Sink Hole Creek Restoration Plan
Mitchell County, North Carolina

EEP Project Number D06125-C

Prepared For

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Sink Hole Creek Restoration Plan
Mitchell County, North Carolina

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EXECUTIVE SUMMARY

Michael Baker Engineering, Inc. (Baker) proposes the restoration or enhancement of 4,181 linear feet (LF) of perennial stream channel and 489 LF of intermittent stream channel along Sink Hole Creek and three unnamed tributaries (UT1,UT2, and UT3) in Mitchell County, NC (ES Figure 1.0). Additionally, this plan proposes 1,076 LF of preservation within the headwaters of UT1. Sink Hole Creek is a tributary to the North Toe River approximately one mile below the project site. The nearest town, Bakersville, is approximately four miles northeast of the Sink Hole Creek Project site. The site lies in the French Broad River Basin within North Carolina Division of Water Quality (NCDWQ) sub-basin 04-03-06 and local watershed unit 06010108040010.

The goals for the restoration project are as follows:

- To create geomorphically stable conditions on the Sink Hole Creek project site;
- The reduction of sediment and nutrient loading through restoration of riparian areas and stream banks;
- To improve and restore hydrologic connections between the creek and floodplain;
- The restoration and preservation of headwater tributaries to the North Toe River, French Broad River Basin; and
- To improve aquatic and terrestrial habitat along the project corridor.

To accomplish these goals, we recommend the following actions:

- Restore the existing incised, eroding, and channelized stream by creating a stable channel which has access to its floodplain.
- Improve water quality by establishing buffers for nutrient removal from runoff and by stabilizing stream banks to reduce bank erosion.
- Improve in-stream habitat by providing a more diverse bedform with riffles and pools, creating deeper pools, developing areas that increase oxygenation, providing woody debris for habitat, and reducing bank erosion.
- Improve terrestrial habitat by planting riparian areas with native vegetation and protecting these areas with a permanent conservation easement so that the riparian area will increase storm water runoff filtering capacity, improve bank stability, provide shading to decrease water temperature and improve wildlife habitat.

Table ES.1 Restoration Plan Overview Sink Hole Creek Restoration Plan			
Project Feature	Existing Condition (LF)	Design Condition (LF)	Approach
Sink Hole Creek			
Reach 1	1,036	1,036	Priority I Restoration
Reach 2	1,062	1,062	Priority I Restoration
UT1			
Reach 1	1,076	1,076	Preservation
Reach 2	489	489	Priority II Restoration
UT2			
Reach 1	579	595	Priority I Restoration
Reach 2	879	902	Priority I Restoration
UT3			
Reach 1	586	586	Priority I Restoration
Total Stream Work	5,707 LF	5,746 LF	Variable

LEGEND:

*Date of aerial photography: 1998

Proposed Project Component

Preservation

Priority I Restoration

Priority II Restoration

Proposed Easement

Streams

0 200 400 800 Feet

Figure ES.1 Proposed Project Components

Sink Hole Creek Restoration Project
Mitchell County, NC

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1.0 PROJECT SITE IDENTIFICATION AND LOCATION

1.1 Project Description and Directions to Project Site

Baker proposes to restore or enhance 2,098 linear feet (LF) of Sink Hole Creek and complete 2,572LF of channel restoration or enhancement along three unnamed perennial/intermittent tributaries (UT1, UT2, and UT3) to Sink Hole Creek, in Mitchell County, NC. Additionally, this plan proposes 1,076 LF of preservation in the headwaters of UT1.

The Sink Hole Creek project site is located approximately four miles southwest of Bakersville in the small community of Bandana, Mitchell County, North Carolina, as shown in the Project Location Map (Figure 1.1). To reach the project site, follow US Highway 19/23 North from Asheville for approximately 20 miles and take the US Highway 19N exit, Exit 9, towards Burnsville and Spruce Pine. Continue along US Highway 19 (which becomes US-19E), for 25 miles. Turn left onto NC Highway 226 and continue for approximately 6.5 miles to NC Highway 1191. After turning left onto NC Highway 1191, continue for approximately 1.7 miles. Turn left onto NC Highway 80 and travel another 6.5 miles to Water Street (NC Highway 1182). The project area is adjacent to Water Street and continues west of NC Highway 80 where an unnamed tributary (UT1) converges with Sink Hole Creek.

1.2 USGS Hydrologic Unit Code and NCDWQ River Basin Designations

The Sink Hole Creek project site lies in the French Broad River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 04-03-06 and United States Geologic Survey (USGS) local watershed unit 06010108040010.

Sink Hole Creek is shown as a solid blue-line stream throughout the site on the USGS topographic quadrangle map. UT1 is shown as a dashed blue-line stream on the USGS map. It originates in a forested area upstream of NC Highway 80 and is fed by five springs upstream of a small pond. Short feeder channels emanate from the springs and connect to UT1 within 50 to 100 feet of the individual springheads.

Unnamed Tributary 2 and UT3 are tributaries to Sink Hole Creek at the eastern end of the watershed. The project reaches of UT2 and UT3 are located approximately 2,300 feet upstream from the beginning of the proposed restoration section on Sink Hole Creek. This gap in the project is unavoidable because of structural constraints (houses and farm buildings) and multiple small parcels. UT2 is a perennial tributary that is spring fed and has one tributary, UT3, another spring-fed branch. UT3 was also identified as a perennial tributary that went dry during recent drought conditions.

After referencing USGS topographic quadrangle maps to determine stream order, a field evaluation using the North Carolina Division of Water Quality (NCDWQ) stream assessment protocol was conducted. Based on field data, Sink Hole Creek, the restoration reach of UT1 and both UT2 and UT3 are perennial stream channels. NCDWQ Stream Identification Forms completed for the project reaches are included in Appendix A. The total current length of stream within the project is 5,707 LF.

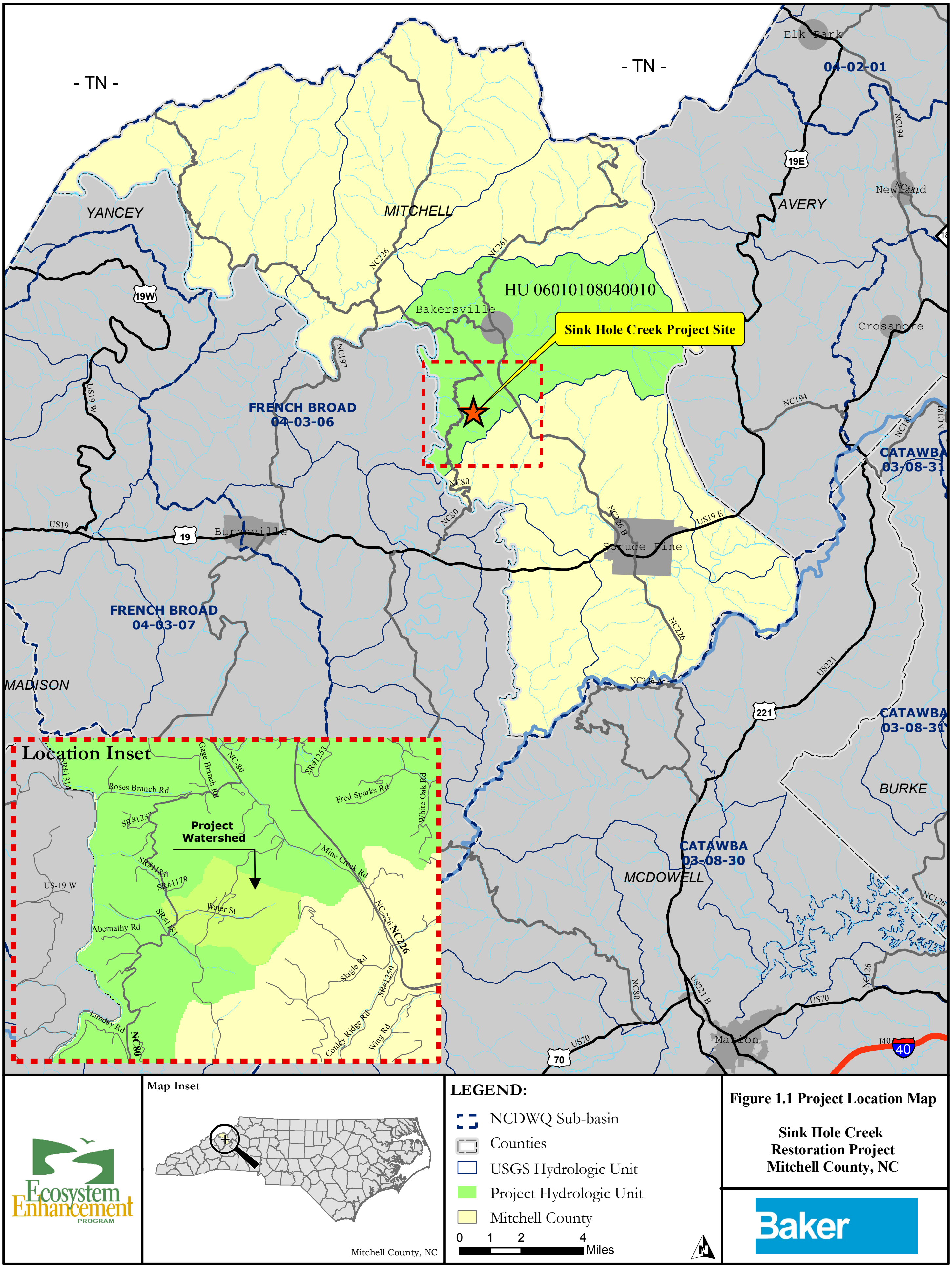


Figure 1.1 Project Location Map

Sink Hole Creek Restoration Project Mitchell County, NC

1.3 Project Components and Structure

Distinct project reaches are summarized in Table 1 below and are depicted in the Project Components figure in the Executive Summary (ES.1). A table (1.1) summarizing project component attributes is also provided.

Table 1.0 Project Restoration Components

Sink Hole Creek Restoration Plan

Project Segment or Reach ID	Existing Feet/ Acres	Type	Approach	Footage or Acreage	Mitigation Ratio	Mitigation Units	Stationing	Comment
Sink Hole Cr. Reach 1	1,036	R	P1	1,036	1.0	1,036	0+00-11+13	Meandering channel construction; excavation of floodplain
Sink Hole Cr. Reach 2	1,062	R	P1	1,062	1.0	1,062	11+13 to 21+74	Meandering channel construction; excavation of floodplain
UT1 Reach 1	1,076	P	-	1,076	5.0	215.2	0+00 to 10+76	No channel alteration (preservation)
UT1 Reach 2	489	R	P2	489	1.0	489	0+00 to 4+94	Meandering channel construction
UT2 Reach 1	579	R	P1	595	1.0	595	0+00 to 5+95	Channel elevation increased for connectivity to floodplain; grade control structure installation
UT2 Reach 2	879	R	P1	902	1.0	902	5+95 to 14+88	New alignment to restore stable dimension; floodplain excavation; grade control structure installaion
UT 3	586	R	P1	586	1.0	586	0+00 to 5+86	Channel elevation increased for connectivity to floodplain; grade control structure installation

Mitigation Unit Summations

Stream (LF)	Riparian Wetland (Ac)	Nonriparian Wetland (Ac)	Total Wetland (Ac)	Buffer (Ac)	Comment
4,885.2	NA	NA	NA	9.46	

Table 1.1 Project Attribute Table
Sink Hole Creek Restoration Plan

Project County	Mitchell						
Physiographic Region	Blue Ridge						
Ecoregion	Blue Ridge Mountains-Southern Crystalline Ridges and Mountains						
Project River Basin	French Broad						
USGS HUC for Project	6010108040010						
NCDWQ Sub-basin for Project	04-03-06						
Planning Area	TLW (French Broad River Basin Report)						
WRC Class	Cold						
% of Project Easement Fenced or Demarcated	100 (post-construction)						
Beaver Activity Observed During Design Phase	No						
Restoration Component Attribute Table							
	Sink Hole Cr.		UT1		UT2		UT3
	Reach 1	Reach 2	Reach 1	Reach 2	Reach 1	Reach 2	
Drainage Area	.72	.84	.07	.09	.02	.08	.02
Stream Order	3rd	4th	1st	1st	1st	2nd	1st
Restored Length (feet)	1,036	1,062	1,076	489	595	902	586
Perennial or Intermittent	P	P	I	P	P	P	P
Watershed Type	Rural						
Watershed LULC Distribution* (Cumulative acreage)							
Developed Open Space	30						
Deciduous Forest	326						
Evergreen Forest	18						
Mixed Forest	10						
Shrub/Scrub	25						
Grassland/Herbaceous	8						
Pasture/Hay	141						
Cultivated Crops	4						
Watershed Impervious Cover(%)	<10%						
NCDWQ AU/Index Number	7-2-56						
NCDWQ Classification	C; Tr	C; Tr	-	-	-	-	-
303d Listed	No	No	No	No	No	No	No
Upstream of 303d Listed Segment	No	No	No	No	No	No	No
Reasons for 303d Listing or Stressor	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Acreage of Easement (Cumulative)	9.46						
Total Vegetated Acreage Within the Easement	-	-	-	-	-	-	-
Total Planted Acreage As Part of the Restoration	~9.46						

Rosgen Classification of Pre-existing	Channelized Eb/Cb/G		N/A	B-Cb	Aa+	A	Ba
Rosgen Classification of As-built (Design)	B-Cb		N/A	B-C	Aa+	A	Ba
Valley Type	II	II	II	II	II	II	II
Valley Slope	.0280-.030		N/A	.028	.1	.0546	0.1
Valley Side Slope Range	U	U	U	U	U	U	U
Valley Toe Slope Range	U	U	U	U	U	U	U
Cowardin Classification	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trout Waters Designation	Yes	Yes	-	-	-	-	-
Species of Concern, Endangered, etc.	No	No	No	No	No	No	No
Dominant Soil Series and Characteristics							
Series	Bandana	Bandana	Dillsboro	Bandana	Saunook-Thunder	Dellwood-Reddies	Saunook-Thunder
Depth	>80"	>80"	~87"	>80"	>80"	>80"	>80"
Clay %	10-20	10-20	27-35	10-20	7-20/ 15-28	5-15/ 5-18	7-20/ 15-28
K	.15	.15	.1	.15	.05/.02	.05	.05/.02
T	4	4	5	4	5	3	5

