Goldsboro Housing Authority
Stream Restoration Plan
Goldsboro, North Carolina

North Carolina Department of Environment and Natural Resources
Ecosystem Enhancement Program

NORTH CAROLINA
PROFESSIONAL
SEAL
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ENGINEER
SHEILA STALLINGS REEVES
6/5/06

Ecosystem Enhancement
PROGRAM

June 2,2006
Final Submittal

Prepared by: Dewberry
2301 Rexwoods Drive
Raleigh, North Carolina 27607
Phone - 919-881-9939
Fax - 914881-9923

Project Manager - Sheila Reeves, P.E.

Contact Information:
E-mail - sreeves8dewberry.com
Phone - 919-881-9939

The center point of the restored stream of interest in this study is at 35.3908 degrees North and 78.0039 degrees West.
The center point of the proposed wetland of interest in this study is at 35.3897 degrees North and 78.0069 degrees West.
The upstream extent of the reference reach used for comparison was 35.3783 degrees North and 78.0142 degrees West, and the downstream extent was 35.3783 degrees North and 78.0156 degrees West.

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Executive Summary

The North Carolina Ecosystem Enhancement Program (EEP) identified two streams located within the West Haven Apartments Complex, owned by the Goldsboro Housing Authority (GHA), as a candidate stream for restoration and, under a later amendment, revised the study streams to include only a portions of one of the streams and also identified a stream-side area, owned by NCDOT, as a candidate for a constructed wetland as a stormwater Best Management Practice (BMP). The stream length encompasses 2,170 linear feet of the Unnamed Tributary to Borden Field Ditch (UTBFD), and the wetland will cover approximately 1.5 acres of land. Working together, the GHA and EEP have agreed on a conservation easement for the stream length identified for restoration and the NCDOT and EEP agreed on a conservation easement for the BMP. Dewberry & Davis, Inc. (Dewberry) has prepared this Stream Restoration Plan for the identified stream and BMP.

This Restoration Plan documents the assessment and restoration approach for the UTBFD and the creation of the BMP. At the downstream project limits, the UTBFD has a drainage area of approximately 255 acres (0.40 square miles). At the point of confluence with the original proposed restoration reach named Unnamed Tributary (UT), UTBFD has a drainage area of approximately 110 acres; while the UT has a drainage area of approximately 140 acres. At the Oak Street culvert crossing, the UTBFD has a drainage area of approximately 101 acres, and a drainage area of approximately 30 acres at the upstream limits of study. The drainage area for both the UTBFD and the UT are highly urbanized watersheds, characterized by significant commercial and residential development and impervious cover ranging from 34 to 42 percent. Within the project limits, the streams lack sinuosity and have riparian buffer zones that have been removed or highly impacted by routine lawn maintenance operations. Maintenance operations were observed to extend from the overbanks to the stream bed during data collection phase of this project. The UTBFD enters the site as a first order stream and becomes a second order stream upon its confluence with the first order UT near the downstream project limits.

The proposed restoration design is based on natural channel design methods that include the use of reference reaches. Using the Rosgen classification system and field observation, the reach of the UTBFD upstream of the UT, is predominantly an F5 classification. Below its confluence with the UT, UTBFD is a G5c stream that has actively eroding stream banks. The UT is also G5c that is incised.

The proposed stream restoration for the UTBFD utilizes several restoration approaches including:

- Priority 2 restoration of 625 feet to a C5/E5 stream
- Priority 3 restoration of 900 feet to a C5/E5 stream with an entrenchment ratio limited by easement and utility constraints
- Enhancement of 275 feet by bank grading and construction of a bankfull or near bankfull bench

Per modification of the restoration scope, no work is proposed on the UT or on the UTBFD downstream of the confluence of the UT. The streams are located in an urban setting, with an unusual number of site constraints that have been incorporated into the Restoration Plan. These concerns include:

- Maintaining resident safety and overall awareness of flooding potential;
- Offsetting the stream appropriately from nearby buildings, utilities including gas, sanitary sewer, water, electric, etc., and recreational areas;
- Preserving/Replacing pedestrian crossings;
- Integrating existing grade control points, such as stormwater culverts into the design; and
- Designing within a limited easement width

The design considered fencing around the stream as a means to provide safety protection for resident children playing near the stream and provide deterrence from littering in the stream. However, at the request of EEP, no fencing has been provided in the Restoration Plan due to access control issues, maintenance issues, and the questionable effectiveness of litter reduction within the stream.

The UTBFD currently has three pedestrian bridges located within the project limits. The design includes replacement of two pedestrian crossings along the proposed stream restoration reach. New bridges are required because the existing bridges are within the current floodprone flow area of the stream and do not have adequate span available for the proposed cross-sectional dimensions and therefore would restrict the planned grading along these segments of the stream. The proposed restoration methods, in response to these constraints, are shown in Table 1.

Table 1 Project Restoration Structure and Objectives

Project Number 73142900						
Restoration Segment / Reach ID	Station Range	Restoration Type	Priority Approach	Existing Linear Footage or Acreage	Designed Linear Footage or Acreage	Comment
UTBFD	3+75 - 6+50	Enhancement		Minimal Addition of Linear Footage of Stream	275	Overbank Improvement
UTBFD	08+25 - 10+25	Restoration	P2		200	Relocation and Overbank Improvement
UTBFD	10+25 - 11+25	Restoration	P3		100	Overbank Improvement
UTBFD	11+25 - 11+75	Restoration	P2		50	Relocation and Overbank Improvement
UTBFD	11+75 - 13+00	Restoration	P3		125	Overbank Improvement
UTBFD	13+00 - 15+00	Restoration	P2		200	Relocation and Overbank Improvement
UTBFD	15+00 - 21+75	Restoration	P3		675	Overbank Improvement
UTBFD	21+75 - 23+50	Restoration	P2		175	Relocation and Overbank Improvement

1 INTRODUCTION

1.1 Project Description

This Restoration Plan documents the evaluation and development of a conceptual stream design for approximately 2,170 linear feet of the Unnamed Tributary to Borden Field Ditch (UTBFD) and the creation of a constructed wetland (BMP). The stream and wetland site are located within the City of Goldsboro, in Wayne County NC. The identified stream length is located within the West Haven Apartment Complex, which is owned by the Goldsboro Housing Authority (GHA) and the wetland site is adjacent to West Haven Apartment Complex within the NCDOT Right-of-way. Working together, the GHA and the Ecosystem Enhancement Program (EEP) have developed an agreement for a Conservation Easement along the stream reaches identified for restoration and the NCDOT and EEP have developed an agreement for a Conservation Easement on the wetland site. Dewberry & Davis, Inc. (Dewberry) is working with EEP to develop stream restoration documents for the identified stream reaches and BMP.

As part of the development of the Stream Restoration Plan for the identified stream reaches, Dewberry has performed the following tasks:

- Watershed and Stream Data Collection
- Topographic Study (excluding a Boundary Survey)
- Existing Stream Analysis
- Reference Reach Identification and Analysis
- Hydrologic and Hydraulic Study
- Conceptual and Restoration Plan Development
- Phase I Environmental Assessment
- Geotechnical Investigations

Dewberry began the restoration plan process by collecting existing GIS databases from various sources for reference use on this project. Some of the databases include color aerial photography (dated approximately 2002), USGS stream data, NRCS soil survey information, etc. A Digital Elevation Model (DEM) was obtained from the NC Floodplain Mapping Program website for use in developing contours for the project site and watershed. Using these contours in conjunction with stormwater infrastructure maps obtained from the City of Goldsboro, watersheds were developed for the study streams. Aerial photography was analyzed for land use within each watershed. As part of this data collection process, Dewberry also collected data on endangered species that potentially could be located in/near the project site.

A detailed topographic survey was conducted along the study stream and an Unnamed Tributary (UT) which flows into the UTBFD on the downstream end. The topographic survey included approximately 150 feet in width (centered along each stream) extending the length of each study stream. Survey included location of large trees and utilities within the survey extents. Utility location was performed by Locating Contractors. Stream profiles, general channel features, and typical cross sections were collected and geomorphic features were mapped for each study stream.

Numerous site constraints exist due to the location of the study streams in relation to an active apartment complex. Location information has been collected for site constraints; including existing culverts, pedestrian bridges, utilities, building locations, etc. These constraints have been carefully evaluated as part of the Restoration Plan development

Property and utility easement location information was obtained from the recorded Subdivision Plan for the GHA property. The Conservation Easements shown were obtained from EEP as a boundary survey provided by another surveyor (see Appendix B-1: Project Site – Site Map with Easement).

As part of the existing stream analysis, surveyed stream features were analyzed to develop the Rosgen morphological table. The riparian buffer was evaluated to determine the existing plant species, including any invasive plant species. Soil samples were collected within the riparian buffer area and sent to the NCDA Agronomic Division for analysis. Results from this analysis are included as Appendix B-7: NCDA Soils Analysis.

A search was conducted to locate an urban reference reach with similar watershed characteristics to the project reaches. Urban reference reach (REF-1) was located, and survey was performed to document stream features, including typical cross sections and native vegetation (see Appendix A-I: Physiographic Region Map for reference reach and watershed location in comparison to the project location). A morphological table was developed for this site based on collected data. An additional reference reach (REF-2) was obtained from the Stream Restoration Institute to use for supplemental data.

The collected data has been analyzed and applied in the development of the Conceptual Plan (submitted to EEP July 6, 2004). The Conceptual Plan was revised based on Amendment 1 to evaluate the feasibility of a BMP for the site. The draft Restoration Plan was revised based on Amendment 2 to incorporate the BMP design and redesign the stream restoration to fit the limited conservation easement provided by the GHA.

2 Goals and Objectives

2.1 Goals and Objectives

This stream restoration project will support the EEP's mission to restore wetlands, streams, and riparian (streamside) areas throughout the state. Further the BMP will assist EEP in meeting the Neuse Kivcr Basin water quality goals for Nitrogen reduction.

In general, the restoration and BMP support, wholly or in part, the following EEP goals:

- Protect and improve water quality by restoring stream and riparian area functions and values lost through historic, current, and future impacts

Specifically, the stream restoration will:

- Reduce downstream sedimentation by stabilizing eroding stream banks along the study stream lengths
- Replace a degraded stream reach with a stabilized stream which supports natural stream processes
- Decrease property loss within the Goldsboro Housing Authority and adjacent property
- Enhance aesthetics of the restored stream reach

And the BMP will:

- Reduce downstream sedimentation by providing capture of total suspended solids from the UT
- Provide water quality treatment equivalent to one-inch of runoff from a previous untreated mixed use residential area totaling 123 acres
- Enhance aesthetics and create wetland habitat

The proposed wetland will provide nitrogen reduction upstream of the nutrient sensitive waters of the Neuse River. The created wetland can provide up to a forty percent reduction of nitrogen, however the actual removal percentage will be influenced by the intermediate flooding of the wetland. Since the wetland is and overbank wetland and will receive flow only during above bankfull events, treatment will not occur during low flow periods.

The restoration project endeavors to support the North Carolina Division of Water Quality's (NCDWQ) efforts to improve water quality as identified in the Neuse River Basinwide Water Quality Plan. In general, the project supports, wholly or in part, the following sections of the Neuse River Basinwide Water Quality Plan:

- 4.16 Sedimentation Pollution Control
- 4.17 Habitat Degradation
- 4.19 Algal Bloom
- 4.2.1 Protection and Maintenance of Existing Forested Riparian Areas
- 4.2.5 Nutrient Management
- 4.5 Implement Wetlands and Riparian Restoration Plans

3 LOCATION INFORMATION

3.1 River Basin Information

North Carolina contains 17 river basins either partially or completely. The project watershed is situated just east of the Piedmont Physiographic Region, entirely within the Coastal Plain Physiographic Region and within the Neuse River Basin. With a drainage area greater than 6,100 square miles, the Neuse is the third largest river basin in North Carolina.

3.2 USGS &digit Catalog Number

The United States Geological Survey (USGS) categorizes the nation into 21 regions, into sub-regions, into accounting units, and finally into cataloging units. Each of these divisions results in the assignment of two digits. The result is that these cataloging units or watersheds each possess a unique 8-digit hydrologic unit code (HUC). The Neuse is sub-divided into 14 of these 8-digit units. The project watershed has a HUC of 03020201 (03 South-Atlantic Gulf, 02 Neuse-Pamlico, 02 Neuse, 01 Upper Neuse). A map of the 8-digit HUCs is provided in Appendix A-l: Physiographic Region Map.

The North Carolina State Office of the USGS has further subdivided the 8-digit watersheds, devised at the federal level, into 14-digit sub-watersheds. The project watershed's 14 digit HUC is 03020201200020. A map of the UTBFD's 14 digit HUC is provided in Appendix A-1: Physiographic Region Map.

