-25.0	9.5-11.9	1.9-2.1	2.5-2.9	4.5-5.7	232-345	20.0-34.5	2.9-3.2	1.1-1.2	1.2-1.4	

POOLS

X-SECT #	A BKFL	W BKFL	DAVE	DMAX	LBH	BHR	DMAX/DAVE	LPOOL
3	20.6	11.7	1.8	2.8	3.3	1.2	1.6	
8	19.5	10.5	1.9	3.0	4.0	1.3	1.6	
AVE	20.1	11.1	1.9	2.9	3.7	1.3	1.6	
DIAN	19.5	11.7	1.9	3.0	4.0	1.7	1.6	

Cross Section



section: **X-Section Riffle 0A**

Riffle

---

description:

height of instrument (ft): 99.76

notes	omit pt.	distance (ft)	FS (ft)	elevation
FP extends	☑	0	3.36	96.4
	☑	5	5.58	94.18
TOB	☐	10	6.14	93.62
	☐	11.4	6.93	92.83
	☐	11.6	9.29	90.47
	☐	12	9.33	90.43
thalweg	☐	12.5	9.37	90.39
	☐	14	9.22	90.54
water eleva	☐	15.6	9.1	90.66
	☐	17.5	8.89	90.87
	☐	18.5	8.26	91.5
	☐	19.8	7.08	92.68
TOB	☐	20.5	5.95	93.81
	☑	23	5.98	93.78
	☑	33	6.16	93.6
	☑	55	6.23	93.53
	☑	78	6.1	93.66
	☑	94	6.1	93.66
up steepist	☐			
	☐			
stk: 3.95	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

☐

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.51	6.14	16.0		
93.25	93.62			

dimensions

19.8	x-section area	2.1	d mean
9.5	width	12.8	wet P
2.9	d max	1.6	hyd radi
3.2	bank ht	4.5	w/d ratio
~~16.0~~ 237	W flood prone area	~~1.7~~ 25	ent ratio

hydraulics

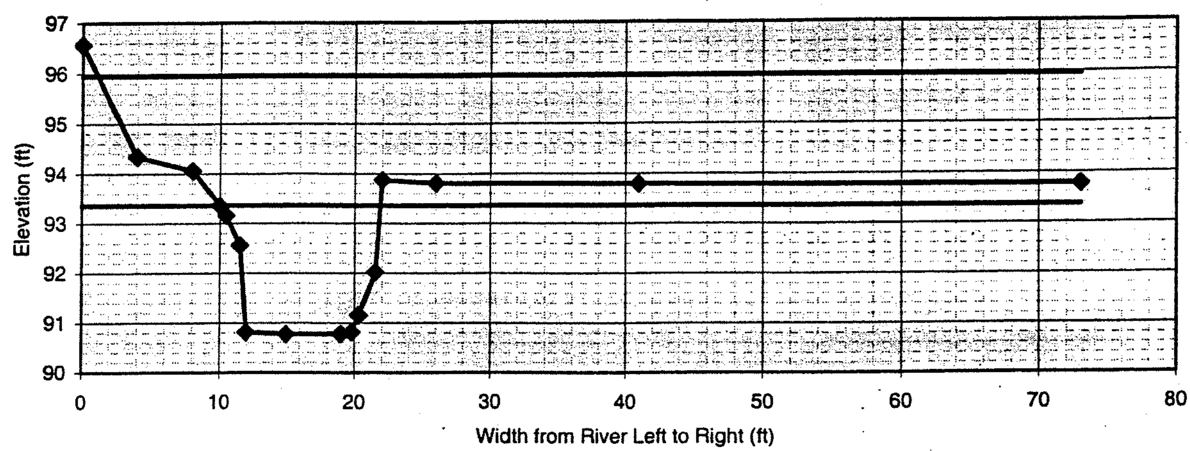
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material

0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section

X-Section Riffle 0B @ station 8



section:	X-Section Riffle 0B
	Riffle

	---
description:	
height of instrument (ft):	99.77

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	☐	0	3.2	96.57
	☐	4	5.43	94.34
	☐	8	5.71	94.06
bankfull	☐	10	6.41	93.36
	☐	10.5	6.61	93.16
	☐	11.5	7.21	92.56
	☐	12	8.95	90.82
	☐	15	9	90.77
water depth	☐	19	8.99	90.78
water edge	☐	19.8	8.95	90.82
	☐	20.3	8.62	91.15
	☐	21.5	7.75	92.02
TOB	☐	22	5.9	93.87
	☐	26	5.96	93.81
	☐	41	5.98	93.79
	☐	73	6	93.77
	☐			
stk: 3.94	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

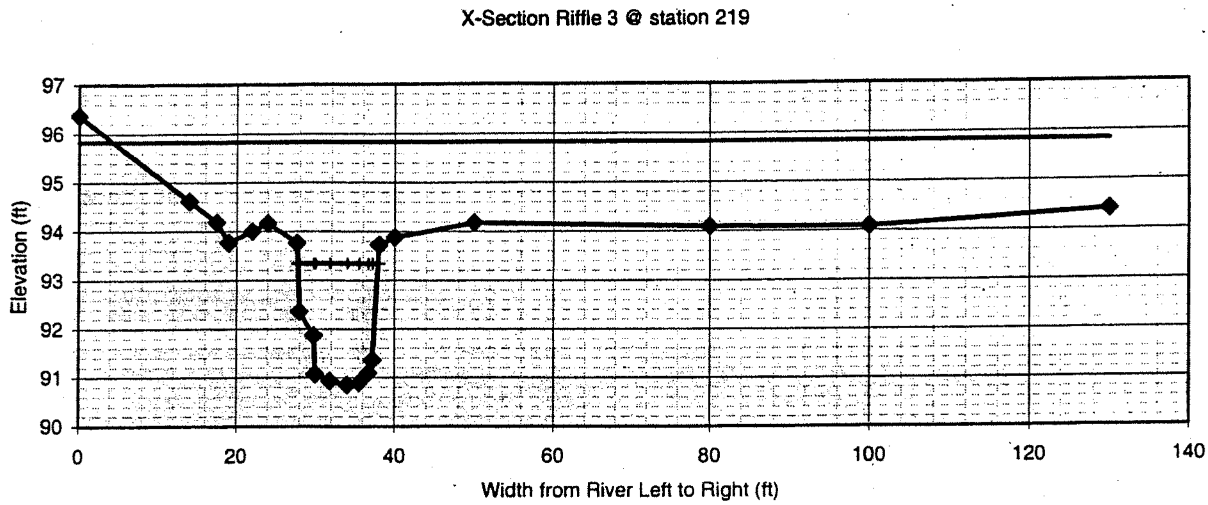
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.41	5.9			
93.36	93.87			

dimensions			
25.0	x-section area	2.1	d mean
11.9	width	14.8	wet P
2.6	d max	1.7	hyd radi
3.1	bank ht	5.6	w/d ratio
~~0.0~~ 237	W flood prone area	~~0.0~~ 20.0	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	X-Section Riffle 3
	Riffle --- ---
description:	
height of instrument (ft):	100.14

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	☑	0	3.77	96.37
	☑	14	5.52	94.62
	☑	17.5	5.95	94.19
	☑	19	6.37	93.77
	☑	22	6.14	94
	☑	24	5.97	94.17
TOB	☐	27.7	6.38	93.76
MB	☐	28	7.78	92.36
MB	☐	29.8	8.27	91.87
	☐	30	9.07	91.07
EOW	☐	31.8	9.21	90.93
thawleg	☐	34	9.29	90.85
	☐	35.5	9.25	90.89
	☐	36.7	9.05	91.09
MB	☐	37.2	8.78	91.36
TOB	☐	38	6.42	93.72
	☑	40	6.26	93.88
	☑	50	5.96	94.18
	☑	80	6.04	94.1
	☑	100	6.05	94.09
	☑	130	5.73	94.41
FP extend:	☐			
	☐			
stk: 4.30	☐			
	☐			
	☐			
	☐			
	☐			

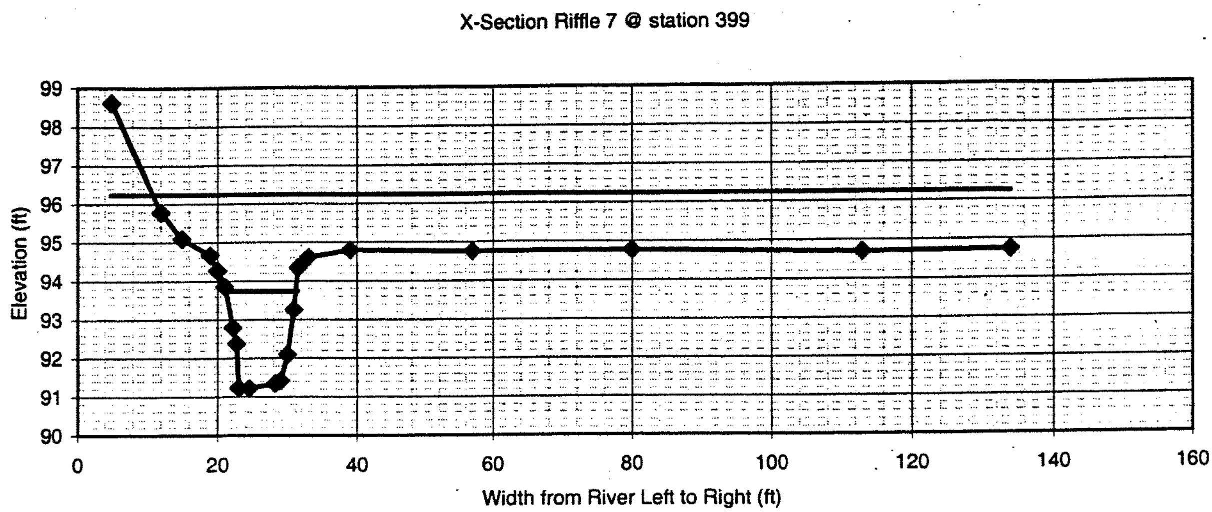
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.8	6.42	150.0		0.034
93.34	93.72			

dimensions			
20.5	x-section area	2.0	d mean
10.1	width	13.1	wet P
2.5	d max	1.6	hyd radi
2.9	bank ht	5.0	w/d ratio
~~150.0~~ 232.0	W flood prone area	~~14.9~~ 23.0	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: **X-Section Riffle 7**

Riffle

---

description:

height of instrument (ft): **100.76**

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	☑	5	2.14	98.62
	☑	12	4.98	95.78
	☑	15	5.66	95.1
	☑	19	6.09	94.67
	☑	20	6.49	94.27
	☐	21	6.91	93.85
	☐	22.2	7.97	92.79
	☐	22.7	8.38	92.38
EOW: depl	☐	23	9.53	91.23
	☐	24.5	9.54	91.22
EOW	☐	28.2	9.42	91.34
	☐	29	9.34	91.42
MB	☐	30	8.67	92.09
MB	☐	30.9	7.51	93.25
TOB	☐	31.5	6.42	94.34
	☑	33	6.15	94.61
	☑	39	5.96	94.8
	☑	57	6	94.76
	☑	80	5.99	94.77
	☑	113	6.06	94.7
	☑	134	6.02	94.74
	☐			
stk: 3.99	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.03	6.42	18.5		
93.73	94.34			