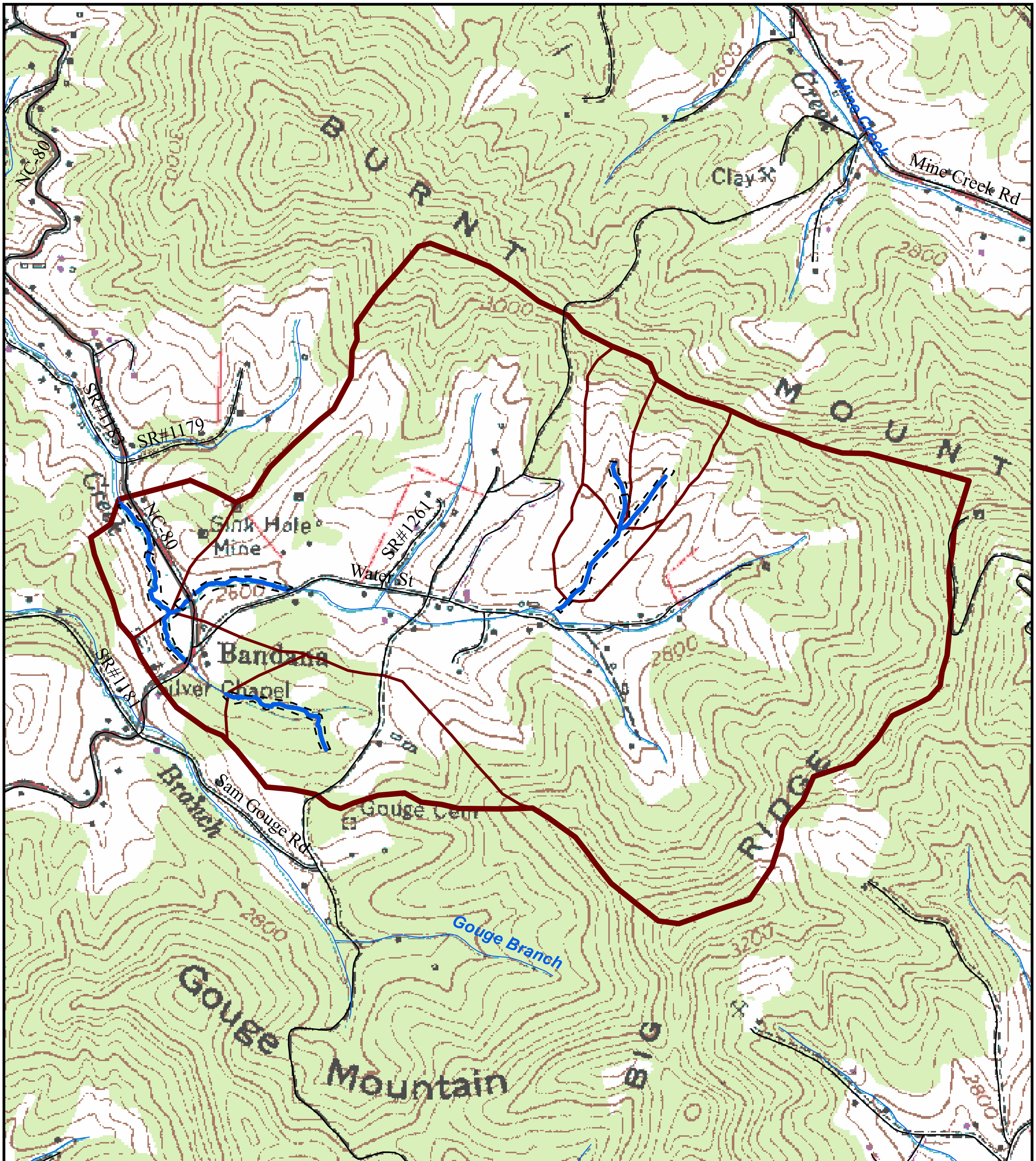
2.0 WATERSHED CHARACTERIZATION

2.1 Watershed Delineation

The Sink Hole Creek Restoration project is located in Mitchell County in the French Broad River Basin as illustrated in the executive summary figure (ES. 1). The drainage area for Sink Hole Creek is 0.84 square miles at the downstream project limit. Unnamed Tributary 1 contributes 60 acres, UT2 contributes 75 acres, and UT3 contributes 15 acres. Watershed areas are provided in Table 2.1 for stream reaches within the project boundaries. Figure 2.1 provides a topographic view of the watershed drainage area for Sink Hole Creek by project reach. A total of 9.46 acres will be placed in conservation easement status through the Sink Hole Creek project.

Table 2.1 Drainage Areas By Reach
Sink Hole Creek Restoration Plan

Reach	Reach Length (LF)	Watershed Size at Downstream End of Reach (square miles)
Sink Hole Creek		
Reach 1	1,036	.72
Reach 2	1,062	.84
UT1		
Reach 1	1,076	.07
Reach 2	489	.09
UT2		
Reach 1	579	.02
Reach 2	879	.08
UT3	586	.02
Total Existing Stream Length	5,707	.84



LEGEND:

- Project Reach
- Proposed Easement Boundary
- Streams
- Watershed Boundary
- Subwatershed Boundaries

0 400 800 1,600 Feet

Figure 2.1 Project Watershed Map (Bakersville Quadrangle)

Sink Hole Creek Restoration Project Mitchell County, NC

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2.2 Surface Water Classification/ Water Quality

The NCDWQ designates surface water classifications for water bodies such as streams, rivers, and lakes which define those uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications are associated with water quality standards that govern those uses. All surface waters in North Carolina must at least meet the standards for Class "C" (fishable/swimmable) waters. Other classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). In addition to these primary classifications, supplemental classifications are sometimes assigned to water bodies to protect special uses or values.

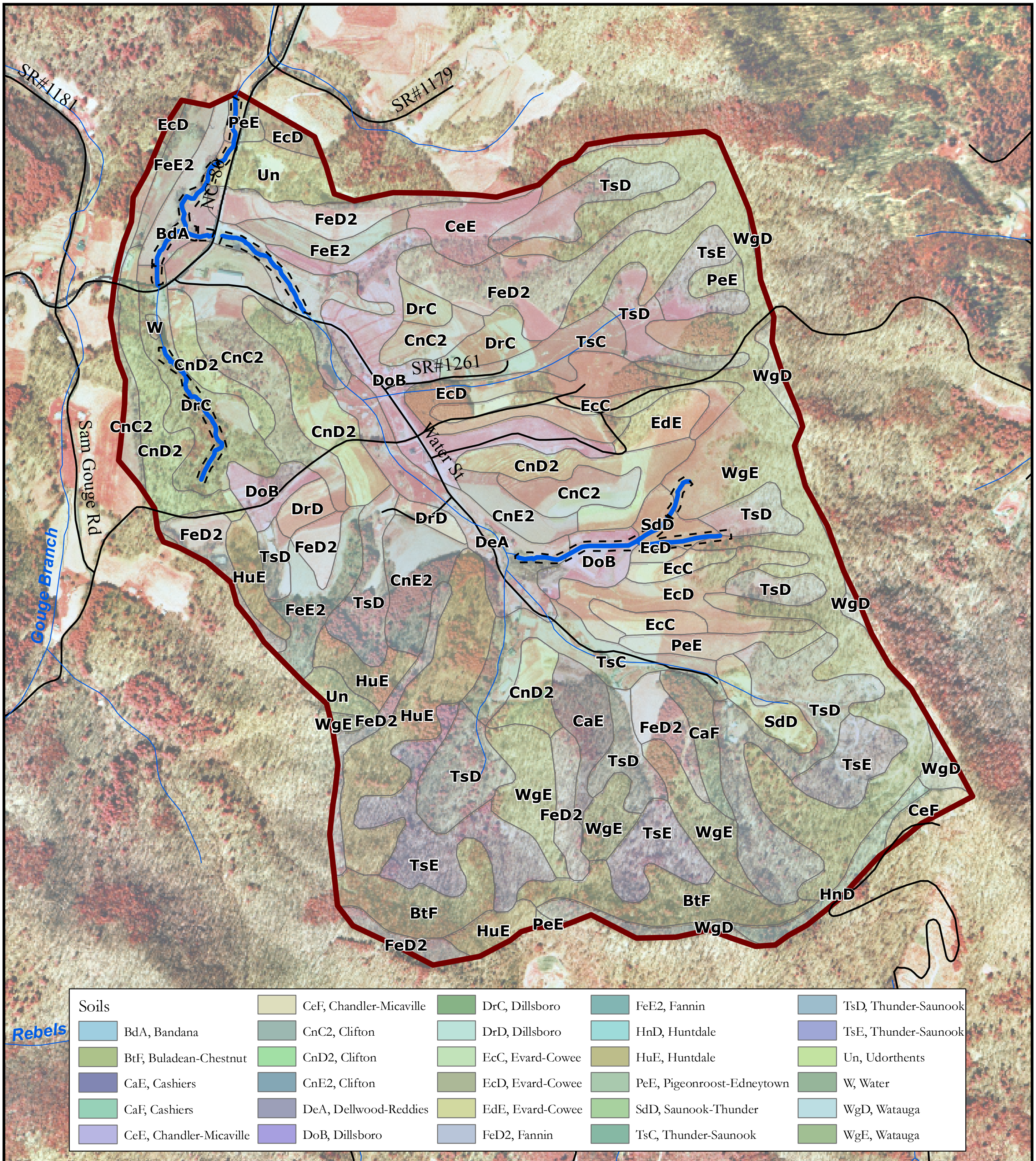
The NCDWQ has classified Sink Hole Creek as a Class C waterbody with a supplemental classification of "Tr"(DWQ Index No. 04-03-06). The "Tr" supplemental classification is intended to protect habitat for natural trout propagation and survival of stocked trout. This classification primarily affects the quality of permitted discharges and recognizes a 25-foot riparian buffer administered by the Division of Land Quality.

2.3 Physiography, Geology and Soils

The Sink Hole Creek restoration site lies within the Blue Ridge physiographic province of western North Carolina. The Blue Ridge province hosts a series of intricate, opposing ridges and valleys that have undergone numerous episodes of metamorphosis. As noted by the N.C. Geological Survey, the Blue Ridge province contains the highest mountains in eastern North America, including nearby Mt. Mitchell which rises to 6,684 feet above sea level.

The Sink Hole Creek restoration project is located on the eastern flank of the Blue Ridge lithotectonic belt described above. Its geological features are primarily composed of middle Proterozoic to early Paleozoic-aged muscovite-biotite gneiss according to the 1° by 2° geologic map of the Knoxville Quadrangle prepared by the USGS (Hadley, and Nelson, 1971, Map I-654) and the 1985 Geologic Map of North Carolina issued by the state geological survey office. This rock unit can be locally sulfidic and is interlayered with mica schist, amphibolite and hornblende gneiss. Amphibolite inclusions located in this area are well foliated. Metamorphosed intrusive and extrusive mafic rock on-site may also include metasedimentary rock.

Soil types at the site were determined using Natural Resources Conservation Service (NRCS) soil survey data for Mitchell County. The project area was also assessed during site visits to determine the potential presence of any hydric soil inclusions. There are eight general soil series and complexes found within the project boundaries. The boundaries of each soil type are depicted in Figure 2.2. A summary of information on each soil type is presented in Tables 2.2 and 2.3.



LEGEND:

- Project Reach
- Proposed Easement Boundary
- Streams
- Watershed Boundary

0 200 400 800 Feet

Ecosystem Enhancement PROGRAM

Figure 2.2 Project Soil Types

Sink Hole Creek Restoration Project
Mitchell County, NC

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Table 2.2 Project Soil Types and Descriptions
Sink Hole Creek Restoration Plan

Soil Name	Taxonomic Class	Location	Description
Bandana sandy loam	Coarse-loamy, mixed, active, nonacid, mesic Aeric Fluvaquents	Floodplains	The Bandana series consists of a poorly drained, moderately permeable upper soil layer with rapid or very rapid permeability in the lower part of the soil. Formed in recent alluvium consisting of loamy soil material that is underlain by sandy-skeletal soil material within a depth of 40 inches. Slopes range from 0 to 3 percent.
Udorthents	Udorthents	Abandoned mica mine	Loamy, micaeous material consisting of wasted soil and tailings from prior mining and site excavation activities.
Pigeonroost-Edneytown Complex	Fine-loamy, mixed, active, mesic Typic Hapludults	Strongly sloping to very steep ridges & side slopes of low and intermediate mountains	The Pigeonroost-Edneytown complex consists of moderately to very deep, well-drained, moderately permeable soils. Formed in residuum affected by soil creep in the upper part and weathered from felsic to mafic, igneous and high-grade metamorphic rocks. Slopes typically range between 30-50% to 15-50%.
Dillsboro clay loam and Dillsboro stony	Fine, mixed, active, mesic Humic Hapludults	High stream terraces, toeslopes, benches and colluvial fans in coves	Very deep, well drained, moderately permeable soils. Dillsboro series soils formed from old alluvium and/or colluvium material made up of weathered felsic to mafic, igneous and high grade metamorphic rocks. Slope typically 2-15%, but can range from 2 to 50%. Located on slopes of 2-15% on-site.
Saunook-Thunder Complex	Fine-loamy, mixed, superactive, mesic Humic Hapludults/ Loamy-skeletal, mixed, active, mesic Humic Hapludults	Benches, fans and toe slopes in coves/ Colluvial toe slopes, drainageways and coves.	The Saunook-Thunder complex consists of very deep, well drained, moderately permeable soils. Soils in this complex originated in colluvium consisting of weathered felsic to mafic, igneous and high-grade metamorphic rocks. Slopes typically range from 5% to 30%, but can range from 2 to 80%. Located on slopes of 15-30% on-site.
Dellwood-Reddies Complex	Sandy-skeletal, mixed, mesic Oxyaquic Dystrudepts/	Gently sloping to nearly level floodplains	Moderately well drained, moderately rapidly to very rapidly permeable soils. Originated from coarse textured alluvium on flood plains. Slope ranges from 0 to 5%.
Watauga sandy loam	Fine-loamy, paramicaceous, mesic Typic Hapludults	Mountain slopes, ridgelines and summits	Deep, well drained soil with moderate permeability. Originated in residuum from micaceous metamorphic rock and phyllite. Slopes range from 30 to 50%.

Note:
NRCS, USDA. Official Soil Series Descriptions
http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdname.cgi
http://soildatamart.nrcs.usda.gov/Default.aspx

Mapped soils within the Sink Hole Creek project area include Bandana sandy loam, Watauga sandy loam, Pigeonroost-Edneytown complex, Dillsboro clay loam (and stony), Saunook-Thunder complex, Dellwood-Reddies complex and Udorthents. The area mapped as Udorthents is an abandoned mica mine that includes mine shafts and tailings. Bandana sandy loam covers most of the project reaches on Sink Hole Creek. This soil is somewhat poorly drained, unlike the Dillsboro unit and Pigeonroost complex which are situated on gently sloping to moderately steep slopes and are well drained. Dillsboro stony soils are present over much of the UT1 project reach. Soils located in the vicinity of UT2 and UT3 include the Saunook-Thunder complex, Dillsboro clay loam, and Dellwood-Reddies complex. The Saunook-Thunder complex soils are stony and situated on steep slopes where the sources for UT2 and UT3 are located. Channel down cutting on UT2 begins once the channel reaches the Dillsboro clay loam and persists through the Dellwood-Reddies complex. On-site observations of soil conditions do not indicate any limitations to performing the work prescribed under this project.

