Hanging Rock Creek Mitigation Plan Banner Elk, North Carolina

State Work Order Number 6.739003T
T.I.P. Number R-2237WM
Consulting Project Number 00-BU-01

North Carolina Department of Transportation
Project Development and Environmental Analysis Branch

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Prepared For:

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Project Development and Environmental Analysis Branch

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Executive Summary

The North Carolina Department of Transportation (NCDOT) proposes to restore 3,687 feet of Hanging Rock Creek and an unnamed tributary to improve the stream's natural resources and for the purpose of obtaining stream mitigation credit. Hanging Rock Creek is located in Avery County, North Carolina and is part of the Watauga River Basin. The watershed has a total drainage area of 3 square miles and is located in the Elk River drainage, eight-digit hydrologic unit code (HUC) 06010103. The proposed project area is at the very lower end of Hanging Rock Creek.

Hanging Rock Creek in the project area is an unstable gravel bed stream (Rosgen classification C4 and E4 stream types with bank height ratios ranging from 1.3 to 1.9). Past land use activities, including the clearing of riparian vegetation, channel straightening and grazing, have resulted in bank erosion and ongoing channel widening, loss of bedform diversity and aquatic habitat degradation. Current bank erosion is producing an estimated annual sediment load in excess of 25 tons per year.

The project is divided into two reaches with varying existing conditions and restoration potential. This report describes the recommended restoration approach for both reaches, including detailed descriptions of channel geometry modifications, structure installations, and riparian vegetation and wetland plantings. Wetland enhancement is also proposed along an existing stormwater ditch. The table below lists the existing and proposed reach lengths, restored buffer area and the restoration approach for each study reach.

Reach	Existing Length (ft)	Restored Length (ft)	Restored Buffer (acre)	Restoration Approach
1	2,311	2,808	10.2	Restore Stream Dimension, Pattern and Profile
2 (Tributary)	817	879	1.4	Stream Enhancement
Wetland easement	NA	NA	1.0	Wetland Enhancement
Total	**3,128**	**3,687**	**12.6**	

In addition to providing mitigation credits to offset unavoidable impacts to streams within the same watershed, other environmental benefits will be realized. Restoration of the stream channel to a natural form will stabilize the stream and greatly reduce bank erosion and sediment pollution from the project area. Restoration of native floodplain vegetation and a forested riparian buffer will protect water quality through improved floodplain and wetland functionality. Increased stream diversity in the form of meanders, pool and riffle sequences and vegetated stream banks will improve aquatic habitat, the local trout fishery and the natural aesthetics of the stream corridor.

Table of Contents

List of Figures

List of Tables

List of Sheets

1 Introduction

1.1 Project Description

The North Carolina Department of Transportation (NCDOT) proposes to restore **3,687** feet of Hanging Rock Creek and an unnamed tributary using natural channel design and bioengineering techniques. NCDOT believes that this work will enhance the natural resource value of the stream and riparian area and will qualify for stream mitigation credit. Hanging Rock Creek is located in Avery County, North Carolina and is part of the Watauga River Basin. The watershed has a total drainage area of 3 square miles and is located in the Elk River drainage, eight-digit hydrologic unit code (HUC) 06010103. The project location is shown on Figure 1.1 and the watershed delineation is shown on Figure 1.2.

The project stream flows through a 45-acre tract presently being considered for low density development. Current plans call for conversion of open grazing lands to home sites, a small commercial area and recreational areas. Some pasture land would be maintained for horses. NCDOT has worked with the landowner to determine the feasibility of stream restoration and riparian buffer establishment on the site. The landowner is interested in stream and buffer restoration to improve the local trout fishery and the natural aesthetics of the stream corridor. The landowner is willing to donate a 12.6-acre conservation easement on the site, including most of the land below the 100-year flood plain elevation, to protect wetland and riparian areas.

The project is divided into two reaches, Hanging Rock Creek (Reach 1) and the unnamed tributary (Reach 2). Reach 1 begins at Dobbins Road and continues downstream to Highway 184. Both roads cross Hanging Rock Creek with culverts. The unnamed tributary enters Hanging Rock Creek from the South. Several ditches used to drain pastures also enter Hanging Rock Creek throughout the project reach. The project reaches are shown in Figure 1.3. The lengths and drainage areas for the two reaches are shown in Table 1.1.

Table 1.1 Project Reaches with Existing Length and Drainage Area.

Reach	Length (ft)	Drainage Area (mi^2)
Reach 1 – Hanging Rock Creek	2,311	3.0
Reach 2 – Unnamed Tributary	817	0.26
Total	**3,128**	

1.2 Goal and Objectives

The goals of this project are to:

1. Restore the channel to a natural stable form,
2. Improve floodplain and wetland functionality,
3. Reduce sediment load discharged to the Elk River
4. Restore native floodplain vegetation through a forested riparian buffer,
5. Improve the trout fishery and natural aesthetics of the stream corridor, and
6. Acquire mitigation credits for other unavoidable impacts to streams within the same HUC (06010103).

The project will provide mitigation credits to offset unavoidable impacts to streams and wetlands within the same watershed and other environmental benefits will be realized. In addition, restoration of the stream channel to a natural form will stabilize the stream and greatly reduce bank erosion and sediment pollution from the project area. Restoration of native floodplain vegetation and a forested riparian buffer will reduce water temperatures and protect water quality through improved floodplain and wetland functionality. Increased stream diversity in the form of meanders, pool to riffle sequences and vegetated stream banks will improve aquatic habitat, the local trout fishery and the natural aesthetics of the stream corridor.

2 Existing Condition Survey

2.1 Summary Information for Existing Project Reaches

Summary information for the existing Hanging Rock Creek stream reaches is presented below in Table 2.1. Narrative descriptions describing the existing condition of the project reaches are given in sections 2.4 through 2.5.

Table 2.1 Selected natural channel existing condition parameters for Hanging Rock Creek.

Reach Name		Reach 1 Hanging Rock	Reach 2 Unnamed Trib.
Rosgen Stream Type		C4	C4
Drainage Area (square miles)		3.0	0.26
Reach Length (ft)		2,311	817
Dimension	Bankfull Area (sq ft)	41	7
	Bankfull Width (ft)	28	10.4
	Width/Depth Ratio (ft)	20	24
	Bankfull Mean Depth (ft)	1.4	0.4
	Bank Height Ratios	1.3	1.6
Pattern	Meander Length (ft)	600	na
	Radius of Curvature (ft)	100	na
	Meander Belt Width (ft)	120	na
	Sinuosity	1.4	1.2
Prof ile	Valley Slope (ft/ft)	0.0089	0.0020
	Channel Slope (ft/ft)	0.0064	0.0017

2.2 Geology and Soils

Hanging Rock Creek is located in a wide alluvial valley. The valley is composed of fine alluvium (sand and silt), which has been deposited on the floodplain to a depth of two to three feet. Larger gravels and cobble are found below the alluvium and in the streambed. Various types of schist found in the Grandfather Mountain Formation underlie the valley. Outcrops are prevalent along the hillslope.

The soils along the stream are classified as Cullowhee loam with characteristic very deep profiles (>60 in to bedrock), frequent flooding, and slope less than 3 percent. These soils have somewhat poor drainage but rapid permeability and a low shrink swell potential. The seasonal high water table appears between 1.5 to 2.0 feet and these soils have very low erosion potentials. The surface layer contains a significant amount of organic matter and is typically a dark brown loam. The subsoil is typically a brown loam with dark grayish brown iron depletions. Underlying material usually contains a dark gray sandy loam with yellowish brown iron accumulations overlying a yellowish brown loamy sand with dark gray iron depletions. Cobbles increase in number with increasing depth in the underlying layers.

Auger samples were taken on site and some variation was observed within the Cullowhee soil series. Some surface layers were more sandy in texture and other soil profiles showed an increasing clay content with depth, becoming a sandy clay loam in the underlying layers. These profiles were noted inclusions in this area according to soil survey information obtained.

2.3 Land Use

The watershed is predominantly agricultural, forested and rural residential. The aerial photograph presented in Figure 2.1 demonstrates the low density nature of the watershed. There are no land use zoning restrictions for any portions of the Hanging Rock watershed. A golf course and low-density residential neighborhood (Diamond Creek, John McNeely) is currently under construction upstream of the project area. As long as standard sediment control practices are implemented, this development does not threaten the proposed restoration project. According to the Avery County Planning and Inspections Department, other than “The Farm at Banner Elk” development planned for the project site, no new development is proposed within the watershed.

The current land use adjacent to the project reach is pastureland. The cattle presently have full access to Hanging Rock Creek, the unnamed tributary, drainage ditches, and wetland areas. Over the next year, the land use on the project parcel will change from pastureland to low density residential and commercial although some pastureland will be maintained for horses. Figure 2.2 shows the proposed development plan for the area surrounding the project. However, development will remain outside of the 100-year floodplain providing an extensive floodplain width and belt width for restoration.