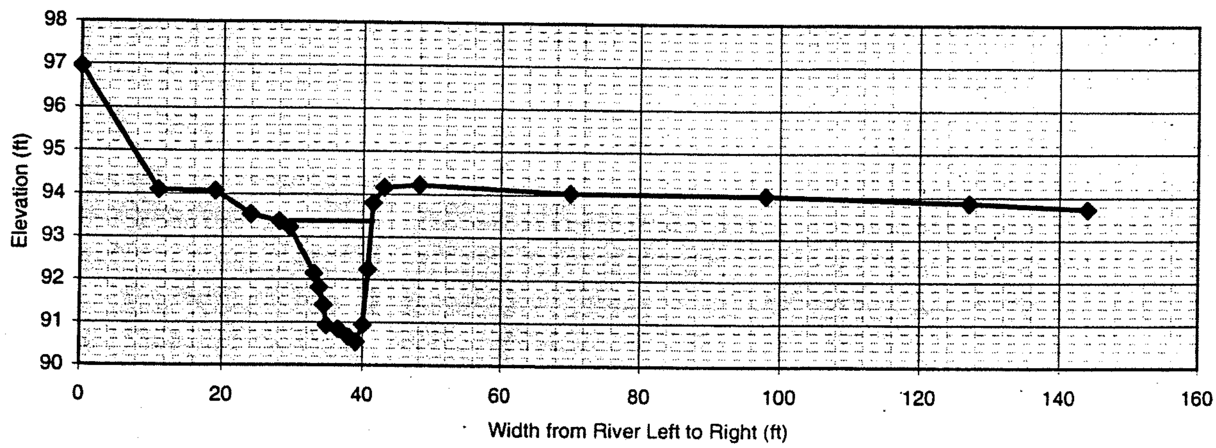
dimensions			
19.3	x-section area	1.9	d mean
10.0	width	12.5	wet P
2.5	d max	1.5	hyd radi
3.1	bank ht	5.2	w/d ratio
~~18.5~~ 345.0	W flood prone area	~~1.8~~	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section

X-Section Pool 3 @ station 162.5



section:	Pool --- ---
description:	
height of instrument (ft):	100.17

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	☑	0	3.22	96.95
	☑	11	6.08	94.09
	☑	19	6.1	94.07
	☑	24	6.64	93.53
	☑	28	6.8	93.37
	☐	29.5	6.95	93.22
	☐	33	8.03	92.14
	☐	33.7	8.35	91.82
	☐	34.4	8.77	91.4
EOW	☐	34.8	9.24	90.93
	☐	36.5	9.33	90.84
	☐	38	9.51	90.66
thalweg	☐	39	9.63	90.54
EOW	☐	40	9.23	90.94
	☐	40.7	7.93	92.24
TOB	☐	41.4	6.37	93.8
	☑	43	6.01	94.16
	☑	48	5.95	94.22
	☑	70	6.13	94.04
	☑	98	6.16	94.01
	☑	127	6.31	93.86
	☑	144	6.44	93.73
	☐			
stk: 5.99	☐			

☐

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.8	6.37			
93.37	93.8			

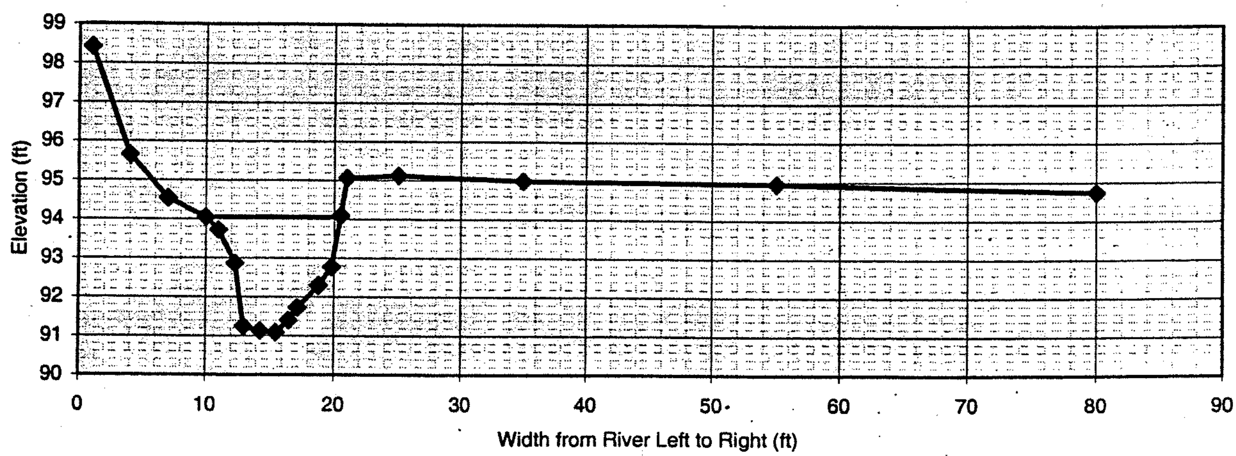
dimensions			
20.6	x-section area	1.8	d mean
11.7	width	13.9	wet P
2.8	d max	1.5	hyd radi
3.3	bank ht	~~6.7~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
~~12~~	measured D84 (mm)		
~~46.2~~	relative roughness	~~12.3~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section

X-Section Pool 8 @ station 445



section: Pool

---

description:

height of instrument (ft): 101.02

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	✓	1	2.61	98.41
	✓	4	5.37	95.65
	✓	7	6.48	94.54
	☐	10	6.97	94.05
	☐	11	7.3	93.72
	☐	12.3	8.16	92.86
EOW: dept	☐	13	9.77	91.25
	☐	14.3	9.89	91.13
	☐	15.5	9.93	91.09
EOW	☐	16.5	9.62	91.4
	☐	17.2	9.29	91.73
	☐	18.8	8.72	92.3
MB	☐	19.8	8.25	92.77
MB	☐	20.5	6.93	94.09
TOB	✓	21	5.95	95.07
	✓	25	5.9	95.12
	✓	35	6.03	94.99
	✓	55	6.08	94.94
	✓	80	6.28	94.74
	☐			
stk: 3.78	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.97	5.95			
94.05	95.07			

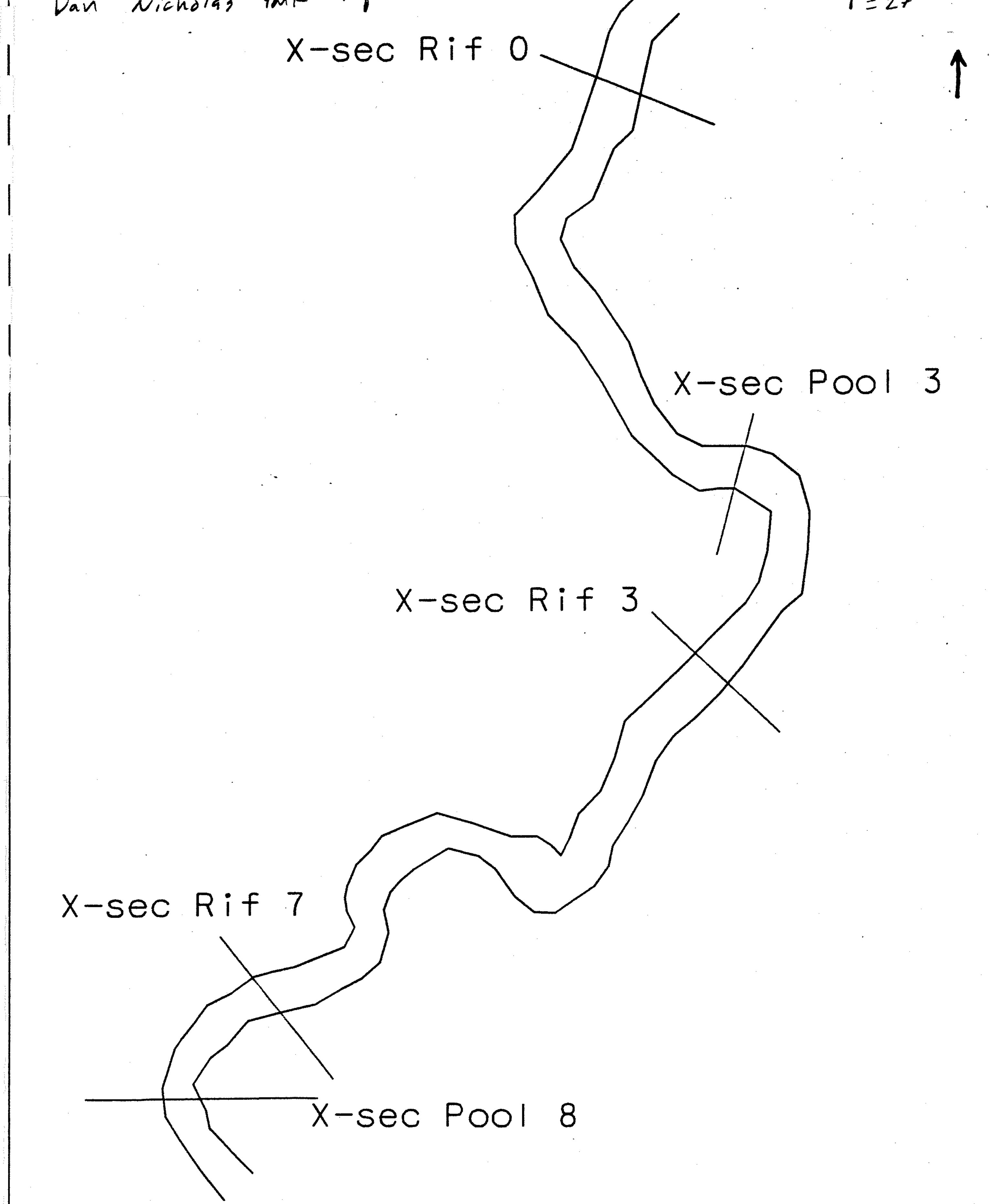
dimensions

19.5	x-section area	1.9	d mean
10.5	width	12.9	wet P
3.0	d max	1.5	hyd radi
4.0	bank ht	~~5.6~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics

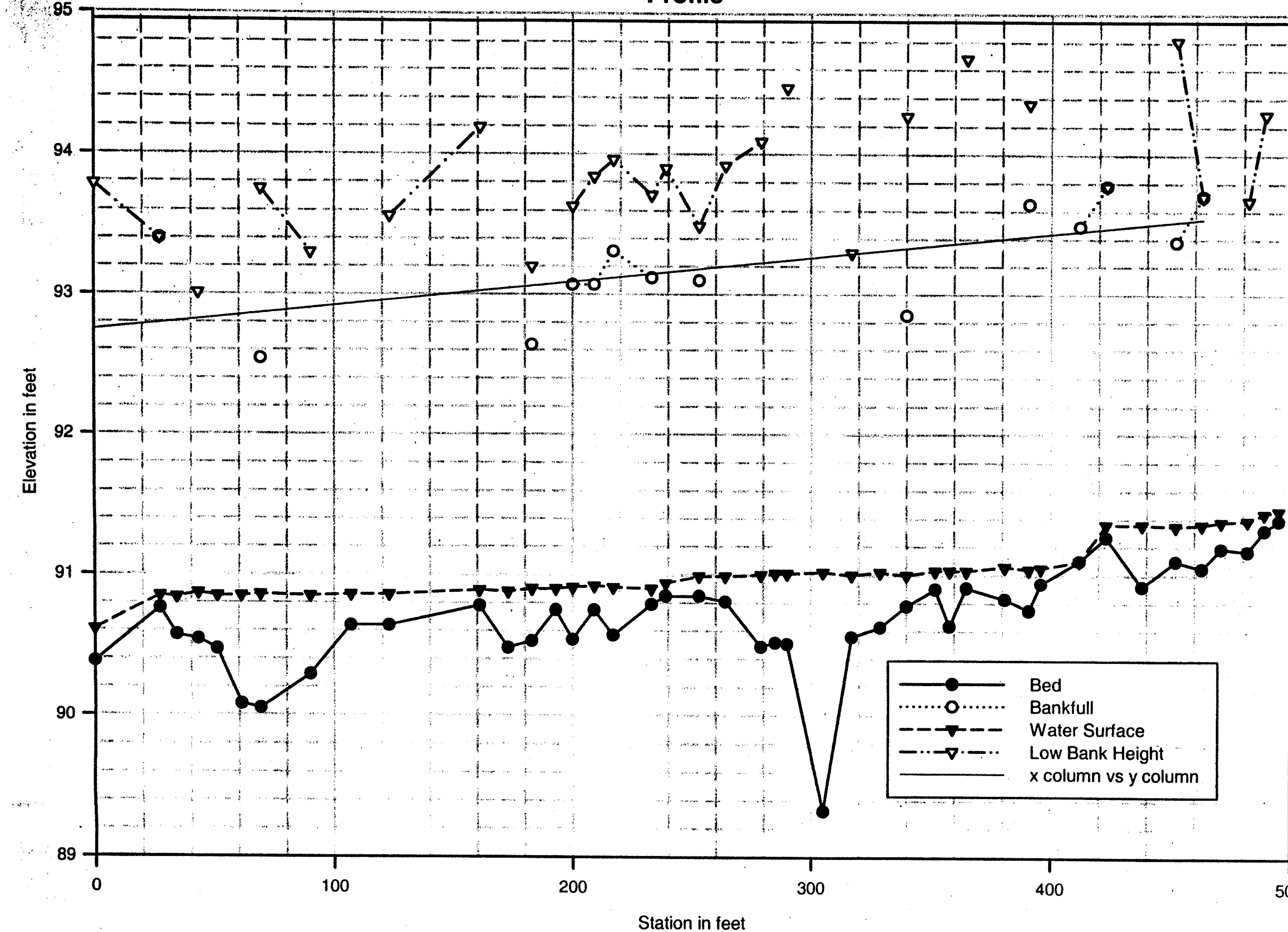
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material