Table 2.3 Project Soil Type Characteristics
Sink Hole Creek Restoration Plan

Series	Max Depth (in)	% Clay on Surface	Erosion Factor K	Erosion Factor T	Runoff Class	OM%
Bandana sandy loam	>80	10-20	.15	4	Very Low	4.0-8.0
Udorthents	variable	4-40	0.24	5	N/A	0-0.5
Pigeonroost-Edneytown complex	>80	8-25	.17/.10	3	High to Very High (progressive with slope)	2.0-6.0
Dillsboro clay loam and Dillsboro stony	87	27-35	0.1	5	Medium to Rapid	4.0-10.0
Saunook-Thunder complex	>80	7-20/ 15-27	.05/.02	5	Very low to medium/ Low on gentle slopes; high on steeper slopes	4.0-10.0/ 6.0-14.0
Dellwood-Reddies complex	>80	5-15/ 5-18	.05	3	Runoff is slow for both soils. Permeability is moderately rapid in the A-horizon and rapid or very rapid in the C-horizon in Dellwood soils. Permeability for the Reddies soil is moderately rapid in the A- and B-horizons and rapid in the C-horizon.	4.0-8.0
Watauga sandy loam	99	5-0	.24	5	Well drained; medium to rapid runoff; moderate permeability.	1.0-8.0

2.4 Historical Land Use and Development Trends

The Sink Hole Creek restoration project streams drain a watershed that is predominantly forested with a considerable percentage of land in agricultural use (Table 2.4). A small number of residences are also located within the drainage area for the Sink Hole Creek project. While a majority of the watershed is in forested cover, a quarter of the drainage is in some form of pasture land or hay production. Potential for land use change in the area adjacent to the conservation easement is low.

Sink Hole Creek and its tributaries have been impaired by historical and current land management practices which include timber harvesting, pasture conversion, channelization, and livestock grazing. In addition, a small, historic mica mine is located near NC Highway 80 on a hill about 500 feet north of Sink Hole Creek. Stream channelization and channel dredging are evident through much of the project site. Over time, these practices have contributed excessive sediment and nutrient loading to Sink Hole Creek and ultimately to the North Toe River which is home to the endangered Appalachian elktoe mussel.

During development of the land for agricultural use, a significant portion of streambank vegetation has been removed. Livestock currently have open access to portions of Sink Hole Creek, the upper section of UT2, and UT3. Most of the lower section of UT2 has been fenced off; however, the landowner periodically allows cattle access to this area as well and the channel is open for a short distance through a cattle feed lot at the confluence. Past dredging activities have cut Sink Hole Creek off from its floodplain resulting in an incised channel; while in other sections, stream banks have been trampled down, creating over widened channel conditions that contribute to additional sediment and nutrient loading. Land immediately surrounding UT1 is in forested cover for much of the preservation reach. A pond and equipment yard is located between the pond and NC Hwy. 80 and the stream is piped under this area.

Although the project site is less than five miles from the town of Bakersville, the Sink Hole Creek watershed is not located near any major population centers. Land use within the watershed is rural in character and is unlikely to change significantly in the near future. Management of land in the project area for agricultural purposes has induced changes to Sink Hole Creek and its tributaries primarily through alteration of drainage patterns, removal of vegetation in the riparian zone, and open access of cattle to the branches. Restoration of the site and removal of livestock from the stream corridors will reduce the sediment and nutrient loading to Sink Hole Creek and in turn improve water quality in the North Toe River.

Table 2.4 Sink Hole Creek Watershed Land Use
Sink Hole Creek Restoration Plan

Land Use Category[1]	Area (acres)	Percent Area
Developed Open Space	30	6
Deciduous Forest	326	61
Evergreen Forest	18	3
Mixed Forest	10	2
Shrub/Scrub	25	0.4
Grassland/Herbaceous	8	1
Pasture/Hay	141	26
Cultivated Crops	4	1

Note: 1. Values calculated using USGS land use data from 2001.

2.5 Watershed Planning

The Sink Hole Creek project site lies within the North Toe River Watershed. The North Toe Watershed, which lies within the North Carolina Division of Water Quality (NCDWQ) French Broad River sub-basin 04-03-06 and United States Geologic Survey (USGS) local watershed unit 06010108040010, was identified in the state's 2005 basin plan for the French Broad as one of 28 local watersheds that presented the greatest need or opportunities for stream and wetland restoration activities. This watershed was targeted based on degraded habitat conditions and water quality problems associated with turbidity levels. Because it is a targeted local watershed, projects within the North Toe River watershed are given higher priority for implementation by the NCEEP than projects that are located in nontargeted watersheds.

Some of the key measures of the Sink Hole Creek restoration project will involve stabilizing channels and restoring access of the channels to floodplains, as well as improving in-stream habitat by incorporating woody debris and providing a more diverse bedform with improved riffle/step-pool sequencing. Terrestrial habitat will also be improved by re-establishing riparian areas with vegetation native to the area. These buffers will be protected under a conservation easement and will improve water quality by aiding in sediment and nutrient removal from stormwater runoff. These measures ultimately support the state's efforts of water quality improvement within the North Toe River Watershed through a reduction in site runoff from unstable streambanks and channel dimension as well as restoration of both aquatic and terrestrial habitat.

2.6 Endangered/Threatened Species

Some populations of plants and animals are declining as a result of various natural forces including loss of habitat and competition with humans for resources. The North Carolina Natural Heritage Program (NHP) and United States Fish and Wildlife Service (USFWS) compiled a list of rare and protected animal and plant species that includes eleven federally listed species known to exist in Mitchell County (USFWS, 2008 and NHP, 2009).

The cornerstone of legal protection for federally listed species (Threatened (T) or Endangered (E) status), is conferred by the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1534). This act makes illegal the killing, harming, harassing, or removing of any federally listed animal species from the wild; plants are similarly protected but only on federal lands. Section 7 of this act requires federal agencies to ensure that actions they fund or authorize do not jeopardize any federally listed species.

Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded state protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979.

Species that the NHP lists under federal protection in Mitchell County as of April 08, 2009 are shown in Table 2.5. Pedestrian surveys of the project area and adjacent lands did not result in the observation of any federally protected species listed. An April 22, 2008 search of the NHP database indicated an occurrence of the bog turtle, Appalachian elktoe, and Virginia spiraea within two miles of the project site, but in or closer to the North Toe River. A brief description of the characteristics and habitat requirements of the federally protected species is included in the following section, along with a conclusion regarding potential project impacts.

Table 2.5 Species of Federal and State Status in Mitchell County

Sink Hole Creek Restoration Plan

Family	Scientific Name	Common Name	Federal Status	State Status	Habitat Present / Biological Conclusion
Vertebrate					
Accipitridae	*Haliaeetus leucocephalus*	Bald Eagle	BGPA	T	No/No effect
Vespertilionidae	*Myotis sodalist*	Indiana Bat	E	E	No/No effect
Sciuridae	*Glaucomys sabrinus coloratus*	Carolina Northen Flying Squirrell	E	E	No/No Effect
Emydidae	*Glyptemys muhlenbergii*	Bog Turtle	T (S/A)	T	No/No Effect
Invertebrate					
Unionidae	*Alasmidonta raveneliana*	Appalachian Elktoe	E	E	No/No Effect
Dipluridae	*Microhexura montivaga*	Spruce-fir Moss Spider	E	SR	No/No Effect
Vascular Plant					
Rubiaceae	*Houstonia montana*	Roan Mountain Bluet	E	E	No/No Effect
Rosaceae	*Geum radiatum*	Spreading Avens	E	E-SC	No/No Effect
Asteraceae	*Liatris helleri*	Heller's Blazing-Star	T	T-SC	No/No Effect
Asteraceae	*Solidago spithamaea*	Blue Ridge Goldenrod	T	E	No/No Effect

Rosaceae	*Spiraea virginiana*	Virginia Spiraea	T	E	No/No Effect
Nonvascular Plant					
Cladoniaceae	*Gymnoderma lineare*	Rock Gnome Lichen	E	T	No/No Effect
Notes:					
BGPA: Bald and Golden Eagle Protection Act. As of August 8, 2007, the Bald and Golden Eagle Protection Act (Eagle Act) (16 U.S.C. 668 d) is the primary law protecting bald and golden eagles. The Eagle Act prohibits take of bald and golden eagles and provides a statutory definition of "take" that includes "disturb".					
E: An endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.					
EX: Extirpated – a species that is no longer believed to exist in the state.					
T: Threatened					
S/A: The Endangered Species Act authorizes the treatment of a species (subspecies or population segment) as threatened even though it is not otherwise listed as threatened if: (a) The species so closely resembles in appearance a threatened species that enforcement personnel would have substantial difficulty in differentiating between the listed and unlisted species; (b) the effect of this substantial difficulty is an additional threat to a threatened species; and (c) such treatment of an unlisted species will substantially facilitate the enforcement and further the policy of the Act. The bog turtle (southern population) has this designation due to similarity of appearance to bog turtles in the threatened northern population.					
SR: Reported from North Carolina, but without persuasive documentation for either accepting or rejecting the report.					
SC: A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).					

The North Carolina Wildlife Resources Commission (NCWRC) has been contacted and has not expressed concerns regarding protected species on the project site. Baker will consider the effects of construction activities and plan to avoid direct and indirect impacts during the project. A copy of the NCWRC letter is included in Appendix B.

The USFWS was notified of the project and Baker's finding of "No Effect" for the federally listed species in Mitchell County on April 4, 2007. To date, no letter of response has been received. We assume "no response" means that they also do not have any concerns regarding this project.

2.6.1 Federally Listed Endangered Species

2.6.1.1 Vertebrates

Haliaeetus leucocephalus (Bald Eagle)

Bald eagles are large raptors, 32 to 43 inches long, with a white head, white tail, yellow bill, yellow eyes, and yellow feet. The lower section of the leg has no feathers. Wingspread is about seven feet. The characteristic plumage of adults is dark brown to black with young birds completely dark brown. Juveniles have a dark bill, pale markings on the belly, tail, and under the wings and do not develop the white head and tail until five to six years old.

According to the NHP species account, bald eagles in the Southeast frequently build their nests in the transition zone between forest and marsh or open water. Nests are cone-shaped, six to eight feet from top to bottom, and six feet or more in diameter. They are typically constructed of sticks lined with a combination of leaves, grasses, and Spanish moss. Nests are built in dominant live pines or cypress trees that provide a good view and clear flight path, usually less than 0.5 miles from open water. Winter roosts are usually in dominant trees, similar to nesting trees, but may be somewhat farther from water. In North Carolina, nest building takes place in December and January, with egg laying (clutch of one to three eggs) in February and hatching in March. Bald eagles are opportunistic feeders consuming a variety of living prey and carrion. Up to 80 percent of their diet is fish, which is self caught, scavenged, or robbed from ospreys. They may also take various small mammals and birds, especially those weakened by injury or disease.

(Henson 1990, Potter et al. 1980, USFWS 1992a)

Biological Conclusion: No Effect

According to the NHP virtual workroom website, a recorded occurrence of bald eagle habitat has not been documented within five miles minimum of the project site. This five mile radius includes the nearest large body of water, the North Toe River, approximately one mile downstream of the project area. The Sink Hole Creek project area consists of headwater streams with small drainage areas. Sink Hole Creek does support prey-sized fish while UT1, UT2 and UT3 are too small to support prey for bald eagle populations. The lack of recorded observations and the fact that the bald eagle is not listed as occurring in Mitchell County make it highly unlikely that bald eagle populations would be adversely affected by this project.

Canopy improvements made to the riparian zone within the restoration and enhancement reaches of the project area could actually support bald eagles in the long term should any of the planted trees become dominant canopy trees. Therefore, a determination was made that the proposed project will have no adverse effect on this species.

Myotis sodalis (Indiana Myotis)

The Indiana bat is 3.5 inches long, with mouse-like ears, plain nose, dull, grayish fur on the back, and lighter, cinnamon-brown fur on the belly. Its “wingspread” ranges from 9.5 to 10.5 inches. From early October until late March and April, Indiana bats hibernate in large clusters of hundreds or even thousands in limestone caves and abandoned mines, usually near water. During summer, females establish maternity colonies of two dozen to several hundred under the loose bark of dead and dying trees or shaggy-barked live trees, such as the shagbark hickory. Hollows in live or dead trees are also used. Most roost trees are usually exposed to the sun and are near water. Males and non-reproductive females typically roost singly or in small groups. Roost trees can be found within riparian areas, bottomland hardwoods, and upland hardwoods (Adams 1987, USFWS 1992a).

Biological Conclusion:

The preferred summer habitat for maternity colonies (female and young) of the Indiana bat populations consists of tree hollows and trees with loose bark such as the shagbark hickory. In addition, the bats favor trees near small-to medium-sized streams. Because the few trees located along the project reach are primarily poplar or adelgid-infested hemlock, they do not offer roosting opportunities. Any other large trees that are located in the project area will be avoided and protected during construction. Because no potential habitat will be impacted by this project, there should be no effect on this species.

Glaucomys sabrinus coloratus (Carolina Northern Flying Squirrel)

The Carolina northern flying squirrel is a small nocturnal gliding mammal some 260 to 305 millimeters (10 to 12 inches) in total length and 95-140 grams (3-5 ounces) in weight. It possesses a long, broad, flattened tail (80 percent of head and body length), prominent eyes, and dense, silky fur. The broad tail and folds of skin between the wrist and ankle form the aerodynamic surface used for gliding. Adults are gray with a brownish, tan, or reddish wash on the back, and grayish white or buffy white ventrally. Juveniles have uniform dark, slate-gray backs, and off-white undersides. The northern flying squirrel can be distinguished from the southern flying squirrel by its larger size; the gray base of its ventral hairs as opposed to a white base in the southern species; the relatively longer upper tooth row; and the short, stout baculum (penis bone) of the males.

(Cooper et al. 1977, Murdock pers. comm., Terwilliger et al. 1995, USFWS 1992a, Weigl 1987)

Biological Conclusion:

The Carolina northern flying squirrel prefers the ecotone between coniferous and mature northern hardwood forests usually 4,500' above sea level (ASL) or narrow, north-facing valleys above 4,000' (ASL). This project site is located in pasture land with very few trees and does not contain habitat as described above. Dominant woody vegetation observed during a May 1, 2007 site visit consisted of tag alder, tulip poplar, hemlock, fescue and multiflora rose. The maximum elevation of the project area is approximately 2,680' ASL, well below what is considered the habitable range for this species. Due to a lack of suitable habitat, there will be no effect on this species.

Clemmys muhlenbergii (Bog Turtle)

The Bog Turtle is among the smallest turtles of North America at only 3-4.5 inches in length with an average weight of 4 ounces. Its shell is light brown to ebony in color and it has a notable bright orange, yellow or red blotch on each side of its head. The bog turtle's preferred habitat in the southern Appalachians includes sphagnum bogs, slowly drained swamps, and mucky, slow moving spring-fed streams in meadows and pastures that are typically less than 4 acres in size (USFWS 1997a).

Biological Conclusion: No Effect

The Sink Hole Creek site is located in a sunny, open area, but it lacks shallow spring-fed fens, and sphagnaceous bogs. There are several small, depressional, moist areas located in pasture land on-site, the largest of which is approximately .30 acres in size. This largest area is a seep that contains juncus and sedges. However, these areas lack evidence that conditions remain wet enough to support bog turtles. In combination with the area being actively grazed by cattle, these conditions make it highly unlikely that the bog turtle would be present. Perennial streams at the Sink Hole Creek site typically have a moderate flow while the intermittent streams have dried up in the summer months during the drought. Insignificant areas of marginal habitat quality make the presence of this species highly unlikely and no individuals were observed during the site assessment. Preliminary discussions with USFWS staff indicate that the project streams are unlikely to be suitable habitat for bog turtles. Therefore, the project should have no effect on this species.