2.4 Reach 1 – Hanging Rock Creek

2.4.1 <u>Channel Morphology</u>

Hanging Rock Creek is classified as an unstable Rosgen C4 stream type (one of five riffle cross sections has a width to depth ratio less than 12, resulting in an E4 stream classification). The existing condition survey is shown in Appendix 1 and includes cross sections, a longitudinal profile, and a bed surface material distribution. The existing plan view drawing is shown in Figure 2.3. In general, Hanging Rock Creek is overly wide. Therefore the stream is too shallow for optimum fish habitat and has a reduced sediment transport capacity. The width/depth ratio ranges from 12 to more than 20 with the highest width/depth ratios in sections with high streambank erosion. Generally, reference reach streams with similar slope and substrate have much lower width/depth ratios. Bedrock knickpoints and the downstream culvert at Highway 184 control the grade of the channel. Even though the stream was likely straightened in the past, these structures have prevented the channel from down cutting. The bank height ratios range from 1 to 1.5, meaning that the top of bank elevation ranges from equaling bankfull to being 1.5 times higher than bankfull. Low bank height ratios indicate that the stream has access to its floodplain during large discharge events.

Hanging Rock Creek is moderately sinuous for a C4 channel. Unlike most North Carolina streams in alluvial valleys, Hanging Rock Creek was not relocated to the edge of the hillslope (except a short section towards the upper end of the reach). However, based on the layout of the drainage ditches, and the long straight sections, the stream was probably channelized in the past.

The longitudinal profile (shown in Appendix 1) shows some diversity of riffles and pools with long sections of runs. The average slope for this reach is 0.0064 ft/ft, a moderate yet appropriate slope given the C4/E4 stream types.

Streambank erosion is prevalent throughout the reach. Bank erosion was characterized at three sites within the project area using a Bank Erosion Hazard Index (BEHI) (Rosgen, 2001). Field measurements of bank height, bankfull height, root depth, root density, bank angle and surface protection were used along with bank material and stratification information to determine a BEHI score. BEHI scores for Hanging Rock Creek ranged from 43 to 50, resulting in ratings of Very High to Extreme erosion potential (Patterson, 2001). BEHI scores on stable stream banks are generally well below 20.

Streambank erosion rates have been measured at the BEHI sites over the past two years. High erosion has been noted at stations 2+50, 4+43, 4+87, 6+45 and 15+00. Measured erosion rates ranged from 0.3 to 0.7 ft/yr with typical bank heights of 1.2 to 1.6 ft. Approximately 680 feet of stream bank in the project area are typical of erosion rates of 0.3 ft/yr and approximately 250 feet are likely eroding at 0.7 ft /yr (Patterson, 2001). From this it is estimated that Reach 1 is producing an annual sediment load in excess of 25 tons per year.

2.4.2 Floodplain Vegetation Assessment

The floodplain is open active pasture consisting primarily of fescue (*Festuca* spp.) and Bermuda grass (*Cynodon dactylon*). Streambank vegetation consists of multiflora rose (*Rosa multiflora*), black willow saplings (*Salix nigra*), soft rush (*Juncus effusus*), sedges (*Carex* spp.), rice-cutgrass (*Leersia oryzoides*), and fescue. A clump of mature red maple (*Acer rubrum*) and sweet birch (*Betula lenta*) trees exist along the streambanks near the downstream area of the project study. The ditches within the floodplain are vegetated with sedges, soft rush, rice-cutgrass, water primrose (*Ludwigia palustris*), and sparse black willow saplings.

2.4.3 Wetland Assessment

One ¼-acre wetland is located in the floodplain adjacent to the right bank near the downstream end of the project reach. This wetland is best described as a disturbed freshwater marsh. Dominant vegetation consists of soft rush, sedge, rice-cutgrass, and fescue. Wetland vegetation is also present in many of the ditches in the project area.

2.4.4 Benthic Macroinvertebrate Assessment

Benthic macroinvertebrates were collected at three sites within and adjacent to the project area on April 7, 2001 (Figure 2.4). Two sites were located on Hanging Rock Creek, one in the downstream section of Hanging Rock Creek (Site 1, Test site) within the project area, and one in a reach upstream of the project area (Site 3, Reference site), below the confluence of Horse Bottom Creek and Hanging Rock Creek. A collection was also performed in the unnamed tributary (Site 2) just upstream of the project area and is described in the Reach 2 section below. The sampling methodology followed the Qual-4 protocol listed in the NC DWQ's *Benthic Macroinvertebrate Monitoring Protocols for Compensatory Stream Restoration Projects*. Summary of the results of benthic macroinvertebrate sampling at the individual stations are presented in Table 2.2, with complete results presented in Appendix 2. Metrics summarizing the data are also compiled in the table. The samples collected describe diverse communities of benthic macroinvertebrates, although the samples collected at Site 2 (unnamed tributary) had fewer taxa than those collected at the other stations.

Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), collectively referred to as EPT taxa, are considered by aquatic ecologists to be intolerant of pollution or other forms of environmental degradation. Therefore, presence of substantial numbers of EPT taxa and individuals is considered indicative of relatively undisturbed "higher quality" streams.

Table 2.2 Summary of Benthic Macroinvertebrates data from Hanging Rock Creek

Sites	EPT Taxa Richness*	EPT Abundance	EPT Biotic Index	Biotic Index	Total Taxa Richness	Overall Rating**
Site 1	25	115	3.22	3.93	44	Good
Site 2	17	64	3.11	4.48	29	Good-Fair
Site 3	23	104	2.58	2.98	43	Good

*EPT taxa are generally intolerant of pollution or other forms of environmental degradation.
** Overall Rating was calculated by incorporating both EPT Taxa Richness and Biotic Index ratings derived from NCDWQ's Standard Operating Procedures for Benthic Macroinvertebrates. However, NCDWQ has not yet developed an official rating scheme for the QUAL-4 Method that was used for this project.

Total and EPT taxa richness values were similar between Site 1 (44 and 25) and Site 3 (43 and 23). Both biotic and EPT Biotic Indices were lower for Site 3 than Site 1. Lower biotic indices generally reflect better water quality. While total and EPT taxa richness values were similar between Sites 1 and 3, the benthic community structure between the two sites was somewhat different (46.8% similarity). The major differences between the two sites were observed in the shredder and scraper communities. The taxa richness and abundance for the shredder community were higher in Site 3 (7 genera), dominated by significant numbers of *Tallaperla* stoneflies, *Tipula* craneflies, and *Pycnopsyche* caddisflies. Site 3 also had high numbers of the *Paraleptophlebia* mayfly, a collector-gatherer of coarse particulate organic material (CPOM) and a faculatative shredder (Merritt and Cummins, 1996). The presence of shredders and collector-gatherers of CPOM within a community reflects the availability of CPOM resources such as autumn-shed leaves and woody debris from the riparian buffer vegetation. The riparian buffer along the upper section of Site 3 is composed of woody vegetation including ironwood (*Carpinus caroliniana*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), sweet birch (*Betula lenta*), red maple (*Acer rubrum*), multiflora rose (*Rosa multiflora*) and other woody vegetation. The leaf litter and woody debris from this buffer provide an excellent source of CPOM for that site.

The lack of a substantial shredder community at Site 1 (two *Pteronarcys* stoneflies, one *Tallaperla* stonefly and one *Tipula* cranefly) may reflect the lack of available CPOM resources (i.e. no woody riparian buffer) at the site. This was supported by the scarcity of leaf packs observed at the site. Establishing a woody riparian buffer should help in recruiting additional shredder species. Sites 2 and 3 provide excellent refugia for those additional species.

The taxa richness and abundance for the scraper community were higher in Site 1 (17 genera) than Site 3 (12 genera). Most of the species found at Site 1 but not at Site 3 were intolerant and include *Psephenus herricki* (water penny), *Glossosoma* and *Goera* caddisflies, and *Stenonema pudicum* (mayfly). This increase in scraper species may be in response to more available food resource (periphyton) caused by the more open canopy at Site 1. Establishing a riparian buffer along this site will provide more stream shading, limiting periphyton photosynthesis. This may reduce the percentage of scrapers while increasing shredder community significance within the overall community.

2.5 Reach 2 –Unnamed Tributary

2.5.1 <u>Channel Morphology</u>

Along with three significant ditches, an unnamed tributary to Hanging Rock Creek enters at the middle of Reach 1 from the south side. The stream drains a small, semi-forested watershed (0.26 mi^2). The section of stream flowing adjacent to the wood line is classified as a F4 stream type. The stream is currently building a new floodplain at a lower elevation than the pasture and is evolving into an E4 type stream. Downstream of the wood line, the tributary looks more like a drainage ditch. The tributary has been straightened to serve as a ditch and so is less sinuous than most natural C4 channels. The streambanks have been graded and the bed widened. The bed is mostly vegetated as shown in the cross section photo in Appendix 1.

The longitudinal profile (shown in Appendix 1) shows minor diversity of riffles and shallow pools with long sections of runs. The average slope for this reach is 0.0017 ft/ft, a gentle slope that could support an E4 stream type.

Streambank erosion is not severe in this reach although some erosion results from hoof shear as cattle cross the stream. Bank erosion is particularly evident at the upper end of the reach. Grass dominated vegetation on the banks does assist with bank stability as the bank heights are relatively low at the lower end of the reach.