\gps\reference\danref.dgn Sep 10 2002 14:45:56

Dan Nichoias Park Reference Stream Profile



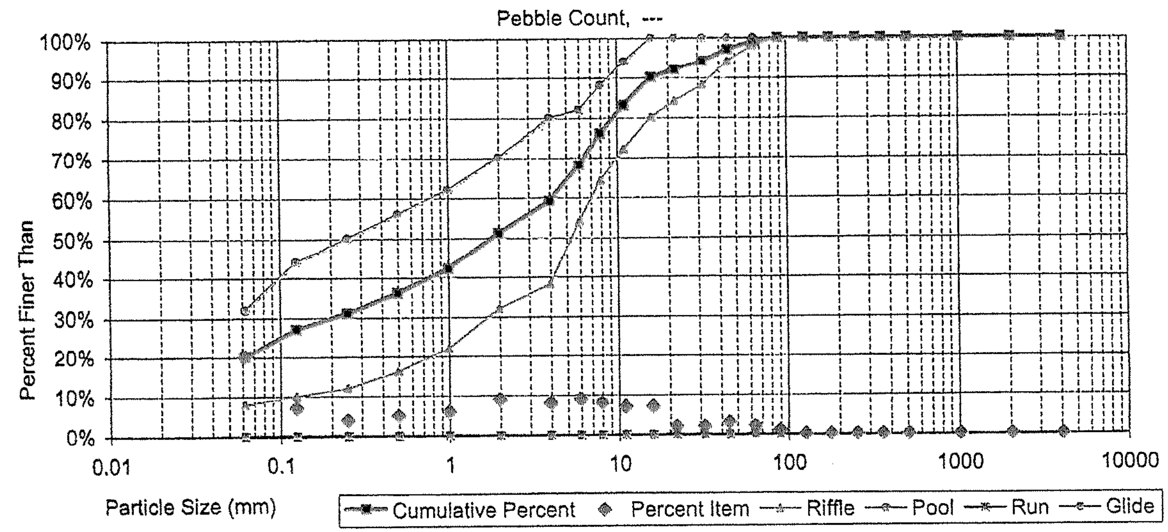
Weighted Pebble Count

Percent Riffle:	50	Percent Run:	0
Percent Pool:	50	Percent Glide:	0

Pebble Count,

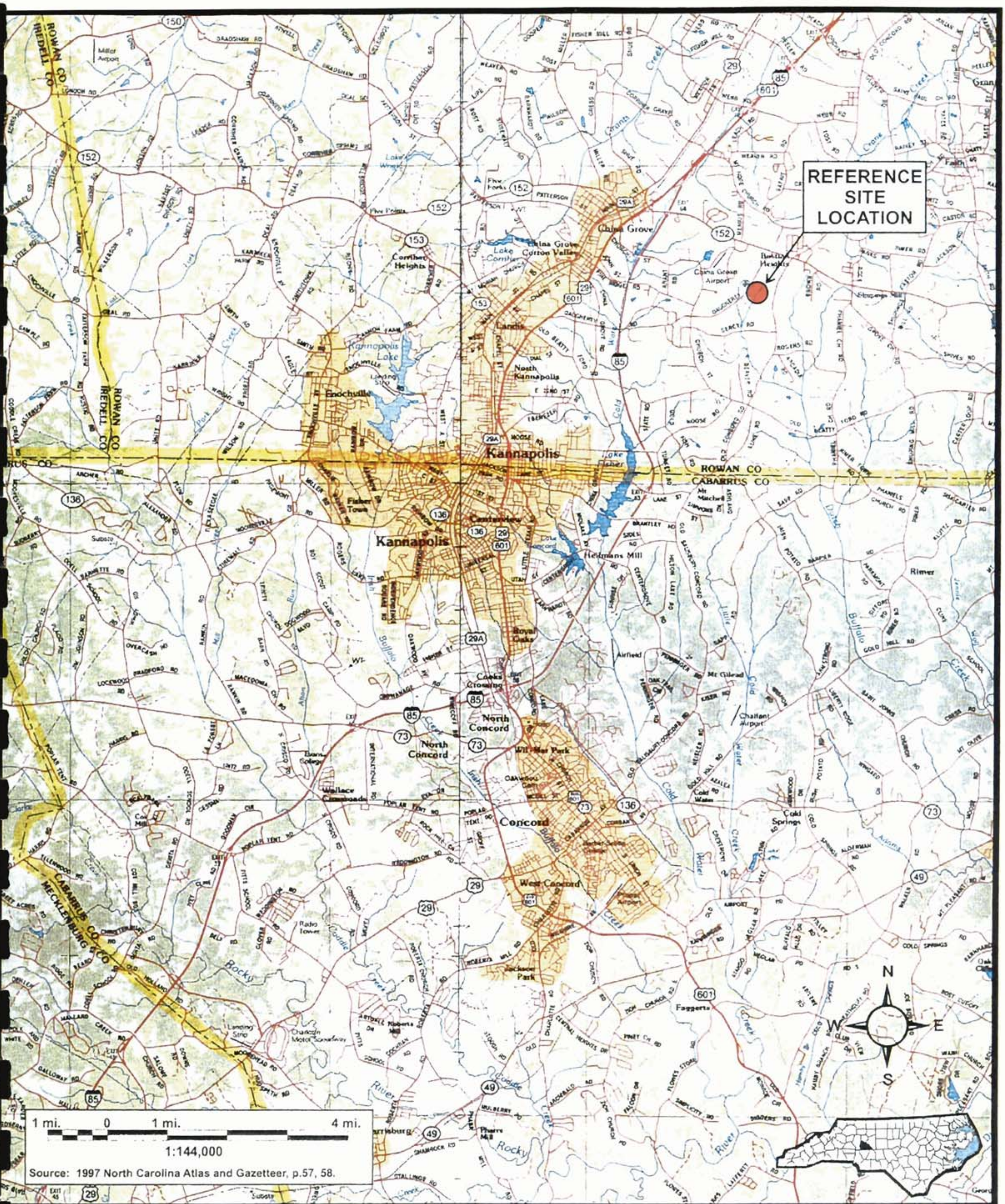
Note: **Dan Nicholas Weighted**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	20.0	# #
very fine sand	0.062	0.13	7.0	# #
fine sand	0.13	0.25	4.0	# #
medium sand	0.25	0.5	5.0	# #
coarse sand	0.5	1	6.0	# #
very coarse sand	1	2	9.0	# #
very fine gravel	2	4	8.0	# #
fine gravel	4	6	9.0	# #
fine gravel	6	8	8.0	# #
medium gravel	8	11	7.0	# #
medium gravel	11	16	7.0	# #
coarse gravel	16	22	2.0	# #
coarse gravel	22	32	2.0	# #
very coarse gravel	32	45	3.0	# #
very coarse gravel	45	64	2.0	# #
small cobble	64	90	1.0	# #
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	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.44	1.9	12	36

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
20%	31%	48%	1%	0%	0%



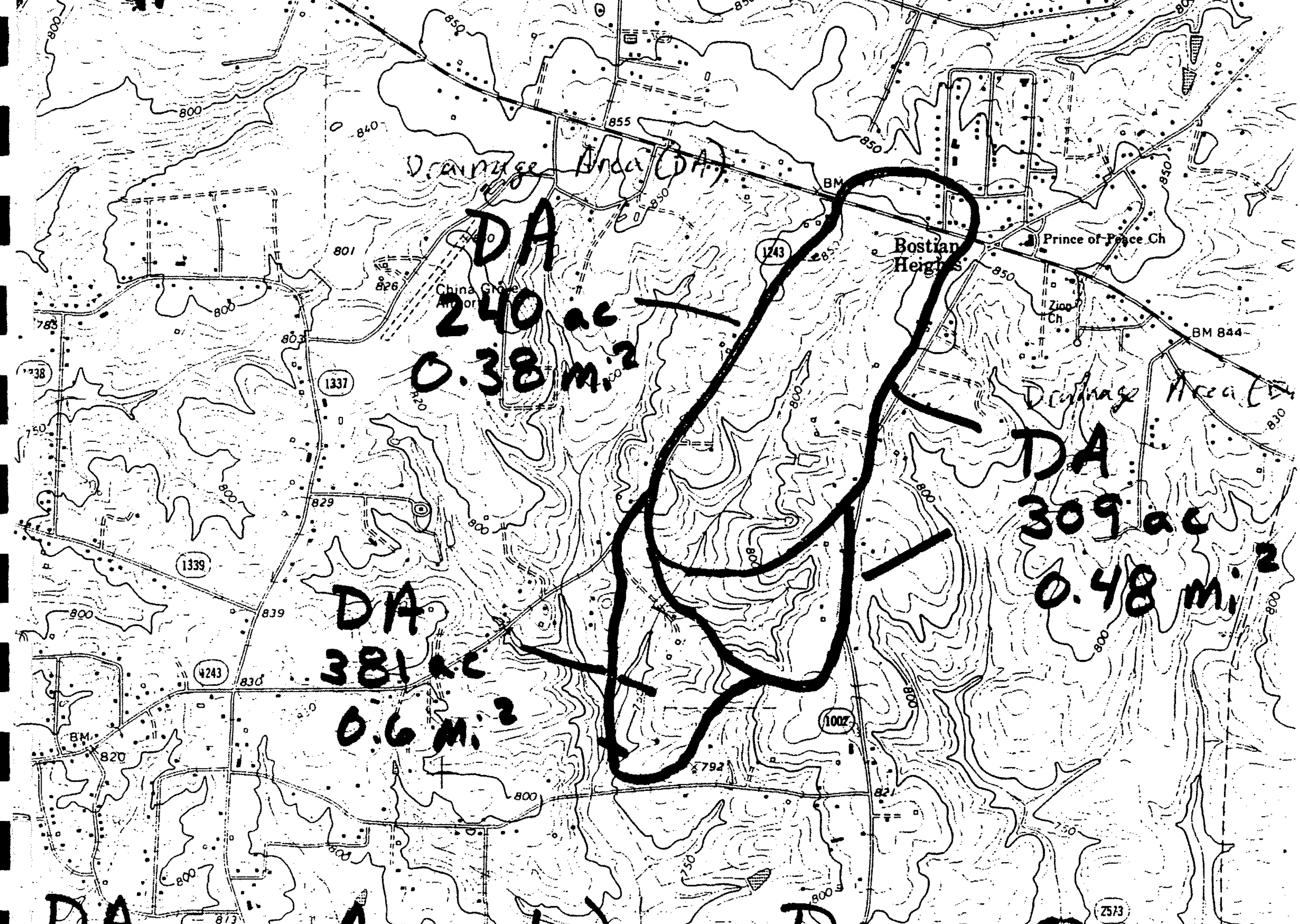
EcoScience Corporation
Raleigh, North Carolina

UT to DUTCH BUFFALO CREEK
Reference Site
Rowan County, North Carolina

Dwn. by: MAF		APPENDIX B
Ckd by: WGL		Figure
Date: DEC 2002		2C
Project: 02-113.04		

Helms

[illegible] Rural Curve Data



DA	A	W	D	Q
0.38	11.1 ft²	9.4 ft	1.2 ft	44 cfs
0.48	13.0 ft²	10.2 ft	1.3 ft	52 cfs
0.6	15.2 ft²	11.2 ft	1.4 ft	62 cfs