2.6.1.2 Invertebrates

Alasmidonta raveneliana (Appalachain Elktoe)

The Appalachian elktoe has a thin, but not fragile, kidney-shaped shell, reaching up to about 3.2 inches in length, 1.4 inches in height, and one inch in width (Clarke 1981). Like other freshwater mussels, the Appalachian elktoe feeds by filtering food particles from the water column. The specific food habits of the species are unknown, but other freshwater mussels have been documented to feed on detritus, diatoms, phytoplankton, and zooplankton (Churchill and Lewis 1924). The species has been found in relatively shallow, medium-sized creeks and rivers with cool, clean, well-oxygenated, moderate- to fast-flowing water. The species is most often found in riffles, runs, and shallow flowing pools with stable, relatively silt-free, coarse sand and gravel substrate associated with cobble, boulders, and/or bedrock. Stability of the substrate appears to be critical to the Appalachian elktoe, and the species is seldom found in stream reaches with accumulations of silt or shifting sand, gravel, or cobble. Individuals observed in these areas are believed to have been scoured out of upstream areas during periods of heavy rain, and have not been found on subsequent surveys (USFWS Webpage C. McGrath, pers. comm. 1996; J.A. Fridell, pers. observation 1995, 1996, 1999).

Biological Conclusion: No Effect

The Appalachian elktoe prefers morphologically stable stream reaches with no silt accumulation or heavily shifting substrate. These conditions do not currently exist at this project site. Preliminary discussions with NCWRC and USFWS staff indicate that the project streams are unlikely to be suitable habitat for the Appalachian elktoe. Stream banks throughout much of the project are unstable due to cattle trampling and have contributed to excessive amounts of silt in the stream. Although the elktoe has been documented within two miles of the project area in the North Toe River, the described habitat does not exist within the project reach and no individual specimens were observed. This project will have no direct impacts to a population or habitat for this species. Project erosion control measures will ensure that impacts to downstream habitats are avoided. Project objectives may produce improved long-term habitat conditions and water quality contributed to the North Toe River from Sink Hole Creek.

Microhexura montivaga (Spruce-fir Moss Spider)

The spruce-fir moss spider prefers to occupy moist, well-drained moss and liverwort mats growing on rocks or boulders in relatively undisturbed forested areas. Specifically, these moss-covered rocks and boulders should be located within well-shaded areas of mature, high-elevation Fraser fir and fir dominated spruce-fir forests.

Biological Conclusion:

No stands of high-elevation Fraser fir or spruce-fir forests exist within the project site. Additionally, the project area is located in a previously disturbed area that remains actively managed as pasture land for livestock. This project will have no direct impacts to a population or habitat for this species.

2.6.1.3 Vascular Plants

Houstonia Montana (Roan Mountain Bluet)

Roan Mountain bluet is a shallow-rooted, perennial herb of the coffee family that grows 4-6 inches (10-15 cm) tall. According to a species account summarized by the NHP, small leaves are located along the four-cornered stem of the Roan Mountain bluet. Its leaves can be lance or ellipse-shaped and are 0.2-1.2 inches (0.8-3 cm) long. The Roan Mountain bluet is also characterized by a rosette of leaves that grows at the base of the plant, which is not always visible during flowering. The deep-purple colored flowers of the plant are funnel-shaped and grow in clusters of 1-4. The N.C. Natural Heritage Program and USFWS websites list the preferred habitat for the Roan Mountain Bluet as grassy balds, cliffs, outcrops, and steep slopes with full sun at high elevations 4,590-6,230'ASL (1400-1900 m). This plant is typically found in gravelly soils among rock outcrops. Soils requirements consist of units derived from metamorphic, acidic rock. Adjacent forests are usually spruce-fir forests. In the southern Appalchians, these forests are dominated by red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*).

(Murdock per. com; Radford et al. 1964; USFWS 1992a, 1996b.)

Biological Conclusion:

The upper limits of the project area are located at an elevation of approximately 2,680'ASL and do not contain spruce-fir forests or gravelly outcrops. Current and favored site conditions are not conducive to sustaining populations of the Roan Mountain Bluet. It is not anticipated that the project will have a direct impact on this species or its habitat.

Geum radiatum (Spreading Avens)

Spreading avens is a perennial herb of the rose family. It can grow 8-20 inches (20-50 cm) high and has dense, spreading hairs. Most leaves of the spreading avens grow from a rosette at the plant base. These leaves are large and kidney shaped, with uneven, serrated edges. Spreading avens plant stems typically have between two to five smaller leaves. According to the NHP species account, "…an indefinite cyme of 1-3 flowers grows at the end of each stem, with 5 lance-shaped sepals, and 5 bright yellow petals 0.5-0.8 inch (1.3-2 cm) long, with numerous stamens and pistils." Similar to the Roan Mountain Bluet, the Spreading avens thrives on (preferably north-facing) high-elevation cliffs, outcrops, grassy balds, and steep slopes that receive full sunlight. Adjacent forests in which the spreading avens occurs are dominated by red spruce *(Picea rubrens)* and Fraser fir *(Abies fraseri)*. Spreading avens prefers shallow, acidic soils located in the cracks and crevices of weathering igneous, metamorphic and metasedimentary rocks. This plant can survive in well drained soil, though the soil must receive a constant source of moisture.

(Early 1991; Hardin 1977; Radford et al. 1964; USFWS 1992a and 1993c.)

Biological Conclusion:

Topographical and exposed geologic features of the project site are not favored by the spreading avens. The lack of habitat indicators in the project site has been visually confirmed during previous field visits. This project will have no direct impacts to a population or habitat of this species.

Liatris helleri (Heller's Blazing-Star)

According to the NHP and USFWS species accounts, Heller's Blazing-star is a perennial herb of the aster family. It can have one or more erect stems that grow to 16 inches (40 cm) tall, out of a tuft of pale green leaves at the base of the plant. Its upper leaves are alternate, long and narrow. The flowers of this perennial are scattered in 3-8 inch long spiky clusters along the stem(s). Individual flowers are tubular-shaped and lavender in color. Habitat conditions suited for Heller's Blazing-star consist of high-elevation, rock ledges and shallow acidic soils which are exposed to full sunlight (Radford et al. 1964, USFWS 1992a).

Biological Conclusion:

Current and favored site conditions are not conducive to the presence of Heller's Blazing-star. In fact, Heller's Blazing-star is believed to have been eradicated in Mitchell County according to a NHP species account for this plant. This project will have no direct impacts to a population or habitat for this species.

Solidago spithamaea (Blue Ridge Goldenrod)

The NHP species account for the Blue Ridge goldenrod lists the plant as a hairy perennial with erect and angled stems that is strongly ribbed at the base. The Blue Ridge goldenrod can grow 4-16 inches (10-41 cm) tall and has yellow-green leaves alternate leaves that line the stem. Its elliptical shaped leaves can be 1 to 2.5 inches (3-6 cm) long, and have a smooth surface with serrated edges. The flowering head consists of 20-30 flat-topped, yellow flowers. Flower petals on the edge of the flower head are usually 0.8-1.6 inches (2-4 cm) long. The N.C. Natural Heritage Program lists the preferred habitat for the Blue Ridge Goldenrod as grassy balds, cliffs, outcrops, and ledges of higher mountain peaks, above 4600'ASL (1400 m) in elevation that are exposed to full sun (Hardin 1977; Lowe et al. 1990; Radford et al. 1964; USFWS 1987 and 1992a.). The Blue Ridge Goldenrod favors soils that are generally acidic and consist of shallow humus or clay loams that are intermittently saturated.

Biological Conclusion:

The project site is located at a maximum elevation of approximately 2,600’ ASL and contains no spruce-fir forests or rocky areas. The habitat described for this species was not present on-site. This project will have no direct impacts to a population or habitat for this species.

Spiraea virginiana (Virginia Spiraea)

Preferred habitat of the Virginia spiraea ranges from flood-scoured, high-gradient rocky riverbanks, gorges, and canyons to braided areas of stream reaches. Virginia spiraea has also been observed in disturbed rights-of-way. Virginia spiraea prefer sunlight and moist, acidic soils (primarily sandstones). This plant grows in thickets, and is commonly associated with a variety of grape species (*Vitis* spp.) and royal fern (*Osmunda regalis*), though it may still be located in thickets where these other plants are not present. Habitat conditions for the Virginia spiraea must be present in some combination in order for the spiraea to flourish. Due to the specificity of site conditions needed, the Virginia spiraea is limited to a specific ecological niche (Radford et al. 1964, USFWS 1992a.).

Biological Conclusion:

Sink Hole Creek and its tributaries contain moderate to high levels of silt and have a medium gradient. With the exception of UT1 and reaches were cattle access to the stream is controlled, stream banks within the project area are generally unstable due to livestock trampling. UT1 is primarily a hardwood forest that has limited problems with *multiflora* rose and other invasive vegetation. The land use surrounding the project areas on UT2 and Sink Hole Creek is primarily pasture land. The dominant plant community in these areas consist of a variety of grasses with some scattered individual trees, particularly along Sink Hole Creek. In addition, the ecological niche described does not exist within the project area. Virginia spiraea has not been observed on-site during previous field visits. Therefore it was determined that this project will not directly impact a population of Virginia spiraea or its habitat.

2.6.1.4 Lichen

Gymnoderma lineare (Rock Gnome Lichen)

Rock Gnome Lichen grows in dense colonies of narrow straps (squamules) that appear a bluish-grey on the surface and a shiny white on the lower surface. The squamules are about 1 millimeter across near the tip, tapering to the blackened base, sparingly and subdichotomously branched, and generally about 1 to 2 centimeters (.39 to .79 inches) long, although they can vary somewhat in length, depending upon environmental factors. Flowering occurs from July to September; fruiting bodies are located at the tips of the squamules and are also black. The squamules are nearly parallel to the rock surface, with the tips curling away from the rock, in a near perpendicular orientation to the rock surface.

The rock gnome lichen is endemic to the southern Appalachian Mountains of North Carolina and Tennessee, where it is limited to 32 populations. Only seven of the remaining 32 populations cover an area larger than 2 square meters . Most populations are 1 meter or less in size (USFWS, 1997b).

Rock gnome lichen habitat is located around humid, high elevation rock outcrops or vertical cliff faces or in rock outcrops in humid gorges at lower elevations. Most populations occur above an elevation of (5,000 feet) (USFWS, 1997b).

Biological Conclusion:

Due to the degraded stream conditions within the project site and the lack of other habitat criteria necessary, it is not likely that the rock gnome lichen is present with the project area. No rock gnome lichen have been observed during previous field visits to the project area, nor are there any known populations of the lichen within five miles of the site. Project activities are not expected to adversely impact rock gnome lichen populations or their habitat in Mitchell County.

2.7 Cultural Resources

On April 4, 2007, a letter was sent to the Eastern Band of Cherokee Indians' Tribal Historic Preservation Office (THPO) and on April 9, 2007 to the North Carolina State Historic Preservation Office (SHPO), requesting their review and comment concerning cultural resources in the vicinity of the Sink Hole Creek restoration site. A response was received on April 30, 2007, from SHPO in which they requested a Phase I Archaeological Survey be conducted due to the proximity of the project area to a previously recorded prehistoric site nearby. Baker contracted with Archaeological Consultants of the Carolinas, Inc. to complete the survey during which one potential site was located. However, it was concluded that the site was not eligible for listing in the National Register of Historic Places and it lacked sufficient archaeological resources to yield significant historic or prehistoric information. On August 1, 2007, Baker received a letter from the SHPO concurring with the findings of the archaeological survey and agreeing that no further archaeological investigation was required. The THPO also submitted a response on August 3, 2007 stating their concurrence with the recommendations provided within the Phase I Archaeological Survey Report for the project. A copy of the SHPO and THPO correspondence is included in Appendix B.

2.8 Potential Constraints

Baker assessed the Sink Hole Creek project site in regards to potential fatal flaws and site constraints. No fatal flaws have been identified to date.

2.8.1 Property Ownership, Boundary and Site Access

Baker has obtained a conservation easement from the current landowners for the Sink Hole Creek project area. The easement is held by the State of North Carolina and has been recorded at the Mitchell County Courthouse (Deed Book 471, Page Number 144). The easement allows Baker to proceed with the restoration project and restricts the land use in perpetuity.

The site can be accessed for construction and post-restoration monitoring. Construction access and staging areas will be identified during final design.

2.8.2 Utilities

Baker anticipates no constraints from utilities at the Sink Hole Creek project site. No easements for power and telephone utilities are present within the project conservation easement. Existing right-of-ways have been excluded from the conservation easement.

2.8.3 Hydrologic Trespass and Floodplain Characterization

The FEMA Flood Insurance Rate Map (FIRM) for Mitchell County, NC, (Panel Numbers 0852 and 0862) indicate that the project is not located within a regulatory floodplain. The project is located within an area determined to have less than a 0.2% chance of exceeding or equaling a 100-year flood event per year and is thus categorized as being in regulatory floodplain Zone X (NCFMP 2009).

No formal flood study is currently planned as a part of this project. Preliminary modeling has been performed to evaluate the restoration design approach. The modeling indicates that the project will be completed with Priority I and Priority II design approaches. Baker will coordinate with the county floodplain program administrator as necessary to ensure local and state floodplain management guidelines have been satisfactorily addressed.

2.9 Potentially Hazardous Environmental Sites

An Environmental Data Resources, Inc. report that identifies and maps both previously documented or potentially hazardous environmental sites within two miles of the project area was prepared for the site on April 6, 2007. A copy of the report with an overview map is included in Appendix C. Site searches conducted under the report included but were not limited to the following queries: Superfund Database (National Priorities List, NPL) (for hazardous waste treatment, storage, or disposal facilities); the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS) Database (for suspect state hazardous waste, solid waste or landfill facilities). A search regarding prior incidents of leaking underground storage tanks in the proposed project area also yielded no results. Based on the EDR report, there are no known or potentially hazardous waste sites within or adjacent to the project area. During field data collection, there was no evidence of these sites in the proposed project vicinity, and conversations with landowners did not reveal any further knowledge of hazardous environmental sites in the area. Therefore, the overall environmental risk for this site was determined to be low.

3.0 PROJECT SITE STREAMS

3.1 Existing Conditions Survey

The project area was flown to obtain a 1-foot accuracy aerial topographic survey using LIDAR technology. Detailed channel morphology was surveyed with a total station. Along with providing detailed topography, this survey included eight cross-sections on Sink Hole Creek, two cross-sections on each unnamed tributary, and longitudinal profiles for all reaches. Baker also collected substrate samples in the semi-alluvial portion of the project to characterize stream sediments. Figure 3.1 illustrates the locations of cross-section surveys and each project reach. Surveyed cross-sections and profiles are included in Appendix D. A photo log that depicts the existing conditions at the Sink Hole Creek project site is provided in Appendix E.

The existing conditions of designated project reaches are described below with Table 3.1 summarizing the representative geomorphic conditions currently present at the Sink Hole Creek restoration site. The table also provides regional curve data for comparison based on the drainage area of each reach. This data has limited applicability given the small sizes and steep slopes present within the project. A more detailed discussion of the assessment conducted to determine channel stability and channel forming discharge for project streams is included in Sections 3.5 through 3.7.

