FINAL

Restoration Plan

North Muddy Creek Site

McDowell and Burke Counties, North Carolina
RFP No. 16-D06115

Prepared for:

NCDENR-Ecosystem Enhancement Program
1652 Mail Service Center
Raleigh, North Carolina 27699-1652

Submitted by:

Environmental Banc & Exchange

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Prepared by:

Kimley-Horn and Associates, Inc.
4651 Charlotte Park Drive, Suite 300
Charlotte, NC 28217

Phone Number:	(704) 333-5131
Fax Number:	(704) 333-0845
Project Manager:	William R. Wilhelm, P.E.

Submitted by:

Environmental Banc & Exchange
909 Capability Drive, Suite 3100
Raleigh, NC 27606

Phone Number:	(919) 829-9909
Fax Number:	(919) 829-9913
Project Manager:	Norton Webster, PWS

Executive Summary

Site Description

The North Muddy Creek site, hereafter referred to as the "site," consists of three separate project areas. The first Unnamed Tributary 1 (UT1) is located just north of Interstate 40 on the McDowell and Burke County line. Unnamed Tributary 5 (UT5) and Unnamed Tributary 6 (UT6) are both located south of Interstate 40 in McDowell County. The project site is located in the USGS Hydrologic Unit Code 03050101040020, and the project stream is located in the Catawba River Basin and NCDWQ 03-08-30 sub-basin.

In response to RFP 16-D06115, the site was proposed by Environmental Banc and Exchange (EBX) and accepted by the North Carolina Division of Natural Resources (NCDENR) to provide stream mitigation in the Catawba 03-08-30 Basin.

Muddy Creek is listed in a North Carolina Ecosystem Enhancement Program (NCEEP) targeted local watershed but is not a 303d-listed stream. Part of the site currently is being used for cattle grazing and timber production, while a portion remains undisturbed forest. Most of the project reaches appear to have been historically straightened, and the cattle have open access to most of the streams. There is little or no woody riparian buffer located within project reaches.

Restoration Project Goals and Objectives

The goals of the restoration project are to improve water quality, function, and habitat by:

- Removing excess nutrients and sediment through the use of vegetative buffers
- Increasing dissolved oxygen concentrations through the use of in-stream structures and the turbulence they produce in pools
- Stabilizing the stream bank using natural channel design techniques
- Improving substrate through the use of structures and the elimination of major sediment sources from the stream
- Creating habitat diversity by introducing woody structures such as log vanes and/or root wads
- Reducing temperature by restoring canopy in the buffer areas
- Reconnecting streams to their adjacent floodplains and wetlands
- Raising groundwater levels in adjacent streams by raising adjacent channel bed elevation
- Removing/plugging ditches used to drain historic wetlands
- Creating micro-topography by regrading and ripping wetlands
- Breaking up historically compacted soils by cattle to allow the groundwater to come to the surface and wetland vegetation to flourish
- Improving crossings by replacing pipes and/or stabilizing outfalls
- Controlling the invasive exotics by removing them during construction

- Preserving stable on-site streams, wetlands, and riparian buffers draining into the enhancement/restoration reaches
- Excluding livestock through fencing
- Re-vegetating the stream banks, wetlands, and riparian area to improve bio-diversity and ecology

The pattern, profile, and dimension of the channel will be adjusted to approximately match Regional Curve values and to mimic reference reach conditions. Structures such as rock cross vanes, a-vanes, rock vanes, log sills, log vanes, and root wads will be used to provide grade control, added habitat, and/or bedform diversity. On-site wetlands will be restored and enhanced to Piedmont/Mountain Bottomland Forest wetlands as described by Schafale and Weakley.

Table 1: Stream Restoration Summary

Restoration Type	Existing Linear Footage	Designed Linear Footage
Stream Restoration	3,695	4,267
Stream Enhancement	673	673
Stream Preservation	2,039	2,039

Table 2: Wetland Restoration Summary

Restoration Type	Existing Acreage	Designed Acreage
Riverine Wetland Restoration	0.0	9.0
Riverine Wetland Enhancement	0.0	1.6
Riverine Wetland Preservation	6.2	6.2
Non Riverine Wetland Restoration	0.0	1.0

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Report Tables

10.0 Restoration Tables

1.0 Project Site Identification and Location

1.1 Directions to Project Site

UT1: Follow I-40 West toward Marion, take exit 94, and take a right onto Dysartville Road. Turn left onto Hwy 70, travel approximately 1 mile west, and turn left onto Seals Road. Follow the dirt road for approximately 0.5 miles.

UT5: Follow I-40 West toward Marion, take exit 94, and take a right onto Dysartville Road. Turn left onto Hwy 70, travel approximately 1 mile west, and turn left onto Muddy Creek Road. Follow Muddy Creek Road for approximately 1 mile crossing under I-40 and turn left onto a private drive owned by Mr. Benfield.

UT6: Follow I-40 West toward Marion, take exit 94, and take a left onto Dysartville Road. Turn right onto Bee Tree, travel approximately 1 mile west, and turn left onto the private dirt road owned by Mr. Price.

1.2 USGS Hydrologic Unit Code and NCDWQ River Basin Designations

The project site is located in the USGS Hydrologic Unit Code 03050101040020, and the project stream is located in the Catawba River Basin and NCDWQ 03-08-30 sub-basin.

1.3 Project Vicinity Map

Please refer to **Figure 1** located in the appendix for the project site vicinity map.

2.0 Watershed Characterization

2.1 Drainage Area

Table 2 provides hydrological and surface water classification information for the major project reaches.

Table 3: Drainage Area and Stream Classification

Reach	Drainage Area (mi^2)	Surface Water Classification	Stream Order
UT1	0.20	C	1st
UT5	0.10	C	1st
UT6	0.23	C	1st

2.2 Surface Water Classification/Water Quality

The North Carolina Division of Water Quality (NCDWQ) stream index numbers for Muddy and South Muddy Creeks are 11-32 and 11-32-2-(8.5) respectively. Both streams have a NCDWQ classification of C. Class C waters are protected for secondary recreation; fishing; wildlife, fish, and aquatic life propagation and survival; and agriculture. Secondary recreation includes wading, boating, and other activities that involve human body contact with water and take place in an infrequent, unorganized, or incidental manner. There are no restrictions on watershed development or types of discharges for Class C waters. Neither stream appears on the 2006 North Carolina 303(d) list of impaired waters.

2.3 Physiography, Geology, and Soils

The project site is located in the Piedmont Province, which consists of generally rolling, well-rounded hills and ridges with a few hundred feet of elevation difference between the hills and valleys. Elevations in the piedmont range from 300 to 600 feet above sea level near the border of the Coastal Plain to 1,500 feet at the foot of the Blue Ridge. Resistant knobs and hills, called monadnocks, which occur in the Piedmont Province, include the Sauratown, South, and Uwharrie Mountains (NC Geological Survey, 2004). The project site is also located in the Inner Piedmont geologic region and is comprised mainly of mica schist (CZms), which is a metamorphic rock.

According to the 2006 Natural Resources Conservation Service (NRCS) Soil Survey for Burke County, North Carolina, Arkaqua loam (occasionally flooded) soils cover the floodplain of UT1. UT5 and UT6 are located in McDowell County and, according to the 1995 NRCS Soil Survey, Iotla sandy loam (occasionally flooded) soils cover both UTs' floodplains. Both Arkqua loam and Iotla sandy loam are considered hydric soils.

2.4 Historical Land Use and Development Trends

2.4.1 Historical Land Use

Historically, active pastures and forests have dominated the landscape. **Table 3** shows the change in distribution of land cover within the watershed over time.

Table 4: Historical Land Use

Land Cover	Percentage of Total Coverage			
	1963	1983	1988	1998
Agriculture	15%	20%	25%	27%
Forest	84%	79%	74%	72%
Impervious	<1%	<1%	<1%	<1%

2.4.2 Development Trends

The North Muddy Creek site is located in a rural watershed. The landowners have not expressed an interest in developing the land adjacent to the project streams. Based on historical aerials (1963, 1983, 1988, and 1998) from the McDowell County NRCS, it is anticipated that there will be a minimal increase in impervious surface area in the project watershed within the next 5 years. However, some development may occur, and the reconnection of the stream and its tributaries to a floodplain will allow the streams system to adequately store and convey flood flows.