3.3 County Information

The project watershed is located within the city of Goldsboro in central Wayne County. A map of Wayne and surrounding counties can be seen in Appendix A-1: Physiographic Region Map.

5.4 Stream Classifications

Though the UTBFD has not been classified by NCDWQ, it drains to streams that drain into the Neuse River, which has been assigned a C nutrient sensitive water (NSW) surface water classification near Goldsboro by NCDWQ.

A "C" classification indicates waters defined to have a best use of aquatic life propagation/protection and secondary recreation. Waters that have a primary classification of "C" are waters which have sufficient water quality to support fish consumption, aquatic life, and secondary recreation (i.e., wading, boating and minimal human body contact with water). NSWs tend to experience water quality problems associated with excessive plant growth resulting from nutrient enrichment.

Within Appendix B2 of the Neuse Basinwide Watershed Restoration Plan (2001), the NCDWQ noted that the benthic macro invertebrate bio-classifications were completed at two locations near the UTBFD and the UT. These locations, SR 1915 and US 117, on the Neuse River consistently received "GOOD" and "GOOD-FAIR ratings between 1984 and 2000. The NCDWQ's "GOOD-FAIR" benthic macro invertebrate bioclassification rating indicates a use support rating of "Partially Impaired" for benthic organisms.

3.5 USGS Quadrangle Information

The UTBFD is located within Northwest Goldsboro, and is shown in Appendix **A-2:** USGS 7.5 Minute Quadrangle Map. This quadrangle map shows the extent of urbanization in the area, and the location of the watershed in respect to the Neuse River.

3.6 Additional Watershed Identifications

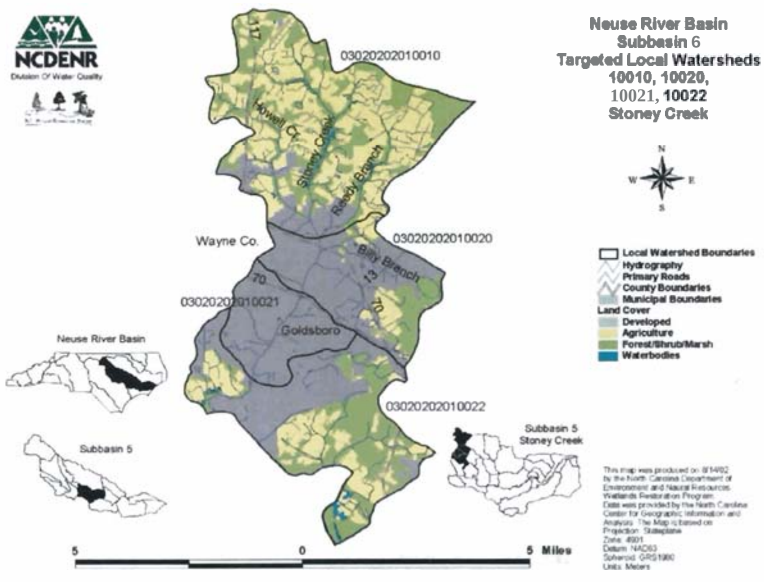
The North Carolina Department of the Environment and Natural Resources (DENR) uses several different methods to categorize and organize the state's watersheds. Three (3) of these identifications are listed below with their descriptions.

The North Carolina Division of Water Quality (DWQ) Watershed Restoration Plan for the Neuse River Basin (2001) and The Basinwide Assessment Reports (Neuse River 2001) both give the watershed a DWQ identifier of Neuse River Subbasin 03-04-05.

The DWQ's Nonpoint Source Management Program recognizes that the project watershed lies within a "Category 1 Basin" or a basin "Needing Restoration." The Nonpoint Source Management Program uses the North Carolina Unified Watershed Assessment 8 Digit Cataloging Category to identify watersheds. These cataloging units are synonymous with the USGS units. The project watershed's 8-digit number is 03020201.

The EEP identifies small watersheds that are of special concern called Targeted Local Watersheds. There are several EEP Targeted Local Watersheds (defined by their NRCS 14-digit hydrologic unit) within the same North Carolina Unified Watershed Assessment 8 Digit Cataloging Category. The project site is closest to EEP's Neuse River Targeted Local Watershed numbers 030202020-10010, -010020, -010021, and -010022. These watersheds are located just west of the project watershed, see Figure 1. The EEP uses these watersheds to concentrate multiple restoration projects within a local watershed to maximize program resources and result in greater benefits to water quality. A benefit of identifying Targeted Local Watersheds is to encourage other groups and organizations to consider implementing projects in these areas also.

Figure 1 Map of Targeted Local Watersheds



4 GENERAL WATERSHED INFORMATION

4.1 General Description

The project watershed is located entirely within the City of Goldsboro and is roughly bounded by Graham Street to the North, Walnut Street to the South, US 117 to the West, and North Center Street in the East. The project watershed is urban in nature, and is characterized by significant commercial and high density residential development.

4.2 Drainage Area

The UTBFD has a drainage area of approximately 255 acres (0.40 square miles) at the downstream project limits. The UTBFD enters the site as a first order stream and becomes a second order stream upon its confluence with the UT. At its confluence with UT, the drainage area for UTBFD is approximately 110 acres (0.17 square miles). The UTBFD is a second order stream at the downstream project site boundary. While UTBFD has several culverts draining directly into the stream along the project reach, the majority of flow enters the stream at a 3 0 cormgated metal pipe (CMP), located at Astor Court.

The drainage area at the upstream limit is approximately 30 acres and increases to 101 acres at the culvert at Oak Street.

4.3 Existing Land Use

The project watershed is an urban watershed with significant amounts of commercial, residential, and industrial uses, as shown in Table 2 and Appendix A-3: Project Watershed Land Use Map. Approximately 39% of the project watershed has a commercial land use, while roughly 37% is used for residential purposes. Less than 10% of the space in the watershed is open space.

Table 2 Project Watershed Land Use Summary

Land Use	% by area
Commercial	39.4
Residential	
1/3 acre	2.5
1/2 acre	34.9
Industrial	14
Open	9.2

An analysis was performed to evaluate impervious area of the watershed. GIS layers representing building footprints, driveways, parking areas, and roadways were obtained from the City of Goldsboro to facilitate this evaluation. Based on this data and an analysis of aerial photography, impervious area for the watershed is 35%, with sub-basin impervious areas ranging from 34 to 41%.

4.4 Future Land Use

A review of the aerial photography indicates that the project watershed is "built-out" to its ultimate potential. It appears that parcels have already been developed under the current zoning regulations. It is assumed that there will not be a significant change in zoning or land use in the foreseeable future. Therefore, there is no expectation of significant changes in the hydrologic function of the watershed.

4.5 Project Watershed Soils

The project watershed contains several different soil mapping units, which are predominantly the Norfolk, Johns, Lumbee, and **Wickham** soil series. The Leaf, Kalmia, Goldsboro, and Rains series are also found in small pockets (Appendix A-4: Project Watershed Soils Map). Table 3 lists the soil mapping units and the percentage of the watershed area made up by each soil mapping unit, in which each series described below, is found. Soils in the project watershed are predominately loamy sand and sandy loams. The soil textures and corresponding percentage of watershed area are shown in Table 4.

Table 3 Project Watershed Soil Series

Soil Mapping Unit	% of Watershed	Soil Mapping Unit	% of Watershed
Norfolk	44.4	Leaf	3.3
Johns	21.1	Kalmia	2.5
Lumbee	14.9	Goldsboro	2.3
Wickham	11.2	Raines	0.4

Table 4 Project Watershed Soil Textures

Soil Texture	% of Watershed
Loamy Sand	58.0
Sandy Loam	**38.7**

* The remaining 3.3 percent of the soils are classified as loam.

Norfolk Series

This series consists of nearly level well drained soils found mostly on broad smooth divides. Despite these soils being low in natural fertility and organic matter content, they are important soils for farming in Wayne County. The soil is easily kept in good tilth; infiltration is moderate and surface runoff is slow. Most Norfolk soils are classified as loamy sand.

Johns Series

Like the Norfolk and Kalrnia soils, Johns Series soils are found predominantly on broad, smooth terraces and short slopes and upland divides. Typically these soils are formed in stream sediment. Again, like the Norfolk and Kalmia soils, Johns Series soils are low in natural fertility and organic matter content. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. Most Johns soils are classified as sandy loams.

Lumbee Series

This series consists of poorly drained soils found on broad, smooth terraces and shallow drainage ways. Like the Norfolk series they are also low in natural fertility and organic matter content. Lumbee soils are usually classified as sandy loam. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. These soils are usually formed in stream sediment.

5 DESCRIPTION OF EXISTING CONDITIONS

5.1 Project Site

The UTBFD is located within the West Haven Apartment Complex, owned by the GHA. The property is roughly defined by US 117 and 13 to the east, West Holly Street to the north, NC 581 to the south, and Railroad track to the west. The project reach of UTBFD, flows thru the central area of the apartment complex, while the UT flows along a property boundary of the apartment complex. The project site (taken as the approximate limits of the Conservation Easement) has residential buildings, common recreational areas, and numerous utilities located within the site. The project site and easement can be viewed in Appendix B-1: Project Site – Site Map with Easement.

Along the project reach, the UTBFD has three existing pedestrian bridges, which provide access to the recreational facilities and other residential buildings. No sidewalks are provided to the pedestrian bridges. There are worn pathways leading to and from each pedestrian bridge. The stream banks and riparian buffer are routinely maintained lawn areas, with moderated tree cover in most locations along the UTBFD. The stream has minimal slope and minimal pattern.

Development of the Conceptual and Restoration plans required many factors to be carefully considered since the stream reaches and BMP are located in an active, urbanized area. As part of the Restoration Plan, Dewberry considered many constraints including, but not limited to the following:

- Preserving large trees along the project reaches
- Utilizing/re-utilizing existing pedestrian crossings along the stream reach
- Protecting utility crossings along the stream
- Protecting infrastructure (Buildings, basketball courts, light poles)
- Managing the lack of grade along project reaches
- Maintaining existing grade control points, (existing culverts)
- Incorporating Conservation Easement limits
- Maintaining base flow in the UT while directing stream flows into the BMP

While there is not a significant tree stand along the project reach, efforts to minimize tree removal have been made, as they provide environmental benefits and an aesthetic benefit as well. Large diameter trees (greater than 4 inches dbh) have been surveyed along the project reach and shown on the Restoration Plan.

EEP and GHA have expressed interest in maintaining two of the existing three pedestrian crossings along the stream with a desire to re-use the existing pedestrian bridges. Due to the length of the existing bridges, the option of re-use the bridges would force grade control points and restrict stream width through the stream crossing.

Utility crossings and alignments along the stream are important to consider in determining potential conflicts. Spatial (X, Y) locations of utilities have been identified along the project reach by Locating Contractors, a sub-consultant for this project. Dewberry survey crews have surveyed the utility locations as designated by Utility Contractors. Known utilities include electric, gas, water, telephone, cable television, stormwater, and sanitary-sewer lines. Potential utility contlicts were considered during development of the Restoration Plan.

5.2 Existing Hydrologic Features

The stream enters the project area via stormwater culverts/drainage systems. The UTBFD is a first-order stream at the upstream project limits. Near the downstream project limits, the UTBFD becomes a second-order stream. The UTBFD flows into Borden Field Ditch approximately 1,500 linear feet downstream of the project limits. Borden Field Ditch flows into the Little River, and ultimately into the Neuse River.

Anecdotal information indicates the stream floods out of bank frequently and is flashy in nature. The upper sections of the UTBFD receive the majority of the drainage area in two point discharges. Each stormwater discharge point has established scour holes. These observations are consistent with the urban setting and the hydrology developed for the design.

5.3 Project Site Soils

An analysis has been made of the soils within the project limits using NRCS GIS soil data. For the purposes of this analysis, the project limits are taken as the extents of the approximate Conservation Easement, as provided to Dewberry by EEP.

Based on this dataset, the predominant soils of the project site are the Lumbee and Leaf series. Both are poorly drained, nearly level soils found on broad, smooth terraces and shallow drainage ways. Typically, both are found in stream sediments in the coastal plain. With both of these soils, the seasonal high water mark is at the surface. The soil types, textures, and corresponding percentage of project area are shown in Table 5 and Table 6. While these are the soils that are reported by the NRCS, it appears that the soils have been altered from this state, due to the development of the West Haven Apartment Complex.

Table 5 Project Soil Series

Soil Mapping Units	% of Project Site	Soil Mapping Units	% of Project Site
Lumbee	55.6	Wickham	9.4
Leaf	27.8	Johns	7.2

Lumbee Series

This series consists of poorly drained soils found on broad, smooth terraces and shallow drainage ways. They are low in natural fertility and organic matter content. Lumbee soils are usually classified as sandy loam. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. These soils are usually formed in stream sediments.