Baker assessed the stream and valley types present and considered their evolutionary stage and likely endpoint in order to develop a basis for the proposed restoration efforts. The project contains both colluvial and alluvial valleys with a wide range of slopes present. Alluvial valleys still have colluvial deposits and floodplains of limited width and may be referred to as semi-alluvial in other parts of this report. There are Aa+, A, B, Eb, Cb, and G-type streams found within the project reaches. All streams including the E and C-types have been altered by straightening, manmade levy creation, or livestock impacts.

3.2 Channel Classification

Both reaches on Sink Hole Creek and the upper segment of UT1, Reach 2 are classified as Eb, Cb, or G-type streams. The E and C stream types vary from moderately stable to unstable depending on the degree of impact present. High bank height ratios are common in these reaches and in the G-type sub-reaches. The lower portion of UT1, Reach 2 is classified as a B-type stream in its existing condition. Streams classified as B systems are usually moderately entrenched and have a moderate width-depth ratio with a sinuosity greater than 1.2. These streams are found in stable alluvial fans, colluvial deposits and drainageways managed by structures on gradients between 2-4%. At the Sink Hole Creek project site, these streams are primarily located within colluvial watersheds. UT2 and UT3 are classified as A-type streams based on the steep gradient and confined valley conditions present. A-type streams are typically headwater channels with a low sinuosity, low width/depth ratio and steep gradient (> 4%).

3.3 Valley Classification

In addition to determining stream types present at the Sink Hole Creek project site, valley types were also considered. All of the reaches in the Sink Hole Creek restoration project are located in a Type II valley setting. Type II valleys are moderately steep colluvial valleys with gently sloping side slopes (Rosgen 1996). The channel types present in the project are commonly seen in Valley Type II drainages throughout the Blue Ridge Province where channelization, dredging and other practices associated with agricultural land use activities have directly impacted the channel and riparian zone, resulting in an unstable system.

LEGEND:

*Date of aerial photography: 1998

Project Reaches

- Sink Hole Creek, Reach 1
- Sink Hole Creek, Reach 2
- UT1, Reach 1
- UT1, Reach 2
- UT2, Reach 1
- UT2, Reach 2
- UT3, UT3
- Cross-sections
- Proposed Easement
- Streams

0 200 400 800 Feet

Figure 3.1 Project Reaches and Surveyed Cross-Section Locations

Sink Hole Creek Restoration Project Mitchell County, NC

Ecosystem Enhancement PROGRAM

Baker

Table 3.1 Representative Geomorphic Data for Sink Hole Creek and Unnamed Tributaries
Stream Channel Classification Level II
Sink Hole Creek Restoration Plan

Parameter	Value						Units
	Sink Hole Creek		UT1	UT2		UT3	
	Reach 1 XS14/XS8	Reach 2 XS9/XS10	Reach 2 XS6/XS7	Reach 1 XS 1	Reach 2 XS5	Reach 1 XS3	
Reach Length	1,036	1,062	489	579	879	586	Linear Feet
Feature Type	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	
Drainage Area	.72	.84	.09	.02	.08	.02	Square Miles
NC Mountain Regional Curve (W_{bkf})	16.9	17.7	7.8	4.5	7.5	4.5	Feet
NC Mountain Regional Curve (D_{bkf})	1.00	1.04	.53	.33	.51	.33	Feet
NC Mountain Regional Curve (A_{bkf})	17.7	19.2	5.1	2.1	4.7	2.1	Feet
Bankfull Width (W_{bkf})	12.5/17.7	13.8/11.1	7.5/10.96	2.99	2.38	3.83	Feet
Bankfull Mean Depth (d_{bkf})	1.46/1.15	1.43/1.42	.34/.48	.69	.95	.34	Feet
Cross-Sectional Area (A_{bkf})	18.3/20.4	19.7/15.7	2.6/5.2	2.1	2.3	1.29	Square Feet
Width/Depth Ratio (W/D ratio)	8.6/15.4	9.6/7.8	21.9/23	4.3	2.5	11.4	
Bankfull Max Depth (d_{mbkf})	2.32/2.18	2.28/2.15	.78/.93	1.05	1.24	.79	Feet
Floodprone Area Width (W_{fpa})	>30	12.6/>27	>19/19.8	4.8	3.6	7.2	Feet
Entrenchment Ratio (ER)	>2.4/>1.8 (>2.2)	1.3/>2.4	>2.4/1.85	1.6	1.5	1.9	
Bank Height Ratio (BHR)**	1.8/1.0	2.4/1.6	2.0/2.3	3.1	4.2	3.5	
Channel Materials (Particle Size Index – d_{50})	Medium gravel	Coarse gravel	Coarse gravel	N/A	N/A	N/A	
d_{16}	.063	.317	.16	N/A	N/A	N/A	Mm
d_{35}	6.56	9.32	11.7	N/A	N/A	N/A	Mm
d_{50}	13.8	26.4	32	N/A	N/A	N/A	Mm
d_{84}	71.3	80.1	81.1	N/A	N/A	N/A	Mm
d_{95}	110	123	155	N/A	N/A	N/A	Mm

Water Surface Slope (S)	.028/.026	.022	.039	.108	.059	.105	Ft/Ft
Channel Sinuosity (K)	1.08/1.09	1.16	1.12	1.07	1.04	1.02	
Rosgen Stream Type	E5b*/Cb	G/Eb*	Cb/B	Aa+	A	A	
* Low sinuosity E-type channel present due to prior channelization. ** High bank height ratios should be noted, values in excess of 1.5 have little or no chance for self-recovery.							

3.4 Project Reach Characterization

3.4.1 Sink Hole Creek (Mainstem) – Reaches 1 and 2

In general, the bedform diversity of Sink Hole Creek is lacking. Coarse riffles are predominant with infrequently spaced pools ranging from 30 feet to 378 feet apart. The mainstem is broken into reaches based on geomorphic character (slope and channel condition) and at significant changes in drainage area. The mainstem of Sink Hole Creek flows through a valley that is not confined but neither is the valley particularly wide. Both colluvial and alluvial processes are present. Land cover consists of forest and pasture land. The overall valley slope is 0.028 ft/ft, but local variation on a reach scale is present. Through this project, Sink Hole Creek will be transformed from straightened “Eb” and “G”stream types to a slightly sinuous “Eb” stream type with prevalent grade control.

3.4.1.1 Sink Hole Creek Reach 1

Sink Hole Creek Reach 1 enters the project area at the outlet of a corrugated metal culvert north of Water Street where it then courses through pasture for roughly 821LF before entering another culvert under NC Highway 80. Reach 1 then continues west of NC Highway 80 for approximately 215 LF where it converges with UT1.

Three cross-sections were surveyed on this reach. Bankfull elevations were determined by field identification, and were later verified in HEC-RAS (Bruner, 2005) and through comparison to reference reaches and the NC Mountain Regional Curve (Harman et al., 2000). This reach has a typical bank height ratio of 1.5 or greater. The typical cross-section referenced resulted in the classification of this reach as an Eb-type stream. Reach 1 has a 0.028 ft/ft slope with several long riffle sections and infrequently spaced pools. This reach has a sinuosity of 1.08, a result of prior straightening. Sediment analysis yielded the average particle size to be medium gravel, although several pools were noted to contain moderate amounts of silt.

At the head of the reach, the existing culvert outlet has a large scour pool and remnants of bank armoring. Evidence of dredging and side-casting of dredged material is common in the reach. Stream banks along the reach are actively eroding due to a lack of woody vegetation and frequent access by cattle.

The segment of Reach 1 below the culvert crossing at NC Hwy. 80 was classified as a Cb stream type and exhibits many of the same geomorphic characteristics as the upper portion of Reach 1. A similar bed profile is present as is a similar slope (0.026 ft/ft) and sinuosity (1.09). This segment of Sink Hole Creek is also characterized by bedrock outcroppings which serve as grade control. The reach has some connection to its floodplain, as indicated in the cross-section. HEC-RAS modeling and the regional curve support bankfull determinations made. Like the upper segment of Reach 1 on Sink Hole Creek, small berms present along parts of the stream reveal past dredging activities. In other areas cattle crossings and grazing have worn down sections of bank. The stream is overly wide just below the culvert outfall, and is aggradational. Vegetation present mainly consists of grasses, herbaceous cover, and woody vegetation which is more prevalent at the lower end of the reach.

3.4.1.2 Sink Hole Creek Reach 2

Reach 2 extends 1,062 LF downstream from the confluence of Sink Hole Creek and UT1. This reach has slightly different geomorphic characteristics as compared to Reach 1 and was also broken out due to the increase in watershed area with the addition of UT1. The slope throughout this reach is 0.022 ft/ft and the existing conditions channel geometry exhibits a low width-depth (W/D) ratio. The extent of entrenchment varies by subreach. Those portions of the channel that are only slightly entrenched have been classified as low sinuosity, E-type streams. The sinuosity is extremely low due to prior channelization. More entrenched segments were classified as G-type channels. This reach exhibits well-defined riffle-pool sequencing with well-sorted gravel and cobble riffles.

Bankfull elevation was determined in this reach by field-identified and surveyed bankfull indicators. Indicators were later verified in the HEC-RAS existing conditions model and compared to the regional curve and project reference data. Field assessments of this reach indicate areas of channel manipulation resulting in incision and instability. Although invasive, exotic plants are present, riparian vegetation conditions improve along this section of the Sink Hole project area, particularly along the left bank. A strip of wooded buffer on the left bank separates the creek from the pasture upslope of the project area. Buffer width varies from approximately 10 feet to greater than 25 feet. The right bank generally lacks woody vegetation with the exception of a few isolated areas.

3.4.2 Unnamed Tributaries

Three unnamed tributaries are included in the Sink Hole Creek restoration project. UT1 is located in the southern part of the project area and runs from southeast to northwest, turning in a northerly direction just before the confluence with Sink Hole Creek. UT1 is divided into two sections by an in-line pond, pipe beneath a developed area and NC Highway 80. The upper portion above the pond, is located in a forested cove and will be preserved as is. The lower reach (Reach 2) begins below the pond and NC Hwy 80 and continues to the confluence with Sink Hole Creek. UT2 and UT3 are similar in character and are headwater contributors to Sink Hole Creek from the valley that runs from east to west in the project area. UT3 contributes to UT 2 high on the side slope of the valley and UT2 has a confluence with Sink Hole Creek at the foot of the slope near Water Street. This confluence is well upstream of the beginning of Reach 1.

While UT1, Reach 1 will be preserved as is, Reach 2 has been subjected to relocation, straightening, and cattle impacts. As a result, the bedform diversity is poor. The valley of UT1 has both alluvial and colluvial in processes affecting the channel. Land cover in Reach 2 consists of pastureland. The valley slope is approximately 0.04 ft/ft. Through this project, UT1 will be transformed from a straightened “Cb” or “B” stream type to a step-pool B-type channel with sufficient grade control to prevent down-cutting, dissipate energy and create a step-pool sequence to improve bedform diversity.

UT2 and UT3, located north of the upper end of Water Street, are somewhat isolated from the other project reaches due to land ownership and physical constraints. UT2 and UT3 are both located on moderately steep to steep pasture land. UT3 is approximately 586 LF in length and drains into UT2. UT2 is a tributary to Sink Hole Creek; it is referred to as Reach 1 above the confluence with UT3, and as Reach 2 below it. Reach 2 of UT2 ends at its confluence with Sink Hole Creek. Below this point, there is a break in the project until the beginning of Reach 1 of the mainstem a few thousand feet downstream.

Both UT2 and UT3 have extremely poor bedform diversity. The streambed is almost entirely silted in as a result of severe impacts from cattle grazing. The valley where UT2 and 3 originate is steep and confined and is of a colluvial nature, although little or no rock is visible in the channel at present. Land cover consists of a forested area from the ridgeline of the project watershed boundary downslope to the project area. The forested area transitions to pasture a few hundred feet above where these channels emerge from springs. Through this project, the tributaries will be converted to step-pool channels with abundant grade control features to stabilize these streams. Revegetation and cattle exclusion practices will also help to restore coarse substrate to UT2 and UT3. The tributaries will be transformed from degraded and straightened “Aa+”, “A”, and “Ba” stream types to streams of a similar type but with highly improved grade control, substrate, flood relief, with appropriate dimensions, and improved vegetation in comparison to their existing condition.

3.4.2.1 UT1 Reach 1

The upstream reach of UT1, which drains approximately 44 acres at its junction with the in-line pond, is in good condition and will be placed preserved as is under the project conservation easement. Reach 1 of UT1 flows 1,076 LF through a largely deciduous forest. The reach has stable banks and a bankfull channel that supports frequent floodplain inundation.

3.4.2.2 UT1 Reach 2

Reach 2 begins downstream of NC Hwy. 80 at the south end of the project and continues downstream 489 linear feet to the confluence with the mainstem. Woody vegetation is mostly absent in this reach. Like the mainstem, this channel has been moved up against the left valley wall to create more pasture. Cattle have trampled the stream banks and prior channelization is evident. The water surface slope is 0.039, and is much higher than the downstream mainstem.

The watershed drainage area for Reach 2 is 60 acres at its confluence with the mainstem. Reach 2 exhibits some entrenchment and incision over most of the reach, but not nearly as severe or uncharacteristic as UT2 Reach 2. This reach has an entrenchment ratio varying from 1.9 to greater than 2.4, and a width/depth ratio in the low 20’s.

3.4.2.3 UT2 Reach 1

UT2, a perennial stream, extends from the eastern watershed boundary. Reach 1 starts at the source of UT2 (a persistent spring) and continues downstream 579 LF where it converges with UT3. Reach 1 on UT2 consists of a steep, narrow, stream bounded by pasture land that is currently used for cattle grazing. Vegetation adjacent to the channel consists of grasses with no woody species.

UT2 has been severely impacted by cattle grazing and some head-cutting and is incised over much of its length. Reach 1 of UT2 is primarily impacted by livestock but is not particularly incised considering its location in the valley. This reach is classified as an Aa+ stream and has a water surface slope of 10.8 %. The watershed area drained by Reach 1 is 53 acres. Reach 1 has a bank height ration (BHR) of 3.1 and a width/depth ratio of 4.3. The reach has an entrenchment ratio of 1.6, slightly high for an A-type stream but within the acceptable variation for entrenchment ratio in the channel classification scheme.

3.4.2.4 UT2 Reach 2

All tributary reaches are moderately to severely entrenched with Reach 2 of UT2 having the highest entrenchment values. Reach 2 of UT2 is much more unstable and has the highest bank height ratio of any reach on the entire project. Numerous headcuts are present in this reach.

Reach 2 continues downstream of the confluence with UT3 for 879 LF where it enters Sink Hole Creek. Reach 2 has a flatter water surface slope than its contributing reaches (0.059 ft/ft). It has a deeply incised and entrenched channel. The width/depth ratio for this channel is 2.5 while the bank height ratio is 4.2. Reach 2 ends at the fence line near Water Street. Woody vegetation is sparse in this reach; the dominant ground cover present is grass. Channel substrate overwhelmingly consists of fine sediments, presumably generated from the disturbance of banks by livestock.

3.4.2.5 UT3

UT3 is the other contributing branch to Reach 2 of UT2 and is located in the same pasture just to the east of UT2 Reach 1. UT3 is approximately 586 LF in length and is an intermittent stream based on the NC Stream Identification Form. The watershed drainage area for UT3 is 15 acres. UT3 exhibits entrenchment and incision over most of the reach, but it is not as severe as the lower reach on UT2. The pasture where these two streams are located has a steep gradient on the order of 10%. There is no woody vegetation present along UT3 to aid in bank stabilization.