Major Transportation Projects

The North Carolina Department of Transportation has listed several projects in their State Transportation Improvement Program 2007-2013 (STIP) that are located within the project site vicinity in McDowell County. These projects include:

- B-3492 – SR1763 Replace Bridge #56 over North Muddy Creek
  - Construction will begin FY08
  - Project is located off-site and is not expected to negatively affect any of the proposed construction activities
- B-4778 – SR1769 Replace Bridge #8 over South Muddy Creek
  - Project is currently unfunded with no set construction schedule
  - Project is located off-site and is not expected to negatively affect any of the proposed construction activities

2.5 Endangered/Threatened Species

Under the provisions of Section 7 of the Endangered Species Act (ESA) of 1973, as amended, Federal Law requires that any action likely to affect a federally protected species adversely be subject to review by the U.S. Fish and Wildlife Service. A search of the U.S. Fish and Wildlife Service website (www.endangered.fws.gov) and the North Carolina Natural Heritage Program (NHP) website (http://207.4.179.38/nhp/) indicates one federally endangered species for McDowell County, NC: Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*). Three species are listed as federally threatened: bald eagle (*Haliaeetus leucocephalus*), mountain golden heather (*Hudsonia montana*), and small-whorled pogonia (*Isotria medeoloides*). The bog turtle (*Clemmys muhlenbergii*) also is listed as a federally threatened species due to similarity of appearance. A review of the NHP database of documented occurrences did not reveal the presence of any of these federally endangered or threatened species within a one-mile radius of the proposed mitigation site. Each species, its habitat, and its status are described in **Table 4.**

Under the provisions of Section 7 of the Endangered Species Act (ESA) of 1973, as amended, Federal Law requires that any action likely to affect a federally protected species adversely be subject to review by the U.S. Fish and Wildlife Service. A search of the U.S. Fish and Wildlife Service website and the North Carolina NHP website also indicates one federally endangered species for Burke County, NC: Spreading Avens (*Geum radiatum*). Five species are listed as federally threatened: bald eagle (*Haliaeetus leucocephalus*), mountain golden heather (*Hudsonia montana*), small-whorled pogonia (*Isotria medeoloides*), Dwarf-flowered Heartleaf (*Hexastylis naniflora*), and the Heller's Blazing Star (*Liatris helleri*). The bog turtle (*Clemmys muhlenbergii*) is listed as a federally threatened species due to similarity of appearance. Review of the NHP database of documented occurrences did not reveal the presence of any of these species within a one-mile radius of the proposed mitigation site in Burke County. Each species, its habitat, and its status are described in **Table 4.**

The Carolina northern flying squirrel *(Glaucomys sabrinus coloratus)* is identifiable by the loose fold of furred skin that connects the front and hind limbs from the wrist to the ankles. These mammals have whitish underparts and brownish upperparts. They can be distinguished from the Southern flying squirrel by the gray coloring at the base of the belly hair. Preferred habitat for the Carolina northern flying squirrel includes spruce-fir forest and mixed conifer-northern hardwood forest. Spruce-fir forest and conifer-northern hardwood forest do not occur on the proposed project property. Therefore, a suitable habitat for the Carolina northern flying squirrel does not exist within the proposed mitigation areas. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed mitigation site, and neither EBX nor Kimley-Horn biologists have observed the presence of this species or of a suitable habitat for this species during site investigations.

The Spreading Avens (*Geum radiatum*) has mostly basal leaves with large terminal lobes. The stem is 8 to 20 inches tall. It has an indefinite cyme of large, bright yellow flowers. Habitat requirements for this species include high elevation cliffs, outcrops, and steep slopes that are exposed to full sun. This species also has been found in gravel-like soils of grassy areas near summits. The record status for the spreading avens in Burke County is “Historic.” This species is listed in Burke County; however, suitable habitat for small spreading avens is not present in the proposed mitigation areas. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed project property and presence of this species or of suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

The bald eagle *(Haliaeetus leucocephalus)* is a large raptor that typically inhabits the shorelines of large rivers, lakes, and ponds. Bald eagles construct nests in large trees near the shoreline and make use of the large bodies of water for foraging. A suitable habitat for bald eagle does not exist within the proposed mitigation areas, as there are no large bodies of water on or near the proposed project property. No occurrences of the bald eagle have been documented in the NHP database within a one-mile radius of the proposed mitigation site, and neither EBX nor Kimley-Horn biologists have observed the presence of this species or of a suitable habitat for this species during site investigations.

Mountain golden heather *(Hudsonia montana)* is a small, needle-leaved shrub with yellow flowers and a long-stalked fruit capsule. This species is usually found in clumps 4 to 8 inches across and approximately 6 inches high. Habitat for this non-flowering plant includes exposed quartzite edges in ecotones between bare rock and sand myrtle-dominated heath balds that merge into pine/oak forest. A suitable habitat for mountain golden heather is not present in the proposed mitigation areas. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed mitigation site, and the presence of this species or of a suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

The small whorled pogonia *(Isotria medeoloides)* is a perennial species with long, pubescent roots. The stem is smooth and hollow measuring 9.5 to 25 centimeters tall. The flower and a whorl of 5 or 6 light-green, elliptical leaves are present at the top of the stem. There are 23 known populations of the small whorled pogonia in the southeastern U.S. Habitat requirements for this species include montane oak-hickory or acidic cove forests. This species has been found in areas with dense rhododendron thickets to open shrub strata. Recently, the project site has been used for cattle pasture and hay production. A suitable habitat for the small whorled pogonia is not present in the proposed mitigation areas. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed project property, and the presence of this species or of a suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

The bog turtle (*Clemmys muhlenbergii)* is a small, dark-brown to black turtle that lives in small, widely separated colonies. The turtle's head, neck, and limbs are typically dark brown, with variable reddish to yellow spots and streaks. The bog turtle is a highly specialized species that occupies ephemeral wetlands such as bogs, fens, wet meadows, sedge marshes, and alder, tamarack, or spruce swamps. This species prefers an open habitat with slow flowing streams that have silt or soft mud bottoms. The southern population of bog turtles is listed as threatened because its physical appearance is similar to that of the northern population of bog turtle, which is listed as threatened. The two populations are separated by roughly 250 miles. A suitable habitat for the bog turtle does not exist in the proposed mitigation areas, which are currently used as cattle pasture, or the upland forests located on the proposed project property. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed mitigation site, and the presence of this species or of a suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

The dwarf-flowered heartleaf (*Hexastylis naniflora*) is the smallest flower of any North American Hexastylis; most are less than 0.4 inch long, with narrow sepal tubes (never more than 0.28 inch wide). The jug-shaped flowers range from beige to dark brown, sometimes greenish or purplish. Leathery evergreen leaves are dark green and heart-shaped. Habitat for this species is acidic sandy loam soils along bluffs and nearby slopes, hillsides, and ravines, or in boggy areas adjacent to creekheads and streams. Soil type is the most important habitat requirement (Pacolet, Madison, or Musella types). The plant needs sunlight in early spring for maximum flowering and seed production. This species is listed in Burke County. Recently, this site has been used for cattle pasture and hay production. Suitable habitat for small whorled pogonia is present in the proposed mitigation areas, however these areas are degraded and impacted by cattle. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed project property and presence of this species or of suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

The Heller's blazing star (*Liatris Helleri*) has a spike of lavender flowers on one or more erect stems (maximum height of 16 inches) arising from a tuft of narrow pale green basal leaves. This species differs from other high-elevation Liatris by its much shorter pappus (usually half the length of the corolla tube or less) and ciliate petioles, internally pilose corolla tubes, and lower, stockier habit. The habitat for Heller's blazing star is high elevation ledges of rock outcrops and cliffs in shallow acidic soils in full sun. This species is listed in Burke County. Recently, this site has been used for cattle pasture and hay production. Suitable habitat for Heller's blazing star is not present in the proposed mitigation areas. No occurrences of this species have been documented in the NHP database within a one-mile radius of the proposed project property and presence of this species or of suitable habitat for this species has not been observed by either EBX or Kimley-Horn biologists during site investigations.

Table 5: Endangered Species—McDowell County and Burke County

Common Name	Scientific Name	Habitat Requirement	State Status	Federal Status	Habitat Present
Carolina Northern Flying Squirrel	*Glaucomys sabrinus coloratus*	Spruce-fir forest and mixed conifer-northern hardwood forest	E	E	No
Spreading avens	*Geum radiatum*	High elevation cliffs, outcrops, and steep slopes which are exposed to full sun	E	E	No
Bald eagle	*Haliaeetus leucocephalus*	Shorelines of large rivers, lakes, and ponds	T	T (PD)	No
Mountain golden heather	*Hudsonia montana*	Exposed quartzite edges in ecotones between bare rock and sand myrtle-dominated heath balds that merge into pine/oak forest	E	T	No
Small whorled pogonia	*Isotria medeoloides*	Montane oak-hickory or acidic cove forests	E	T	No
Heller's blazing star	*Liatris Helleri*	High elevation ledges of rock outcrops and cliffs in shallow acidic soils in full sun	T	T	No
Dwarf-flowered heartleaf	*Hexastylis naniflora*	Acidic sandy loam soils along bluffs and nearby slopes, hillsides and ravines, in boggy areas adjacent to creekheads and streams	T	T	No
Bog turtle	*Clemmys muhlenbergii*	Ephemeral wetlands such as bogs, fens, wet meadows, sedge marshes, and alder, tamarack, or spruce swamps	T	TS/A	No

Notes: E=Endangered; T=Threatened; T (PD)=Proposed for delisting; TS/A=Threatened due to similarity in appearance.