Reference Dimension

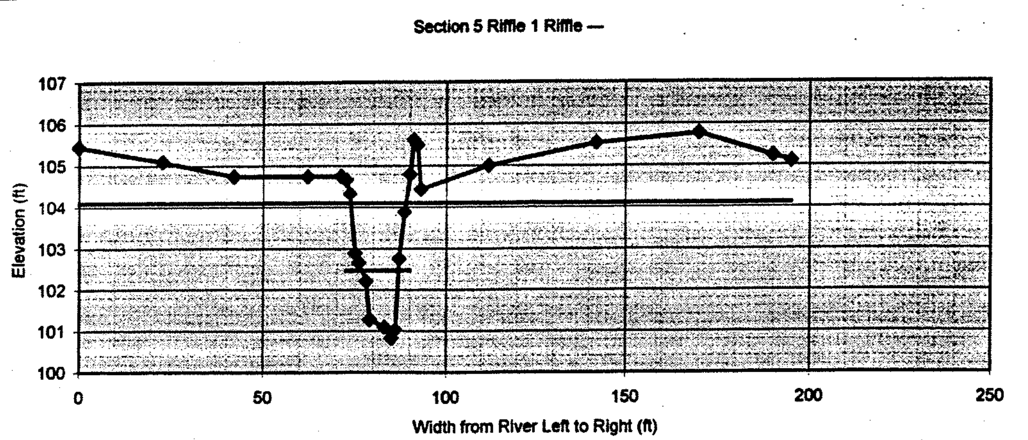
Riffles

X-Sect #	A BKFL	W BKFL	Dave	Dmax	W/D	FPA	Ent Ratio	Low Bank Height	Bank Height Ratio	Dmax/Dave	Stream Type
1	11.7	11.5	1.0	1.4	11.4	16.0	1.4	3.2	2.3	1.4	G ~~B~~
3	10.2	9.7	1.1	1.4	9.1	17.5	1.8	3.3	2.4	1.3	~~B~~ G
5	11.1	10.0	1.1	1.6	9.0	18.5	~~1.9~~ 1.9	3.8	2.4	1.5	~~B~~ G
…e	11.0	10.4	1.1	1.5	9.8	17.3	1.7	3.4	2.4	1.4	
…ian	11.1	10.0	1.1	1.4	9.1	17.5	1.8	3.3	2.4	1.4	G
…ange	10.2-11.7	9.7-11.5	1.0-1.1	1.4-1.6	9.0-11.4	16.0-18.5	1.4-1.9	3.2-3.8	2.3-2.4	1.3-1.5	

Pools

X-Sect #	A BKFL	W BKFL	Dave	Dmax	~~W/D~~	~~FPA~~	~~Ent Ratio~~	Low Bank Height	Bank Height Ratio	Dmax/Dave	L pool
2	10.9	8.8	1.2	2.0				3.3	1.7	1.7	12
4	12.0	12.4	1.0	2.2				3.9	1.8	2.2	15
…e	11.5	10.6	1.1	2.1				3.6	1.8	2.0	13.5

Cross Section



section:	Section 5 Riffle 1
	Riffle — —
description:	
height of instrument (ft):	110.07

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	4.61	105.46
	☑	23	4.97	105.1
	☑	42	5.32	104.75
	☑	62	5.33	104.74
	☑	71	5.32	104.75
TOB	☐	72.5	5.4	104.67
	☐	73.5	5.74	104.33
	☐	75	7.18	102.89
	☐	76	7.41	102.66
	☐	78	7.86	102.21
	☐	79	8.79	101.28
	☐	83	8.97	101.1
thalweg	☐	85	9.24	100.83
	☐	86	9.04	101.03
	☐	87	7.32	102.75
	☐	88.5	6.19	103.88
TOB	☐	90	5.27	104.8
levee	☑	91	4.45	105.62
levee	☑	92	4.57	105.5
FP	☑	93	5.64	104.43
	☑	112	5.07	105
	☑	142	4.53	105.54
	☑	170	4.3	105.77
	☑	190	4.84	105.23
	☑	195	4.97	105.1
FP edge u|	☑			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

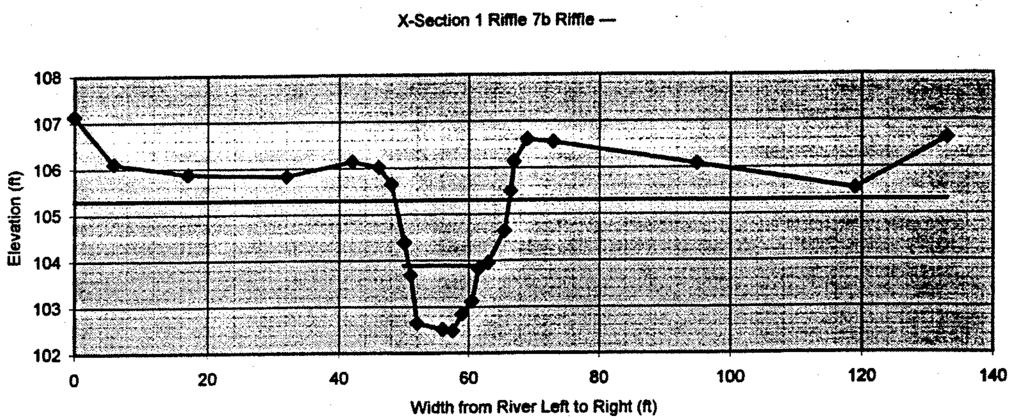
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.6	5.4	18.5		
102.47	104.67			

dimensions			
11.1	x-section area	1.1	d mean
10.0	width	11.3	wet P
1.6	d max	1.0	hyd radi
3.8	bank ht	9.0	w/d ratio
18.5	W flood prone area	1.9	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	X-Section 1 Riffle 7b
	Riffle — —
description:	
height of instrument (ft):	111.49

notes	omit pt.	distance (ft)	FS (ft)	elevation
up steep	☑	0	4.35	107.14
	☑	6	5.38	106.11
	☑	17	5.62	105.87
	☑	32	5.66	105.83
	☑	42	5.35	106.14
	☑	46	5.47	106.02
TOB	☑	48	5.84	105.65
MB	☐	50	7.1	104.39
MB	☐	51	7.8	103.69
	☐	52	8.84	102.65
	☐	56	8.97	102.52
thalweg	☐	57.5	9.01	102.48
	☐	59	8.64	102.85
	☐	60.5	8.37	103.12
	☐	61.5	7.66	103.83
	☐	63	7.54	103.95
	☑	65.5	6.85	104.64
MB	☑	66.5	5.99	105.5
	☑	67	5.36	106.13
TOB	☑	69	4.88	106.61
	☑	73	4.93	106.56
	☑	95	5.41	106.08
	☑	119	5.95	105.54
FP up shal	☑	133	4.87	106.62

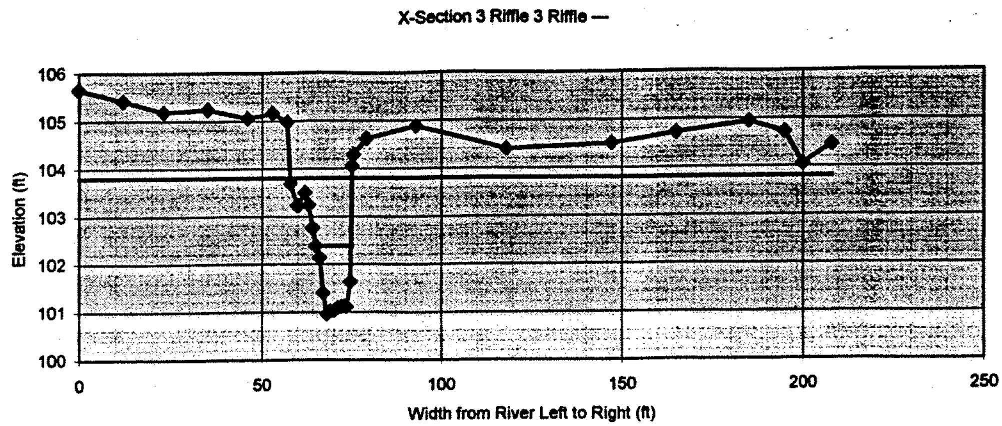
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.6	5.84	16.0		
103.89	105.65			

dimensions			
11.7	x-section area	1.0	d mean
11.5	width	12.3	wet P
1.4	d max	0.9	hyd radi
3.2	bank ht	11.4	w/d ratio
16.0	W flood prone area	1.4	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	X-Section 3 Riffle 3
	Riffle — —
description:	
height of instrument (ft):	110.38

notes	omit pt.	distance (ft)	FS (ft)	elevation
FP+60	☑	0	4.72	105.66
	☑	12	4.97	105.41
	☑	23	5.19	105.19
	☑	35	5.14	105.24
	☑	46	5.32	105.06
	☑	53	5.21	105.17
	☑	57	5.4	104.98
	☑	58	6.69	103.69
	☑	60	7.15	103.23
	☑	62	6.88	103.5
	☑	63	7.13	103.25
	☑	64	7.62	102.76
	☐	65	8	102.38
	☐	66	8.25	102.13
	☐	67	8.98	101.4
thalweg	☐	68	9.42	100.96
Bed	☐	69	9.36	101.02
Bed	☐	70	9.35	101.03
Bed	☐	71	9.29	101.09
Bed	☐	72	9.27	101.11
Bed	☐	73	9.25	101.13
Bed	☐	73.5	9.27	101.11
MB	☐	74.5	8.75	101.63
	☐	75	6.33	104.05
TOB	☑	75.5	6.09	104.29
	☑	79	5.76	104.62
	☑	93	5.5	104.88
	☑	118	5.98	104.4
	☑	147	5.87	104.51
	☑	165	5.66	104.72
	☑	185	5.44	104.94
	☑	195	5.66	104.72
slough	☑	200	6.33	104.05
	☑	208	5.92	104.46
FP up stee	☐			
	☐			
	☐			
	☐			

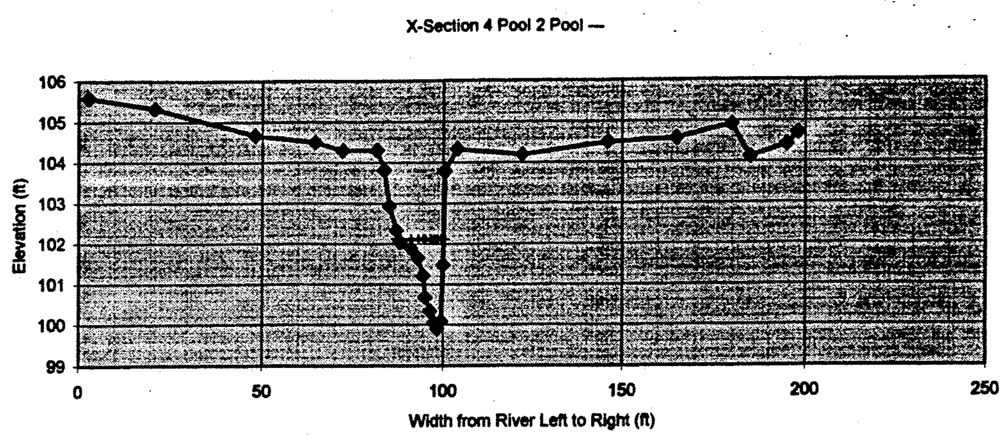
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8	6.09	17.5		
102.38	104.29			

dimensions			
10.2	x-section area	1.1	d mean
9.7	width	10.8	wet P
1.4	d max	1.0	hyd radi
3.3	bank ht	9.1	w/d ratio
17.5	W flood prone area	1.8	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	X-Section 4 Pool 2
	Pool — —
description:	
height of instrument (ft):	109.84

notes	omit pt?	distance (ft)	FS (ft)	elevation
up shallow	☑	3	4.26	105.58
	☑	21	4.52	105.32
	☑	48	5.17	104.67
	☑	64.5	5.35	104.49
	☑	72	5.54	104.3
TOB	☑	81.5	5.54	104.3
	☑	83.5	6.03	103.81
	☑	85	6.91	102.93
	☐	87	7.5	102.34
	☐	88	7.79	102.05
	☐	91	7.94	101.9
	☐	93	8.18	101.66
	☐	94.5	8.62	101.22
	☐	95	9.15	100.69
	☐	96.5	9.5	100.34
	☐	97.5	9.78	100.06
	☐	98.5	9.93	99.91
	☐	99.5	9.74	100.1
MB	☐	100	8.36	101.48
TOB	☐	100.5	6.04	103.8
	☑	104	5.51	104.33
	☑	122	5.65	104.19
	☑	146	5.35	104.49
	☑	165	5.26	104.58
	☑	180	4.93	104.91
slough	☑	185	5.72	104.12
	☑	195	5.43	104.41
	☑	198	5.15	104.69
FP edge u	☑			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