3.5 Channel Morphology, Evolution and Stability Assessment

Channel stability is defined here as the stream's ability to transport incoming flows and sediment loads supplied by the watershed without undergoing significant changes over a geologically short time-scale. A generalized relationship of stream stability was proposed by Lane (1955); it states that the product of sediment load and sediment size is in balance with the product of stream slope and discharge, or stream power. A change in any one of these variables induces physical adjustment of one or more of the other variables to compensate and maintain the proportionality.

Longitudinally, the water and sediment flows delivered to each subsequent section are the result of the watershed and upstream or backwater (downstream) conditions. Water and sediment pass through the channel, which is defined by its shape, material, and vegetative condition. Flow and sediment are either stored or passed through at each section along the reach. The resulting physical changes are a balancing act between gravity, friction, and the sediment and water being delivered into the system (Leopold et al., 1964).

Observed stream response to induced instability, as described by Simon's (1989) Channel Evolution Model, involve extensive modifications to channel form resulting in profile, cross-sectional, and plan form changes which often take decades or longer to achieve resolution. The Simon (1989) Channel Evolution Model characterizes typical evolution in six steps:

1. Pre-modified
2. Channelized
3. Degradation
4. Degradation and widening
5. Aggradation and widening
6. Quasi-equilibrium.

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Channelization, dredging, changing land use, removal of streamside vegetation, upstream or downstream channel modifications, and/or change in other hydrologic variables result in adjustments in channel morphology to compensate for the new condition(s). Disturbance commonly results in an increase in stream power that can cause degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks and, when critical bank heights are exceeded, the banks begin to fail and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually the mass wasting slows, and the stream begins to aggrade. A new, low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form, with a new floodplain constructed of alluvial material (FISRWG, 1998).

Channels within the project area are mostly perennial, have experienced prior channelization or other kinds of watershed disturbance, and are currently impacted by grazing. Channel stability was assessed with the following methods: qualitative and quantitative site observations, comprehensive site-specific hydraulic modeling using detailed topographic data collected for the project, and hydraulic sediment modeling. Conclusions reached from these methods were used to define site stability and determine appropriate restoration approaches for each sub-reach.

Sink Hole Creek is a perennial stream that originates from a watershed that is approximately 66% forested, 28% agricultural and 6% developed. The mainstem channel is aggraded in some areas and moderately incised in other sections as evidenced by an entrenchment ratio range of 1.3 to >2.4. Prior channelization and dredging of Sink Hole Creek is evident across much of the project area. The majority of Sink Hole Creek is in Step 3 of the Simon Channel Evolution Model. These segments have been modified and now have a bank height ratio of 1.0-2.0. Segments where stream banks are overwidened and the channel is aggrading are in Step # 5 of the model. Over much of the project reach the active floodplain has been severely compromised by grazing and vegetation is severely lacking.

UT1 has also been channelized in the past and has undergone additional manipulation during the creation of a small, in-line pond on the east side of NC Hwy 80. Reach 2 is in Step 3 (degradation) of the Simon Channel Evolution Model as the high banks are eroding and aggradation is not evident. A culvert under the highway and the pond have prevented a head cut from moving into Reach 1.

UT2 and UT3 have been manipulated in the past; these channels receive drainage from field drains, have been heavily impacted by grazing and they may also have been dredged. The lack of sinuosity is typical for the gradient of these channels. The watersheds that feed these streams are mostly forested upstream of the project reach, with pasture beginning just above the spring heads. In addition to the steep side slopes of the valley, the channels have reaches that are incised with bank height ratios that exceed 3.0. These streams exhibit shear banks with minimal riparian vegetation. There is head cutting in the channel below the confluence of UT2 and UT3 that is likely to impact upstream reaches. Most of the length of these channels are in a degradational phase of channel evolution and would further degrade and widen for a long time in order to reach a stable state once again. There are smaller reaches on these channels that are exhibiting the beginning of the aggradational phase of channel evolution. UT 2 above the confluence is somewhat aggradational; however, cattle access retards the ability of the channel vegetation to stabilize the bed and widening is not complete.

Tables 3.2 and 3.3 summarize existing channel morphology in the project area. Data was taken from surveyed cross-sections distributed across the project area. Table 3.4 summarizes research findings by Rosgen (2001) concerning bank height ratios as an indicator of channel stability.

The project area consists of channels that are primarily in a degradational phase of the channel evolutionary sequence with small scattered areas of aggradation. As a result, these streams are prime candidates for restoration. Stream restoration techniques act to minimize the erosion and geomorphic disturbance required to achieve a new stable state naturally. Restoration activities proposed in the Sink Hole Creek project will recreate channel types that are appropriate to the valley type and slopes present. In addition to the installation of grade control structures, restoration efforts will involve the alteration of channel alignment. This will be accomplished by excavating new channel segments on the existing floodplain for Sink Hole Creek and Reach 2 of UT1 and UT2. This resets the evolutionary cycle; the structures and measures installed, in conjunction with the protective buffer, should ensure the continued stability of the streams within the project area, barring major disturbance in the unprotected areas of the greater watershed.

Table 3.2 Channel Morphology Features and Stability Indicators for Sink Hole Creek
Sink Hole Creek Restoration Plan

Parameter	Sink Hole Creek Mainstem	
	Reach 1 (XS #14 / #8)	Reach 2 (XS#9 / #10)
Stream Type	Channelized Eb* / Cb	G / Eb*
Riparian Vegetation	Grazed pasture and fields used for hay production on both sides of stream. Gravel road and Christmas tree farm upslope of hay fields. Patches of herbaceous or woody bank vegetation in lower section of the Reach.	Grazed pasture on both sides of stream. Short reaches of herbaceous or woody bank vegetation <25 feet wide.
Channel Dimension		
Bankfull Area (SF)	18.3 / 20.4	19.7 / 15.7
Width/Depth Ratio	8.6 / 15.4	9.6 / 7.8
Channel Pattern		
Meander Width Ratio	N/A	N/A
Sinuosity	1.08 / 1.09	1.16 (same for both XS)
Vertical Stability		
Bank Height Ratio (BHR)	1.8 / 1.0	2.4 / 1.6
Entrenchment Ratio (ER)	>2.4 / 1.6	1.3 / >2.4
Evolution Scenario (I-II-III…)	Eb-G-B* / Cb-G-F-C	Eb-G-B* (same for both XS)
Existing Evolution Stage[2]	Degradation / Stable	Degradation (same for both XS)

Notes:
1. N/A: Meander Width Ratio not measured because channel has been straightened.
2. Simon Channel Evolution

* Sections of Reaches 1 & 2 have been physically moved or otherwise altered (including manmade levies) and are not following a typical evolution scenario.

Table 3.3 Channel Morphology Features and Stability Indicators for Unnamed Tributaries to Sink Hole Creek Sink Hole Creek Restoration Plan				
Parameter	Tributaries to Sink Hole Creek			
	UT1 Lwr (XS #6 / #7)	UT2 Reach 1 (XS#1)	UT2 Reach 2 (XS#5)	UT3 (XS#3)
Stream Type	Cb / B	Aa+	A*	Ba*
Riparian Vegetation	Grazed pasture on both sides of stream. Some vegetation on left bank (growing on slope of valley wall).	Grazed pasture on both sides of stream.	Grazed pasture on both sides of stream.	Grazed pasture on both sides of stream.
Channel Dimension				
Bankfull Area (SF)	2.6 / 5.2	2.1	2.3	1.29
Width/Depth Ratio	21.9 / 23	4.3	2.5	11.4
Channel Pattern				
Meander Width Ratio	N/A	N/A	N/A	N/A
Sinuosity	1.16 (same for both XS)	1.07	1.04	1.02
Vertical Stability				
Bank Height Ratio (BHR)	2.0 / 2.3	3.1	4.2	3.5
Entrenchment Ratio (ER)	1.6 / 1.9	1.6	1.5	1.9
Evolution Scenario	Cb-G-F-C / B-G-Fb-B	Aa+-G-Fb-Aa+	A-G-Fb-A	Ba-G-Fb-B
Existing Evolution Stage[2]	Degradation (same for both XS)	Degradation	Degradation	Degradation

Notes:
1. N/A: Not measured due to conditions or not applicable to channel type
2. Simon Channel Evolution

* functioning like G due to high Bank Height Ratio

Table 3.4 Rosgen Channel Stability Assessment Sink Hole Creek Restoration Plan	
Stability Rating	Bank Height Ratio (BHR)
Stable (low risk of degradation)	1.0-1.05
Moderately unstable	1.06-1.3
Unstable (high risk of degradation)	1.3-1.5
Highly unstable	>1.5

Notes: Rosgen, D. L. (2001) A stream channel stability assessment methodology. Proceedings of the Federal Interagency Sediment Conference. Reno, NV. March, 2001.

3.6 Bankfull Verification

Baker engaged physical, analytical, and empirical methods to verify the bankfull stage and discharge of the project reaches of Sink Hole Creek and its tributaries. These methods were each given weight, with physical field measurements having a slightly higher weight due to their site-specific nature. Subsequent methods were used to interpret and sometimes adjust field observations.

In summary, the following steps were taken:

1. Identified and surveyed representative cross-sections with physical bankfull indicators.
2. Compared the surveyed cross-sections with each other to ensure consistency.
3. Compared values to regional empirical data (regional curves).
4. Used Manning's equation to estimate design discharge through cross-sections.
5. Built and ran a HEC-RAS existing conditions model with estimated flows.
6. Finally, considered all results and determined dimensions and flow that corresponds to bankfull.

3.6.1 Physical Field Measurement

Physical bankfull indicators surveyed during the existing conditions analysis were typically depositional bars, defined breaks in slope at a consistent elevation relative to the water surface or transitions in bank vegetation.

Upon completion of the field survey, data was plotted to check for consistency and correlation with region-specific empirical equations and regional reference data. This data was analyzed to determine the most likely bankfull stages on all project reaches. Once bankfull stage was determined using these methods, a secondary check was performed using HEC-RAS hydraulic models to assess whether a particular flow rate (regional curve flow was used as a first estimate) would produce the bankfull stage at successive cross sections. These verification methods are described below.

3.6.2 Regional Curve Equations

Publicly available and in-house bankfull regional curves are available for a range of stream types and physiographic provinces. The North Carolina Mountain Regional Curve (Harman et al., 2000) was used for comparison to other more site-specific means of estimating bankfull discharge.

Sink Hole Creek and its tributaries are in a small headwater system; therefore, the contributing watershed areas to the streams in this project are not adequately represented on the regional curve. All regional curve equation output was considered too high in terms of discharge and channel dimension to be appropriate for the Sink Hole Creek restoration design.

In an attempt to enhance the validity of the regional curve at lower drainage areas (typical to the project area), reference stream data was obtained for streams of comparable drainage area, physiographic and geomorphologic character and relative geographical proximity to the Sink Hole Creek project. With this added data, there was a minor shift in the curve. The original curve was used for comparison due to the validation of its general agreement with available data for lower drainage areas.

Another factor considered in comparing Sink Hole Creek to regional empirical data is the potential influence of subsurface water storage at the restoration site. Surface water flow at the project site may be influenced by additional subsurface storage area created by an abandoned mine shaft that runs under an extensive portion of the project area. Existing site conditions in stable reaches was highly weighted in the consideration of selecting a design discharge and channel design dimensions.

3.6.3 Role of Hydraulic Modeling Using HEC-RAS 3.1.3 in Design Discharge Selection

Extensive and detailed topographic data was collected during the existing conditions survey. This information was used to create a three dimensional topographic surface (surface model) of the stream channel and floodplain. Stream channel and flood plain cross-sections were extracted from this surface model at an interval of 25 feet and at key stations up and downstream of bridges and culverts. These cross-sections along with the stream pattern were imported into HEC-RAS 3.1.3 to create a detailed hydraulic model of the channel and floodplain.

The model was used to assess stream stage and the degree of connectivity to the floodplain that segments of stream exhibited at different modeled flow rates (mainly those flow rates thought to be reasonable estimates of the bankfull flow based on regional curve and USGS regression flow data). Both longitudinal (see Figure 3.2) and cross-sectional channel data (Figure 3.3) were scrutinized against water surface profiles to assess consistence of the top of bank, benches, slope breaks, and other depositional features throughout reaches of constant drainage area. Running these flows in the HEC-RAS model sometimes resulted in adjustments to the analysis of the physical data collected, especially when bankfull indicators were weak.

Figure 3.2 Existing Longitudinal Profile for Sink Hole Creek Reach 1 and HEC-RAS Water Surface Profile for Approximate Mountain Regional Curve Flow (Q=75 cfs) (LOB=Left Top of Bank, ROB=Right Top of Bank)