*The State defines an endangered **plant species** as "any species or higher taxon of plant whose continued existence as a viable component of the State's flora is determined to be in jeopardy." (GS 19B 106: 202.12).*

*The State defines an endangered **animal species** as "any native or once-native species of wild animal whose continued existence as a viable component of the State's fauna is determined by the Wildlife Resources Commission to be in jeopardy or any species of wild animal determined to be an 'endangered species' pursuant to the Endangered Species Act." (Article 25 of Chapter 113 of the General Statutes; 1987).*

2.6 Cultural Resources

A project scoping letter was sent to the State Historic Preservation Office (SHPO) on February 6, 2007 to request a review of the project for any potential impacts to cultural resources. A reply dated March 8, 2007 was received stating that SHPO has no known archaeological sites within the project boundaries; however, they recommend a comprehensive survey be conducted. Another project scoping letter was sent to the Eastern Band of Cherokee Indians Tribal Historic Preservation Office

(EBCI THPO) on January 22, 2007, requesting a review of the project for any potential impacts to cultural resources. A reply was received on March 16, 2007 and stated that the EBCI THPO requires that a Phase I archaeological survey be conducted to ensure that any potential resources are identified. Copies of these letters are included as part of the Categorical Exclusion in **Appendix 7**. A Phase I archaeological survey has been completed for the site and the results were forwarded to SHPO, EBCI THPO, and NCEEP. SHPO and EBCI have concurred with the findings of the archaeological survey and a copy of the concurrence letters is included in **Appendix 7.**

2.7 Potential Constraints

2.7.1 Property Ownership and Boundary

The conservation easement for each unnamed tributary will be contained on one parcel. The table below provides the property owner, deed book/page number, and the easement area in acres.

Table 6: Ownership

Reach	Current Owner	Proposed Easement Area
UT1	J. David and Betty Jean Connolly	17.5
UT5	James Benfield	7.3
UT6	Robert Price	15.8

The property boundary is shown in **Figure 1** and the conservation easement boundary is shown in the **Restoration Plan Design Sheets**.

2.7.2 Site Access

UT1: It is anticipated that this site will be accessed off of Highway 70 and Seals Road. Seals Road currently is a 1-mile long dirt road. Improvement will be made to both an existing stream crossing and portions of the road itself to allow for the movement of machinery and materials into and out of the project site. Temporary roads will be removed and existing roads will be returned to pre-construction condition or better.

UT6: It is anticipated that this site will be accessed off Muddy Creek Road through existing farm roads that lead to the site from Muddy Creek Road. EBX has obtained permission from the necessary private land owners for access. Some improvements will be made to sections of this road to allow for the movement of machinery and materials into and out of the project site. Per the request of the owners, some portions of the improved access road outside the easement will be left in place for the landowners' use and other portions will be removed and planted back to return it to its pre-construction condition.

UT5: It is anticipated that UT5 will be accessed from UT6. A haul road will be constructed for this access. Portions of a relic logging road will be used where possible to minimize impact to trees. The road will be left in a condition that is satisfactory to the owners (Price and Benfield). There is an alternative entrance into the site which serves as Mr. Price's private paved driveway off of Gilbert Byrd

Road. Access by heavy equipment would likely damage this driveway so it is likely that only light construction traffic (i.e. pick-up trucks, etc.) would enter the site from this direction.

2.7.3 Utilities

The site survey prepared by Suttles Surveying, P.A. did not locate any utilities that will conflict with the restoration activities. The contractor is advised to contact North Carolina One Call prior to beginning any construction activity.

2.7.4 FEMA/Hydrologic Trespass

The project streams are located in Zone AE in the FEMA DFIRM panels 1740 and 1742; however, since these areas are mapped as backwater from the larger Muddy Creek, a detailed model was not necessary for our study areas. Since the project streams do not have a detailed hydrologic model, FEMA coordination with the State of North Carolina is not required. A floodplain development permit will still be required for both Burke and McDowell counties.

There is an increase in flood elevation for all of the project site streams. All project reaches drain into Muddy Creek and the increase in on-site flood elevations will not increase the flood elevation of the larger Muddy Creek, therefore, will not cause any hydrologic trespass to anyone downstream. The increase in flood elevations also is isolated to the project parcels and will not increase flood elevations upstream.

3.0 Project Site Streams

The project site is composed of three unnamed tributaries to Muddy Creek. UT1 flows east to west and drains into Muddy Creek. UT1 is a perennial stream beginning at an off-site pond and is divided into two reaches (Upper UT1 and Lower UT1) due to the different valley and stream types. The stream enters the project site in a steep valley setting and flows into the flat floodplain of Muddy Creek. Cattle have open access to both streams, which is actively degrading the stream buffer, banks, bed, and water quality. Upper UT1 is actively eroding with highly unstable banks and no riparian buffer. Lower UT1 has been historically straightened and dredged due to excessive aggregation. The spoils of the dredging have been deposited on the banks and have formed berms and levees. These berms act like a hydrologic barrier and disallow the more frequent flood flows from inundating the adjacent wetland areas. These berms also confine the flood waters within the channel resulting in higher shear stress due to increased velocities (see **Appendix 1**).

UT5 is a perennial stream that has been historically straightened. The woody vegetation also has been removed and the buffer has been managed, which has created instability. This reach lacks the proper dimension, pattern, and profile for its valley type. Portions of UT5's upstream reach are unstable and lack in-stream habitat. The middle reach of UT5 is stable, has an acceptable buffer, is not incised and therefore, this area will be preserved. The lower reach of UT5 is incised, lacks instream habitat and is not connected to its floodplain. There is minimal to no woody buffer along this section of UT5.

UT6 is a perennial stream that has been historically straightened and cleared. The stream is actively eroding and has unstable, eroding banks. To allow for agriculture, the stream and adjacent ditches have been used to remove hydrology from what historically has been a wetland in the Muddy Creek floodplain. Upper UT6 is in stable condition and will be preserved. UT6 also is used as a reference reach. A culvert crossing, which has acted as a grade control structure, prevented the incision of UT6 from moving upstream into the stable Upper UT6 section. There is approximately 4-5 feet of drop across this culvert.

3.1 Channel Classification

Kimley-Horn performed a geomorphic survey (cross sections, longitudinal survey, and pattern) and sampled stream materials (classification and entrainment pebble counts, bar samples, sub-pavement, and pavement samples) on several reaches representative of the geomorphic settings within the project area. **Table 6** below summarizes the channel classifications of the surveyed reaches within the project area, and **Restoration Table IV** (Section 8) provides detailed morphological data.

Table 7: Summary of Stream Classification

Assessment Reach	Drainage Area (mi^2)	Entrenchment Ratio	A_{bkf}	W_{bkf}	Width/Depth Ratio	K	Slope	Stream Type
Upper UT1	0.1	1.6	2.4	3.6	5.4	1.0	0.0464	G5
Lower UT1	0.2	1.6	2.1	5.2	12.6	1.0	0.0067	F5
UT5	0.1	1.4	2.6	4.6	8.4	1.0	0.0082	G5
UT6	0.2	1.6	2.8	4.6	7.5	1.0	0.0139	E5-C5

3.2 Channel Discharge

The peak flows for the 2-, 10-, 25-, and 100-year storms using the North Carolina rural flood-frequency equations for the Blue Ridge-Piedmont Region (United States Geological Survey 2003) are shown in **Table 7**.

Table 8: Project Site Streams Peak Discharges

Assessment Reach	Area (ac.)	Bankfull Discharge* (cfs)	2yr Q (cfs)	10yr Q (cfs)	25yr Q (cfs)	100yr Q (cfs)
Upper UT1	64	13.3	27	73	108	177
Lower UT1	128	34.2	44	115	169	272
UT5	64	17.4	27	73	108	177
UT6	147	25.9	48	126	184	297

**Calculated using Manning's equation and associated "n" value for stream type.*

3.3 Channel Morphology

All of the project's restoration reaches lack the appropriate dimension, pattern, and profile for their given valley types. These reaches were straightened and their buffers have been cleared and historically managed to maximize usable pasture and/or farmland. As a result of the loss in length associated with straightening, the channels are unstable and do not exhibit any defined riffle pool sequence and/or suitable aquatic habitat. The streams have become incised or hydrologically disconnected from the floodplains resulting in increased shear stress, velocity and the removal of hydrology from the historic adjacent riparian wetlands. **Restoration Table IV** shows complete channel morphology data including channel, pattern, dimension, and profile for all restoration and project reaches.

3.4 Channel Stability Assessment

Appendix 1 displays photos of existing conditions.

The restoration reaches lie within an area currently and historically used for pastures, farmland, and timber production. UT1 allows open access for cattle to the stream. The vegetative buffers, in most cases, have been cleared, managed, and are currently open fields with some invasive species along the banks. The streams also have been historically straightened to maximize usable land. Because of these conditions, the restoration reaches have down cut, creating incised banks and accelerated bank erosion.