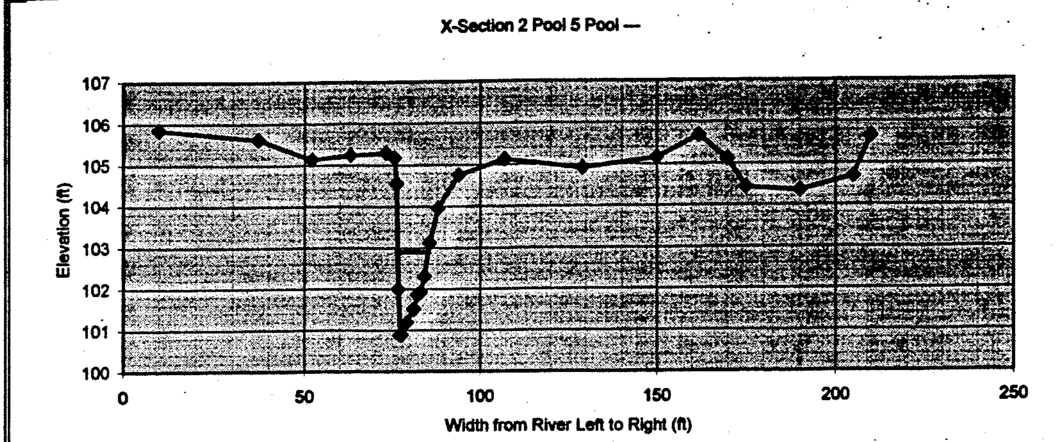
FS bankfull	FS top of bank	[illegible] (ft)	channel slope (%)	Manning's "n"
7.72	6.04	150.0		0.034
102.12	103.8			

dimensions			
12.0	x-section area	1.0	d mean
12.4	width	14.3	wet P
2.2	d max	0.8	hyd radi
3.9	bank ht	~~12.8~~	w/d ratio
~~150.0~~	W flood prone area	~~12.1~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
0	measured D84 (mm)		
~~0.0~~	relative roughness	~~0.0~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section



section:	X-Section 2 Pool 5
description:	Pool — —
height of instrument (ft):	110.76

notes	omit pt.	distance (ft)	FS (ft)	elevation
FP edge, u	☑	10	4.9	105.86
	☑	37	5.13	105.63
	☑	52	5.62	105.14
	☑	63	5.52	105.24
	☑	73	5.46	105.3
TOB	☑	75.5	5.58	105.18
	☐	76	6.21	104.55
MB	☐	76.5	8.76	102
	☐	77.2	9.87	100.89
thalweg	☐	77.5	9.87	100.89
	☐	79	9.57	101.19
	☐	81	9.25	101.51
	☐	82	8.9	101.86
	☐	83	8.84	101.92
	☐	84	8.46	102.3
	☐	85.5	7.64	103.12
	☑	88	6.8	103.96
	☑	94	6	104.76
	☑	107	5.63	105.13
	☑	129	5.84	104.92
	☑	150	5.6	105.16
	☑	162	5.08	105.68
	☑	170	5.64	105.12
depression	☑	175	6.32	104.44
depression	☑	190	6.41	104.35
thalweg	☑	205	6.07	104.69
	☑	210	5.11	105.65
FP edge, u	☑			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.86	6.53			
102.9	104.23			

dimensions

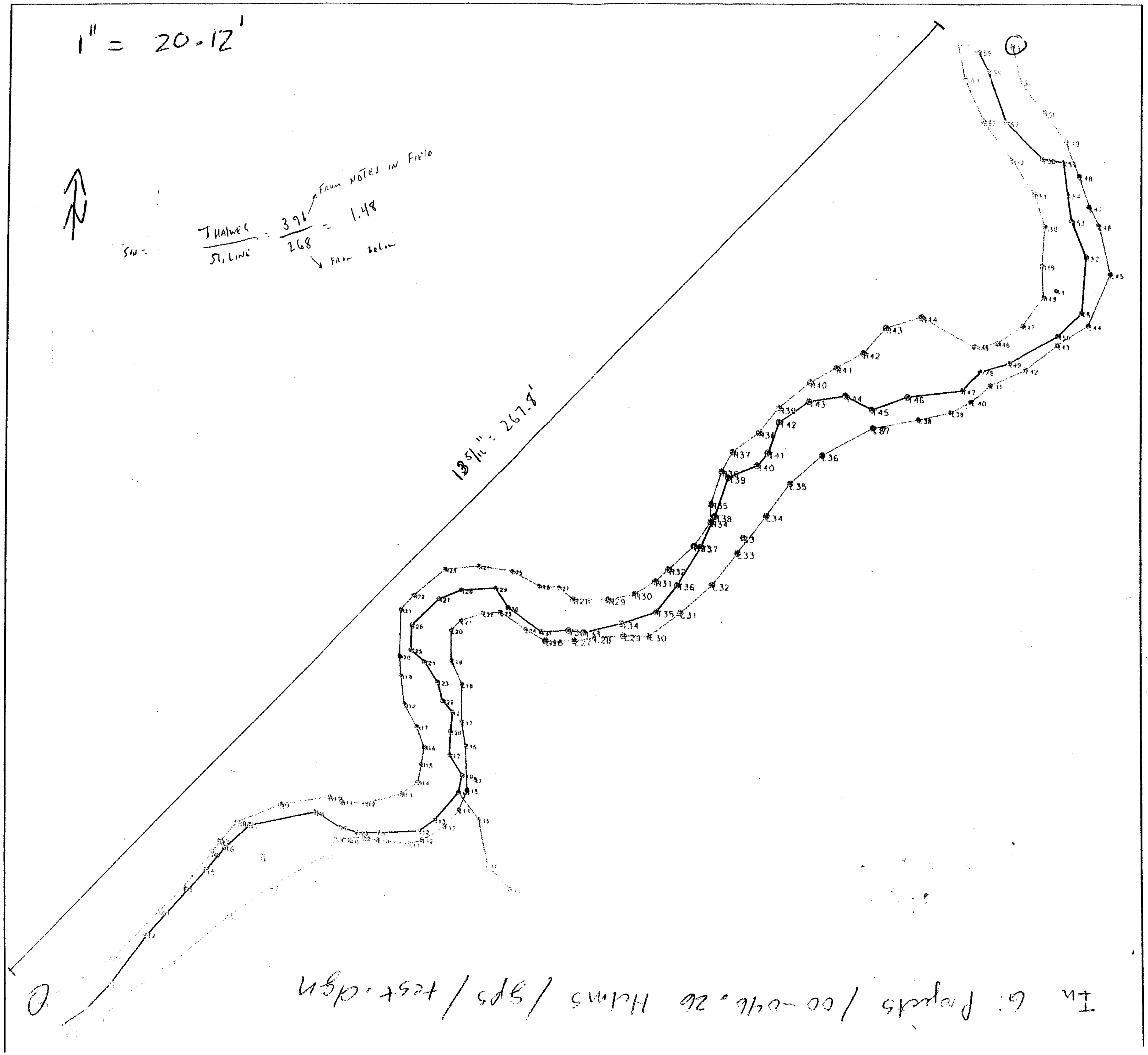
10.9	x-section area	1.2	d mean
8.8	width	10.5	wet P
2.0	d max	1.0	hyd radi
3.3	bank ht	7.0	w/d ratio
0.0	W flood prone area	0.0	ent ratio

hydraulics

0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

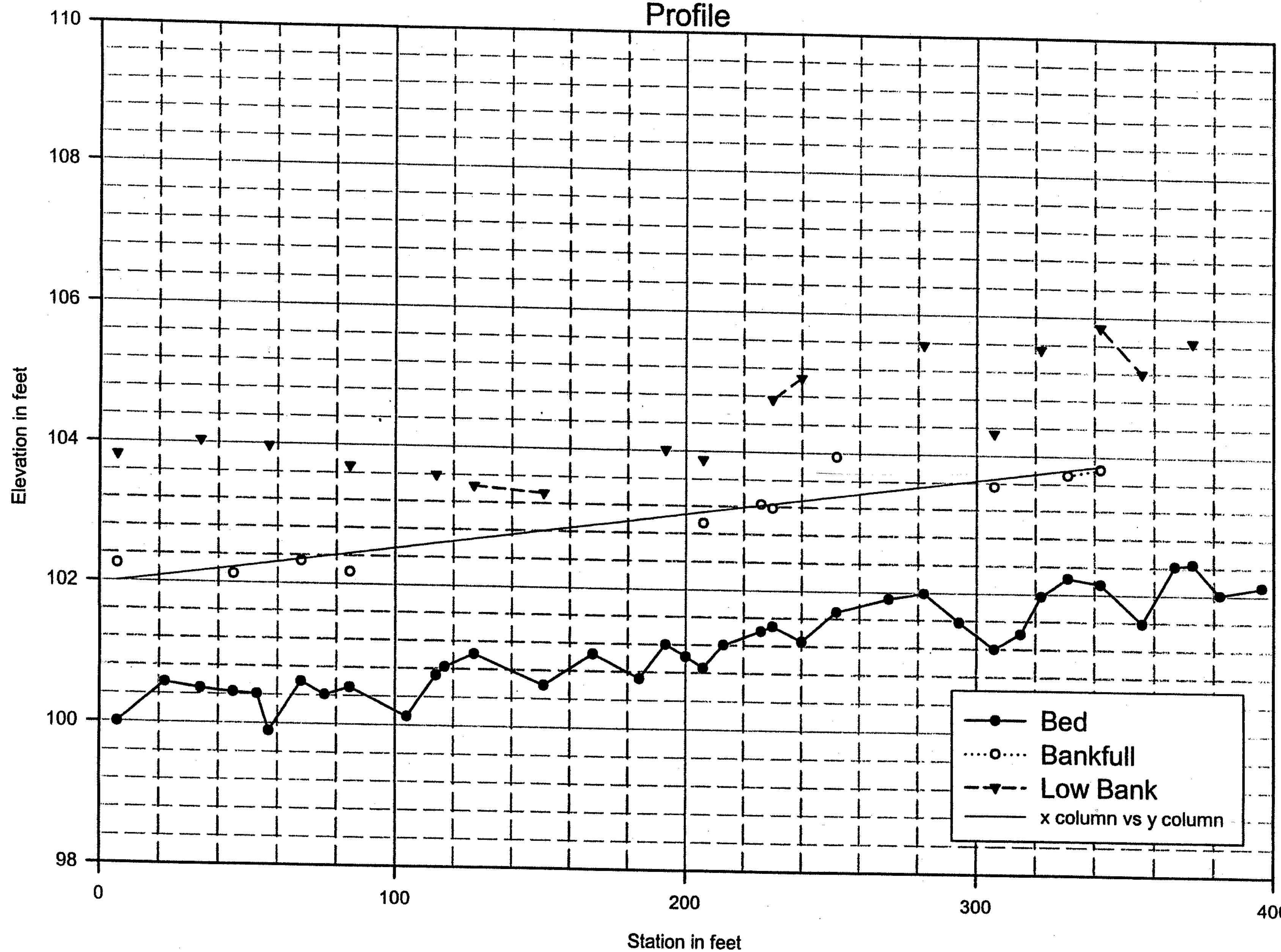
check from channel material

0	measured D84 (mm)		
0.0	relative roughness	0.0	fric. factor
0.000	Manning's n from channel material		



1" = 20.12'
N
SN = Thalweg / St. Line = 391 / 268 = 1.48
From notes in field
From below
13 5/16" = 267.8'
In G: Projects / 00-046.26 Harms / gps / test.dgn

