Duke Swamp
Wetland and Stream Restoration Plan
Gates County, North Carolina

Prepared for:

NCDENR - Ecosystem Enhancement Program
2728 Capital Blvd, Suite 1H 103
Raleigh, NC 27604

FINAL REPORT

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Design Report Prepared by Baker Engineering NY, Inc.

8000 Regency Parkway, Suite 200
Cary, NC 27518

Kayne Van Stell
Project Manager

Kevin Tweedy, PE
Project Engineer

EXECUTIVE SUMMARY

Baker Engineering proposes to restore 5,422 linear feet (LF) of stream and 15 acres (AC) of riverine wetlands along two unnamed tributaries to Duke Swamp. The Duke Swamp Site is located in Gates County, approximately nine miles northeast of the city limits of Gatesville, NC, within cataloging unit 03010203, and NC Division of Water Quality (NCDWQ) sub-basin 03-01-01 of the Chowan River Basin (Exhibits 1.1 and 1.2). The purpose of the project is to restore wetland functions to prior-converted crop fields on the site and to restore stream functions to the impaired stream channels that flow through it.

Wetland functions on the site have been impaired as a result of agricultural conversion. Streams flowing through the site were channelized many years ago to reduce flooding and provide drainage for adjacent agricultural fields. Field areas were graded to promote rapid surface drainage and spoil from channel/pond excavation was spread on floodplain areas. As a result, nearly all wetland functions were destroyed within the field areas. The channelized streams flowing through the site function more as canals than as a Coastal Plain stream, with overall poor in-stream habitat and channel form.

The ditches and channelized streams on the site transport surface and subsurface drainage from the prior-converted crop fields, lowering the water table and keeping soil conditions favorable for agricultural production. Examination of the available hydrology and soil data indicate that there is good potential for the restoration of a productive wetland and stream ecosystem.

The Duke Swamp Restoration Project will restore a “Coastal Plain small stream swamp” system, as described by Schafale and Weakley (1990). Due to the productivity and accessibility of these systems, most have experienced heavy human disturbance. Wetland restoration of the prior-converted farm fields on the site will involve raising the local water table and restoring a natural flooding regime. The streams on the site will be restored to stable conditions and riverine wetland functions will be restored to the adjacent hydric soil areas. Drainage ditches and farm ponds within the restoration areas will be partially filled to decrease surface and subsurface drainage and raise the local water table. In addition, scarification of the fields and breaking of the local plow pan will provide increased surface storage of water and provide favorable conditions for a variety of native wetland plant species.

Table ES.1

Restoration Overview - Duke Swamp Site (see Exhibit 1.4)

Wetland Type / Project Reach	Existing Condition	Design Condition	Restoration Approach
Coastal Plain Small Stream Swamp - PC field areas along UT1a	0 AC	13.1 AC	Wetland Restoration Restoration of hydrology through filling of drainage ditches and features, restoration of the UT1a stream channel, restoration of flooding functions, restoration of natural floodplain topography; planting of wetland vegetation.
Coastal Plain Small Stream Swamp - along UT1b and UT2 (existing jurisdictional wetlands)	5.1 AC	5.1 AC	Wetland Enhancement Enhancement of hydrology through restoration of historic flow patterns and connectivity between UT1b and UT2.
Coastal Plain Small Stream Swamp - existing jurisdictional wetland pockets along UT1a in open field areas and Pond 1.	2.4 AC	2.4 AC	Wetland Enhancement Enhancement of hydrology through filling of drainage canal and restoration of a meandering stable stream system; enhancement of flooding functions; planting of native woody vegetation; lowering of water level in Pond 1 to function as a wetland.
UT1a	2,860 LF	3,983 LF	Stream Restoration Rosgen Priority Level I and II approaches to restore a meandering stream system.
UT1b and UT2	880 LF / 880 LF	924 LF / 515 LF	Stream Restoration Restoration of the system will be achieved through the removal of the spoil pile that separates UT1b and UT2 and the filling of the channelized section of UT1b. This approach will restore flows to historic remnant channels and restore flooding functions and connectivity.
Total	**4,620 LF / 7.5 AC**	**5,422 LF / 20.6 AC**	

Table of Contents

List of Exhibits

* All Exhibits are located at the back of the report, immediately preceding the appendices.

List of Figures

List of Tables

List of Appendices

1.0 INTRODUCTION AND BACKGROUND

1.1 Brief Project Description and Location

Baker Engineering proposes to restore 5,422 linear feet (LF) of stream and 15 acres (AC) of riverine wetlands along two unnamed tributaries to Duke Swamp. Riparian buffers will be restored along reach UT1a and preserved along reaches UT1b and UT2. A perpetual conservation easement consisting of 25.4 acres protects all stream reaches and riparian buffers. The project site is located in Gates County in the Chowan River Basin as shown on Exhibits 1.1 and 1.2.

For analysis and design purposes, Baker Engineering divided the on-site streams into two reaches. The reach locations are shown on Exhibit 1.2. Based on field evaluations of intermittent/perennial status, the stream channels are considered perennial using North Carolina Department of Environment and Natural Resources, (NCDENR) Division of Water Quality (NCDWQ) stream assessment protocols.

UT1 to Duke Swamp is a moderate size, perennial stream with a drainage area of approximately 3.0 square miles at the downstream end of the site (Exhibit 1.3). Historically, the site has been used for agricultural production. Cleared areas in the upstream portion of the project area (UT1a) are currently used for seasonally rotated crop production. The riparian vegetation in this area is predominantly herbaceous that is regularly maintained by mowing. Mowing and crop production have curtailed any efforts for native woody vegetation to establish along the stream banks which has resulted in an inadequate riparian buffer throughout reach UT1a. The downstream portion of the site (UT1b) is wooded with a mature bottomland hardwood swamp forest.

The UT1 stream has been channelized and dredged. This manipulation has created a channel that is overly wide and overly deep for the given drainage area. There is little slope to the system (0.0003) and essentially the channel is functioning as a long, linear pond, holding backwater from the downstream swamp throughout the entire reach. In most cases the estimated cross-sectional area (21 ft^2) from the coastal regional curve is below water surface. Feature formation is poor with very little habitat diversity or woody debris.

UT2 to Duke Swamp is a small size, perennial stream with a drainage area of approximately 0.03 square miles and begins at the outlet of a small cypress pond north of the project boundary (Exhibits 1.2 & 1.3). The historic flow pattern and flooding regime of UT2 appears to have been altered significantly. Backwater effects have been the result of an existing spoil pile that runs along the right bank of UT1b in the forested wetland area. Flows are being diverted along this spoil pile and blocking the natural connection between UT1 and UT2. UT2 begins as single thread system and transitions into a multi-channel (DA) system which has been hydraulically impacted by the channelization of UT1b. The stream has a mature bottomland hardwood swamp forest canopy along its entire length as it connects with UT1.

1.2 Project Goals and Objectives

The proposed restoration areas are shown in Exhibit 1.4. The proposed stream and wetland restoration project will provide numerous ecological benefits within the Chowan River basin. While many of these benefits are limited to the project area, others, such as pollutant removal and improved aquatic and terrestrial habitat, have more far-reaching effects. Expected improvements to water quality, hydrology, and habitat are outlined below as project goals.

Water Quality

- Reduce nutrient loading to receiving waters by establishment of riparian buffers.
- Reduce sediment supply by slowing/filtering surface runoff across riparian buffers.
- Increase dissolved oxygen concentrations by adding water turbulence in riffle areas.
- Improve streambank stability by lowering bank height ratios and establishing root mass.
- Increase pollutant retention through wetland filtering.

Water Quantity/Flood Attenuation

- Increase water storage/flood control by establishment of vegetated floodplain.
- Reduce downstream flooding by reconnecting stream with its widened floodplain capacity.
- Improve ground water recharge throughout floodplain areas by increasing infiltration rates.
- Improve/restore hydrologic connections by facilitating wetland/floodplain functionality.

Aquatic and Terrestrial Habitat

- Improve substrate and in-stream cover by installing structures and large woody debris.
- Reduce water temperature by establishing riparian vegetation and increasing shading.
- Restore terrestrial habitat by improving connectivity between stream and wetland systems.
- Improve aesthetics by restoring ecosystem diversity and functionality.

1.3 Report Overview

This report has been arranged and formatted to maximize its utility. Readers unfamiliar with stream and wetland restoration science and methodology may wish to review the background material in Sections 2 and 3. Those familiar with Baker Engineering's design processes and procedures may wish to focus on Sections 4, 5, 6, 7, and 8 of the report, which are specific to the project site. These sections cover the site assessment findings, selection and application of design criteria, and site design. Section 8 summarizes post-construction monitoring and evaluation procedures.

2.0 STREAM RESTORATION BACKGROUND SCIENCE AND METHODS

2.1 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain comprise a dynamic environment where the floodplain, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflect all of these factors (Leopold et al., 1992; Knighton, 1988). The result is a dynamic equilibrium where the stream maintains its dimension, pattern, and profile over time, and neither degrades nor aggrades. Land use changes in the watershed, including increases in imperviousness and removal of riparian vegetation, can upset this balance. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). By understanding and applying natural stream processes to stream restoration projects, a self-sustaining stream can be designed and constructed that maximizes stream and biological potential (Leopold et al., 1992; Leopold, 1994; Rosgen, 1996).

In addition to transporting water and sediment, natural streams provide the habitat for many aquatic organisms including fish, amphibians, insects, mollusks, and plants. Trees and shrubs along the banks provide a food source and regulate water temperatures. Channel features such as pools, riffles, steps, and undercut banks provide diversity of habitat, oxygenation, and cover (Dunne and Leopold, 1978). Stream restoration projects can repair these features in concert with the return of a stable dimension, pattern, and profile. The following sections provide an overview of the primary channel forming process and typical stream morphology.

2.1.1 Channel Forming Discharge

The channel forming discharge, also referred to as bankfull discharge, effective discharge, or dominant discharge, creates a natural and predictable channel size and shape (Leopold et al., 1992; Leopold, 1994). Channel forming discharge theory states that there is a unique flow that over a long period of time would yield the same channel morphology that is shaped by the natural sequence of flows. At this discharge, equilibrium is most closely approached and the tendency to change is minimized (Inglis, 1947). Uses of the channel forming discharge include channel stability assessment, river management using hydraulic geometry relationships, and natural channel design (Soar and Thorne, 2001).

Proper determination of bankfull stage in the field is vital to stream classification and the natural channel design process. The bankfull discharge is the point at which flooding occurs on the floodplain (Leopold, 1994). This flood stage may or may not be the top of the stream bank. On average, bankfull discharge occurs every 1.5 years (Leopold, 1994; Harman et al., 1999; McCandless, 2003). If the stream has become incised due to changes in the watershed or streamside vegetation, the bankfull stage may be a small depositional bench or scour line on the stream bank (Harman et al., 1999). In this case, the top of the bank, which was formerly the floodplain, is called a terrace. A stream with terraces at the top of its banks is considered to be incised.

2.1.2 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials are largely dependent on valley slope and geology. In simple terms, steep, straight streams are found in steep, colluvial valleys, while flat, meandering streams are found in flat, alluvial valleys. Colluvial valleys have slopes between two percent and four percent, while alluvial channels have slopes less than two percent. A colluvial valley forms through hillslope processes. Sediment supply in colluvial valleys is controlled by hillslope erosion and mass wasting, i.e., the sediments in the stream bed originated from the hillslopes. Sediments reaching the channel in a colluvial valley are typically poorly sorted mixtures of fine and coarse grained materials ranging in size from sand to boulders. In contrast, an alluvial valley forms through stream and floodplain processes. Sediments in alluvial valleys include some coarse gravel and cobble transported from steeper upland areas, but are predominantly fine-grained particles such as gravel and sand. Grain size generally decreases with valley slope (Leopold et al., 1992).

2.1.2.1 Step/Pool Streams

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter, alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and plunge pool downstream. Smaller particles collect in the interstices of steps creating stable, interlocking structures (Knighton, 1988).

In contrast to meandering streams that dissipate energy through meander bends, step/pool streams dissipate energy through drops and turbulence. Step/pool streams have relatively low sinuosity. Pattern variations are commonly the result of debris jams, topographic features, and bedrock outcrops.

2.1.2.2 Gravel Bed Streams

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger size particles. During low flow periods, the water depth at a riffle is relatively shallow and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, and the resulting turbulence provide oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1988). Pools are typically located on the outside bends of meanders between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features and riffles are scour features.

At high flows, the water surface becomes more uniform: the water surface slope at the riffles decreases and the water surface slope at the pools increases. The increase in pool slope coupled with the greater water depth at the pools causes an increase in shear stress at the bed elevation. The opposite is true at riffles. With a relative increase in shear stress, pools scour. The relative decrease in shear stress at riffles causes bed material deposits at these features during the falling limb of the hydrograph.

2.1.2.3 Sand Bed Streams

While gravel bed streams have riffle/pool sequences, with riffles composed of gravel-size particles, sand bed channels are characterized by median bed material sizes less than 2 millimeters in diameter (Bunte and Abt, 2001). Bed material features called ripples, dunes, planebeds, and antidunes characterize the sand bedform. Although sand bed streams technically do not have riffles, the term is often used to describe the crossover reach between pools. We use "riffle" in this report as equivalent to the crossover section.

The size, stage, and variation of sand bedforms are formed by changes in unit stream power as described below. These bedforms are symptomatic of local variations in the sediment transport rate and cause minor to major variations in aggradation and degradation (Gomez, 1991). Sand bedforms can be divided between low flow regimes and high flow regimes with a transitional zone between the two. Ripples occur at low flows where the unit stream power is just high enough to entrain sand size particles. This entrainment creates small wavelets from random sediment accumulations that are triangular in profile with gentle upstream and steep downstream slopes. The ripple dimensions are independent of flow depth and heights are less than 0.02 meters.

As unit stream power increases, dunes eventually replace ripples. Dunes are the most common type of sand bedform and have a larger height and wavelength than ripples. Unlike ripples, dune height and wavelength are proportional to flow depth. The movement of dunes is the major cause of variability in bed-load transport rates in sand bed streams. Dunes are eventually washed out to leave an upper-flow plane bed characterized by intense bedload transport. This plane bed prevents the patterns of erosion and deposition required for dune development. This stage of bedform development is called the transitional flow regime between the low flow features and the high flow regime features (Knighton, 1998).

As flow continues to increase, standing waves develop at the water surface and the bed develops a train of sediment waves (antidunes), which mirror the surface forms. Antidunes migrate upstream by way of scour on the downstream face and deposition on the upstream face, a process that is opposite of ripples and dunes. Antidunes can also move downstream or remain stationary for short periods (Knighton, 1998).

2.1.3 Stream Classification

The Rosgen stream classification system categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system presents several stream types based on a hierarchical system. The classification system is illustrated on Exhibit 2.1. The first level of classification distinguishes between single and multiple thread channels. Streams are then separated based on degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are also evaluated to subdivide the streams. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

Bankfull stage is the basis for measuring the width/depth and entrenchment ratios, two of the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. A detailed discussion of bankfull stage was provided in Section 2.1.1.

2.1.4 Stream Stability

A naturally stable stream must be able to transport the sediment load supplied by its watershed while maintaining dimension, pattern, and profile over time so that it does not degrade or aggrade (Rosgen, 1994). Stable streams migrate across alluvial landscapes slowly over long periods of time while maintaining their form and function. Instability occurs when scouring causes the channel to incise (degrade) or excessive deposition causes the channel bed to rise (aggrade). A generalized relationship of stream stability proposed by Lane (1955) is shown as a schematic drawing in Exhibit 2.2. The drawing shows that the product of sediment load and sediment size is proportional to the product of stream slope and discharge or stream power. A change in any one of these variables causes a rapid physical adjustment in the stream channel.

2.1.5 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in runoff due to build-out in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) channel evolution model characterizes evolution in six steps, including:

I. sinuous, pre-modified,
II. channelized,
III. degradation,
IV. degradation and widening,
V. aggradation and widening, and
VI. quasi-equilibrium.

Exhibit 2.3 illustrates the six steps of the Simon channel evolution model.

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). According to research summarized by the Federal Interagency Stream Restoration Working Group (FISRWG), incision eventually leads to over-steepening of the banks and, when critical bank heights are exceeded, the banks begin to fail and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually the mass wasting slows and the stream begins to aggrade. A new low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form with a new floodplain constructed of alluvial material (FISRWG, 1998).

2.1.6 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. High, steep stream banks, poor or absent in-stream or riparian habitat, increased erosion and sedimentation, and low sinuosity are all characteristics of incised streams. Complete restoration of the stream, where the incised grade of the channel is raised so that an abandoned floodplain terrace is reclaimed, is ideally the overriding project objective. There may be scenarios, however, where such an objective is impractical due to encroachment into the abandoned floodplain terrace by homes, roadways, utilities, etc. A priority system for the restoration of incised streams, developed and used by Rosgen (1997), considers a range of options to provide the best level of stream restoration possible for the given setting. Exhibit 2.4 illustrates various restoration/stabilization options for incised channels within the framework of the Rosgen's priority system. Generally:

Priority 1 – Re-establishes the channel on a previous floodplain (i.e., raises channel elevation); meanders a new channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel. This option requires that the upstream start point of the project not be incised.

Priority 2 – Establishes a new floodplain at the existing bankfull elevation (i.e., excavates a new floodplain); meanders channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised.

Priority 3 – Converts a straight channel to a different stream type while leaving the existing channel in place by excavating bankfull benches at the existing bankfull elevation. Effectively, the valley for the stream is made more bowl-shaped. This approach uses in-stream structures to dissipate energy through a step/pool channel type.

Priority 4 – Stabilizes the channel in place using in-stream structures and bioengineering to decrease erosion of the stream bed and stream bank. This approach is typically used in highly constrained environments.

2.2 Natural Channel Design Overview

Restoration design of degraded stream reaches first involves accurately diagnosing their current condition. Understanding valley type, stream type, channel stability, bedform diversity, and potential for restoration is essential to developing adequate restoration measures (Rosgen, 1996). This combination of assessment and design is often referred to as natural channel design.

The first step in a stream restoration design is to assess the reach, its valley, and its watershed to understand the relationship between the stream and its drainage basin and to evaluate the causes of stream impairment. Bankfull discharge is estimated for the watershed. After sources of stream impairment are identified and channel geometry is assessed, a plan for restoration can be formulated.

Design commences at the completion of the assessment stage. A series of iterative calculations are performed using data from reference reaches, pertinent literature, and evaluation of past projects to develop an appropriate stable cross-section, profile, and plan form dimensions for the design reach. A thorough discussion of design parameter selection is provided in Section 2.5. The alignment should avoid an entirely symmetrical layout to mimic natural variability, create a diversity of aquatic habitats, and improve aesthetics.

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.6.

After the sediment transport assessment, additional structural elements are then added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.7 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared showing dimension, pattern, profile, and location of additional structures. These drawings are used in the construction of the project.

Following the implementation of the design, a monitoring plan is established to:

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

2.3 Geomorphic Characterization Methodology

Geomorphic characterization of stream features includes the bankfull identification, bed material characterization and analysis, and stream classification.

2.3.1 Bankfull Identification

Correct identification of bankfull is important to the determination of geomorphic criteria such as stream type, bank height ratios, width to depth ratios, and entrenchment ratios. Baker Engineering's field techniques for bankfull identification are as follows:

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high. In that case, the bar may flatten and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.
- Measure the difference in height between the water surface and the bankfull indicator. For example, the indicator may be 2.2 feet above water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the watershed.
- Go to a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator. For example, measure 2.2 feet above water surface and place a flag in both the right and left bank.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross-sectional area.
- Obtain the appropriate regional curve (e.g., rural Piedmont, urban Piedmont, Mountain, or Coastal Plain) and determine the cross-sectional area associated with the drainage area of the reach.
- Compare the measured cross-sectional area to that predicted by the regional curve. If the measured cross-sectional area is not a close fit, look for other bankfull indicators and test them. If there are no other indicators, look for reasons to explain the difference between the two cross-sectional areas. For example, if the cross-sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross-sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle using indicators from depositional features. The cross-sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or maintenance. In such cases, it is important to verify bankfull through other means such as a gauge station survey or reference bankfull information that is specific to the geographic location. The gauge information can be used, along with regional curve information, to estimate bankfull elevation in a project reach that lacks bankfull indicators.

2.3.2 Bed Material Characterization

Baker Engineering typically performs bed material characterization using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed in transects across the streambed, with the number of riffle and pool transects being proportional to the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median particle size of the modified Wolman procedure is known as the d_{50}. The d_{50} describes the bed material classification for that reach. The bed material classification is shown on Exhibit 2.1 and ranges from a classification of 1 for a channel d_{50} of bedrock to a classification of 6 for a channel d_{50} in the silt/clay particle size range.

The modified Wolman pebble count is not appropriate for sand bed streams. When working in sandbed systems, a bulk sampling procedure is used to characterize the bed material. Cores (two to three inches deep) are sampled from the bed along the entire reach. These cores are taken back to a lab and dry sieved to obtain a sediment size distribution. This information is used to classify the stream and to complete the sediment transport analysis.

2.3.3 Stream Classification

Cross-sections are surveyed along stable riffles for the purpose of stream classification. Values for entrenchment ratio and width/depth ratio, along with sinuosity and slope, are used to classify the stream. The entrenchment ratio (ER) is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The width/depth ratio (w/d ratio) is calculated by dividing bankfull width by mean bankfull depth). Exhibit 2.5 shows examples of the channel dimension measurements used in the Rosgen stream classification system.

Finally, the numbers associated with each bed material classification used are used to further classify the stream type. For example, a Rosgen E3 stream type is a narrow and deep, cobble-dominated channel with access to a floodplain that is greater than two times its bankfull width.

2.4 Channel Stability Assessment Methodology

Baker Engineering uses a modified version of stream channel stability assessment methodology developed by Rosgen (2001a). The Rosgen method is a field assessment of the following stream channel characteristics:

- Stream Channel Condition
- Vertical Stability
- Lateral Stability
- Channel Pattern
- River Profile and Bed Features
- Channel Dimension Relations
- Channel Evolution.

This field exercise is followed by the evaluation of various channel dimension relationships. The evaluation of the above characteristics leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each category is provided in the following sections.

2.4.1 Stream Channel Condition Observations

Stream channel conditions are observed during initial field inspection (stream walk). Baker Engineering notes the follow characteristics:

- Riparian vegetation – concentration, composition, and rooting depth and density
- Sediment depositional patterns – such as mid-channel bars and other depositional features that indicate aggradation and can lead to negative geomorphic channel adjustments
- Debris occurrence – presence or absence of woody debris
- Meander patterns – general observations with regard to the type of adjustments a stream will make to reach equilibrium
- Altered states due to direct disturbance – such as channelization, berm construction, and floodplain alterations.

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows comparison across different sets of conditions. The observations also help explain the quantitative measurements described below.

2.4.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to assess vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.1 shows the relationship between bank height ratio (BHR) and vertical stability developed by Rosgen (2001a).

Table 2.1
Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability (Rosgen, 2001a)

Adjective Stability Rating	Bank Height Ratio
Stable (low risk of degradation)	1.0 – 1.05
Moderately unstable	1.06 – 1.3
Unstable (high risk of degradation)	1.3 – 1.5
Highly unstable	> 1.5

The entrenchment ratio is measured as the width of the floodplain at twice the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is considered entrenched (Rosgen, 1996).

2.4.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral erosion are assessed in the field by measuring the meander width ratio (MWR) and the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001a). The MWR is the meander belt width divided by the bankfull channel width, and provides insight into lateral channel adjustment processes depending on stream type and degree of confinement. For example, a MWR of 3.0 often corresponds with a sinuosity of 1.2, which is the minimum value for a stream to be classified as meandering. If the MWR is less than 3.0, lateral adjustment is probable. BEHI ratings along with near bank shear stress estimates can be compared to data from monitored sites and used to estimate the annual lateral stream bank erosion rate.

2.4.4 Channel Pattern

Channel pattern is assessed in the field by measuring the stream's plan features including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width). These dimensionless ratios are compared to reference reach data for the same valley and stream type to assess whether channel pattern has been impacted.

2.4.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. Profile points are surveyed at prescribed intervals and at significant breaks in slope such as the head of a riffle or the head of a pool. This profile can be used to assess changes in river slope compared to valley slope, which affect sediment transport, stream competence, and the balance of energy. For example, the removal of large woody debris may increase the step/pool spacing and result in excess energy and subsequent channel degradation. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design.

2.4.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and relates to channel stability. A greater width/depth ratio compared to reference conditions may indicate accelerated stream bank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and downcutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.2 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001a).

Table 2.2
Conversion of Width/Depth Ratios to Adjective Ranking of Stability (Rosgen, 2001a)

Stability Rating	Ratio of Project to Reference Width/Depth
Very stable	1.0
Stable	1.0 – 1.2
Moderately unstable	1.21 – 1.4
Unstable	> 1.4

While an *increase* in width/depth ratio is associated with channel *widening*, a *decrease* in width/depth ratio is associated with channel *incision*. For incised channels, the ratio of channel width/depth ratio to reference reach width/depth ratio will be less than 1.0. The reduction in width/depth ratio indicates excess shear stress and movement of the channel toward an unstable condition.

2.4.7 Channel Evolution

Simon's channel evolution model (introduced in Section 2.1.5) relies on a qualitative, visual assessment of the existing stream channel characteristics (bank height, evidence of degradation/aggradation, presence of bank slumping, direction of bed and bank movement, etc.). Establishing the evolutionary stage of the channel helps ascertain whether the system is moving towards greater stability or instability. The model also provides a better understanding of the cause and effect of channel change. This information, combined with Rosgen's (1994) priority levels of restoration aids in determining the restoration potential of unstable reaches.

2.5 Design Parameter Selection Methodology

Baker Engineering uses a combination of approaches to develop design criteria for channel dimension, pattern, and profile. These approaches are described in the following sections. A flow chart for selecting design criteria is shown in Exhibit 2.6.

2.5.1 Upstream Reference Reaches

The best option for developing design criteria is to locate a reference reach upstream of the project site. A reference reach is a channel segment that is stable—neither aggrading nor degrading— and is of the same morphological type as the channel under consideration for restoration. The reference reach should also have a similar valley slope as the project reach. The reference reach is then used as the blueprint for the channel design (Rosgen, 1998). To account for differences in drainage area and discharge between a reference site and a project site, data on channel characteristics (dimension, pattern, and profile), in the form of dimensionless ratios, are developed for the reference reach. If the reach upstream of the project does not have sufficient pattern, but does have a stable riffle cross-section, only dimension ratios are calculated. It is ideal to measure a reference bankfull dimension that was formed under the same environmental influences as the project reach.

2.5.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is performed. A database search is conducted to locate known reference reaches in close proximity to the project site. The search includes streams with the same valley as the project reach and stream type as the design. If references are found meeting these criteria, the reference reach is field-surveyed for validation and comparison with the database values which may have been originally collected and provided by a third party. If a search of the database reveals no references which meet the appropriate criteria, a field search is performed locally to identify a reference reach which has not yet been surveyed.

Potential reference reaches are identified by first evaluating U.S. Geological Survey (USGS) topographic quadrangles and aerial photography for an area. In general, the search is limited to subwatersheds within or adjacent to the project watershed. In certain cases, a reference reach may be identified farther away that matches the same valley and stream type as the proposed design of the project site. In such a case, care is taken to ensure that the potential reference reach lies within the same physiographic region as the project reach. Potential reference sites identified on maps are then field-evaluated to determine if they are stable systems of the appropriate stream and valley type. If appropriate, reference reach surveys are conducted. When potential sites are located on private property, landowner permission is acquired prior to any survey work being conducted.

2.5.3 Reference Reach Databases

If a reference reach is not found in close proximity to the project site, a reference reach database is consulted and summary ratios are acquired for all streams with the same valley and stream type within the project's physiographic region. These ratios are then compared to literature values and regime equations along with ratios developed through the evaluation of successful projects.

2.5.4 Regime Equations

Baker Engineering uses a variety of published journals, books, and design manuals to cross-reference North Carolina database values with peer-reviewed regime equations. Examples include *Fluvial Forms and Processes* by Knighton (1998), *Mountain Rivers* by Wohl (2000), and the *Hydraulic Design of Stream Restoration Projects* (Copeland et al., 2001) by the US Army Corps of Engineers (USACE). The most common regime equations used in our designs are for pattern. For example, most reference reach surveys in the eastern United States show radius of curvature divided by bankfull width ratios much less than 1.5. However, the USACE manual recommends a ratio greater than 2.0 to maintain stability in free-forming systems. Since most stream restoration projects are constructed on floodplains denude of woody vegetation, we often use the USACE-recommended value rather than reference reach data. Meander wavelength and pool-to-pool spacing ratios are examples of other parameters that are sometimes designed with higher ratios than those observed on reference reaches, for similar reasons as described for radius of curvature.

2.5.5 Comparison to Past Projects

All of the above techniques for developing ratios and/or regime equations are compared to past projects built with similar conditions. Ultimately, these sites provide the best pattern and profile ratios because they reflect post-construction site conditions. While most reference reaches are in mature forests, restoration sites are in floodplains with little or no mature woody vegetation. This lack of mature woody vegetation severely alters floodplain processes and stream bank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used. Conversely, if past project ratios created stable channels with optimal bedform diversity; they will be incorporated into the design.

Ultimately, the design criteria are selections of ratios and equations made upon a thorough evaluation of the above tasks. Combinations of approaches may be used to optimize the design. The final selection of design criteria for the restoration site is discussed in Section 7.0.

2.6 Sediment Transport Competency and Capacity Methodology

The purpose of sediment transport analysis is to ensure that the stream restoration design creates a stable channel that does not aggrade or degrade over time. The overriding assumption is that the project reach should be transporting all the sediment delivered from upstream sources, thereby being a "transport" reach and classified as a Rosgen "C" or "E" type channel. For sand-bed channels, empirical relationships from stable sand-bed channels in North Carolina are used for this analysis.

Sediment transport is typically assessed by computing channel competency, capacity, or both. Sediment transport competency is a measure of force (lbs/ft^2) that refers to the stream's ability to move a given grain size. Quantitative assessments include shear stress, tractive force, and critical dimensionless shear stress. Since these assessments help determine a size class that is mobile under certain flow conditions, they are most important in gravel bed studies in which the bed material ranges in size from sand to cobble (of which only a fraction are mobile during bankfull conditions). In sand-bed systems, all particle sizes are mobile during bankfull flows; therefore, there is no need to determine the maximum particle size that the stream can transport. Comparing the design shear stress values for a project reach to those computed for sand-bed reference reaches does provide a useful comparison to determine if the stresses predicted for the design channels are within the range of those found in stable systems.

Shear stress placed on sediment particles within a stream channel may be estimated by the following equation:

$$\tau = \gamma RS, \text{ where} \qquad \text{Equation (1)}$$

τ = shear stress (lb/ft^2)

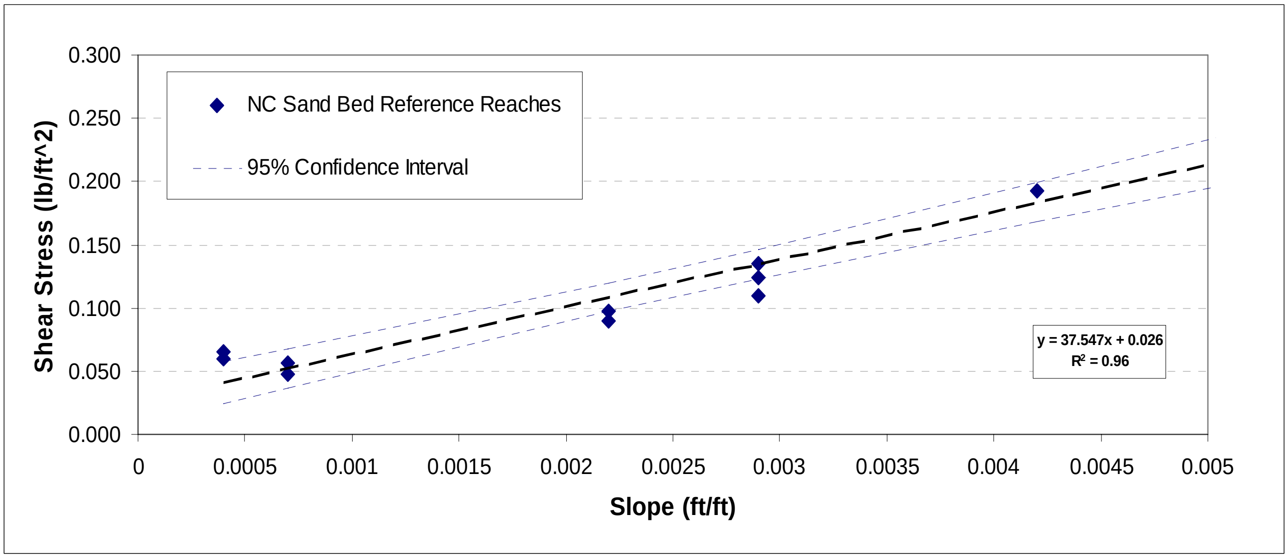
γ = specific gravity of water (62.4 lb/ft^3)

R = hydraulic radius (ft)

S = average channel slope (ft/ft)

Shear stress values are calculated for each design reach and plotted against values from sand-bed reference stream data from the Coastal Plain, as shown in Figure 2.1. If the predicted design shear stress values fall within the range of values documented for stable reference channels, it is assumed that shear stresses within the design reaches will be appropriate to maintain a stable channel.

Figure 2.1
Bankfull Shear Stress Versus Channel Slope for Coastal Plain Reference Reaches.



For sand-bed streams, sediment transport capacity is a much more important analysis tool than competency. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross-section per unit of time, expressed in pounds/second or tons/year. Sediment transport capacity can be assessed directly, using actual monitored data from bankfull events, if a sediment transport rating curve has been developed for the project site. Since this is extremely difficult, other empirical relationships are used to assess sediment transport capacity. The most common capacity equation is stream power. While stream power can be calculated a number of ways, geomorphologists most commonly use:

$\omega = \gamma QS/W$, where Equation (2)

ω = mean stream power in W/m^2

γ = specific weight of water (9,810 N/m^3); $\gamma = \rho g$ where ρ is the density of the water-sediment mixture (1,000 kg/m^3) and g is the acceleration due to gravity (9.81 m/s^2)

Q = bankfull discharge in m^3/s

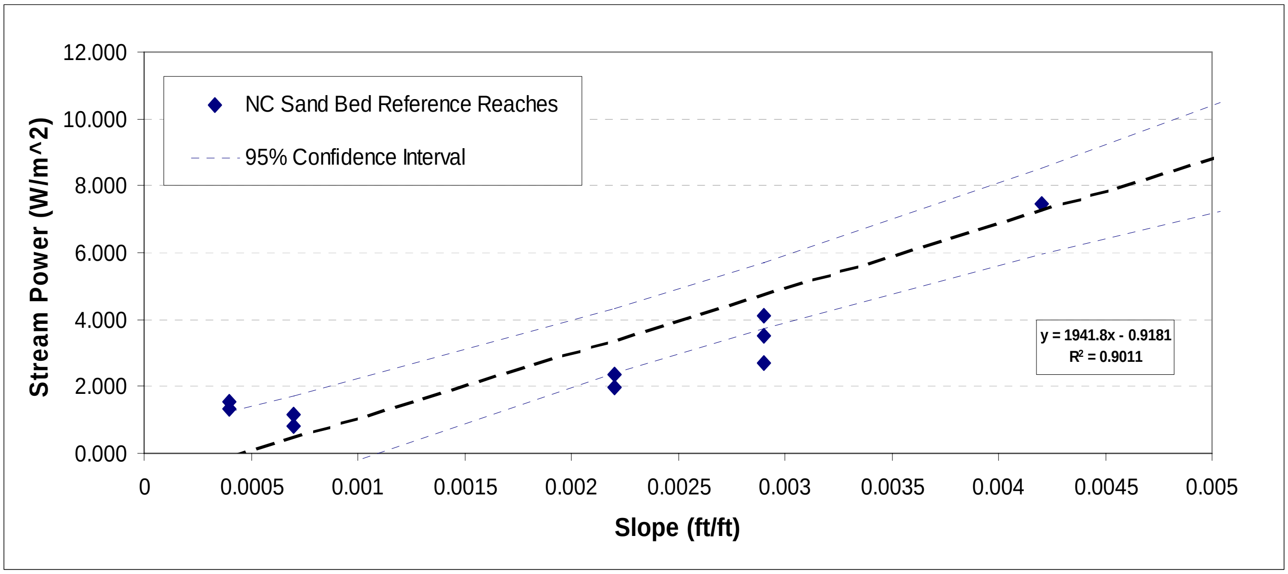
S = design channel slope (dimensionless)

W = bankfull channel width in meters

Note: 1 ft-lb/sec/ft^2 = 14.56 W/m^2

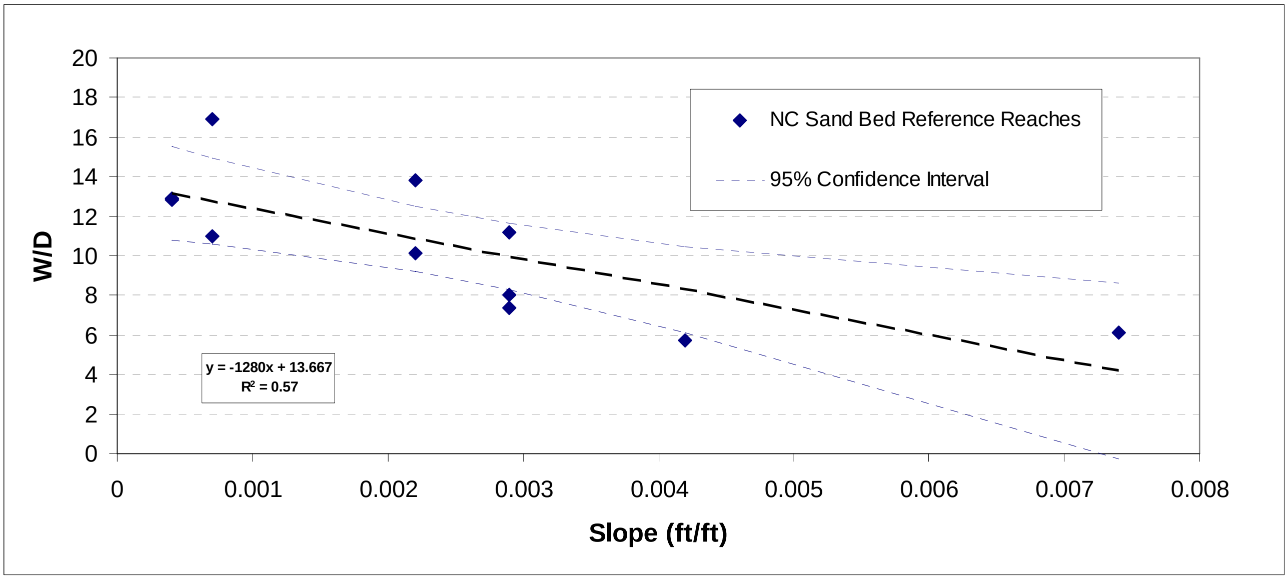
Equation 2 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work (i.e. move sediment). For this analysis, stream power values are calculated and plotted against the range of stream power values documented for stable reference streams, as shown in Figure 2.2. If the design values fall within the range of values given for stable reference streams, then the analysis provides confidence that the design stream will be able to transport its sediment load.

Figure 2.2
Stream Power and Channel Slope for Coastal Plain Reference Reaches.



As an additional check of stream design stability, the design width-to-depth ratios (W/D) are plotted against slope and compared with data from sand-bed reference reaches in the Coastal Plain. Data collected on sand-bed systems in the Coastal Plain of North Carolina indicate a strong correlation between W/D and slope, with W/D decreasing as channel slope increases. The design W/D ratios are compared with reference reach data in Figure 2.3, which shows bankfull W/D ratio versus channel slope. If the design points for the design reaches fall within the range of W/D values shown for reference reaches under similar slope conditions, it is even more likely that the design dimensions of the restored channels will remain stable.

Figure 2.3
Width-to-depth Ratio (W/D) and Channel Slope for Coastal Plain Reference Reaches.



2.7 In-Stream Structures

There are a variety of in-stream structural elements used in restoration. Exhibit 2.7 illustrates a few typical structures. These elements are comprised of natural materials such as stone, wood, and live vegetation. Their shape and location works with the flow dynamics to reinforce, stabilize, and enhance the function of the stream channel. In-stream structures provide three primary functions: grade control, stream bank protection, and habitat enhancement.

2.7.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5 percent is seldom able to maintain the desired slopes and bed features (riffles, runs, pools and glides) until a pavement/sub-pavement layer has been established. Stone and/or log structures installed at the bed elevation and at critical locations in the plan view help to set up the new stream bed for long-term vertical stability. Over time, as the new channel adjusts to its sediment transport regime and vegetative root mass establishes on the banks, the need for grade control diminishes.

2.7.2 Bank Protection

Bank protection is critical during and after construction as bank and floodplain vegetation is establishing a reinforcing root mass. This vegetation establishment lasts for several years, but vegetation is typically providing meaningful bank protection after two to four growing seasons. Bank protection structures generally provide both reinforcement to the stream banks and re-direction of flow away from the banks and toward the center of the channel.

2.7.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. The flow of water over vanes and wing deflectors creates scour pools, which provide diversity of in-stream habitat. Boulder clusters form eddies that provide resting places for aquatic species. Constructed riffles and vane structures encourage oxygenation of the water. Root wads provide cover and shade, and encourage the formation of deep pools at the outside of meander bends.

2.7.4 Selection of Structure Types

Table 2.3 summarizes the names and functions of several in-stream structures.

Table 2.3
Functions of In-Stream Structures (Rosgen, 2001b)

Structure	Function (Primary = 1, Secondary = 2)		
	Grade Control	Bank Protection	Habitat Enhancement
Cross Vane	1	1	2
Single Arm Vane		1	2
J-Hook Vane		1	2
Constructed Riffle	1	1	2
Log Weir	1		2
Wing Deflector	2	1	1
Boulder Cluster			1
Root Wad		1	1
Brush Mattress		1	2
Cover Log			1

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structure installation comprises the main, or possibly only, effort required to restore a stream. More often, structures are used in conjunction with grading, realignment, and planting in an effort to improve channel stability and aquatic habitat.