Upper UT1 is actively incising and has eroding banks. Lower UT1 is experiencing aggregation due to the upstream sediment inputs from the eroding banks and cleared buffer areas. All of the project reaches lack the proper dimension, pattern, profile, and aquatic habitat.

Bank height ratios (low bank height divided by the maximum bankfull depth) were determined for the surveyed reaches. In the methodology used for this report (Rosgen, 2001), bank height ratios between 1.1 and 1.3 are considered “moderately unstable,” ratios between 1.3 and 1.5 are considered “unstable,” and bank height ratios greater than 1.5 are considered “highly unstable.”

Table 9: Restoration Reach Characteristics

Assessment Reach	Bank Height Ratio	Vegetative Buffer		Adjacent Land Use	Disturbance/ Relocation
		Right Bank	Left Bank		
Upper UT1	5.9	Scattered Shrubs/ Field	Scattered Shrubs/ Field	Pasture	Straightening and Clearing
Lower UT1	4.3	Scattered Trees/Shrubs	Open Field	Pasture	Straightening and Clearing
UT5	2.9	Open Field	Scattered Trees/Shrubs	Pasture/Hay Production	Straightening and Clearing
UT6	3.1	Scattered Shrubs/ Field	Scattered Shrubs/ Field	Pasture Hay Production	Straightening and Clearing

3.5 Bankfull Verification

Determination of the bankfull elevation is vital to generating meaningful geomorphic values. There were sufficient bankfull indicators on-site such as benches, point bars, sediment deposits, and rack lines. To verify bankfull elevations, the bankfull area values for the project reaches were compared to the North Carolina Piedmont Rural regional curves (Harman, Jennings et al. 1999). The results indicate a general agreement between the three sets of values (site, references, and regional curve), thus providing a measure of validation.

3.6 Vegetation

There are limited woody buffers on the project streams and buffer widths range from 0 to 10 feet. Each reach has limited species of trees and shrubs lining the banks, including invasives. UT1 is dominated by sycamore, blackberry, privette, and willow. UT5 is dominated by sweetgum, tuliptree, red maple, American hornbeam, honeysuckle, blackberry, and greenbriar. UT6 is dominated by willow, red maple, blackberry, privette, and honey suckle.

4.0 Reference Stream

4.1 Watershed Characterization

Two on-site reference reaches were identified during site inspections as well as one off-site reference reach. The on-site reaches lie within the same watersheds as the project restoration reaches. These watersheds are situated in a rural setting with minimal anticipated urbanization or increase in impervious surfaces. The off-site reference reach is another unnamed tributary to Morgan Creek, located in McDowell County, North Carolina. The UT to Morgan Creek also is located in a rural watershed with minimal growth and urbanization expected.

4.2 Channel Classification

The UT4 reference reach is classified as a Rosgen "B4" channel; the UT6 reference reach is classified as a Rosgen "B3" channel; and the UT to Morgan Creek reference reach is classified as a Rosgen "C4b" channel. The reference stream morphology is included in **Restoration Table IV**.

4.3 Discharge

The peak flows for the 2-, 10-, 25-, and 100-year storms were modeled for the given drainage areas. These flows were calculated using the North Carolina DOT project design discharge charts.

Table 10: Reference Stream Peak Discharges

Reference Reach	Area (ac.)	Bankfull Discharge (cfs)*	2yr Q (cfs)	10yr Q (cfs)	25yr Q (cfs)	100yr Q (cfs)
UT4	77	19.3	30	82	121	198
Upper U 6	90	21.6	34	91	134	218
UT to Morgan Creek	30	10.8	16	46	69	115

**Calculated using Manning's equation and appropriate "n" for stream.*

4.4 Channel Stability Assessment

During site inspections, the reference reach streams appeared stable with morphological measurements indicating stable dimension, pattern, and profile. These reaches are stable due to vegetative banks; proper dimension, pattern, and profile; and access to an active floodplain (see reference stream photo, page 2). All three reaches exhibited stable banks, low bank height ratios (1.0 to 1.1), and established or emergent vegetative buffers. (See **Appendix 4** for photographs.)

4.5 Bankfull Verification

Determination of the bankfull elevation is vital to generating meaningful geomorphic values. There were sufficient bankfull indicators on-site such as benches, point bars, sediment deposits, and rack lines. To verify bankfull elevations, the bankfull area values for the project reference reaches were compared to the North Carolina Piedmont Rural regional curves (Harman, Jennings et al. 1999). The results indicate a general agreement between the three sets of values (site, references, and regional curve), thus providing a measure of validation. Results can be seen in the **Restoration Tables.**

4.6 Vegetation

The vegetative community found in the reference areas is described as Piedmont/Mountain Bottomland Forest. These areas are typically found in floodplain ridges and terraces other than active levees adjacent to the river channel throughout the Piedmont and lower parts of the Blue Ridge. The canopy is dominated by various bottomland trees such as tuliptree (*Liriodendron tulipifera)*, sweetgum (*Liquidambar styraciflua)*, cherrybark oak (*Quercus pagoda)*, swamp chestnut oak *(Quercus michauxii),* American elm *(Ulmus Americana),* dwarf hackberry (*Celtis laevigata),* green ash (*Fraxinus pennsylvanica),* loblolly pine (*Pinus taeda),* shagbark hickory (*Carya ovata),* and bitternut hickory (*Carya cordiformis)*. Understory trees include American hornbeam (*Carpinus caroliniana),* southern sugar maple (*Acer floridanum),* red maple (*Acer rubrum),* flowering dogwood *(Cornus florida),* American holly *(Ilex opaca)*, and pawpaw (*Asimina triloba)*. Shrubs include species such as painted buckeye (*Aesculus sylvatica)*. Giant cane (*Arundinaria gigantean)* may form dense thickets. Vines are frequently prominent, including poison ivy (*Toxicodendron (Rhus) radicans)*, Virginia creeper (*Parthenocissus quinquefolia),* crossvine (*Bignonia (Anisostichus) capreolata),* greenbriar (*Smilax spp.),* common moonseed (*Menispermum canadense)*, and grape (*Vitis spp.*) Herbs include falsenettle (*Boehmeria cylindrical),* Christmas fern (*Polystichum acrostichoides),* sedge (*Carex spp.),* Canadian honewort *(Cryptotaenia Canadensis),* jumpseed *(Polygonum (Tovara) virginianum),* Jack in the pulpit *(Arisaema triphyllum),* violet (*Viola spp.),* golden ragwort (*Senecio aureus),* Virginia wildrye (*Elymus virginicus),* wreath goldenrod (*Solidago caesia),* mountain aster (*Aster divaricatus),* Indian woodoats (*Chasmanthium (Uniola) latifolium)*, and slender woodoats (*Chasmanthium (Uniola) laxum)*. Some places are heavily invaded by Japanese honeysuckle (*Lonicera japonica)* and Nepalese browntop (*Microstegium vimineum)*. (Schafale and Weakley 1990).

5.0 Project Site Wetlands

5.1 Jurisdictional Wetlands

UT1 contained two on-site jurisdictional wetlands, WA-1 and WA-2. UT5 contained a jurisdictional wetland (WA-3) located at the toe of slope of the valley. All three wetland areas contained similar vegetative species. The canopy is dominated by various bottomland trees such as tuliptree, sweetgum, swamp chestnut oak, American elm, dwarf hackberry, and green ash. The understory species include American hornbeam, and red maple. Shrubs include giant cane. Herbs include falsenettle, Christmas fern, sedge, and Jack in the pulpit. WA-2 will be used as a reference wetland for the entire project site.

Table 11: Existing Wetland Vegetation

Wetland ID		WA-1	WA-2	WA-3
Latitude		-81.860	-81.863	-81.859
Longitude		35.694	35.696	35.684
Cowardin Classification		PFO1	PFO1	PFO1
Acreage		4.1	2.1	2.0
Scientific Name	**Common Name**			
Canopy				
Acer	*rubrum*	**x**	x	x
Liquidambar	*styraciflua*	**x**	x	x
Understory				
Juncus	*effusus*	**x**	x	x
Scirpus	*cyperinus*		x	
Morella	*cerifera*	**x**	x	x
Baccharis	*halimifolia*	**x**	x	x

5.2 Hydrological Characterization

5.2.1 Groundwater Modeling

The on-site reference wetlands (preservation areas) have similar position in the valley, soils, and relation to the adjacent stream when compared to the restoration areas. This allows us to use them as a base for establishing quantitative criteria for a simplified hydrologic budget and simple groundwater model. Rainfall, groundwater, and surface water inputs from adjacent streams, evaporation, infiltration, and ground water flows should be relatively equal for the reference site and the proposed restoration/enhancement sites. Given that fact, a ratio of wetland area to contributing drainage area can be established as a basis to determine that the hydrologic inputs are sufficient for the proposed restoration. Based on the reference wetland, a minimum drainage area (not including the stream inputs) to wetland area is a ratio of 4:1. The ratio for the restoration areas range from 4:1 to 20:1. This data helps verify that the source hydrology and groundwater would support these wetlands once the hydrologic modifications are returned to reference (i.e. ditches are removed, and adjacent channels are raised to historic or reference levels). The surface water modeling combined with a bank height ratio matching the streams adjacent to the reference wetland (<1.2) allows us to know that the bankfull event (approximately the 67% storm) also will provide additional hydraulic input into the riparian wetlands.