UT to Dutch Buffalo Creek Reference Stream Profile



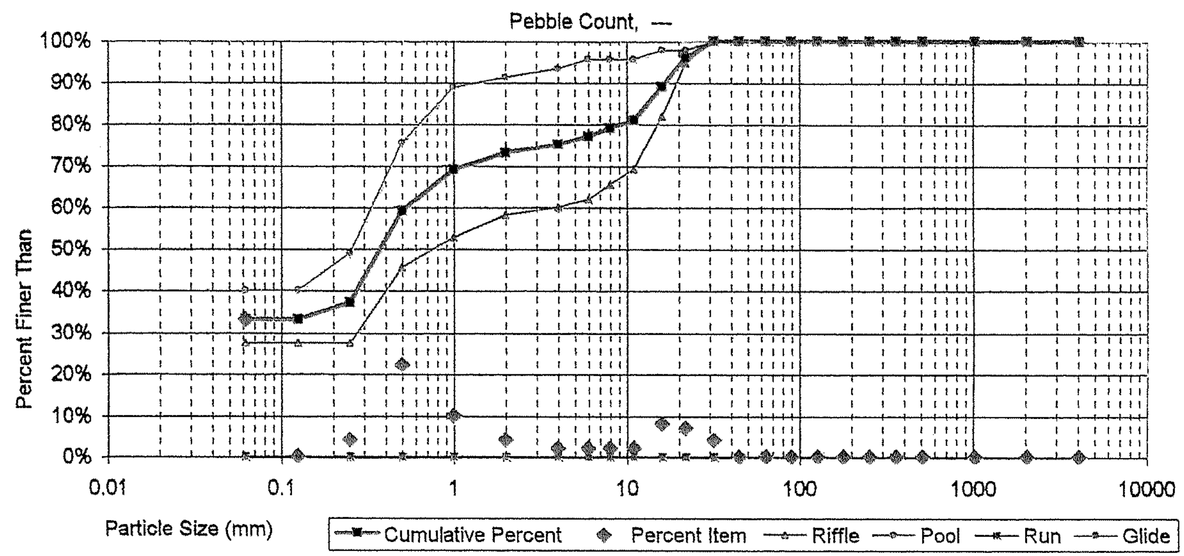
Weighted Pebble Count

Percent Riffle:	**55**
Percent Pool:	**45**
Percent Run:	**0**
Percent Glide:	**0**

Pebble Count,

Note: **Helms Upstream Weighted**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	33.0	# #
very fine sand	0.062	0.13	0.0	# #
fine sand	0.13	0.25	4.0	# #
medium sand	0.25	0.5	22.0	# #
coarse sand	0.5	1	10.0	# #
very coarse sand	1	2	4.0	# #
very fine gravel	2	4	2.0	# #
fine gravel	4	6	2.0	# #
fine gravel	6	8	2.0	# #
medium gravel	8	11	2.0	# #
medium gravel	11	16	8.0	# #
coarse gravel	16	22	7.0	# #
coarse gravel	22	32	4.0	# #
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	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.18	0.4	13	21

Percent by substrate type						
silt/clay	sand	gravel	cobble	boulder	bedrock	
33%	40%	27%	0%	0%	0%	

APPENDIX D
DRAINMOD SIMULATIONS

Groundwater Discharge Zone of Influence on Wetland Hydroperiod
Chewacla Soil

Floodplain Surface Elevation Above Channel Invert[2] (feet)	Groundwater Discharge Zone of Influence[1] (feet) (Surface Hydroperiods <5% of the growing season)	Number of Years Wetland Criteria Met	Groundwater Discharge Zone of Influence (feet) (Surface Hydroperiods < 12.5% of the growing season)*	Number of Years Wetland Criteria Met
Fallow Field/Pasture Conditions (relatively low surface water storage and rooting functions)				
0	-----	29/31	-----	29/31
1	10	14/31	45	15/31
2	50	15/31	90	15/31
4	100	15/31	140	14/31
6	145	15/31	185	15/31
8	170	15/31	220	15/31
Floodplain Elevation Above Channel Invert (feet)	Groundwater Discharge Zone of Influence[1] (feet) (Surface Hydroperiods <5% of the growing season)	Number of Years Wetland Criteria Met	Groundwater Discharge Zone of Influence (feet) (Surface Hydroperiods < 12.5% of the growing season)	Number of Years Wetland Criteria Met
Forested Conditions (relatively high surface water storage and rooting functions)				
0	-----	30/31	----	26/31
1	10	15/31	75	15/31
2	45	8/31	145	15/31
4	85	13/31	215	15/31
6	110	13/31	265	15/31
8	125	15/31	290	15/31

1: Discharge Zone of Influence is equal to ½ of the modeled drainage spacing

SOIL PROPERTIES

Name: WEHADKEE
Number of Horizons: 3
Root Zone Depth : 0.

dp	rf	ca	clay	silt	om	cs	mp	cp	dbmom	flag	Ksat
8.	1.4	.20	12.5	41.9	3.5	6.1	4	3	1.48	0	4.36
32.	.3	.20	27.5	52.5	1.2	4.3	3	2	1.40	0	.23
10.	.0	.20	.0	.0	.4	.0	2	2	.00	0	59.08

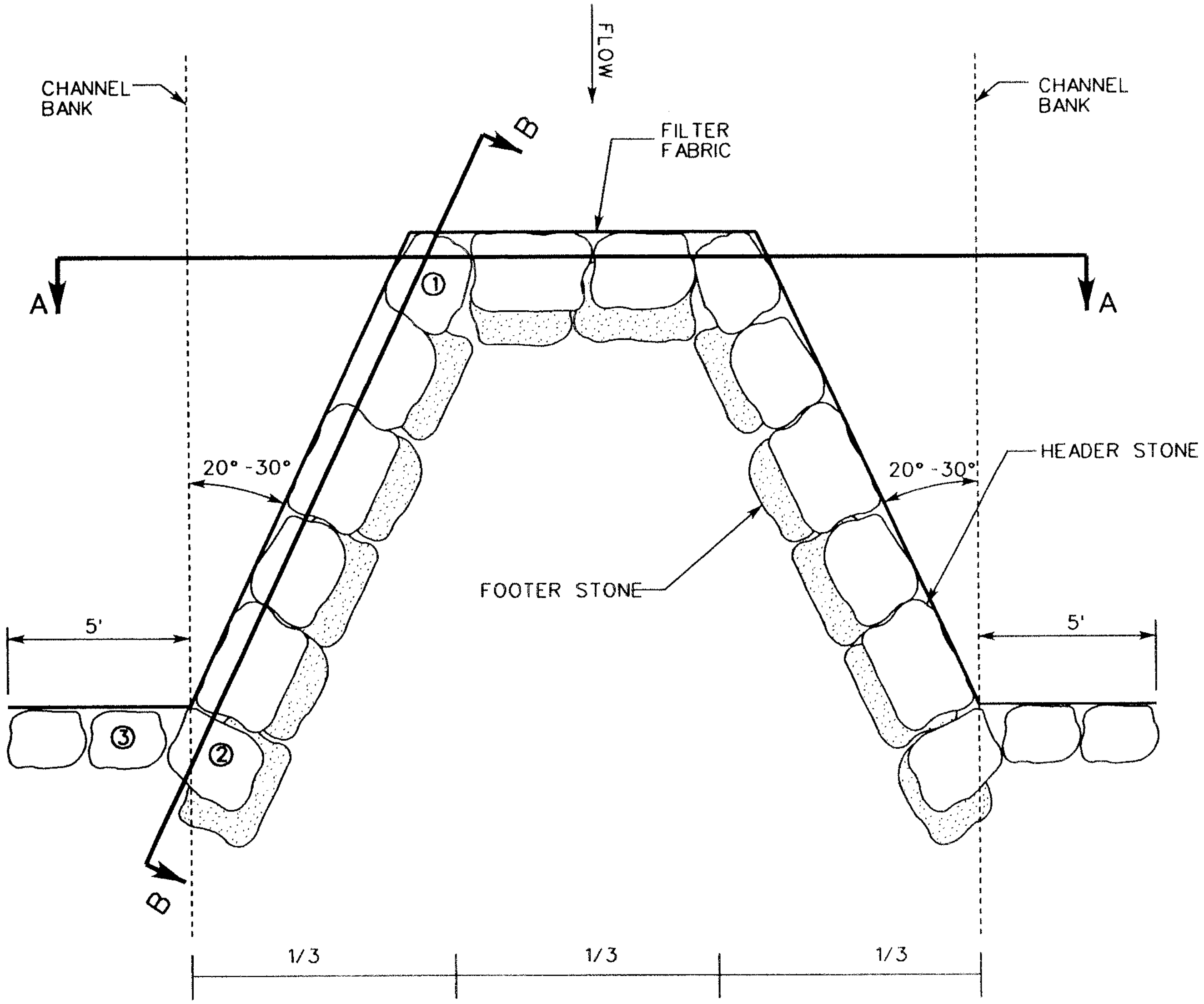
DEPTH OF WATER TABLE (cm)	DRAINED WATER VOLUME (cm)	UPFLUX FROM WATER TABLE (cm/hr)	GREEN-AMPT PARAMETERS A (sq.cm/hr)	GREEN-AMPT PARAMETERS B (cm/hr)	WATER CONTENT (THETA) (cc/cc)	MATRIC SUCTION (HEAD) (cm)
.0	.0	.2000	.00	.00	.46	.0
10.0	.0	.2000	.34	3.53	.46	-5.0
20.0	.2	.2000	.42	1.88	.45	-10.0
30.0	.3	.1243	.47	1.33	.44	-20.0
40.0	2.6	.0119	6.05	12.83	.42	-30.0
50.0	5.9	.0020	12.85	22.08	.41	-40.0
60.0	9.2	.0012	19.29	28.24	.38	-60.0
70.0	12.6	.0007	25.29	32.65	.36	-80.0
80.0	15.9	.0004	30.84	35.95	.35	-100.0
90.0	19.3	.0003	35.98	38.52	.32	-150.0
100.0	22.6	.0002	40.74	40.58	.29	-200.0
120.0	29.4	.0000	49.23	43.66	.26	-300.0
140.0	36.1	.0000	56.57	45.86	.26	-340.0
160.0	42.9	.0000	62.99	47.52	.24	-400.0
200.0	56.3	.0000	73.68	49.83	.22	-600.0
250.0	71.4	.0000	84.15	51.68	.19	-1000.0
300.0	88.3	.0000	92.44	52.91	.16	-2000.0
400.0	122.0	.0000	104.87	54.45	.12	-5000.0
500.0	155.8	.0000	113.90	55.38	.10	-10000.0
700.0	223.2	.0000	126.42	56.44	.09	-15300.0
1000.0	324.4	.0000	138.26	57.23	.06	-102000.0

SOIL PROPERTIES

Name: CHEWACLA
Number of Horizons: 5
Root Zone Depth : 0.