2.8 Vegetation

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize stream banks, creates habitat and a food source for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of a restoration project typically includes live dormant staking of the stream banks, riparian buffer plantings, invasive species removal, and seeding for erosion control. The stream banks and the riparian area are typically planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Establishing vegetation along the stream banks is a very desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration. During high flows, plants lie flat and stems and leaves shield and protect the soil surface from erosion. In most settings, vegetation is more aesthetically appropriate than engineered stabilization structures.

Stream banks are delineated into four zones when considering a planting scheme:

1. Channel bottom **-** extending up to the low flow stage. Emergent, aquatic plants dominate bank range, extending from the low flow stage to the bankfull stage
2. Lower bank - frequently flooded, extending from the low flow stage to the bankfull stage. A mix of herbaceous and woody plants including sedges, grasses, shrubs and trees
3. Upper bank – occasionally flooded, but most often above water. Dominated by shrubs and small trees.
4. Riparian area – infrequently flooded, terrestrial, and naturally forested with canopy-forming trees.

The most appropriate source of plant material for any project is the site itself. Desirable plants that need to be removed in the course of construction should be salvaged and transplanted as part of the restoration plan. The next best alternative is to obtain permission to collect and transplant native plants from nearby areas. This transplant process ensures that the plants are native and adapted to the locale. Finally, plants may need to be purchased. They should be obtained from a nearby reputable nursery that guarantees that the plants are native and appropriate for the locale and climate of the project site.

2.8.1 Live Staking

Live staking is a method of revegetation that utilizes live, dormant cuttings from appropriate species to cheaply, and effectively establish vegetation. The installation of live stakes on stream banks serves to protect the banks from erosion and at the same time provide habitat, shade and improved aesthetics. Live staking must take place during the dormant season (November to March in the southeast US). Live stakes can be gathered locally or purchased from a reputable commercial supplier. Stakes should be at least ½ inches in diameter and no more than 2 inches in diameter, between 2 and 3 feet in length, and living based on the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet.

2.8.2 Riparian Buffer Re-Vegetation

Riparian buffers are areas of perennial vegetation adjacent to rivers and streams and are associated with a number of benefits. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow groundwater flow. Buffers provide habitat and travel corridors for wildlife populations and are an important recreational resource. It is also important to note that riparian buffer areas help to moderate the quantity and timing of runoff from the upland landscape and contribute to the groundwater recharge process.

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Although width generally increases the capacity of riparian buffers to improve water quality and provide greater habitat value, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd et al., 1987). An estimated minimum width of 30 feet is required for creating beneficial forest structure and riparian habitat.

In stream and wetland restoration, where buffer width is often limited, the following design principles apply:

- Design for sheet flow into and across the riparian buffer area.
- If possible, the width of the riparian buffer area should be proportional to the watershed area, the slope of the terrain, and the velocity of the flow through the buffer.
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat.
- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat.

2.9 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and, most importantly, the execution of the construction phase. There are many factors that ultimately determine the success of these projects and many of the factors are beyond the influence of a designer. To compile all of the factors is beyond the scope of this report. Further, it is impossible to consider and to design for all of them. However, it is important to acknowledge those factors such as daily temperatures, the amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics, that are beyond the control of the designer.

Many restoration sites will require some post-construction maintenance, primarily because newly planted vegetation plays a large role in channel and floodplain stability. Stream restoration projects are most vulnerable to adjustment and erosion immediately after construction, before vegetation has had a chance to become fully established. Risk of instability diminishes with each growing season. Streams and floodplains usually become self-maintaining after the second year of growth. However, unusually heavy floods often cause erosion, deposition and/or loss of vegetation in even the most stable channels and forested floodplains.

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. Factors that may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

3.0 WETLAND RESTORATION BACKGROUND SCIENCE AND METHODS

3.1 The Importance of Wetlands

Wetlands are unique landscape features that can provide numerous benefits to ecosystems. They are usually delineated based on three components: hydric soils, wetland hydrology, and hydrophytic vegetation. Natural wetlands are generally formed when the geology and hydrology of an area allow for surface or groundwater to accumulate near the soil surface. Wetlands offer unique habitats for flora and fauna, remove nutrients and other contaminants, allow for surface water storage, and recharge groundwater aquifers. Wetlands help to reduce the impacts of floods, improve water quality, and provide aesthetic and recreational benefits (Mitsch and Gosselink, 2000; King et al, 2000). The functions performed by wetlands are site-specific, depending on the location in the ecosystem and environmental conditions.

Many natural processes or anthropogenic activities can impact wetlands. Wetland restoration seeks to restore wetland functions to areas that currently possess hydric soils but no longer support wetland hydrology or vegetation. Wetland restoration design must take into consideration each of the three components of wetlands (soils, hydrology, and vegetation). The following sections will provide an overview of the restoration process used by Baker Engineering.

3.2 Hydric soils

Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper horizons (Federal Register, July 13, 1994). Soil development is directly affected by the hydrology of an area, as well as by its climate, parent material, time, soil organisms, and topography. Anaerobic conditions result in specific soil biogeochemical processes, such as the retention of organic matter, the chemical reduction of nitrogen (NO_3), iron (Fe), manganese (Mn), sulfur (S), and carbon (C). When a soil is saturated, aerobic microorganisms deplete the remaining oxygen in the system. As oxygen becomes more and more limiting, anaerobic organisms begin to utilize oxidized soil components that are further reduced (Mausbach et al, 1994). The first reaction that occurs under anaerobic conditions is the reduction of nitrate. As the oxidation-reduction (redox) potential continues to decrease, manganese is reduced, then iron, and finally, sulfur and carbon. The soil pH, temperature, and mineral content are all important factors in the rates of transformation (Mitsch and Gosselink, 2000). These reduction processes result in characteristic hydric soil indicators, such as the retention of organic matter, gleyed soils, soils with low-matrix chromas, sulfur odor, etc.

There are two main types of hydric soils: organic soils and mineral soils. Organic soils, or Histosols, are soils that have more than 30 percent organic matter to a depth of 40 centimeters and that develop under nearly continuous saturation or inundation (Buol et al, 1989). These soils are also called peat or mucks. All organic soils are considered to be hydric except for Folists, which occur on dry slopes.

Hydric soils with less than 30 percent organic matter are classified as mineral soils. When saturated or inundated for extended periods of time, mineral soils develop characteristic indicators, which are a result of depletion of oxygen within the soil (Mitsch and Gosselink, 2000; US Department of Agriculture (USDA), 1996a). The reduction of nitrogen, iron, and manganese forms hydric soil indicators that are referred to as redoximorphic features (Vepraskas, 1996). Redoximorphic features include, but are not limited to: gleyed soils, soils with low-matrix chroma, redox concentrations, oxidized rhyzospheres, and iron and manganese concretions.

Wetlands are commonly referred to as the kidneys of the landscape (Mitsch and Gosselink, 2000). The analogy is applicable because wetlands filter the water that flows through them, trapping sediment and sequestering nutrients, including carbon, nitrogen, and phosphorous (Craft, 2000). Wetland soils may be factors in changing the global cycles of nitrogen, sulfur, methane, and carbon dioxide. Wetland soils help to return excess nitrogen to the atmosphere through denitrification. The use of fossil fuels has greatly increased the amount of atmospheric sulfate. When these sulfates are washed out of the atmosphere into wetlands, they can be reduced and even removed permanently from the sulfur cycle (Mitsch and Gosselink, 2000). Carbon can be sequestered into wetland soils, helping to reduce carbon dioxide concentrations.

When hydric soils are converted to agriculture, changes to the soils' chemistry and structure often occur. Once drained, wetland areas are typically graded smooth to improve surface drainage, a process that removes much of the sites' natural topographic variability. The organic content of the soils often decreases due to the oxidation caused by aeration. Concentrations of major and micro-nutrients are often increased due to the application of fertilizers. "Loose" soil structures of many wetland soils are typically converted to more blocky and massive structures, due to years of mechanized equipment traffic. Plow pans, or layers of highly compacted soil, are often present approximately 12 to 18 inches below the surface.

Assessment of on-site hydric soils begins with collected soil survey data from the Natural Resources Conservation Service (NRCS). Since soil survey data are collected on a regional scale, on-site investigations begin by evaluating the accuracy of NRCS mapping. Soil borings are conducted across the restoration site to confirm the presence of hydric soil series and the boundaries. Soil profiles are recorded for each location. For hydrologic analysis purposes, measurements of in-situ saturated hydraulic conductivity are also conducted. Under high water table conditions, the auger hole method, as described by van Beers (1970), is used. Under lower water table conditions, a constant head permeameter (amoozemeter) is used. Measurements are made at representative locations across the site to determine the variability in hydraulic conductivity across the site.

3.3 Wetland Vegetation

Wetland hydrology and hydric soils create what can be considered a harsh environment for many biotic organisms. Since many wetlands are only periodically inundated or saturated, water levels may not be consistently high or low. Many aquatic plants are not able to flourish when wetlands temporarily dry, and many xeric species are not able to adapt to conditions that are periodically wet. Wetland plants have adapted to life in this unpredictable environment.

Wetland plants, also referred to as hydrophytic vegetation, possess a range of adaptations that enable them to tolerate or avoid water stress. The three major types of adaptations are morphological, physiological, and reproductive. Morphological adaptations enable plants to increase the oxygen supply, either by growing into aerobic environments or by allowing oxygen to penetrate the anoxic zone (Mitsch and Gosselink, 2000). Various morphological adaptations that vascular plants may exhibit are buttressed tree trunks, adventitious roots, shallow root systems, floating leaves, hypertrophied lenticels, and/or multi-trunks.

Physiological adaptations to wetland environments include oxidized rhizospheres, changes in water uptake, nutrient absorption, and respiration. Some species are capable of transferring oxygen from the root system into the adjacent soil, producing oxidized rhizospheres surrounding the root. Under saturated conditions, many hydric plants have no change in their nutrient uptake, whereas flood-intolerant species lose the ability to control nutrient absorption (Mitsch and Gosselink, 2000).

Reproductive adaptations allow wetland vegetation to establish and grow within inundated soil conditions. Some of these adaptations include prolonged seed viability (including production of a large seed bank), timing of seed production in the non-saturated season, production of buoyant seeds, flood-tolerant species, and germination of seeds while fruit is attached to the tree. These reproductive, morphological, and hydrophytic adaptations allow wetland plants to flourish in relatively harsh environments and create communities of plants adapted to wetland conditions.

Plant communities generally exist along a topographic gradient. Hill tops or southwest-facing slopes tend to have the most xeric vegetation, whereas bottomlands tend to have the most mesic species. These topographic gradients tend to have plant communities directly associated with them. It should be noted that some species will be found in both xeric and mesic community types. Plant communities are based on species assemblages and not on individual species. Hydrophytic vegetation is defined by the USACE Wetland Delineation Manual as "the sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present" (USACE, 1987). According to the manual, species that have an indicator status of Obligate Wetland Plants (OBL), Facultative Wetland Plants (FACW), or Facultative Plants (FAC) are considered to be typically adapted for life in wetlands or anaerobic soil conditions. Typically, a wetland plant community contains more than 50 percent of the dominant species as OBL, FACW, or FAC species.

When restoring wetlands, Baker Engineering utilizes native plants to approximate the community that would naturally live within that physiographic community type. Species selection is based on reference wetland vegetation analyses, professional knowledge of availability and viability of specific plants, and expected post-restoration hydrologic conditions. Special emphasis is placed on re-creating a community type that is adapted to the conditions of the restoration site. The re-creation is accomplished by planting hard mast tress, lightly-seeded trees, and various understory or midcanopy, woody species. The utilization of hard mast species creates additional wildlife food sources and allows for late, successional species to become established. The utilization of lightly-seeding species allows for the faster development of wildlife cover and habitat. The planting of understory species helps to ensure a more diverse plant community that will provide long-term benefits to wildlife.

3.4 Wetland Hydrology

Wetland hydrology is often sited as the primary driving force influencing wetland development, function, and persistence (Gosselink and Turner, 1978; Sharitz et al., 1990) and also one of the hardest variables to assess and predict accurately. Hydrology drives the development of hydric soil characteristics, water and soil chemistry, and hydrophytic plant communities. Most functions commonly attributed to wetlands (water filtering, nutrient cycling, sediment trapping, ecosystem diversity, etc.) are a direct result of the hydrologic characteristics of wetland systems. For these reasons, Baker Engineering places significant emphasis on the correct assessment of wetland hydrologic conditions, under both pre- and post-restoration conditions.

Assessment of wetland hydrology begins by touring the project site to observe hydrologic conditions. When possible, site tours are conducted during dry times (several weeks following the last rainfall event) and wet times (immediately following large rainfall events). Evaluation of site conditions during dry periods provides valuable evidence about existing site function and indicates the hydrologic variability across the site. Wetland hydrology assessments during dry periods focus on the following key questions:

1. *Are there areas that are currently exhibiting wetland hydrology?* These areas require special attention and will likely be subject to regulatory permit conditions.
2. *Where are the areas of the site that appear especially dry?* These areas will likely require the greatest attention to restore wetland hydrology.
3. *What are the sources of water on the site that can be manipulated during restoration?* Sources may include groundwater discharge, run-off, surface water flows, and stream flows. Various design techniques are available for storing more water within the restoration site to

increase wetness. The primary source of water available will directly affect the type of design that will be most effective at restoring wetland hydrology.

Evaluation during wet periods allows for observations regarding runoff patterns, areas of ponding and water storage, flow routing, and surface flow interactions. Wetland hydrology assessments during wet periods focus on the following key questions:

1. *How is runoff currently being routed across the site?* Most degraded sites have been topographically manipulated to direct runoff to a drainage outlet as quickly as possible. Restoration must reduce the loss of water from the site and restore water storage functions of natural wetland sites.
2. *Are there any surface water sources that could be used in the restoration design?* Sources may include ephemeral and intermittent ditches, drainage swales, and overland flow.
3. *If steam flow or overbank flow is believed to have once contributed to wetland hydrology, can these sources be restored?* Evaluation of stream channels primarily involves the evaluation of bankfull stage in relation to existing bank heights, whether streambed elevations can be altered, and hydrologic trespass.

When necessary for accurate assessment of existing hydrologic conditions, monitoring wells are installed to document local water table conditions. Wells are installed to a depth of approximately 40 inches, following the procedures outlined under USACE's Wetland Research Program (WRP) Technical Note ERDC TN-WRAP-00-02 (July, 2000). Monitoring wells are typically installed as combinations of automated and manually-read wells. Automated wells are installed in areas where precise measurement of hydrologic conditions is necessary. Such areas may include areas near drainage features, where the prediction of the drainage effect is needed, areas where the hydrologic functioning is difficult to predict through visual assessments, and areas where the hydrologic status of an area is questionable (i.e., does wetland hydrology exist?). Manually-read wells are typically read on a monthly basis and are used to supplement the data collected with automated wells. Manual wells are typically installed in areas where the hydrologic status is predictable based on visual assessments, but measured data will allow for more conclusive evaluation of pre- and post-restoration conditions. Manual wells, installed as piezometers, can also be installed in nests to determine the direction of groundwater movement.

Accurate site mapping is essential to the evaluation of site hydrology and restoration design. Topographic maps of the site are produced using either ground or aerial survey methods. Digital elevation models (DEMs) are developed that include topographic contours (typically 1.0 foot contours or less), locations of all drainage features and outlets, structures, existing wetland areas, and monitoring well locations. DEMs are used to visually depict the hydrologic features of the site, develop hydrologic model inputs, and evaluate proposed restoration practices.

3.5 Wetland Hydrologic Analyses

Hydrology data collected at the proposed restoration site is essential for documenting the hydrologic conditions of the site at the time of collection; however, data collected over several months to a year are limited for evaluating the site's long-term performance under varying rainfall and climatic conditions. Existing condition data alone also provides little insight into how the site will perform once restoration activities are completed. For these reasons, hydrologic modeling is often used to further evaluate the potential restoration site.

The most common hydrologic model used by Baker Engineering to evaluate wetland hydrology is DRAINMOD (version 5.1). DRAINMOD has been identified as an approved hydrologic tool for assessing wetland hydrology by the NRCS (1997). DRAINMOD was developed by NC State University for the study and design of water management systems on poorly-drained, shallow water table soils. A combination of methods is used in the model to simulate infiltration, drainage, surface runoff, evapotranspiration, and seepage processes on an hour-by-hour, day-by-day basis. DRAINMOD was modified by Skaggs et al., (1991) for application to wetland determinations by the addition of a counter that calculates the number of times the water table rises above a specified depth and remains there for a given period during the growing season. For more information on DRAINMOD and its application to high water table soils, review Skaggs (1980).

DRAINMOD is used to develop hydrologic simulation models to represent conditions at a variety of locations across the proposed restoration area. Model parameters are selected based on field measurements and professional judgment about site conditions. Rainfall and air temperature information are collected from the nearest automated weather station. If automated weather stations are too far away, automated rain gauges may be installed on site. Soil parameters are determined from on-site evaluations of soil stratification and in-situ-measured hydraulic conductivity.

Measured field parameters are entered into the model, and initial model simulations are compared with observed data collected from monitoring wells. To calibrate the model, parameters not measured in the field are adjusted within the limits typically encountered under similar soil and geomorphic conditions, until model simulations most closely match observed well data.

It is important to note that DRAINMOD uses simplifying assumptions to estimate water table depths. When applied to a site with complex hydrologic processes, the model can be used to assess overall trends and relationships but is unlikely to offer exact predictions of water table hydrology. Calibration of the model is aimed at matching the relative response of water table drawdown and the overall depth that the water table reaches at different times during the year. Once these objectives are met, the model is assumed to adequately reflect the hydrologic response of the site to varying precipitation and climatic events.

Once model simulations are developed that reflect the existing conditions of the site, other simulations may be developed to represent the hydrology of the site after restoration practices have been implemented. Inputs that describe the drainage features of the site are altered to represent the restoration conditions. Inputs typically include: drainage feature spacing (increased due to the removal of ditches), drainage feature depth (typically decreased when restoring an associated stream and raising the streambed or filling and plugging drainage ditches), surface storage (increased through scarification practices), and crop inputs (conversion to trees instead of row crops). Model simulations are used to predict the changes in water table hydrology as a result of the proposed restoration practices.

DRAINMOD computes daily water balance information and develops summaries that describe the loss pathways for rainfall over the model simulation period. To compare long-term results, the amounts of rainfall, infiltration, drainage, runoff, and evapotranspiration estimated for the existing condition can be compared with simulations run for the proposed restoration practices. Infiltration represents the amount of water that percolates into the soil and is lost via drainage or runoff. Drainage is the loss of infiltrated water that travels through the soil profile and is discharged to the drainage ditches or to underlying aquifers. Runoff is water that flows overland and reaches the drainage ditches before infiltration. Evapotranspiration is water that is lost by the direct evaporation of water from the soil or through the transpiration of plants. Comparisons may include average annual amounts, annual maximums and minimums, and even day-to-day comparisons of hourly water table hydrographs.

3.6 Assessment of Existing Wetland Areas

Conditions across a potential restoration site will often vary dramatically. While much of the site may be targeted for restoration due to lack of wetland hydrology and functions, there may be areas of the site that still support wetland hydrology and wetland functions to some degree. These areas require special consideration as part of a proposed restoration design.

The proposed project area is reviewed for the presence of wetlands and waters of the United States in accordance with the provisions of Executive Order 11990, the Clean Water Act, and subsequent federal regulations. Wetlands have been defined by the USACE as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" [33 CFR 328.3(b) and 40 CFR 230.3 (t)]. Within the project area, locations that display one or more wetland components are reviewed to determine the presence of wetlands using hydrophytic vegetation, permanent or periodic inundation or saturation, and hydric soils.

Following an in-office review of the National Wetland Inventory (NWI) maps, NRCS Soil Surveys, and USGS Quadrangle maps, a pedestrian survey of the project area is made to investigate suspect areas and to delineate all wetlands and waters of the U.S. The project area is examined utilizing the jurisdictional definition detailed in the USACE Wetlands Delineation Manual. Supplementary information to further support wetland determinations is found in the *National List of Plant Species that Occur in Wetlands: Southeast (Region 2)* (Reed, 1988).

Baker Engineering collects data on the three wetland components and completes USACE wetland determination field sheets for each identified wetland area. These sheets document the wetland conditions that were observed on-site, including the presence of hydrophytic (wetland) vegetation, hydric soils, and wetland hydrology. The wetland systems are also classified using the *Classification of the Natural Communities of North Carolina, Third Approximation,* by Schafale and Weakley (1990). This classification system includes descriptions of all the natural community types in North Carolina (112 types and subtypes), including vegetation, soils, physical environment, dynamics, distinguishing features, examples, and associated rare plants. Wetlands are also classified using the *Hydrogeomorphic Classification of Wetlands* (HGM) by Brinson (1993). Since HGM subtypes are still being developed for North Carolina, HGM principles are used to describe the geomorphic setting, water sources, hydrodynamics, and functioning of identified wetland systems.

Where jurisdictional wetlands are identified, the wetland boundary is flagged with marking tape, at intervals of 25 to 50 feet. Baker Engineering follows the USACE Wilmington District procedures for survey and recordation of wetland boundaries. Surveys of wetland boundaries are conducted with either sub-meter accuracy Global Positioning System (GPS) equipment or total station survey equipment. A professional land surveyor (PLS) oversees any detailed land surveys. Wetland drawings are prepared using Geographic Information Systems (GIS) and/or computer aided design and drafting (CADD) applications and submitted to USACE and the NCDWQ for jurisdictional determination and verification when required.

3.7 Reference Wetlands

Reference wetlands are natural wetland systems that are similar in function and geomorphic setting to the proposed restoration site. Reference wetlands can be used as templates for the proposed restoration design. Data collected from reference wetland sites, including vegetation communities, hydrologic characteristics, and topographic features, can provide valuable information for the evaluation of proposed restoration practices. Analysis of the vegetation communities within the reference site is used as a tool for developing the planting plan for the restoration site. Reference wetlands can also be used for comparison purposes to determine whether the restored wetland site is on a trajectory for success during the required monitoring period.

The reference wetland site should be located as close to the proposed restoration site as possible. The reference wetland should be of the same hydrogeomorphic classification as the proposed restoration site, and generally located within the same climatic, physiographic, and ecological region. Soil characteristics should closely match those of the proposed restoration site. Fully functioning wetland systems appropriate for reference sites may be difficult to locate in some areas; as a result, reference sites are often located some distance from the restoration site.

Once a potential reference site is located, Baker Engineering secures landowner permission to further evaluate the area as a potential reference site. On-site evaluations are similar to those previously described for jurisdictional wetland areas on restoration sites and include the documentation of vegetation communities, soil series, and visual observations regarding wetland hydrology. USACE wetland determination field sheets are completed for the reference wetland.

If the reference site is found to be appropriate for the restoration project, several groundwater wells are installed across the reference site to capture the range of hydrologic conditions. Automated and manual wells are generally installed in combination, with automated wells installed at the wettest and driest extremes of conditions and manual wells installed in more average conditions. This approach allows for accurate documentation of the hydrologic range of conditions across the site. Well data are downloaded monthly throughout the required monitoring period.

3.8 Wetland Restoration Techniques

Restoration techniques will vary by the type of wetland to be restored and the goals of the restoration. The purpose of this section is to describe some of the techniques that Baker Engineering commonly uses to restore lost functions and values on wetland restoration sites.

3.8.1 Restoration Techniques for Wetland Hydrology

The restoration of appropriate hydrology is the cornerstone of any wetland restoration project. Without the appropriate hydrology, all other wetland functions will be compromised. Several commonly used techniques are described below.

Restoration of Stream Channels – Many wetland restoration sites will contain stream channels that have been channelized and straightened. Channelization of streams lowers the baseflow water elevation in the channel, lowers the adjacent water table, increases the loss of water from the site through both increased surface and subsurface drainage, and decreases the frequency and severity of flooding events on adjacent lands.

The restoration of stream channels to restore wetland hydrology involves raising the streambed elevation such that the stream is reconnected to the abandoned hydric floodplain (i.e., agricultural fields). This process raises the local water table by raising the elevation of the drainage outlet, and restores a natural flooding regime to the site. For more information on stream restoration practices, see Sections 2.1, 2.2, and 2.5.

Filling and Blocking of Drainage Features – Drainage features may include ditches, channels, swales, and subsurface drains. Ditches are the most common drainage feature encountered on agricultural sites. Ditches are generally constructed on parallel spacings that are based on the drainage characteristics of the soils. Ditches and subsurface drains provide an outlet for subsurface drainage that is often several feet lower than the surrounding ground elevation. The effect is that groundwater moves toward the ditches where it is discharged, thus lowering the water table elevation.

Filling and blocking of drainage features removes the drainage effect they provide. The choice between partially blocking and completely filling the drainage features is primarily driven by the amount of soil that must be disposed of during construction. When there is an excess of soil to be disposed of, ditches and swales are completely filled. When the quantity of soil for disposal is limited, ditches and swales are blocked by partially filling, or plugging, the features at specific locations. Plugs are at least 50 to 100 feet in length, and soil material placed for the plugs is compacted with heavy equipment, used on site during construction. The actual length of the plugs will be based on the predicted hydraulic conductivity of the compacted fill material. The spacing between plugs will vary, depending on the slope of the site and the amount of soil for disposal.

Once ditches have been filled in or plugged, additional fill material will be piled over the filled ditch to a height of no more than six inches, to allow for subsidence and settling of the fill over time. Without additional material, settling of the fill could cause the drainage feature to partially reform over time and affect the hydrology of the site.

Subsurface drains, such as tiles and plastic pipe, are located and excavated so that they no longer function. Once drains have been removed, excavated soil material is placed back in the excavated trench and compacted.

Run-off Diversions – In some areas, it is beneficial to construct shallow diversions and swales to direct surface water run-off into the site. This practice is commonly used when restoration areas are adjacent to long hill slopes, where significant amounts of run-off may be produced during large rain events. The diversions are used to direct the run-off to areas of the restoration site where the additional water inputs are most needed.

Shallow Depressions and Floodplain Pools – To increase the diversity of hydrologic conditions across the site, shallow depressions and floodplain pools can be excavated or created by leaving sections of ditches only partially filled in certain areas. The depressions are constructed to mimic the function of natural sloughs and pools commonly found across many wetland ecosystems. These areas provide increased surface storage of precipitation and floodwaters, improve biotic diversity, and provide breeding areas for a number of amphibian and reptile species.

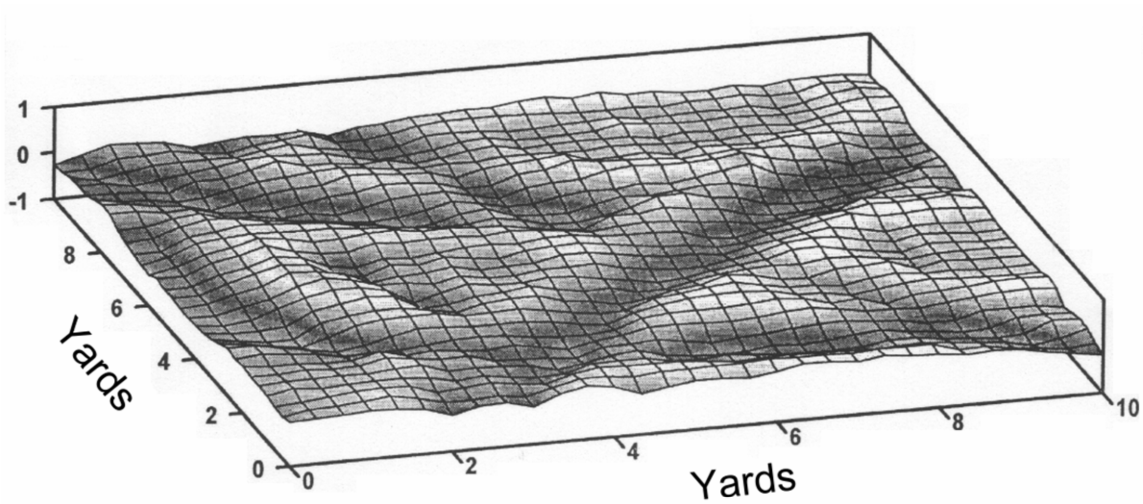
Depressions and pools are generally constructed to be less than one foot deep. The size of depressions can vary, depending on the site; however, depressions 200 feet by 100 feet are typical of many sites. The depressions are designed to hold water for extended periods, ranging from several weeks to many months. For many amphibian species, it is crucial that the pools dry up completely during the late summer months. These ephemeral pools are typically constructed in higher elevation areas away from the active stream channel. For other species, pools that retain some degree of ponded water throughout the year are most beneficial. These features, which represent backwater sloughs, oxbow ponds, and floodplain pools, are typically constructed near the active stream channel, where the high water table conditions and frequent flooding will maintain water levels in the pools.

Restoration of Microtopography – In order to improve drainage and increase agricultural production, farmed wetland soils are often graded to a smooth surface and crowned to enhance run-off. Microtopography contributes to the properties of forest soils and to the diversity and patterns of plant communities (Lutz, 1940; Stephens, 1956; Bratton, 1976; Ehrnfeld, 1995). The introduction of microtopography also increases surface storage on the site, reducing run-off and erosion and enhancing infiltration.

Microtopography is established on the restored site after design grades have been achieved, using the procedures described by Scherrer (2000). The equipment should leave a furrow approximately seven feet wide and six inches deep, and a corresponding mound approximately seven feet wide and six inches high. The equipment should be run in parallel lines approximately 25 feet apart, and then over the same area in “figure 8” patterns to create a random pattern of interconnected and isolated furrows and ridges, as shown in Figure 3.1.

The actual distance between furrows and mounds and the height of the mounds can be adjusted depending on the targeted amount of surface storage to be restored.

Figure 3.1
Typical Pattern of Restored Wetland Microtopography (Scherrer, 2000).



3.8.2 Restoration Techniques for Wetland Soils

Soil Scarification and Tillage – Disking and tillage practices commonly used in agriculture can be used to break the plow pan and reduce compaction of the soil caused by years of agricultural production. Tillage practices will also be used to remove any field crowns, restoring a more natural topography to the site. When necessary, rippers will be used to till to depths of 12 to 18 inches to break any compacted pan layers.

Soil Amendments – Samples of top soil from the site can be collected and tested to determine soil fertility and chemical properties. If necessary, soil amendments (fertilizer, lime, etc.) will be applied at rates appropriate for the target vegetation. For land which has been in agricultural production for a number of years, it is likely that soil fertility will be high and amendments will not be necessary.

3.8.3 Restoration Techniques for Wetland Vegetation

Tree Planting Techniques – Under typical conditions, bare-root tree species will be planted within all areas of the site conservation easement. Bare-root vegetation is typically planted at a target density of 680 stems per acre, or an 8 by 8 foot grid. Experience has shown this density to be favorable for overall survival of at least 320 planted stems at the end of 5 years, which is a common success criterion for mitigation sites. Planting of bare-root trees is conducted during the dormant season, which lasts from late November to early March for most of the state.

Species selection is based on reference wetland vegetation analyses, professional knowledge of availability and viability of specific plants, and expected post-restoration hydrologic conditions. Species selection for revegetation of the site will generally follow those suggested by Schafale and Weakley (1990) and tolerances cited in WRP Technical Note VN-RS-4.1 (1997). Tree species selected for restoration will generally range from weakly tolerant to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive on soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997).

Observations are made during construction of the site regarding the relative wetness of areas to be planted. Planting zones are determined based on these assessments, and planted species will be matched according to their wetness tolerance and the anticipated wetness of the planting area.

When feasible, trees are transported to the site from the nursery and stored on-site in a refrigerated cooler prior to planting. If on-site refrigeration is not available, trees are planted within two days of being transported to the site. Soils across the site are sufficiently disked and loosened prior to planting. Trees are planted by manual labor, using a dibble bar, mattock, planting bar, or other similar method. Planting holes for the trees are made sufficiently deep to allow the roots to spread out and down without "J-rooting." Soil is loosely compacted around trees once they have been planted to prevent them from drying out.

<u>Permanent Seed Mixtures</u> – Permanent seed mixtures are applied to all disturbed areas of the project site. Different mixtures may be specified for different areas of the site, depending on the wetness and degree of stabilization required at the site. Mixtures will also include temporary seeding to allow for application with mechanical broadcast spreaders and rapid ground cover following application. Temporary seeding is applied to all disturbed areas of the site that are susceptible to erosion, including constructed streambanks, access roads, side-slopes, spoil piles, etc.

3.9 Application of Fluvial Processes to Stream and Wetland Restoration

A stream and its wetland floodplain (referred to here as the riparian area) comprise a dynamic environment where the floodplain, wetland areas, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflects all of these factors (Leopold et al., 1992; Knighton, 1998). The size and flow of the stream channel also influence the size and functioning of wetland areas adjacent to the channel. The result is a dynamic equilibrium in which the stream maintains its dimension, pattern, and profile over time, and adjacent wetland areas evolve with the meandering of the stream across its floodplain. Land use changes in the watershed, including increases in imperviousness, removal of riparian vegetation, and drainage of adjacent wetlands can upset this balance. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). These adjustments in channel form often have negative effects on associated wetland areas, as processes of channel incision increase drainage of adjacent areas. By understanding and applying the processes of riparian form and function to stream and wetland restoration projects, a self-sustaining riparian system can be designed and constructed that maximizes ecosystem function and potential.

In riparian systems, wetland functions cannot be restored without also addressing the restoration of stream functions; therefore, it is crucial that the degraded stream system be restored to the appropriate dimension, pattern, and profile while allowing the stream access to the abandoned floodplain and associated wetland areas. In this way, the stream becomes one of the primary sources of water and nutrient inputs to the wetland system. As such, the development of stream and wetland design components becomes an iterative process.

4.0 WATERSHED ASSESSMENT RESULTS

4.1 Watershed Delineation

The Duke Swamp Restoration Project is located in Gates County, approximately nine miles northeast of the city limits of Gatesville. The area lies within cataloging unit 03010203, and NCDENR sub-basin 03-01-01 of the Chowan River Basin (Exhibit 1.1).

The watershed areas for the project reaches were determined by delineating watersheds on the USGS 7.5 minute topographic quadrangle. The drainage areas for the site were difficult to determine due to level of altered drainage patterns and lack of topographic relief in the area. The UT1 drainage area at the outlet of the project area is estimated to be approximately 3.0 square miles and the UT2 drainage area is approximately 0.03 square mile. Exhibit 1.3 shows the watershed boundaries for the project.

4.2 Surface Water Classification

NCDWQ designates surface water classifications for water bodies such as streams, rivers, and lakes, which define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications carry with them an associated set of water quality standards to protect those uses. All surface waters in North Carolina must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Classifications and their associated protection rules may also be designed to protect the free flowing nature of a stream or other special characteristics.

The project will involve two sections of unnamed tributaries (UT1 & UT2) to Duke Swamp, which flow into Lassiter Swamp. Duke Swamp, in this area, is classified as "C" waters, indicating that the streams are considered to support aquatic life and secondary recreational uses. These waters also have a nutrient sensitive waters (NSW) designation, meaning that such waters are subject to excessive growth of microscopic or macroscopic vegetation (NCDENR, 2006). Restoration of the site would reduce the amount of sediment and nutrients being discharged into the system, improving the overall water quality in Duke and Lassiter Swamps.

4.3 Geology

The Duke Swamp Site is located in central Gates County in the Coastal Plain physiographic region of North Carolina. The underlying geology of the project area is within the Yorktown and Duplin formations. The Yorktown formation consists of fossiliferous clay and varying amounts of bluish gray fine-grained sand, shell material. The Duplin formation consists of medium to course grained bluish gray shelly sand, sandy marl, and limestone (Geologic Map of North Carolina, NC Geological Survey, 1998).

4.4 Land Use

The land uses within the project area consist of row crop agriculture and forest. The watershed is mostly rural with land uses that include crop agriculture, forested areas and some residential property. Kellogg Fork Road (SR1320), a paved roadway, bounds the project site on the upstream portion. An unpaved farm road crosses the UT1a with a culvert.

4.5 Endangered/Threatened Species

Some populations of plants and animals are declining, either as a result of natural forces or difficulty in competing with humans for resources. Plants and animals with a federal classification of Endangered (E), Threatened (T), Proposed Endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. Federally classified species listed for Gates County, and any likely impacts to these species as a result of the proposed project construction, are discussed in the following sections.

Federally protected species listed as occurring in Gates County by the North Carolina Natural Heritage Program (NCNHP) as of August 15, 2006, are listed in Table 4.1. A brief description of the characteristics and habitat requirements of these species follows the table, along with a conclusion regarding potential project impact.

Letters were sent to the US Fish and Wildlife Service (USFWS) and NC Wildlife Resources Commission (NCWRC) in July 2006, requesting each agency comment on the proposed project. USFWS has no comments on the proposed project. Correspondence with these resource agencies was previously provided to the Ecosystem Enhancement Program (EEP).

Table 4.1
Species Under Federal Protection in Gates County

Family	Scientific Name	Common Name	Federal Status	Date Listed	State Status	Habitat Present / Biological Conclusion
			Vertebrates			
Alligatoridae	*Alligator mississippieniss*	American Alligator	T (S/A)	6-4-1987	T	No /No Effect
Picidae	*Picoides borealis*	Red-cockaded woodpecker	E	10-13-1970	E	No /No Effect

Notes:

E An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.

T Threatened

S/A Threatened due to similar appearance

4.5.1 Federally Protected Species

4.5.1.1 Vertebrates

American Alligator

Alligators are large, lizard-like reptiles with broadly rounded snouts. Adults are 6 to 12 feet long and can reach lengths of 15 feet or more. They are blackish in appearance, but have pale crossbands on the back and vertical markings on the sides. Alligators inhabit rivers, swamps, estuaries, lakes, and marshes throughout the southeastern United States, from North Carolina to Texas.

A Biological Conclusion is not required, since Threatened Due to Similarity of Appearance [T (S/A)] species are not afforded full protection under the ESA; however, there is no suitable habitat present within the project boundaries, and the project is not expected to have any impact on this species.

Red-Cockaded Woodpecker

The red-cockaded woodpecker once occurred from New Jersey to southern Florida and west to eastern Texas. It occurred inland in Kentucky, Tennessee, Arkansas, Oklahoma, and Missouri. The red-cockaded woodpecker is now found only in coastal states of its historic range and inland in southeastern Oklahoma and southern Arkansas. In North Carolina moderate populations occur in the Sand Hills and southern Coastal Plain. The few populations found in the Piedmont and northern Coastal Plain are believed to be relics of former populations.

The red-cockaded woodpecker is approximately eight inches long with a wingspan of 14 inches. Plumage includes black and white horizontal stripes on its back, with white cheeks and under parts. Its flanks are streaked black. The cap and stripe on the throat and side of neck are black, with males having a small red spot on each side of the cap. Eggs are laid from April through June. Maximum clutch size is seven eggs with an average of three to five.

Red-cockaded woodpeckers are found in open pine stands that are between 80 and 120 years old. Longleaf pine stands are most commonly utilized. Dense stands are avoided. A forested stand must contain at least 50 percent pine, lack a thick understory, and be contiguous with other stands to be appropriate habitat for the red-cockaded woodpecker. These birds forage in pine and pine hardwood stands, with preference given to pine trees that are 10 inches or larger in diameter. The foraging range of the red cockaded woodpecker is up to 500 acres. The acreage must be contiguous with suitable nesting sites. While other woodpeckers bore out cavities in dead trees where the wood is rotten and soft, the red-cockaded woodpecker is the only one that excavates cavities exclusively in living pine trees. The older pines favored by the red-cockaded woodpecker often suffer from a fungus called red heart disease which attacks the center of the trunk, causing the inner wood to become soft. Cavities generally take one to three years to excavate. The red-cockaded woodpecker feeds mainly on beetles, ants, roaches, caterpillars, wood-boring insects and spiders, and occasionally fruits and berries.

Mature pinewoods and pocosin species are not present in the immediate area of the proposed project. It is concluded that the project will not impact this endangered species.

4.5.2 Federal Species of Concern and State Status

Federal Species of Concern (FSC) are not legally protected under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. Table 4.2 includes FSC species listed for Gates County and their state classifications. Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded state protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979. However, the level of protection given to state-listed species does not apply to NCDENR EEP activities.

Table 4.2
Federal Species of Concern in Gates County

Scientific Name	Common Name	Federal Status	State Status
Ammodramus henslowii susurrans	Eastern Henslow's sparrow	FSC	SR
Myotis austroriparius	Southeastern myotis	FSC	SC
Dendroica virens waynei	Black-throated green warbler	FSC	SR
Corynorhinus rafinesquii macrotis	Rafinesque's big-eared bat	FSC	T
Ludwigia ravenii	Raven's seedbox	FSC	SR-T
Litsea aestivalis	Pondspice	FSC	SR-T
Trillium pusillum var. virginianum	Virginia least trillium	FSC	E
Sagittaria weatherbiana	Grassleaf arrowhead	FSC	SR-T

4.6 Cultural Resources

Baker Engineering sent a letter on July 31, 2006 requesting that the North Carolina State Historic Preservation Office (SHPO) review the potential for cultural resources in the vicinity of the Duke Swamp restoration site. A response letter dated August 23, 2006 indicated that SHPO had reviewed the proposed project and was not aware of any historic resources which would be affected by the project. A copy of the SHPO correspondence is included in Appendix A.

4.7 Potentially Hazardous Environmental Sites

Baker Engineering obtained an EDR Transaction Screen Map Report, dated August 2, 2006, that identifies and maps real or potential hazardous environmental sites within the distance required by the American Society of Testing and Materials (ASTM) Transaction Screen Process (E 1528). The overall environmental risk for this site was determined to be low. Environmental sites, including Superfund (National Priorities List [NPL]); hazardous waste treatment, storage, or disposal facilities; the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS); suspect state hazardous waste, solid waste, or landfill facilities; or leaking underground storage tanks were not identified by the report in the proposed project area. During field data collection, there was no evidence of these sites in the proposed project vicinity. A copy of the EDR Report is included in Appendix B.