5.2.2 Surface Water Modeling

The HEC-RAS model developed for this project was used to ensure that the design is optimized to maintain or increase the frequency of overbank flooding in the areas of wetland enhancement and restoration. The frequency of overbank flooding along with elevation the groundwater level will be key to ensuring hydrologic success of the wetlands. As cross sections are developed for 90% complete plans, the HEC-RAS model will become increasingly important to serve as a guide for adjusting grading plans in areas adjacent to wetlands. HEC-RAS results of the 60% complete design are included in **Appendix 9.**

5.2.3 Hydrologic Budget

The proposed wetland enhancement areas are hydrated by their connection to the groundwater table, hill slope seepage, runoff, and overbank flooding from the nearby streams. The proposed wetland restoration sites have been drained by ditching and/or by stream channelization that was conducted in order to drain the wetlands and improve drainage for agriculture and/or livestock. In some areas the wetland areas have been graded or tilled which has removed the microtopography. The compaction from the cattle on the UT1 site also has effected the saturation of the surface soils. The effects of the drainage improvements have been reduction of over bank flooding, lowering of the local groundwater table, and reduction of the length of inundation.

See Section 5.2.1 for details on how the hydrologic budget was determined.

5.3 Soil Characterization

Kimley-Horn has engaged Soil Water & Environment Group (SWE) to provide licensed soil scientist services. SWE personnel investigated the project site to confirm NRCS soil survey mapping data, record detailed soil descriptions for selected areas representing different landscape positions across the site, and to determine the extent of hydric soils for the purpose of wetland restoration site criteria. A series of hand augerings were accomplished across selected areas of the proposed wetland restoration site at maximum depths of approximately 18 to 24 inches. Detailed soil descriptions including depth of horizon, color, texture, structure, and consistence were recorded (**Appendix 12**). For areas where relic redoximorphic features occur at a depth of greater than 12 inches due to site disturbance from farming, minor grading of less than or equal to 6 inches would most likely result in a change to more hydric conditions and an elevated water table similar to adjacent soil areas. Typically, wetland areas include soils that a matrix with chroma 1 or 2 within the upper 12 inches. The wetland enhancement area which includes soil boring 6 (SB-6) was delineated following the guidelines presented in the 1987 *U.S. Army Corps of Engineers Wetland Delineation Manual*. This area was determined by KHA biologist to be a low quality wetland. The soil boring which was completed by a licensed soil scientist (Scott Frederick, EI, NCLSS) verified that the 6 to 24 inches layer may have borderline chroma levels however, there are multiple other wetland indicators present including reducing conditions as indicated by the mottles, root channels, and the water table is less than 6 inches from the surface. This area is currently disturbed including periodic tilling and open cattle access. This wetland is proposed to be enhanced through livestock exclusion and supplemental plantings and by doing so the soils will begin to take on the same characteristics of the adjacent undisturbed reference wetlands.

5.3.1 Taxonomic Classification

See **Appendix 12** for the taxonomic report performed by SWE on June 11, 2007.

5.3.2 Profile Description

See **Appendix 12** for the taxonomic report performed by SWE on June 11, 2007.

5.3.3 Hydraulic Conductivity

According to the soil survey of Burke and McDowell counties, the soils found onsite in the wetland areas are somewhat poorly drained and has moderately rapid permeability. Saturated hydraulic conductivity (Ksat) is moderately rapid to rapid in the stratum and rapid to very rapid in the substratum. The index of surface runoff is negligible. Flooding is occasional to frequent with very brief duration.

5.4 Plant Community Characterization

The vegetative community found in the reference areas is described as Piedmont/Mountain Bottomland Forest. These areas are typically found in floodplain ridges and terraces other than active levees adjacent to the river channel throughout the Piedmont and lower parts of the Blue Ridge. The canopy is dominated by various bottomland trees such as tuliptree, sweetgum, cherrybark oak, swamp chestnut oak, American elm, dwarf hackberry, green ash, loblolly pine, shagbark hickory, and bitternut hickory. Understory trees include American hornbeam, southern sugar maple, red maple, flowering dogwood, American holly, and pawpaw. Shrubs include species such as painted buckeye. Giant cane may form dense thickets. Vines are frequently prominent, including poison ivy, Virginia creeper, crossvine, greenbriar, common moonseed, and grape Herbs include falsenettle, Christmas fern, sedge, Canadian honewort, jumpseed, Jack in the pulpit, violet, golden ragwort, Virginia wildrye, wreath goldenrod, mountain aster, Indian woodoats, and slender woodoats. Some places are heavily invaded by Japanese honeysuckle, and Nepalese browntop. (Schafale and Weakley 1990).

6.0 Reference Wetland

6.1 Hydrological Characterization

The reference wetland areas are fed by their connection to the groundwater table, hill slope seepage, runoff, and overbank flooding from the nearby streams.

6.2 Soil Characterization

For the purposes of the restoration, the on-site wetland will be used for soil characterization, as the soil characteristics will be most similar to the restoration and enhancement sites. The soil characteristics are described in Section 5 (above) and in **Appendix 12**.

6.2.1 Taxonomic Classification

See Section 5 (above) and **Appendix 12**.

6.2.2 Profile Description

See Section 5 (above) and **Appendix 12**.

6.2.3 Hydraulic Conductivity

See Section 5 (above) and **Appendix 12**.

6.3 Plant Community Characterization

6.3.1 Community Description

The vegetative community found in the reference areas is described as Piedmont/Mountain Bottomland Forest. These areas are typically found in floodplain ridges and terraces other than active levees adjacent to the river channel throughout the Piedmont and lower parts of the Blue Ridge. The canopy is dominated by various bottomland trees such as tuliptree, sweetgum, cherrybark oak, swamp chestnut oak, American elm, dwarf hackberry, green ash, loblolly pine, shagbark hickory, and bitternut hickory. Understory trees include American hornbeam, southern sugar maple, red maple, flowering dogwood, American holly, and pawpaw. Shrubs include species such as painted buckeye. Giant cane may form dense thickets. Vines are frequently prominent, including poison ivy, Virginia creeper, crossvine, greenbriar, common moonseed, and grape. Herbs include falsenettle, Christmas fern, sedge, Canadian honewort, jumpseed, Jack in the pulpit, violet, golden ragwort, Virginia wildrye, wreath goldenrod, mountain aster, Indian woodoats, and slender woodoats. Some places are heavily invaded by Japanese honeysuckle and Nepalese browntop. (Schafale and Weakley 1990)

7.0 Project Site Restoration Plan

7.1 Restoration Project Goals and Objectives

The goals of the restoration project are to improve water quality, function, and habitat by:

- Removing excess nutrients and sediment through the use of vegetative buffers
- Increasing dissolved oxygen concentrations through the use of in-stream structures and the turbulence they produce in pools
- Stabilizing the stream bank using natural channel design techniques
- Improving substrate through the use of structures and the elimination of major sediment sources from the stream
- Creating habitat diversity by introducing woody structures such as log vanes and/or root wads
- Reducing temperature by restoring canopy in the buffer areas
- Reconnecting streams to their adjacent floodplains and wetlands
- Raising groundwater levels in adjacent streams by raising adjacent channel bed elevation
- Removing/plugging ditches used to drain historic wetlands
- Creating micro-topography by regrading and ripping wetlands
- Breaking up historically compacted soils by cattle to allow the groundwater to come to the surface and wetland vegetation to flourish
- Improving crossings by replacing pipes and/or stabilizing outfalls
- Controlling the invasive exotics by removing them during construction
- Preserving stable on-site streams, wetlands, and riparian buffers draining into the enhancement/restoration reaches
- Excluding livestock through fencing
- Re-vegetating the stream banks, wetlands, and riparian area to improve bio-diversity and ecology

Stream Restoration Approach

Using Rosgen priority I and II methodologies, natural channel design techniques are used to adjust the channel dimension, pattern, and profile to a stable configuration for all restoration reaches. The configuration was based on reference reach morphology, values from regional curves, regime equations, experience from other restoration projects, and the existing channel morphology. These reference and proposed values are presented in **Restoration Table IV**. The stream restoration either restores the streams in place or creates a new channel. The specific restoration approach is shown on the Design Sheets in Section 12.0 for each reach.

Dimension

The channels' riffle cross-sectional areas were calculated using the hydraulic geometry curves, which were derived from the reference reaches and regional curves. The proposed riffle cross sections were shaped to have a mean depth and width capable of transporting existing and predicted future sediment loads for the designed channel slope. Pool cross sections were shaped based on riffle-to-pool cross section relationships found in the appropriate reference reach. Each reach will be restored to a channel type that matches the associated valley type. Upper UT1 will have a lower width-to-depth ratio because it is in a steep valley type. Lower UT1, UT5, and UT6 will have a high width-to-depth ratio, which will increase sediment transport, provide areas for excess sediment to deposit, and allow point bars to form. The reference dimensionless ratios are included in the morphological table (**Restoration Table IV**).