2.5.2 <u>Floodplain Vegetation Assessment</u>

The floodplain below the wood line along the tributary is similar to Reach 1. The vegetation along and within the streambanks below the wood line is also similar to that described for the drainage ditches in Reach 1, consisting primarily of sedges, soft rush, rice-cutgrass, fescue and water primrose.

The forested buffer farther upstream is dominated by red maple, eastern hemlock (*Tsuga canadensis*), sweet birch, beech (*Fagus grandifolia*), black oak (*Quercus velutina*), northern red oak (*Q. rubra*) and rhododendron (*Rhododendron maximum*). Fescue and sedges form the herbaceous layer along the streambanks of this section.

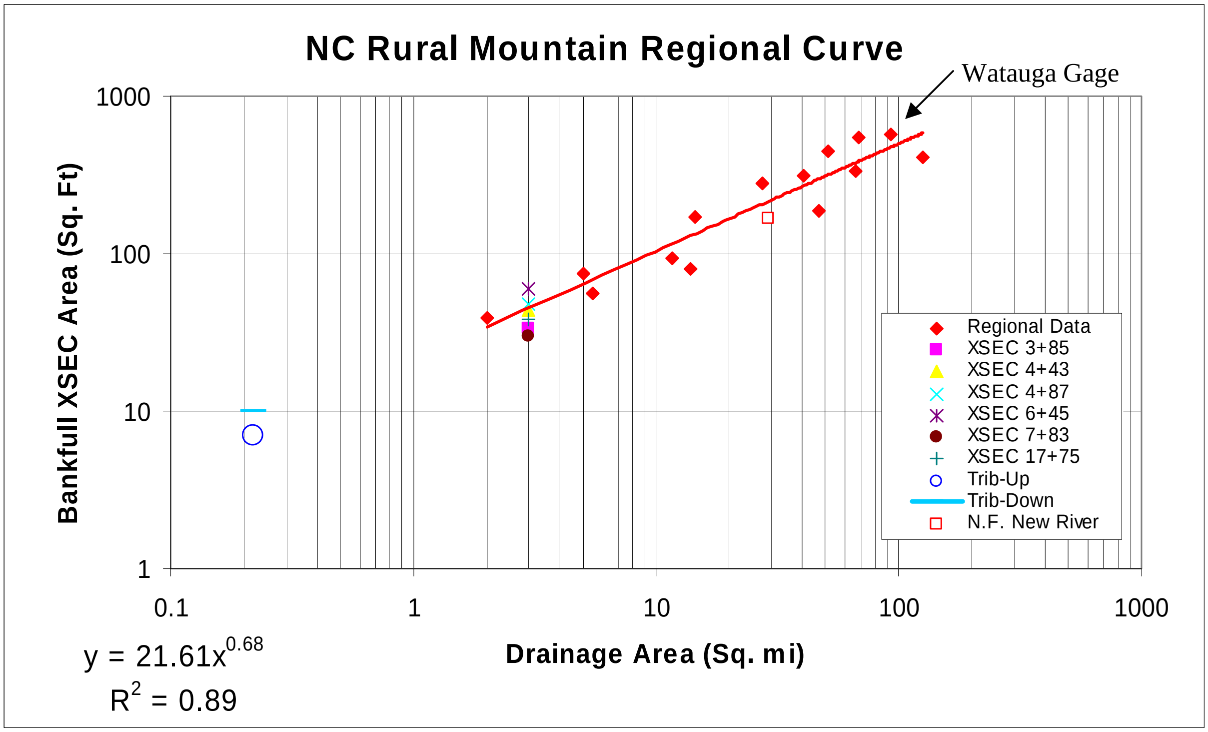
2.5.3 Benthic Macroinvertebrate Assessment

Site 2 was sampled within the wooded buffer area just upstream of the project area of Reach 2. Data are presented in Appendix 2. This site is used as a reference site for the section below the wood line that is heavily silted in and choked with herbaceous vegetation. The total and EPT taxa richness was less at this site compared to Sites 1 and 3 (Table 2.2) but still showed fairly high numbers (29 and 17, respectively). The biotic index (4.48) was fairly low, indicating good water quality, but not as good as at Site 1 (3.93) and Site 3 (2.98). The small stream size of Site 2 (.26 mi^2) relative to Site 3 (3 mi^2) may contribute to the difference of the metrics between the sites. Larger sites (2^{nd} and 3^{rd} order streams) typically support more fauna than small 1^{st} order streams due to having more diverse habitat (i.e. larger substrate). Site 2 had evidences of cow crossings that would negatively impact the stream, thus affecting the taxa richness and biotic index numbers. Overall, this site provides an excellent source of refugia for the project area downstream.

3 Bankfull Stage Verification

The bankfull stage was identified in the field as the top of the streambank and the back of a bar (bench). These indicators average two feet above the baseflow water surface elevation. The bankfull cross sectional area measured in the field was overlaid with the NC Mountain Regional Curve (Harman et al, 2001) to verify the field indicators. The overlay is shown in Figure 3.1.

Figure 3.1 Bankfull stage verification for Hanging Rock Creek and the Unnamed Tributary.



The Watauga Gage station was previously surveyed under a different project and is included in the Mountain Regional Curve. The Watauga Gage point is highlighted on Figure 3.1 and shows that the project site is representative of the Mountain Regional Curve.

4 Reference Reach Analyses

The North Fork New River was selected as the reference reach for the Hanging Rock Creek Project. The North Fork has a drainage area of 29 square miles and is located near Creston, Ashe County, North Carolina. More specifically, the project site is located at the River Bend Estates. The North Fork reference reach is classified as a C3 stream type because the median particle size (d50) is 75mm, cobble size. This is much larger than the d50 of Hanging Rock Creek, which is approximately 1mm (Appendix 1). Larger size bed material often creates a larger width/depth ratio because there is more friction exerted by the bed meaning that the channel is therefore not as efficient hydraulically (all other factors being equal). The stable riffles in Hanging Rock Creek had a width/depth ratio of 12 to 15, whereas the North Fork had a width/depth ratio of 16. Given that the riffles were stable and the median bed material size was smaller than the North Fork, the Hanging Rock Creek stable riffles were used as a reference for the design cross section.

The North Fork New River, however, had much more natural pattern and profile than Hanging Rock. The North Fork also did not have signs of bank erosion. Therefore, the North Fork was used as a reference for channel pattern and profile for the Hanging Rock Creek design channel. Reference channel dimension came from stable cross sections along Hanging Rock Creek and the NC mountain regional curve. The summary data and reference reach ratios are shown on the design table in Table 5.1. Reference data describing the North Fork New River were developed by the NRCS (Jessup, pers. Comm.).

No C4/E4 reference reaches are present in the Hanging Rock Creek watershed. Each potential reference reach in the watershed either passes through pastureland or is a steep gradient stream of type A or B. Even though the North Fork New River is not in the same watershed as Hanging Rock Creek, both watersheds have similar valley slopes, climate and watershed hydrology.

In addition to the North Fork New River reference reach other Watauga River Basin restoration projects were used to guide design. Successful restoration projects on Cove Creek, Worley Creek and the Shawneehaw River provided a valuable dataset used to fine tune the proposed hanging Rock Creek design.

The Mill Branch was selected as the reference reach for the tributary, Reach 2. The Mill Branch is a small tributary in Surry County that possesses good pattern. The summary data and reference reach ratios are shown on the design table in Table 5.2. The Mill Branch was surveyed by the North Carolina State University Biological and Agricultural Engineering (Clinton, 2000).

5 Natural Channel Design

5.1 Design Summary

The proposed natural channel design is the highest level of restoration achievable given the valley and stream type. The proposed development for the restoration area, “The Farm at Banner Elk,” will not impede the restoration effort because the majority of the stream corridor has been secured with a conservation easement. Therefore, the proposed design will restore channel dimension, pattern, and profile, as well as the adjacent floodplain and wetlands. In addition, stormwater Best Management Practices (BMPs) will be installed to treat runoff from the proposed development. A summary of the proposed design for Hanging Rock Creek (Reach 1) is provided in Table 5.1, the proposed tributary design (Reach 2) is provided in Table 5.2. A description of the design, including the planting design within the conservation easement boundary is discussed below.

5.2 Reach 1 - Hanging Rock Creek

5.2.1 <u>Morphological Restoration</u>

The reach upstream of Dobbins Road will be stabilized using a rock cross vane and root wads. The root wads will be driven into the streambank to prevent bank erosion and provide aquatic habitat. The rock cross vane will be installed upstream of the culverts to prevent bank erosion around the culverts and to direct the higher velocities in the center of the channel.

On the downstream side of the culvert, a stable dimension, pattern, and profile will be established. In addition, the culvert will be extended approximately 6 feet to accommodate road shoulder widening. A plunge pool and rock cross vane will be designed to dissipate stream power at the culvert exit and maintain channel grade.