4.8 Potential Constraints

Baker Engineering assessed the Duke Swamp project site in regards to potential fatal flaws and site constraints. No fatal flaws have been identified during project design development.

4.8.1 Property Ownership and Boundary

Baker Engineering has entered into an agreement for the acquisition of a perpetual conservation easement with the landowners of the Duke Swamp Tributary Project. The conservation easement plat and documents have been reviewed and approved by the State Property Office. At the publication of this report, the required signatures have been obtained from the landowners and the easement documents were recorded at the Gates County courthouse on April 2, 2007. Copies of the recorded conservation easement deeds are located in Appendix A.

4.8.2 Hydrologic Trespass

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Panels 370103-0134B and 370103-0150B classify the Duke Swamp project site as a Zone A Special Flood Hazard Area (SFHA). Lands classified as Zone A-SFHA are subject to inundation during the occurrence of 1% annual chance (100-year) flow. Flood flows may reach the area either from the upstream contributing watershed or due to backwater flooding from downstream water bodies. Detailed hydraulic analyses have not been performed for areas classified as Zone-A, and base flood (100-year) elevations for these areas have not been determined by FEMA.

One of the factors that affect the hydrology of the Duke Swamp project site is its downstream boundary condition. A defined drainage channel approximately 4 feet deep runs through the center of the site. At the downstream end of the site, the invert of the drainage channel rises to meet the existing floodplain (overbank) elevation, transitioning into the swamp and wetland area of the Duke Swamp stream. This downstream condition causes base flow levels through the Duke Swamp site to be regulated by the highest terrain elevation between the upstream area of the site where there is a defined channel and the area downstream of the site that forms part of the Duke Swamp wetland area. Flood stages through the site occurring during low flows will be defined by the magnitude of discharge received from the upstream contributing watershed. However, during high flows the entire site will be flooded with backwater from the Duke Swamp wetland area immediately downstream, and flood levels will be defined by downstream flood elevations.

A hydraulic model was constructed within the HEC-RAS software environment to study flow behavior through the site under the 10-, 25-, 50-, and 100-year flows. For this hydraulic model, it was required to set a downstream boundary flood elevation which the model would use as datum to perform its calculations. For this site, the downstream boundary flood elevation would be the water surface elevation at the highest point of the downstream end of the site, which is equivalent to the flood elevations at the downstream Duke Swamp stream and swamp/wetland area. However, since flood levels have not been determined by FEMA for the Duke Swamp stream and wetland area, information on flood elevations for the Duke Swamp area for the various flows under study were not available.

Lacking specific flood elevations to set as the hydraulic model's downstream boundary condition, the model was run numerous times, varying the downstream boundary flood elevation from the minimum expected during dry periods (terrain elevation of the highest point at the downstream end of the site) to the highest expected during the 100-year flood (terrain elevation enclosing the limits of the 100-year floodable area shown in the FEMA FIRM map; this elevation is at least 3 feet above floodplain level at the downstream Duke Swamp area). The model was run for the 10-, 25-, 50-, and 100-year flows, and for each flow magnitude the hydraulic simulation was repeated varying the downstream boundary elevation increments of 0.25 ft. This procedure was done for both existing and proposed site conditions.

The results from this hydraulic analysis showed that for the entire range of boundary conditions tested, construction of the proposed stream restoration project will not increase flood levels upstream nor downstream of the site, for any of the 10-, 25-, 50-, or 100-year flows.

No specific base flood elevations have been determined for Zone A areas.

4.8.3 Site Access

The site is connected to North Carolina Department of Transportation (NCDOT) right of way (ROW) (SR 1320) and a farm road which can be accessed for construction and post-restoration monitoring.

4.8.4 Utilities

The site has an underground fiber optic line that runs along the NCDOT ROW (SR 1320) on the project side but will not impact the design/construction and will be avoided.

4.8.5 Threatened and Endangered Species

Rare, threatened, and endangered species occurrences were examined as part of the existing conditions survey (Section 4.6). It is anticipated that no rare, threatened, or endangered species will be affected by this project.

4.8.6 Cultural Resources

No known cultural or archaeological sites are recorded within the property boundary. It is anticipated that this project will have no impact on such sites.

4.8.7 Farm Operations

The Duke Swamp Site Parcel is actively used for agricultural purposes. Therefore, the project must not interfere with the operational needs of the farm. The final project design will need to incorporate one stream crossing and field access.

4.8.8 Soils

Soils have been investigated and no constraints or fatal flaws were identified.

5.0 EXISTING WETLAND CONDITIONS

5.1 Wetland Assessment Results

The proposed project area was reviewed for the presence of wetlands and waters of the United States in accordance with the provisions of Executive Order 11990, the Clean Water Act, and subsequent federal regulations. Wetlands have been defined by the USACE as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (33 CFR 328.3(b) and 40 CFR 230.3 (t)). The areas in the project area that displayed one or more wetland characteristics were reviewed to determine the presence of wetlands. The wetland characteristics included:

1. Prevalence of hydrophytic vegetation.
2. Permanent or periodic inundation or saturation.
3. Hydric soils.

5.1.1 Wetland Impacts

Under existing conditions, the field areas proposed for wetland restoration are drained by a series of lateral ditches, drain tiles, and excavated ponds that provide conditions favorable for agricultural production. Most wetland areas that once existed on the site were drained and manipulated to promote agricultural uses. Approximately 3,740 LF of stream were channelized within the project area to improve surface and subsurface drainage and to decrease flooding. As a result, the open field areas of the site have been designated "prior-converted," or PC, by the NRCS (Exhibit 5.1).

5.1.2 Jurisdictional Wetland Findings

The adjacent areas on both sides of UT1a have been cleared of woody vegetation along the entire reach. The stream bank areas of UT1a are periodically maintained by mowing. A small amount of wooded buffer is present at the downstream end along reach UT1b but the channel is overly wide with side cast spoil present on both sides. The site agricultural areas proposed for restoration are drained and mapped primarily as "A" list hydric soils (Nawney series). Nawney soils are classified as poorly drained soils that formed in loamy fluvial sediments. The site is mapped as PC wetlands by the NRCS.

Based on available map sources (U.S. Geological Survey 7.5-minute Topographic Quadrangle; USDA, NRCS Soils Survey for Gates County; and USFWS National Wetlands Inventory), the ditched channel (UT1) and delineated wetlands within the project area are depicted on Exhibit 5.1. Specific field review by Baker wetland scientists on November 21, 2006 and GIS mapping developed for the project (2-foot Topographic Contours; 2005 Color Aerial Photography; Exhibit 5.1) confirmed that current jurisdiction, per the USACE 1987 Wetland Delineation Manual, is limited to the ditched channel and vegetated banks, excavated ponds (open water and vegetated littoral zones), and several small wet pockets within the field areas. Former wetlands adjacent to the stream channel no longer support hydrophytic vegetation and have been designated PC by the NRCS. Jurisdictional waters were delineated in the field using hand-held Global Positioning System (GPS) technology with sub-meter accuracy. The flagged jurisdictional boundaries are depicted on Exhibit 5.1.

As a result of the Supreme Court decisions in United States v. Rapanos and United States v. Carabell, USACE and the U.S. Environmental Protection Agency (EPA) are developing a policy that will clarify the methods that describe and document jurisdictional determinations. This policy may impact jurisdictional determinations, in cases where there are intermittent or ephemeral streams or wetlands adjacent to intermittent, ephemeral or perennial streams. In light of the pending release of formal guidance on this issue, when there are these types of waters present on a site, the USACE Wilmington District will not issue a final determination until the final or additional interim guidance is issued by headquarters. USACE has not been given a timeframe for the issuance of any formal guidance. The Wilmington District will continue to make jurisdictional determinations, based on existing procedures, for waters not affected by the rulings. These include:

- Traditional navigable waters (Section 10);
- Isolated, non-navigable, intrastate (SWANCC);
- Wetlands or waters abutting Section 10 waters; and
- Natural tributaries that are relatively permanent, standing or continuously flowing, bodies of water such as streams and rivers.

The pending guidance affects procedures for processing stand-alone jurisdictional determinations. The Wilmington District is continuing to process and issue permits without delay. If forthcoming guidance should change USACE jurisdiction, then permit holders can request a revised jurisdictional determination; and corresponding permit requirements, such as mitigation, may be re-visited.

5.2 Soils

Soils types at the site were evaluated using NRCS Soil Survey data for Gates County (USDA 1996b), along with on-site evaluations to verify areas of hydric soil. A map depicting the boundaries of each NRCS soil type is presented in Exhibit 5.2. The majority of the site is mapped as the Nawney Series. The Nawney series is a Hydric “A” soil and consists of poorly drained soils that formed in loamy fluvial sediments. Slopes range from 0 to 2 percent. Nawney soils are typically found on flood plains throughout Gates County and are frequently flooded for long periods. Nawney soils have moderate water capacity and permeability.

Table 5.1
Project Soil Types and Descriptions (from Gates County Soil Survey, USDA-NRCS, 1996)

Soil Name	Location	Hydric List	Description
Nawney	Flood plains	A	Poorly drained soils that formed in loamy fluvial sediments. Slopes range from 0 to 2 percent with moderate water capacity and permeability
Noboco	Broad smooth upland areas	-	Well drained soil with slopes from 0 to 2 percent. Permeability and water capacity are moderate.
Goldsboro	Smooth ridges	-	Moderately well drained. Permeability and water capacity is moderate with slopes from 0 to 3 percent.

The Noboco, and Goldsboro series are mapped on small areas along the boundary of the site. Noboco soil is found on the southern boundary of the project. These soils are well drained and have a moderate permeability and available water capacity. They are typically found on broad smooth upland areas. Goldsboro soils are found in the northeast section of the project boundary. This is a moderately well drained soil with moderate permeability and water capacity. Noboco and Goldsboro soils are located on higher elevation areas of the site outside the boundaries of the proposed wetland restoration areas.

While on-site investigations indicated variations in soil profile, all areas proposed for restoration were found to exhibit hydric indicators. Typical hydric indicators included a gleyed and a reduced matrix in the sub-soil, indicating that the soils were formed under reduced conditions and that the site once functioned as a wetland system.

5.3 Climatic Conditions

The average growing season (defined as the period in which temperatures are maintained above 28 degrees Fahrenheit under average conditions) for Gates County is 232 days, beginning on March 25 and ending November 11. Gates County has an average annual rainfall of 50.39 inches (NRCS, 1996). In much of the Coastal Plain of North Carolina, approximately 36 inches of water are lost to evapotranspiration during an average year (Evans and Skaggs, 1985). Since average rainfall exceeds average evapotranspiration losses, the Coastal Plain experiences a moisture excess during most years. Excess water leaves a site by groundwater flow, runoff, channelized surface flow, or deep seepage. Annual losses due to deep seepage, or percolation of water to confined aquifer systems, are typically less than one inch of water for most Coastal Plain areas and are not a significant loss pathway for excess water. Although groundwater flow can be significant in some systems, most excess water is lost via surface and shallow subsurface flow.

Monthly precipitation amounts observed from January through December 2006 are compared with Gates County WETS table average monthly rainfall, in Table 5.2. Precipitation data collected during the monitoring period from August 2006 through January 2007 indicate that slightly lower than average rainfall occurred, however, monthly variability was high. Rainfall for the beginning of the monitoring period was lower than average, yet higher than average rainfall occurred during November at the end of the growing season.

Table 5.2
Comparison of Monthly Rainfall Amounts for Project Site and Long-Term Averages

Month-Year	Observed Monthly Precipitation (in)	WETS Table Average Monthly Precipitation (in)	Deviation of Observed from Average (in)
Jan-06	2.28	4.49	-2.21
Feb-06	1.33	4.26	-2.93
Mar-06	0.64	4.71	-4.07
Apr-06	2.91	3.52	-0.61
May-06	2.96	4.56	-1.6
Jun-06	8.85	3.95	4.9
Jul-06	8.88	4.52	4.36
Aug-06	2.13	4.85	-2.72
Sep-06	2.4	4.45	-2.05
Oct-06	4.55	3.65	0.9
Nov-06	8.19	3.28	4.91

Dec-06	2.61	4.15	-1.54
Sum	**47.73**	**50.39**	**-2.66**

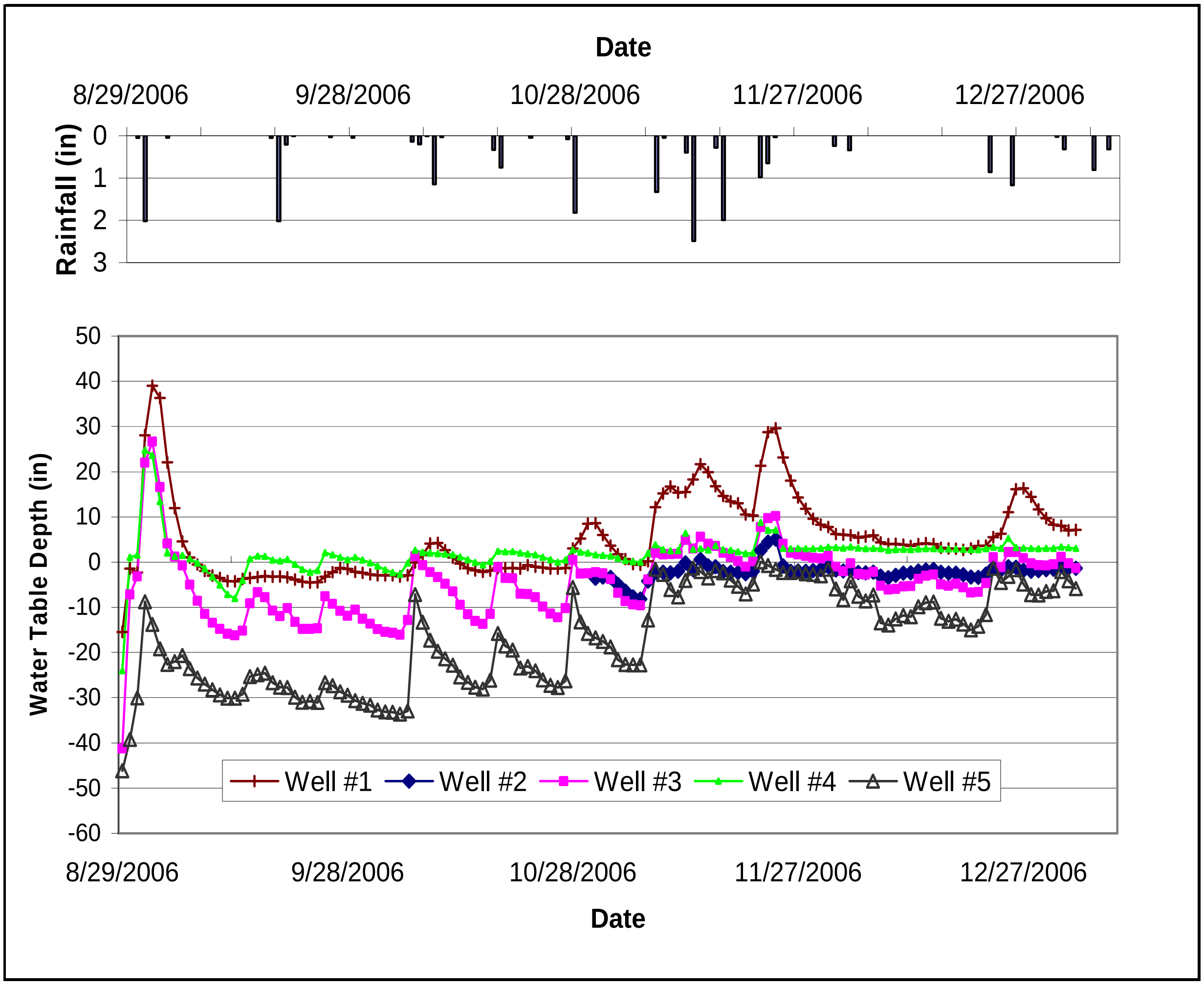
5.4 Site Hydrology

The presence of hydric soils over much of the project site is evidence that the site historically supported a wetland ecosystem. As is the case in much of the Coastal Plain, local drainage patterns have been altered over the last two centuries to increase drainage and promote agricultural production. Exhibit 5.3 demonstrates the amount of ditching and channelization that has been performed on UT1, the main stream that runs through the property. During conversion of the site, stream channels and wetland systems through the site were channelized to improve drainage. The existing hydrology of the site is controlled by a channelized stream (UT1) which bisects the project boundaries. There are three irrigation ponds and approximately 6.5 acres of existing wetlands within the project limits. Precipitation that falls on the farm field areas diverts to the drainage ditches and channelized stream.

Five automated groundwater wells were installed in or near the project area to evaluate current hydrologic conditions across the site, as shown in Exhibit 5.3. These wells provide a base for comparing pre- and post-restoration hydrology on the site. Water table data were collected from the five automated groundwater wells, from August 2006 through January 2007; therefore, the majority of the data were collected during the dormant season. The automated wells were installed in open field areas targeted for restoration, within existing wet pockets in the fields and in the swamp at the lower end of the site. The wells were installed to a depth of 40 inches, and automated loggers (Infinities USA pressure transducer units) were programmed to record water table levels every 12 hours.

Well #1 is located in the middle of the existing swamp system at the western end of the project site. In this area, the swamp was saturated or flooded for the entire period of monitoring from August to January and is considered to be in a jurisdictional wetland area. Well #2 is located along the northern side of UT1. This area is lower in topography than the wells on the eastern side of the project limits. Flooding and backwater conditions from the downstream swamp drive the hydrology of this area. During the monitoring period, the water table has been just below the surface, due to consistent rainfall and backwater flooding from the swamp. Well #3 is located adjacent to the southern side of the UT1 and the third pond located in the middle of the project limits. The location of Well #4 is midway between the second and third ponds. Well #5 is located next to UT1 and the first pond, at a slightly higher elevation than the other wells. The greatest drainage effect of the channelized stream is shown in the hydrographs of Well #3 and #5, where there are periods during which the water table is at the surface during high rainfall but quickly recedes after the rain ends. The peaks of the hydrograph correlate well with the rain events (Figure 5.1). Data collected from these well locations represent the range of conditions across the project site.

Figure 5.1
Hydrographs of the Groundwater Monitoring Wells Compared to Local Rainfall on the Duke Swamp Site (August 2006 through December 2006).



5.5 Hydrologic Modeling

To further investigate the current hydrologic status of the site and provide a means for evaluating proposed restoration plans, hydrologic models were developed to simulate site hydrology. DRAINMOD (version 5.1) was used to develop hydrologic simulation models to represent conditions across the proposed restoration area. DRAINMOD was identified as an approved hydrologic tool for assessing wetland hydrology by the NRCS (1997). For more information on DRAINMOD and its application to high water table soils, review Skaggs (1980).

Model parameters were selected based on field measurements and professional judgment about site conditions. Rainfall and air temperature information were collected from the nearest automated weather station, in Elizabeth City (Elizabeth City, NC, COOP: 312724). Missing data from the Elizabeth City station were supplemented with data from the Roanoke Rapids (COOP: 317319) and Scotland Neck (COOP: 318500) weather stations. Measured field parameters were entered into the models, and initial model simulations were compared with data collected from the monitoring wells. To calibrate the model, parameters not measured in the field were adjusted within the limits typically encountered under similar soil and geomorphic conditions, until model simulations most closely matched observed well data.

Trends in the observed data were well represented by the model simulations; however, it should be noted that a limited amount of observed data were available for comparison. It is important to note that DRAINMOD uses simplifying assumptions in the estimation of water table depths. When applied to a site such as the Duke Swamp Site, with complex hydrologic processes, the model can be used to assess overall trends and relationships but is unlikely to offer exact predictions of water table hydrology. See Appendix C for DRAINMOD Analysis Files & Restoration Site Water Table Data.

DRAINMOD computes daily water balance information and produces summaries that describe the loss pathways for rainfall over the model simulation period. Table 5.3 summarizes the average annual amount of rainfall, infiltration, drainage, runoff, and evapotranspiration estimated for the existing condition of the project area, based on 58-year simulations. The average amounts for the simulated areas, as well as the minimum and maximum values, are presented in the table. Infiltration represents the amount of water that percolates into the soil and is lost via drainage or runoff. Drainage is the loss of infiltrated water that travels through the soil profile and is discharged to drainage ditches or underlying aquifers. Runoff is water that flows over land and reaches drainage ditches before infiltration. Evapotranspiration is water that is lost through direct evaporation of water from the soil or through the transpiration of plants.

From the data provided, it is clear that a significant amount of the rainfall on the site is lost to evapotranspiration, which is typical for farm fields in the Coastal Plain of North Carolina. Drainage is also a significant loss pathway for water under the existing farm conditions. Restoration of the site will involve restoring a floodplain area, plugging the network of drainage ditches, raising the bottom elevation of the stream, and increasing the amount of surface storage available to pond water. In this way, the respective amounts of drainage and runoff are decreased, and the excess water allows the water table to remain higher throughout the year, thus restoring wetland hydrology.

Table 5.3
Water Balance Data for Existing Conditions of the Project Site

Hydrologic Parameter	Annual Amount over 58-Year Simulation Period (in of water)	Annual Amount over 58-Year Simulation Period (% of average rainfall)
Precipitation	47.5 (62.1 to 34.6)	100
Drainage	17.3 (11.6 to 26.3)	36.4 (24.4 to 55.4)
Runoff	6.7 (1.24 to 17.0)	14.1 (2.6 to 35.8)
Evapotranspiration	23.4 (17.2 to 29.6)	49.3 (36.2 to 62.3)

6.0 STREAM CORRIDOR ASSESSMENT RESULTS

6.1 Reach Identification

For analysis and design purposes, Baker Engineering divided the Duke Swamp tributaries into two reaches labeled UT1 and UT2 to Duke Swamp. The reach locations are shown in Exhibit 1.2. The reaches are shown as perennial blue-line streams on the USGS topographic map. UT1 begins at a culvert under SR1320 and ends inside the forested wetland boundary. UT2 begins at the outlet of a small cypress pond on the northwestern corner of the project site. Based on field evaluations of intermittent or perennial status, conducted during the proposal phase of the project, the UT1 and UT2 stream channels were determined to be a perennial stream (based on a minimum score of 30 for perennial streams and the presence of biological indicators), using the NCDWQ *Determination of the Origin of Perennial Streams* guidelines (see forms in Appendix D). The total current length of streams on the project site is 4,620 LF.

6.2 Geomorphic Characterization and Channel Stability Assessment

Baker Engineering performed general topographic and planimetric surveying of the project site and produced a contour map based on survey data in order to create plan set base mapping. Cross-section surveys of the stream reaches were also performed to assess the current condition and overall stability of the channels. Cross-section locations are shown on Exhibit 6.1. The following report subsections summarize the survey results for all project reaches. The watershed sizes were calculated at the terminus of the project and summarized in Table 6.1. Appendix D contains summaries of existing condition parameters, cross-section survey results, and bed material distribution graphs for the site.

Table 6.1
Reach Descriptions and Watershed Size

Reach	Reach Length (linear feet)	Watershed Size (square miles)	NCDWQ Intermittent/Perennial Stream Form Score
UT1 to Duke Swamp	3,740	2.9	47
UT2 to Duke Swamp	880	0.03	37

6.2.1 UT1 to Duke Swamp

UT1 to Duke Swamp has been straightened and dredged in the past. Currently, UT1 is difficult to classify using the Rosgen stream classification (Rosgen, 1996). The past manipulation has essentially created a channel that is overly wide and overly deep for the given drainage area. There is little slope within the system, with 0.0003 ft/ft over the entire reach. Essentially the channel is functioning as a long, linear pond, holding backwater throughout the entire reach from the swamp downstream. The NC Coastal Regional Curve (See Table 6.3) estimates a bankfull cross-sectional area of approximately 21 ft^2 for a 2.9 mi^2 watershed. In most cases the existing channel has a cross-sectional area at top-of-bank of approximately 40 to 155 ft^2. Since Rosgen's stream classification system (Rosgen, 1996) depends on the proper identification of bankfull, the stream classification is difficult under these conditions, but was assessed as a channelized E channel due to low bank heights relative to base-flow conditions. Additionally, feature formation throughout the channelized reach is poor with very little habitat diversity or woody debris. Bed features are far below baseflow water levels due to backwater effects. The stream is not protected by adequate riparian vegetation with the exception of the forested areas at the end of the project reach. Ditch banks within the field areas are routinely maintained by mowing.

Within the existing wetland area at the downstream end of the project, UT1 most likely existed prior to conversion as a multi-channel (DA) system, or a transition system between a single thread and multi-thread system. This is evidenced by the presence of several historic channel features in the area. Currently, the system has been channelized to its confluence with Duke Swamp, where channelization ends. Spoil from the channelization was placed along the right bank, creating a linear spoil pile that disconnected the historic flow patterns of UT1 and UT2. The area does flood during large storm events, but the flooding patterns, frequency, and distribution have been disrupted due to the channelization in the area.

The modified Wolman pebble count (Rosgen, 1994) is not appropriate for sand-bed streams; therefore, a bulk sampling procedure was used to characterize the bed material. The majority of the reach had an organic muck stream bottom due to the backwater conditions in the channel. Bed material samples were collected. The samples collected were taken back to a lab and dry sieved to obtain a sediment size distribution. The sieve data show that the UT1 to Duke Swamp has a D_{50} of 0.10-mm indicating that the dominant bed material in the stream channel is fine sand, silt, and muck under current conditions.

The stream displays no measurable meander geometry due to its channelized condition. These conditions generally lead to lateral instability over time; however, a low-flow regime, backwater conditions, and herbaceous vegetation on the banks have served to maintain some stability along the reach.

6.2.2 UT2 to Duke Swamp

UT2 to Duke Swamp begins at the outlet of a small cypress pond on the northwestern corner of the project site. Based on field reconnaissance and surrounding topography, the historic flow pattern and flooding regime of UT2 appears to have been altered significantly. UT2 is difficult to classify using the Rosgen stream classification (Rosgen, 1996) because of inconsistent geomorphic data; however the existing channel was assessed as a manipulated multi-channel (DA) due to low slope, variable sinuosity and configuration. Currently, UT2 is experiencing backwater ponding and damming effects as a result of an existing spoil pile that runs along almost the entire right bank of UT1 in the forested wetland area. Flows are being diverted along this large spoil pile and ultimately blocking the natural connection between UT1 and UT2. The NC Coastal Regional Curve (See Table 6.3) estimates a bankfull cross-sectional area of approximately 0.7 ft^2 for a 0.03 mi^2 watershed. A surveyed cross-section along the existing channel had a cross-sectional area at top-of-bank that was within this approximate bankfull area.

UT2 exists as a multi-channel (DA) system, or a transition system between a single thread and multi-thread system, which has been hydraulically impacted by the channelization of UT1. This is evidenced by the presence of several historic channel features in the forested wetland area. Since the modified Wolman pebble count (Rosgen, 1994) is not appropriate for sand-bed streams, a random sampling procedure was used to characterize the bed material. The majority of the reach had an organic muck stream bottom due to the backwater conditions and low slope. The stream has a mature canopy along its entire length.

Table 6.2
Geomorphic Data for Duke Swamp Site – Stream Channel Classification Level II

Parameter	Value		Units
	UT1	UT2	
Rosgen Stream Type	E5	DA	
Drainage Area	2.9	0.03	Square miles
Reach Length Surveyed	3,558	240	Feet
Bankfull Width (W_{bkf})	17.9 – 40.9	2.6	Feet
Bankfull Mean Depth (d_{bkf})	2.1 – 4.2	0.3	Feet
Cross-Sectional Area (A_{bkf})	40.4 - 154.9	0.7	Square feet
Width/Depth Ratio (W/D ratio)	4.5 - 15.4	9.4	
Bankfull Max Depth (d_{mbkf})	4.0 – 5.4	0.6	Feet
Floodprone Area Width (W_{fpa})	124.8 – 181.1	43.6	Feet
Bank Height Ratio (BHR)	1.1 – 1.3	1.8	
Entrenchment Ratio (ER)	4.1 – 10.1	16.7	
Meander Width Ratio	N/A	N/A	
Channel Materials (Particle Size Index – d_{50})	Very fine sand		
d_{16}	0.06	N/A	mm
d_{35}	0.08	N/A	mm
d_{50}	0.1	N/A	mm
d_{84}	0.18	N/A	mm
d_{95}	0.23	N/A	mm
Slope (S)	0.0003	0.0028	Feet per foot
Channel Sinuosity (K)	1.05	1.15	
Evolution Scenario	Channelized E-C, E-C-DA		

Notes:
1. Where multiple cross-sections were surveyed in reach UT1 and data varied, the data are presented as a range of values.
2. N/A: Meander Width Ratio not measured because UT1 channel has been straightened and UT2 transitions into a multi-threaded channel.
3. N/A: UT2 geomorphic data values vary due to inconsistent channel formations. UT2 channel materials consisted of organic clay/muck and were not dry sieved.

6.3 Bankfull Verification

An accurate identification of bankfull stage could not be made throughout the Duke Swamp project area due to backwater conditions. Some indicators were apparent, but the reliability of the indicators was questionable due to the altered condition of the stream channels. For this reason, bankfull stage was identified through the use of regional curve information. Regional curve equations developed from the North Carolina Rural Coastal Plain study are provided by Sweet and Geratz (2003) and Doll (2003) and are shown in Table 6.3. The stream has been channelized and dredged so deep and overly wide that backwater conditions no longer allow for channel forming processes to occur.

TABLE 6.3
NC Rural Coastal Plain Regional Curve Equations

North Carolina Coastal Plain Rural Regional Curve Equations	
EcoScience Data (Sweet and Geratz, 2003)	
$Q_{bkf} = 8.79\ A_w^{0.76}$	R^2=0.92
$A_{bkf} = 9.43\ A_w^{0.74}$	R^2=0.96
$W_{bkf} = 9.64\ A_w^{0.38}$	R^2=0.95
$D_{bkf} = 0.98\ A_w^{0.36}$	R^2=0.92
NCSU Data (Doll, 2003)	
$Q_{bkf} = 16.56\ A_w^{0.72}$	R^2=0.90
$A_{bkf} = 14.52\ A_w^{0.66}$	R^2=0.88
$W_{bkf} = 10.97\ A_w^{0.36}$	R^2=0.87
$D_{bkf} = 1.29\ A_w^{0.30}$	R^2=0.74

6.4 Stream Reference Site

The Beaver Dam Branch stream reference site is located in Jones County, approximately six miles southeast of the town of Trenton, North Carolina, and approximately 100 miles south of the project site (Exhibit 6.2). The site is an example of a "Coastal Plain small stream swamp," as described by Schafale and Weakley (1990). These systems exist as the floodplains of small "blackwater" and "brownwater" streams in which separate fluvial features and associated vegetation are too small or poorly developed to distinguish. Hydrology of these systems is palustrine – intermittently, temporarily, or seasonally flooded. Flows tend to be highly variable, with floods of short duration, and periods of very low flow. It appears that the site has experienced little disturbance in recent time and is believed to be representative of undisturbed conditions on the project site. The reference stream site was used along with evaluation data from past projects to develop design criteria. These procedures are described in Section 5.

This reference site was selected for design purposes due to its low valley slope and similar morphological features as those on the Duke Swamp project site.

Field surveys of the reference site were conducted in early spring, 2002. The site has been visited on a yearly basis since the original survey to evaluate any changes on the site. It was determined during a site visit in January of 2006 that the site has remained stable and is therefore a viable reference site. Survey data were used to evaluate the natural channel parameters describing the dimension, pattern, and profile of the stream. Natural channel design parameters are summarized in Appendix E.

The reference stream is classified as a "C5c" channel using the Rosgen Stream Classification System (Rosgen, 1994). Longitudinal profile and cross-sections are presented in Appendix E. The channel is classified as a "C" channel since the average width/depth ratio is 14. "C" type channels are more typical of lower gradient sand-bed stream systems that meander through alluvial valleys. "C" type streams typically form point-bar features as a result of the relatively high amount of bedload that is transported. Out-of-bank flooding occurs at stages greater than the bankfull flow. The "5" indicates that the stream is a sand-bed system. Median particle size of the bed material is approximately 0.7 mm (see Appendix E for particle size distribution data). The "c" indicates that the slope of the channel is less than 0.001 feet/feet. The reference reach stream has appropriate bed features for a sand-bed system, with shallow pools in the meander bends, and deeper pools formed by scour features such as roots and debris jams.

Unlike many other Coastal Plain stream systems, the section of channel surveyed for the reference reach shows no evidence of having been altered or channelized in the recent past. Trees can be found within the riparian areas that appear to be in excess of 50 years of age. The channel has good meander pattern with low bank heights.

6.4.1 Reference Stream Vegetation

The reference stream is well buffered along both stream banks, with tree species that include sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), willow oak (*Quercus phellos*), water oak (*Quercus nigra*), swamp chestnut oak (*Quercus michauxii*), and green ash (*Fraxinus pennsylvanica*). The small tree/shrub layer is dominated by sweetbay magnolia (*Magnolia virginiana*), American holly (*Ilex opaca*), sugarberry saplings (*Celtis laevigata*), giant cane (*Arundinaria gigantea*), elderberry (*Sambucus canadensis*), coastal doghobble (*Leucothoe axillaris*), sweet pepperbush (*Clethra alnifolia*), beautyberry (*Callicarpa americana*), and blackberry (*Rubus* spp.). The herb and vine strata contain false nettle (*Boehmeria cylindrica*), jewel-weed (*Impatiens capensis*), cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Onoclea sensibilis*), green-briar (*Smilax* spp.), Virginia creeper (*Parthenocissus quinquefolia*), grape (*Vitis* spp.), poison ivy (*Toxicodendron radicans*), and honeysuckle (*Lonicera japonica*).

7.0 RESTORATION DESIGN

7.1 Potential for Restoration and Approach

The project is located in a rural watershed, with no plans for significant land use changes in the foreseeable future. A culvert and three off-line ponds were considered during the design of the stream pattern for UT1. A farm road crossing near the lower end of the site must be maintained for farm operations. There are no other known or foreseen constraints at the site, associated with structure and/or infrastructure encroachments.

After examining the assessment data collected at the site and exploring the site's potential for restoration, an approach to the site was developed that would address restoration of both stream and wetland functions within the agricultural field areas. The approach also needed to take into account the existing swamp system at the downstream end of the site, which had been impacted in the past by channelization. Topography and soils on the site indicate that the project area most likely functioned in the past as a tributary stream system with associated wetlands, feeding into the larger Duke Swamp system.

Therefore, a design approach was formulated to restore this type of system. First, an appropriate stream type for the valley type, slope, and desired wetland functions was selected and designed to tie in at the upstream road culvert. Then a grading plan was developed to restore the adjacent wetland areas which had been converted to farmland. Finally, an enhancement approach was developed for the downstream swamp area, to remove the past effects of channelization and restore historic flow patterns within the swamp. Special consideration was given to minimizing disturbance to existing wetland and wooded areas.

Table 7.1
Project Design Stream Types

Reach	Restored Stream Type	Rationale
UT1a (upstream end)	C	Reference reach studies indicate that low slope sand-bed systems typically form C type channels, with high width-to-depth ratios. A higher width-to-depth ratio channel will also support the restored adjacent wetland hydrology. Rosgen Priority Level 1 and 2 approaches will be used. Riparian buffers at least 50 feet wide will be established along the stream reach, with the exception of an estimated 470 LF near stream station 16+50 thru 19+50. This area will have a 15-foot buffer along the right bank due to landowner agricultural requirements. All buffer areas will be protected by a perpetual conservation easement.
UT1b (downstream end)	DA	Restoration will focus on restoring a multi-threaded swamp system within existing wetland areas. This approach will allow for restoration of historic flow patterns, with very little disturbance to the existing wetland system. Remnant channel features will be used and tied into at the boundary of the jurisdictional wetland area. The riparian buffer system will be protected by a perpetual conservation easement.

UT2 to Duke Swamp	DA	Restoration will focus on restoring a multi-threaded swamp system within existing wetland areas. This approach will allow for restoration of historic flow patterns, with very little disturbance to the existing wetland system. Currently, flows are diverted along a large spoil pile, which is causing increased ponding upstream and blocking the natural connection between UT1 and UT2. The riparian buffer system will be protected by a perpetual conservation easement.

7.2 Design Criteria Selection

Selection of channel design criteria is based on a combination of approaches, including review of reference reach data, regime equations, and evaluation of results from past projects, as discussed in Section 2.5.

Selection of a general restoration approach was the first step in selecting design criteria for UT1 and UT2. The approach was based on the potential for restoration as determined during the site assessment. After selection of the general restoration approach, specific design criteria were developed so that plan view layout, cross-section dimensions, and profile could be described for the purpose of developing construction documents.

7.2.1 Reference Reach Survey

As discussed in Section 6.4, a stream reference reach was identified and surveyed. The Beaver Dam Branch site is an example of a reference quality C5c channel under similar geomorphological conditions as the project site. The riparian area adjacent to the channel classifies as a "Coastal Plain small stream swamp," as described by Schafale and Weakley (1990). Specific natural channel parameters are provided in Appendix E.

7.2.2 Reference Reach Database

An internal reference reach database has been developed by Baker Engineering for the evaluation of reference reach parameters from multiple sites within a geographic area. The database includes four sand-bed reference reaches, in addition to the Beaver Dam Branch reference reach, that were surveyed in the Coastal Plain and have been used for design purposes on other projects. Collectively, the data provide valuable information regarding the range of conditions documented for similar headwater stream systems. Shear stress and stream power relationships developed for these reference sites are used in the sediment transport analysis shown in Figures 2.1, 2.2, and 2.3.

Table 7.2
Reference Parameters Used to Determine Design Ratios

Parameter	Beaver Dam Reach (See Appendix E)	Composite Reference Data from NC Coastal Plain[1]	
		MIN	MAX
Drainage Area, DA (sq mi)	3.2		
Stream Type (Rosgen)	E5 / C5		
Bankfull Discharge, Qbkf (cfs)	25.8		
Bankfull Riffle XSEC Area, Abkf (sq ft)	25.3		
Bankfull Mean Velocity, Vbkf (ft/s)	1.0		

Width to Depth Ratio, W/D (ft/ft)	14	8	14
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	>10	4	13
Riffle Max Depth Ratio, Dmax/Dbkf	2.3	1.2	1.8
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.25	1.0	1.3
Meander Length Ratio, Lm/Wbkf	4.9-6.7	4	17
Rc Ratio, Rc/Wbkf	1.8-2.4	1.5	3.0
Meander Width Ratio, Wblt/Wbkf	2.9-6.3	2.0	6.3
Sinuosity, K	1.66	1.22	1.77
Valley Slope, Sval (ft/ft)	.0007	0.0007	0.0029
Channel Slope, Schan (ft/ft)	.0004	0.0004	0.0022
Pool Max Depth Ratio, Dmaxpool/Dbkf	3.3	1.8	2.0
Pool Width Ratio, Wpool/Wbkf	5.4	0.8	1.4
Pool-Pool Spacing Ratio, Lps/Wbkf	100		
d16 (mm)	0.3		
d35 (mm)	0.4		
d50 (mm)	0.5		
d84 (mm)	0.9		
d95 (mm)	1.2		
Notes: Composite reference reach information from Johannah Creek, Johnston County; Panther Branch, Brunswick County; and Rocky Swamp, Halifax County			

7.2.3 Design Criteria Selection Method

Specific design parameters were developed using a combination of reference reach data, past project experiences, and best professional judgment. The design philosophy at the Duke Swamp site is to use conservative values for the selected stream types and to allow natural variability in stream dimension, facet slope, and bed features to form over long periods of time under the processes of flooding, re-colonization of vegetation, and watershed influences. The proposed stream types for the project are summarized in Table 7.1.

7.3 Channel Design Parameters

7.3.1 UT1a Channel Restoration

A stable cross-section will be achieved by restoring a meandering channel across the abandoned floodplain (currently agricultural field areas), increasing the width/depth ratio, and raising the streambed to restore a channel that is appropriately sized for its drainage area. Due to the upstream road culvert and the need to not increase flooding conditions of the road, minor floodplain grading will be performed to allow for increased capacity during large storm events. Grading activities will also be aimed at restored historic flow patterns and adjacent wetland hydrology by removing past channel spoil and other agricultural land manipulations. The channel will be restored to a C-type stream, and the sinuosity will be increased by adding meanders to lengthen the channel and restore bed-form diversity. Minimal grade control will be required for the project, due to the low channel slope and low potential for channel incision. In-stream wooden structures, such as log vanes, rootwads, and cover logs will be included in the channel design to provide improved aquatic habitat. Table 7.3 presents the stream restoration dimensions and design criteria for the UT1a channel.

Table 7.3
Natural Channel Design Parameters for UT1a

Parameter	UT1a Design Values		Design Criteria		Rationale
	MIN	MAX	MIN	MAX	
Drainage Area, DA (sq mi)	2.9		--	--	
Design Stream Length (feet)	3,983		--	--	
Stream Type (Rosgen)	C5c		--	--	Note 1
Bankfull (bkf) Discharge, Qbkf (cfs)	25.6		--	--	Note 2
Bankfull Mean Velocity, Vbkf (ft/s)	0.95		--	--	V=Q/A
Bankfull Riffle XSEC Area, Abkf (sq ft)	27		--	--	Note 3
Bankfull Riffle Width, Wbkf (ft)	19.4		--	--	$\sqrt{Abkf*W/D}$
Bankfull Riffle Mean Depth, Dbkf (ft)	1.4		--	--	d=A/W
Width to Depth Ratio, W/D (ft/ft)	14.0		10	15	Note 3
Width Floodprone Area, Wfpa (ft)	50	>100	--	--	
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	8	12	5.5	>10	Note 4
Riffle Max Depth @ bkf, Dmax (ft)	1.8	2.5	--	--	
Riffle Max Depth Ratio, Dmax/Dbkf	1.5	1.7	1.2	1.6	Note 5
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0		1.0		Note 6
Meander Length, Lm (ft)	92	125	--	--	
Meander Length Ratio, Lm/Wbkf *	8.0	12.0	8.0	12.5	Note 7
Radius of Curvature, Rc (ft)	30	60	--	--	
Rc Ratio, Rc/Wbkf *	2.0	3.0	2.0	3.0	Note 7
Belt Width, Wblt (ft)	49	105	--	--	
Meander Width Ratio, Wblt/Wbkf *	5.0	8.0	3.0	8.0	Note 7
Sinuosity, K	1.6		1.3	1.8	TW length/ Valley length
Valley Slope, Sval (ft/ft)	0.0003		--	--	
Channel Slope, Schan (ft/ft)	0.0002	0.0002	--	--	Sval / K
Slope Riffle, Srif (ft/ft)	0.0003	0.0003	--	--	
Riffle Slope Ratio, Srif/Schan	1.2	1.4	--	--	Note 8
Slope Pool, Spool (ft/ft)	0.0000	0.0007	--	--	
Pool Slope Ratio, Spool/Schan	0.0	0.2	--	--	Note 8
Pool Max Depth, Dmaxpool (ft)	2.3	4.4	--	--	
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.0	3.0	2.0	3.0	Note 7
Pool Width, Wpool (ft)	14.0	22.0	--	--	
Pool Width Ratio, Wpool/Wbkf	1.3	1.7	1.2	1.5	Note 9

Pool-Pool Spacing, Lps (ft)	55.0	100	--	--	
Pool-Pool Spacing Ratio, Lps/Wbkf	4.0	6.0	4.0	6.0	Note 7
d_{16} – mm	0.06		< 0.062		
d_{35} – mm	0.08		0.125		
d_{50} – mm	0.10		2.0		
d_{84} – mm	0.18		22		
d_{95} – mm	0.23		64		

Notes:

[1] A C5c stream type is appropriate for a very low-slope, wide, alluvial valley with a sand streambed. The choice of a C5c channel dimension was based on relationships of W/D ratio to slope in NC Coastal Plain reference reach streams, as well as sediment transport analyses and past project evaluation.