Leaf Series

This series consists of poorly drained nearly level soils found on broad, smooth terraces and shallow drainage ways on uplands. The seasonal high water table is at the surface. Leaf soils are usually classified as sandy loam. This series has slow permeability, high water availability capacity, and their shrink swell capacity is usually high. These soils are usually formed in stream sediments.

Table 6 Project Soil Textures*

Soil Texture	% of Project Site
Sandy Loam	62.8
Loam	27.8

* The remaining 9.4% of the soils are classified as Loamy Sand.

In addition, soil testing and seasonal high water elevation information was obtained as part of the geotechnical testing performed by S&ME, Inc. The geotechnical report is provided as a separate document from the Restoration Plan.

5.4 Plant Communities

For a description of the project plant communities, the project area was categorized into two sections. Oak Street effectively bisects the project into an upstream eastern section and a downstream western section.

The upstream section of the project is to the east of Oak Street. The majority of the riparian buffer in this section is routinely mowed right up to the stream bank. However, there are some large scattered trees within the riparian zone. This area is dominated by sweetgum (Liquidambar *styraciflua*) typically covered in poison ivy (Toxicodendron *radicans*). Other lesser species include willow oak (Quercus phellos), American elm (Ulmus Americana), tulip poplar (*Liriodendron tulipifera*), red maple (Acer *rubrum*), loblolly pine (*Pinus taeda)*, black cherry (*Prunus serotina* Ehrh), sycamore (Platanus occidentalis), Chinese privet (*Ligustrum* sinense Lour.), sugarberry (Celtis laevigata *Willd*), winged elm (Ulmus alata *Michx*.), and river birch (Betula nigra L.). The Chinese privet is not widespread, but will be removed during construction. The existing grass will need to be removed or eradicated within the buffer zone to allow for more native plants to take over the area after construction.

The downstream section of the project is to the west of Oak Street. This area includes the lower portion of the UTBFD, as well as the entire portion of the UT. Both have similar vegetation characteristics. The majority of this area is less frequently maintained than the upstream section. However, the majority of the northern side of the UTBFD is mowed regularly, except where loblolly pine (*Pinus taeda*) is growing and shading out the lawn grass. The southern side of the UTBFD as well as along the UT has some large trees made up of sweetgum (Liquidambar *styraciflua*) and willow oak (Quercus phellos). Other lesser species include sycamore (Platanus occidentalis), eastern red cedar (Juniperus virginiana L.), Chinese privet (Ligustrum sinense Lour.), and black willow (*salix* nigra). Only portions of the downstream section will be altered as part of this project. This is the 275 feet of the upstream of the UT and BMP site that abuts the UT on the East and the UTBFD on the North. Alterations to the buffer will be limited to these areas. The Chinese privet is not widespread, but will be removed during construction. The existing grass will need to be removed or eradicated within the buffer zone to allow for more native plants to take over the area after construction.

5.5 Threatened/Endangered Species Study

A search of the United States Fish and Wildlife Service (USFWS) and the North Carolina Natural Heritage Program (NCNHP) indicates three endangered or threatened species (Table 7) could be potentially found in Wayne County and in the Northwestern Goldsboro 7.5 minute USGS Quadrangle Map (Appendix A-2: USGS 7.5 Minute Quadrangle Map).

Table 7 Endangered Species

Major Group	Scientific Name	Common Name	*State Status	*Federal Status
Bird	Picoides borealis	Red-cockaded Woodpecker	E	E
Mollusk	Strophitis *undulatus*	Squawfoot	E	FSC
Mollusk	Villosa *delumbis*	Eastern Creekshell	E	FSC

*State Status Abbreviations: E= Endangered, T = Threatened. & FSC = Federal Species of Concern

It can be reasonably assumed that the Red-cockaded Woodpecker (RCW) is not found on or near the project site due to the lack of suitable habitat on the project site. The red-cockaded woodpecker has highly specialized habitat requirements, which account for its endangered status (http://www.geocities.com/Heartland/5960/rcockade.html). Its cavity trees are found only in mature pine forests containing trees greater than about 60 years of age which are fairly open and free of a hardwood understory. The project site has very few pine trees and is typically too crowded by large hardwood trees, which would not be favorable for RCW nesting.

Neither of the mollusk species is reasonably assumed to be present within the project limits. Given the urban nature of the project watershed, the poor water quality resulting from significant commercial and industrial runoff, and the relatively low base flow in the streams, the project streams are assumed to be not suitable for sensitive mollusk species. The consistent presence of large amounts of litter in the stream also serves to diminish water quality and aquatic habitat.

The assumption that these species are not likely to be found in this watershed cannot be substantiated without a full investigation by a qualified professional, which is beyond the scope of this project. However, the existing conditions of the project site suggest that there is no reasonable expectation of finding any of the above listed species within the project site.

5.6 Rosgen Suwey and Classification

A stream survey and classification has been performed using Rosgen methodology. A morphological investigation of the streams is a key component of the survey. It includes the collection of cross sections and an assessment of stream dimensions, pattern, profile, and substrate materials. These characteristics were collected and evaluated using the techniques outlined in a number of references, including:

- *Applied River Morphology* (Rosgen, 1996)
- The United States Forest Service General Technical Repot RM-245 (Harrelson et al., 1994)
- *Stream Restoration: A Natural Channel Design Handbook* prepared by the North Carolina Stream Restoration Institute and North Carolina Sea Grant
- Publications from several State and Federal Agencies including, but not limited to, the United States Geological Survey (USGS), the Natural Resource Conservation Service (NRCS), the North Carolina Division of Water Quality (DWQ), were also consulted as part of the stream analyses

The UTBFD study reach can generally be characterized as a low gradient stream, lacking in well defied riffle-pool sequence, and having significant areas of bank erosion below its confluence with the UT and in areas near existing stormwater outfalls. The UT can be similarly characterized as having a very low gradient, lacking well defined riffle-pool sequence, and having significant bank erosion along the study reach.

Field observation of the streams indicates the UTBFD upstream of the confluence with the UT is a Rosgen F5 stream type and below the UT the stream is a Rosgen G5 stream type. The UT was also observed to be a G5 stream. Both streams have sand beds and have area of active erosion.

Rosgen's classification, based on Rosgen survey, on the upstream reach of the UTBFD (upstream of the confluence of UT) was inconclusive. The stream is, and is believed to have been historically maintained along and within the channel. Scour and erosion indicators were observed during the survey, but these indicators are for discharge events that occur more frequently and at lower stage than bankfull. Bankfull indicators were not observable in the field and the data presented in Table 9 represents values based on the observed scour lines and are for informational purposes only. Table 9 indicates the erosion indicators surveyed are entrenched and would tend to create an unstable stream. Review of the field conditions, the field survey and the watershed hydrology indicates bankfull is entrenched within the majority of the upstream reach, indicating an F5c stream. The areas where bankfull appears to be less entrenched are generally inconsistent in dimension with the upper reach and are believed to be modified, possibly by maintenance, and not good indicators of the stream type.

The downstream reach (below the confluence with the UT) of the UTBFD, based on Rosgen survey, has a width to depth ratio of less than twelve to one (12 to 1). From downstream of the confluence with the UT to the project limits, the UTBFD is classified as a Rosgen G5c stream type. The entrenchment ratio in the downstream portion of the UTBFD is 1.3 on average which results in an entrenched classification. The average width to depth ratio is low at 7.1 and the sinuosity is low at 1.00. This reach is constrained by buildings on the north overbank.

The UT has 470 linear feet of entrenched sand bed with low sinuosity and a width to depth ratio of less than twelve to one (12:1). Based on the Rosgen survey, the UT is classified as a Rosgen G5c stream type. The UT is entrenched with a 1.2 average entrenchment ratio. The average width to depth ratio is low at 6.0 and the sinuosity is low at 1.16. This reach is also constrained by buildings on the east overbank. There are two 90-degree turns just before its confluence with the UTBFD.

The discussion below describes the methodology and results of each portion of the stream survey and classification.

5.6.1 Cross-sections

Survey of the streams included collection of a stream profile and cross sections for both study reaches. Cross-sections were taken at representative riffles, maximum pools, and head of pools. The data collected at each cross-section included longitudinal and cross-sectional stations, bankfull station and elevation, thalweg location and elevation, edge of water location and elevation, breaks in slope, flood prone area, and top of bank. A topographic survey, including large diameter tree location, was performed with a 150 foot approximate width, centered along each project stream length.

The reach of the UTBFD, upstream of confluence with the UT, is comprised of several riffle-pool sequences. In total eleven (11) pools and ten (10) riffles were identified along the approximately 1,810 linear foot reach. It was noted that each of the features are weak and the stream has a general lack of profile features. Cross sections were collected at three (3) representative riffles and four (4) representative pools.

Along the UTBFD, downstream of the confluence with the UT, three (3) riffles and two (2) pools were identified along an approximately 360 linear feet reach. A representative cross section was collected for each feature type.

Weak riffle-pool sequence was noted along the study length of the UT. Three (3) pools and three (3) riffles were identified along the approximately 470 linear feet of stream. A representative riffle cross section was taken.

5.6.2 Dimension

The most dominant bankfull indicators were the highest scour line and break in slope on each stream bank. Point bars and inner berm, which the Army Corp of Engineers often refers to as the Mean High Water Elevation, were minimally present and are weak features. Review of the field data and the watershed hydrology indicates the indicators located during survey were for discharge events that occur more frequently than bankfull. The stream had cleared of vegetation prior to the survey and true bankfull indicators were not located. Bankfull is entrenched in the majority of the upper reach, but was not observable because of field conditions.

The UTBFD, upstream of Oak Street, has been analyzed separately from the reach downstream of Oak Street. The scour indicators observed during survey had cross-sectional areas for the upstream reach of UTBFD of approximately 6.4 square feet and flow top widths of 10.9 feet. These indicators are well entrenched and the observed scour lines indicate the stream currently has erosion potential at multiple stages and discharge levels. Summary dimension measurements, as measured in the field can be found in Appendix B-2: Project Site Dimension Data. Please note these are presented for information purposes only, as these are not true bankfull data.

The UTBFD, downstream of the UT, and the UT are more incised and entrenched than the upstream reach of the UTBFD. The downstream reach of the UTBFD has mean values for bankfull area, width, and entrenchment ratio of 9.4 square feet, 8.2 feet, and 1.3, respectively. For the UT these values are 5.9 square feet, 5.9 feet, and 1.2, respectively. Summary dimension measurements can be found in Appendix B-2: Project Site Dimension Data and Table 8.

Table 8 Misc. Dimension Measurements

Stream Reach	Width/Depth Ratio	Entrenchment Ratio
UTBFD – upstream of Oak St.	Not observed*	Not observed*
UTBFD – downstream of Oak St.	7.1	1.3
UT	6.0	1.2

* See preceding text. Bankfull has been obscured by maintenance preceding field work. Field data, field observations and the hydrology indicate the majority of the reach is entrenched and consistent with the classification of F5.

5.6.3 Pattern

Above the confluence with the UT the existing meander wavelengths range from 75 feet to 646 feet. The average wavelength is 207.3 feet. The values, for radius of curvature, found in the upstream section vary from less than 10 feet to in excess of 100 feet with an average radius of 27.6 feet. The existing range of belt-width values is 5 to 86 feet with a mean width of 27.4 feet. Complete pattern measurements can be found in Appendix B-3: Project Site Pattern Data.

Below the confluence with the UT, the UTBFD contains no curves and therefore, has no pattern. The UT contains only two turns, both of which are 90 degrees, and as a result it has limited pattern. The belt width associated with the two turns is 20 feet.

Overall the UTBFD has a sinuosity of 1.05. When analyzing the upstream and downstream section independently; the upstream reach has a sinuosity of 1.06, and the reach downstream of the UT does not have any curves, giving it a sinuosity of 1.00. The UT has two 90 degree turns, which were excluded, and otherwise straight for the entire length on property, so sinuosity is 1.00.

5.6.4 Profile

The UTBFD drops approximately 9.5 feet in elevation while traveling 2,334 feet through the UTBFD project site, including the length of the culvert under Oak Street. This results in an overall slope of 0.0044ft/ft or 0.44%. The UTBFD and the UT lack a true riffle-pool sequence, but for the purpose of this report the channel features will be categorized and reported as riffle and pool features. Over the entire reach the UTBFD consists of approximately 51% riffles and 49% pools. The average pool to pool spacing is 172 feet and the average riffle to riffle spacing is 161 feet. These distances exceed what would be expected of a stable coastal stream of this bankfull width. Most of the features are weak and the reach is predominately run. Complete profile measurements can be found in Appendix B-4: Project Site Profile Data and Table 9.