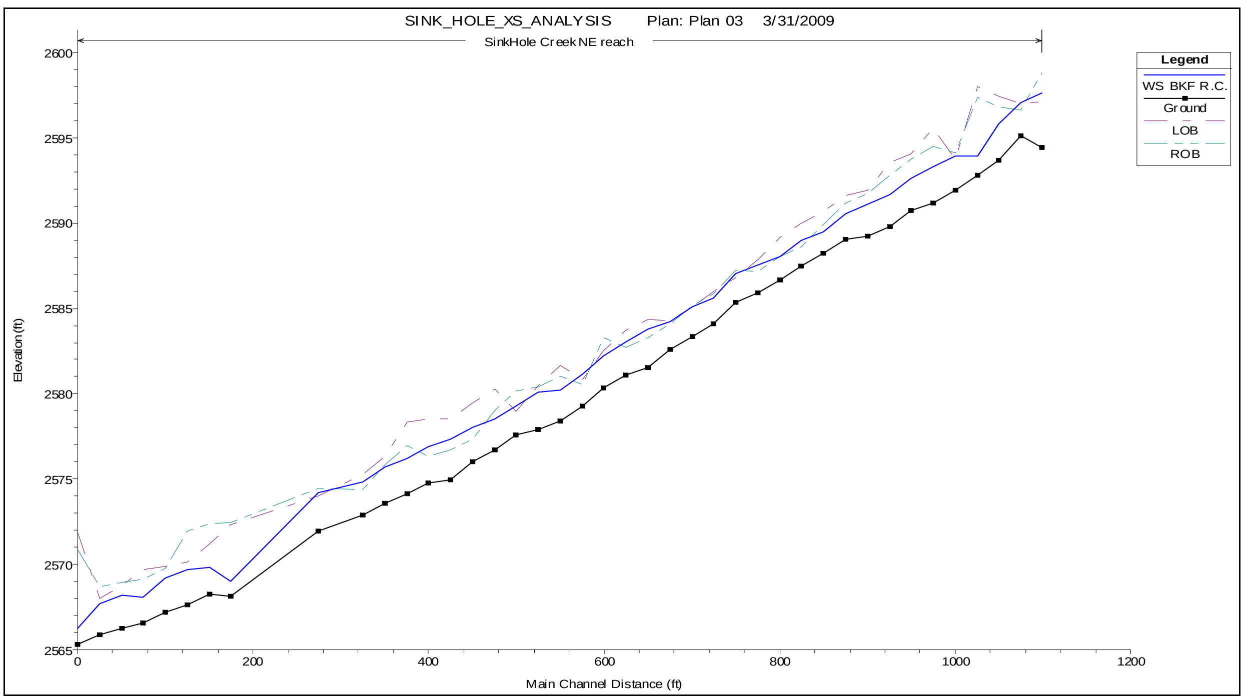
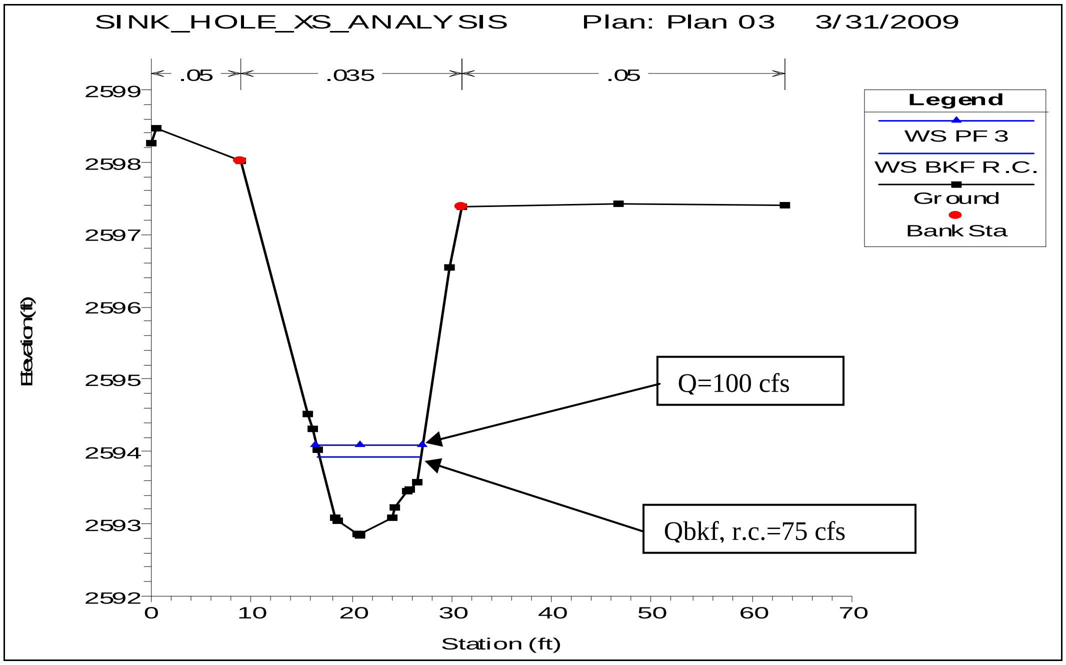


Figure 3.3 Cross-section and HEC-RAS Water Surface Elevations for Mountain Regional Curve Flow (75 cfs) and Higher Flow (100 cfs) at Cross-section of Sink Hole Reach 1



3.7 Conclusions for Channel Forming Discharge

The insight gained from the HEC-RAS model, the field identified bankfull indicators, and the Manning's discharge estimation method (see table below) helped us determine that the discharge values on the mainstem of Sink Hole Creek and its tributaries are extremely dependent on slope and therefore do not correspond particularly well with the predicted values on the regional curve (a cross-section with a bankfull area comparable to the regional curve value for that drainage area produces a much higher discharge due to high gradient of the streams on the project). In the lower reaches, were the drainage area is approaching 1 square mile, the slopes become more in-line with data from the regional curve (on the order of 2%), and the bankfull indicators and Manning's flow estimates exhibit a stronger correlation with the NC rural regional curve estimate. The mountain regional curve was developed from higher order streams, so it is logical that this technique would become a more accurate prediction method as the drainage area increases.

Table 3.5 provides a discharge analyses based on the regional curve flows for the drainage area being considered, the Manning's equation discharges calculated from the representative cross-sections for each reach (based on the bankfull calls identified in the field and adjusted based on detailed analysis), and the design discharge calculated based on the proposed design cross-sections for each reach of the Sink Hole Creek restoration project.

Table 3.5 Design Discharge Summary for Sink Hole Creek and Tributaries by Reach Sink Hole Creek Restoration Plan					
Stream	Reach	Downstream Drainage Area (mi^2)	Q, Mountain Regional Curve (cfs)	Q, 1-D Manning's Formula (n=0.037) (cfs)	Design Q* (cfs)
Sink Hole Creek Mainstem	1	.72	78	161 (XS#14)	84
	2	.84	88	139 (XS#9)	85
UT 1	1	.09	16	22 (XS#7)	20
UT 2	1	.02	5	24 (XS#1)	10
	2	.08	15	14 (XS#5)	19
UT 3	1	.02	5	11 (XS#3)	10

* Q 1-D and Design Q is based on Manning's Equation for the specified or design riffle cross-section and an assumed n-value of n=0.037

3.8 Vegetation Community and Disturbance History

The habitat within and adjacent to the proposed project area primarily consists of agricultural areas, and Dry-Mesic Oak-Hickory Forest as described by Schafale and Weakely (1990) below. Riparian areas within the project area ranged from relatively disturbed to very disturbed. The primary form of disturbance is associated with livestock grazing as described in this plan. A general description of each community follows.

3.8.1 Dry-Mesic Oak-Hickory Forest

This ecological community is located on the upland fringes of the grazing areas and low ridges near the project area. The dominant canopy species of the dry mesic oak forest area includes white oak (*Quercus alba*), northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), mockernut hickory (*Carya alba* (*tomentosa*)), red hickory (*Carya ovalis*), and pignut hickory (*Caryus glabra*). Yellow poplar (*Liriodendron tulipifera*) are also present on-site. Understory species in this forest community typically include red maple (*Acer rubrum*), flowering dogwood (*Cornus florida),* sourwood *(Oxydendrum arborem)*, and american holly *(Ilex opaca)*. Shrubs include downy arrowwood (*Viburnum rafinesquianum),*deerberry *(Vaccinium stamineum),*Blue Ridge blueberry *(Vaccinium pallidum (vacillans))*, and strawberry bush *(Evonymus americana)*. Herbs are fairly sparse, with *Hexastylis spp.*, downy rattlesnake plantain, striped prince's pine *(Chimaphila maculata)*, nakedflower ticktrefoil *(Desmodium nudiflorum)*, and rattlesnakeweed common.

3.8.2 Agricultural Area

Tree farming and pasture land are adjacent to the existing stream corridor throughout the project site. Cattle have direct access to sections of Sink Hole Creek; there is little or no buffer in these areas. The current property owner practices rotational grazing across pasture land within the project area. Livestock are currently granted open access to UT2 and UT3. Plant species in pasture land areas are composed primarily of herbaceous species that included fescue (*Fescue* spp.), golden rod (*Solidago* spp.), pokeweed (*Phytolacca americana*), dog fennel (*Eupatorium capillifolium*), New York ironweed (*Vernonia noveboracensis*), partridge pea (*Cassia fasciculate*), arrow-leaf sida (*Sida rhombifolia*), false nettle (*Boehmeria cylindrica*), horse nettle (*Solanum carolinense*), and soft rush (*Juncus effusus*).

4.0 REFERENCE INDICATORS

Design ratios for pattern and profile were based on evaluating dimensionless ratios from reference reach sites in the NCDOT reference reach database and on-site data from a stable section of stream within Reach 2 on Sink Hole Creek. Design ratios used by Baker that have been successful at many similar sites were also referenced (Table 4.1).

Upon review of the data, a number of reference sites (including several from the same physiographic region), were chosen to supplement the mountain regional curve data. This allowed us to review geomorphic data for a watershed comparable to the project drainage area. In the process of extending the curve beyond the range of the published data, slightly modified regional curve power functions were developed to account for the increased range in data. The regional curve results were used as part of the design decision making process. Values derived from these new power functions are summarized in Section 7 where design criteria are presented in numeric form.

Craig Creek (Pisgah National Forest) was evaluated by NC State University as part of a thesis research project and has been used as a reference stream for multiple stream restoration projects completed by Baker. Mickey Reach, a Baker stream restoration project in Surry County was also used to compare to design data for the Sink Hole Creek restoration project due to its similar watershed size, substrate, sinuosity, and slope. The specific design parameters are described in detail in Section 7. On-site data, restoration project design data, and reference reach data were used in this design and these data are described below and summarized in Table 4.2. Surveyed cross-sections and profile data from Sink Hole Creek are included in Appendix D.

Table 4.1 Ratios from Reference Reaches used in the Design of Sink Hole Creek and its Tributaries
Sink Hole Creek Restoration Plan

Parameter	MIN	MAX	MIN	MAX	MIN	MAX
Stream Type (Rosgen)	A/A6a+		B4c		Cb/E4	
Bankfull Mean Velocity, Vbkf (ft/s)	4.0	6.0	4.0	6.0	3.5	5.0
Width to Depth Ratio, W/D (ft/ft)	12.0	18.0	12.0	18.0	10.0	14.0
Riffle Max Depth Ratio, Dmax/Dbkf	1.2	1.4	1.2	1.4	1.1	1.3
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.1	1.0	1.1	1.0	1.1
Meander Length Ratio, Lm/Wbkf	N/A	N/A	N/A	N/A	7.0	12.0
Rc Ratio, Rc/Wbkf	N/A	N/A	N/A	N/A	2.0	3.0
Meander Width Ratio, Wblt/Wbkf	N/A	N/A	N/A	N/A	3.5	8.0
Sinuosity, K	1.1	1.2	1.1	1.2	1.2	1.6
Riffle Slope Ratio, Srif/Schan	1.1	1.8	1.1	1.8	1.5	2.0
Pool Slope Ratio, Spool/Schan	0	.4	0	.4	0	.2
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.0	3.5	2.0	3.5	2.0	3.5
Pool Width Ratio, Wpool/Wbkf	1.1	1.5	1.1	1.5	1.3	1.7
Pool-Pool Spacing, Lps/Wbkf	1.5	5.0	1.5	5.0	4.0	7.0

Reach 1 of Sink Hole Creek is located in a pasture that is intersected by N.C. Highway 80. Downstream of the culvert under N.C. Highway 80 and an aggradational area, the channel appears to be relatively stable for a short distance in comparison to channelized reaches above and below. There was minimal erosion, good floodplain connectivity, and good habitat (including the presence of some woody vegetation) present in this segment of the reach. Other notable features present include bedrock which is also located in the lower half of Reach 2 on Sink Hole Creek.

Mickey Reach is a previous Baker restoration project in Surry County. It is an unnamed tributary to the Mitchell River with similar design conditions. The design stream type for Mickey Reach was a B4 channel with structures installed to restore a step-pool stream system with appropriate bedform diversity. The project has been monitored for six years following construction and has remained stable, with diverse bedforms and excellent aquatic habitat.

Craig Creek is located in the Pisgah National Forest and was evaluated by NC State University as part of a thesis research project evaluating morphology relationships in reference streams. The stream is an example of a B4 stream type with a small drainage area, similar to the project reaches. The stream was also used as a reference reach for the Mickey Reach design (described above).

Table 4.2 Reference Reach Geomorphic Parameters: Sink Hole Creek Sink Hole Creek Restoration Plan								
	Sink Hole Creek Existing Conditions		Sink Hole Creek Design		Mickey Reach Design		Craig Creek Reference Reach	
	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	Channelized Eb/Cb/G		B/C		A6a+/B4c		A6a+/B4c	
2. Drainage Area (square miles)	.72	.84	.72	.84	.45	.45	1.6	1.6
3. Bankfull Width (w_{bkf}) (ft)	11.1	17.7	12.3	13.0	11.7	21.7	27.6	27.6
4. Bankfull Mean Depth (d_{bkf}) (ft)	1.15	1.46	1.0	1.1	0.6	1	1	1.1
5. Width/Depth Ratio (W/D ratio)	7.8	15.4	11.8	12.0	10.7	17	25	27
6. Cross-sectional Area (A_{bkf}) (ft^2)	15.7	20.4	12.6	14.0	13.1	10.2	26	33
7. Bankfull Mean Velocity (v_{bkf}) (ft/s)	4.2	5.4	6.0	6.7	---	---	---	---
8. Bankfull Discharge (Q_{bkf}) (ft^3/s)	84	85	84	85	---	---	---	---
9. Bankfull Max Depth (d_{mbkf}) (ft)	2.15	2.32	1.4		.9	2.5	1.6	1.6
10. d_{mbkf} / d_{bkf} ratio	1.6	1.9	1.3		1.1	3.1	1.6	1.6
11. Low Bank Height to d_{mbkf} Ratio	2.2	3.7	---	---	1	1	---	---
12. Bank Height Ratio dlow/dmax	1.0	1.6	1.0		1	1	---	---
13. Floodprone Area Width (w_{fpa}) (ft)	21	31	70	100	20	410	36	38.6
14. Entrenchment Ratio (ER)	1.6	2.4	5.4	8.1	1.7	32	1.3	1.4
15. Meander length (L_m) (ft)	42	191	138	145	70	260	---	---
16. Meander length to bankfull width (L_m/w_{bkf})	4.1	10.8	11.2		4.4	17.6	---	---
17. Radius of curvature (R_c) (ft)	23	102	31	45	28	47	---	---
18. Radius of curvature to bankfull width (R_c / w_{bkf})	2.3	5.8	2.5	3.5	2	3	---	---
19. Belt width (w_{blt}) (ft)	5	41	45	74	16	55	---	---
20. Meander Width Ratio (w_{blt}/W_{bkf})	.49	2.3	3.7	5.7	1.1	4.1	---	---
21. Sinuosity (K) Stream Length/ Valley Distance	1.1	1.2	1.1	1.2	1.19	1.19	1.1	1.1
22. Valley Slope – feet per foot	.0239	.0275	.0280	.0300	.0398	.0396	.0364	.0364
23. Channel Slope ($s_{channel}$) – feet per foot	.0235	.0275	.0250	.0255	.0333	.0333	.0331	.0331
24. Pool Slope (s_{pool}) (feet per foot)	.0034	.0372	.0050	.0051	0	.005	0	0
25. Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	.14	1.4	.20		0	.15	0	0
26. Maximum Pool Depth (d_{pool}) (ft)	.61	2.1	1.8	3.0	2.2	2.5	2.1	2.1
27. Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	.63	1.1	1.8	2.8	2	4	2.1	
28. Pool Width (w_{pool}) (ft)	3.4	14.7	13.5	19.5	14.3	14.6	26	26
29. Pool Width to Bankfull Width (w_{pool} / w_{bkf})	.33	.83	1.1	1.5	.9	.9	.9	.9
30. Pool Area (A_{pool}) (ft^2)	---	---	---	---	14.8	15.9	37.1	37.1
31. Pool Area to Bankfull Area (A_{pool}/A_{bkf})	---	---	---	---	1.1	1.2	1.1	1.4
32. Pool-to-Pool Spacing (L_{ps}/W_{bkf})	53	271	18	65	48	231	42	156.5
33. Pool Spacing to Bankfull Width (p-p/w_{bkf})	5.2	15.3	1.5	5.0	3	7	1.5	6.7
34. Riffle Slope (s_{riffle}) (feet per foot)	.03585	.0550	.0382	.0500	.2	1.9	1.9	7.6
35. Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	1.5	2.0	1.5	2.0	.2	1.9	1.9	7.6
36. Pool Length (ft)	26.0	82.1	18	65	13	16	---	---
37. Particle Size Distribution of Riffle Material	Medium-Coarse Gravel		Medium-Coarse Gravel					
d_{16} – mm	.063	.317	.3	.6				
d_{35} – mm	6.56	9.32	8.0	10.0				
d_{50} – mm	13.8	26.4	10.0	19.9				
d_{84} – mm	71.3	80.1	50.0	74.7				
d_{95} – mm	110.0	123.0	95.0	121.0				
- : data not available								