[2] Bankfull discharge was estimated using Manning's equation.

[3] A final W/D ratio was selected based on relationships of W/D ratio to slope in NC Coastal Plain reference reach streams, as well as sediment transport analyses and past project evaluation.

[4] Required for stream classification.

[5] This ratio was based on past project evaluation of similar C5 design channels.

[6] A bank height ratio near 1.0 ensures that all flows greater than bankfull will spread onto a floodplain. This minimizes shear stress in the channel and maximizes floodplain functionality, resulting in lower risk of channel instability.

[7] Values were chosen based on Beaver Dam Branch reference reach data, other sand-bed reference reach data, and past project evaluation.

[8] Due to the extremely low channel slopes, facet slopes were not calculated for the proposed design. Past project experience has shown that these minor changes in slope between features form naturally within the constructed channel, provided that the overall design channel slope is maintained during construction.

[9] Values were chosen based on reference reach database analysis and past project evaluation. It is more conservative to design a pool wider than the riffle. Over time, the pool width may narrow, which is a positive evolutionary step.

7.3.2 UT1b Channel Restoration

As discussed in Section 6.2, UT1b has been channelized through an existing wetland swamp system. The channelization and piling of spoil along the right bank has disrupted the historic flow and flooding patterns of the site, and disconnected the natural confluence of UT1 and UT2. However, historic channel remnants exist within the area adjacent to the current canal. Restoration of this reach will seek to restore historic flow and flooding processes, while avoiding and minimizing disturbance to the existing wetland vegetation. The restoration of UT1a through the farm fields will end at the edge of the jurisdictional wetland system. At this location, the UT1a channel will connect with a historic channel remnant which will form the beginning to UT1b. A small excavator will enter the existing wetland area along UT1b by traversing the existing spoil pile, thereby avoiding disturbance to wetland vegetation. Beginning at the downstream end, the excavator will place the spoil material back into the channel and restore the topography in the area of the spoil pile. In this fashion, flows through UT1b will be allowed to follow historic flow patterns and spread out through numerous channel remnants, in the same way the system once functioned. The historic connection between UT1 and UT2 will also be restored.

7.3.3 UT2 Channel Restoration

As discussed in the preceding section, restoration in the area of UT1b and UT2 will involve removing the existing spoil pile which is affecting the flow of UT2. Currently, UT2 is experiencing backwater ponding and damming effects as a result of the spoil pile. By removing the spoil pile and restoring the surrounding topography, the historic flow pattern and flooding regime of UT2 will be restored. Rather than ponding and flowing along the spoil pile, the restored UT2 will be able to spread across its floodplain and flows will mix with flood flows from UT1.

7.4 Sediment Transport

The purpose of sediment transport analysis is to ensure that the stream restoration design creates a stable sand-bed channel that does not aggrade or degrade over time. The overriding assumption is that the project reach should be transporting all the sediment delivered from upstream sources, thereby being a "transport" reach and classified as a Rosgen "C" or "E" type channel. Empirical relationships from stable sand-bed channels in North Carolina are used in this analysis, as described in Section 2.6.

Shear stress, stream power, and W/D values for the UT1a design reach are plotted against stable reference stream data in Exhibits 7.1, 7.2, and 7.3. The values were calculated based on design conditions of the reach, and a summary of the data is provided in Table 7.4. The design shear stress and stream power values plot within the scatter of data points collected from reference reaches. This analysis provides evidence that the stresses predicted for the design channels are well within the range of stable values calculated for the reference reaches. Therefore, scour of design channels is not expected.

Sediment transport analyses as described above and in Section 2.6 were not applied to design reaches UT1b and UT2. The designs for these reaches involve the restoration of diffuse flow paths through multiple channels; in essence, the restoration of a swamp system. These systems are aggradational by nature, exhibiting very low flow velocities and scour stresses. Under normal conditions, sediment deposits in these systems. However, sediment supply is typically limited, such that over time, these systems remain stable and deposited sediment becomes part of the natural processes of soil formation. Observations from the project site confirm that sediment supply from upstream sources are limited, therefore sediment transport relationships are predicted to function normally in the restored reaches of UT1b and UT2.

Table 7.4
Calculated Sediment Transport Data for Design Reach UT1a

Design Reach	Design Bankfull Area (ft^2)	Bankfull Discharge (ft^3/sec)	Bankfull Velocity (ft/sec)	Shear Stress (lbs/ft^2)	Stream Power (W/m^2)
UT1a to Duke Swamp	27	25.6	0.95	0.038	0.041

7.5 In-Stream Structures

A variety of in-stream structures are proposed for the project reaches. Structures such as root wads, log weirs, log vanes, and cover logs will be used to stabilize the newly-restored stream and improve aquatic habitat functions. Table 7.5 summarizes the use of in-stream structures at the site.

Table 7.5 In-stream Structure Types and Locations	
Structure Type	**Location**
Root wads	Throughout project
Log vanes	Throughout project
Log weirs	Only in locations where grade control is a concern (limited due to channel slope)
Cover logs	Throughout project

7.5.1 Root Wads

Root wads are placed at the toe of the stream bank along the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also serve as a food source for aquatic insects. Root wads will be placed throughout the project reaches primarily to improve aquatic habitat and provide cover.

7.5.2 Log Vanes

A log vane is used to provide cover for aquatic organisms with a potential secondary benefit of protecting stream banks. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes are located just downstream of the point where the stream flow intersects the bank at an acute angle in a meander bend.

7.5.3 Log Weir

Log weirs are used to provide grade control as well as provide a secondary habitat benefit for aquatic organisms. A log weir consists of two logs stacked (a header log and a footer log) and installed perpendicular to the direction of flow. This center structure sets the invert elevation of the stream bed.

7.5.4 Cover Logs

A cover log is placed along the outside of a meander bend to provide habitat in the pool area. It is most often installed in conjunction with rootwads. The log is buried into the outside bank of the meander bend; the opposite end extends through the deepest part of the pool and may be buried in the inside of the meander bend, in the bottom of the point bar. The placement of the cover log near the bottom of the bank slope on the outside of the bend encourages scour in the pool. This increased scour provides a deeper pool for bedform variability. Cover logs will be used on all reaches; however, fewer will be placed in the small reaches because the habitat value is not as great.

7.6 Restoration of Wetland Hydrology

The existing agricultural fields across the site are currently drained by UT1 to Duke Swamp. To restore wetland hydrology to the site, the existing stream will be fully to partially filled depending on the amount of fill material that can be produced from minor land grading and excavation of the new stream channel. When complete filling of the stream and ditches is not possible, ditch plugs will be installed from compacted earth for a distance of at least 100 feet. Ditch plugs will also be used in locations where the restored stream channel will cross the existing stream channel. In these locations, the existing stream will be plugged for at least 100 feet on both sides of the restored channel to prevent drainage losses and channel avulsion. In areas where restored stream flows will contact fill material, root wads will be installed to provide additional protection and deflect stream energies. Due to the relatively small size of the restored channel and the low energy nature of the system, these practices will be sufficient to prevent erosion and channel avulsion. These practices have been used on numerous other projects with excellent results. Some sections of existing channel may be only partially filled depending on the amount of fill material that can be produced. These partially filled areas will be discontinuous and will mimic small vernal pools or tree throws within the wetland areas that will add to the diversity of habitat on the project site.

Grading activities will focus on removing any field crowns, surface drains, irrigation ponds, or swales that were imposed during conversion of the land for agriculture. Existing and proposed graded contours are provided in the plan sheets. In general, grading activities will be minor, other than the filling of the two existing irrigation ponds, since the site exhibits a rather flat existing topography.

The topography of the restored site will be patterned after natural floodplain wetland reference sites, and will include the restoration of minor depressions and tip mounds (microtopography) that promote diversity of hydrologic conditions and habitats common to natural wetland areas. These techniques will be instrumental to the restoration of site hydrology by promoting surface ponding and infiltration, decreasing drainage capacity, and imposing higher water table conditions across the restoration site. In order to improve drainage and increase agricultural production, farmed wetland soils are often graded to a smooth surface and crowned to enhance runoff (Lilly, 1981). Microtopography contributes to the properties of forest soils and to the diversity and patterns of plant communities (Lutz, 1940; Stephens, 1956; Bratton, 1976; Ehrnfeld, 1995). Microtopography will be established after floodplain areas have been established to design grades, using the procedures described in Section 3.8.

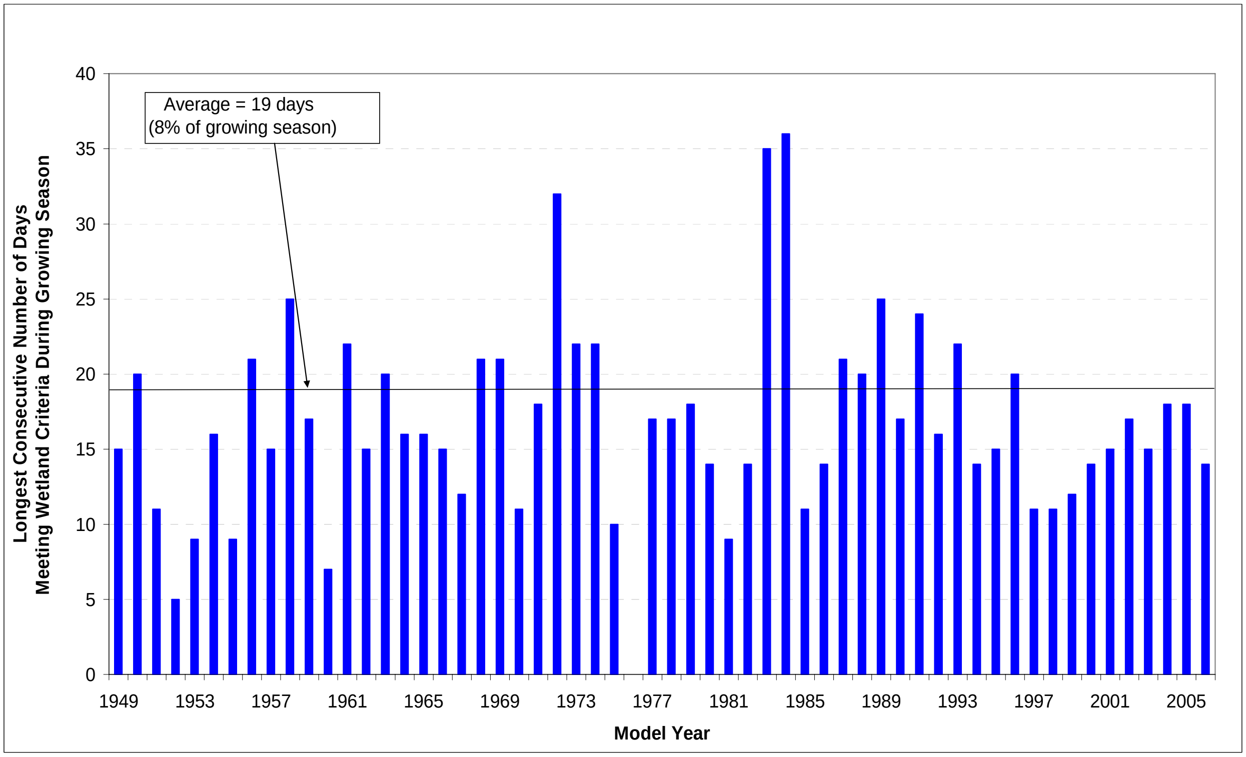
The restoration design for the wetland is based on the reference wetland area (Section 3.7). The targeted type of riverine wetland would be a “Coastal Plain small stream swamp” as identified by Schafale and Weakley (1990). Hydrology of this system will be palustrine, “intermittently, temporarily, or seasonally flooded”, as the restored channel is designed to carry the bankfull flow, and to flood (flow out of its banks) at discharges greater than bankfull. Vegetation of this system will mimic that of the reference wetland.

7.7 Hydrologic Model Analyses

The DRAINMOD simulations developed to evaluate the current hydrologic status of the restoration site (Section 5.5) were used to estimate the hydrologic conditions of the site under the proposed restoration practices. Model parameters that describe the depth of stream and topographic surface storage were changed to values representative of the described restoration practices. For example, drain depths were reduced to approximately 55 centimeters to represent the water level in the restored, meandering channel. Surface storage parameters were increased from two to four centimeters to represent surface roughing practices. Input files that describe cropping conditions were changed to represent forested conditions.

To estimate the average hydrologic condition of the restored site, a model scenario was evaluated for an average distance from the restored channel with a surface storage of two centimeters. Since wetlands are being restored from the restored stream channel out to a distance of approximately 225 feet, an average distance of 115 feet was used in the model. In a similar manner, a maximum surface storage of 4 centimeters was chosen based on reference site information and represents typical topographic conditions across the restored site. A 58-year simulation was run following the procedure described in Section 3.5. Results of the simulation are presented in Figure 7.1, and the DRAINMOD input file is provided in Appendix C.

Figure 7.1
Fifty-Eight Year Model Simulation for the Longest Period of Consecutive Days Meeting Wetland Criteria for Conditions Encountered at Restoration Site.



The simulation runs indicate that, on average, the water table will be less than 30 centimeters deep continuously for approximately 8 percent of the growing season. This scenario can be assumed to represent average conditions across the site, with the majority of the restored acreage on the site being represented by this hydrologic scenario. It is probable that there will be areas slightly drier or slightly wetter than the modeled scenario within the restoration area. The modeled scenario provides a basis for estimating the average hydrologic condition over the restored site, based on the proposed restoration practices. However, it is important to note that the hydrology of the targeted restored wetland system (Coastal Plain small stream swamp) is highly variable across a given site, supporting the ecological and functional diversity that makes these systems so valuable.

7.8 Wetland Reference Site Overview

The reference wetland site for this project will be located within the existing jurisdictional wetlands adjacent to reaches UT1b and UT2 at the western end of the project site. This area is an example of a "Coastal Plain small stream swamp", as described by Schafale and Weakley (1990). These systems exist as the floodplains of small "blackwater" streams in which separate fluvial features and associated vegetation are too small or poorly developed to distinguish. Hydrology of these systems is palustrine, intermittently, temporarily, or seasonally flooded. Flows tend to be highly variable, with floods of short duration, and periods of very low flow. The "Coastal Plain small stream swamp" wetland system would be typical for the watershed size and the geomorphologic setting of the site.

This area has experienced disturbance in the past, as described in Section 6, including past channelization and logging. Restoration of the area will involve the restoration of historic flow patterns and hydrology. Currently, the site exists as a jurisdictional wetland with a mature, healthy vegetative community. Due to variability in topography, hydrology varies across the site, as is expected in floodplain wetland systems. Wetland data forms for the site are provided in Appendix F.

7.8.1 Reference Wetland Site Soils

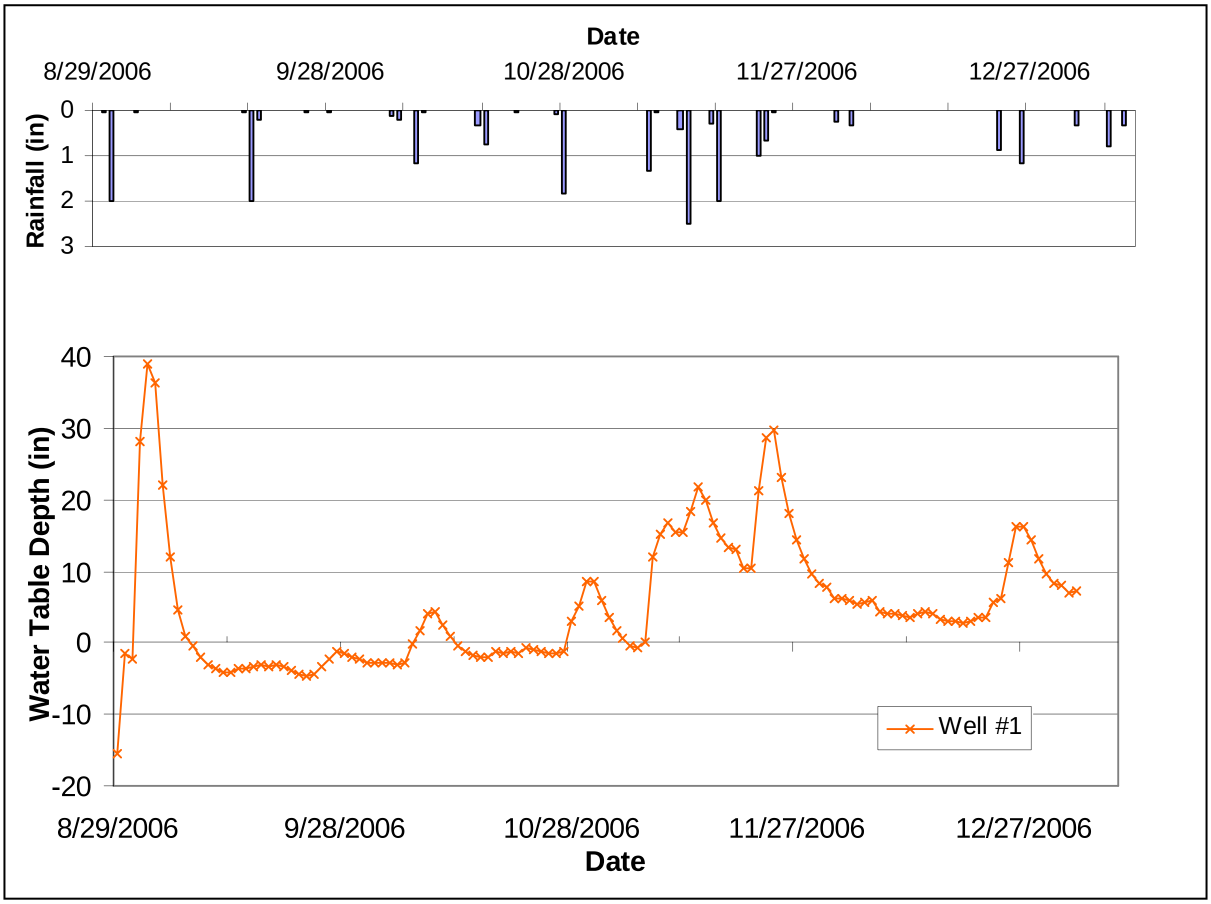
The reference site is located in the Coastal Plain physiographic region of North Carolina adjacent (to the southwest) of the project site. Soils located within the wetland areas of the reference site are mapped as the Nawney series (NRCS, 1999). The Nawney series consists of poorly drained soils typically found on floodplains along streams in the Coastal Plain. Permeability is moderate, and the seasonal high water table is within 0.5 feet of the soil surface. The Nawney soil series is listed as “A” list hydric soils by NRCS (NRCS, 1999). On the upslope areas adjacent to the wetland areas, soils of the Noboco and Goldsboro series are found.

7.8.2 Reference Site Hydrology

Climatic conditions for the proposed reference wetland site will be the same as those for the project site. The reference site is classified as a “Coastal Plain small stream swamp” (Schafale and Weakley, 1990). Small stream swamp communities are palustrine with variable flows and are intermittently, temporarily, or seasonally flooded (Shafale and Weakly, 1990). Site hydrology is controlled by the main stream channel that flows through the site, as well as several small drainages that flow onto the site and provide additional water to the floodplain areas during wet periods. As discussed in this section, the restoration approaches proposed for this area will restore historic flow patterns and flooding regimes to the reference area.

A water table monitoring well was installed within the reference site, and monitoring data were collected from August 2006 to January 2007. An example subset of the data is shown in Figure 7.2. Based on the data collected, the site exhibits wetland hydrology, and exhibits a range of saturation and wetness during the wetter periods of the year (late fall, winter, and early spring). The well was located near the confluence of UT1 and Duke Swamp, in an area of high saturation and frequent flooding. During the post-construction monitoring phase for the site, several wells will be installed across the site to document the range of hydrologic conditions that are present. This data will provide a base of comparison to evaluate the restored hydrology within the existing open field areas.

Figure 7.2
Water Table Depths Recorded in a Monitoring Well Installed within the Reference Site.



7.9 Vegetation Plan

The vegetative components of this project include stream bank and floodplain planting. In addition, any areas of the site that lack diversity or are disturbed or adversely impacted by the construction process will be replanted.

Bare-root trees, live stakes, and permanent seeding will be planted within designated areas of the conservation easement. A minimum 50-foot buffer will be established along all restored stream reaches, with the exception of a 470-foot reach near the upstream end of UT1a. In many areas, the buffer width will be in excess of 50 feet. In general, bare-root vegetation will be planted at a target density of 680 stems per acre, or an 8-foot by 8-foot planting area. Planting of bare-root trees and live stakes will be conducted during the dormant season, with all trees installed between the last week of November and the third week of March.

Selected species for hardwood re-vegetation are presented in Table 7.6 below. Tree species selected for restoration areas will be weak to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive in soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997).

Observations will be made during construction of the site regarding the relative wetness of areas to be planted. Planting zones will be determined based on these observations, and planted species will be matched according to their wetness tolerance and the anticipated wetness of the planting area.

Once trees are transported to the site, they will be planted within two days. Soils across the site will be sufficiently disked and loosened prior to planting. Trees will be planted by manual labor using a dibble bar, mattock, planting bar, or other approved method. Planting holes for the trees will be sufficiently deep to allow the roots to spread out and down without “J-rooting.” Soil will be loosely compacted around trees once they have been planted to prevent them from drying out.

Live stakes will be installed randomly two to six feet apart using triangular spacing—or at a density of 40 to 200 stakes per 1,000 square feet—along the stream banks, between the toe of the stream bank and bankfull elevation. Site variations may require slightly different spacing.

Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 7.7 lists the species, mixtures, and application rates that will be used. A mixture is provided that is suitable for floodplain and streambank areas. Mixtures will also include temporary seeding (rye grain or browntop millet) to allow for application with mechanical broadcast spreaders. To provide rapid growth of herbaceous ground cover and biological habitat value, the permanent seed mixture specified will be applied to all disturbed areas outside the banks of the restored stream channel. The species provided are deep-rooted and have been shown to proliferate along restored stream channels, providing long-term stability.

Temporary seeding will be applied to all disturbed areas of the site that are susceptible to erosion. These areas include constructed streambanks, access roads, side slopes, and spoil piles. If temporary seeding is applied from November through April, rye grain will be used and applied at a rate of 130 pounds per acre. If applied from May through October, temporary seeding will consist of browntop millet, applied at a rate of 40 pounds per acre.

Table 7.6 Proposed Bare-root and Live Stake Species			
Common Name	**Scientific Name**	**Percent Planted by Species**	**Planting Density**
Stream Restoration Buffer			
River Birch	*Betula nigra*	15%	102 stems per acre
Sugarberry	*Celtis laevigata*	5%	34 stems per acre
Green Ash	*Fraxinus pennsylvanica*	7.5%	51 stems per acre
Black Walnut	*Juglans nigra*	5%	32 stems per acre
Swamp Tupelo	*Nyssa sylvatica var.biflora*	10%	68 stems per acre
Sycamore	*Platanus occidentalis*	20%	136 stems per acre
Overcup Oak	*Quercus lyrata*	10%	68 stems per acre
Swamp Chestnut Oak	*Quercus michauxii*	10%	68 stems per acre
Willow Oak	*Quercus phellos*	7.5%	51 stems per acre
Bald Cypress	*Taxodium distichum*	10%	68 stems per acre
Streambanks (Live Stakes)			
Buttonbush	*Cephalanthus occidentalis*	10%	10 to 20 stems per 1,000 SF
Black Willow	*Salix nigra*	10%	10 to 20 stems per 1,000 SF
Silky Dogwood	*Cornus amomum*	40%	50 to 100 stems per 1,000 SF
Elderberry	*Sambucus canadensis*	40%	50 to 100 stems per 1,000 SF

Table 7.7 Proposed Permanent Seed Mixture				
Common Name	**Scientific Name**	**Percent of Mixture**	**Seeding Density (lbs/acre)**	**Wetness Tolerance**
Streambank and Floodplain Areas				
Virginia wildrye	*Elymus virginicus*	15%	2.25	FAC
Switchgrass	*Panicum virgatum*	15%	2.25	FAC+
Fox sedge	*Carex vulpinoidea*	15%	2.25	OBL
Smart Weed	*Polygonum pennsylvanicum*	15%	2.25	OBL
Soft rush	*Juncus effusus*	25%	3.75	FACW+
Hop sedge	*Carex lupulina*	15%	2.25	OBL

7.10 Invasive Species Removal

The site has minimal existing native riparian vegetation other than field grasses with the exception of the existing wetland area at the downstream end of the project. Invasive species such as Multiflora rose (*Rosa multiflora)* and privet (*Ligustrum sinense*) are present, although in relatively small amounts. Grading operations will remove these invasive species within the restored field areas.

Within the existing wetland areas, these species will be addressed through manual cutting and spot treatment with herbicides. If these or other invasive species re-establish and persist during the monitoring period, hand cutting and herbicide treatment will be used to treat problem areas.

8.0 MONITORING AND EVALUATION

Channel stability, vegetation survival, and viability of wetland function will all be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success. Different monitoring approaches are proposed for the restored stream reaches, based on the restoration approaches to be used. For reach UT1a, which involves a more traditional restoration of a single thread channel, monitoring approaches follow those recommended by the *Stream Mitigation Guidelines* (USACE and NCDWQ 2003). For reaches UT1b and UT2 which involve the restoration of historic flow patterns through an existing mature wetland system, monitoring will focus primarily on visual assessments and documentation. These approaches are described below.

8.1 Stream Monitoring - Reach UT1a

Geomorphic monitoring of UT1a will be conducted for five years to evaluate the effectiveness of the restoration practices. Monitored stream parameters include stream dimension (cross-sections), pattern (longitudinal survey), profile (profile survey), and photographic documentation. The methods used and any related success criteria are described below for each parameter.

8.1.1 Bankfull Events

The occurrence of bankfull events within the monitoring period will be documented by the use of a crest gage and photographs. The crest gage will be installed on the floodplain within 10 feet of the restored channel. The crest gage will record the highest watermark between site visits, and the gage will be checked at each site visit to determine if a bankfull event has occurred. Photographs will be used to document the occurrence of debris lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events must be documented within the 5-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years.

8.1.2 Cross-Sections

Two permanent cross-sections will be installed per 1,000 LF of stream restoration work, with one located at a riffle cross-section and one located at a pool cross-section. Each cross-section will be marked on both banks with permanent pins to establish the exact transect used. A common benchmark will be used for cross-sections and consistently used to facilitate easy comparison of year-to-year data. The annual cross-section survey will include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg, if the features are present. Riffle cross-sections will be classified using the Rosgen Stream Classification System.

There should be little change in as-built cross-sections. If changes do take place they should be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting or erosion) or a movement toward increased stability (e.g., settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sections shall be classified using the Rosgen Stream Classification System, and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

8.1.3 Pattern

Annual measurements taken for the plan view of the restoration site will include sinuosity, meander width ratio, and radius of curvature. The radius of curvature measurements will be taken on newly constructed meanders for the first year of monitoring only.

8.1.4 Longitudinal Profile

A longitudinal profile will be completed in years one, three, and five of the monitoring period. The profile will be conducted for of the entire length of the UT1a restored channel. Measurements will include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these measurements will be taken at the head of each feature (e.g., riffle, run, pool, glide) and the maximum pool depth. The survey will be tied to a permanent benchmark.

The longitudinal profiles should show that the bedform features are remaining stable (i.e., they are not aggrading or degrading). The pools should remain deep with flat water surface slopes, and the riffles should remain steeper and shallower than the pools. Bedforms observed should be consistent with those observed for channels of the design stream type.

8.1.5 Bed Material Analyses

Since the streams through the project site are dominated by sand-size particles, pebble count procedures would not show a significant change in bed material size or distribution over the monitoring period; therefore, bed material analyses are not recommended for this project.

8.1.6 Photo Reference Sites

Photographs will be used to document restoration success visually. Reference stations will be photographed before construction and continued for at least five years following construction. Reference photos will be taken once a year. Photographs will be taken from a height of approximately five to six feet. Permanent markers will be established to ensure that the same locations (and view directions) on the site are documented in each monitoring period.

The stream will be photographed longitudinally beginning at the downstream end of the restoration site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to provide an overall view of the reach. The angle of the shot will depend on what angle provides the best view and will be noted and continued in future shots. When modifications to photo position must be made due to obstructions or other reasons, the position will be noted along with any landmarks and the same position will used in the future.

Lateral reference photos. Reference photo transects will be taken at each permanent cross-section. Photographs will be taken of both banks at each cross-section. The survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame, and as much of the bank as possible will be included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time.

Structure photos. Photographs will be taken at each grade control structure along the restored stream. Photographers should make every effort to consistently maintain the same area in each photo over time.

8.2 Stream Monitoring - Reaches UT1b and UT2

Geomorphic monitoring of reaches UT1b and UT2 will be conducted for five years to evaluate the effectiveness of the restoration practices. Since restoration of these reaches involves the restoration of historic flow patterns and flooding functions to remnant channel segments in a multi-threaded swamp system, monitoring efforts will focus on visual documentation of stability and the use of wells to document saturation and flooding functions. The methods used and any related success criteria are described below for each parameter.

8.2.1 Bankfull Events and Flooding Functions

The occurrence of bankfull events and flooding functions within the monitoring period will be documented by the use of monitoring gages and photographs. At least five monitoring gages will be installed within the restored system to document groundwater and flooding levels. Loggers will be programmed to collect data at a minimum of every 12 hours. Installation of monitoring stations will follow the USACE standard methods found in WRP Technical Notes ERDC TN-WRAP-00-02 (July 2000).

Two bankfull flow events must be documented within the 5-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years. Gages should document the occurrence of periodic inundation and varying groundwater levels across the restored site. Gages should also document the connectivity of flooding between the restored UT1b and UT2 reaches.

8.2.2 Photo Reference Sites

Photographs will be used to document restoration success visually. Reference stations will be photographed before construction and continued for at least five years following construction. Reference photos will be taken at least twice per year, and will be taken in enough locations to document the condition of restored system. Photographs will be taken from a height of approximately five to six feet. Permanent markers will be established to ensure that the same locations (and view directions) on the site are documented in each monitoring period.

The stream systems will be photographed longitudinally beginning at the downstream end of the restoration reach and moving upstream to the end of the reach. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to provide an overall view of the reach. The angle of the shot will depend on what angle provides the best view and will be noted and continued in future shots. When modifications to photo position must be made due to obstructions or other reasons, the position will be noted along with any landmarks and the same position will used in the future.

Additional photographs will be taken to document any observed evidence of flooding patterns, such as debris, wrack lines, water marks, etc.

8.3 Wetland Monitoring

8.3.1 Wetland Hydrologic Monitoring

Groundwater-monitoring stations will be installed across the project area to document hydrologic conditions of the restored site. Up to five groundwater monitoring stations will be installed, with all five stations being automated groundwater gauges. Ground water monitoring stations will follow the USACE standard methods found in WRP Technical Notes ERDC TN-WRAP-00-02 (July 2000).

In order to determine if the rainfall is normal for the given year, rainfall amounts will be tallied using data obtained from the Gates County WETS Station and an onsite rain gage.

The objective is for the monitoring data to show the site is saturated within 12 inches of the soil surface for at least 8 percent of the growing season as indicated by the DRAINMOD model in Section 8.2 and that the site exhibits an increased frequency of flooding. The restored site will be compared to a reference site where the groundwater and surface water levels (overbank events) will be monitored. In addition, the restored site's hydrology will be compared to pre-restoration conditions both in terms of groundwater and frequency of overbank events.

8.4 Vegetation Monitoring

Successful restoration of the vegetation on a wetland mitigation site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, vegetation-monitoring quadrants will be installed across the restoration site, as directed by EEP monitoring guidance. At least 12 permanent monitoring quadrants will be established within the restored wetland areas. No monitoring quadrants will be established within the floodplain areas of UT1b or UT2 since these areas are already wooded. The size of individual quadrants will be 100 square meters for woody tree species, 25 square meters for shrubs, and 1 square meter for herbaceous vegetation. Vegetation monitoring will occur in spring, after leaf-out has occurred. Individual quadrant data will be provided and will include diameter, height, density, and coverage quantities. Relative values will be calculated, and importance values will be determined. Individual seedlings will be marked such that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living, planted seedlings and the current year's living, planted seedlings.

At the end of the first growing season, species composition, density, and survival will be evaluated. For each subsequent year, until the final success criteria are achieved, the restored site will be evaluated between July and November.

Specific and measurable success criteria for plant density on the project site will be based on the recommendations found in the WRP Technical Note and correspondence from review agencies on mitigation sites recently approved under the Neu-Con Mitigation Banking Instrument.

The interim measure of vegetative success for the site will be the survival of at least 320, 3-year old, planted trees per acre at the end of year three of the monitoring period. The final vegetative success criteria will be the survival of 260, 5-year old, planted trees per acre at the end of year five of the monitoring period. While measuring species density is the current accepted methodology for evaluating vegetation success on restoration projects, species density alone may be inadequate for assessing plant community health. For this reason, the vegetation monitoring plan will incorporate the evaluation of additional plant community indices to assess overall vegetative success.

Herbaceous vegetation, primarily native grasses, planted at the site shall have at least 80 percent coverage of the seeded/planted area. Any herbaceous vegetation not meeting these criteria shall be replanted. At a minimum, at all times ground cover at the project site shall be in compliance with the North Carolina Erosion and Sedimentation Control Ordinance.

8.5 Reporting Requirements

A mitigation plan and as-built report documenting both stream and wetland restoration will be developed within 60 days of the completion of planting and the installation of wells on the restored site. The report will include all information required by EEP mitigation plan guidelines at the time of contract signing, including elevations, photographs, well and sampling plot locations, a description of initial species composition by community type, and monitoring stations. The report will include a list of the species planted and the associated densities. The monitoring program will be implemented to document system development and progress toward achieving the success criteria referenced in the previous sections. Stream morphology, as well as the restored wetland hydrology and vegetation, will be assessed to determine the success of the mitigation. The monitoring program will be undertaken for 5 years, or until the final success criteria are achieved, whichever is longer. Monitoring reports will be prepared in the fall of each year of monitoring and submitted to EEP. The monitoring reports will include:

- A detailed narrative summarizing the condition of the restored site and all regular maintenance activities
- As-built topographic maps showing location of monitoring gauges, vegetation sampling plots, permanent photo points, and location of transacts
- Photographs showing views of the restored site taken from fixed-point stations
- Hydrologic information
- Vegetative data
- Identification of any invasion by undesirable plant species, including quantification of the extent of invasion of undesirable plants by either stem counts, percent cover, or area, whichever is appropriate
- A description of any damage done by animals or vandalism
- Wildlife observations
- Reference wetland hydrology and stream data.

8.6 Maintenance Issues

Maintenance requirements vary from site to site and are generally driven by the following conditions:

- Projects without established woody floodplain vegetation are more susceptible to erosion from floods than those with a mature hardwood forest.
- Projects with sandy non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- Local wildlife can impact the rate at which the native buffer can be established.
- Extreme and/or frequent flooding can cause floodplain and channel erosion.
- Extreme hot, cold, wet, or dry weather during and after construction can limit vegetation growth, particularly temporary and permanent seed.
- The presence and aggressiveness of invasive species can affect the extent to which a native buffer can be established.