Above the confluence with the UT the existing stream falls 8.6 feet in 2,005 feet, for a slope of 0.0043ft/ft or 0.43%. The upper reach contains a similar number of riffle and pools, specifically 57% riffles and 43% pools. The average pool to pool spacing is 190.4 feet (roughly 17.5 bankfull widths). The average riffle to riffle spacing is 164 feet (17.5 bankfull widths).

Below the confluence with the UT the slope is lower than the upstream reach. The downstream portion of the UTBFD has a channel slope of 0.0026 ft/ft or 0.26%. Unlike the upstream portion, the stream is dominated by pools and runs. Riffle features make up less than 15% of the reach downstream of the UT. The average pool to pool spacing is 24.0 feet (roughly 2.9 bankfull widths). The average riffle to riffle spacing is 150.1 feet (approximately 18.3 bankfull widths). Complete profile measurements can be found in Appendix B-4: Project Site Profile Data.

The UT has very poorly defined features. In its current state, it is more like a drainage ditch than a sand bed stream. The few weak features it has are spaced a considerable distance from each other for a stream of the UT's bankfull width. The average pool to pool spacing is 167.6 feet (approximately 28.3 bankfull widths). The average riffle to riffle spacing is 170.9 feet (29 bankfull widths). Complete profile measurements can be found in Appendix B-4: Project Site Profile Data.

5.6.5 Pebble Counts

Pebble counts were taken at eight (8) locations along the UTBFD. Six (6) of these locations were taken above the confluence with the unnamed tributary and two (2) were taken below the confluence. Two (2) locations were sampled along the UT. At each location, one-hundred samples were taken, and the D_{50} for all of the reaches was determined to be 0.5 mm. Data sheets can be found in Appendix B-5: Project Site Pebble Count Data.

5.7 Pavement and Sub-pavement Samples

A representative riffle was chosen for the pavement and sub-pavement samples. The samples were extracted from the portion of the riffle with the most aggradation (not in the thalweg). A five (5) gallon bottomless bucket was used to define the sample area and shield it from flow. The sample was processed by a geotechnical lab for sieve analysis tests. The D_{50} of the pavement was determined to be 0.89 mm. The D_{50} of the sub-pavement was 0.87 mm. Data sheets can be found in Appendix B-6: Project Site Pavemenflub-pavement Data.

5.8 Topographic Survey

A topographic survey was completed using conventional and GPS survey techniques within the stream and along the immediate overbanks. The topographic survey included the location of top and bottom of banks for each stream, stream thalweg, and breaks in slope. Additionally, location of bridges, culverts, large trees, buildings, and utilities were included. Cross-sections for both hydraulic modeling and for Rosgen analyses were also surveyed.

Horizontal and vertical control was established from two Trimble 4700 Global Positioning System units. The (GPS) static observations were made at multiple locations on the project site. The data was then analyzed using the Online Positioning User Service (OPUS) provided by the National Geodetic Survey (NGS). The NGS operates the OPUS as a means to provide GPS users' easier access to the National Spatial Reference System (NSRS). OPUS used the "PONG 1997" NGS base station (monument) with a point identification numbers (PID) of AI6453 in its analyses. OPUS provided NAD83/95 positions (North American Datum of 1983/ epoch 1995) and NAVD88 (North American Vertical Datum) elevations. Due to the BMP site being added by amendment after the completion of the site survey an alternate data source was utilized. The survey data on this site was supplemented with Lidar data from EEP to complete the topography for the entire site. The vertical and horizontal datum for the Lidar data is the same as the survey data.

Table 9 Morphological Table - Existing Conditions

	Parameter	Units	Existing		Existing		Existing		Existing	
General	Reach Name		UTBFD U/S Oak Street		UTBFD D/S Oak Street U/S UT***		UTBFD D/S of UT**		UT**	
General	Stream Type		F5		G5					
General	Drainage Area	mi^2	0.08		0.17					
General	Bankfull Discharge, Q_{BKF}	cfs	73		160					
General	Bankfull Velocity, V_{BKF}	ft/s	--		--					
Dimension	Bankfull X-Sec. Area, A_{BKF}	ft^2	6.1		12.0					
Dimension	Bankfull Width, W_{BKF}	ft	11.2		11.5					
Dimension	Bankfull Mean Depth, D_{BKF}	ft	0.6		1.0					
Dimension	Width/Depth, W_{BKF} / D_{BKF}		21.5		11.0					
Dimension	Bankfull Max Depth, D_{MAX}	ft	1.2		1.9					
Dimension	D_{MAX} / D_{BKF}		2.0		1.8					
Dimension	W. Flood Prone Area, W_{FPA}	ft	17.5		1.6					
Dimension	Entrenchment, W_{FPA} / W_{BKF}		1.5		1.6					
Dimension	Bank Height Ratio, BHR		2.4		3.0					
	Parameter	Units	Min	Max	Min	Max	Min	Max	Min	Max
Pattern	Meander Length, L_M	ft	75	646			No existing pattern in this portion of the project reach.			
Pattern	M.L.Ratio, L_M / W_{BKF}		6.9	59.4						
Pattern	Radius of Curvature, R_C	ft	2.7	103.1						
Pattern	RC Ratio, R_C / W_{BKF}		0.3	9.5						
Pattern	Belt Width, W_{BLT}	ft	5	86						
Pattern	BW Ratio, W_{BLT} / W_{BKF}		0.5	7.9						
Profile	L.Pool Spacing, L_{ps}	ft	49.5	346.9			24.0	24.0		
Profile	P.S.Ratio, L_{ps} / W_{BKF}		4.5	31.9			4.0	4.0		
Profile	Pool Width, W_p	ft	8.2	18.5			6.6	6.6		
Profile	P.W. Ratio, W_p / W_{BKF}		0.7	1.7			1.1	1.1		
Profile	Pool Depth, D_p	ft	0.6	1.0			1.6	1.6		
Profile	P.D. Ratio, Dp / D_{BKF}		0.06	0.09			0.27	0.27		
Profile	Valley Slope, S_{Val}		0.46%				0.26%			
Profile	Channel Slope, S_{Ch}		0.43%				0.26%			
Profile	Sinuosity, K		1.11				1.01			
Profile	Pool Slope, S_P		0.07%				0.07%			
Substrate	D_{16} - Channel	mm	Silt/Clay				Silt/Clay			
Substrate	D_{50} - Channel	mm	0.5							
Substrate	D_{84} - Channel	mm	5.7							

* - Values presented are for the scour lines observed during survey, but are not for bankfull data and are included for informational purposes only. The information provided is for discharge events less than bankfull and are shown to indicate entrenchment of the observed data and indicate overall channel instability.

** - This data was collected but will not be applied. The reach downstream of the UT will not have Rosgen methods applied to its design due to the constraints in the area and length of this reach.
*** - Because of the shortness of the reach only limited field data was collected for the portion of the stream between the UT and Oak Street. This segment was found to be generally consistent with the portion of stream downstream of the UT for Pattern, Profile and Substrate. Therefore, these values were used for both stream segments.

5.9 Bank Erosion Hazard Index

Bank Erosion Hazard Index forms were completed at 9 representative features throughout the length of the UTBFD and the UT. Seven (7) of the nine (9) BEHI evaluations were performed in the upstream portion of the UTBFD. One (1) BEHI evaluation was completed in each the downstream reach of the UTBFD and the UT. Eight (8) of nine (9) of the BEHI evaluations resulted in either a high or extremely high potential for erosion. These forms can be found in Appendix B-8: Project Site BEHI Data Sheets or in summary form in Table 10.

Table 10 Summary of BEHI Evaluations

Cross Section #	Index Value	Rating
1	25.9	Moderate
2	34.9	High
3	45.1	Very High
4	33.7	High
5	36.8	High
6	37.7	High
7	44.8	Very High
8 (UT)	33.1	High
9 (Downstream)	40.8	Very High

5.10 Wildlife Observed

At the time of wildlife assessment, much of the project site had recently been denuded as part of a maintenance operation. Consequently, this potentially resulted in loss of habitat for some species. During the wildlife assessment, a limited variety of terrestrial species were encountered. A few species seen on-site include American Crows (*Corvus* brachyrhynchos), Cardinals, (Cardinalis *cardinalis*), Snapping Turtles (Chelydra *serpentina*), River Cooters (*Pseudemys concinna*), grey squirrels (*Sciurus* carolinensis), and other unidentified small birds, snails, and frogs. Residents have seen raccoon (Procyon *lotor*) and several varieties of snakes along the project site.

A minimally diverse aquatic community was noted along the project reach. Crayfish (*Procambarus* clakii), unidentified leaches, and unidentified small fish were sighted.

5.11 Summary of Hydrologic and Hydraulic Findings

Neither of the study streams are streams that have been studied by FEMA and, consequently, are not subject to regulation under Federal Emergency Management Act (FEMA) National Flood Insurance Program (NFIP). The GHA has requested that a flooding potential study be performed for this project to evaluate the risk of increased flooding potential that could result from the stream restoration. This has been provided in section 5.11.2.

Methodologies used to develop the flooding study for this project have been made largely consistent with those methodologies used by the State of North Carolina Floodplain Mapping. Design flows for this project have been determined based on Urban Regression Equations presented in ***Estimation of Flood-Frequency Characteristics of Small Urban Streams in North Carolina,*** USGS report 96-4084 by Jeanne C Robbins and Benjamin F Pope III.

5.11.1 Hydrology

The equations used to determine design flows are presented in the Table 11. In the formulas listed below: Drainage Area (DA) is given in square-miles, Impervious Area (IA) is given in percent, and Flow (U,) is given in cubic feet per second. Watersheds can be viewed in Figure 2.

Table 11 Urban Regression Equations

Design Storm	Urban Regression Equation
10-yr storm	$U_{10} = 109 * DA^{0.625} * IA^{0.515}$
25-yr storm	$U_{25} = 209 * DA^{0.570} * IA^{0.436}$
50-yr storm	$U_{50} = 280 * DA^{0.558} * IA^{0.396}$
100-yr storm	$U_{100} = 363 * DA^{0.547} * IA^{0.358}$

Table 12 Summary of Calculated Flows for the Project Watershed

Basin ID	Cum. DA (acre)	Cum. IA (acre)	IA (%)	U10 (cfs)	U25 (cfs)	U50 (cfs)	U100 (cfs)
6	30.10	12.60	41.86	110	186	223	260
6+5	76.81	30.61	39.85	193	311	369	426
6+5+4	109.25	37.23	34.08	222	355	422	488
6+5+4+3	248.57	91.43	36.78	386	587	689	787
6+5+4+3+2	255.50	92.90	36.36	391	593	696	795
6+5+4+3+2+1	259.00	92.94	35.88	391	594	698	797

As discussed in Section 4.4, the project watershed can be considered to be in its ultimate "build-out" condition. Therefore, the flows calculated based on existing conditions are considered to be reasonable, representative ultimate condition flows.

A stream gage was installed on June 16,2004, along the UTBFD just upstream of its confluence with UT. Data collected from the stream gage can be used to better understand the hydrological characteristics of the stream and can be used as ancillary data to calibrate flow estimation. However, at the time of this report, no storm data has been collected. Final calculated flows can be referenced in Table 12.

Figure 2 Map of Sub-watersheds showing the Industrialized/Urbanized Nature of the Basin

5.11.2 Hydraulics

A hydraulics model has been developed far the project site to determine the existing flooding potential risk and the flooding potential risk for the proposed stream restoration condition. The model was prepared in a manner largely consistent with the North Carolina Floodplain Mapping Program methodology for each of the design storms, and has been included in Appendix D-4: Hydraulic Model. The proposed channel design reduces the water surface elevations from existing conditions. Therefore, this project is not anticipated to increase flooding potential. The average decrease in flood elevation is 0.08-ft with the most significant decrease being 0.29-ft at the most upstream extent of the model, just downstream of N. Astor Ct.

6.1 Site Identification and Description

Factors that were evaluated to select reference streams, include finding a stream with comparable watershed size, watershed soils, stream bed/bank soils, stream classification, stream stability, watershed land use / land cover, impervious area, valley slope, stream slope, and steam order to the project reach. While many sites were investigated for potential as a reference reach, finding a stable stream in good condition in an urban setting is challenging. To enlist a full compliment of Rosgen reference parameters, two (2) reference streams were analyzed.

The first reference reach analyzed is an unnamed tributary (REF-I) to the Little River (Appendix C-1: Reference Site Dimension Data). REF-I has an urban watershed comparable in size and impervious coverage to the project watershed. The REF-I stream is located in close proximity to the project watershed (southeast of the project watershed and within the City of Goldsboro), and the REF-I watershed borders the project watershed. Characteristics of REF-1 used in the natural channel design methodology include: dimension, profile, and sediment transport measurements. As with many urban streams REF-I has been artificially confined and its natural pattern has been truncated.