The remainder of Hanging Rock Creek will consist of a newly constructed C4 stream type. J-Hook or single rock vanes will be installed entering each meander bend. A root wad complex will be installed in the apex of the bend with cover logs for habitat. Cross vanes will be installed between each glide and riffle. The plan view of the proposed new channel, including structures, is presented on Sheet 1. Design cross sections are presented in Appendix 3. A C4 stream type was selected rather than an E4 for several reasons listed below:

1. Stable cross sections along the existing alignment have bankfull width/depth ratios of 12, which is characteristic of a “C” stream type.
2. A “C” stream type is less vulnerable than an “E” to bank erosion during the first few years after construction when vegetation is re-establishing. Sod mats from onsite sources can be used; however, there is not enough supply to stabilize the

entire channel. Since the “C” stream type has a higher bankfull width/depth ratio, the shear stresses are lower and streambank vegetation typically establishes quickly.

3. Once streambank vegetation becomes established, the stream will naturally narrow and evolve from a “C” towards an “E” stream type in years to come.

Three ford crossings of Reach 3 will be installed to allow horses to move between pastures (see Figure 2.1 and Sheet 1). At some later date, one or more of these crossings may be converted by the landowners to a footbridge. The crossings will be approximately 8 feet wide and will be constructed of fiber cloth covered with Grade A stone. A sewer crossing will likely be constructed at a later date towards the bottom of Reach 1 (see Figure 2.1 and Sheet 1).

Table 5.1 Natural channel design parameters for Hanging Rock Creek (Reach 1).

Reach 1 Parameters		**Existing**	**Design**	**North Fork New River**
Rosgen Stream Type		C4	C4	C3
Drainage Area (sq mi)		3.0	3.0	29
Reach Length (ft)		2,311	2,808	1,500
Dimension	Bankfull Width (ft)	28	22	52
	Bankfull Mean Depth (ft)	1.4	1.9	3.2
	Width/Depth Ratio (ft)	20	12	16
	Bankfull Area (sq ft)	41	41	169
	Bankfull Mean Velocity (ft/sec)	5.6	5.7	5.9
	Bankfull Discharge (cfs)	232	232	1000
	Bankfull Max Depth (ft)	2.9	2.3	4.5
	Width of Floodprone Area (ft)	300	300	235
	Entrenchment Ratio	11	14	4.5
	Max Pool Depth (ft)	4	5	3.5
	Ratio of Pool Depth to Bankfull Depth	1.4	2.2	1.1
	Pool Width (ft)	35	28	51
	Ratio of Pool Width to Bankfull Width	1.3	1.3	1
	Pool to Pool Spacing (ft)	--	100 - 200	320
	Ratio of Pool to Pool Spacing to Bankfull Width	--	4.5 – 9.0	6.1
	Bank Height Ratio	1.3	1.0	1.0
Pattern	Meander Length (ft)	600	200 – 350	640
	Meander Length Ratio	21	9 – 18	18 - 20
	Radius of Curvature (ft)	100	40 – 66	42 - 69
	Radius of Curvature Ratio	3.6	1.8 – 3.0	0.8 – 1.3
	Meander Belt Width (ft)	< 120	74 - 120	192 - 300
	Meander Width Ratio	na	3.4 – 5.5	3.7 – 5.7
	Sinuosity	1.4	1.5	1.5
Profile	Valley Slope (ft/ft)	0.0089	0.0089	0.0072
	WS Slope (ft/ft)	0.0064	0.0059	0.0048
	Pool Slope (ft/ft)	0	0	0
	Ratio of pool slope to WS slope	0.1	0.1	0.1

Table 5.2 Natural channel design parameters for the Hanging Rock Creek tributary (Reach 2).

Reach 2 Parameters		Existing	Design	Mill Branch
Rosgen Stream Type		C4	E4	E4
Drainage Area (sq mi)		0.26	0.26	4.7
Reach Length (ft)		817	879	224
Dimension	Bankfull Width (ft)	10.4	7	13.7
	Bankfull Mean Depth (ft)	0.4	0.9	2.1
	Width/Depth Ratio (ft)	24	8	6.6
	Bankfull Area (sq ft)	7	7	28
	Bankfull Mean Velocity (ft/sec)	2.9	2.9	5.9
	Bankfull Discharge (cfs)	20	20	80
	Bankfull Max Depth (ft)	1.4	1.4	3.6
	Width of Floodprone Area (ft)	300	300	415
	Entrenchment Ratio	29	42	30
	Max Pool Depth (ft)	na	2.0	4.2
	Ratio of Pool Depth to Bankfull Depth	na	1.4	1.2
	Pool Width (ft)	na	10.5	19.6
	Ratio of Pool Width to Bankfull Width	na	1.5	1.4
	Pool to Pool Spacing (ft)	na	50 - 80	73 - 76
	Ratio of Pool to Pool Spacing to Bankfull Width	na	7.1 – 11.4	5.3 – 5.5
	Bank Height Ratio	1.6	1.0	1.0
Pattern	Meander Length (ft)	--	140	95 – 108
	Meander Length Ratio	--	20	7 - 8
	Radius of Curvature (ft)	--	13 - 22	23 - 126
	Radius of Curvature Ratio	--	1.8 – 3.0	1.7 – 9.0
	Meander Belt Width (ft)	--	40	23 - 54
	Meander Width Ratio	--	5.7	2 - 4
	Sinuosity	1.2	1.4	1.7
Profile	Valley Slope (ft/ft)	0.0020	0.0020	0.0136
	WS Slope (ft/ft)	0.0017	0.0017	0.008
	Pool Slope (ft/ft)	0	0	0
	Ratio of pool slope to WS slope	0.1	0.1	0.1

5.2.2 <u>Riparian Buffer Restoration</u>

A combination of native herbaceous and woody vegetation will be established in the riparian buffer along the project reach. To inhibit competition of fescue, most of the fescue will be removed during construction and, if necessary, the remaining fescue may be treated with herbicide. The buffer width will be a minimum of 50 feet from the top of the right and left banks. Species used for seeding and woody vegetation will depend upon availability and cost at the time of planting. Permanent seeding may include, but not be limited to, switch grass (*Panicum virgatum*), deer-tongue grass (*Panicum clandestinum*), soft rush (*Juncus effusus*), sedge (*Carex* spp.), ironweed (*Vernonia noveboracensis*), joe pye weed (*Eupatorium fistulosum*), and virginia wildrye (*Elymus virginicus*). Trees and shrubs that may be used include, but are not limited to, persimmon (*Diospyros virginiana*), sycamore (*Platanus occidentalis)*, black walnut (*Juglans nigra*), blackgum (*Nyssa sylvatica*), river birch (*Betula nigra*), sweet birch (*Betula lenta*), witch-hazel (*Hamamelis virginiana*), hornbeam (*Carpinus caroliniana*, silverbell (*Halesia caroliniana*), spicebush (*Lindera benzoin*), and alder (*Alnus serrulata*). Species to be used for live staking include silky dogwood (*Cornus amomum*) and black willow *(Salix nigra*). Temporary vegetation for erosion control will consist of annual rye (cool season) or millet (warm season) depending on the construction schedule. Planting details are provided in Appendix 4.

5.2.3 <u>Wetland Restoration</u>

Emergent plants that may be used for the proposed wetland restoration areas (ditches and disturbed wetlands draining into Hanging Rock Creek), include soft rush (*Juncus effusus*), wool grass (*Scirpus cyperinus*), sedges (*Carex* spp.), rice cutgrass (*Leersia oryzoides*), burreed (*Sparganium americanum*), arrow-arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), arrow-head (*Saggitaria latifolia*), lizard-tail (*Saururus cernuus*), cardinal flower (*Lobelia cardinalis*), tearthumb (*Polygonum sagittatum*), and bushy seedbox (*Ludwigia alternifolia*). All these plants can be planted by seed, however, a combination of seed and container-grown plants would provide quicker establishment of the emergent plant community.

5.3 Reach 2 - Unnamed Tributary to Hanging Rock Creek

5.3.1 <u>Morphological Restoration</u>

Given the constraint of a narrow easement (50 feet from the centering of the existing stream channel), the pattern of the tributary will not be altered for most of the reach. Restoration will primarily involve dimension improvement with the addition of a bankfull bench. This will achieve a bank height ratio of 1.0 and so give the tributary full access to a flood plain.

A 134-foot section at the bottom of the reach will be restored to a natural E channel form. This small section will connect the tributary to the new Reach 1 configuration.

There are three components to the unnamed tributary design. First, a bankfull bench will be constructed along the left bank from the fence line to the tree line. This will increase the entrenchment ratio from 2.0 to 6.6 and change the stream type from a F4 to a C4. Once the inner berm feature naturally aggrades to bankfull, the stream type will evolve to an E4. Second, bankfull benches will be constructed along both banks through the pasture reach. This reach is already a C4 because it has a large entrenchment ratio (29). However, the bank height ratios are greater than 1.6. The bankfull bench will promote wetter conditions throughout a greater portion of the corridor. Third, a short section of E4 channel will be constructed to tie the existing channel into the Hanging Rock Creek design channel. Sod mats will be used to build the banks and therefore a lower width/depth ratio can be achieved. The plan view of the proposed new channel, including structures, is presented on Sheet 1. Design cross sections are presented in Appendix 3.

Two ford crossings of Reach 2 will be installed to allow horses to move between pastures (See Figure 2.1 and Sheet 1). The crossings will be approximately 8 feet wide and will be constructed of fiber cloth covered with Grade A stone.