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. Factors that may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

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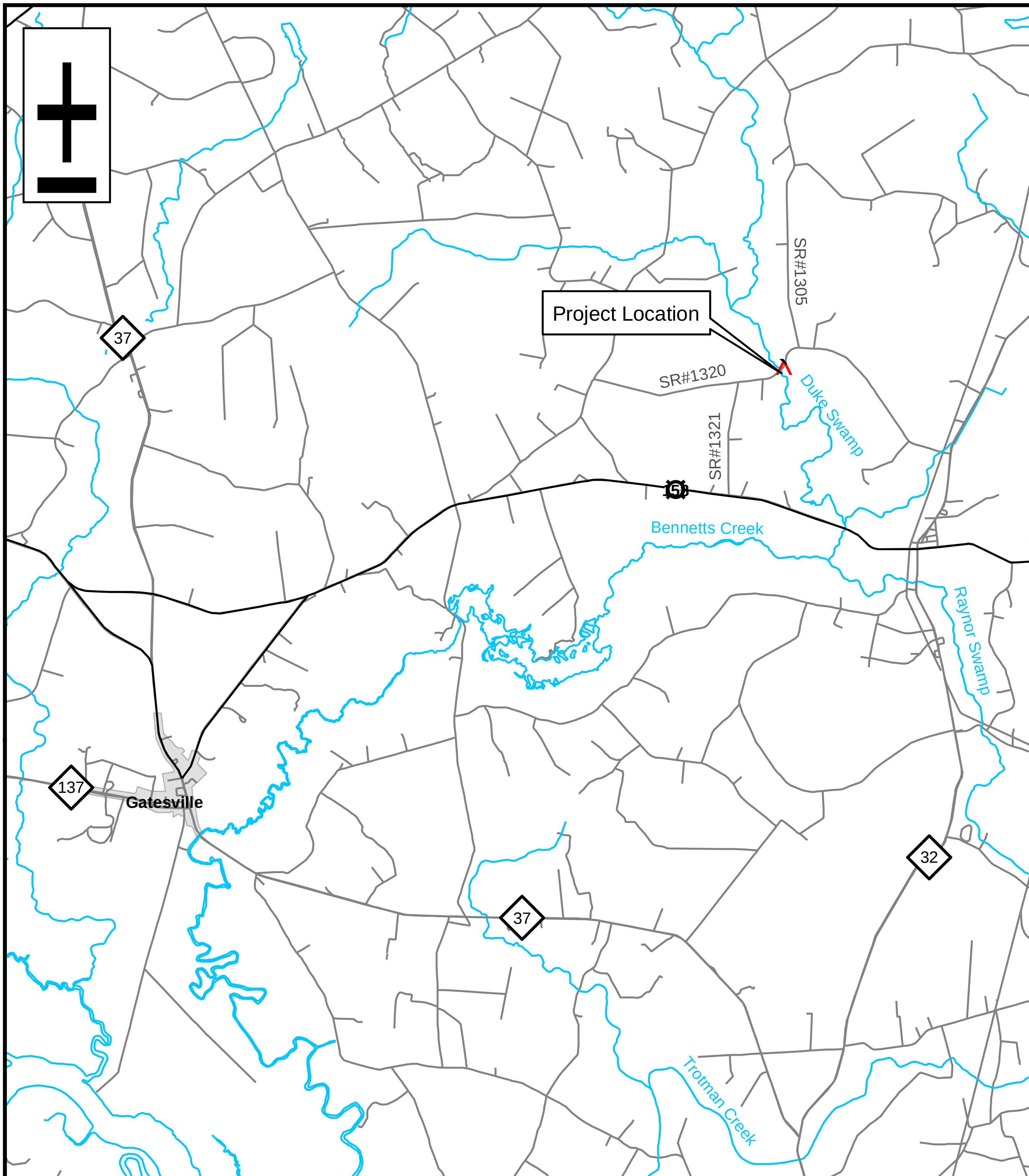
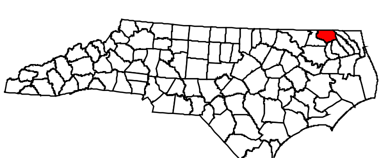
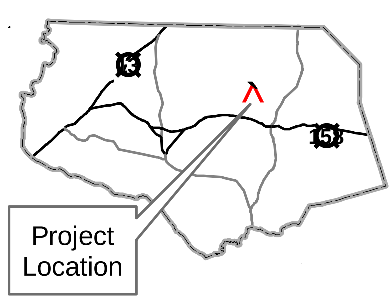
Exhibits







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Cary, NC 27518

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Exhibit 1.1. Project Vicinity Map
Duke Swamp Site

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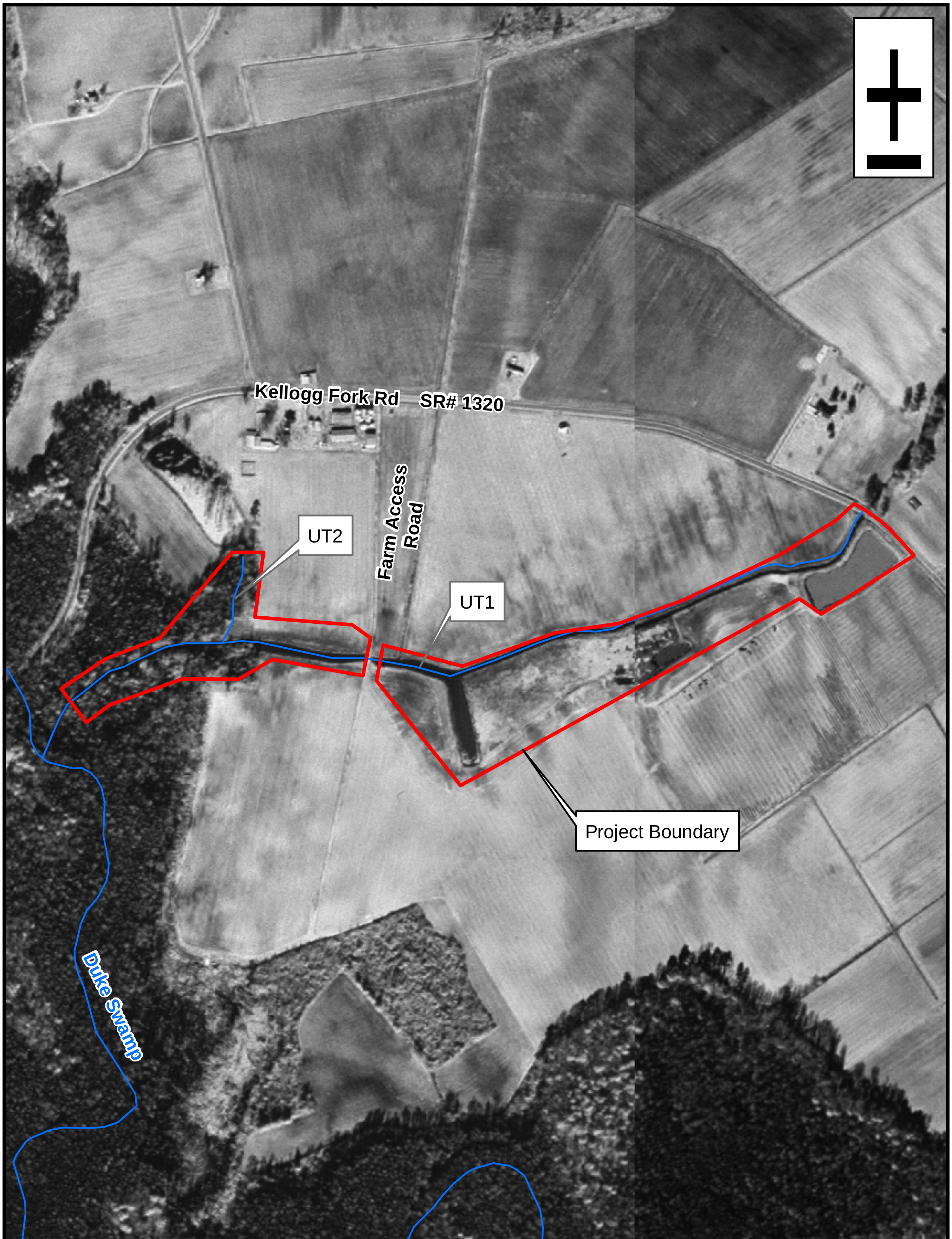

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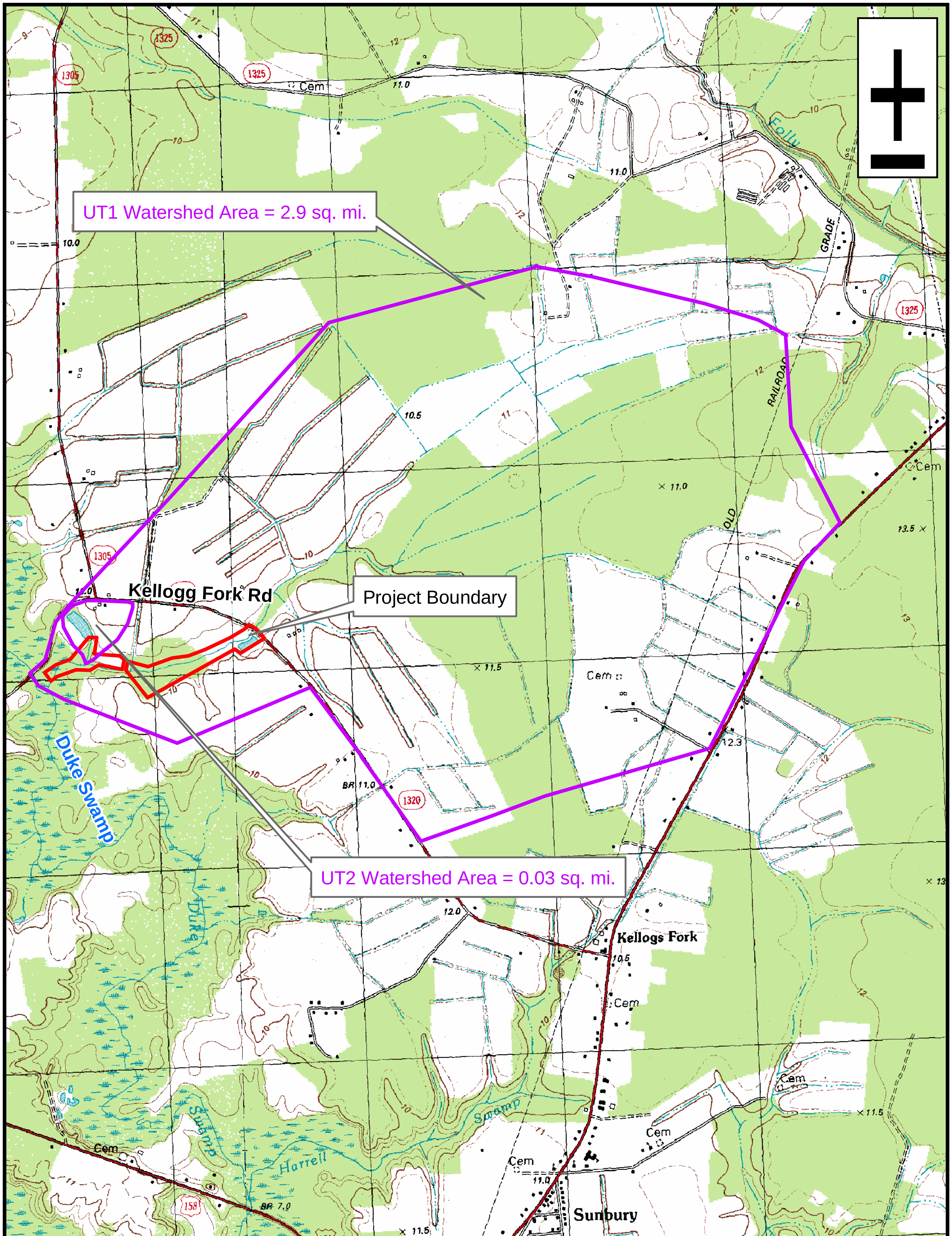
Exhibit 1.2
Site Location Map
Duke Swamp Site



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Feet

Exhibit 1.3
Project Watershed Boundaries
Duke Swamp Site

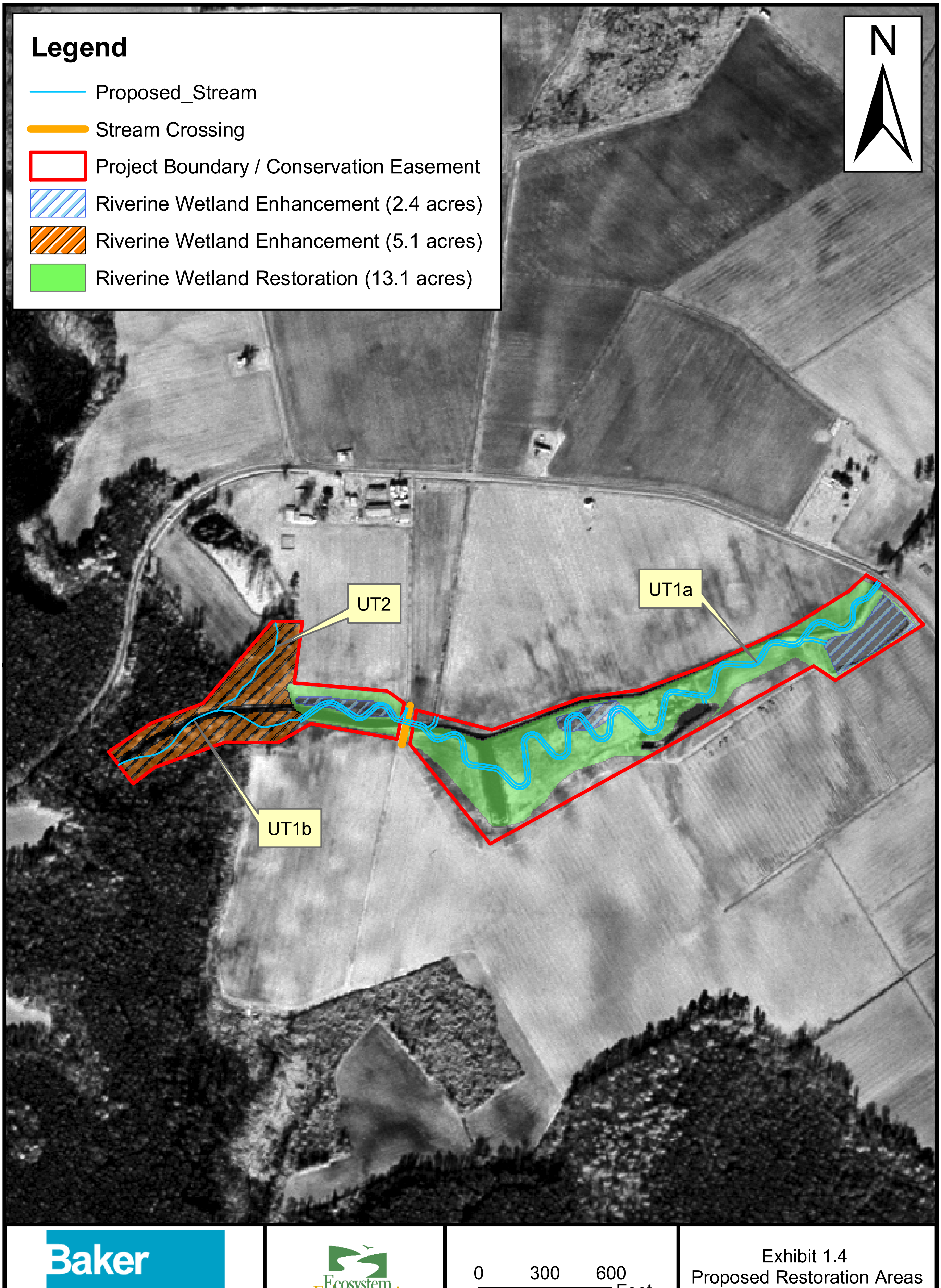

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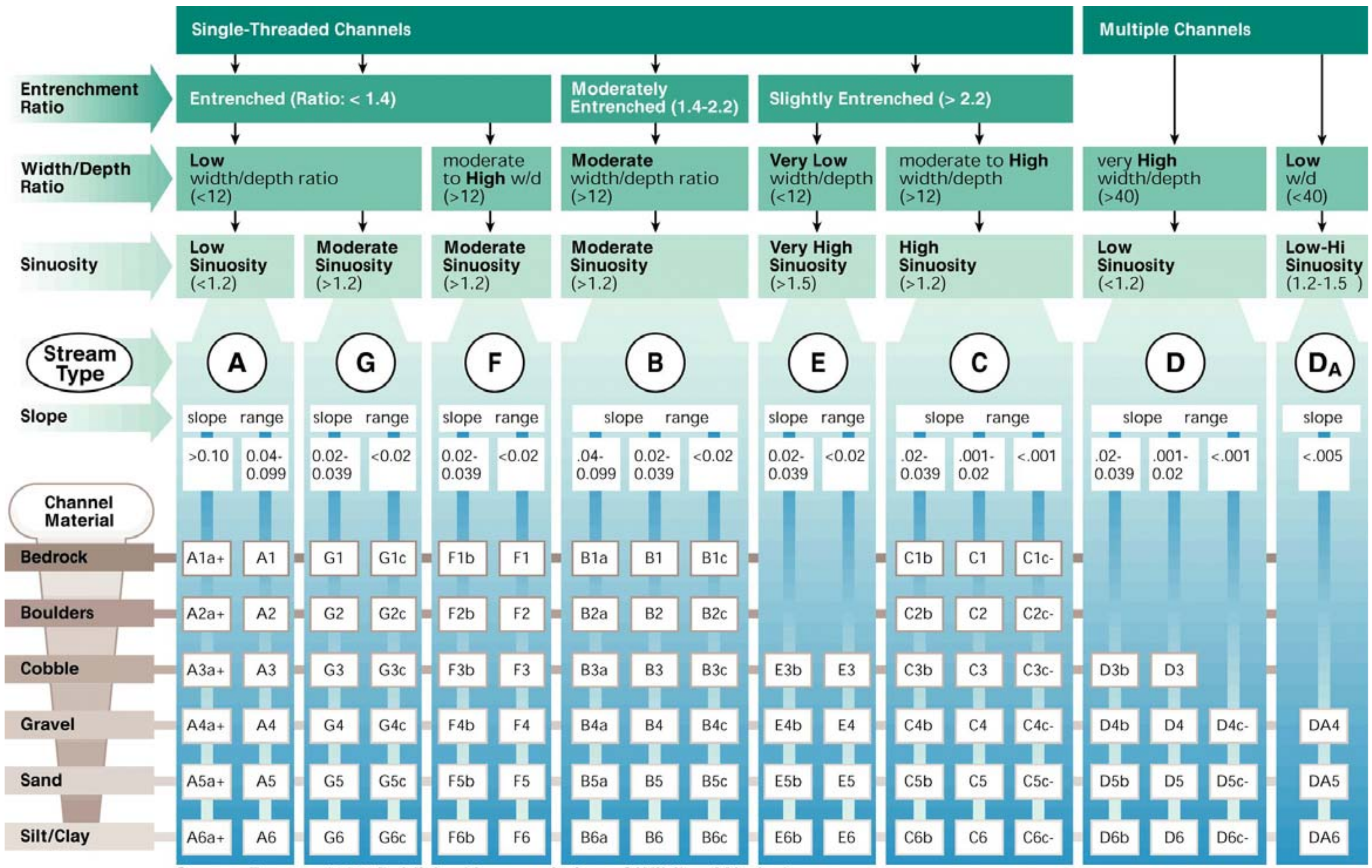
Exhibit 1.4
Proposed Restoration Areas
Duke Swamp Site

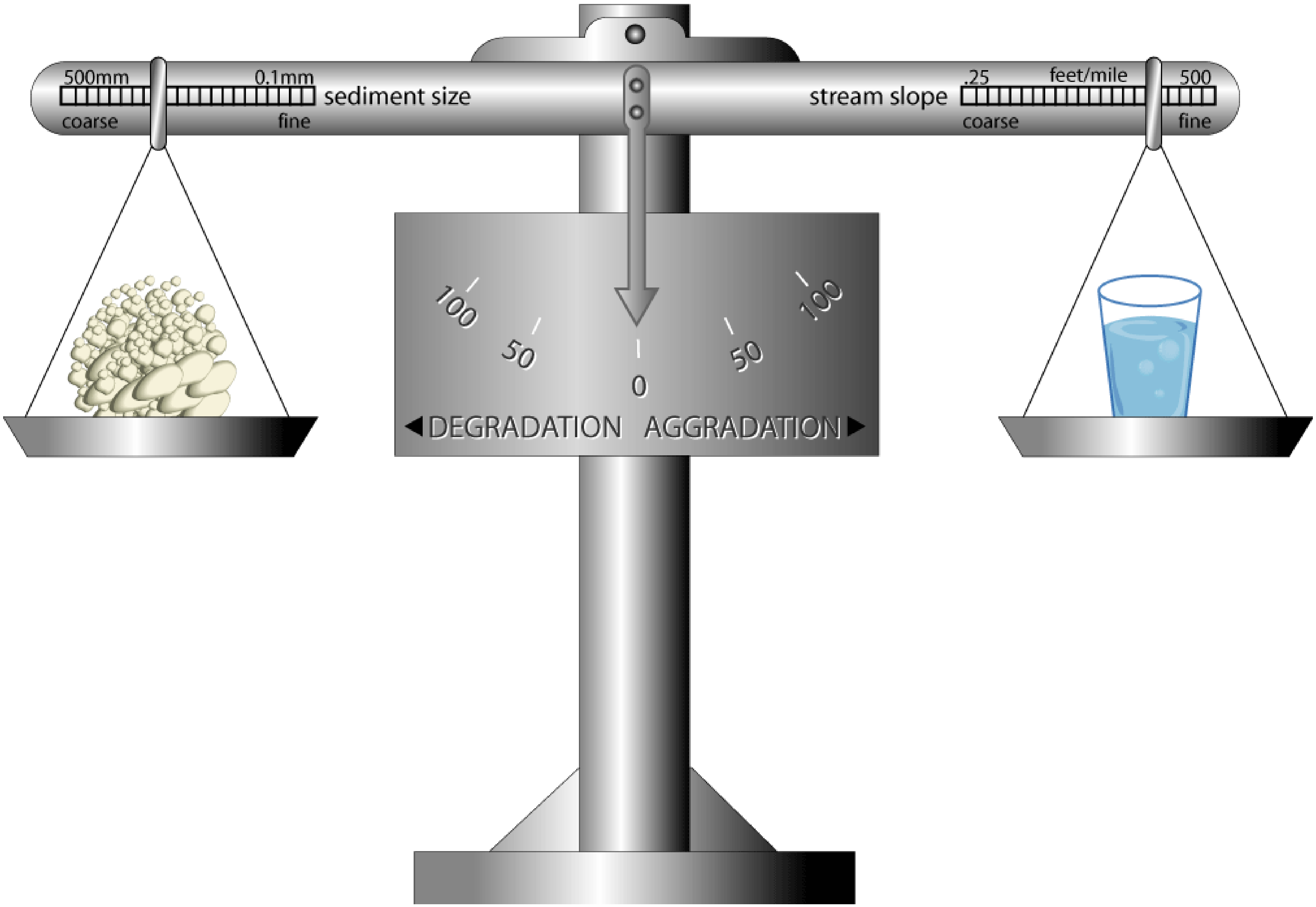


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

Fig. 7.12 -- Rosgen's stream classification system (Level II).
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

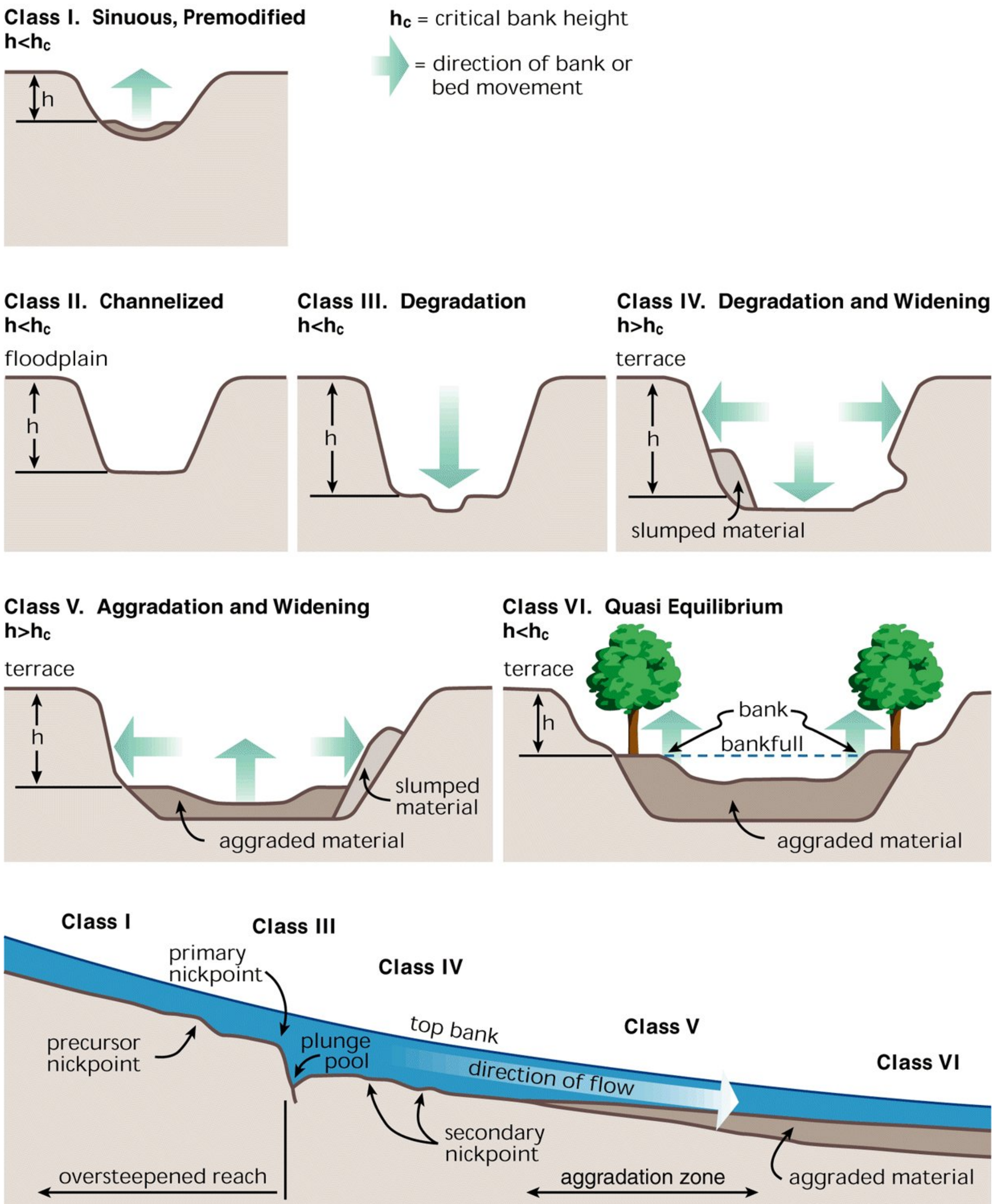
Exhibit 2.1
Rosgen Stream Classification

Source: Rosgen, David L., *Applied River Morphology*, Wildland Hydrology, 1996



After: Lane, 1955

Exhibit 2.2
Factors Influencing Stream Stability



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

Exhibit 2.3
Simon Channel Evolution Model

Source: Simon, 1989

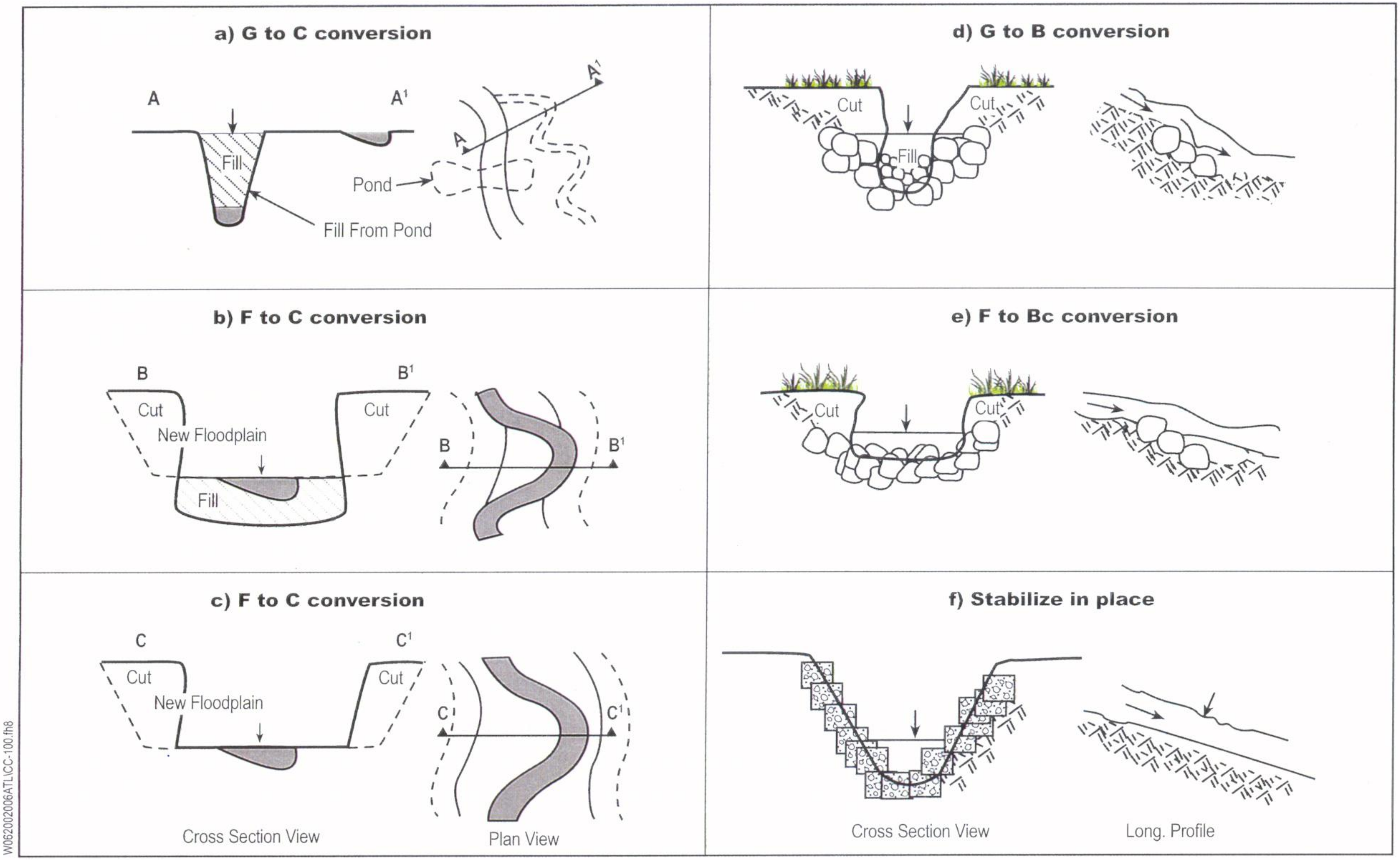
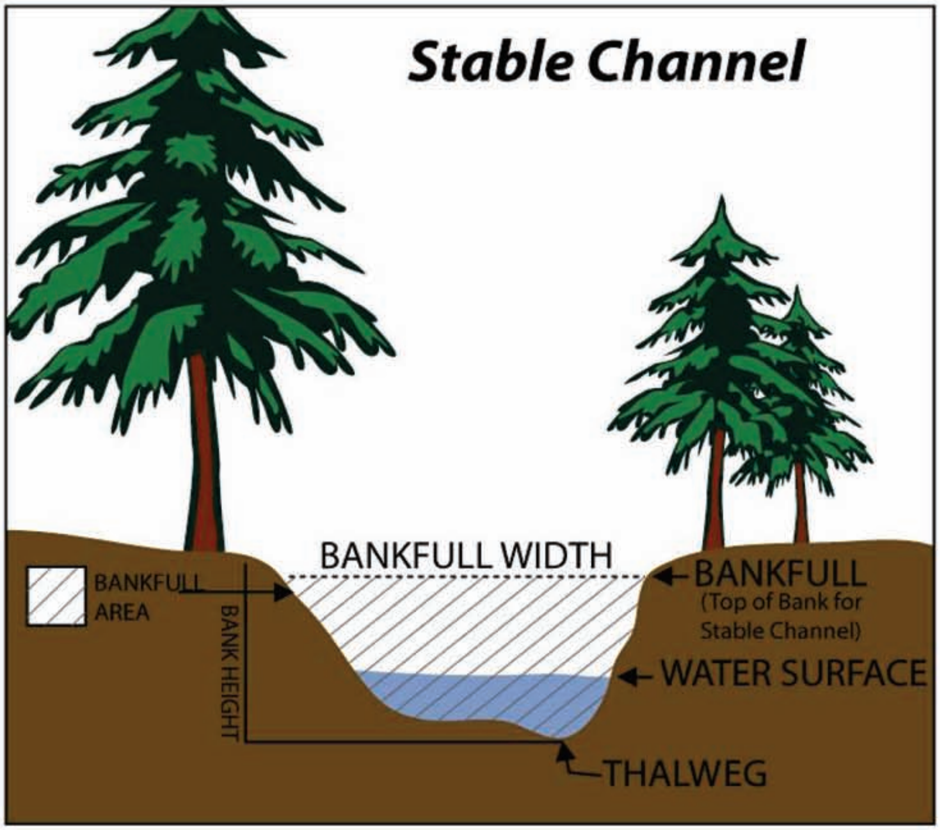
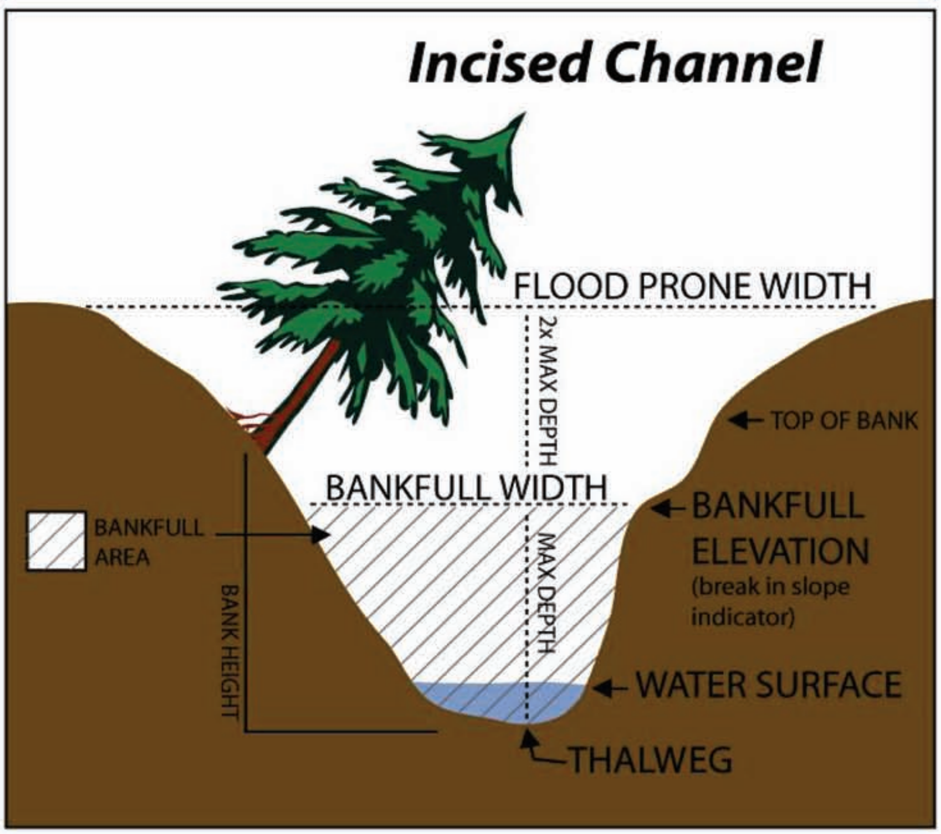


Exhibit 2.4
Restoration Priorities for Incised Channels

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





Channel Dimension Measurements

Bankfull Elevation is associated with the channel forming discharge. It is the point where channel processes and flood plain processes begin.

Bankfull width: the distance between the left bank bankfull elevation and the right bank bankfull elevation

Bankfull mean depth: the average depth from bankfull elevation to the bottom of the stream channel

Max depth (dmax): the deepest point within the cross-section measured to the bankfull elevation

Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

Bank Height Ratio: Bank height (measured from top of bank to the bottom of the stream channel) ÷ the max depth of the bankfull elevation (dmax)

Flood Prone Width: Width measured at the elevation of two times (2x) the maximum depth at bankfull (dmax)