A second reference stream (REF-2) was required to supplement the pattern data provided by REF-I. REF-2 is situated in a much less urban watershed in Moores Crossroads, NC (Appendix C-2: Reference Site Pattern Data). This reference stream was analyzed by the North Carolina State Extension Service (NCSES). Data from REF-2 used in the natural channel design methodology was focused on stream pattern. The REF-2 watershed is much larger and more rural than the project watershed. REF-2 does have a favorable channel slope, sediment transport capacity, stream classification, and pattern measurements when compared to the project reach. Measurements and values are provided in the morphological table for this reference and were provided by the NCSES. Data presented for REF-2 was not collected by Dewberry and was taken directly from NCSES.

6.2 Rosgen Classification

REF-1 has an entrenchment ratio of 1.7 and a width to depth ratio of 9.7 to 1. The sinuosity is 1.0 and the slope is 0.22%. The D_{50} of the stream is a 0.25 mm particle. The REF-1 stream is a stable E5 stream that is nested in a large valley that is a G Rosgen stream classification. Thus, the entrenchment number of REF-1 is artificially lower than would naturally be associated with an E stream classification. This condition is a frequent condition found in urban streams. The width to depth ratio, slope, channel material, and site visits indicate that the stream is a Rosgen E5 stream. In addition to the mean values mentioned above, the complete reference measurements and ratios can be found in the Morphological Table (Table 13).

REF-2 has an entrenchment ratio of 21.9 and a width to depth ratio of 5.2 to 1. The sinuosity is 1.2 and the slope is .46%. The D_{50} of the stream is a 1.0 mm particle. These characteristics indicate that the stream is a Rosgen E5 stream. Reference measurements can be found in the Morphological Table (Table 13).

6.2.1 Cross-sections

Cross-sections were taken at representative riffles, maximum pools, and head of pools along REF-I. The data collected at each cross-section includes longitudinal and cross-sectional station, bankfull station and elevation, thalweg location and elevation, edge of water location and elevation, breaks in slope, flood prone area, and top of bank. Topographic survey was completed within the REF-1 and along its banks.

The surveyed reach of REF-1 is comprised of several riffle-pool sequences. There were II features identified along the 459 foot study length of REF-I. Many of the features are in good condition and cross-sections were surveyed at three (3) representative riffles and two (2) representative pools.

6.2.2 Dimension

The most dominant bankfull indicator was the break in slope on each stream bank. The highest scour line and inner berm, which the Army Corp of Engineers often refers to as the Mean High Water Elevation, were minimally present and typically were weak features. Point bars were absent along in the REF-1 channel.

The bankfull area at the representative riffles ranged from 21.4 to 25.4 feet, with an average area of 23.2 square feet. The average bankfull width was 15.0 feet with a maximum of 17.5 and a minimum value of 13.5 feet. These values produce an average bankfull mean depth of 1.5 feet with a range of 1.3 to 1.8 feet. Cross-section data for REF-I can be found in Appendix C-l: Reference Site Dimension Data.

6.2.3 Pattern

As stated previously, the REF-1 watershed has many similarities to the project watershed, including weak pattern measurements, which need to be supplemented. REF-2 is less closely related to the project watershed, due to it being more rural than REF-I, but has stronger pattern measurements. REF-2 was, therefore, used only to supplement the necessary pattern measurements. REF-2 has a valley length of 219 feet and a stream length of 264 feet, which indicates a sinuosity of 1.21. Two belt width measurements were taken and measured approximately 24 and 34 feet. The meander wavelength was taken at two locations, and resulted in measurements of roughly 60 and 62 feet. The radius of curvature measurements ranged from a radius of 15 feet to one of 29 feet with a mean value of 23.7 feet. Pattern data for REF-2 can be found in Appendix C-2: Reference Site Pattern Data.

6.2.4 Profile

The surveyed reach (REF-I) has an elevation drop of 1.0 feet along a channel length of 459 feet, which results in an overall slope of 0.0022 ft/ft or .22%. The average riffle to pool spacing is 34 feet or roughly 2.25 bankfull widths. The average pool to pool spacing is 97 feet, or roughly 6.5 bankfull widths. The average riffle to riffle spacing is 120 feet or approximately 8 bankfull widths. Profile data for REF-1 can be found in Appendix C-3: Reference Site Profile Data.

6.2.5 Pebble Counts

A pebble count study was performed along REF-1. Pebble counts were taken at two (2) riffles and two (2) pools. The pebble counts indicate a sand bed stream with a D_{50} of .25mm. Complete pebble count data sheets can be found in Appendix C 4 : Reference Site Pebble Count Data.

6.3 Morphological Table

Based on the data collected, Rosgen parameters and ratios were generated for the REF-I and REF-2. Table 13 summarizes the key morphological values for both reaches.

Table 13 Morphological Table - Reference Reaches

	Parameter	Units	Ref. Reach 1		Ref. Reach 2	
General	Reach Name		REF-1		REF-2	
	Stream Type		E5		E5	
	Drainage Area	mi^2	0.43		2.28	
	Bankfull Discharge, Q_{BKF}	cfs	73		66	
	Bankfull Velocity, V_{BKF}	ft/s	3.1		4.1	
Dimension	Bankfull X-Sec. Area, A_{BKF}	ft^2	23.2		16.2	
	Bankfull Width, W_{BKF}	ft	15.0		9.2	
	Bankfull Mean Depth, D_{BKF}	ft	1.5		1.8	
	Width/Depth, W_{BKF} / D_{BKF}		9.7		5.2	
	Bankfull Max Depth, D_{MAX}	ft	2.0		1.9	
	D_{MAX} / D_{BKF}		1.3		1.1	
	W. Flood Prone Area, W_{FPA}	ft	26.1		200.0	
	Entrenchment, W_{FPA} / W_{BKF}		17		21.9	
	Bank Height Ratio, BHR		1.0		1.0	
	Parameter	Units	Min	Max	Min	Max
Pattern	Meander Length, L_M	ft	Nominal pattern in this portion of the Reference reach.		60	62
	M.L.Ratio, L_M / W_{BKF}				6.6	6.8
	Radius of Curvature , R_C	ft			15.0	29.0
	RC Ratio, R_C / W_{BKF}				1.6	3.2
	Belt Width, W_{BLT}	ft			24.0	34.0
	BW Ratio, W_{BLT} / W_{BKF}				2.6	3.7
Profile	L.Pool Spacing, L_{ps}	ft	86.91	106.4	25.0	69.0
	P.S.Ratio, L_{ps} / W_{BKF}		5.8	7.1	2.7	7.5
	Pool Width, W_p	ft	19.2	19.4	11.2	14.1
	P.W. Ratio, W_p / W_{BKF}		1.3	1.3	1.2	1.5
	Pool Depth, D_p	ft	2.2	2.5	1.6	1.6
	P.D. Ratio, Dp / D_{BKF}		1.50	1.70	0.92	0.92
	Valley Slope, S_{Val}		0.22%		0.56%	
	Channel Slope, S_{Ch}		0.22%		0.46%	
	Sinuosity, K		1.005		1.205	
	Pool Slope, S_P		0.03%		0.02%	
Substrate	D_{16} - Channel	mm	Silt/Clay		Silt/Clay	
	D_{50} - Channel	mm	0.25		1.0	
	D_{84} - Channel	mm	1.0		1.0	

6.4 Plant Communities

The reference site was found with a thin riparian buffer along each side, which consisted of forested vegetation approximately twenty (20) feet wide. Outside of that area was open mowed fields. The vegetation was thick and the stream was completely shaded. The vegetation was found to be relatively free of invasive species. The site was dominated by canopy trees with some midstory on the field edges and little herbaceous cover. The site was found to contain American elm (*Ulmus*

Americana), winged elm (Ulmus alata Michx.), sugarberry (Celtis laevigata Willd.), loblolly pine (*Pinus* taeda), red mulberry (*Morus* rubra), sycamore (Platanus occidentalis), black locust (Robinia pseudoacacia), black willow (*Salix* nigra), and silktree (Albizia julibrissin). The soil was characterized by a relatively high percentage of organic material in the upper surface.

6.5 Current Land Use/ Land Cover

This section describes the land use of the reference watershed for REF-I. The reference watershed is an urban watershed largely characterized by commercial and residential use (Appendix C-5: Reference Watershed Land Use/Land Cover Map and Table 14). Approximately 44% of the project watershed has a residential land use, roughly 32% is used for commercial purposes, and a little more than 17 % of the watershed is open space. Less than 10% of the space in the watershed is used for industrial sites.

Table 14 Watershed Land Use / Land Cover

Land Cover (REF-1)	% by area	Area (Acres)
Residential	44.4	120.3
Commercial	31.6	85.8
Open Space	17.4	47.2
Industrial	6.6	18.0
Totals	**100.0**	**271.2**

Table 15 shows a comparison of the project watershed to the reference watershed for REF-I. Both have nearly 40% commercial and 40% residential land usage. Open space or industrial sites comprise the remaining percentage of each watershed. Neither of these land uses exceeds 15% in either watershed.

Table 15 Comparison of Watershed Land Use / Land Cover

Project Watershed			Reference Watershed (REF-1)		
Land Cover	**%**	**Acres**	**Land Cover**	**%**	**Acres**
Commercial	39.4	100.9	Commercial	31.6	85.8
Residential	37.4	95.7	Residential	44.4	120.3
Industrial	14.0	35.8	Industrial	6.6	18.0
Open Space	9.2	23.7	Open Space	17.4	47.2
Totals	**100.0**	**256.0**	**Totals**	**100.0**	**271.2**

6.6 Soils

The reference watershed for REF-1 contains several soil mapping units, namely the Johns, Kalmia, Lumbee, Wickham, Norfolk, and Myatt (Appendix C-6: Reference Watershed Soils Map). Lakeland, Ruston, and Kenansville are also found in smaller amounts. Table 16 lists the soil mapping units and their corresponding percentage of the watershed area. The REF-I watershed soils are predominately sandy loams and to a lesser degree loamy sands (Table 17). Descriptions of the soil mapping units found in the largest percentages are provided below.

Table 16 REF-1 Watershed Soil Series

Soil Mapping Units	% of Watershed	Soil Mapping Units	% of Watershed
Johns	35.0	Norfolk	7.9
Kalmia	23.4	Myatt	6.8
Lumbee	11.4	Lakeland	2.7
Wickham	10.0	Ruston/Kenansville	<2

Johns Series
Like the Norfolk and Kalmia soils, Johns Series soils are found predominantly on broad, smooth terraces and short slopes and upland divides. Typically these soils are formed in stream sediments. Like the Norfolk and Kalmia soils, Johns Series soils are low in natural fertility and organic matter content. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. Most Johns soils are classified as sandy loams.

Kalmia Series
This series consists of poorly drained soils found on broad, smooth terraces and shallow drainageways. Infiltration is moderate and surface runoff is usually slow with most Kalmia soils. Kalmia soils are usually classified as loamy sands. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. These soils are usually formed in stream sediments

Lumbee Series
This series consists of poorly drained soils found on broad, smooth terraces and shallow drainageways. Like the Norfolk series they are also low in natural fertility and organic matter content. Lumbee soils are usually classified as sandy loams. This series has moderate permeability, medium water availability capacity, and their shrink swell capacity is usually low. These soils are usually formed in stream sediments.

Table 17 Watershed Soil Textures*

Soil Textures	% of Watershed
Sandy Loam	53.1
Loamy Sand	44.2

* The remaining 2.7% of the soils are classified as sand.

The soil series (Table 18) and the soil textures (Table 19) in the reference site compare well with those found in the project watershed. The soils are listed alphabetically for comparison purposes.

Table 18 Comparison of Watershed Soil Series

Project Watershed		Reference Watershed	
Soil Mapping Units	% of Watershed	Soil Mapping Units	% of Watershed
Johns	21.1	Johns	35.0
Kalmia	2.5	Kalmia	23.4
Lumbee	14.9	Lumbee	11.4
Norfolk	44.4	Norfolk	7.9
Wickham	11.2	Wickham	10.0
Other	6.0	Other	11.4

Both the project watershed and REF-1 watershed have sandy soils. The combination of sandy loams and loamy sands make up 96.7% of the project watershed and 97.3% of the REF-I watershed (Table 19).

Table 19 Comparison of Watershed Soil Textures

Project Watershed		Reference Watershed (REF-1)	
Soil Textures	% of Watershed	Soil Textures	% of Watershed
Loamy Sand	58.0	Sandy Loam	53.1
Sandy Loam	38.7	Loamy Sand	44.2
Loam	3.3	Sand	2.7

7 Natural Channel Design and Stream Restoration Plan

The proposed restoration will primarily include two (2) restoration approaches on the UTBFD. For the reach between the culvert and the UT, enhancement will include construction of a bankfull or near bankfull bench and bank grading to decrease bank slopes to a more stable configuration. From a point 80 feet upstream of the culvert to the upstream project limit; the approach will be a combination of Priority 2 and Priority 3 restoration to create a C5/E5 channel with overbank grading to establish a bankfull bench and floodprone area. A short reach, 335 feet, at the upstream project limit is constrained by a narrow easement width, and as a result the reach will have the design bankfull channel that is slightly incised based on the available floodprone area and resultant entrenchment ratio.