5.3.2 <u>Riparian Buffer Restoration</u>

A combination of native herbaceous and woody vegetation similar to Reach 1 will be used for this reach. The buffer width for this section will be approximately 50 feet. Planting details are provided in Appendix 4.

6 Stormwater Wetland Design

A stormwater wetland is proposed for a portion of new development of “The Farm at Banner Elk” and adjacent activities. The wetland will take the place of a long narrow ditch currently being used to receive runoff from a 15-acre watershed and carry it to Hanging Rock Creek. The watershed includes local residences, a church, and a Holiday Inn motel. The drainage extends westward to Hwy 184 to Four Diamond Ridge on the east. Proposed development of the area includes a six-acre commercial park on NC Hwy 184, just before Dobbins Rd that will increase runoff dramatically (approximately 85%, NRCS Method) into the drainage and eventually into Hanging Rock Creek. Proposed locations for the stormwater wetland and a stormwater retention basin are presented on Figure 2.1 and Sheet 1.

The floodplain area along Hanging Rock Creek that is allocated for the wetland has soil features consistent with the Cullowhee series with no more than a 1% slope. Several auger samples were taken on the site and information was gathered from soil survey field sheets and data provided by the USDA/NRCS office in Avery County. The land is currently utilized as a cattle pasture with a good cover of vegetation and evidence of compaction and organic matter accumulation in the surface layer. The soils are very deep (>60 inches to bedrock), frequently flooded, and somewhat poorly drained.
Most of the area is classified as a Cullowhee loam, with variations present in the proposed wetland location. This area was found to have a deeper water table than the typical Cullowhee loam, extending to a depth of about 4 feet with evidence of redoximorphic features starting at 3 feet below the surface. Soils in the area also tend to have a more clayey subsoil which is suitable for installation and maintenance of a constructed wetland. The surface layer is a dark brown sandy loam or loam with increasing clay content in the sandy clay loam underlying layer. The subsoil contains a large amount of cobbles and rock increasing with depth. Iron depletions become evident near the water table with a transition between dark brown to a deep gray color and increase with depth. The soil below the water table also has distinctive green hues that become more apparent with depth.

The erosion potential of the Cullowhee series is typically very low and this is evident at the site. The ditch running through the middle of the pasture is well vegetated and shows only small amounts of erosion; however, areas adjacent to Hanging Rock Creek and its banks have experienced much erosion and impact due to the free access of cattle to the stream.

Installation of a stormwater wetland and stormwater retention basin will have several benefits for the watershed and decrease the impacts of the new proposed development. Stormwater will be collected from parking lots and roadways and transported to the wetland by pipes for treatment and retention. The wetland will be installed to improve water quality by removing sediment, excess nutrients, and other pollutants from the stormwater. The wetland will also increase retention time of the water for better water quality treatment and a reduction in flooding potential. It will also provide an aesthetically pleasing atmosphere for potential greenways and walkways and will encourage wildlife, aquatic vegetation, and fish to inhabit the area.

The proposed stormwater wetland will be approximately 1.7 acres in size, with the width not to exceed the 125 ft easement and the length not to exceed 600 ft. It will be designed to hold about 5 acre-inches of runoff volume. The wetland will be designed with an open pond area in the middle where a pedestrian walkway will pass over. Shallow flow (0-6 in) will meander between deeper pools (30-36 in) and shallow land (6-12 in) to increase retention time and pollutant removal from the stormwater while providing adequate and diverse habitats for fish, a variety of aquatic plants and wetland species. The wetland will first have to be excavated at least four feet to reach the low water table and ensure the wetland has enough water availability to support aquatic vegetation and organisms inhabiting the area. A forebay will be installed to capture much of the sediment coming from pipes.

The wetland will be designed to store runoff from a standard first flush, containing one inch of rainfall. The runoff volume was calculated using the NRCS curve number equation to yield inches of runoff and then multiplying by the 15 acre area for a volume. Existing runoff in the watershed is about 3.3 acre-inches, but with the addition of the proposed development site, the runoff volume increases to 5 acre-inches which will be the storage capacity of the stormwater wetland.

Outflow of water into Hanging Rock Creek will be controlled by a weir and draw down device, and the wetland will be designed to hold a 10-year, 24-hour storm. The wetland is located in the 100-yr floodplain but it will be designed so that there will be no danger to area residents, and water can circumvent the outlet structure during larger storms.

7 Sediment Transport Analysis

A stable stream has the ability to move its sediment load without aggrading or degrading over long periods of time. The total load of sediment transported through a cross section can be described by bedload and suspended load fractions. Suspended load is normally composed of fine sand, silt and clay particles transported in the water column. Bedload is generally composed of larger particles, such as course sand, gravels and cobbles, transported by rolling, sliding, or hopping (saltating) along the bed.

The ability of the stream to transport its total sediment load is quantified through two measures; sediment transport competency and sediment transport capacity. Competency is a stream's ability to move particles of a given size and is a measurement of force, often expressed as units of lbs/ft^2. Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of lbs/(ft•sec). Competency and capacity analyses were conducted for this project to ensure that the design streambed does not aggrade or degrade during bankfull conditions. These two analyses are discussed below.

7.1 Competency Analysis

Median substrate size has an important influence on the mobility of particles in stream beds. Critical dimensionless shear stress (τ^*_{ci}) is the measure of force required to initiate general movement of particles in a bed of a given composition. At shear stresses exceeding this critical value, essentially all grain sizes are transported at rates in proportion to their presence in the bed (Wohl, 2000). τ^*_{ci} can be calculated for gravel-bed stream reaches using surface and subsurface particle samples from a stable, representative riffle in the reach (Andrews, 1983). Critical dimensionless shear stress is calculated as:

$$\tau *_{ci} = 0.0834\left(\frac{d_i}{\hat{d}_{50}}\right)^{-0.872} \qquad \text{[Equation 7.1]}$$

Where, τ^*_{ci} = critical dimensionless shear stress
d_i = median particle size of riffle bed surface (mm)
$\hat{d}_{50}$ = median particle size of subsurface sample (mm)

The critical dimensionless shear stress for Hanging Rock Creek was calculated using bed material samples from a stable riffle within the project reach near cross section 7+83. The channel dimension of this stable cross section is presented in Appendix 5. A sample of the pavement was collected by placing a bottomless 5-gallon bucket at a representative spot in the riffle cross section. The particle sample was collected at a point midway between the thalweg and edge of channel so as to best represent average channel stress. Particles on the bed surface (pavement) were removed in order from smallest to largest working from one side of the bucket to the other. The intermediate axis of the largest pavement particle was then measured. The subpavement was excavated to a depth of 1.5 to 2 times the measured diameter of the largest pavement particle. The subpavement sample was placed in a separate bag and both samples were sieved back in the lab (Brunte and Abt, 2001). A cumulative frequency curve of the sample is shown in Figure 7.1.

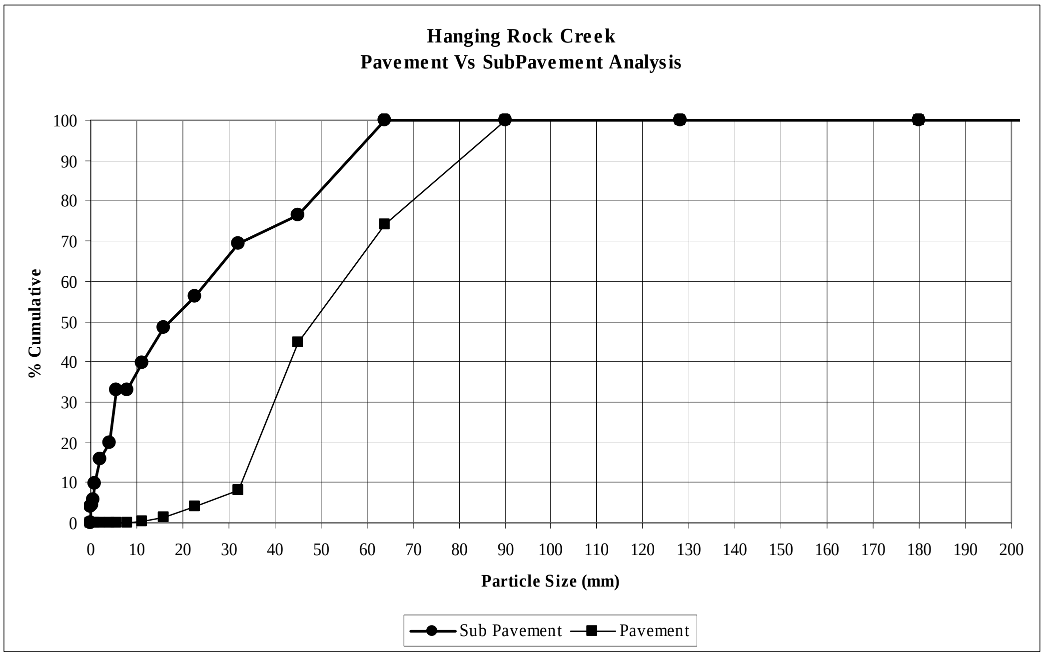


Figure 7.1 Pavement / Subpavement Analysis for Hanging Rock Creek.