Entrenchment Ratio: Floodprone width ÷ bankfull width

Exhibit 2.5
Channel Dimension Measurements

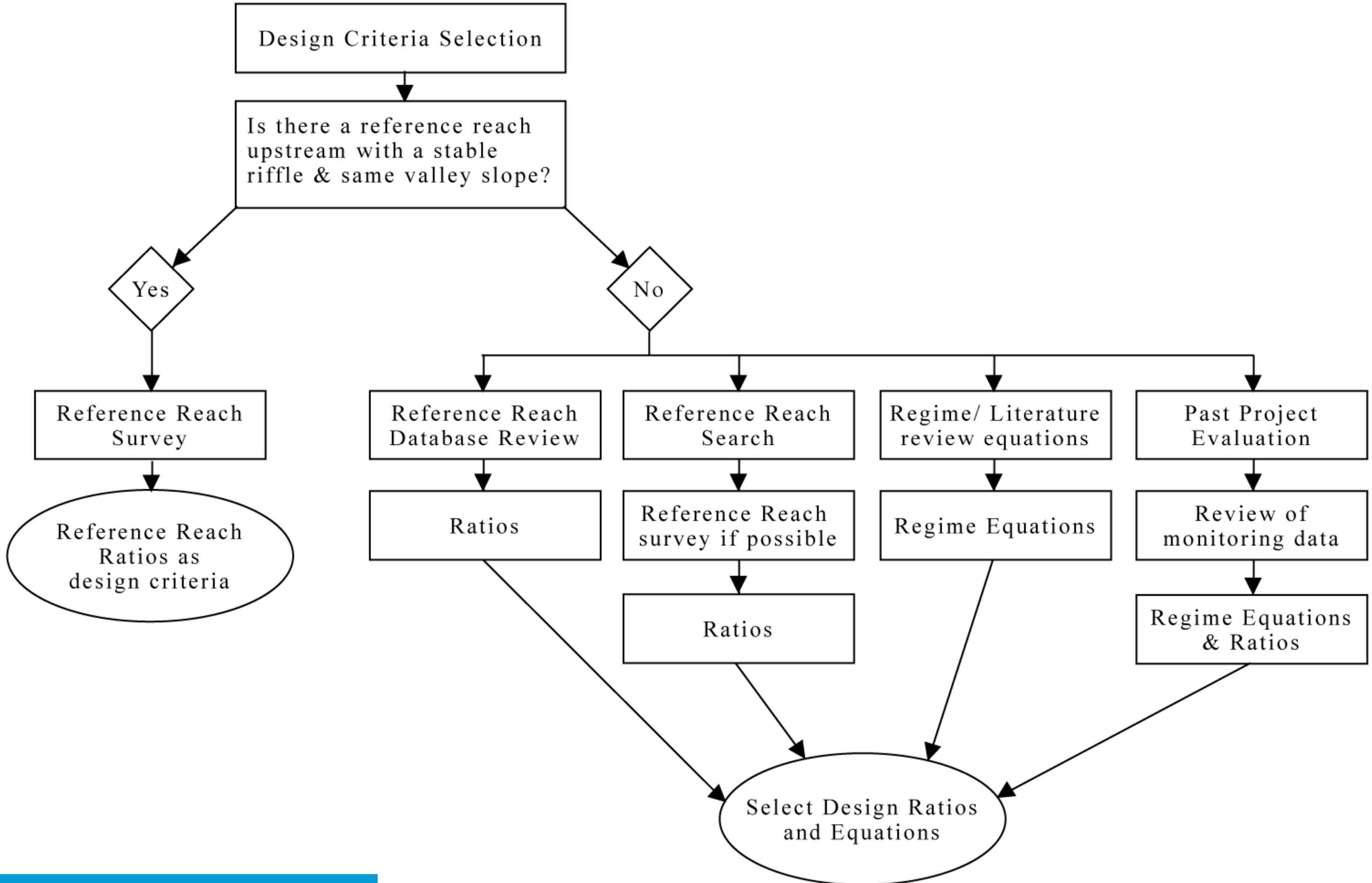


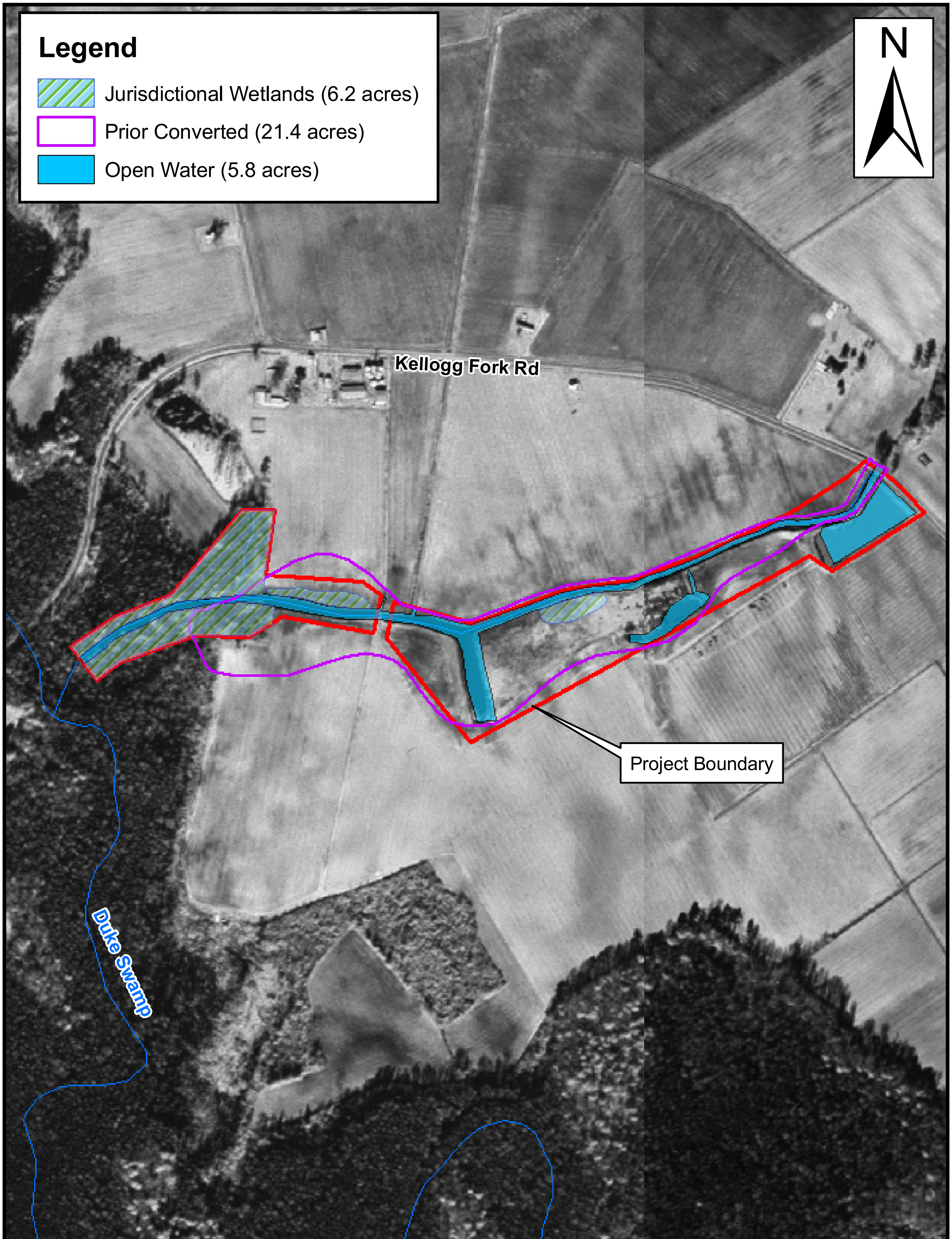
Exhibit 2.6
Design Criteria Selection

Log Vane

Log Weir

Root Wads

Exhibit 2.7
Examples of In-stream Structures

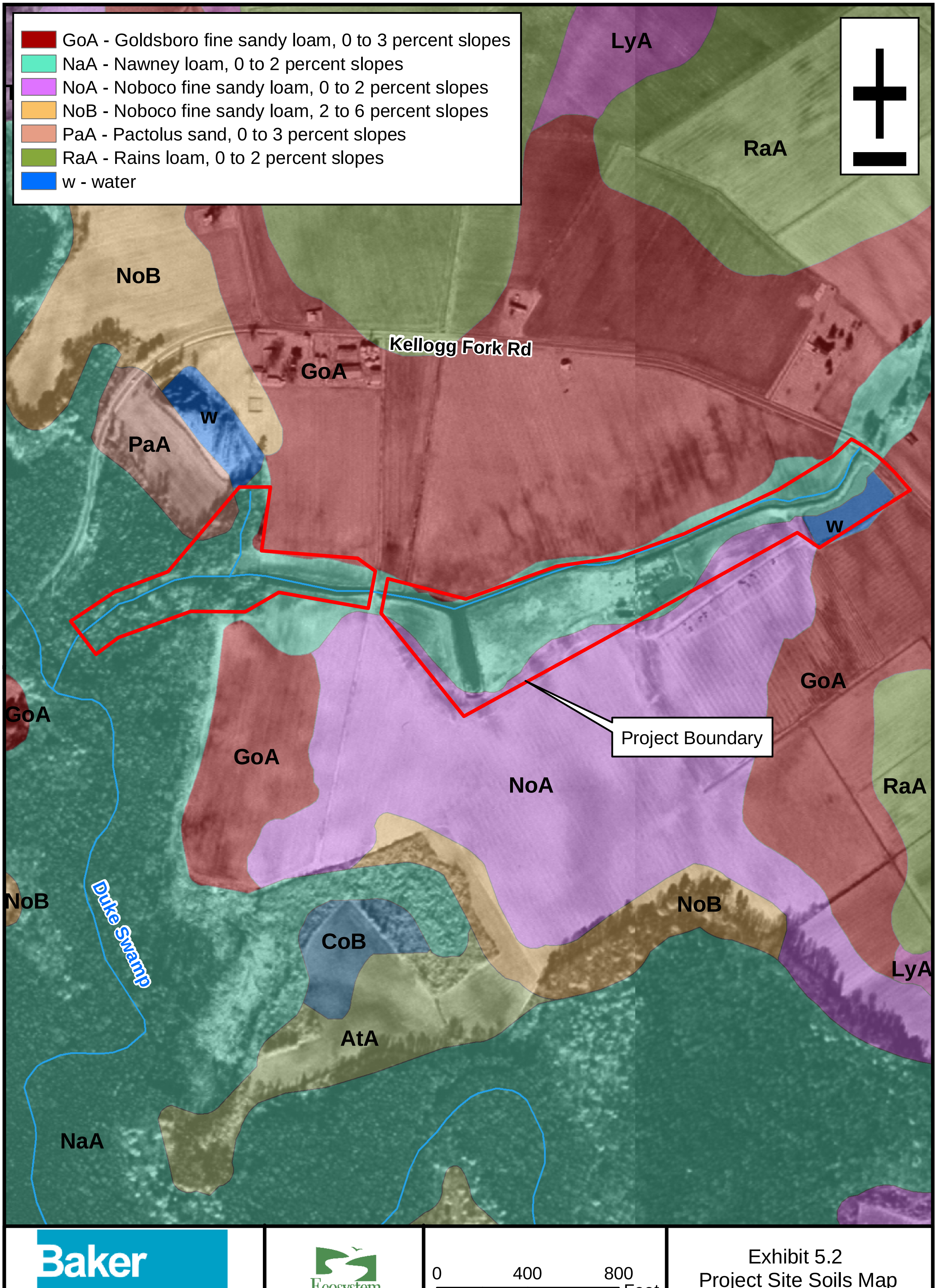


Baker
8000 Regency Parkway, Suite 200
Cary, NC 27518

Ecosystem Enhancement Program
D06065-A

0 400 800 Feet

Exhibit 5.1
Site Wetlands Map
Duke Swamp Site



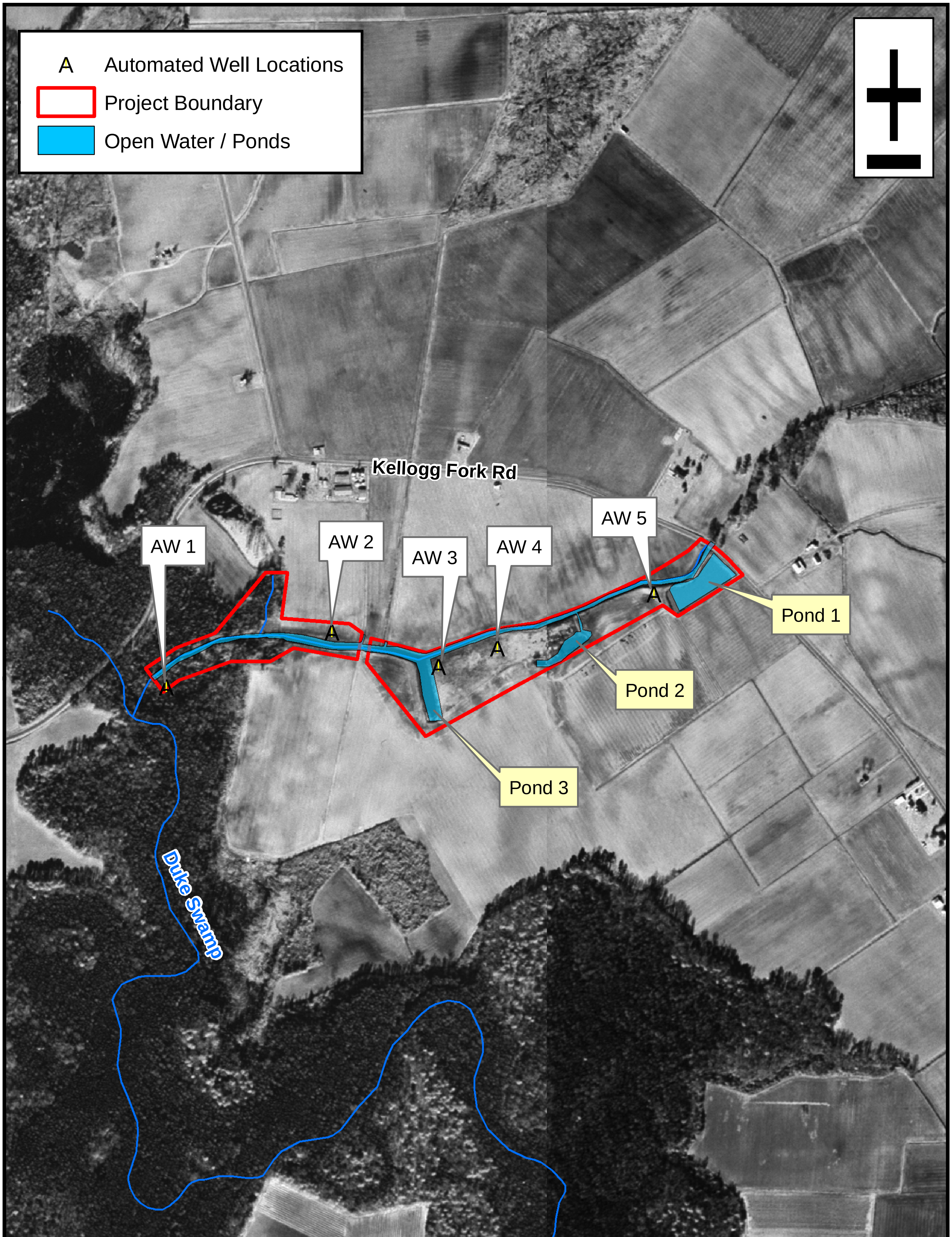
Baker

8000 Regency Parkway, Suite 200
Cary, NC 27518

Ecosystem Enhancement Program

D06065-A

Exhibit 5.2
Project Site Soils Map
Duke Swamp Site

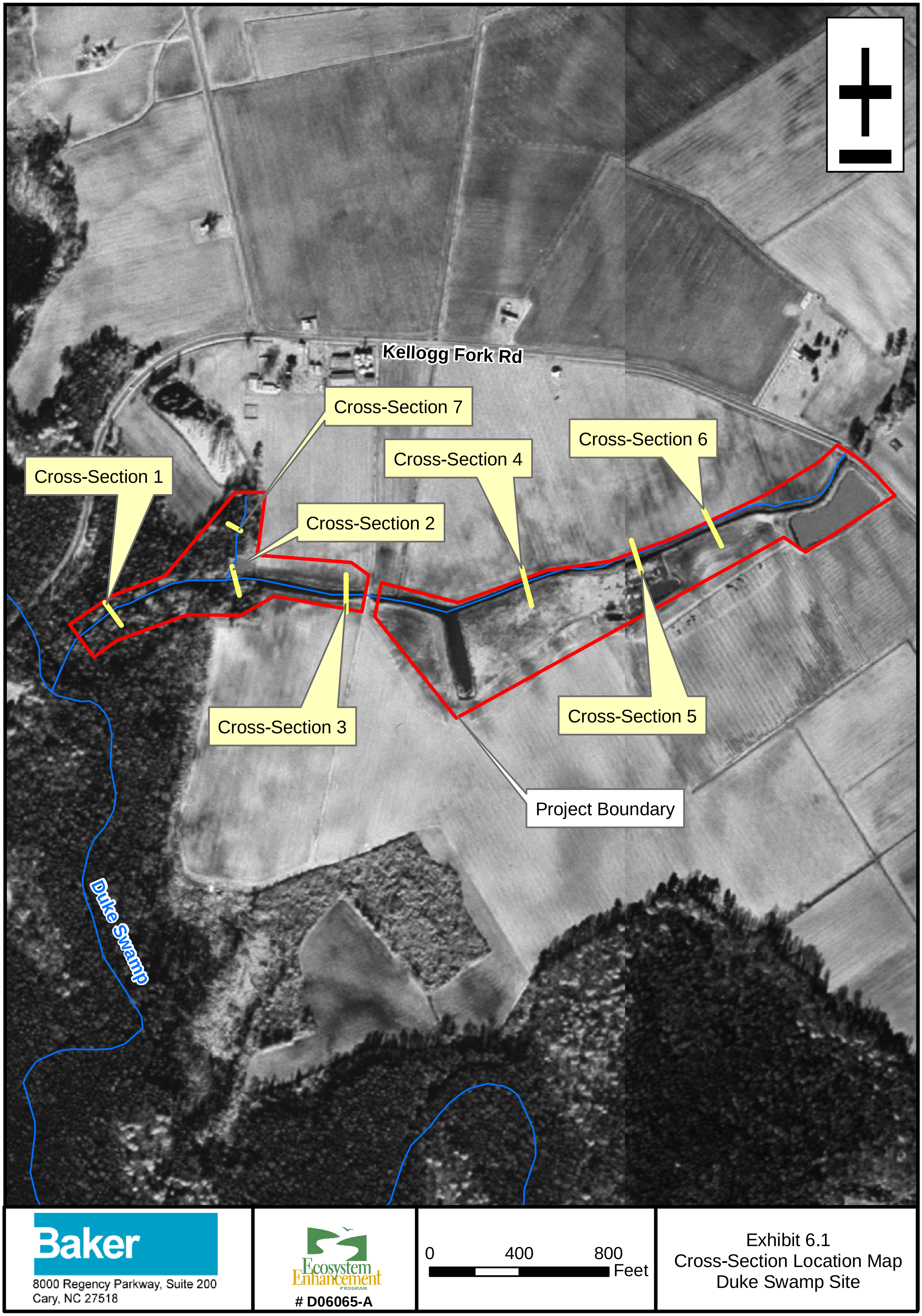


Baker
8000 Regency Parkway, Suite 200
Cary, NC 27518

Ecosystem Enhancement Program
D06065-A

0 400 800 Feet

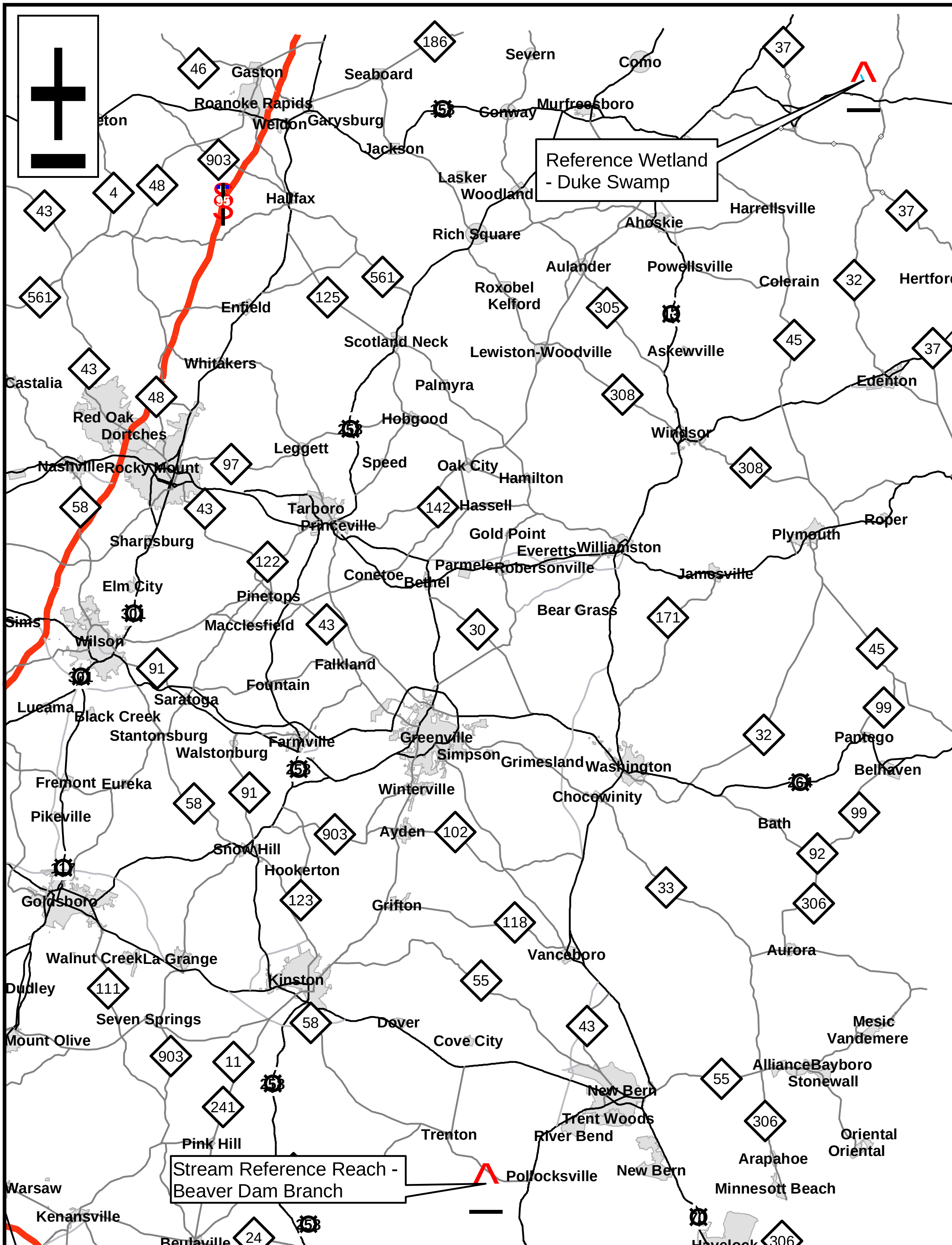
Exhibit 5.3
Site Hydrology Map & Location of Water Table Monitoring Wells
Duke Swamp Site



Baker
8000 Regency Parkway, Suite 200
Cary, NC 27518

Ecosystem Enhancement Program
D06065-A

Exhibit 6.1
Cross-Section Location Map
Duke Swamp Site



Baker

8000 Regency Parkway, Suite 200
Cary, NC 27518

Ecosystem Enhancement Program

D06065-A

0 3.5 7 14 Miles

Exhibit 6.2
Location of Reference Reach
& Reference Wetland
Duke Swamp Site

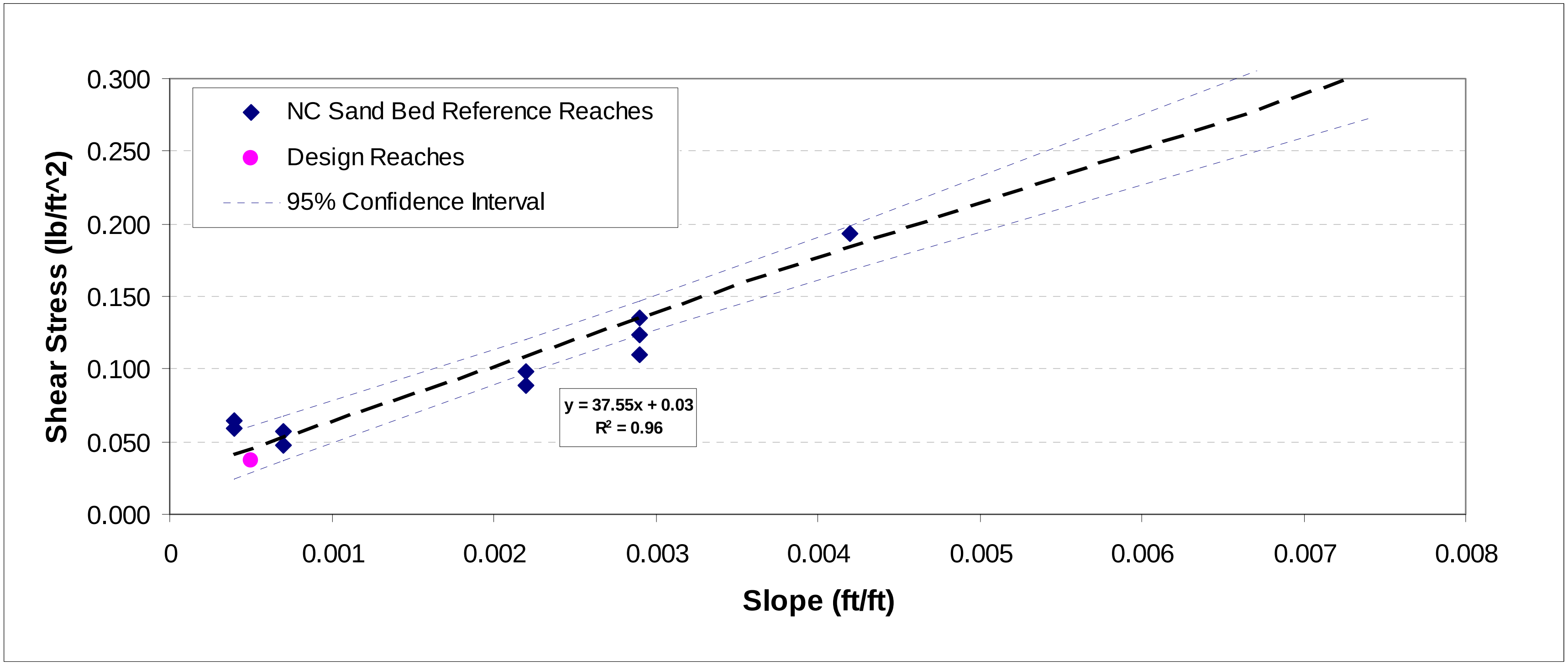


Exhibit 7.1
Comparison Between Bankfull Shear Stress and Channel Slope for Coastal Plain Reference Reach Data and Design Reach Data.

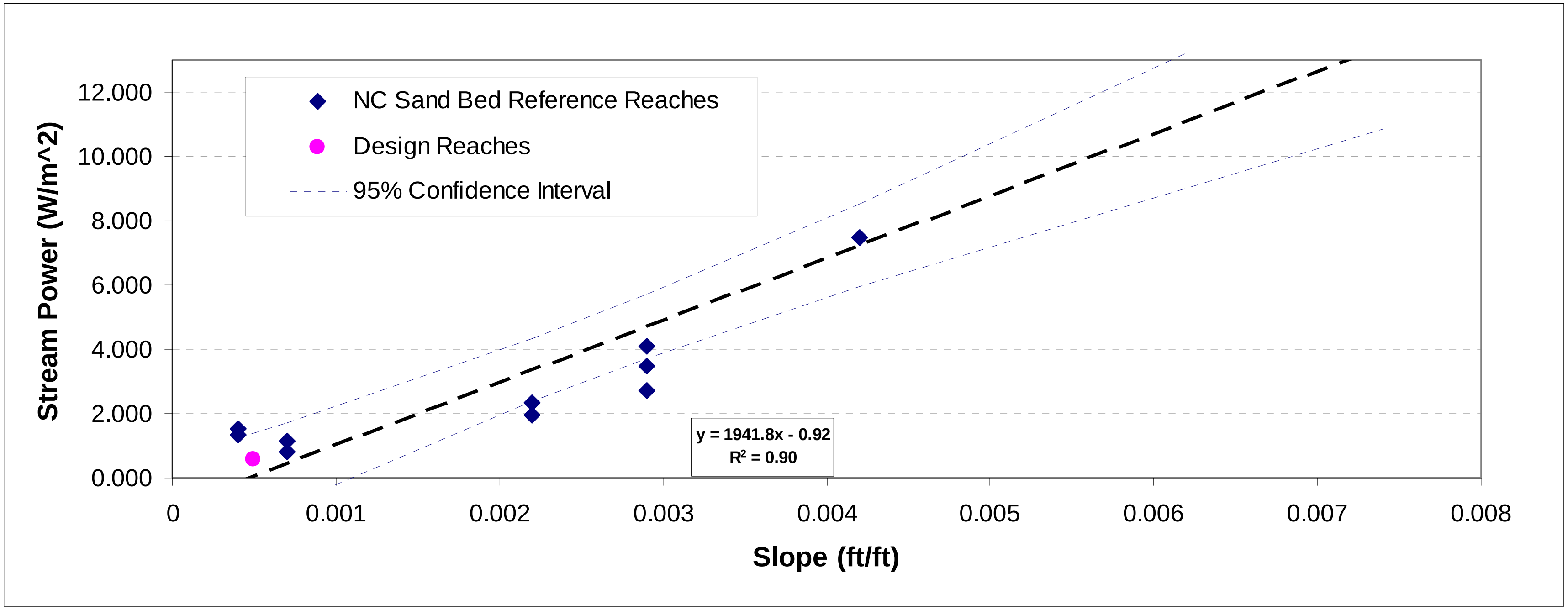


Exhibit 7.2
Comparison Between Stream Power and Channel Slope for Coastal Plain Reference Reach Data and Design Reach Data.

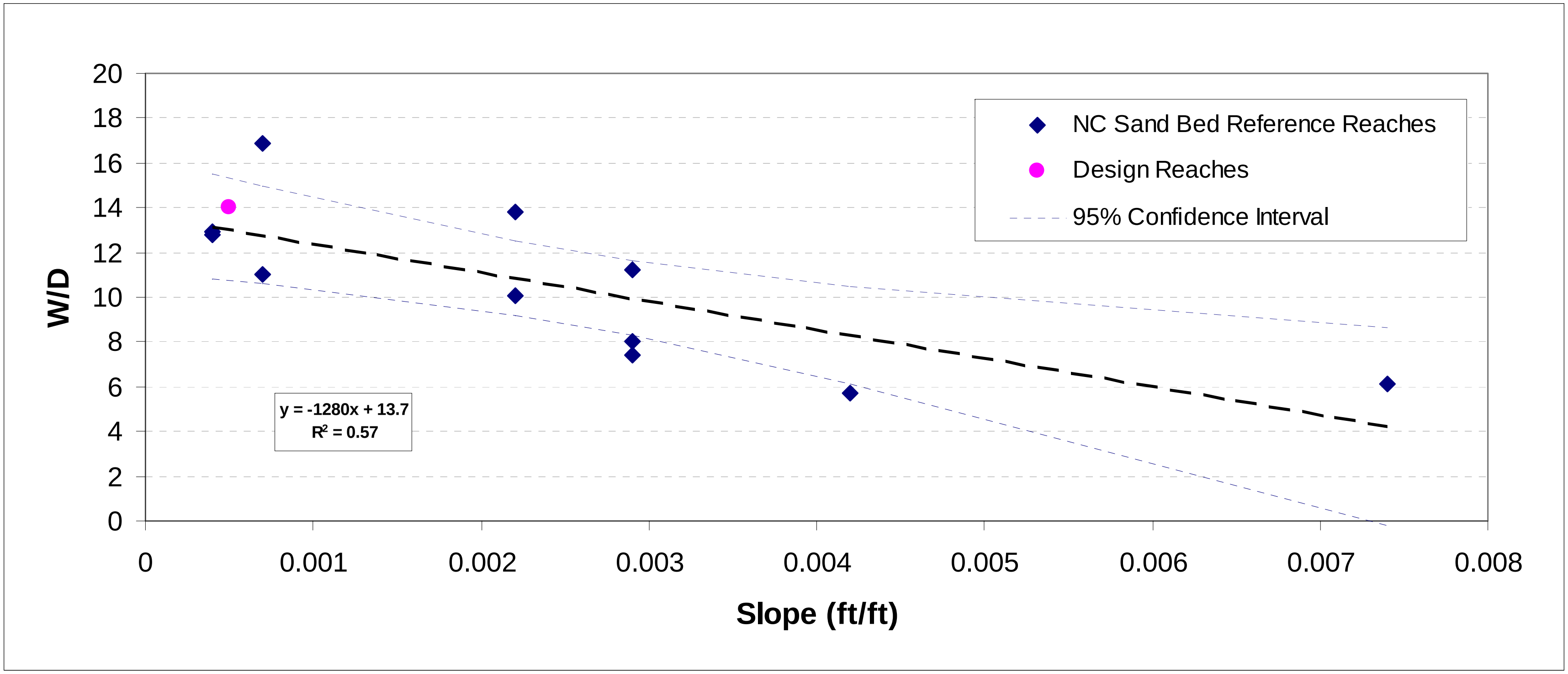


Exhibit 7.3
Comparison Between Width-to-depth Ratio (W/D) and Channel Slope for Coastal Plain Reference Reach Data and Design Reach Data.

Appendices

Appendix A

SHPO Correspondence &

Recorded Conservation Easement Deeds

North Carolina Department of Cultural Resources

State Historic Preservation Office

Peter B. Sandbeck, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

August 23, 2006

Ken Gilland
Buck Engineering
8000 Regency Parkway, Suite 200
Cary, NC 27511

Re: EEP, Wetland and Stream Mitigation, Unnamed Tributary to Duke Swamp, Gates County, ER 06-2096

Dear Mr. Gilland:

Thank you for your letter of July 31, 2006, concerning the above project.

We have conducted a review of the proposed undertaking and are aware of no historic resources that would be affected by the project. Therefore, we have no comment on the undertaking as proposed.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Peter B. Sandbeck

Peter Sandbeck by mPm

	Location	Mailing Address	Telephone/Fax
ADMINISTRATION	507 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-4763/733-8653
RESTORATION	515 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6547/715-4801
SURVEY & PLANNING	515 N. Blount Street, Raleigh, NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6545/715-4801

FILED in GATES County, NC
on Apr 02 2007 at 02:00:29 PM
by: SHARON G. HARRELL
REGISTER OF DEEDS
BOOK 256 PAGE 903

This certifies that there are no delinquent ad valorem real Estate taxes, which the Gates County Tax Collector is Charges with collecting that are a lien on:

PIN #: 05-00481

Gates County Office of Land Records. This is not a Certification that the PIN # matches the deed description.

Marie D. Lowater 4-2-07

Tax Collector Date
Delinquent Tax Collector
Tax Clerk

Record: $53.00
Excise Tax: $133.00

STATE OF NORTH CAROLINA

GATES COUNTY

SPO File Number: 37-ZZK

Prepared by and
Return to: Robert H. Merritt, Jr.
Bailey & Dixon, LLP
P. O. Box 1351
Raleigh, NC 27602

CONSERVATION EASEMENT PROVIDED PURSUANT TO FULL DELIVERY MITIGATION CONTRACT (TRACTS A and A-1)

Issued Apr 02 2007
$133.00
State of North Carolina GATES County
Real Estate Excise Tax
2303

THIS CONSERVATION EASEMENT DEED, made this 27th day of February, 2007, by EMMITT EARL PARKER, JR. and wife, BETTY S. PARKER; EMMITT EARL PARKER, III and wife, TERRI PARKER; JENNIFER PARKER (unmarried); TANYA PARKER JONES and husband, KEVIN JONES; CLAYTEN PARKER and wife, MARCIE PARKER; and CLINTEN PARKER and wife, LEE PARKER, ("**Grantor**"), whose mailing address is c/o Emmitt Earl Parker, Jr. 410 Kellogg Fork Road, Sunbury, NC 27979, to the State of North Carolina, ("**Grantee**"), whose mailing address is State of North Carolina, Department of Administration, State Property Office, 1321 Mail Service Center, Raleigh, NC 27699-1321. The designations of Grantor and Grantee as used herein shall include said parties, their heirs, successors, and assigns, and shall include singular, plural, masculine, feminine, or neuter as required by context.

WITNESSETH:

WHEREAS, pursuant to the provisions of N.C. Gen. Stat. § 143-214.8 et seq., the State of North Carolina has established the Ecosystem Enhancement Program (formerly known as the Wetlands Restoration Program) within the Department of Environment and Natural Resources for the purposes of acquiring, maintaining, restoring, enhancing, creating and preserving wetland and riparian resources that contribute to the protection and improvement of water quality, flood prevention, fisheries, aquatic habitat, wildlife habitat, and recreational opportunities; and

FILED in GATES County, NC
on Apr 02 2007 at 02:05:25 PM
by: SHARON G. HARRELL
REGISTER OF DEEDS
BOOK 256 PAGE 917

This certifies that there are no delinquent ad valorem real Estate taxes, which the Gates County Tax Collector is Charges with collecting that are a lien on:

PIN #: 05-00483

Gates County Office of Land Records. This is not a Certification that the PIN # matches the deed description.

Marie A. Rountree 4-2-07

Tax Collector Date
Delinquent Tax Collector
Tax Clerk

Record: $44.00
Excise Tax: $377.00

STATE OF NORTH CAROLINA

GATES COUNTY

SPO File Number: 37-ZZK

CONSERVATION EASEMENT PROVIDED PURSUANT TO FULL DELIVERY MITIGATION CONTRACT (TRACTS B and B-1)

Issued Apr 02 2007
$377.00
State of North Carolina GATES County
Real Estate Excise Tax

Prepared by and
Return to: Robert H. Merritt, Jr.
Bailey & Dixon, LLP
P. O. Box 1351
Raleigh, NC 27602

THIS CONSERVATION EASEMENT DEED, made this 2nd day of April, 2007, by EMMITT EARL PARKER, JR. and wife, BETTY S. PARKER, ("**Grantor**"), whose mailing address is 410 Kellogg Fork Road, Sunbury, NC 27979, to the State of North Carolina, ("**Grantee**"), whose mailing address is State of North Carolina, Department of Administration, State Property Office, 1321 Mail Service Center, Raleigh, NC 27699-1321. The designations of Grantor and Grantee as used herein shall include said parties, their heirs, successors, and assigns, and shall include singular, plural, masculine, feminine, or neuter as required by context.

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WHEREAS, this Conservation Easement from Grantor to Grantee has been negotiated, arranged and provided for as a condition of a full delivery contract between Buck Engineering, a unit of Michael Baker Corporation, 8000 Regency Parkway, Suite

Appendix B

EDR Transaction Screen Map Report

The EDR Radius Map
with GeoCheck®

UT to Duke Swamp
410 Kellogg Fork Road
Sunbury, NC 27979

Inquiry Number: 1727919.1s

August 02, 2006

EDR® Environmental Data Resources Inc

The Standard in Environmental Risk Management Information

440 Wheelers Farms Road
Milford, Connecticut 06461

Nationwide Customer Service

Telephone: 1-800-352-0050
Fax: 1-800-231-6802
Internet: www.edrnet.com

TABLE OF CONTENTS

SECTION **PAGE**

GEOCHECK ADDENDUM

Thank you for your business.
Please contact EDR at 1-800-352-0050
with any questions or comments.

EXECUTIVE SUMMARY

A search of available environmental records was conducted by Environmental Data Resources, Inc (EDR). The report was designed to assist parties seeking to meet the search requirements of EPA's Standards and Practices for All Appropriate Inquiries (40 CFR Part 312), the ASTM Standard Practice for Environmental Site Assessments (E 1527-05) or custom requirements developed for the evaluation of environmental risk associated with a parcel of real estate.

TARGET PROPERTY INFORMATION

ADDRESS

410 KELLOGG FORK ROAD
SUNBURY, NC 27979

COORDINATES

Latitude (North):	36.469200 - 36˚ 28' 9.1''
Longitude (West):	76.636100 - 76˚ 38' 10.0''
Universal Tranverse Mercator:	Zone 18
UTM X (Meters):	353411.2
UTM Y (Meters):	4037034.0
Elevation:	19 ft. above sea level

USGS TOPOGRAPHIC MAP ASSOCIATED WITH TARGET PROPERTY

Target Property Map:	36076-D6 MERCHANTS MILLPOND, NC
Most Recent Revision:	1997
East Map:	36076-D5 SUNBURY, NC
Most Recent Revision:	1997

TARGET PROPERTY SEARCH RESULTS

The target property was not listed in any of the databases searched by EDR.

DATABASES WITH NO MAPPED SITES

No mapped sites were found in EDR's search of available ("reasonably ascertainable ") government records either on the target property or within the search radius around the target property for the following databases:

FEDERAL RECORDS

NPL	National Priority List
Proposed NPL	Proposed National Priority List Sites
Delisted NPL	National Priority List Deletions
NPL RECOVERY	Federal Superfund Liens
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERC-NFRAP	CERCLIS No Further Remedial Action Planned

EXECUTIVE SUMMARY

CORRACTS Corrective Action Report
RCRA-TSDF Resource Conservation and Recovery Act Information
RCRA-LQG Resource Conservation and Recovery Act Information
RCRA-SQG Resource Conservation and Recovery Act Information
ERNS Emergency Response Notification System
HMIRS Hazardous Materials Information Reporting System
US ENG CONTROLS Engineering Controls Sites List
US INST CONTROL Sites with Institutional Controls
DOD Department of Defense Sites
FUDS Formerly Used Defense Sites
US BROWNFIELDS A Listing of Brownfields Sites
CONSENT Superfund (CERCLA) Consent Decrees
ROD Records Of Decision
UMTRA Uranium Mill Tailings Sites
ODI Open Dump Inventory
TRIS Toxic Chemical Release Inventory System
TSCA Toxic Substances Control Act
FTTS FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
SSTS Section 7 Tracking Systems
ICIS Integrated Compliance Information System
PADS PCB Activity Database System
MLTS Material Licensing Tracking System
MINES Mines Master Index File
FINDS Facility Index System/Facility Registry System
RAATS RCRA Administrative Action Tracking System

STATE AND LOCAL RECORDS

SHWS Inactive Hazardous Sites Inventory
NC HSDS Hazardous Substance Disposal Site
IMD Incident Management Database
SWF/LF List of Solid Waste Facilities
OLI Old Landfill Inventory
LUST Regional UST Database
LUST TRUST State Trust Fund Database
UST Petroleum Underground Storage Tank Database
AST AST Database
INST CONTROL No Further Action Sites With Land Use Restrictions Monitoring
VCP Responsible Party Voluntary Action Sites
DRYCLEANERS Drycleaning Sites
BROWNFIELDS Brownfields Projects Inventory
NPDES NPDES Facility Location Listing

TRIBAL RECORDS

INDIAN RESERV Indian Reservations
INDIAN LUST Leaking Underground Storage Tanks on Indian Land
INDIAN UST Underground Storage Tanks on Indian Land

EDR PROPRIETARY RECORDS

Manufactured Gas Plants EDR Proprietary Manufactured Gas Plants

SURROUNDING SITES: SEARCH RESULTS

Surrounding sites were not identified.

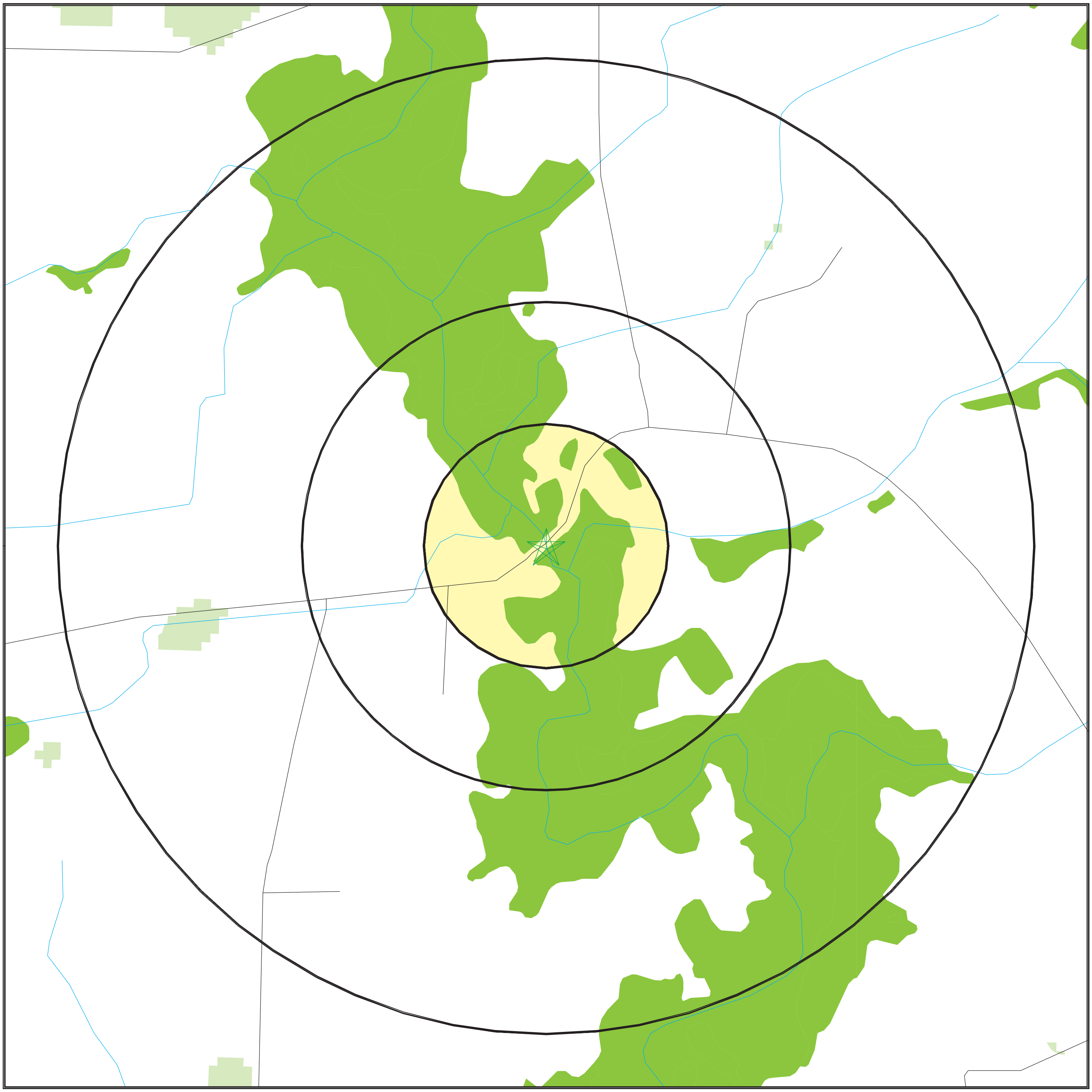
Unmappable (orphan) sites are not considered in the foregoing analysis.