7.1 Design Considerations

The project site is located in an active urban apartment complex, and has a number of physical constraints that limit the design and restoration. Some of the most significant design considerations include: limited conservation easement (average width of 40 feet), proximity of existing infrastructure (buildings, recreational areas, etc), maintaining specified grade control points at stream crossings, the presence of multiple utilities that run along or cross the stream, and the preservation of large trees.

7.1.1 Infrastructure Constraints

The Goldsboro Housing Authority and EEP have agreed upon the establishment of a conservation easement that will protect the proposed stream and a limited portion of its riparian buffer zone. The riparian buffer zone is as shown on the plans and has a variable width from the stream banks along the length of the stream. In many areas it is not feasible to protect or restore any part of the riparian buffer zone. These are areas where the stream constraints require the use of the entire easement. The project stream flows through an active urban apartment complex and the maximum width of the easement is sixty five feet with an average of forty feet, so the space available to implement pattern in the stream and buffer zone is not feasible beyond what currently exists and what is required to accommodate adjustments due to utilities.

The proximity of buildings to the project guided the decision of whether to raise the stream to its existing floodplain or to lower the floodplain to the existing stream. The proposed natural channel design recommends the construction of a floodplain at the stream's current elevation in an effort to limit increases in water surface elevations.

7.1.2 Grade Control Points

The project stream has two types of stream crossings; pedestrian bridges and a culvert, where both are located along the upstream reach of UTBFD. As part of the design, GHA and EEP have requested that the culvert crossing be maintained in its existing state and that two pedestrian crossings along the stream be replaced. The culvert located along UTBFD under West Oak Street is a single barrel, 48-inch corrugated metal pipe. This culvert is to be maintained with the proposed natural channel design, which results in a grade control point that must be maintained in the proposed design.

There are three existing bridge locations along the upstream reach of UTBFD. The GHA and EEP have requested Dewberry to replace at least two (2) pedestrian crossing points along UTBFD as part of the natural channel design. Dewberry evaluated the feasibility of re-using the existing steel pedestrian bridges and determined that the length of the existing bridges was too short to re-use the bridges with the proposed restoration cross sections. Re-use of the existing bridges would limit the stream cross section through the bridge opening and increase flow velocity through the opening likely causing additional erosion potential. Table 20 summarizes slopes determined at each grade control location.

Table 20 Summary of Grades at Grade Control Points

Stream Reach	Upstream Slope (%)
Project Start (Pipe) to Bridge 1.	0.08
Bridge 1 to Bridge 2	0.30
Bridge 2 to U/S Invert of Culvert	0.58
D/S Invert of Culvert to End of Project (PIPE)	0.85

7.1.3 Utility Constraint.

Within the project area there are multiple utilities, including: electric, gas, water, telephone, cable television, storm water, sanitary sewer lines, and force mains. While utilities have been located as part of the Restoration Plan development, contractors will be responsible for verification of all utility information prior to construction. Each utility crossing has been considered in the development of the natural channel design, since they provide both vertical and spatial constraints. The location of the force main, gravity sewer line, and manholes were given additional review because they are all within protected easements and the cost to relocate these utilities would be prohibitive. In general conflicts with the utilities are being avoided where feasible by maintaining the current vertical and horizontal location of the stream thalweg. However, utility adjustments of minor utilities such as phone, cable television and gas will be required in limited areas. The contractor will be required to coordinate relocation of these utilities with appropriate utility companies.

7.1.4 Preservation of Large Trees

The stream has minimal tree stand along the project reach. It is the intent of this project to preserve existing large trees. The locations of trees along the project study reach have been surveyed, and the tree types and diameters have been noted. The size and location of trees are an important consideration in the development of the plan and profile of the natural channel design, particularly in areas where large trees are sparse along the reach. The proposed design will utilize root structure of the large trees as a part of the design to encourage stream stability of the proposed stream.

7.2 Proposed Stream Classification

The proposed UTBFD will have a C5/E5 classification. Flood prone areas will be graded to increase the entrenchment ratios until they exceed 2.2, resulting in a slightly entrenched classification. The design width to depth ratio is 12.7. The sinuosity will be increased by relocating the stream in two short reaches, but the pattern and pattern improvement is limited due to site constraints. The UT will not be modified as part of the project.

Sections 7.3 through 7.8 provide brief general discussion of the issues, analyses, and constraints that affected the proposed design. Detailed design values are presented in Table 21.

7.3 Rosgen Priority Level

Historically, the Housing Authority site was at a lower elevation, but the property was raised to build the housing complex. This has artificially raised the floodplain, resulting in incision and removing pattern.

To offset the incisions upstream of Oak Street, the proposed restoration will be a Priority Level 2/3 restoration with 46 percent as Priority 2 and 56 percent as Priority 3. Most of the proposed reach will be re-attached to the floodplain, by excavating the existing soil to the bankfull elevation. This will lower the bank height ratios and increase the entrenchment ratio. Priority 2 areas will include relocation of the stream.

The constraints noted herein limited the proposed stream design which minimized the restoration options, including changes to the stream length and stream sinuosity. The low grade along the stream also limited the length and slope that could be provided in the proposed design.

7.4 Bankfull Discharge

Manning's equation was used to develop the bankfull discharge for the project reaches. Typical existing cross sections were used to develop parameters used in the equation. Bankfull discharge values ranging from 73 to 81 cfs were established for UTFBD above Oak Street. Below Oak Street discharges increase to approximately 85 cfs.

North Carolina's coastal regional curves were considered during the development of bankfull flows. However, the supporting data set used to formulate the coastal curves is limited and does not yet include areas with greater than 10% impervious area. The project watersheds were determined to be over 35% impervious area, so the regional curves were not considered to be applicable for this site.

7.5 Dimension

The proposed cross-sectional dimensions were based on a combination of data collected from the project site and from the reference site. For reasons stated in section 7.4, the North Carolina's regional curves and dimensions measured at the reference sites were not used during the development of the proposed bankfull flows.

The cross-sectional shape for UTBFD has been designed with a more narrow width to depth ratio than the existing conditions. Channel banks are provided at 3:1 slopes, stabilized with erosion control matting and rip rap near existing utilities. In general decreased bank slopes will reduce BEHI scores and will help improve bank stability.

7.6 Pattern

The pattern predominantly matches the existing stream geometry except in two reaches. Some of the most significant design constraints include: proximity of existing infrastructure (buildings, recreational areas, etc), maintaining specified grade control points at stream crossings, the presence of utilities along and crossing the stream, and the preservation of large trees.

7.7 Profile

The existing and proposed profiles for the UTBFD are constrained by several grade control points including: stormwater outfall pipes along the reach, the culvert under W. Oak Street, and the culvert under US 13-117. The project does not include relocation of the outfalls and culverts, so the proposed channel inverts are consistent with the existing channel inverts. To the extent possible, existing riffle and pool features will be maintained. The large number of site constraints prohibits construction of additional features.

7.8 Morphological Table

A Rosgen Level 1 through 4 analyses was completed on the UTBFD, the UT, and the reference reaches. Sections 3 through 6 of this report summarize this data, and also detail the results of the four levels of investigation for each of the stream reaches.

Using the data collected in Sections 1 through 5, Rosgen parameters and ratios were generated for the reference reaches, and the UTBFD. Table 21 summarizes the key morphological values for the reference reaches, the UTBFD, and the proposed or design values for the UTBFD. The values in the table include the channel dimension, pattern, and profile data for both the existing conditions and the proposed design.

Table 21 Morphological Table - Comprehensive

	Parameter	Units	Ref. Reach 1		Ref. Reach 2		Existing		Proposed	
General	Reach Name		REF-1		REF-2		UTBFD U/S of Oak St.		UTBFD U/S of Oak St.	
General	Stream Type		E5		E5		F5		C5/E5	
General	Drainage Area	mi^2	0.43		2.28		0.08		0.08	
General	Bankfull Discharge, Q_{BKF}	cfs	73		66		73		73	
General	Bankfull Velocity, V_{BKF}	ft/s	3.1		4.1		*		3.0	
Dimension	Bankfull X-Sec. Area, A_{BKF}	ft^2	23.2		16.2		6.1		24.2	
Dimension	Bankfull Width, W_{BKF}	ft	15.0		9.2		11.2		17.5	
Dimension	Bankfull Mean Depth, D_{BKF}	ft	1.5		1.8		0.6		1.4	
Dimension	Width/Depth, W_{BKF} / D_{BKF}		9.7		5.2		21.5		12.7	
Dimension	Bankfull Max Depth, D_{MAX}	ft	2.0		1.9		1.2		2.3	
Dimension	D_{MAX} / D_{BKF}		1.3		1.1		2.2		1.6	
Dimension	W. Flood Prone Area, W_{FPA}	ft	26.1		200		17.5		40.0+	
Dimension	Entrenchment Ratio, W_{FPA} / W_{BKF}		1.7		21.9		1.5		2.3+	
Dimension	Bank Height Ratio, BHR		1.0		1.0		2.4		1.0	
	Parameter	Units	Min	Max	Min	Max	Min	Max	Min	Max
Pattern	Meander Length, L_M	ft	Nominal pattern in this portion of the Reference Reach.		60	62	75	646	Nominal pattern in this portion of the Reference Reach.	
Pattern	M.L.Ratio, L_M / W_{BKF}				6.6	6.8	6.9	59.4		
Pattern	Radius of Curvature, R_C	ft			15.0	29.0	2.7	103.1		
Pattern	RC Ratio, R_C / W_{BKF}				1.6	3.2	0.3	9.5		
Pattern	Belt Width, W_{BLT}	ft			24.0	34.0	5	86		
Pattern	BW Ratio, W_{BLT} / W_{BKF}				2.6	3.7	0.5	7.9		
Profile	L.Pool Spacing, L_{ps}	ft	86.9	106.4	25.0	69.0	49.5	346.9	86.9	106.4
Profile	P.S.Ratio, L_{ps} / W_{BKF}		5.8	7.1	2.7	7.5	4.5	31.9	4.9	6.0
Profile	Pool Width, W_p	ft	19.2	19.4	11.2	14.1	8.2	18.5	12.3	15.8
Profile	P.W. Ratio, W_p / W_{BKF}		1.3	1.3	1.2	1.5	0.7	1.7	0.7	0.9
Profile	Pool Depth, D_p	ft	2.2	2.5	1.6	1.6	0.6	1.0	2.5	2.9
Profile	P.D. Ratio, Dp / D_{BKF}		1.42	1.61	0.92	0.92	0.06	0.09	1.8	2.1
Profile	Valley Slope, Sval		0.217%		0.557%		0.46%		0.40%	
Profile	Channel Slope, S_{ch}		0.216%		0.462%		0.43%		0.38%	
Profile	Sinuosity, K		1.005		1.21		1.11		1.10	
Profile	Pool Slope, S_P		0.03%		0.02%		0.07%		0.02%	
Substrate	D_{16} - Channel	mm	Silt/Clay		Silt/Clay		Silt/Clay		Silt/Clay	
Substrate	D_{50} - Channel	mm	0.25		1.0		0.50		0.50	
Substrate	D_{84} - Channel	mm	1.0		1.0		5.7		5.7	

* - Values presented are for the scour lines observed during survey, but are not for bankfull data and are included for informational purposes only. The information provided is for discharge events less than bankfull and are shown to indicate entrenchment of the observed data and indicate overall channel instability.

7.9 Sediment Transport Analysis

Channel bed and bank materials influence many stream characteristics, including the cross-sectional form, plan-view, and longitudinal profile. They also determine the extent of sediment transport and provide the means of resistance to hydraulic stress (Rosgen, 1996). The term "channel materials" refers primarily to the surface particles that make up both the bed and banks within the bankfull channel. Typically, streams will have coarser material comprising the stream bed, which is referred to as pavement. Finer particles, sub-pavement, are normally found under the pavement. The sub-pavement is indicative of the range of sizes of sediment that are likely to be mobilized when stream flows are approaching or are at bankfull discharge levels (Rosgen, 1996).

The pebble count method was used for field determination of the particle size distribution of channel materials (Rosgen 1996). Pebble counts were sampled by Dewberry in riffle sections for the UTFBD. Pebble count data has been analyzed by Dewberry to determine the median size of bed sediment, D_{50}, for the upstream section of the UTFBD (upstream of confluence with the UT), the downstream section of the UTFBD (downstream of confluence with the UT), and the entire study reach of the UTFBD. This data is presented in Table 22.