Data presented in Figure 7.1 were used to determine parameters for Equation 7.1 (d_i = 48 mm and d_{50} = 17 mm). Critical dimensionless shear stress was calculated as τ^*_{ci} = 0.034 and is used in the aggradation analysis below.

7.1.1 Aggradation Analysis Through Critical Minimum Depth Calculation

An aggredation analysis was performed to predict whether the decreased channel slope called for in the design will cause the stream to aggrade. The design channel slope will be slightly less steep than the existing channel (0.0059 vs. 0.0064 ft/ft) as a result of increased sinuosity.

The aggredation analysis presented below is based upon calculations of the critical depth needed to transport large sediment particles, in this case defined as the largest particle of the riffle subpavement sample. Critical depth can be compared with the design mean riffle depth to check that the stream has sufficient competency to move large particles and thus prevent thalweg aggradation. The critical water depth is calculated by:

$$Dcr = \frac{1.65(\tau *_{ci})D_i}{s} \qquad \text{[Equation 7.2]}$$

Where,
- Dcr = water depth (ft)
- τ^*_{ci} = critical dimensionless shear stress
- D_i = Largest particle of bar or subpavement sample (ft)
- s = average channel slope (ft/ft)

Using a design slope of 0.0059 ft/ft and the largest subpavement particle of 64 mm (from Figure 7.1), Equation 7.2 can be used to calculate a critical depth for Hanging Rock Creek under design conditions of 2.0 ft. The largest particle of the subpavement is used as this represents the largest grain size typically moved during a bankfull event (Rosgen 2001).

This means that at a water depth of 2.0 ft, particles up to 64 mm would be mobile in the design channel. Mean design bankfull riffle depths are 1.9 ft (Table 7.1), a close match to the calculated critical depth. This analysis indicates that the design channels will be able to transport the larger materials presently in the stream and that the decreased slope called for in the design will not cause the stream to aggrade.

7.1.2 Aggradation Analysis Through Boundary Shear Stress and Shield's Curve Comparison

As a compliment to the critical depth calculations, boundary shear stresses were calculated for design riffle cross sections and compared with Shield's Curve to predict sediment competency. The shear str0ess placed on the sediment particles is a measure of the force that entrains and moves the particles. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma Rs \qquad \text{[Equation 6.3]}$$

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

Boundary shear stresses estimated for the design cross-sections ranged from 0.63 to 0.66 lbs/ft^2 (Table 7.1). Note that during bankfull events each design cross-section will have higher shear stress than under existing conditions. This suggests that even with decreased slope under design conditions, narrower cross-sections will provide for increased sediment transport competency.

From Shield's Curve (Figure 7.2), calculated shear stress values are predicted to be able to move particle sizes from 35 to 50 mm. Particles of this size are smaller than the D_i of the subpavement (64 mm). However, the Shield's Curve is derived primarily from laboratory studies. Field measurements have demonstrated larger partices moving for a given shear stress than predicted by the Shield's Curve (Rosgen, pers. com). Also, limited field data from Surry County North Carolina suggest that particles larger than 64mm can be moved by a shear stress of 0.6 lbs/ft^2. Shear stresses in the range calculated for design-cross sections are expected to move sediment competently in Hanging Rock Creek and prevent aggredation.

Table 7.1 Boundary shear stresses for Reach 1 existing and design riffle cross sections*.

Shear Stress Analysis	XSEC 3 + 85		XSEC 4 + 87		XSEC 17 + 75	
	Existing	Design	Existing	Design	Existing	Design
Bankfull Area (sq ft)	32.9	41.7	35.1	40.0	37.2	40.3
Bankfull Width, W (ft)	19.9	22.3	35.2	21.5	32.0	21.7
Bankfull Mean Depth, D (ft)	1.7	1.9	1.0	1.9	1.2	1.9
Wetted Perimeter	22.0	23.3	37.2	24.2	34.4	24.7
Hydraulic Radius, R (ft)	1.5	1.8	1.0	1.7	1.1	1.7
Slope (ft/ft)	0.0064	0.0059	0.0064	0.0059	0.0064	0.0059
Flow velocity, V (ft/sec)	7.1	5.6	6.6	5.8	6.2	5.8
Boundary Shear Stress, τ (lbs/sq ft)	0.60	0.66	0.40	0.63	0.44	0.63
Stream Power, ω (lbs/(ft•sec))	4.3	3.7	2.6	3.7	2.7	3.7

***** Note that riffles at stations 6+45 and 7+83 are proposed to be converted to pools. Therefore, shear stress comparison between existing and proposed channel shapes are not presented for these two cross sections.

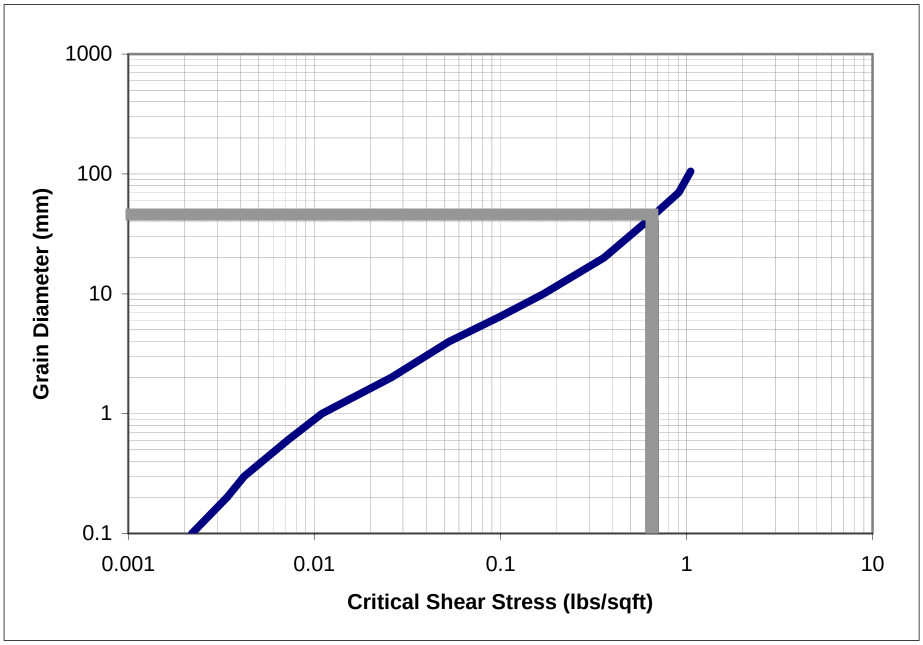


Figure 7.2. Shield's Curve for Grain Diameter of Transported Particle in Relation to Critical Shear Stress. Shaded areas represent the range of values calculated for proposed design channels.

7.1.3 <u>Degradation Analysis</u>

As the design cross sections generally have smaller cross sectional areas than the existing channel, a degradation analysis was performed in order to assess whether increased bankfull stream velocity will result in undue scour and bed downcutting. Potential for degradation was evaluated by examining the upper competency limits for design cross sections and by a review of grade control structures.

The calculated shear stresses discussed in Section 7.1.2 can be used to describe the upper competency limits for the design channel. Boundary shear stresses estimated for the design cross-sections ranged from 0.63 to 0.66 lbs/ft^2 (Table 7.1). From Shield's Curve (Figure 7.2), calculated shear stress values are predicted to be able to move particle sizes only as large as 35 to 50 mm. While field observations suggest that a given shear stress can move particles somewhat larger than indicated by the Sheild's Curve (Rosgen, pers. com.) the particles predicted to be moved by bankfull events are all smaller than the D_i of the subpavement (64 mm). Based on these calculations, shear stresses in the design channel do not threaten to degrade the channel bed.

Further confidence in vertical stability of the stream bed comes from a review of grade control at the project site. Culverts at both the top and bottom of the project control the overall project slope and will prevent any sever degradation. Rock cross vanes throughout the project will also work to control grade. Together these structures will insure that the stream bed will be vertically contained and will not degrade.

7.2 Sediment Transport Capacity

Stream power was calculated for both existing and design channel conditions to determine the effect of the proposed restoration on sediment transport capacity. Stream power for existing and design cross sections are presented in Table 7.1. Note that for two of the three cross section the design channels provide more power than existing channels during bankfull conditions. As Hanging Rock Creek is presently overly wide at points and trending towards an inefficient channel dimension, increased stream power was an intended design feature.

Stream power was also calculated for an existing stable cross section that demonstrated evidence of the best existing sediment transport in the project area and exhibited no sign of downcutting. This cross section was located near cross section 7+83 at the sample point for the pavement/subpavement collection. Stream power at this stable cross section was 3.7 lbs/ft•sec (Appendix 5). Stream power at this existing stable riffle is the same as the power of the design cross sections (Table 7.1). This indicates that the design channel will have sufficient power to transport bed materials containing particles as large as 64 mm and provides assurance that the design channel will not aggrade.