EXECUTIVE SUMMARY

Due to poor or inadequate address information, the following sites were not mapped:

Site Name	Database(s)
SOUTHERN FOOD MARKET	LUST, IMD
PERRY'S TEXACO	LUST, LUST TRUST, IMD
H. B. LILLEY	UST
G.P. KITTRELL & SON. INC.	UST
WOLFREY GROCERY	UST
GEORGE P. GATLING	UST
CHARLES T. HOFLER	UST
HOLIDAY FOOD STORE #205	UST
STEWART FORD INC	UST
SUNBURY EXCHANGE	UST
FAMILY FOODS	UST
BRIGGS EQUIPMENT COMPANY	UST
HOBB'S RADIO & T.V.	UST
HOFLER TRACTOR & IMPLEMENT CO	UST
SUNBURY ELEMENTARY SCHOOL	UST
CHARLES T HOFLER	UST
MIDWAY CHEVROLET. INC.	UST
GEORGE P GATLING	UST
H S HOFLER & SONS	UST
H S HOFLER & SON	UST
CORAPEAKE COLLISION CENTER	RCRA-SQG, FINDS
GATES COUNTY SCHOOLS-TS COOPER	IMD

OVERVIEW MAP - 1727919.1s

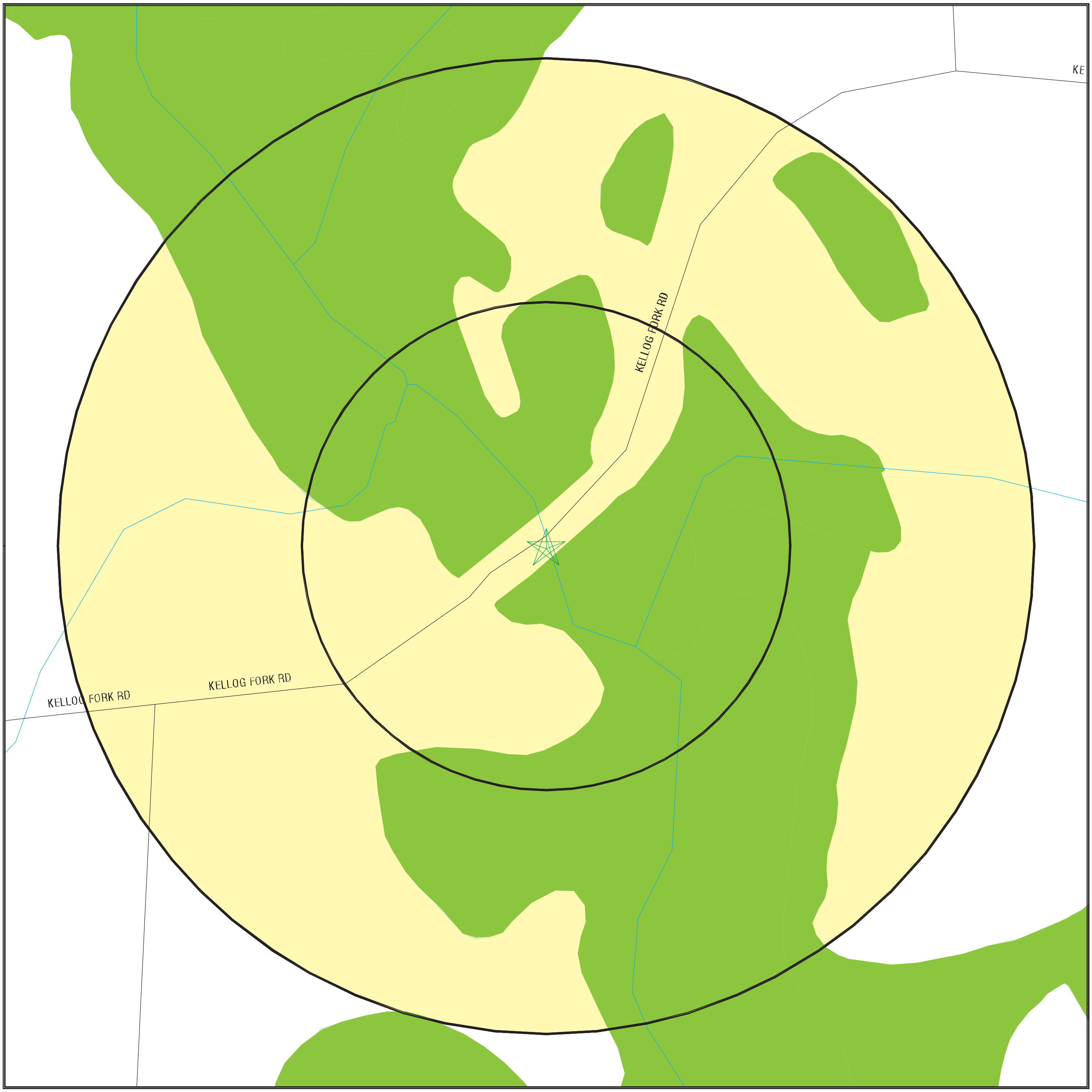


0 1/4 1/2 1 Miles

- Target Property
- Sites at elevations higher than or equal to the target property
- Sites at elevations lower than the target property
- Manufactured Gas Plants
- National Priority List Sites
- Landfill Sites
- Dept. Defense Sites
- Indian Reservations BIA
- Oil & Gas pipelines
- National Wetland Inventory
- State Wetlands
- Hazardous Substance Disposal Sites

SITE NAME: UT to Duke Swamp ADDRESS: 410 Kellogg Fork Road Sunbury NC 27979 LAT/LONG: 36.4692 / 76.6361	CLIENT: Buck Engineering CONTACT: Ken Gilland INQUIRY #: 1727919.1s DATE: August 02, 2006

DETAIL MAP - 1727919.1s



0 1/16 1/8 1/4 Miles

- Target Property
- Sites at elevations higher than or equal to the target property
- Sites at elevations lower than the target property
- Manufactured Gas Plants
- Sensitive Receptors
- National Priority List Sites
- Landfill Sites
- Dept. Defense Sites
- Indian Reservations BIA
- Oil & Gas pipelines
- National Wetland Inventory
- State Wetlands
- Hazardous Substance Disposal Sites

SITE NAME:	UT to Duke Swamp	CLIENT:	Buck Engineering
ADDRESS:	410 Kellogg Fork Road Sunbury NC 27979	CONTACT:	Ken Gilland
		INQUIRY #:	1727919.1s
LAT/LONG:	36.4692 / 76.6361	DATE:	August 02, 2006

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
FEDERAL RECORDS								
NPL		1.000	0	0	0	0	NR	0
Proposed NPL		1.000	0	0	0	0	NR	0
Delisted NPL		1.000	0	0	0	0	NR	0
NPL RECOVERY		TP	NR	NR	NR	NR	NR	0
CERCLIS		0.500	0	0	0	NR	NR	0
CERC-NFRAP		0.500	0	0	0	NR	NR	0
CORRACTS		1.000	0	0	0	0	NR	0
RCRA TSD		0.500	0	0	0	NR	NR	0
RCRA Lg. Quan. Gen.		0.250	0	0	NR	NR	NR	0
RCRA Sm. Quan. Gen.		0.250	0	0	NR	NR	NR	0
ERNS		TP	NR	NR	NR	NR	NR	0
HMIRS		TP	NR	NR	NR	NR	NR	0
US ENG CONTROLS		0.500	0	0	0	NR	NR	0
US INST CONTROL		0.500	0	0	0	NR	NR	0
DOD		1.000	0	0	0	0	NR	0
FUDS		1.000	0	0	0	0	NR	0
US BROWNFIELDS		0.500	0	0	0	NR	NR	0
CONSENT		1.000	0	0	0	0	NR	0
ROD		1.000	0	0	0	0	NR	0
UMTRA		0.500	0	0	0	NR	NR	0
ODI		0.500	0	0	0	NR	NR	0
TRIS		TP	NR	NR	NR	NR	NR	0
TSCA		TP	NR	NR	NR	NR	NR	0
FTTS		TP	NR	NR	NR	NR	NR	0
SSTS		TP	NR	NR	NR	NR	NR	0
ICIS		TP	NR	NR	NR	NR	NR	0
PADS		TP	NR	NR	NR	NR	NR	0
MLTS		TP	NR	NR	NR	NR	NR	0
MINES		0.250	0	0	NR	NR	NR	0
FINDS		TP	NR	NR	NR	NR	NR	0
RAATS		TP	NR	NR	NR	NR	NR	0
STATE AND LOCAL RECORDS								
State Haz. Waste		1.000	0	0	0	0	NR	0
NC HSDS		1.000	0	0	0	0	NR	0
IMD		0.500	0	0	0	NR	NR	0
State Landfill		0.500	0	0	0	NR	NR	0
OLI		0.500	0	0	0	NR	NR	0
LUST		0.500	0	0	0	NR	NR	0
LUST TRUST		0.500	0	0	0	NR	NR	0
UST		0.250	0	0	NR	NR	NR	0
AST		0.250	0	0	NR	NR	NR	0
INST CONTROL		0.500	0	0	0	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0
DRYCLEANERS		0.250	0	0	NR	NR	NR	0
BROWNFIELDS		0.500	0	0	0	NR	NR	0
NPDES		TP	NR	NR	NR	NR	NR	0

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
TRIBAL RECORDS								
INDIAN RESERV		1.000	0	0	0	0	NR	0
INDIAN LUST		0.500	0	0	0	NR	NR	0
INDIAN UST		0.250	0	0	NR	NR	NR	0
EDR PROPRIETARY RECORDS								
Manufactured Gas Plants		1.000	0	0	0	0	NR	0

NOTES:

TP = Target Property

NR = Not Requested at this Search Distance

Sites may be listed in more than one database

MAP FINDINGS

Map ID Direction Distance Distance (ft.) Elevation	Site	Database(s)	EDR ID Number EPA ID Number
	NO SITES FOUND		

ORPHAN SUMMARY

City	EDR ID	Site Name	Site Address	Zip	Database(s)
CORAPEAKE	U003562611	H. B. LILLEY	ROUTE 1	27926	UST
CORAPEAKE	S105765513	SOUTHERN FOOD MARKET	HWY 32	27926	LUST, IMD
CORAPEAKE	U001195948	G.P. KITTRELL & SON. INC.	RT.1 BOX 4	27926	UST
CORAPEAKE	1004747153	CORAPEAKE COLLISION CENTER	1017 NC HWY 32 N	27926	RCRA-SQG, FINDS
SUNBURY	U001195659	WOLFREY GROCERY	ROUTE 1	27979	UST
SUNBURY	U001195941	GEORGE P. GATLING	ROUTE 1, BOX 75	27979	UST
SUNBURY	U001200976	CHARLES T. HOFLER	ROUTE 1, BOX 99 HIGHWAY 32	27979	UST
SUNBURY	U000331845	HOLIDAY FOOD STORE #205	ROUTE 158 & 32	27979	UST
SUNBURY	U001195947	STEWART FORD INC	HIGHWAY 158	27979	UST
SUNBURY	U001196158	SUNBURY EXCHANGE	HIGHWAY 158	27979	UST
SUNBURY	U001206065	FAMILY FOODS	1000 HWY 158 EAST	27979	UST
SUNBURY	U003562631	BRIGGS EQUIPMENT COMPANY	HIGHWAY 158	27979	UST
SUNBURY	U003562632	HOBB'S RADIO & T.V.	HIGHWAY 158	27979	UST
SUNBURY	S105912253	GATES COUNTY SCHOOLS-TS COOPER	SR 32 SOUTH	27979	IMD
SUNBURY	U000821740	HOFLER TRACTOR & IMPLEMENT CO	HWY 32	27979	UST
SUNBURY	U001203478	SUNBURY ELEMENTARY SCHOOL	HIGHWAY 32	27979	UST
SUNBURY	U001205512	CHARLES T HOFLER	HWY 32	27979	UST
SUNBURY	U003562633	MIDWAY CHEVROLET. INC.	HWY 32	27979	UST
SUNBURY	U003563338	GEORGE P GATLING	HWY 32	27979	UST
SUNBURY	U003563339	H S HOFLER & SONS	HWY 32	27979	UST
SUNBURY	U003563340	H S HOFLER & SON	HWY 32	27979	UST
SUNBURY	S101523756	PERRY'S TEXACO	NC HWY 32	27979	LUST, LUST TRUST, IMD

EDR LoanCheck® Basic: Environmental Risk Review

September 15, 2006

Property Name

UT TO DUKE SWAMP
410 KELLOGG FORK RD
SUNBURY, NC 27979

440 Wheelers Farms Road
Milford, CT 06460
Phone:800-352-0050
Fax:800-231-6802
Web:www.edrnet.com

EDR™ Environmental Data Resources Inc

ENVIRONMENTAL RISK LEVEL

To help evaluate environmental risk, the *EDR LoanCheck®Basic* provides an Environmental Risk Level, based on a search of current government records requested to be searched by Buck Engineering.

[ ]	**ELEVATED RISK**	Based on the records found in this report, the environmental risk level for this property is elevated.
X	**LOW RISK**	Based on the records found in this report, the environmental risk level for this property is minimal.

User Instructions

For more information regarding this Environmental Risk Level, please refer to page 2 and other supporting reports.

User Comments

____

____

____

Reports and Databases

The following reports an/or databases were requested by customer and were included in the Environmental Risk Level where available:

- EDR Radius Map Report

EDR LoanCheck® Basic: Environmental Risk Review

FINDINGS CONTRIBUTING TO THE ENVIRONMENTAL RISK LEVEL

The environmental LOW RISK is based upon the findings listed below. Refer to the supporting report(s) for additional detail.

TARGET PROPERTY

Current Govt. Records

No records identified (if any) were determined to be of elevated risk.

SURROUNDING PROPERTIES

Current Govt. Records

No records identified (if any) were determined to be of elevated risk.

Appendix C

DRAINMOD Analysis Files &

Restoration Site Water Table Data

```
***************************************************************************
                             D R A I N M O D  5.1
                Copyright 1980-05 North Carolina State University
                            LAST UPDATE: SEPT 1999
                              LANGUAGE FORTRAN 77/90
            DRAINMOD IS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR
            THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS
            DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND
            AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY
            UNDER THE DIRECTION OF R. W. SKAGGS.
***************************************************************************
 DATA READ FROM INPUT FILE: C:\Program Files\Drainmod\INPUTS\DUKE SWAMP_PROP
 Cream selector (0=no, 1=yes) =  0

                      TITLE OF RUN
                      ************
 ANALYSIS OF WETLAND HYDROLOGIC CRITERIA FOR DUKE SWAMP for proposed conditions, STmax=4.0cm,
thwtd=30cm

                       CLIMATE INPUTS
                       ******* ******
     DESCRIPTION                              (VARIABLE)     VALUE   UNIT
 --------------------------------------------------------------------------
 FILE FOR RAINDATA .............R:\109351-DUKE SWAMP\DRAINMOD\DUKE SWAMP RAIN.RA
 FILE FOR TEMPERATURE/PET DATA .R:\109351-DUKE SWAMP\DRAINMOD\DUKE SWAMP TEMP.TE
 RAINFALL STATION NUMBER.........................(RAINID)          1
 TEMPERATURE/PET STATION NUMBER..................(TEMPID)          1
 STARTING YEAR OF SIMULATION..................(START YEAR)       1949   YEAR
 STARTING MONTH OF SIMULATION................(START MONTH)          1   MONTH
 ENDING YEAR OF SIMULATION......................(END YEAR)       2006   YEAR
 ENDING MONTH OF SIMULATION....................(END MONTH)         12   MONTH
 TEMPERATURE STATION LATITUDE..................(TEMP LAT)      36.50   DEG.MIN
 HEAT INDEX.........................................(HID)      85.00

 ET MULTIPLICATION FACTOR FOR EACH MONTH
    2.52  3.30  2.49  1.69  1.31   .99   .90   .87   .94  1.20  1.45  2.01

                               DRAINAGE SYSTEM DESIGN
                               **********************
                              *** CONTROLLED DRAINAGE  ***
          JOB TITLE: ANALYSIS OF WETLAND HYDROLOGIC CRITERIA FOR DUKE SWAMP
                   for proposed conditions, STmax=4.0cm, thwtd=30cm

                    STMAX = 4.00 CM                  SOIL SURFACE
+         __/)____________________________________________________________/)__
                :                                                    :
                :                                                    :
                :                                                    :
           ADEPTH =300. CM                                  DDRAIN = 55. CM
                :                                                    :
                :                                                    :
                :     O-------------SDRAIN = 3505. CM -----------O  -
                :     *                                              :
                : EFFRAD =**** CM                                    :
                :                                           HDRAIN =184. CM
          - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                :
                :                                    IMPERMEABLE LAYER
+         ___________________________________________________________________
          ///////////////////////////////////////////////////////////////////

                     DEPTH      SATURATED HYDRAULIC CONDUCTIVITY
                     (CM)                    (CM/HR)

                    .0 -  100.0               4.000
                 100.0 -  300.0               1.000

 DEPTH TO DRAIN =  55.0 CM
 EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 184.4 CM
 DISTANCE BETWEEN DRAINS =  3505.0 CM
 MAXIMUM DEPTH OF SURFACE PONDING =  4.00 CM
 EFFECTIVE DEPTH TO IMPERMEABLE LAYER =  239.4 CM
 DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) =  2.50 CM/DAY
 MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) =   2.50 CM/DAY
 ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 300.0 CM
 SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
   CAN MOVE TO DRAIN = 2.00 CM
 FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.65
```

WIDTH OF DITCH BOTTOM = 60.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 15.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	55.0	55.0	55.0	55.0	55.0	55.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	55.0	55.0	55.0	55.0	55.0	55.0

SOIL INPUTS
****
TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	22.5
2.0	35.7
3.0	50.0
4.0	65.0
5.0	77.5
6.0	89.4
7.0	101.0
8.0	110.5
9.0	120.0
10.0	128.6
11.0	137.1
12.0	145.7
13.0	153.3
14.0	160.0
15.0	166.7
16.0	173.3
17.0	180.0
18.0	186.7
19.0	193.3
20.0	200.0
21.0	206.7
22.0	213.3
23.0	220.0
24.0	226.7
25.0	233.3
26.0	240.0
27.0	246.7
28.0	253.3
29.0	260.0
30.0	266.7
35.0	300.0
40.0	366.7
45.0	433.3
50.0	500.0
60.0	600.0
70.0	700.0
80.0	800.0
90.0	900.0

1

TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3700	.00	.2000
10.0	.3000	.25	.1000
20.0	.2820	.80	.0800
30.0	.2720	1.60	.0250
40.0	.2660	2.30	.0112
50.0	.2580	3.00	.0058
60.0	.2540	3.60	.0031
70.0	.2480	4.40	.0018
80.0	.2440	5.20	.0010
90.0	.2410	6.05	.0007
100.0	.2380	6.90	.0004
110.0	.2360	7.95	.0002
120.0	.2340	9.00	.0000
130.0	.2320	10.17	.0000
140.0	.2300	11.33	.0000
150.0	.2280	12.50	.0000
160.0	.2272	14.00	.0000
170.0	.2264	15.50	.0000
180.0	.2256	17.00	.0000
190.0	.2248	18.50	.0000
200.0	.2240	20.00	.0000
210.0	.2236	21.50	.0000
220.0	.2232	23.00	.0000
230.0	.2228	24.50	.0000
240.0	.2224	26.00	.0000
250.0	.2219	27.50	.0000
260.0	.2215	29.00	.0000
270.0	.2211	30.50	.0000
280.0	.2207	32.00	.0000
290.0	.2203	33.50	.0000
300.0	.2199	35.00	.0000
350.0	.2178	38.75	.0000
400.0	.2158	42.50	.0000
450.0	.2137	46.25	.0000
500.0	.2117	50.00	.0000
600.0	.2076	60.00	.0000
700.0	.2034	70.00	.0000
800.0	.1993	80.00	.0000
900.0	.1952	90.00	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	1.000
100.000	3.300	1.000
150.000	6.000	1.000
200.000	9.200	1.000
500.000	25.000	1.000
1000.000	25.000	1.000

TRAFFICABILITY
****

	FIRST PERIOD	SECOND PERIOD
REQUIREMENTS		
-MINIMUM AIR VOLUME IN SOIL (CM):	3.00	3.00
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/31
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/31
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

```
                                  CROP
                                  ****

 SOIL MOISTURE AT  WILTING POINT =    .17

 HIGH WATER STRESS:  BEGIN STRESS PERIOD ON   4/10
                     END STRESS PERIOD ON     8/18
                     CROP IS IN STRESS WHEN WATER TABLE IS ABOVE  30.0 CM

 DROUGHT STRESS:     BEGIN STRESS PERIOD ON   4/10
                     END STRESS PERIOD ON     8/18

                              MO   DAY   ROOTING DEPTH(CM)
                               1    1         3.0
                               4   16         3.0
                               5    4         4.0
                               5   17        15.0
                               6    1        25.0
                               6   20        30.0
                               7   18        30.0
                               8   20        20.0
                               9   24        10.0
                               9   25         3.0
                              12   31         3.0

   ***** Wetlands Parameter Estimation *****

               Start Day =   84          End Day =  315
               Threshold Water Table Depth (cm) =  30.0
               Threshold Consecutive Days       =    19


   ****************** NEW CROP *********************
 C:\PROGRAM FILES\DRAINMOD\CROPS\FOREST.CIN
   CROP ROTATION NUMBER:  1

 DAY TO BEGIN WORKING FIELD:  73    DAY TO FINISH HARVESTING FIELD: 264
  INWEIR =  2

     DEPTH OF WEIR FROM THE SURFACE
     ------------------------------
 DATE         1/  1   2/  1   3/  1   4/  1   5/  1   6/  1
 WEIR DEPTH    45.0    45.0    45.0    45.0    45.0    45.0

 DATE         7/  1   8/  1   9/  1   10/  1  11/  1  12/  1
 WEIR DEPTH    45.0    45.0    45.0    45.0    45.0    45.0


                              TRAFFICABILITY
                              **************

                                                                          FIRST       SECOND
    REQUIREMENTS                                                          PERIOD      PERIOD
       -MINIMUM AIR VOLUME IN SOIL (CM):                                   3.90        3.90
       -MAXIMUM ALLOWABLE DAILY RAINFALL(CM):                              1.20        1.20
       -MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:               2.00        2.00

    WORKING TIMES
       -DATE TO BEGIN COUNTING WORK DAYS:                                  4/ 1       12/31
       -DATE TO STOP COUNTING WORK DAYS:                                   9/ 2       12/31
       -FIRST WORK HOUR OF THE DAY:                                         8           8
       -LAST WORK HOUR OF THE DAY:                                         20          20

                                  CROP
                                  ****
 HIGH WATER STRESS:  BEGIN STRESS PERIOD ON   4/28
                     END STRESS PERIOD ON     6/15
                     CROP IS IN STRESS WHEN WATER TABLE IS ABOVE  40.0 CM

 DROUGHT STRESS:     BEGIN STRESS PERIOD ON   4/28
                     END STRESS PERIOD ON     9/10
```

```
                              MO   DAY   ROOTING DEPTH(CM)
                               1    1       45.0
                               4    1       45.0
                               4   28       45.0
                               5   20       45.0
                               6   19       45.0
                               7   18       45.0
                               8   18       45.0
                               9    2       45.0
                               9   10       45.0
                              12   31       45.0

                               YIELD INPUTS
                               ************

 last planting day without yield loss (JLAST):        123
 length of growing season (IGROW)            :        136
 1st planting day reduction factor (PDRF)    :       2.000000
 days using 1st planting delay fact (DELAY1) :      27.000000
 2nd planting day reduction factor (PDRF2)   :       2.000000
 total days of work before planting (REQWRK) :       1.000000
 IOW:         32
 IOH:          6
 YSLOPE:       1.220000
 YRDMAX:     100.000000
 DSLOPE:   7.100000E-01
 PD :        118
 IGR:        130
 SDF:          1
 IPS(I),IPE(I),CSD(I),I=1,IOH
    0   29       .2000
   30   49       .2200
   50   69       .3200
   70   89       .1900
   90  109       .0800
  110  136       .0200
 CSI(I),I=1,IOW
           .0000       .0000       .0000       .0000       .0000
           .0000       .0500       .0500      1.0000      1.0000
          1.0000      1.0000      1.7500      2.1000      2.1000
          1.3000      1.3000      1.3000      1.3000      1.3000
          1.2000      1.0000       .5000       .0000       .0000
           .0000       .0000       .0000       .0000       .0000
          .0000       .0000


****************************** END OF INPUTS ******************************

 ----------RUN STATISTICS ----------          time:  1/31/2007  @ 15:12
input file:   C:\Program Files\Drainmod\INPUTS\DUKE SWAMP_PROP
parameters:    controlled drainage        and yields calculated
              drain spacing =    3505. cm   drain depth =   55.0 cm
------------------------------------------------------------------------
```

Appendix D

Existing Conditions Summaries, Cross-Sections, Bed Material Analyses, and NCDWQ Stream Determination Forms

Summary Table for the Project Reach UT1 to Duke Swamp:

Parameter	Value	Units
Rosgen Stream Type	E5	
Drainage Area	2.9	Square miles
Reach Length Surveyed	3558	Feet
Bankfull Width (W_{bkf})	17.9 - 40.9	Feet
Bankfull Mean Depth (d_{bkf})	2.1 - 4.2	Feet
Cross-Sectional Area (A_{bkf})	40.4 - 154.9	Square feet
Width/Depth Ratio (W/D ratio)	4.5 - 15.4	
Bankfull Max Depth (d_{mbkf})	4.0 - 5.4	Feet
Floodprone Area Width (W_{fpa})	124.8 - 181.1	Feet
Bank Height Ratio (BHR)	1.1 - 1.3	
Entrenchment Ratio (ER)	4.1 - 10.1	
Meander Width Ratio (MWR)	N/A	
Channel Materials (Particle Size Index – d_{50})	Very fine sand	
d_{16}	0.06	mm
d_{35}	0.08	mm
d_{50}	0.1	mm
d_{84}	0.18	mm
d_{95}	0.23	mm
Slope (S)	0.0003	Feet per foot
Channel Sinuosity (K)	1.05	
Evolution Scenario	E-G-F-E	

Notes:

1. Multiple cross-sections were surveyed in reach UT1 and data varied, the data are presented as range of values.

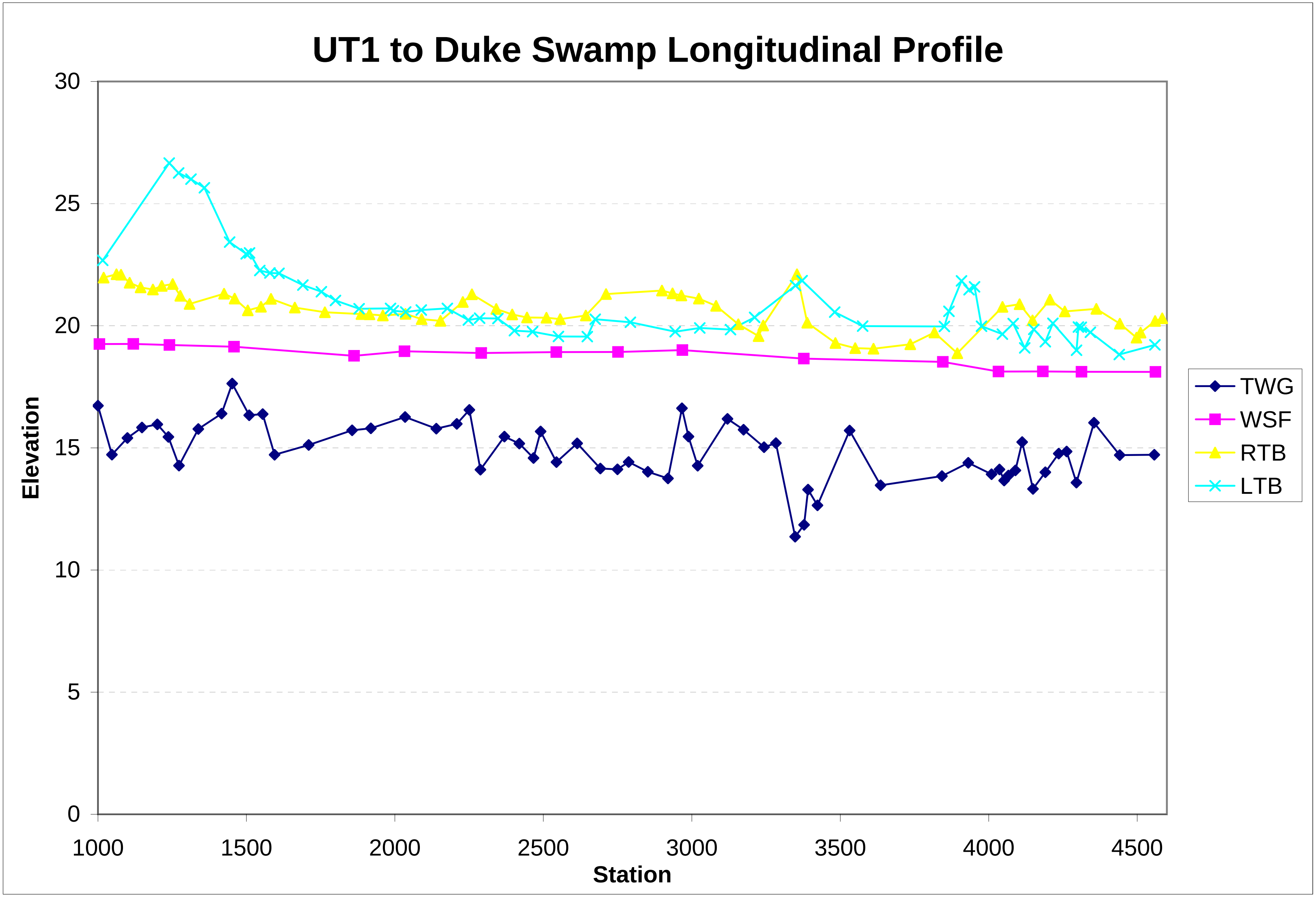
2. N/A: Meander Width Ratio not measured because channels have been straightened.

Summary of Cross-section Data:

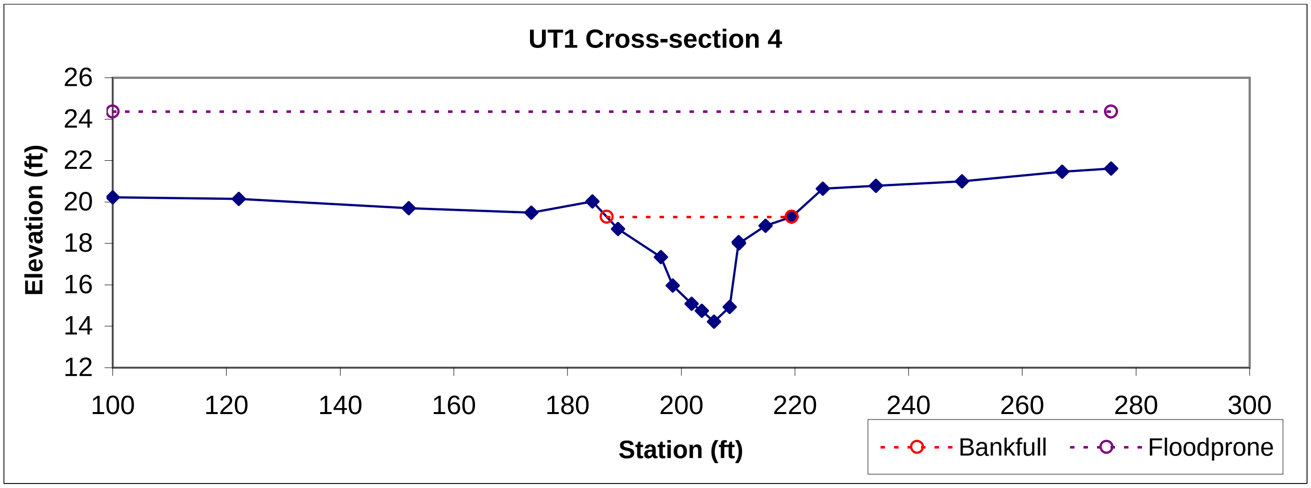
Cross-section Descriptor	X1	X2	X3	X4	X5	X6
Feature	Pool	Pool	Pool	Pool	Riffle	Riffle
Bankfull Width (ft)	23.94	18.85	40.9	32.55	19.6	17.94
Bankfull Mean Depth (ft)	2.79	4.16	3.79	2.11	3.77	2.25
Width/Depth Ratio	8.59	4.53	10.79	15.43	5.19	7.97
Bankfull Area (sq ft)	66.71	78.45	154.96	68.67	73.99	40.43
Bankfull Max Depth (ft)	4.03	5.37	5.14	5.07	5.41	4
Width of Floodprone Area (ft)	124.79	131.77	168.22	175.6	150.99	181.07
Entrenchment Ratio	5.21	6.99	4.11	5.39	7.7	10.09
Bank Height Ratio	1.04	1.2	1.29	1.19	1.18	1.34
Longitudinal Station of Cross-section	4559.8	3977.48	3478.04	2638.28	2125.28	1764.51

Summary of Bed Material Analyses:

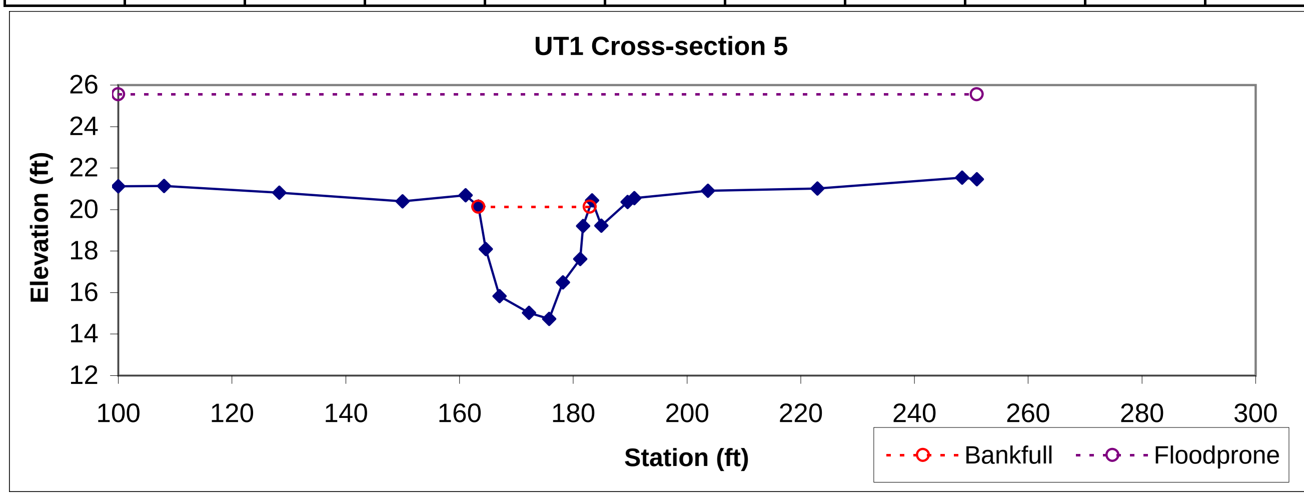
Size Distribution	mm
D16	0.06
D35	0.08
D50	0.1
D84	0.18
D95	0.23


UT1 to Duke Swamp Longitudinal Profile
Elevation
30
25
20
15
10
5
0
1000
1500
2000
2500
3000
3500
4000
4500
Station
TWG
WSF
RTB
LTB

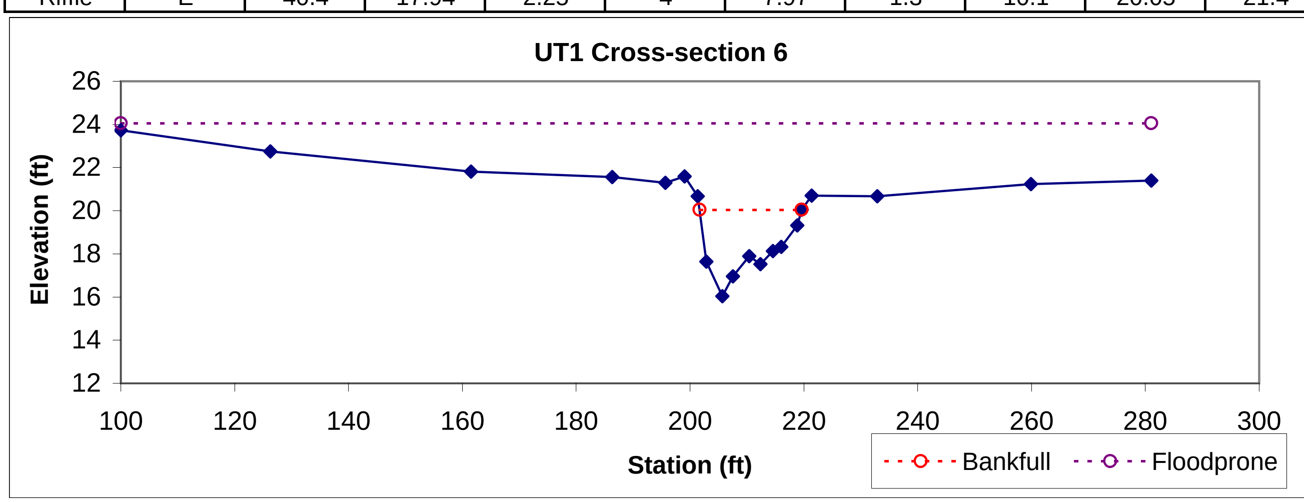
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		68.7	32.55	2.11	5.07	15.43	1.2	5.4	19.29	20.22



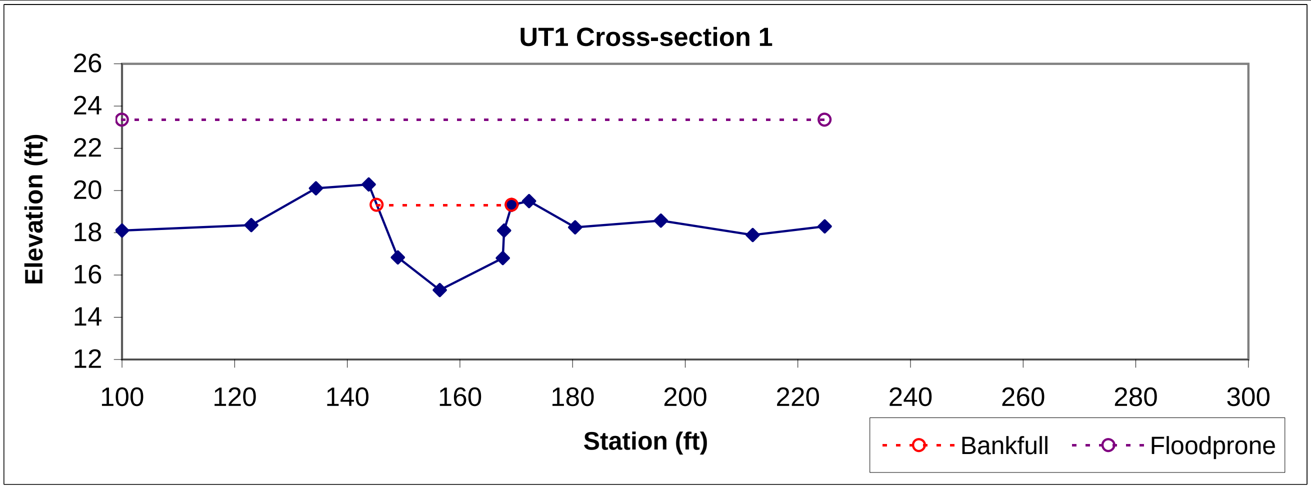
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	74	19.6	3.77	5.41	5.19	1.2	7.7	20.14	21.14



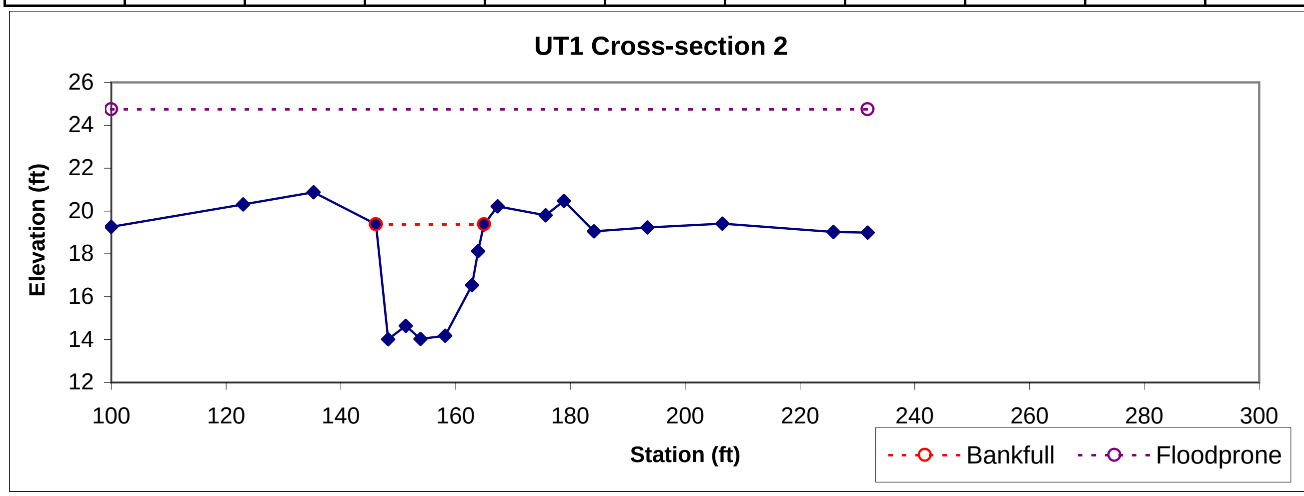
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	40.4	17.94	2.25	4	7.97	1.3	10.1	20.05	21.4



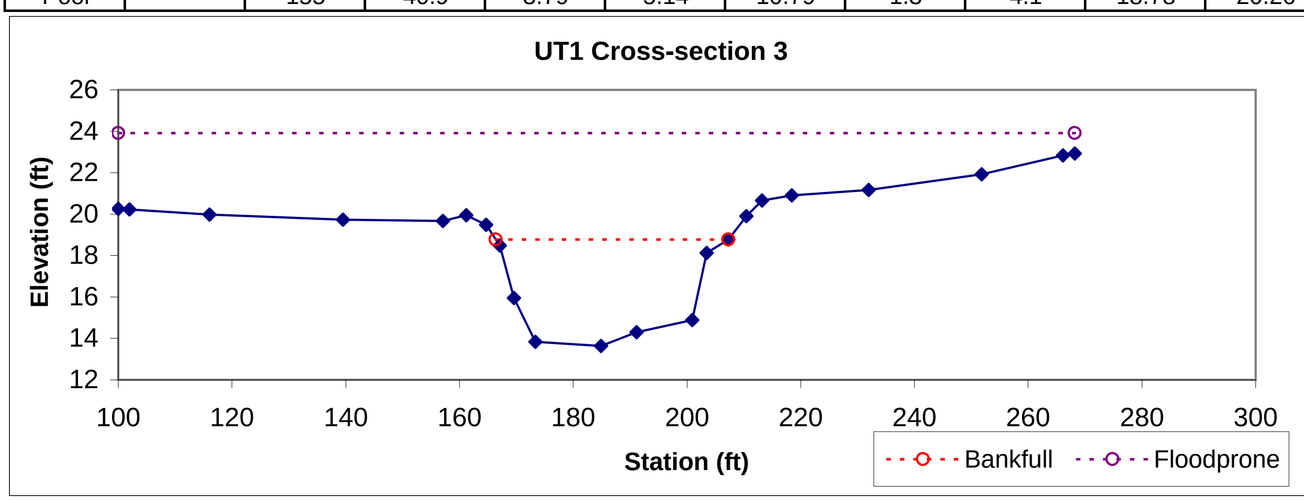
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		66.7	23.94	2.79	4.03	8.59	1	5.2	19.32	19.5



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		78.5	18.85	4.16	5.37	4.53	1.2	7	19.38	20.47

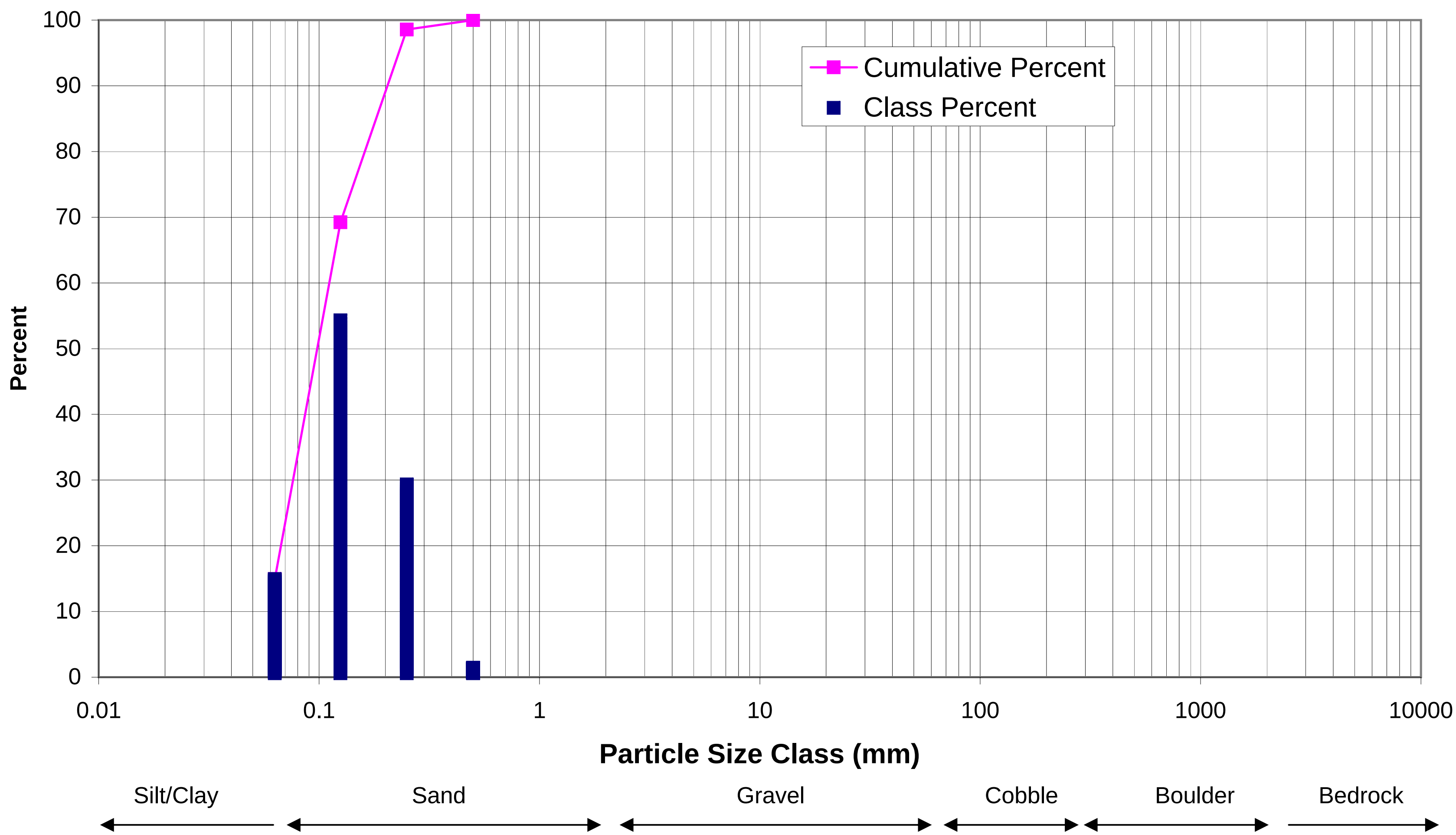


Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		155	40.9	3.79	5.14	10.79	1.3	4.1	18.78	20.26



Sediment Distribution

UT1 to Duke Swamp



Summary Table for the Project Reach UT2 to Duke Swamp:

Parameter	Value	Units
Rosgen Stream Type	DA	
Drainage Area	0.03	Square miles
Reach Length Surveyed	240	Feet
Bankfull Width (W_{bkf})	2.61	Feet
Bankfull Mean Depth (d_{bkf})	0.28	Feet
Cross-Sectional Area (A_{bkf})	0.72	Square feet
Width/Depth Ratio (W/D ratio)	9.43	
Bankfull Max Depth (d_{mbkf})	0.61	Feet
Floodprone Area Width (W_{fpa})	43.64	Feet
Bank Height Ratio (BHR)	1.77	
Entrenchment Ratio (ER)	16.71	
Meander Width Ratio (MWR)	N/A	
Channel Materials (Particle Size Index – d_{50})	Very fine sand	
d_{16}	N/A	mm
d_{35}	N/A	mm
d_{50}	N/A	mm
d_{84}	N/A	mm
d_{95}	N/A	mm
Slope (S)	0.0028	Feet per foot
Channel Sinuosity (K)	1.15	
Evolution Scenario	E-G-F-DA	

Notes:

1. One cross-section was surveyed in reach UT2 along the upper portion which is a single threaded channel.

2. N/A: Meander Width Ratio not measured because channel has been altered significantly towards the lower end of the reach before connecting to UT1. Channel transitions from a single thread to multi-threaded channel.