Table 22 Summary of Pebble Count Analysis

Stud Reach	D_{50} (mm)
UTFBD, u stream section	
UTFBD, entire reach	

Based on this analysis, the stream bed is comprised of medium sand for the UTFBD.

In addition to pebble counts, a pavementlsub-pavement core was taken at the downstream section of the UTBFD, just downstream of the confluence with the UT. Field inspection of the pavement, sub-pavement, and the material below the sub-pavement revealed nearly homogeneous soils for a depth much greater than that of the sub-pavement. Sieve analysis (completed by Froehling & Robertson, Inc.,) was performed on this sample and is summarized in Table **23.**

Table 23 Summary of Pavement/Sub-pavement sample for UTFBD

Sample	D_{50} (mm)
Pavement	0.89
Sub pavement	0.87

The study streams for this project have sand beds, so some of the more common sediment transport analysis equations, including the Shields equation, are not suitable for this stream.

The Blench Regime Formula has been selected to use for sediment transport analysis for the study reach. This formula is intended to apply only to sand bed streams that are in equilibrium and have dune-covered beds (Vanoni, 1977). The study reach is characterized by sand bed throughout, thus this formula has been selected as a tool to calculate sediment transport.

The Blench Regime Formula is cited in Vanoni (1977) as equation **2.232.**

$$\frac{(1+0.12\times10^5\,(C_m/\gamma))^{11/12}}{1+(1/233\times10^5)(C_m/\gamma)} = \frac{3.63\,g\,b^{1/4}q^{1/12}S}{k_m\upsilon^{1/4}[1.9(d_{50,\,mm})^{0.5}]^{11/12}}$$

in which C_m= sediment discharge concentration, in pounds per cubic foot; $d_{50,\,mm}$= median size of bed sediment, in millimeters; b = width of stream, in feet; k_m =a meander coefficient with values of 1.25 for straight reaches, 2.0 for streams with well-developed meanders, and 2.75 for very sinuous streams, g = gravity in ft/s^2, q = water discharge, in cubic feet per second per foot of width; υ = kinematic viscosity in ft^2/s; and γ = specific weight of water in pounds per cubic foot. The Blench Regime Formula for sand bed streams can be used to calculate sediment discharge concentration, C_m.

To maintain that the proposed stream has similar sediment transport capability as the existing stream, the proposed stream's sediment discharge concentration ($C_{m,\ proposed}$) must be equal to the existing sediment discharge concentration ($C_{m,\ existing}$). The sediment discharge concentration is the only variable, so the left side of the equation will be equal for the existing and proposed conditions. Therefore, the right side of the equation must be equal for the existing and proposed equations. All variables for the existing condition are known, and we can solve for the median size of bed sediment transported in the proposed condition.

Existing Condition **Prowsed Condition**

$$\frac{3.63\,g\,b^{1/4}q^{1/12}S}{k_m\upsilon^{1/4}[1.9(d_{50,\,mm})^{0.5}]^{11/12}} = \frac{3.63\,g\,b^{1/4}q^{1/12}S}{k_m\upsilon^{1/4}[1.9(d_{50,\,mm})^{0.5}]^{11/12}}$$

Table 24 below summarizes the equation variables:

Table 24 Summary of Sediment Transport Equation Variables

Variable	Existing Value	Proposed Value	Unit
D_{50}	0.87	**0.781**	mm
b	11.2	17.5	ft
k_m	1.25	1.25	
γ	62.4	62.4	Lb/ft^3
q	6.52	4.17	$Ft^3/s/ft$
S	0.0043	0.0038	Ft/ft
v	1.217E-05	1.217E-05	Ft^2/s
g	32.2	32.2	Ft/s^2

Solving the equation for D_{50} in the proposed condition, D_{50} equals 0.781 mm. The median size of sediment in transport for the proposed condition is similar to the existing size for sediment in transport for the existing stream; the proposed stream should be adequately sized to transport similar sized sediment.

8 TYPICAL DRAWINGS

8.1 Typical Cross-Sections

The proposed cross-sections will modify the UTBFD to a stream with a C5/E5 Rosgen stream that is reattached to the floodplain. The proposed cross-sections have a bankfull cross-sectional area of approximately 24.2 square feet, a bankfull width of 17.5 feet, a bankfull maximum depth of 2.25 feet, and a bankfull mean depth of 1.4 feet. The width to depth ratio is approximately 12.7 and the entrenchment ratio will modified to greater than 2.2. The typical section is shown in the provided plan set in Sheets 24 and 25.

8.2 Structures

Natural stream design structures will not be used for this restoration due to constraints noted previously.

Two woad bridges built on concrete abutments have been designed to span the constructed stream. The bridges will be built so that the low chord of the bridge sits above the floodplain bench, and will transition back to grade based on ADA requirements. Structural drawings can be viewed in Sheet 30 in the provided plan set.

8.3 Channel Plugs

Channel plugs will be necessary for the locations where the new channel leaves the old channel. Permanent erosion control matting will be used in place of root wads in high velocity areas due to conservation easement and utility constraints.

9 CONSTRUCTED WETLAND DESIGN

9.1 Stormwater Best Management Practice Selection

The EEP has expressed an interest in constructing a best management practice (BMP) capable of reducing nitrogen since the submission of the original Conceptual Plan (submitted July 6,2004). Through investigation of the site and its limitations, it has been decided that a constructed wetland will provide the greatest amount of nitrogen reduction potential based on area available for use (presented in Amended Concept Plan submitted January 28,2005).

Pocket wetlands offer characteristics that make them the most favorable nitrogen reduction BMP application for this project site. Pocket wetlands that are designed following the recommended design guidance offer the most nitrogen reducing credit; reducing the nitrogen load by 40%. This will provide the most efficient BMP for removing nitrogen at this site. In addition, constructed wetlands are shallower in nature, providing a safer environment (when compared to wet detention ponds with large areas of open water) for the residents and children of the GHA.

9.2 Constructed Wetland Description

The proposed wetland will be located on property owned by the NC Department of Transportation, and receive flow from the UT to the UTBFD. The UT is a jurisdictional stream, and regulatory agencies typically will not permit treatment facilities, such as BMP's, to be located on-line with the jurisdictional stream. Consequently, this BMP will be located off-line from the contributing drainage area and will rely on an inflow weir from the channel bank of the UT to provide flow into the BMP. The inflow weir will be located above the bankfull elevation, such that the base flow for the jurisdictional stream will not be diverted into the BMP, but only excess flow during storm events will be diverted. This BMP cannot be designed in full compliance with the Design Guidelines for BMP's established by NCDENR (on-line). Therefore, the nitrogen load reduction can only be estimated as a portion of the total potential removal of an on-line BMP.

The drainage area to the UT is approximately 125 acres with approximately 50 acres of imperviousness. The existing Nitrogen load to the UT at the location of the BMP is approximately 1229 lb/yr. It is anticipated that the BMP will receive flow during several storm events each year, as the typical one inch storm event and the one year design storm are expected to overtop the weir by 1.8 or 2.7 feet, respectively.

9.3 Design Parameters

The proposed wetland design follows the guidelines provided by NCDENR to establish characteristic features such as Low Marsh, High Marsh and Open Water sedimentation forebays. Certain guidelines were modified such as flow regime and percentage of area dedicated to each marsh type due to site constraints. The completed design based on NCDENR guidance is provided in Appendix D-2: Supporting Wetland Design and Nitrogen Load Calculations.

9.4 Control Structure Evaluation

The design of the inflow and outflow control structures for the wetland was evaluated based on a series of flow calculations. These include the 1-inch flow, estimated base flow and 2-yr flow for the UT. These flows and corresponding water surface elevations were used to establish the appropriate inflow elevation from the UT that would comply with DWQ requirements. Further these flows and the seasonal high groundwater elevations were used to establish the normal pool and treatment elevations of the wetland. The final design inflow elevation is 69.5 NAVD which is also the normal pool of the wetland. The supporting calculations for the flows and elevations can be found in Appendix D-3: Supporting Wetland Inflow Calculations.

An evaluation of flow control devices was also performed at the request of EEP. The following table summarizes the factors considered for each device:

Table 25 Flow Control Device Evaluation Summary

Device	**Relative** Cast	Limitations	Benefits
Concrete Riser	High	1. Requires placement of concrete or within stream buffer if cast-in-place 2. Requires the use of heavy equipment to install as pre-cast 3. Fixed control elevation	1. Low maintenance 2. 100 yr life cycle
CMP Flashboard Riser	Moderate	1. Requires excavation within stream 2. Limited life cycle (50 yrs)	1. Installation by hand or small equipment 2. Easily adjustable control elevation
Concrete Weir	High	1. Requires placement of concrete or within stream buffer if cast-in-place 2. Requires the use of heavy equipment to install as pre-cast 3. Fixed control elevation 4. No backflow control	1. Low maintenance 2. 100 yr life cycle
Stabilized Berm Overflow	Low	1. No backflow control 2. Fixed control elevation	1. Low maintenance 2. Unlimited life cycle 3. Installation by hand or small equipment
Rubber "duckbill" backflow preventer	High	1. Cost	1. Low maintenance 2. 50 Yr life cycle 3. Installation by hand or small equipment
Aluminum Flap Gate	Low	1. High maintenance 2. Can fail to shut or open if not maintained 3. 5-10 yr life cycle	1. Installation by hand or small equipment

Based on the information provided above Dewberry recommends the use of CMP flashboard risers for both structures with a rubber "duckbill" backflow preventer on the inflow structure.

9.5 Maintenance Recommendations

Constructed wetlands require periodic maintenance. This is due to design intent to retain portions of the storm flow for removal of Nitrogen. This function also results in the settling of solids from the water column in the quiescent pool of the wetland. In order to limit the impact to the wetland from maintenance a **forebay,** or deep settling pool of open water is incorporated in the wetland design. The majority of the large particle settling will take place in this area limiting distribution of sediments into the rest of the wetland.

Since the base flow will not be treated in the proposed BMP for this site the amount of sediments trapped should be less than normally expected. It is recommended that-the forebay be monitored for depth annually and the wetland visually inspected for sedimentation deposits. A reduction of 30% of the depth of the forebay or more indicates the need for maintenance. This can be accomplished by manual or mechanical removal of the accumulated sediments from the forebay. Further if sedimentation deposits are observed within the wetland these should also be removed manually taking if possible. If the quantity of sediments in the wetland is not feasible to be removed by hand mechanical equipment can be used. However, care should be taken to minimize the disturbance of the vegetation where possible. It is anticipated that periodic maintenance of the BMP will be required on a 10 year cycle.

10 PLANTING PLAN

10.1 Riparian Buffer

As part of the stream restoration, the project will include the restoration and repair of the riparian buffer along the project reach. Within the project reach, the riparian buffer is in need of varying levels of restoration ranging from complete restoration to augmentation.

The riparian buffer augmentation and restoration will extend out from the stream channel to the limits of the easement boundary. Three zones of planting were established based on hydrologic regime. The first zone is the bench, an engineered levee beginning at the edges of the thalweg and within the main channel. Zone One (1) is designed to receive the bankfull flood. Zone Two (2) is the slope from the bench to the top of the greater channel. Zone Two will receive less frequent flooding than Zone One. The third zone extends from the top of the slope to the limits of the easement. Zone Three is within the 100-year floodplain of the stream.

Zones One and Two will be planted with a density of 400 woody saplings per acre and 10,000 herbaceous plants per acre. The plants to be planted in these Zones are hydrophytic and flood-tolerant. Zone Three will be planted with herbaceous plants and six (6) specimen trees.

The buffer will be planted with a seed mix of native permanent grasses, graminoids and woody plant seed. The seed mix is a combination of hardy cool and warm season grasses designed to create a stable and durable riparian zone. In conjunction with the permanent seeding, a temporary seed mix of annual grasses will be applied for immediate erosion control purposes.