7.3 Sediment Transport Analysis Summary

Taken together, the aggredation and degradation analyses predict that bankfull conditions in the design channel will entrain particles ranging from 35 to 64 mm. Therefore, the design channel is predicted to maintain a stable profile, neither aggrading nor down cutting over time. Even with a decrease in slope from existing conditions, the design channel will exhibit slightly increased stream power and sediment transport capacity. This assures that the design channel will not aggrade. As shear stress in the design channel will not be so great as to cause downcutting of the streambed, and culverts and cross vanes will control bed elevation throughout the restoration area, the design channel will not degrade and is predicted to remain vertically stable over time.

8 Monitoring and Evaluation

Environmental components monitored in this project will be those that allow an evaluation of channel stability and riparian survivability. Specifically, the success of channel modification, erosion control, seeding, and woody vegetation plantings will be evaluated. This will be accomplished through the following activities for 5 years after the project is built. Another environmental component monitored in this project will be the recovery of the benthic macroinvertebrate community, which is described in more detail in section 7.6.

8.1 Photo Reference Sites

Photographs used to evaluate restored sites will be made with a 35-mm camera using slide film or a digital camera. Reference sites will be photographed before construction and continued for at least 5 years following construction. Reference photos will be taken once a year. After construction has taken place, reference sites will be marked with wooden stakes.

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

<u>Lateral reference photos</u>: Reference photo transects will be taken at each permanent cross section. Photographs will be taken of both banks at each cross section. The survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame and as much of the bank as possible included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time. Photos of areas that have been treated differently should also be included; for example two different types of erosion control material used. This will allow for future comparisons.

<u>Success Criteria</u>: Photographs will be used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation and effectiveness of erosion control measures. Longitudinal photos should indicate the absences of developing bars within the channel or an excessive increase in channel depth. Lateral photos should not indicate excessive erosion or continuing degradation of the bank over time. A series of photos over time should indicate successional maturation of riparian vegetation. Vegetative succession should include initial herbaceous growth, followed by increasing densities of woody vegetation and then ultimately a mature overstory with herbaceous understory.

8.2 Cross Sections

Permanent cross sections will be established at a minimum of one riffle and one pool per reach, for a total of 6. These cross sections may be the same as ones taken to develop construction plans. Each cross section will be marked on both banks with permanent pins to establish the exact transect used. A common benchmark will be used for cross-sections and consistently used to facilitate easy comparison of year-to-year data. The annual cross section survey will include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg. Riffle cross sections will be classified using the Rosgen stream classification system.

Success Criteria: There should be little or no change in as built cross-sections. If changes do take place they should be evaluated to determine if they represent a movement toward a more unstable condition (down-cutting, erosion) or are minor changes that represent an increase in stability (settling, vegetative changes, deposition along the banks, decrease in width/depth ratio).

8.3 Longitudinal Profiles

A complete longitudinal profile will be completed once the first year and then every two years for a total of five years (for a total of 3 times). Measurements will include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these measurements will be taken at the head of each feature, e.g. riffle, run, pool, and glide, and the max pool depth. The survey will be tied to a permanent benchmark.

Success Criteria: The as-built longitudinal profiles should show that the bedform features are remaining stable, e.g. they are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steep and shallow.

8.4 Bank Erosion Estimates

Permanent bank erosion pins and bank profiles will be made at each permanent cross section. A bank toe pin will be installed close to the observed bank. The bank profile toe pin will be tied to a station in the longitudinal profile. Measurements will be made once per year at the same time the cross section is measured. A bank erodibility hazard index (BEHI) score will also be made. An estimate of near-bank shear stress will be made by measuring the water surface slope along the observed bank length, as well as for the entire feature length, following the thalweg.

Success Criteria: The BEHI score should be low by the second year of restoration. Bank erosion measurements should be less than 0.1 ft/year.

8.5 Survival Plots

Survival of planted vegetation will be evaluated using survival plots or counts. Survival of live stakes will be evaluated using enough plots or a size plot, that allows evaluating at least 100 live stakes. Evaluations of live stake survival will continue for at least 5 years. When stakes do not survive a determination will be made as to the need for replacement; in general if greater than 25% die, replacement will be done.

All rooted vegetation will be flagged and evaluated for at least 5 years to determine survival. At least 2 staked survival plots will be evaluated. Plots will be 25 ft by 100 ft and all flagged stems will be counted in those plots. Success will be defined as 320 stems per acre after 5 years. When rooted vegetation does not survive, a determination will be made as to the need for replacement; in general, if greater than 25% die, replacement will be done.

8.6 Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrate monitoring will likely be required for this project because the project exceeds 1000 ft of compensatory stream restoration. Benthic macroinvertebrate data will be collected from the reference reaches (upstream of restoration reaches) and within the restoration reaches. Monitoring will be conducted prior to stream disturbance followed by at least three years of biological monitoring starting one year after the stream is restored. Data will be collected during similar seasonal periods for each year of analysis.

Sample collection will follow protocols described in the standard operating procedures of the Biological Assessment Unit of the NC Division of Water Quality. The Qual-4 collection method will be used for this project. A NC certified laboratory will conduct the identification of the biological samples. The metrics to be calculated will include total and EPT taxa richness, EPT abundance and biotic index values.

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Sheets

Appendix 1

Existing Condition Profiles, Cross Sections and Bed Material Analysis

Appendix 2

Benthic Macroinvertebrates Collected in Hanging Rock Creek

Benthic Macroinvertebrates Collected in Hanging Rock Creek

SPECIES	Site 1	Site 2	Site 3	T.V.	F.F.G.
ARTHROPODA					
Insecta					
Ephemeroptera					
Baetidae					
Baetis tricaudatus			A	1.63	CG
Ephemerellidae					
Ephemerella sp.	A	R	A	2.04	SC
Eurylophella sp.	A	C	C	4.34	SC
Ephemeridae					
Ephemera sp.	C		R		CG
Hexagenia sp.	R	R		4.9	CG
Heptageniidae					
Epeorus sp.			R	1.27	CG
Epeorus pleuralis	A	R	C	1.84	CG
Stenacron interpunctatum			R	6.87	SC
Stenonema pudicum	R			2.01	SC
Stenonema sp.	A				SC
Stenonema modestum	C		A	5.5	SC
Stenonema terminatum		C		4.1	SC
Isonychiidae					
Isonychia sp.	R			3.45	SC
Leptophlebiidae					
Leptophlebia sp.	A	A		6.23	CG
Paraleptophlebia sp.			A	0.94	CG
Plecoptera					
Nemouridae					
Amphinemura delosa		R		3.33	SH
Peltoperlidae					
Tallaperla sp.	R	A	A	1.18	SH
Perlidae					
Acroneuria abnormis	C		C	2.06	P
Perlodidae					
Isoperla sp.	A		A		P
Pteronarcidae					
Pteronarcys sp.	R			1.67	SH
Trichoptera					
Calamoceratidae					
Heteroplectron sp.		R	R	3.23	SH
Glossosomatidae					
Glossosoma sp.	C			1.55	SC
Hydropsychidae					
Ceratopsyche bronta	R			2.47	FC
Cheumatopsyche sp.	C	R	C	6.22	FC
Diplectrona modesta		A		2.21	FC

SPECIES	Site 1	Site 2	Site 3	T.V.	F.F.G.
Hydropsyche sp.	A			2.21	FC
Hydropsyche betteni	C		C	7.78	FC
Lepidostomatidae					
Lepidostoma sp.			R	6.22	FC
Limnephilidae					
Goera sp.	R	C		0.13	SC
Hydatophylax argus			R	2.17	SH
Pycnopsyche sp.		A	C	2.52	SH
Odontoceridae					
Psilotreta sp.		C		6.37	SC
Philopotamidae					
Chimarra aterrima	A	R	C	2.76	FC
Phryganeidae					
Ptilostomis sp.	R			6.37	SC
Polycentropodidae					
Nyctiophylax sp.	C		A	0.85	FC
Polycentropus sp.			R	3.53	FC
Rhyacophilidae					
Rhyacophila fuscula	C	R	C	1.88	P
Uenoidae					
Neophylax sp.	C	C	C	2.2	SC
Odonata					
Aeshnidae					
Boyeria vinosa		R	R	5.89	P
Calopterygidae					
Calopteryx maculata	C			7.78	P
Gomphidae					
Gomphus sp.	R			5.8	P
Megaloptera					
Sialidae					
Sialis sp.		C	R	7.17	P
Coleoptera					
Elmidae					
Promoresia sp.			R	2.35	SC
Haliplidae					
Haliplus sp.			R	8.71	SH
Psephenidae					
Ectopria sp.	R		R	4.16	SC
Psephenus herricki	A			2.35	SC
Diptera					
Chironomidae		R	R		
Brillia flavifrons			R	5.18	SH
Cricotopus sp.	R				CG
Diamesa sp.		C		8.12	CG
Larsia sp.	C			9.3	P
Microtendipes sp.	C			5.33	CG
Paramerina sp.		R		4.29	P