Pattern

The channel planform was dictated by reference ratios for meander wavelength and a radius of curvature derived from the reference reaches and typical Rosgen reference reach values for C- and B-type channels. The belt widths were based on reference ratios but were limited in some areas by the topography of the valley. The proposed planform sinuosity allowed pool-to-pool spacing and riffle locations to match reference conditions. The proposed sinuosity provided the appropriate slope to transport the material coming into the reach. The B-type channels are designed as step pool systems because they are in a high-gradient setting. The planform values and ratios are provided in the morphological table in **Restoration Table IV,** and the **Restoration Plan Design Sheets** provide the designed channel alignment.

Bedform

The C-type design channel bedform predominantly consists of a riffle–pool sequence with runs and glides between them. The design depths and pool-to-pool spacing of the features were based on reference reach values and typical Rosgen reference reach values for C-type channels (**Restoration Table IV**). The pools were located in the apexes of meander bends with riffles located between the pools in the tangent portions of the channel. The pools will be over-dug to allow for some sedimentation during construction activities. The B-type channels will be step-pool systems with the pools designed to be closer together than in C-type channels to help eliminate energy vertically since the stream may not have access to a floodplain. In general the pool-to-pool spacing decreases as the slope increases. The profile section of the **Restoration Plan Design Sheets** shows the designed channel bedform.

Structures

In-stream structures will be placed in the design channel to provide grade control and maintain overall design slope. In-stream structures also will be appropriately located to protect stream banks and increase aquatic habitat diversity. The types of structures incorporated into the restoration project design include rock cross vanes, rock A-vanes, root wads, boulder sills, and log vanes. Root wads will be used only for providing habitat and are usually combined with a log van or other hydraulic structure.

7.1.1 Designed Channel Classification and Wetland Type

Upper UT1 is designed as a Rosgen B stream because of its setting in a steep valley. Lower UT1, UT5, and UT6 are designed as Rosgen C streams with high width-to-depth ratios and point bars. The wetlands on UT1 and UT5 are designed to be riparian bottomland hardwood areas. The wetlands on UT6 are designed to be mostly riparian bottomland hardwood areas with some non-riparain areas and the toe of slope away from the streams. Topography combined with surface water modeling of the streams was used to determine the break between riparian and non-riparian wetland on UT6.

7.1.2 Target Wetland Communities/Buffer Communities

The target riparian community as described in Schafale's Fourth Approximation of North Carolina Vegetative Communities is a Piedmont/Mountain Bottomland Forest. These areas are typically found in floodplain ridges and terraces other than active levees adjacent to the river channel throughout the Piedmont and lower parts of the Blue Ridge. The canopy is dominated by various bottomland trees such as tuliptree, sweetgum, cherrybark oak, swamp chestnut oak, American elm, dwarf hackberry, green ash, loblolly pine, shagbark hickory, and bitternut hickory. Understory trees include American hornbeam, southern sugar maple, red maple, flowering dogwood, American holly, and pawpaw. Shrubs include species such as painted buckeye. Giant cane may form dense thickets. Vines are frequently prominent, including poison ivy, Virginia creeper, crossvine, greenbriar, common moonseed, and grape. Herbs include falsenettle, Christmas fern, sedge, Canadian honewort, jumpseed, Jack in the pulpit, violet, golden ragwort, Virginia wildrye, wreath goldenrod, mountain aster, Indian woodoats, and slender woodoats. Some places are heavily invaded by Japanese honeysuckle and Nepalese browntop. (Schafale and Weakley 1990)

See **Figure 11** for the Reference Site Vegetative Communities Map.

7.2 Sediment Transport Analysis

7.2.1 Methodology

The shields curve was used to calculate the sediment transport for Upper UT1 because its stream bed substrate is a gravel-like material and the stream slope is steep. Sediment transport was calculated using shear stress equations and shields curve to verify that the designed channel will be able to transport its bedload at bankfull without aggrading or degrading. The shields curve was used for the initiation of particle movement and to estimate the range of particles transported for a given shear stress.

Stream power was used to predict sediment transport because Lower UT1, UT5, and UT6 are sand bed streams. Stream power was calculated using the shear stress equation multiplied by the stream velocity to verify that the designed channel would be able to transport its bedload at bankfull without degrading.

Two physical characteristics of the channel design that affect the stream power of the channel are the slope of the channel and hydraulic radius. The shear stress equation is as follows:

$\tau = \gamma R s$

Where: τ= shear stress (lb/ft^2)
γ = specific gravity of water (62.4 lb/ft^3)
R = hydraulic radius (ft)
s = water surface slope (ft/ft)

The hydraulic radius equals the cross sectional area divided by the wetted perimeter.

$$R = \frac{A}{P}$$

Where: R = hydraulic radius
A = cross-sectional area (ft^2)
P = wetted perimeter (ft)

To determine the velocity of the existing and proposed channels the Manning's equation was used:

$$v = \frac{k}{n}\left(\frac{A}{P}\right)^{(2/3)} \sqrt{S}$$

Where: v = velocity (ft/s)
k =1.49 (constant)
n = roughness coefficient
A = cross-sectional area (ft^2)
P = wetted perimeter (ft)
S = average stream slope (ft/ft)

The stream power of the channel is equal to the shear stress multiplied by the velocity.

$Ps = \tau v$

Where: Ps = stream power (lbs/ft*s)
τ = shear stress (lb/ft^2)
v = velocity (ft/s)

7.2.2 Calculations and Discussion

Upper UT1 was designed with a mean depth and slope sufficient to transport a range of particles. This channel is designed to eliminate bank erosion, flush the sands, and transport the characteristic sediments. The characteristic sediments were determined by analyzing bed materials in comparative streams with less impacted watersheds. **Table 11** provides the results of the sediment transport calculations using the shear stress equation and Shields curve. The results show that the proposed channel should transport a range of materials that includes the existing or characteristic (in case of the sand laden channels) channel materials.

Table 12: Summary of Shear Stress Calculations

Restoration Reach	Proposed Slope (ft/ft)	Proposed Hydraulic Radius (ft)	Shear Stress (lb/ft²)	Particle Transport Size* (mm)
Existing Upper UT1	0.04064	0.7	2.03	164
Proposed Upper UT1	0.04061	0.6	1.52	120

Lower UT1, UT5, and UT6 were designed so that stream power values would be in the range 1.0 to 2.4 ft-lb/sec/ft^2. According to studies by Brookes (1991), sand bed streams with power values that are less than 1.0 ft-lb/sec/ft^2 fail through deposition. On the other hand, streams with power values greater than 3.4 ft-lb/sec/ft^2 will erode the channel. **Tables 12 and 13** provide the results.

Table 13: Summary of Existing Stream Power Calculations

Assessment Reach	Existing Slope (ft/ft)	Existing Hydraulic Radius (ft)	Existing Shear Stress (lb/ft²)	Existing Stream Power (lbs/ft*s)
Lower UT1	0.0067	0.4	0.17	1.04
UT5	0.0082	0.6	0.26	1.78
UT6	0.0139	0.6	0.21	2.35

Table 14: Summary of Proposed Stream Power Calculations

Assessment Reach	Proposed Slope (ft/ft)	Proposed Hydraulic Radius (ft)	Proposed Shear Stress (lb/ft²)	Proposed Stream Power (lbs/ft*s)
Lower UT1	0.0055	0.5	0.25	1.29
UT5	0.0078	0.6	0.37	1.21
UT6	0.0108	0.7	0.47	1.98

7.3 HEC-RAS Analysis

A HEC-RAS model (v. 3.1.3) was run to analyze the existing and proposed conditions of the project streams.

UT1: A priority 1 stream restoration approach was used to design this stream in order to restore dimension, pattern, and profile. This approach resulted in raising the streambed, creating an overall net rise in elevation of approximately 1 foot throughout the restoration area. Based on the HEC-RAS model, the existing stream contained the bankfull, 2 year, and 10 year events. For the proposed stream, the HEC-RAS model indicates that the bankfull and higher flow events flood out of the channel and hydrate the surrounding wetland, verifying the increase in frequency of overbank flooding.

UT5: A priority 1 stream restoration approach was used to design this stream in order to restore dimension, pattern, and profile. The HEC-RAS model for this stream indicates that the bankfull event reaches the floodplain and adds hydrology to the surrounding wetland.

UT6: A priority 1 stream restoration approach was used to design this stream in order to restore dimension, pattern, and profile. This approach resulted in raising the streambed, creating an overall net rise of approximately 1 foot in elevation. Based on the HEC-RAS results, the bankfull and higher flow events flood out of the channel and hydrate the surrounding wetland, verifying the increase in frequency of overbank flooding.

Summary sheets showing the results of the model can be seen in **Appendix 9**.