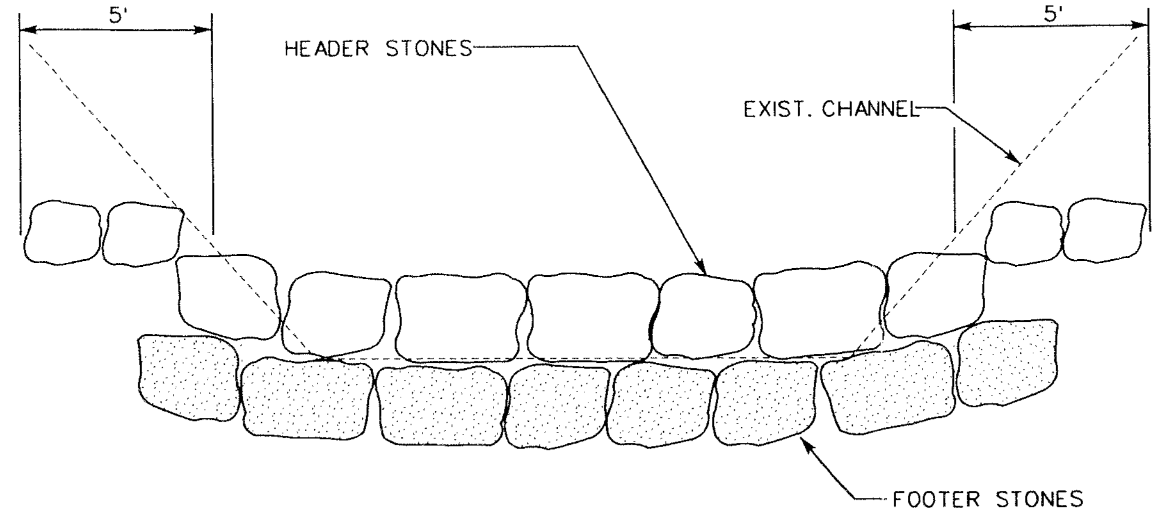
dp	rf	ca	clay	silt	om	cs	mp	cp	dbmom	flag	Ksat
8.	1.4	.20	12.5	19.7	2.5	14.5	4	3	1.45	0	8.91
16.	1.3	.20	27.5	52.5	1.3	4.3	3	3	1.40	0	.30
10.	1.4	.20	26.5	17.7	1.0	8.2	2	2	1.45	0	1.41
24.	7.0	.20	27.5	37.8	1.0	4.4	1	2	1.40	0	.54
12.	.0	.20	.0	.0	.3	.0	1	2	.00	0	55.85

DEPTH OF WATER TABLE (cm)	DRAINED WATER VOLUME (cm)	UPFLUX FROM WATER TABLE (cm/hr)	GREEN-AMPT PARAMETERS A (sq.cm/hr)	GREEN-AMPT PARAMETERS B (cm/hr)	WATER CONTENT (THETA) (cc/cc)	MATRIC SUCTION (HEAD) (cm)
.0	.0	.2000	.00	.00	.41	.0
10.0	.1	.2000	.45	7.19	.40	-5.0
20.0	.4	.0949	.41	3.53	.38	-10.0
30.0	2.1	.0081	2.15	13.60	.36	-20.0
40.0	5.4	.0010	4.61	24.16	.34	-30.0
50.0	8.7	.0005	6.62	30.50	.32	-40.0
60.0	12.0	.0003	8.28	34.73	.30	-60.0
70.0	15.2	.0002	9.70	37.74	.28	-80.0
80.0	18.5	.0001	10.91	40.01	.27	-100.0
90.0	21.8	.0000	11.97	41.77	.25	-150.0
100.0	25.1	.0000	12.90	43.18	.23	-200.0
120.0	31.7	.0000	14.47	45.29	.21	-300.0
140.0	38.3	.0000	15.76	46.80	.21	-340.0
160.0	44.9	.0000	16.84	47.93	.20	-400.0
200.0	58.0	.0000	18.57	49.52	.18	-600.0
250.0	73.3	.0000	20.19	50.78	.16	-1000.0
300.0	89.7	.0000	21.44	51.63	.14	-2000.0
400.0	122.7	.0000	23.28	52.69	.12	-5000.0
500.0	155.6	.0000	24.59	53.32	.10	-10000.0
700.0	221.5	.0000	26.40	54.04	.10	-15300.0
1000.0	320.3	.0000	28.11	54.59	.07	-102000.0



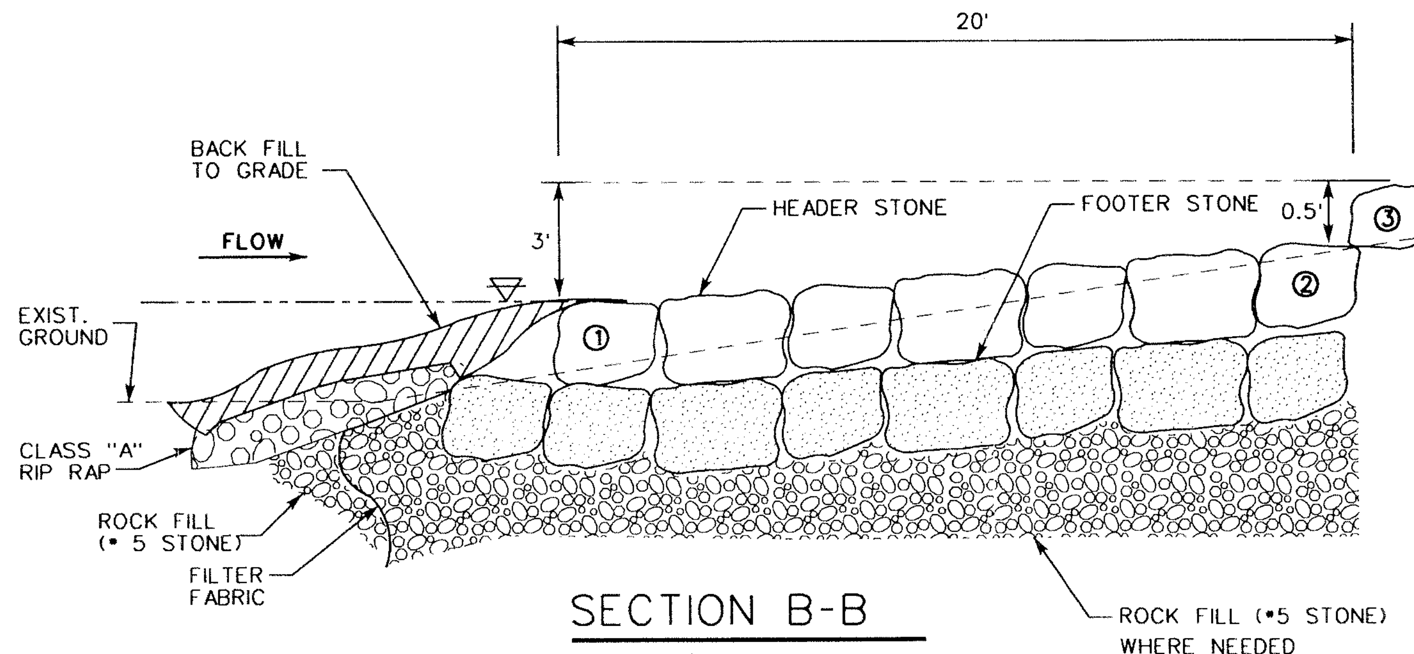
PLAN VIEW

SCALE: N.T.S.



SECTION A-A

SCALE: N.T.S.



SECTION B-B

SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **BACK CREEK MITIGATION SITE**