Table 26 Stream Channel and Riparian Zone Plantings (entire easement area except BMP)

PLANT SCHEDULE: Zones 1,2 and 3					
Scientific Name *	**Common Name**	**Spacing (ft) On-Center**	**Minimum Stock**	**Zone**	**Distribution**
TREES AND SHRUBS					
Sambucus canadensis	Elderberry	2'	Live stake or tubeling	1 or 2	Random mix
Salix nigra	Black Willow	2'	Live stake or tubeling	1 or 2	Random mix
Salix caroliniana	Swamp Willow	2'	Live stake or tubeling	1 or 2	Random mix
Cornus amomum	Silky Dogwood	2'	Live stake or tubeling	1 or 2	Random mix
Platanus occidentalis	Sycamore	2'	Live stake or tubeling	1 or 2	Random mix
Betula nigra	River Birch	2'	Live stake or tubeling	1 or 2	Random mix
Myrica cerifera	Wax Myrtle	2'	Live stake or tubeling	1 or 2	Random mix
Liquidambar styraciflua	Sweet Gum	2'	Live stake or tubeling	1 or 2	Random mix
Alnus serrulata	Alder	2'	Live stake or tubeling	1 or 2	Random mix
Lindera benzoin	Spicebush	2'	Live stake or tubeling	1 or 2	Random mix

PLANT SCHEDULE: Zones 1, 2 and 3					
Scientific Name *	**Common Name**	**Spacing (ft) On-Center**	**Minimum Stock**	**Zone**	**Distribution**
HERBACEOUS					
Asclepias incarnata	Swamp milkweed	2'	Plug	1 or 2	Random mix
Carex vulpinoidea	Fox Sedge	2'	Plug	1 or 2	Random mix
Carex stricta	Tussock Sedge	2'	Plug	1 or 2	Random mix
Iris virginica	Southern Blueflag	2'	Plug	2	Random mix
Scirpus fluviatilis	River Bulrush	2'	Plug	1 or 2	Random mix
Sparganium americanum	Eastern Burreed	2'	Plug	1 or 2	Random mix
Lobelia cardinalis	Cardinal Flower	2'	1 quart pot	2	Random mix
Mertensia virginica	Bluebells	2'	Plug	2 or 3	Random mix
Saururus cernuus	Lizard's Tail	2'	Plug	1 or 2	Random mix
Zizania aquatica	Wild Rice	2'	Plug	1 or 2	Random mix
Eupatorium perfoliatum	Perforated Boneset	2'	Plug	1 or 2	Random mix
Scirpus atrovirens	Green Bulrush	2'	Plug	1 or 2	Random mix
Vernonia noveboracensis	New York Ironweed	2'	Plug	2 or 3	Random mix
Vernonia gigantea	Giant Ironweed	2'	Plug	2 or 3	Random mix
Panicum virgatum	Panicgrass	2'	Plug	2 or 3	Random mix
Penstemon laevigatus	Beardtongue	2'	Plug	3	Random mix
Baptista alba (B. lactea)	Wild White Indigo	2'	Plug	3	Random mix
Phlox caroliniana	Wild Blue Phlox	2'	Plug	3	Random mix
Rudbeckia hirta	Blackeyed Susan	2'	Plug	3	Random mix
Cimicifuga racemosa	Black Cohosh	2'	Plug	3	Random mix
Monarda fistulosa	Bergamot	2'	Plug	3	Random mix
Coreopsis tinctoria	Tickseed	2'	Plug	3	Random mix
		2'			

* A minimum of six (6) of the scheduled species per zone must be planted. Within each zone the plant species are not to be clumped, but randomly mixed. Minimum density of 400 trees and shrubs per acre and 10,000 herbaceous plants per acre.

PLANT SCHEDULE: Zone 3					
Scientific Name **	**Common Name**	**Minimum Stock**	**Minimum Caliper**	**Zone**	**Distribution**
SPECIMEN TREES					
Quercus phellos	Willow Oak	B&B	2"	3	Where noted
Ilex opaca	American Holly	B&B	2"	3	Where noted
Betula nigra	River Birch	B&B	2"	3	Where noted
Platanus occidentalis	Sycamore	B&B	2"	3	Where noted
Juniperus virginiana	Red Cedar	B&B	2"	3	Where noted

**A minimum of three (3) of the scheduled species per zone must be planted.

PLANT SCHEDULE: Permanent Seed Mix for Zones one (1) and two (2)	
Scientific Name	**Common Name**
Elymus virginicus	Virginia Rye
Elymus canadensis	Wild Rye
Chasmanthium latifolium	River Oats
Elymus hystrix (Hystrix patula)	Bottlebrush Grass
Dichanthelium commutatum	Variable Witchgrass
Schizachynium scoparium	Little Bluestem
Andropogon virginicus	Broomsedge
Andropogon gerardii	Big Bluestem
Panicum virgatum	Switchgrass
Lobelia cardinalis	Cardinal Flower
Erianthus giganteus	Plume Grass
Rhus glabra	Smooth Sumac
Sambucus canadensis	Elderberry
Cornus amomum	Silky Dogwood
Betula nigra	River Birch
Platanus occidentalis	Sycamore

Seed mix is applied to all disturbed areas.

10.2 Riparian Vegetation

Within the planted buffer, species survival will be determined by vegetative plots established at the completion of construction. Species density and survival will be documented, along with species not installed during the buffer planting.

10.3 Constructed Wetland BMP Vegetation

As part of this project, a constructed wetland will be constructed to treat stormwater flowing from a very urbanized watershed. In order to obtain maximum benefit of the treatment effects of the constructed wetland, a group of plants will need to be planted that are adapted to shallow water conditions as well as to deeper infrequent flood conditions.

In order to provide the correct plants for the constructed wetland, the BMP area was broken down into three (3) planting zones. These three (3) zones are Low Marsh (LM), High Marsh (HM), and Buffer (Bf). The low marsh zone will be those areas of the constructed wetland with a permanent water depth of 6 to 12 inches. The high marsh zone will be those areas of the constructed wetland with a permanent water depth of 0 to 6 inches. The buffer zone will be all those areas of the constructed wetland above the permanent pool water elevation.

The buffer zone will also include the maintenance corridor along the perimeter of the constructed wetland BMP. The plants, such as switchgrass, can readily handle intermittent vehicle traffic and even can be covered by additional soil/sediment and quickly recover. However, this area should not be mowed regularly as this would be detrimental to these species.

Table 27 Planting Zones and Plant Species List for the Constructed Wetland BMP

Low Marsh (LM): 6 to 12 inches below normal pool

Scientific Name	Common Name	Layer	Spacing (ft) On-Center	Plant Size	Distribution
Schoenoplectus tabemaemontani or Scirpus validus	Softstem Bulrush	Herb	2x2	Plug	Large Mass
Pontederia cordata	Pickerel Weed	Herb	2x2	Plug	Large Mass
Zizaniopsis miliacea	Giant Rice Cutgrass	Herb	2x2	Plug	Large Mass

High Marsh (HM): 0 to 6 inches below normal pool

Scientific Name	Common Name	Layer	Spacing (ft) On-Center	Plant Size	Distribution
Iris virginica	Blue Flag Iris	Herb	2x2	Plug	Large Mass
Juncus spp.	Rush	Herb	2x2	Plug	Large Mass
Peltandra virginica	Arrow arum	Herb	2x2	Plug	Large Mass
Pontederia cordata	Pickerel Weed	Herb	2x2	Plug	Large Mass
Sagittaria latifolia	Duck Potato	Herb	2x2	Plug	Large Mass
Saururus cernuus	Lizard's Tail	Herb	2x2	Plug	Large Mass
Schoenoplectus tabernaemontani or Scirpus validus	Softstem Bulrush	Herb	2x2	Plug	Large Mass

Buffer (Bf): All Areas Above Normal Pool

Scientific Name	Common Name	Layer	Plant Sue	Distribution
Permanent Seeding				
Panicum virgatum	Switchgrass	Herb	Seed	Broadcast Mix
Juncus effusus	Soft Rush	Herb	Seed	Broadcast Mix
Elymus virginicus	Virginia Wild Rye	Herb	Seed	Broadcast Mix
Temporary Erosion Seeding				
Lolium multiflorum	Annual Ryegrass	Herb	Seed	Broadcast Mix
Setaria italica	German Millet	Herb	Seed	Broadcast Mix

10.4 Constructed Wetland BMP Vegetation Monitoring

Within the constructed wetland BMP, plant survival will be determined by vegetative plots established at the completion of construction. Plant coverage and health will be documented, along with any other noted issues during the monitoring visit.

11 STREAM MONITORING PLAN

11.1 Cross-Sectional and Longitudinal Geomorphology

Following construction, the restored or enhanced section of the UTBFD will be resurveyed longitudinally and at permanently established cross-sections. Photo points will also be established for future visits. One year following construction, the restored or enhanced sections of the UTBFD will be resurveyed longitudinally and at the permanent cross-sections. Photographs will again be taken. The stability of the channel will be assessed by comparing this survey to the as-built survey and the survey of the permanent cross-sections. Monitoring will be performed in accordance with the latest monitoring protocol and format template.

12 Stream Success Criteria

12.1 Monitoring Report

The results of the channel survey and vegetative surveys will be summarized in a post-construction monitoring report and presented along with photographs to EEP. The first annual monitoring report will be completed by Dewberry and delivered to EEP one year after construction. Additional long-term monitoring will be the responsibility of the NC Ecosystem Enhancement Program. Monitoring will be performed in accordance with the latest monitoring protocol and format template.

13 CONSTRUCTION SEQUENCING

The general sequence of construction will proceed from upstream to downstream and is described in general terms below. Variance from the construction sequence as shown on the construction plan and specifications will need prior approval from the engineer of record.

13.1 Prior to Construction

Prior to construction, a pre-construction meeting will be held. Following this meeting, and prior to staking, the contractor will coordinate with the landowner and engineer to locate suitable staging areas. The contractor will stake the stream alignment, mark the limits of grading and clearing, and mark the Limits of Disturbance (LOD). The contractor will then install tree protection measures.

Sediment control devices and runoff control measures will be installed. Following inspection of protective measures, all vegetation marked for removal will be removed. The staging, entry, and access routes will be cleared and then constructed.

13.2 During Construction

Each days work will be limited to the amount of work that can be completed and protected with permanent or temporary measures before the work day's end. Sediment and erosion control measures will be inspected and repaired/adjusted daily.

The stream channel will be protected from construction by diverting the natural flow opposite the bank that is under construction. Techniques to divert stream flow may include, but are not limited to: (1) edging with sandbags, (2) conveying water with corrugated metal pipe or corrugated plastic, or (3) bypass water by pump around.

Topsoil will be stripped and stockpiled to be placed over fill as needed. The channel will be excavated, and in-stream structures will be installed. The structures will be surveyed and stream banks will receive final grading to design cross-sectional shape. The channel cross-section will be surveyed and modified as needed.

Finished slopes will be stabilized with coir matting and the area will be temporarily or permanently seeded according to the plans and specifications.

All land disturbance activities associated with the restoration are to be in accordance to the NC Erosion and Sediment Control Planning and Design Manual and the NC Erosion and Sediment Control Field Manual. Sediment and erosion control measures will be shown in detail on the construction plans and a sediment and erosion control plan will be submitted to the NC Division of Land Quality for permitting when construction plans are completed. Section 13.3 provides a general overview of several important sediment and erosion control issues for this restoration.

13.3 Sediment and Erosion Control

Sediment and erosion control measures to be used may include, but are not limited to, diversion ditches, sediment basins, check dams, outlet protection, tree protection fencing, silt fencing, temporary seeding, mulching, and erosion control blankets. Work will be limited to the length of stream that can be constructed and stabilized before the end of the work day. All sediment and erosion control measures will be inspected daily and following storm events, and will be adjusted and/or repaired as needed.

13.3.1 , Tree Protection

The site contains a large number of mature overstory trees. Tree preservation and protection measures will be used to prevent damage to designated trees. Grading around trees that remain in place will be done to minimize soil compaction over the roots.

13.3.2 Erosion Control Features

Silt fencing will be used where necessary to control sediment transport and to protect exposed and steep grades. Additional protection will be required for denuded areas that are not at final grade within seven days, and from any slope that seeps water from the slope face.

Sediment basins and traps, perimeter dikes, sediment barriers and other measures shall be constructed as a first step in any land disturbing activity and will be made functional before upslope land disturbance takes place. Stockpiles will be stabilized or protected with sediment trapping measures.

13.3.3 Temporarily Impacted Areas

Temporary stream crossings may be required for this project. These crossing will be restored prior to the completion of the project.

When stream reaches require dewatering, a pump around detail must be provided to the engineer for review prior to installation.

All disturbed areas above normal water level will receive temporary stabilization with vegetation and/or mulch, weed free straw, hydro-mulch, cover crop, erosion control blanket, or similar. A suitable temporary seed mixture will be provided on the construction plans. Silt fence will be used as needed in addition to temporary seeding.

Temporary accesses, storage, and staging areas are to be restored to preconstruction conditions. The soil will be restored to alleviate compaction. Exposed areas will be stabilized in a manner similar to disturbed areas described above. Where vehicle access intersects paved public roads, provisions shall be made to minimize transport of sediment by vehicular traffic. When sediment is transported to paved surfaces, the surface shall be cleaned thoroughly at the end of each day. Washing will not be allowed until the surface has been shoveled or swept and sediment disposed in a sediment control area.

All temporary sediment and erosion control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed. Trapped sediment and disturbed soil areas resulting from the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.

13.4 Following Construction

All temporary erosion and control measures will be removed within 30 days after final site inspection.

An as-built survey and as-built plans will be performed and prepared by the contractor to ensure that the location and elevation of the alignment and in-stream structures are in good agreement with the design plans.

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Appendices