7.3.1 No-Rise, LOMR, CLOMR

All of the project streams are located in Zone AE in the FEMA DFIRM maps 1740 and 1742, however, since these areas are mapped as backwater from the larger Muddy Creek, a detailed model was not necessary for our study areas. Since the project streams do not have a detailed hydrologic model, FEMA coordination with the State or the community is not required. A floodplain development permit will still be required for both Burke and McDowell Counties.

7.3.2 Hydrologic Trespass

There is an increase in flood elevation for all of the project site streams. All project reaches drain into Muddy Creek and the increase in on-site flood elevations will not increase the flood elevation of the larger Muddy Creek, and, therefore, will not cause any hydrologic trespass to anyone downstream. The increase in flood elevations also is isolated to the project parcels and will not increase flood elevations upstream.

7.4 Stormwater Best Management Practices

7.4.1 Site-Specific Stormwater Concerns

The project sites are situated in a rural setting. It is anticipated that the re-established riparian buffer will be a sufficient filter and treat any stormwater runoff from the adjacent fields. Areas where concentrated stormwater flows enter the easement will be captured in no-maintenance BMPs (pocket wetland/level spreaders) created from grading. There are no site-specific stormwater concerns.

7.5 Hydrologic Modification

7.5.1 Narrative of Modification

Hydrologic modifications to the enhancement and restoration areas will result from a combination of raising stream base flow elevations, plugging of existing drainage ditches, removing berms, and providing microtopography to improve surface water infiltration.

Key hydrological components for the project's wetlands include inputs from over-bank flow, infiltration of ponded waters, and the balance of groundwater inflows and outflows. The frequency and duration of over-bank flows from the smaller more frequent flooding events (bankfull to 0.90 probability events) will be improved by raising the base flow elevations of streams adjacent to the target wetlands and constructing the restored channel with an incipient flood cross-section area that is incrementally smaller than the bankfull cross-sectional area. The incipient flood cross-section area will have direct access to the floodplain in areas were wetland restoration is proposed and should provide more frequent flood events. The frequency and duration of over-bank flows from larger flooding events (less than 0.10 probability events) will remain unchanged. The local groundwater elevations and the balance of groundwater inflows and outflows near the raised base flow elevations of the streams, also should rise. These modifications to the stream channels will enhance the hydrology of adjacent wetlands.

In the restoration areas, the hydrology has been removed because of the ditching and the channelization of the associated streams and the severly limited infiltration of ponded waters. The land surface of these areas has been smoothed, crowned, ditched (UT1 and UT6), altered by cattle access, and stripped of forest cover. These areas may be graded (a maximum of 6 inches) to bring the ground elevation within a foot of the mean growing season water table. The land surface will be reshaped to allow over-bank flows to route though the wetland. The grading also will create microtopography to increase ponded water detention and infiltration times. The areas that currently are open fields will be revegetated with woody species, thereby increasing hydraulic roughness of the floodplain, which will lead to an increase in the duration of flooding in these areas. Restoring the streams and backfilling the ditches will restore the local ground water table and increase the frequency and duration of flooding from smaller storm events. These modifications, shown on the **Restoration Plan**, should restore wetland hydrology.

7.6 Soil Restoration

Soils within the riparian restoration areas will be treated to facilitate the growth and development of plantings. The soils will be ripped prior to planting to break up compacted soils and create a favorable environment for new plants. Plant nutrients and soil amendments will be applied to the soils as prescribed by the soils test report performed by the North Carolina Department of Agriculture and Consumer Services Agronomic Division for sample sites located throughout the project area (**Appendix 12**).

7.7 Natural Plant Community Restoration

The goal of the riparian restoration is to provide long-term improvements to ecological functions of the existing forest community. The Restoration Plan Design Sheets have been developed to provide these functional uplifts through the re-establishment of targeted natural communities. The targeted natural communities were determined by comparing existing site conditions to established communities and verifying appropriate species in the proximate reference natural communities. Based on the North Carolina Natural Heritage Program's Nature Community Classification, the site's riparian area most closely correlates to Piedmont/Mountian Bottomland Forest in the riparian areas (Schafale and Weakley 1990).

7.7.1 Reforestation Scheme

The goal of the planting scheme is to establish a riparian community consistent with the reference community, using an approach that accelerates the successional process and leads to a mature riparian community. The planting plan will use the reference plant communities discussed in the previous paragraph as a base for designing a planting scheme and developing a vegetation list.

Recolonization of cleared riparian habitats characteristically begins with the invasion of a pioneer species that creates an environment (e.g. shading) suitable for species typically found in a mature community. To initialize the proposed riparian community, the restoration area will be planted with a mix of pioneer and climax species that have been selected and arranged to meet the following objectives:

- Establish mix of shade-intolerant canopy and shade-tolerant understory species
- Provide vegetative source of dominant species
- Establish local seed sources for those species less likely to migrate into the restoration area
- Stabilize disturbed or high stress areas

Five planting zones have been developed considering site hydrology, soils, and disturbance regimes and are referenced to natural communities. Each zone has a unique environment that dictates species selection and community structure. A planting list has been developed for each zone to match the vegetation in the reference community and meet the objectives given above. The planting list only includes species that are readily available and have a reasonable expectation of survival. For a given zone and species, a plant source and planting type (e.g. containerized or bare root) are recommended. Then, a planting schedule is developed so that site preparation and plant installation occur at the optimal time and season. After installation, the planting will be verified. Finally, a maintenance plan is developed to promote long-term success of the planting. The planting plan components are described below in more detail.

7.7.2 Planting Zones

The planting plan includes five zones of distinct vegetative composition and structure.

- Zone 1 – Stream Bank (0.7 acres)
- Zone 2 – Riparian/Bankfull Areas (6.5 acres)
- Zone 3 – Transitional Edge (2.0 acres)
- Zone 4 – Wetland Bottomland Hardwood (15.8 acres)
- Zone 5 – Supplemental Plantings (0.4)

The zones are mapped on the **Restoration Plan** and are described below.

Zone 1 – Stream Bank

The stream bank zone includes the stream bank from base flow to bankfull. The zone features the steepest slopes (3 to 8%) of the zones and highest saturation levels. This environment dictates the planting of fast-growing, obligate pioneer species to provide stability to areas at or below bankfull.

Zone 2 – Riparian/Bankfull Areas

The riparian/bankfull areas zone encompasses the area from Zone 1 to the edge of the easement, excluding the areas designated as Zone 3, 4, and 5. Zone 2 is an area exposed to regular stream flows and frequent soil deposition. The most stressed areas are located on the outside bends of meanders. The banks will be planted with fast-growing, deep-rooted species that will provide biostabilization and shading to the stream.

Zone 3 – Transitional

The transitional zone includes an approximate 10-foot buffer between zones 2, 4, and 5 and an adjacent open area such as a field outside of the conservation easement. The planting list consists of smaller species that tolerate full sun and will eliminate an abrupt boundary between the open field and interior zones.

Zone 4 – Wetland Bottomland Hardwood

The wetland bottomland hardwood zone covers planting zones in the wetland restoration areas where the inundation or saturation occurs for a long enough period of time during the growing season to select species more adapted to hydric conditions.

Zone 5 – Supplemental Plantings

The supplemental plantings zone contains similar species to Zone 4 and will be used in areas designated for wetland enhancement.

7.7.3 Plant List

The plant list (See **Restoration Table V**) is based on the target community, reference community, and recommendations from the North Carolina Stream Restoration Institute (Hall 2001) and the North Carolina Ecosystem Enhancement Program (Smith 2004). The selection of species also depends on availability from local nursery sources.

7.7.4 Plant Sources

The planting plan preferentially selects local genetic stock and uses three sources of plants. Two sources—nursery stock and on-site transplants—will be tied directly to the initial planting and will be used in numbers that will meet permit guidelines. The remaining source—recruitment—is factored into the selection of species on the plant list, as the plant list includes a significant portion of species not likely to become established from natural propagation.

Nursery Stock

The planting plan may include any of the following nursery stock forms of woody species: bare roots, containerized seedlings, and ball and burlap. Additionally, the plan may use sod or seeds from commercial sources. The planting plan prescribes that nursery stock be grown under environmental conditions similar to the target environment. The planting list includes alternates in case specific species of pre-ordered plants are not available or acceptable for installation.

On-Site Transplants

Several favorable species grow within the existing site. In the course of constructing a new channel alignment, some individual plants may need to be removed. The individuals of a target species that are of an appropriate size and age may be transplanted into the restoration area.

Recruitment

It is expected that the restoration sites will be populated with species from adjacent communities. The sites will be maintained to keep the number of unwanted species at less than 10% of the total population.

7.7.5 Schedule

The planting plan will be scheduled around stream construction activities and growing season. Special attention will be given to stabilizing disturbed areas that include newly-constructed channels and temporary construction easements. The final vegetation planting will occur after proper site preparation (described below) and during the appropriate season.