DETAILED MITIGATION PLANNING

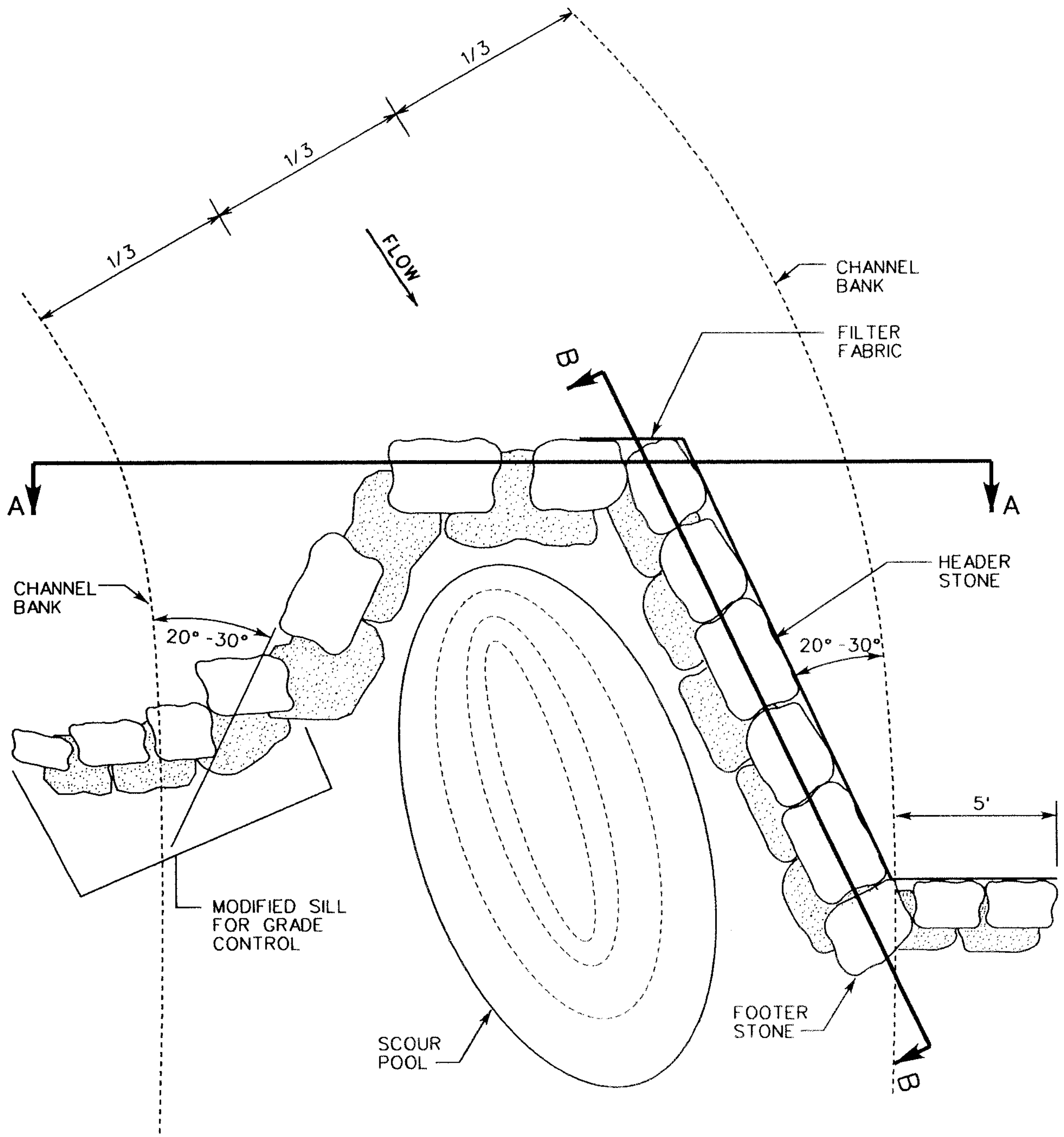
MECKLENBURG COUNTY, NORTH CAROLINA

Title: **TYPICAL CROSS-VANE WEIR**

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown

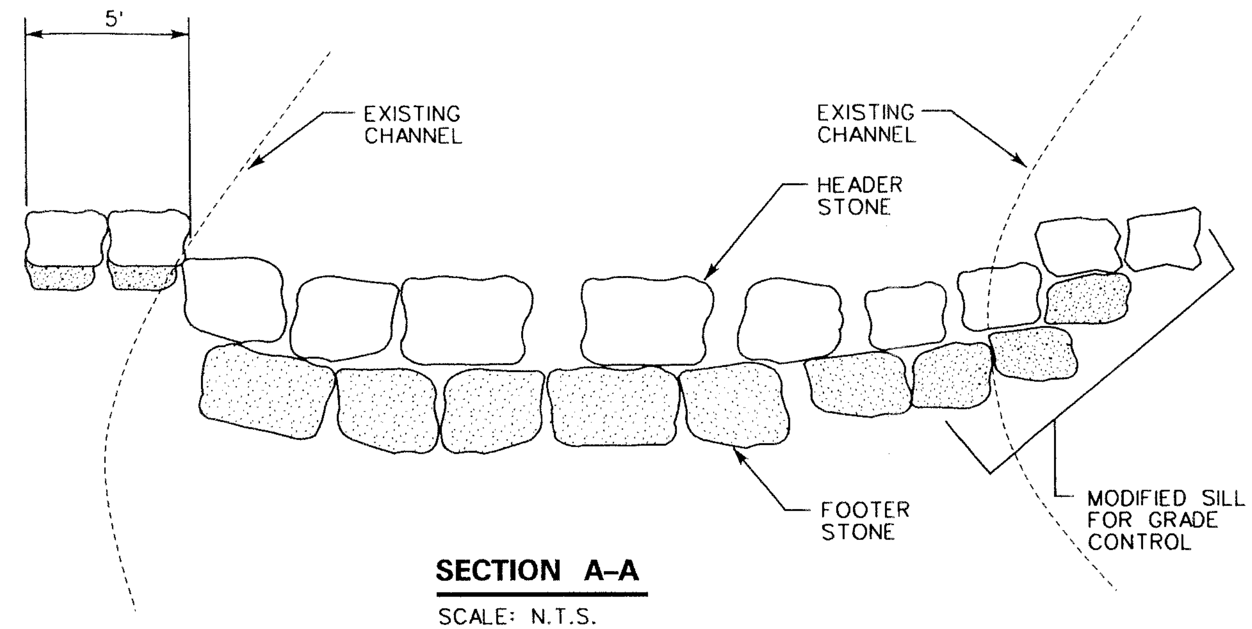
ESC Project No.: 02-113.04

FIGURE **15**



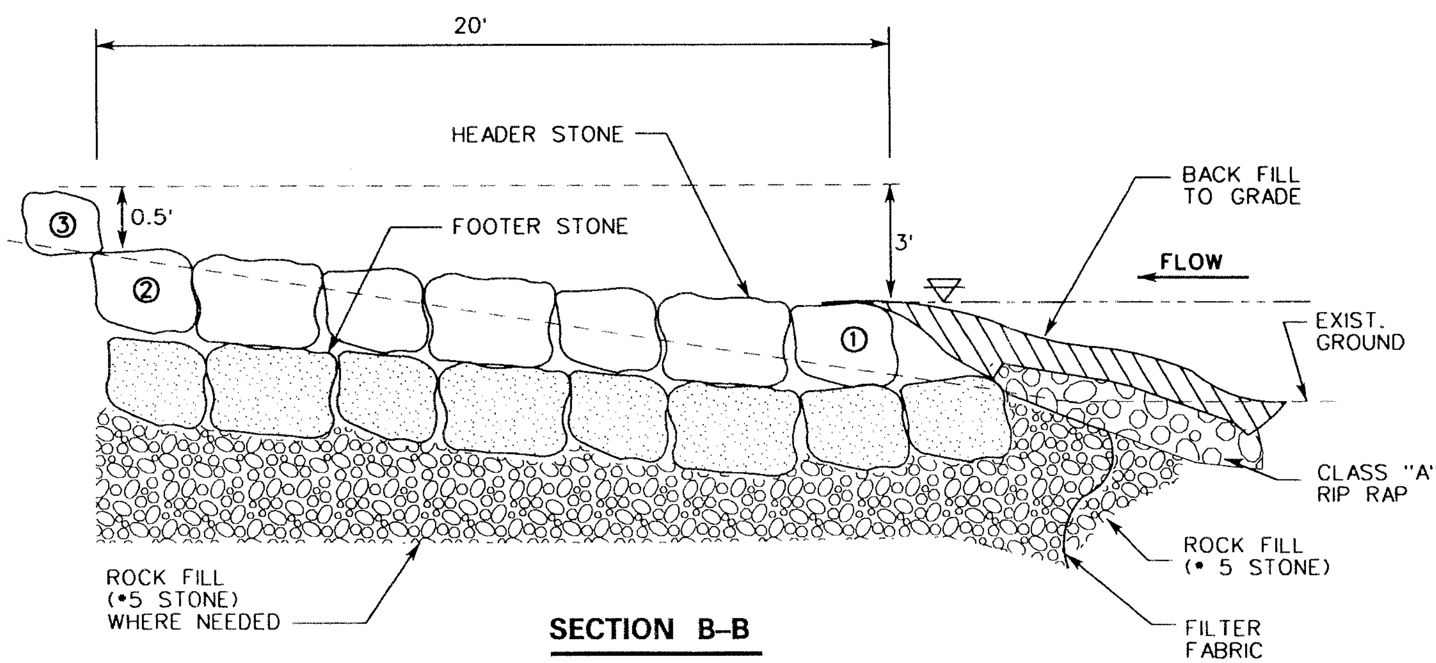
PLAN VIEW

SCALE: N.T.S.



SECTION A–A

SCALE: N.T.S.



SECTION B–B

SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER

EcoScience Corporation

Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **BACK CREEK MITIGATION SITE**

DETAILED MITIGATION PLANNING

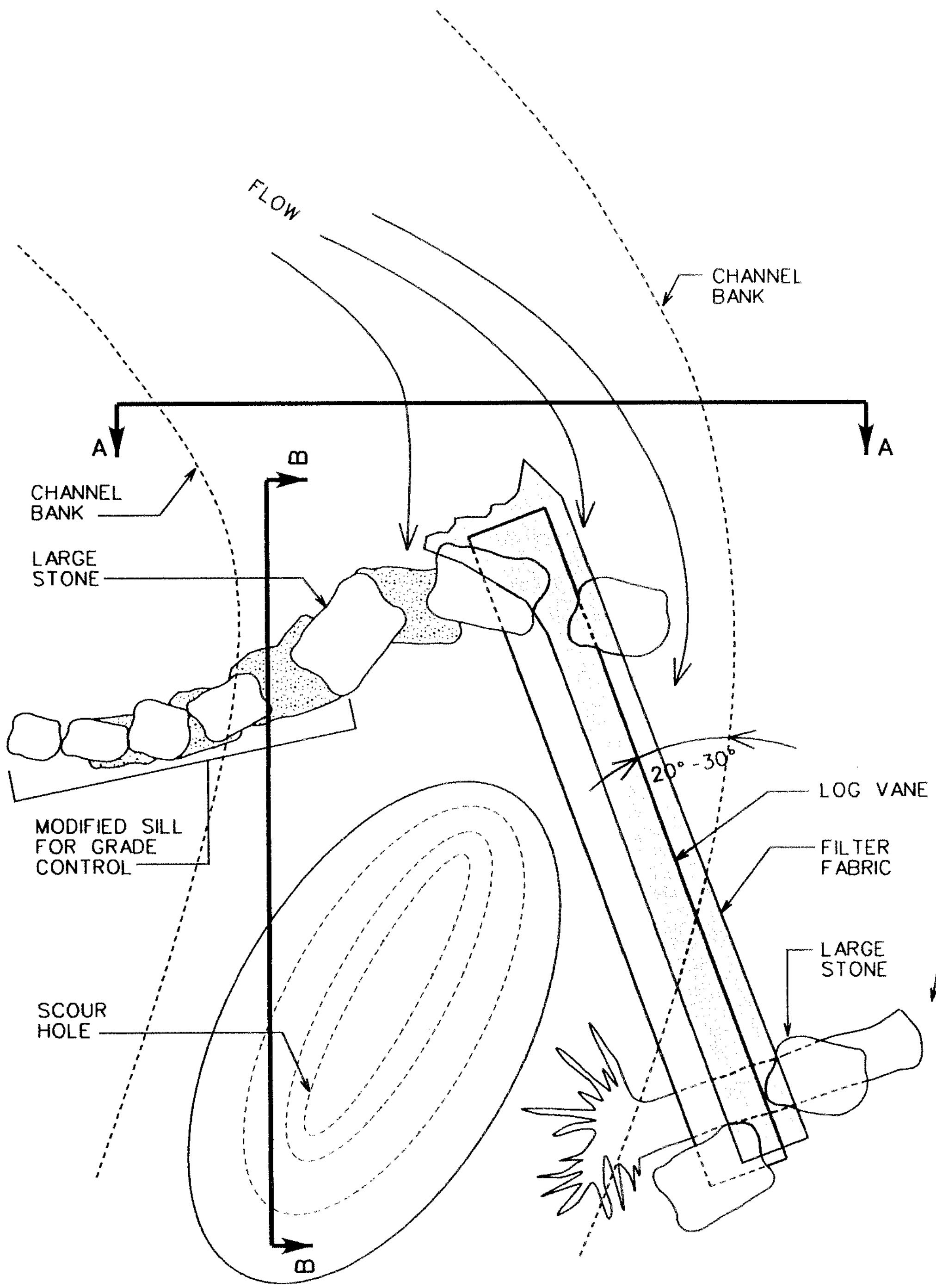
MECKLENBURG COUNTY, NORTH CAROLINA

Title: **TYPICAL J–HOOK VANE**

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown

ESC Project No.: 02-113.04

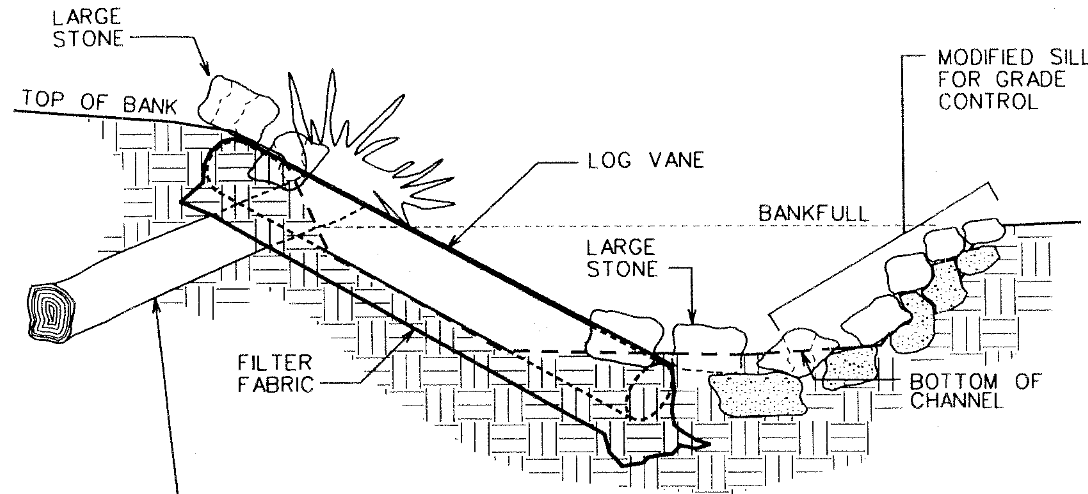
FIGURE **16**



PLAN VIEW

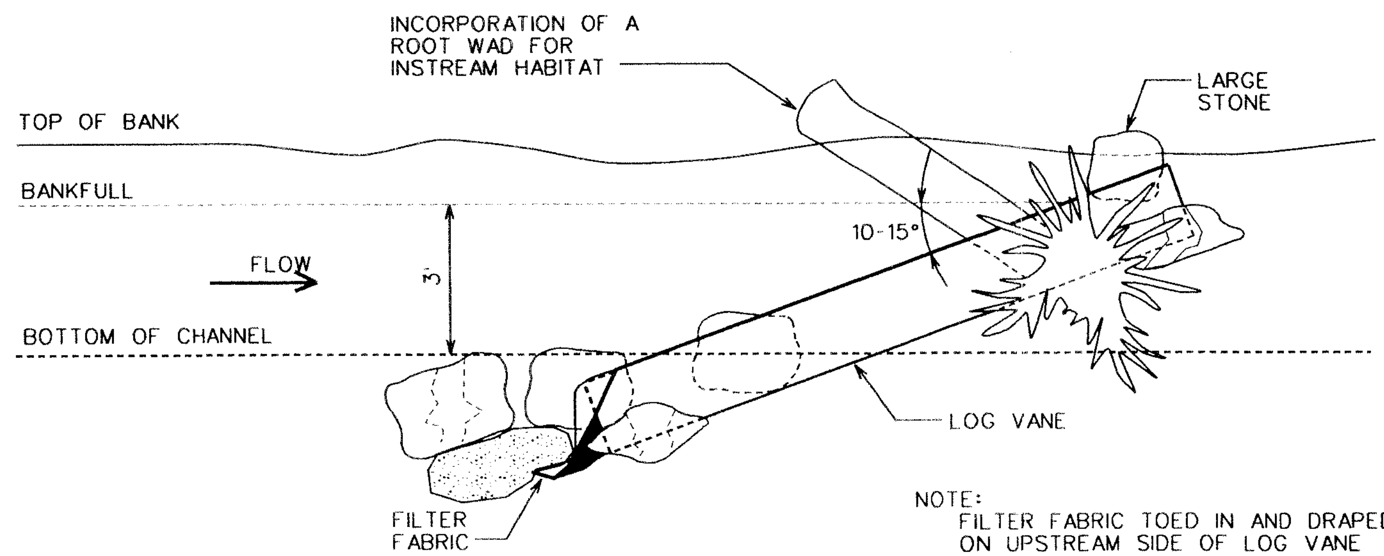
SCALE: N.T.S.

NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.



CROSS-SECTION A-A

SCALE: N.T.S.



PROFILE B-B

SCALE: N.T.S.

NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.

EcoScience Corporation

Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **BACK CREEK MITIGATION SITE**

DETAILED MITIGATION PLANNING

MECKLENBURG COUNTY, NORTH CAROLINA

Title: **TYPICAL LOG VANE WEIR**

Dwn By: MAF	Date: JAN 2003
Ckd By: WGL	Scale: As Shown

ESC Project No.: 02-113.04

FIGURE

17