SPECIES	Site 1	Site 2	Site 3	T.V.	F.F.G.
Parametriocnemus lundbecki	C		R	3.65	CG
Procladius sp.			R	9.1	P
Rheotanytarsus sp.	R		R	5.89	SC
Synorthocladius semvirens			R	4.36	CG
Tanytarsus sp.	A		R	6.76	CG
Thienemannimyia gp.	A	C	C	8.42	P
Tvetenia bavarica gp.	C		C	3.61	CG
Dixidae					
Dixa sp.			R	2.55	CG
Simuliidae					
Simulium sp.	C	A	A	4	SC
Tipulidae					
Antocha sp.	C		R	4.25	CG
Hexatoma sp.		R		4.31	P
Pseudolimnophila sp.		A		7.22	P
Tipula sp.	R	A	A	7.33	SH
MOLLUSCA					
Bivalvia					
Veneroida					
Sphaeriidae					
Pisidium sp.	R			6.48	FC
Gastropoda					
Mesogastropoda					
Pleuroceridae					
Elimia clavaeformis	A	A	A	2.46	SC
Basommatophora					
Ancylidae					
Ferrissia rivularis	C		R	6.55	SC
Planorbidae					
Helisoma anceps	C			6.23	SC
ANNELIDA					
Oligochaeta					
Haplotaxida					
Lumbricidae		R			
TOTAL NO. OF TAXA	**44**	**29**	**43**		
EPT TAXA RICHNESS	**25**	**17**	**23**		
BIOTIC INDEX	**3.93**	**4.48**	**2.98**		

Appendix 3

Design Cross Sections

Appendix 4

Planting Specifications

Permanent Seeding Specifications

Permanent seeding will be used in combination with woody plantings for riparian areas along the right bank and extending to bankfull elevation along the restored reach. Permanent seeding will occur in conjunction with temporary seeding where applicable. This mixture will also be used in any terrestrial (areas not inundated) riparian area that has been disturbed by construction, is designated as wetland and/or riparian enhancement. This mixture shall be planted in combination with woody plant installations. Seeding should be done evenly over the area using a mechanical or hand seeder. A drag should be used to cover the seed with no more than ½ inch of soils. Where a drag cannot safely be utilized, the seed should be covered by hand raking.

Seedbed Preparation

On sites where equipment can be operated safely, the seedbed shall be adequately loosened. Disking may be needed in areas where soil is compacted. Steep banks my require roughening, either by hand scarifying or by equipment, depending on site conditions. If seeding is done immediately following construction, seedbed preparation may not be required except on compacted, polished or freshly cut areas. If permanent seeding is performed in conjunction with temporary seeding, seedbed preparation only needs to be executed once.

Fertilizing/Liming

Areas fertilized for temporary seeding shall be sufficiently fertilized for permanent seeding; additional fertilizer is not required for permanent seeding.

Seeding

A riparian seed mix at the rate of ¼ lb per 1,000 sq ft or 10 lbs per acre shall be used for seeding. The following table lists herbaceous, permanent seed mixture labeled “riparian seed mix.” Species listed below are subject to availability and cost.

Riparian Seed Mix

Common Name	Scientific Name	%
Soft Rush	*Juncus effusus*	20
Deertongue	*Panicum clandestinum*	20
Switchgrass	*Panicum virgatum*	10
Ironweed	*Vernonia noveboracensis*	10
Virginia Wildrye	*Elymus virginicus*	10
Hop Sedge	*Carex lupilina*	10
Fox Sedge	*Carex vulpinoidea*	10
Joe Pye Weed	*Eupatorium fistulosum*	10

Emergent Plants for Designed Wetland Communities

Common Name	Scientific Name
Soft Rush	*Juncus effusus*
Wool Grass	*Scirpus cyperinus*
Sedges	*Carex* spp.
Rice Cutgrass	*Leersia oryzoides*
Burreed	*Sparganium americanum*
Arrow-arum	*Peltandra virginica*
Pickerelweed	*Pontederia cordata*
Arrow-head	*Saggitaria latifolia*
Lizard-tail	*Saururus cernuus*
Cardinal flower	*Lobelia cardinalis*
Tearthumb	*Polygonum saggitatum*
Bushy seedbox	*Ludwigia alternifolia*

WOODY VEGETATION PLANTINGS

Woody vegetation, including live stakes, transplants, and bare root vegetation shall be used in all areas designated as “Floodplain Restoration Area”. The work covered in this section consists of furnishing, installing, maintaining, and replacing vegetation as shown in the plans or in locations as directed by Engineer/Project Manager.

LIVE STAKING

Live stake materials should be dormant and gathered locally or purchased from a reputable commercial supplier. Stakes should by ½ to 2 inches in diameter, 2 to 3 feet in length, and living based on the presence of young buds and green bark. Stakes shall be angled on the bottom and cut flush on the top with buds oriented upwards. All side branches shall be cleanly trimmed so the cutting is one single stem. Stakes should be kept cool and moist to improve survival and to maintain dormancy.

Live staking plant material shall consist of a random assortment of materials selected from the following:

Silky Dogwood (*Cornus amomum*)
Black Willow (*Salix nigra*)
Silky Willow (*Salix sericea*)
Elderberry (*Sambucus canadensis*)

Other species may be substituted upon approval of Engineer/Project Manager.

Planting shall take place in early spring. Stakes should be installed randomly 2 to 3 feet apart using triangular spacing or at a density of 160 to 360 stakes per 1,000 sq ft along the stream banks above bankfull elevation. Site variations may require slightly different spacing. Stakes shall be driven into the ground using a rubber hammer or by creating a hole and slipping the stake into it. The stakes should be tamped in at a right angle to the slope with 4/5 of the stake installed below the ground surface. At least two buds (lateral and/or terminal) shall remain above the ground surface. The soils shall be firmly packed around the hole after installations. Split stakes shall not be installed. Stakes that split during installations shall be replaced.

BARE ROOT VEGETATION

Bare root vegetation to be planted along both sides of the new channel stream banks above bankfull elevation and in the floodplain restoration area shall consist of a random assortment of shrub and tree species including, but not limited to the following:

Common Name	**Scientific Name**
Sycamore	*Platanus occidentalis*
Black walnut	*Juglans nigra*
River Birch	*Betula nigra*
Sweet Birch	*Betula lenta*
Silverbell	*Halesia carolina*
Persimmon	*Diospyros virginiana*
Blackgum	*Nyssa sylvatica*
Witch-hazel	*Hamamelis virginiana*
Spicebush	*Lindera benzoin*
Tag alder	*Alnus serrulata*
Hornbeam	*Carpinus caroliniana*

Planting shall take place in late winter/early spring. Listed species are subject to availability and cost. Immediately following delivery to the project site, all plants with bare roots, if not promptly planted, shall be heeled-in in constantly moist soil or sawdust in an acceptable manner corresponding to generally accepted horticultural practices.

While plants with bare roots are being transported to and from heeling-in beds, or are being distributed in planting beds, or are awaiting planting after distribution, the contractor shall protect the plants from drying out by means of wet canvas, burlap, or straw, or by other means acceptable to Engineer/Project Manager and appropriate to weather conditions and the length of time the roots will remain out of the ground.

Soil in the area of shrub and tree plantings shall be loosened to a depth of at least 5 inches. This is necessary only on compacted soil. Bare root vegetation may be planted in hole made by a mattock, dibble, planting bar, or other means approved by Engineer/Project Manager. Rootstock shall be planted in a vertical position with the root collar approximately ½ inch below the soil surface. The planting trench or hole shall be deep and wide enough to permit the roots to spread out and down without J-rooting. The plant stem shall remain upright. Soil shall be replaced around the transplanted vegetation and tamped around the shrub or tree firmly to eliminate air pockets.

The following spacing guidelines of rooted shrubs and trees are provided in the following table.

Type	**Spacing**	**# Per 1,000 sq ft**
Shrubs (<10 ft tall)	3 to 6 ft	25 to 110
Shrubs and trees (10-25 ft)	6 to 8 ft	15 to 25
Trees (>25 ft tall)	8 to 15 ft	4 to 15

Shrub and Tree Transplants

Shrub and trees less than 3 inches in diameter shall be salvaged onsite in areas designated for construction, access areas, and other sites that will necessarily be disturbed. Vegetation to be transplanted will be identified by the Engineer/ Project Manager personnel. Transplanted vegetation shall carefully be excavated with rootballs and surrounding soil remaining intact. Care shall be given not to rip limbs or bark from the shrub and tree transplants. Vegetation should be transplanted immediately, if possible. Otherwise, transplanted vegetation shall be carefully transported to designated stockpile areas and heeled-in in constantly moist soil or sawdust in an acceptable manner appropriate to weather or seasonal conditions. The solidity of the plants shall be carefully preserved.

Installation of shrub and tree transplants shall be located in designated areas along the stream bank above bankfull elevation or in floodplain restoration areas as directed by Engineer/Project Manager. Soil in the area of vegetation transplants shall be loosened to a depth of at least 1 foot. This is only necessary on compacted soil. Transplants shall be replanted to the same depth as they were originally growing. The planting trench or hole shall be deep and wide enough to permit the roots to spread out and down without J-rooting. The plant stem shall remain upright. Soil shall be replaced around the transplanted vegetation and tamped around the shrub or tree firmly to eliminate air pockets.

Appendix 5

Stable Cross Section Analysis