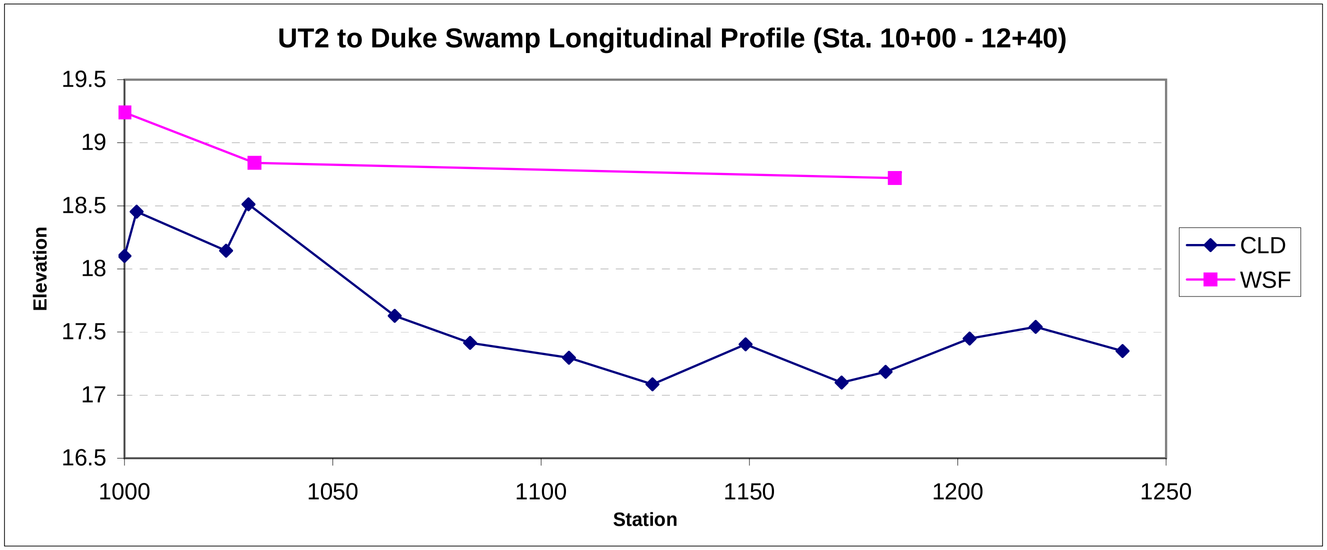
3. N/A: UT2 geomorphic data values vary due to inconsistent channel formations. UT2 channel materials consisted of organic clay and were not dry sieved.

Summary of Cross-section Data:

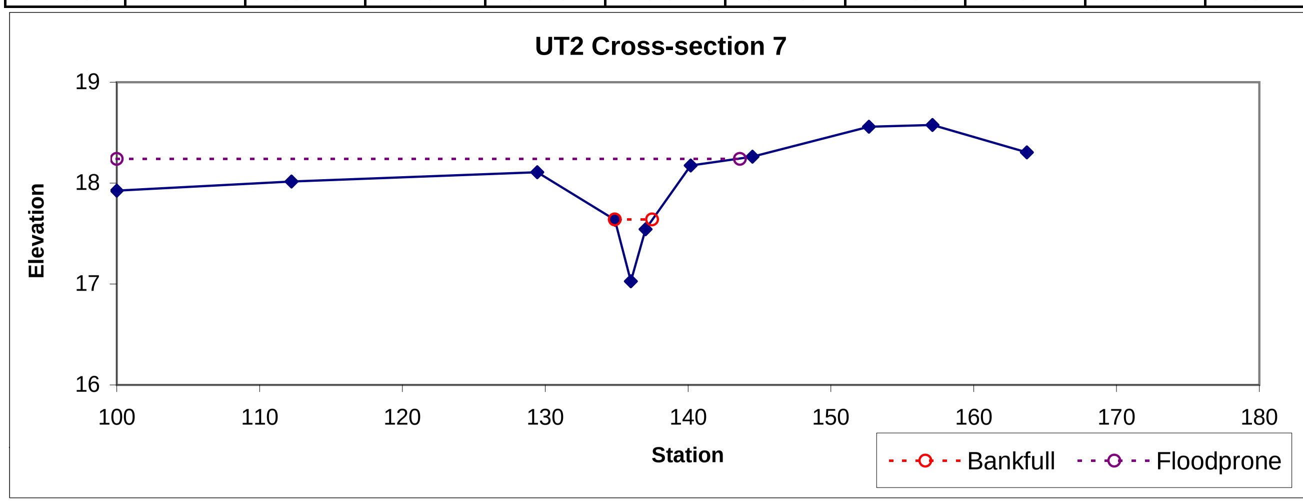
Cross-section Descriptor	X7
Feature	Riffle
Bankfull Width (ft)	2.61
Bankfull Mean Depth (ft)	0.28
Width/Depth Ratio	15.19
Bankfull Area (sq ft)	0.72
Bankfull Max Depth (ft)	0.61
Width of Floodprone Area (ft)	43.64
Entrenchment Ratio	16.71
Bank Height Ratio	1.77
Longitudinal Station of Cross-section	282.86

Summary of Bed Material Analyses:

Size Distribution	mm
D16	N/A
D35	N/A
D50	N/A
D84	N/A
D95	N/A



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	DA	0.7	2.61	0.28	0.61	9.43	1.8	16.7	17.64	18.11



NCDWQ Stream Classification Form

Project Name: UT1 to Duke Swamp	River Basin: Chowan	County: Gates	Evaluator: JWH
DWQ Project Number: N/A	Nearest Named Stream: Duke Swamp	Latitude: 36° 28' 11"	Signature:
Date: 3/10/06	USGS QUAD: Merchants Millpond	Longitude: 76° 37' 51"	Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: (Circle One Number Per Line)

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	**1**	2	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	**3**
3) Are Natural Levees Present?	0	1	**2**	3
4) Is The Channel Sinuous?	0	**1**	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	**3**
6) Is The Channel Braided?	**0**	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	**2**	3
8) Is There A Bankfull Bench Present?	0	**1**	2	3
9) Is A Continuous Bed & Bank Present? (*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)	0	1	2	**3**
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present?		*Yes*=**3**	*No*=0	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: ___**19**__

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	1	2	**3**

PRIMARY HYDROLOGY INDICATOR POINTS: ___3___

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	**2**	1	0
2) Are Rooted Plants Present In Streambed?	**3**	2	1	0
3) Is Periphyton Present?	0	1	**2**	3
4) Are Bivalves Present?	0	1	**2**	3

PRIMARY BIOLOGY INDICATOR POINTS: ____9___

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	**0**	.5	1	1.5
2) Is There A Grade Control Point In Channel?	0	**.5**	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	**1**	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: ___**1.5**___

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaflitter Present In Streambed?	**1.5**	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	**.5**	1	1.5
3) Are Wrack Lines Present?	0	.5	**1**	1.5
4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	**1.5**
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	1	**1.5**
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes*=**1.5**	*No*=0	

SECONDARY HYDROLOGY INDICATOR POINTS: ___**7.5**___

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	0	**.5**	1	1.5
2) Are Amphibians Present?	0	**.5**	1	1.5
3) Are AquaticTurtles Present?	**0**	.5	1	1.5
4) Are Crayfish Present?	0	.5	**1**	1.5
5) Are Macrobenthos Present?	0	.5	1	**1.5**
6) Are Iron Oxidizing Bacteria/Fungus Present?	0	.5	1	**1.5**
7) Is Filamentous Algae Present?	0	.5	**1**	1.5

8) Are Wetland Plants In Streambed?	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(* ***NOTE:*** *If Total Absence Of All Plants In Streambed As Noted Above Skip This Step* ***UNLESS*** *SAV Present**).	*2*	**1**	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS: __**7**____

TOTAL POINTS (Primary + Secondary) =_47___

(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

North Carolina Division of Water Quality – Stream Identification Form; Version 3.1

Date: 3-22-07		**Project:** Duke Swamp		**Latitude:**	
Evaluator: D. Huneycutt		**Site:** UT2		**Longitude:**	
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	37	**County:** Gates		**Other** *e.g. Quad Name:*	

A. Geomorphology (Subtotal = 13.5)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	(2)	3
2. Sinuosity	0	1	(2)	3
3. In-channel structure: riffle-pool sequence	0	(1)	2	3
4. Soil texture or stream substrate sorting	(0)	1	2	3
5. Active/relic floodplain	0	1	2	(3)
6. Depositional bars or benches	0	(1)	2	3
7. Braided channel	0	1	2	(3)
8. Recent alluvial deposits	0	(1)	2	3
9[a] Natural levees	(0)	1	2	3
10. Headcuts	(0)	1	2	3
11. Grade controls	(0)	0.5	1	1.5
12. Natural valley or drainageway	0	(0.5)	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = (0)		Yes = 3	

[a] Man-made ditches are not rated; see discussions in manual

14
11
12
37

B. Hydrology (Subtotal = 11.5)	Absent	Weak	Moderate	Strong
14. Groundwater flow/discharge	0	1	2	(3)
15. Water in channel and > 48 hrs since rain, **or** Water in channel -- dry or growing season	0	1	2	(3)
16. Leaflitter	(1.5)	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	(1.5)
18. Organic debris lines or piles (Wrack lines)	0	0.5	(1)	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = (1.5)	

C. Biology (Subtotal = 12.0)	Absent	Weak	Moderate	Strong
20[b]. Fibrous roots in channel	3	(2)	1	0
21[b]. Rooted plants in channel	3	(2)	1	0
22. Crayfish	0	0.5	(1)	1.5
23. Bivalves	(0)	1	2	3
24. Fish	(0)	0.5	1	1.5
25. Amphibians	0	0.5	(1)	1.5
26. Macrobenthos (note diversity and abundance)	(0)	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	(3)
28. Iron oxidizing bacteria/fungus.	0	0.5	(1)	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = (2.0); Other = 0			

[b] Items 20 and 21 focus on the presence of upland plants, Item 29 focuses on the presence of aquatic or wetland plants.

Notes: (use back side of this form for additional notes.)

Sketch:

Appendix E

Reference Reach Summary –

Beaver Dam Branch, Jones County

Summary Sheet: Reference Reach

Beaver Dam Branch - Jones County, North Carolina

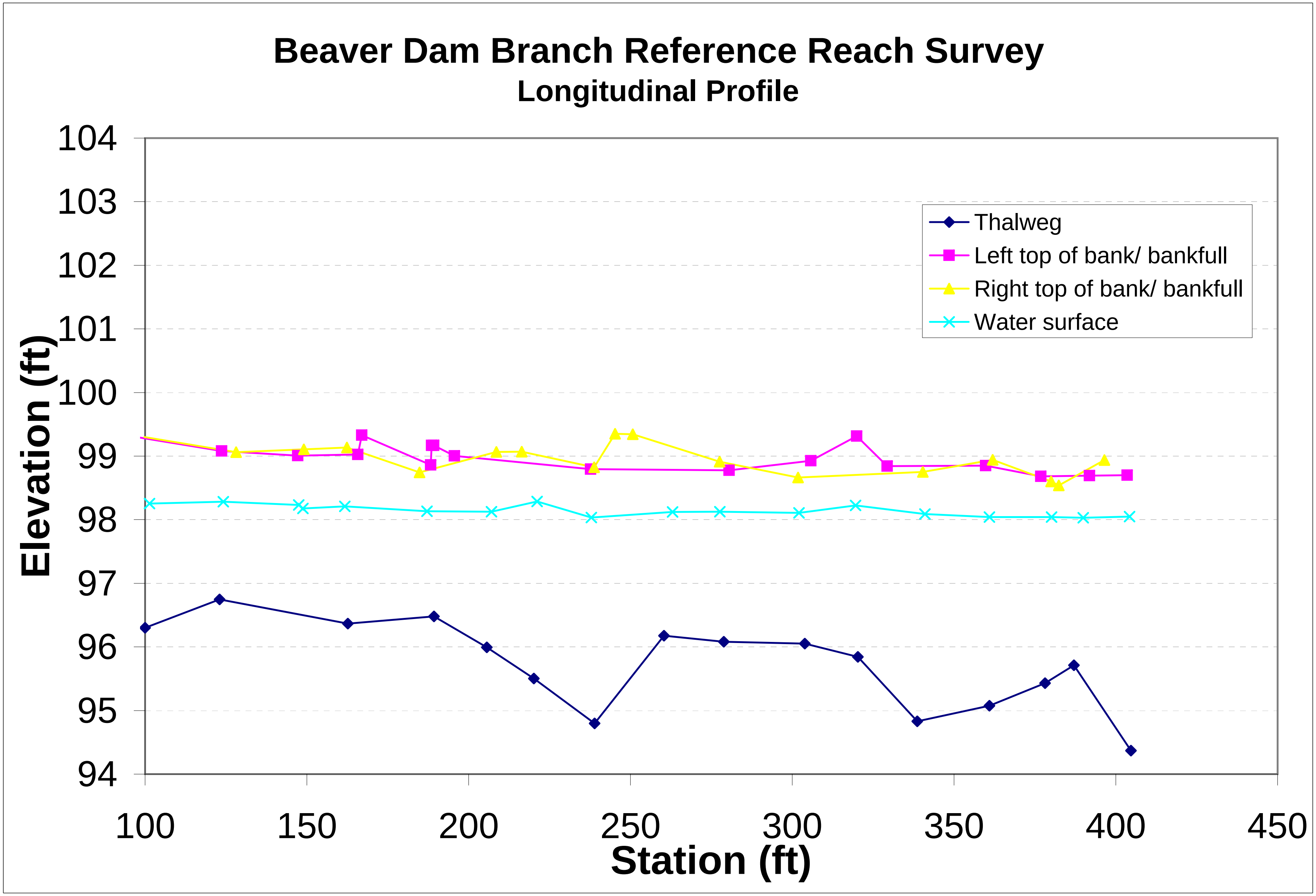
Rosgen Stream Type		E5 / C5
Drainage Area (sq mi)		3.00
Reach Length Surveyed (ft)		305
Dimension	Bankfull Width (ft)	18.6
	Bankfull Mean Depth (ft)	1.4
	Width/Depth Ratio	14
	Bankfull Area (sq ft)	25.3
	Bankfull Max Depth (ft)	2.3
	Width of Floodprone Area (ft)	>100
	Entrenchement Ratio	>10
	Max Pool Depth (ft)	3.3
	Ratio of Max Pool Depth to Bankfull Depth	2.4
	Pool Width (ft)	15.2
	Ratio of Pool Width to Bankfull Width	0.8
	Pool to Pool Spacing (ft)	100
	Ratio of Pool to Pool Spacing to Bankfull Width	5.4
	Bank Height Ratio	1.25
Pattern	Meander Length (ft)	92 - 125
	Meander Length Ratio	4.9 - 6.7
	Radius of Curvature (ft)	30 - 40
	Radius of Curvature Ratio	1.8 - 2.4
	Meander Belt Width (ft)	49 - 105
	Meander Width Ratio	2.9 - 6.3
	Sinuosity	1.66
Profile	Valley Slope* (ft/ft)	0.0007
	WS Slope* (ft/ft)	0.0004
	Pool Slope (ft/ft)	0.00001
	Ratio of Pool Slope to WS Slope	0.025

* Note: Surveyed during high water event

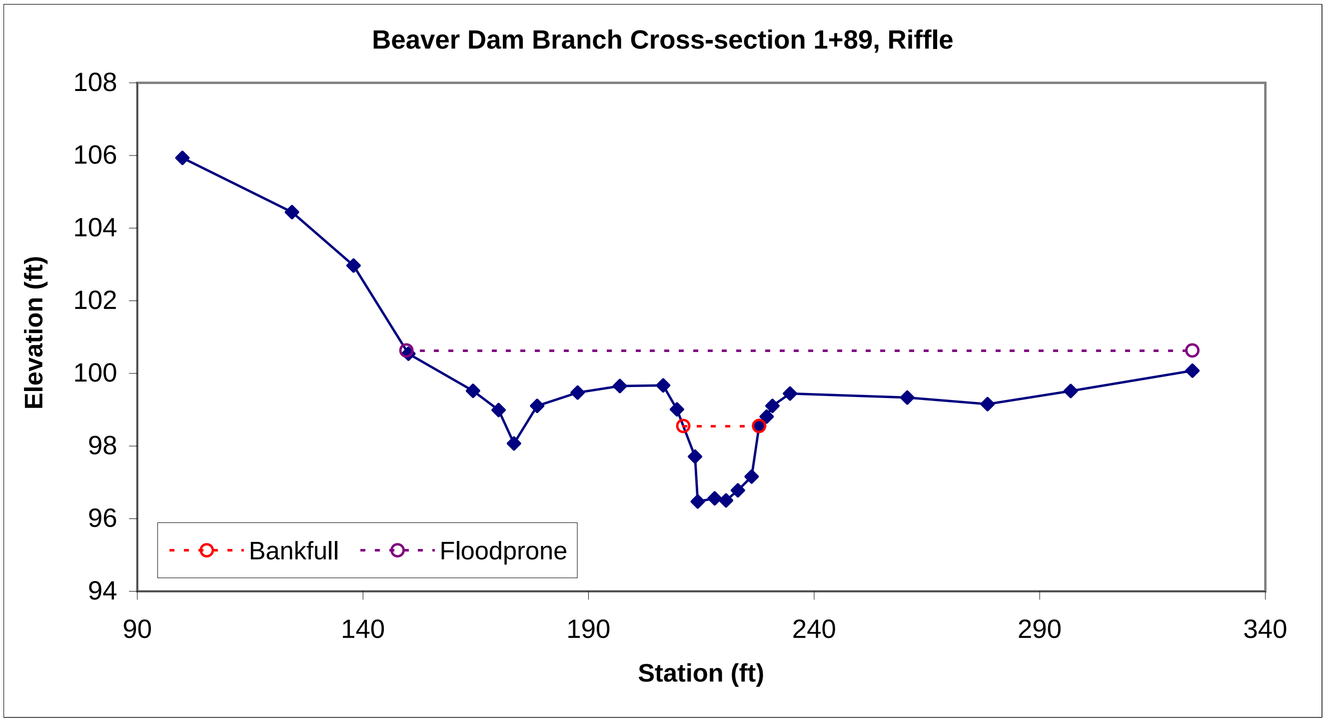
Summary of Cross-section Data:

Cross-section Descriptor	X1	X2	X3	X4	
Feature	Riffle	Pool	Riffle	Pool	
Rosgen Stream Type	E5	----	C5	----	Riffle Mean
Bankfull Width (ft)	16.79	16.31	20.5	14.17	18.645
Bankfull Mean Depth (ft)	1.53	1.51	1.21	1.43	1.37
Width/Depth Ratio	10.98	10.78	16.92	9.88	13.95
Bankfull Area (sq ft)	25.67	24.67	24.83	20.34	25.25
Bankfull Max Depth (ft)	2.08	3.27	2.44	2.91	2.26
Width of Floodprone Area (ft)	174.19	177.78	216.28	164.6	195.235
Entrenchment Ratio	10.38	10.9	10.55	11.61	10.465
Bank Height Ratio	1.22	1.32	1.29	1.19	1.255
Longitudinal Station of Cross-section	189.3	220.18	260.39	320.27	

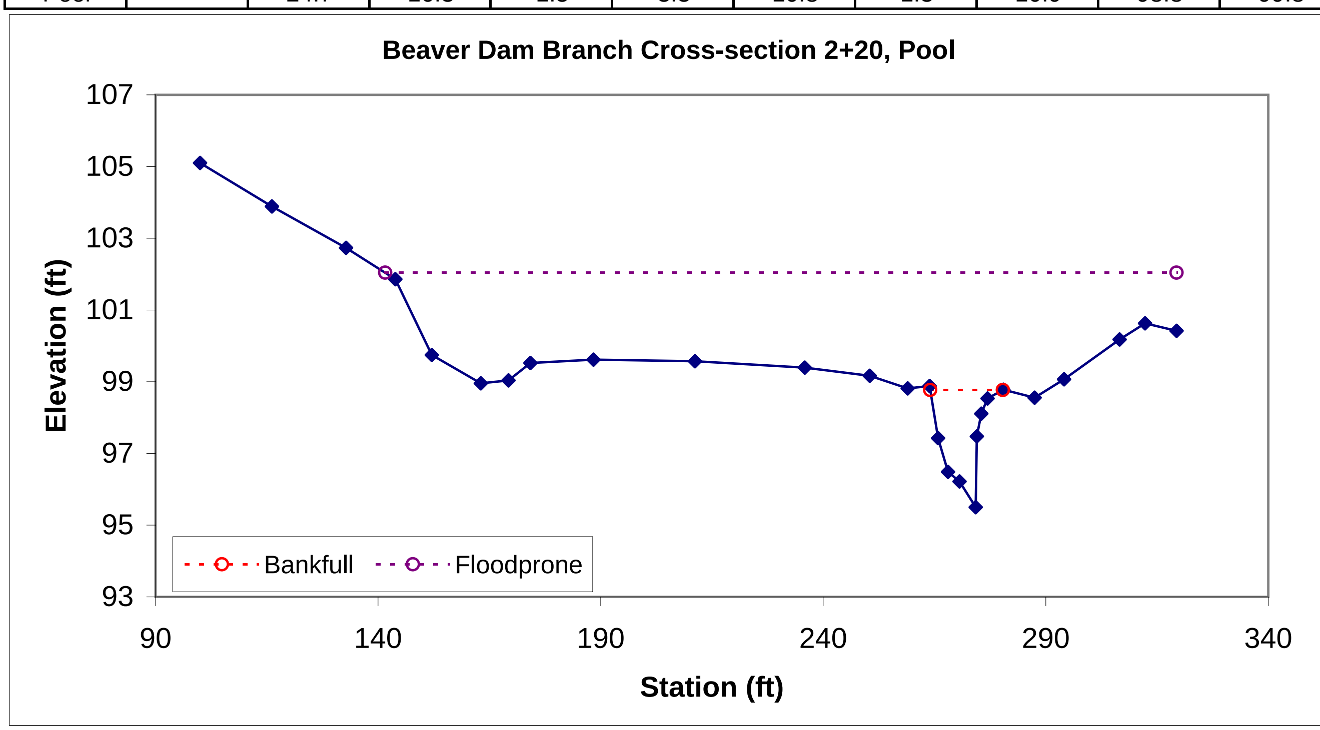
Size Distribution	mm
D16	0.3
D35	0.4
D50	0.5
D84	0.9
D95	1.2


Beaver Dam Branch Reference Reach Survey
Longitudinal Profile
Elevation (ft)
104
103
102
101
100
99
98
97
96
95
94
100
150
200
250
300
350
400
450
Station (ft)
Thalweg
Left top of bank/ bankfull
Right top of bank/ bankfull
Water surface

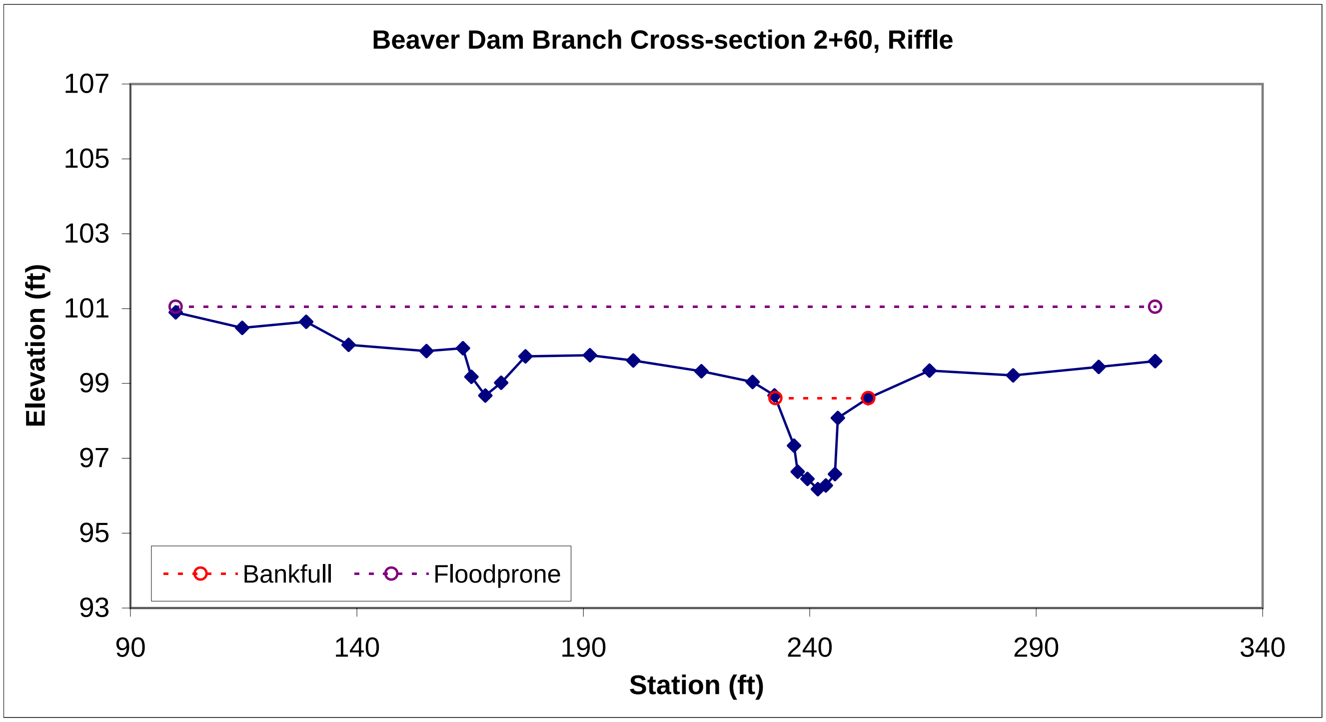
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	25.7	16.8	1.5	2.1	11.0	1.2	10.4	98.6	99.0



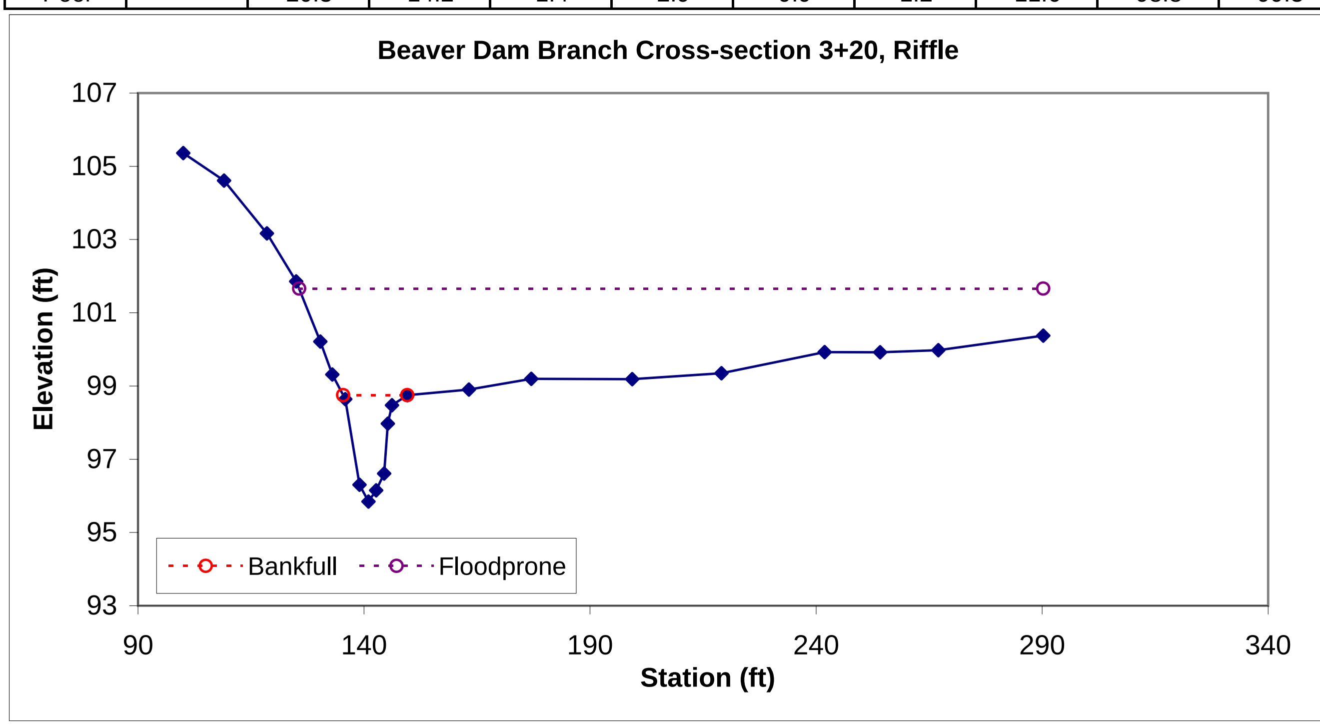
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	----	24.7	16.3	1.5	3.3	10.8	1.3	10.9	98.8	99.8

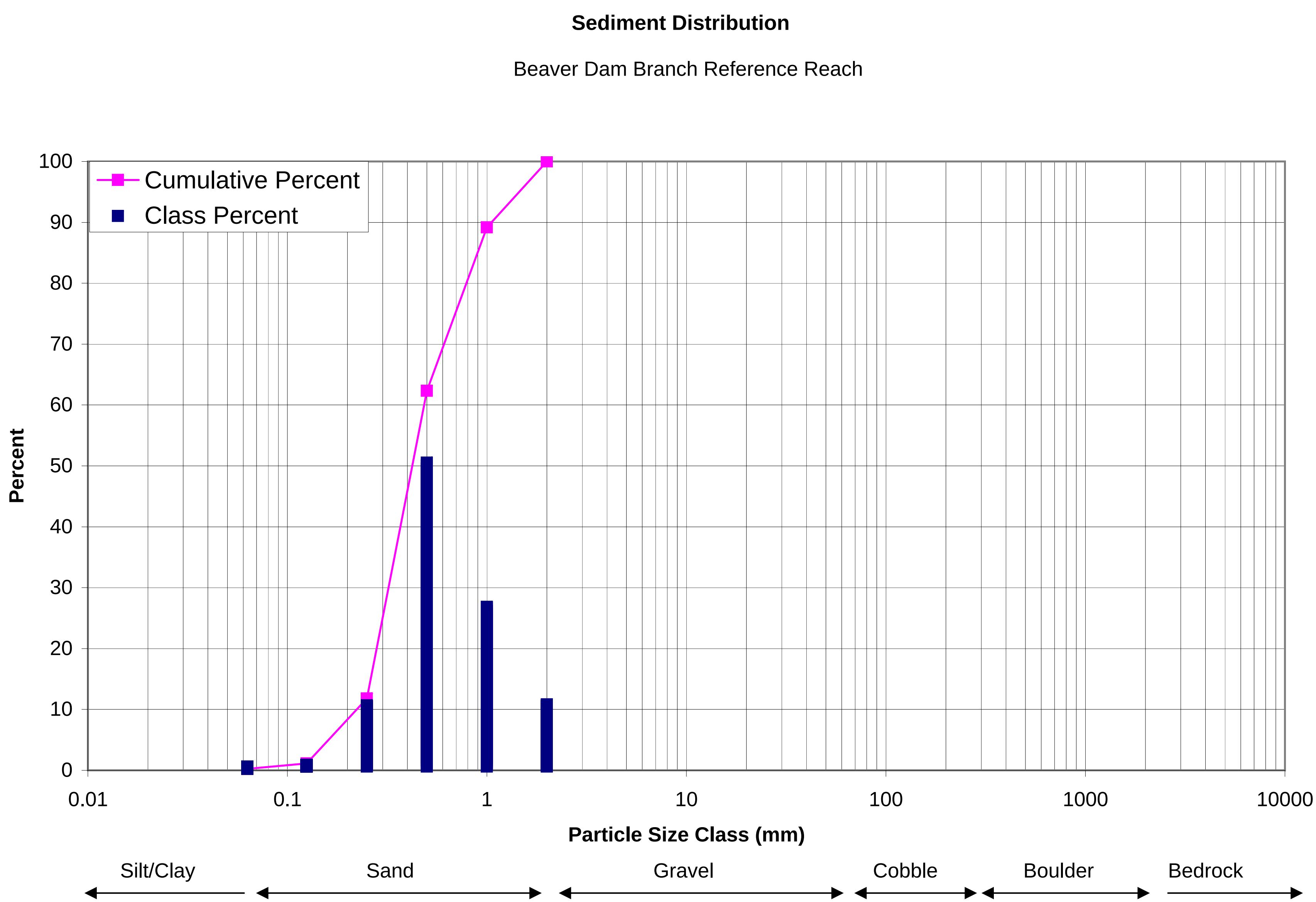


Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C5	24.8	20.5	1.2	2.4	16.9	1.3	10.6	98.6	99.3



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	----	20.3	14.2	1.4	2.9	9.9	1.2	11.6	98.8	99.3





Sediment Distribution
Beaver Dam Branch Reference Reach
Cumulative Percent
Class Percent
Percent
100
90
80
70
60
50
40
30
20
10
0
0.01
0.1
1
10
100
1000
10000
Particle Size Class (mm)
Silt/Clay
Sand
Gravel
Cobble
Boulder
Bedrock

Appendix F

Wetland Delineation Forms

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site:	Duke Swamp	Date:	11/21/06
Applicant/Owner	Buck Engineering	County:	Gates
Investigator:	Richard Darling Reviewer:	State:	NC
Do normal circumstances exist on the site?	(●) Yes ( ) No	Community ID:	W
Is the site significantly disturbed (Atypical Situation)?	( ) Yes (●) No	Transect ID:	1
Is the area a potential Problem Area? (If needed, explain on reverse.)	( ) Yes (●) No	Plot ID:	WDP

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. *Liquidambar styraciflua*	Trees	FAC+	9.	Herbs	#N/A
2. *Acer rubrum*	Trees	OBL	10.	#VALUE!	#N/A
3. *Taxodium distichum*	Trees	OBL	11.	#VALUE!	#N/A
4. *Lonicera japonica*	Vines	FAC-	12.	#VALUE!	#N/A
5. *Rubus sp.*	Vines	FAC	13.	#VALUE!	#N/A
6. *Smilax rotundifolia*	Vines	FAC	14.	#VALUE!	#N/A
7.	Herbs	#N/A	15.	#VALUE!	#N/A
8.	Herbs	#N/A	16.	#VALUE!	#N/A

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 83%

Remarks:

More than 50% of dominants are OBL, FACW, and/or FAC on plant list

HYDROLOGY

- [x] Recorded Data (Describe in remarks)
  - [ ] Stream, Lake, or Tide Guage
  - [ ] Aerial Photographs
  - [x] Other
- [ ] No Recorded Data Available

Field Observations:

Depth of Surface Water:		(in.)
Depth to Free Water in Pit:	4	(in.)
Depth to Saturated Soil:		(in.)

Wetland Hydrology Indicators:

Primary Indicators:
- [ ] Inundated
- [x] Saturated in Upper 12 Inches
- [ ] Water Marks
- [ ] Drift Lines
- [ ] Sediment Deposits
- [x] Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- [ ] Oxidized Root Channels in Upper 12 Inches
- [ ] Water Stained Leaves
- [ ] Local Soil Survey Data
- [ ] FAC-Neutral Test
- [ ] Other (Explain in Remarks)

Remarks:

SOILS

Map Unit Name
(Series and Phase): Nawney loam, 0-2 percent slopes, frequently flooded (Drainage Class D

Taxonomy (Subgroup): Fine-loamy, mixed, acid, thermic Typic Fluvaquer

Field Obsevations Confirm Mapped Type? ○ Yes ○ No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure etc.
	O2				
0 - 12	A1	2.5Y4/2			loam
	B1				
	B2				
	######				
	######				
	######				

Hydric Soil Indicators:

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odorl
- ☐ Aquic Moisture Regime
- ☑ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in Surface Layer in Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	◉ Yes ○ No	
Wetland Hydrology Present?	◉ Yes ○ No	
Hydric Soils Present?	◉ Yes ○ No	Is this Sampling Point Within a Wetland? **Yes**

Remarks:

Approved by HQUSACE 2/92

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Duke Swamp		Date:	11/21/06
Applicant/Owner: Buck Engineering		County:	Gates
Investigator: Richard Darling	Reviewer:	State:	NC
Do normal circumstances exist on the site?	○ Yes ● No	Community ID:	U
Is the site significantly disturbed (Atypical Situation)?	● Yes ○ No	Transect ID:	1
Is the area a potential Problem Area? (If needed, explain on reverse.)	○ Yes ● No	Plot ID:	UDP

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Soy bean	Herbs	FAC	9.	Herbs	#N/A
2.	Herbs	#N/A	10.	#VALUE!	#N/A
3.	Herbs	#N/A	11.	#VALUE!	#N/A
4.	Herbs	#N/A	12.	#VALUE!	#N/A
5.	Herbs	#N/A	13.	#VALUE!	#N/A
6.	Herbs	#N/A	14.	#VALUE!	#N/A
7.	Herbs	#N/A	15.	#VALUE!	#N/A
8.	Herbs	#N/A	16.	#VALUE!	#N/A

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 100%

Remarks:

More than 50% of dominants are OBL, FACW, and/or FAC on plant list

HYDROLOGY

- ☑ Recorded Data (Describe in remarks)
  - ☐ Stream, Lake, or Tide Guage
  - ☐ Aerial Photographs
  - ☑ Other
- ☐ No Recorded Data Available

Field Observations:

Depth of Surface Water:		(in.)
Depth to Free Water in Pit:	4	(in.)
Depth to Saturated Soil:		(in.)

Wetland Hydrology Indicators:

Primary Indicators:
- ☐ Inundated
- ☑ Saturated in Upper 12 Inches
- ☐ Water Marks
- ☐ Drift Lines
- ☐ Sediment Deposits
- ☑ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- ☐ Oxidized Root Channels in Upper 12 Inches
- ☐ Water Stained Leaves
- ☑ Local Soil Survey Data
- ☐ FAC-Neutral Test
- ☐ Other (Explain in Remarks)

Remarks:

SOILS

Map Unit Name
(Series and Phase): Noboco fine sandy loam, 0-2 percent slopes (NoA)

Drainage Class B

Taxonomy (Subgroup): Fine-loamy, siliceous, thermic Typic Paleudults

Field Obsevations Confirm Mapped Type? ○ Yes ○ No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure etc.
	O2				
0 - 18	A1	10YR6/4			sandy loam
	B1				
	B2				
	######				
	######				
	######				

Hydric Soil Indicators:

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odorl
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in Surface Layer in Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	○ Yes ◉ No	
Wetland Hydrology Present?	◉ Yes ○ No	
Hydric Soils Present?	○ Yes ◉ No	Is this Sampling Point Within a Wetland? **No**

Remarks:

Approved by HQUSACE 2/92

Appendix G

Photographic Log

Duke Swamp Photographic Log, page 1 of 4.

Culvert crossing under Kellogg Fork Rd (SR 1320) at beginning of project reach UT1.

Existing fiber optic line along SR1320 ROW at beginning of UT1.

Looking upstream at Farm Pond #1 and existing UT1 channel.

Agricultural fields surrounding reach UT1 during growing season.

Looking at Pond #1 near upper section of reach UT1.

Looking at Pond #2 lacking bank vegetation and buffer protection.

Duke Swamp Photographic Log, page 2 of 4.

Looking at Pond #3 lacking bank vegetation and buffer protection.

Farm access road at existing culvert crossing. Drainage ditch to be tied into proposed UT1.

Existing UT1 culvert crossing along farm access road.

Drainage ditch to tie into proposed reach UT1.

Example of existing drain tile to remain and tie into proposed stream and wetland areas.

Looking downstream towards woodline at overly widened UT1 channel.

Duke Swamp Photographic Log, page 3 of 4.

Looking downstream at UT1 as it enters the existing woodland area.

Looking upstream at Pond #3 tying into UT1 channel.

Far downstream end of reach UT1 after a storm event within forested wetland area.

Automated Well #1 in reference wetland area near Duke Swamp.

Looking at cypress pond outfall near beginning of reach UT2.

Looking downstream at UT2 backwater and excessive duckweed near beginning of reach.

Duke Swamp Photographic Log, page 4 of 4.

Looking upstream at backwater conditions along UT2 channel.

UT2 backwater located at cross-section 7, approximate Sta. 11+80.

Looking downstream at UT2 backwater effects before confluence with UT1.

Looking upstream at UT2 backwater effects before confluence with UT1.