Plantings may be staggered based on surrounding activities. Live stake planting on stream banks (Zone 1) will closely follow after channel construction to provide immediate stabilization. On-site transplants will be planted immediately after they are removed from their existing habitat. Planting of Zones 2-4 will occur from late winter to early spring, after construction, to minimize or eliminate threats from the construction, exotic vegetation treatment, and/or unpredictable weather.

7.7.6 Stabilization

Immediately after construction, the stream banks and all disturbed areas will be seeded with permanent and temporary seed mixes. If the season is appropriate, permanent seeding will be completed in conjunction with construction, and temporary seeding will be applied according to Land Quality Section requirements. Within the stream channel (Zone 1), pioneer species that provide immediate bank stabilization will be planted. Live stakes and bare roots will be planted around structure installations and the outsides of meander bends to provide an area of high-density root mass. Coir fiber matting and live stakes will be used along the entire reach of the restored channels to provide stabilization until vegetation can be established.

7.7.7 Site Preparation

Prior to planting the riparian buffer, efforts will be made to eradicate fescue and invasive plants such as multiflora rose, Chinese privet, and Japanese honeysuckle. A permanent seed mix can be used after application of the pre-emergent, and woody planting can follow during the dormant season.

7.7.8 Planting Review

After the final planting is complete, the planting supervisor will verify that the site was properly planted using stem counts and condition inspection. The planting contractor will be responsible for replacing damaged plants.

7.7.9 Monitoring and Maintenance

Monitoring will verify that the restoration area is meeting restoration goals. Damaged plants will be removed and if the planting survival fails to meet restoration goals, replanting will occur. If monitoring indicates that an area is trending toward greater than 10% coverage by nuisance vegetation, that area will be treated to remove the nuisance vegetation.

8.0 Performance Criteria

8.1 Stream Success Criteria

The stream geometry will be considered successful if the cross-section geometry, profile, and sinuosity are stable or reach a dynamic equilibrium. It is expected that there will be some changes in the designed cross sections, profile, and/or substrate composition. Changes that may occur during the monitoring period will be evaluated to determine whether they represent a trend toward a less stable condition (e.g. down cutting, erosion, etc.) or are simply an increase in stability (e.g. settling, vegetative changes, coarsening of bed material, etc.).

An initial, though not exclusive, indicator of success will be the stream's adherence to design or reference ratios of stream geometry found in the morphological table (**Restoration Table IV)** or in comparable stable reference systems. The channel may not adhere to design or reference ratios of stream geometry, but can be considered stable if the following key indicators are present:

- Stream Type: Maintenance of the design stream type or progression toward or conversion to a stable stream type such as B, C, or E will indicate stability.
- Bank Height Ratio: Bank height ratio between 1.0 and 1.2 will indicate that flood flows have access to the active floodplain and that higher flows do not apply excessive stresses to stream banks.

Determination of true bankfull may be difficult until the stream has had adequate flooding events to create strong bankfull indicators. A minimum of two bankfull events is required during the 5-year monitoring period. If two bankfull events do not occur the monitoring period may be extended at the discretion of the Corps of Engineers (see **Section 8.3 Schedule/Reporting**).

Off-site, upstream land use practices likely will lead to episodic sediment pulses sent downstream through the restored stream network. Additionally, erosion of upstream, unstable stream banks will persistently contribute sediment to the project reaches. Excess sediment will either be routed though the project area or deposited in target areas such as point bars and the floodplain. Minor sedimentation of pools and glides may occur. The pools are designed to be over-dug to account for some sedimentation of pools and glides.

If a large storm event occurs before the woody vegetation has been established, isolated bank erosion may occur in sections where the flood-prone area has been restricted by topography and/or utility easements. Areas of bank erosion will be repaired as necessary.

8.2 Wetland Success Criteria

The success of wetland enhancement/restoration will be measured by comparing the restored wetlands with similar, more functional wetlands with respect to vegetation, soils, and hydrology. Success criteria is summarized in the following sections.

8.2.1 Hydrology

Success of the restoration of wetland hydrology will be measured by improvements to the frequency and duration of saturated soils compared to the reference wetland. Successful wetland hydrology is defined as the saturation of soils for a period equal to or greater than 85% of the period measured in the reference wetland. The minimum requirement for the restoration wetland hydrology will be the USACE guidelines (United States Army Corps of Engineers, 1987) including saturation of the upper surface of the soils for 7% of the growing season. The hydroperiod of the reference wetland will be measured using groundwater gauges.

8.2.2 Vegetation

The prevalent vegetation should consist of macrophytes that typically are adapted for life in saturated soil conditions. These species should have the ability to grow, compete, reproduce, and persist in anaerobic soil conditions. For the restoration areas, study plots showing that the composition and density of vegetation in the restoration areas that compare to the reference areas will indicate restoration success for vegetation.

8.2.3 Soil

A primary measure of the enhancement and restoration of wetland soils will be the establishment of hydric character as defined by USACE guidelines (United States Army Corps of Engineers 1987). Soil enhancement and restoration also may be inferred based on successful enhancement and restoration of wetland hydrology and vegetation.

8.3 Vegetation Success Criteria

The success of riparian and vegetation planting will be gauged by stem counts of planted species. Stem counts of more than 320 trees per acres after three years, and 260 trees per acre after five years will be considered successful. Photos taken at established photo points should indicate maturation of riparian vegetation community.

8.4 Schedule/Reporting

The monitoring plan to evaluate the success of the stream restoration project is based on guidance provided by The Stream Mitigation Guidelines disseminated by the United States Army Corps of Engineers – Wilmington District (McLendon, Fox et al. 2003) and recommendations from the Ecosystem Enhancement Program (EEP). The collection and summarization of monitoring data will be conducted in accordance with the most current version of the EEP documents titled "Content, Format, and Data Requirements for EEP Monitoring Reports."

Upon completion of the restoration project, an as-built survey will be conducted that documents the following conditions:

- Geomorphology (dimension, pattern, and profile)
- Channel materials
- Channel stability and in-stream structure functionality
- Vegetation
- Wetland hydrology (gauge settings)
- Vegetation (wetland and riparian)

The survey of channel dimension will consist of permanent cross sections placed at approximately two cross sections (one riffle and one pool) per unique stream segment. The cross sections will represent approximately 50% riffles and 50% pools. Annual photographs showing both banks and upstream and downstream views will be taken from permanent, mapped photo points. The survey of the longitudinal profile will represent distinct areas of restoration and will cover a cumulative total of 3,000 linear feet of channel. The profile survey will include pattern measurements and include all permanent cross sections. Channel material measurements will be collected by using pebble counts for at least six of the permanent cross sections.

The entire restored length of stream will be investigated for channel stability and in-stream structure functionality. Any evidence of channel instability will be identified, mapped, and photographed. All structures will be inventoried for functionality and photographed.

Wetland hydrology will be measured using groundwater gauges installed on-site and within the reference sites. The gauges will sample groundwater elevations continuously throughout the monitoring period.

Successful restoration of the vegetation buffer on a stream mitigation site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, vegetation-monitoring quadrants will be installed across the restoration site, as directed by NCEEP monitoring guidance. The number of quadrants required will be based on the species/area curve method, as described in NCEEP monitoring guidance documents, with a minimum of at least three quadrants. The size of individual quadrants vegetation-monitoring plots will be installed on approximately 1.0% of the restoration site. The individual monitoring plots will be 0.01 hectare in size. Vegetation monitoring will occur in spring after leaf-out has occurred. Individual quadrant data will be provided and will include diameter, height, density, and coverage quantities. Relative values will be calculated and importance values will be determined. Individual seedlings will be marked such that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living planted seedlings and the current year's living planted seedlings. At the end of the first growing season, species composition, density, and survival will be evaluated. For each subsequent year, until the final success criteria are achieved, the restored site will be evaluated between July and November. Permanent photo points will be set up for each quadrant.

The monitoring will occur annually for five years. The monitoring period should include two separate years with bankfull events. Bankfull events will be verified using an installed crest gauge that will be inspected during each monitoring visit. If a bankfull event has not been documented by the end of the second year of monitoring, a mandatory quarterly check will be required. If there are not two bankfull events, the monitoring period may be extended at the discretion of the Corps of Engineers, Raleigh Regulatory Field Office Project Manager and the NCDWQ 401-Wetlands Unit. Monitoring reports will be submitted during every year for years 1-5.

Monitoring for the progress of vegetation restoration on wetland areas will follow protocol developed by the Carolina Vegetation Survey (CVS) Level 1 and 2 inventory plots. Level 1 maps and tracks the health of planted stems. Level 2 counts all woody stems, including recruits, by size groups. Modules, the standard area of inventory, have dimensions of 10 meters by 10 meters. The modules will be placed randomly throughout the restoration and enhancement areas. The total area inventoried by the modules will compose 3 to 5% of the total restoration and enhancement area. Initial sampling will occur within 60 days of the plantings. The Year 1 monitoring will occur during September with subsequent year's samplings occurring between June 1 and October 31. Permanent photo points will be set up for each quadrant. The monitoring will occur annually for 5 years.

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