Table 4.2 (cont.) Reference Reach Geomorphic Parameters: UT 2 (Reach 1) and UT3

Sink Hole Creek Restoration Plan

	UT2(R1)-UT3 Existing Conditions		UT2(R1)-UT3 Design		Mickey Reach Design		Craig Creek Reference Reach	
	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	Aa+/Ba**		Aa+/B		A6a+/B4c		A6a+/B4c	
2. Drainage Area (square miles)	.02		.02	.02	.45	.45	1.6	1.6
3. Bankfull Width (w_{bkf}) (ft)	3.0	3.8	4.0		11.7	21.7	27.6	27.6
4. Bankfull Mean Depth (d_{bkf}) (ft)	.34	.69	.4		.6	1	1	1.1
5. Width/Depth Ratio (W/D ratio)	4.3	11.4	10.8		10.7	17	25	27
6. Cross-sectional Area (A_{bkf}) (ft^2)	1.3	2.1	1.5		13.1	10.2	26	33
7. Bankfull Mean Velocity (v_{bkf}) (ft/s)	4.8	7.7	3.3		---	---	---	---
8. Bankfull Discharge (Q_{bkf}) (ft^3/s)	10		5		---	---	---	---
9. Bankfull Max Depth (d_{mbkf}) (ft)	.79	1.1	0.5		.9	2.5	1.6	1.6
10. d_{mbkf} / d_{bkf} ratio	1.5	2.3	1.3		1.1	3.1	1.6	1.6
11. Low Bank Height to d_{mbkf} Ratio	2.4	3.7	---		1	1	---	---
12. Bank Height Ratio dlow/dmax	3.1	3.5	1.0		1	1	---	---
13. Floodprone Area Width (w_{fpa}) (ft)	4.8	7.2	70	100	20	410	36	38.6
14. Entrenchment Ratio (ER)	1.6	1.9	17.4	24.8	1.7	32	1.3	1.4
15. Meander length (L_m) (ft)	N/A	N/A	45		70	260	---	---
16. Meander length to bankfull width (L_m/w_{bkf})	N/A	N/A	11.2		4.4	17.6	---	---
17. Radius of curvature (R_c) (ft)	N/A	70	10	14	28	47	---	---
18. Radius of curvature to bankfull width (R_c / w_{bkf})	23.4	27.9	2.5	3.5	2	3	---	---
19. Belt width (w_{blt}) (ft)	36	41	15	23	16	55	---	---
20. Meander Width Ratio (w_{blt}/W_{bkf})	10.7	12.0	3.7	5.7	1.1	4.1	---	---
21. Sinuosity (K) Stream Length/ Valley Distance	1.02	1.07	1.1	1.2	1.19	1.19	1.1	1.1
22. Valley Slope – feet per foot	.1068	.1077	.1000		.0398	.0396	.0364	.0364
23. Channel Slope ($s_{channel}$) – feet per foot	.1050	.1077	.1050	.1077	.0333	.0333	.0331	.0331
24. Pool Slope (s_{pool}) (feet per foot)	N/A	N/A	.0167	.0182	0	.005	0	0
25. Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	N/A	N/A	.20		0	.15	0	0
26. Maximum Pool Depth (d_{pool}) (ft)	N/A	N/A	0.7	1.0	2.2	2.5	2.1	2.1
27. Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	N/A	N/A	1.8	2.8	2	4	2.1	
28. Pool Width (w_{pool}) (ft)	N/A	N/A	4.4	6.0	14.3	14.6	26	26
29. Pool Width to Bankfull Width (w_{pool} / w_{bkf})	N/A	N/A	1.1	1.5	.9	.9	.9	.9
30. Pool Area (A_{pool}) (ft^2)	N/A	N/A	---	---	14.8	15.9	37.1	37.1
31. Pool Area to Bankfull Area (A_{pool}/A_{bkf})	N/A	N/A	---	---	1.1	1.2	1.1	1.4
32. Pool-to-Pool Spacing (L_{ps}/W_{bkf})	N/A	N/A	6	21	48	231	42	156.5
33. Pool Spacing to Bankfull Width (p-p/w_{bkf})	N/A	N/A	1.5	2.0	3	7	1.5	6.7
34. Riffle Slope (s_{riffle}) (feet per foot)	N/A	N/A	.1364	.1667	.2	1.9	1.9	7.6
35. Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	N/A	N/A	1.5	2.0	.2	1.9	1.9	7.6
36. Pool Length (ft)	N/A	N/A	6	20	13	16	---	---
37. Particle Size Distribution of Riffle Material *	N/A		N/A					
d_{16} – mm								
d_{35} – mm								
d_{50} – mm								
d_{84} – mm								
d_{95} – mm								

* : Data not available. No sediment data was collected for UT2 and UT3 based on extremely poor substrate currently present.
** : Functioning like a G-type due to high Bank Height Ratio.

Table 4.2 (cont.) Reference Reach Geomorphic Parameters: UT1, UT2 (Reach 2)
Sink Hole Creek Restoration Plan

	UT1/UT2 (R2) Existing Conditions		UT1/UT2(R2) Design		Mickey Reach Design		Craig Creek Reference Reach	
	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	Cb-B/A		C-B/A		A6+		A6+	
2. Drainage Area (square miles)	.08	.09	.08	.09	.45	.45	1.6	1.6
3. Bankfull Width (w_{bkf}) (ft)	2.4	11.0	6.0	7.4	11.7	21.7	27.6	27.6
4. Bankfull Mean Depth (d_{bkf}) (ft)	.34	.95	.5	.6	.6	1	1	1.1
5. Width/Depth Ratio (W/D ratio)	2.5	23.0	11.4	12.0	10.7	17	25	27
6. Cross-sectional Area (A_{bkf}) (ft^2)	2.3	5.2	3.2	4.6	13.1	10.2	26	33
7. Bankfull Mean Velocity (v_{bkf}) (ft/s)	3.9	8.3	4.4	4.8	---	---	---	---
8. Bankfull Discharge (Q_{bkf}) (ft^3/s)	19	20	15	20	---	---	---	---
9. Bankfull Max Depth (d_{mbkf}) (ft)	.79	1.2	.7	.8	.9	2.5	1.6	1.6
10. d_{mbkf} / d_{bkf} ratio	1.3	2.3	1.3	1.4	1.1	3.1	1.6	1.6
11. Low Bank Height to d_{mbkf} Ratio	.6	5.2	---	---	1	1	---	---
12. Bank Height Ratio (dlow/dmax)	.7	4.2	1.0		1	1	---	---
13. Floodprone Area Width (w_{fpa}) (ft)	3.6	20.2	70	100	20	410	36	38.6
14. Entrenchment Ratio (ER)	1.4	1.9	9.5	16.7	1.7	32	1.3	1.4
15. Meander length (L_m) (ft)	76	271	67	83	70	260	---	---
16. Meander length to bankfull width (L_m/w_{bkf})	31.9	24.7	11.2		4.4	17.6	---	---
17. Radius of curvature (R_c) (ft)	54	56	15	26	28	47	---	---
18. Radius of curvature to bankfull width (R_c / w_{bkf})	5.1	22.6	2.5	3.5	2	3	---	---
19. Belt width (w_{blt}) (ft)	8	19	22	42	16	55	---	---
20. Meander Width Ratio (w_{blt}/W_{bkf})	3.4	1.7	3.7	5.7	1.1	4.1	---	---
21. Sinuosity (K) Stream Length/ Valley Distance	1.0	1.2	1.1	1.2	1.19	1.19	1.1	1.1
22. Valley Slope – feet per foot	.0374	.0592	.0280	.0590	.0398	.0396	.0364	.0364
23. Channel Slope ($s_{channel}$) – feet per foot	.0375	.0571	.0375	.0546	.0333	.0333	.0331	.0331
24. Pool Slope (s_{pool}) (feet per foot)	.0277	.0341	.0050	.0107	0	.005	0	0
25. Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	.7397	.5972	.20		0	.15	0	0
26. Maximum Pool Depth (d_{pool}) (ft)	1.4	3.3	.9	1.7	2.2	2.5	2.1	2.1
27. Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	3.5	4.1	1.8	2.8	2	4	2.1	
28. Pool Width (w_{pool}) (ft)	7.7		6.6	11.1	14.3	14.6	26	26
29. Pool Width to Bankfull Width (w_{pool} / w_{bkf})	.71	3.21	1.1	1.5	.9	.9	.9	.9
30. Pool Area (A_{pool}) (ft^2)	---	---	---	---	14.8	15.9	37.1	37.1
31. Pool Area to Bankfull Area (A_{pool}/A_{bkf})	---	---	---	---	1.1	1.2	1.1	1.4
32. Pool-to-Pool Spacing (L_{ps}/W_{bkf})	214		9	37	48	231	42	156.5
33. Pool Spacing to Bankfull Width (p-p/w_{bkf})**	19.5		1.5	5.0	3	7	1.5	6.7
34. Riffle Slope (s_{riffle}) (feet per foot)	.04	.046	.0382	.0983	.2	1.9	1.9	7.6
35. Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	.81	1.1	1.5	2.0	.2	1.9	1.9	7.6
36. Pool Length (ft)	56	85	9	37	13	16	---	---
37. Particle Size Distribution of Riffle Material *								
d_{16} – mm	.16		.2					
d_{35} – mm	11.7		11.7					
d_{50} – mm	32		32.0					
d_{84} – mm	81.1		81.1					
d_{95} – mm	155		155.3					

*- Particle size distribution data based on existing channel substrate for UT1. No sediment data was collected for UT2 based on extremely poor substrate currently present.
**- Reach 2 of UT1 is primarily a series of cascades and lacked well defined pool features. UT2 lacked well defined pool features as well.

5.0 PROJECT SITE WETLANDS (EXISTING CONDITIONS)

5.1 Jurisdictional Wetlands

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

Following an in-office review of the National Wetland Inventory (NWI) map, NRCS soil survey, and USGS quadrangle map, a field survey of the project area was conducted to delineate wetlands and waters of the U. S. The project area was examined utilizing the jurisdictional definition detailed in the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory, 1987). Supplementary information to further support wetland determinations was found in the *National List of Plant Species that Occur in Wetlands: Southeast (Region 2)* (Reed, 1988).

There are no areas located within the project boundary that display true wetland characteristics. Therefore, no wetland restoration or enhancement activities are proposed under the Sink Hole Creek restoration project.

6.0 REFERENCE WETLANDS

No wetland restoration or enhancement activities are proposed under the Sink Hole Creek Restoration project. Therefore, no reference wetlands were required for this project.

7.0 PROJECT SITE RESTORATION PLAN

This section discusses the design criteria selected for stream restoration on the Sink Hole Creek project site. The design proposed for Sink Hole Creek will include both Rosgen Priority Level 1 and 2 approaches. A Priority Level 1 approach will be applied to incised sections of the project area where the streambed will be raised to reconnect the stream to its floodplain. A Priority Level 2 approach involves the excavation of a floodplain at a lower elevation where changes in the elevation of the streambed are not desired. Both priority levels will involve the use of the existing channel as well as the construction of new channel segments where pattern adjustments are necessary.

Restoration of Sink Hole Creek and tributaries UT1 Reach 2, UT2, and UT3 are justified for the following reasons:

1. Many of the streams have been channelized and moved up against the valley wall. Moving the streams away from the valley wall will reduce erosion, improve floodplain connectivity, and improve floodplain hydrology;
2. The streams are typically incised, with a Bank Height Ratio of 1.5 to 2 or more- this is exacerbated by the man-made levies that were constructed along many reaches of the system as dredged material was wasted at the top of bank. Stream bank erosion is common throughout the site;
3. There are widespread cattle impacts that have resulted in erosion and sedimentation, silt-clogged stream channels and the loss of woody vegetation within the riparian zone;
4. Enhancement or preservation measures would fall short of achieving the highest possible level of restoration.

The stream types for the restored streams will be Rosgen “A”, “B” and “Cb” channels with design dimensions based on reference reaches, hydraulic and sediment transport analyses and geomorphic ratios and guidance from past projects. UT2 and UT3 will have minimal pattern adjustment due to the steep valley slopes and the corresponding designed step-pool channel type. These channels are already in the low points of their valleys. In other areas, where the valley slopes are flatter but still exceed 2%, a hybrid channel that dissipates energy both laterally (with slight meandering) and vertically (through step-pools) will be constructed.

Where abandoned, the old stream channels will be backfilled using fill material generated by the grading of new channel and floodplain benches. Any excess fill material generated during construction will be disposed of on-site in designated disposal areas.

The restoration and enhancement designs will allow stream flows larger than bankfull flows to spread onto the restored floodplain, dissipating flow energies and reducing the stress on streambanks. In-stream structures will be used to control streambed grade, reduce stresses on streambanks, and promote diversity of bedform and habitat. In-stream structures may consist of constructed riffles, boulder steps, log vanes, and log rollers. Reach-wide grade control will be provided by the aforementioned in-stream structures and by bedrock where present. Structures will be spaced at a maximum distance that results in the downstream header protecting the upstream footer to create a redundancy that will ensure long term vertical stability. Where possible, both wood and rock will be incorporated into the structures to promote a diversity of habitat features. Streambanks will be stabilized with a combination of bioengineering measures, erosion control matting, bare-root plantings, and live staking. This section discusses the design criteria selected for stream restoration on the Sink Hole project site.

7.1 Restoration Project Goals and Objectives

The design objectives for Sink Hole Creek and the unnamed tributaries were based on the following goals:

- ✓ Create geomorphically stable conditions;
- ✓ Reduce sediment and nutrient loading by restoring riparian corridors;
- ✓ Restore or enhance hydrologic connectivity between streams and floodplain;

- ✓ Restore and preserve headwater tributaries to the North Toe River; and
- ✓ Increase taxa abundance and diversity by improving aquatic and terrestrial habitat along the project corridor.

Design objectives are a set of guidelines used to accomplish these goals in an effective and efficient manner. The following objectives were incorporated into the design of the streams on this site:

1. Make important design decisions based on geomorphic analyses and supporting information from hydraulic modeling in order to incorporate important elements from both.
2. Use constructability as a guiding consideration in order to produce a realistic design that is possible to build given field constraints and construction tolerances. Design ideas are discussed with knowledgeable construction personnel to determine the constructability, likely footprint, and severity of impacts to on-site resources.
3. Minimize disturbance to ecologically functional and physically stable areas; mimic the character of these areas and borrow materials from them where appropriate to create a more natural design
4. Structures and over-all design will attempt to use native materials and minimize materials brought on-site in order to produce habitat favoring native flora and fauna, reduce compaction and site disturbance from material transport, and produce an aesthetically pleasing result with the goal being minimal evidence of site disturbance.

This project site is an appropriate candidate for restoration as significant erosion will occur before streams in the project area achieve a stable, quasi-equilibrium state. Although aggradation is present, overall stream conditions present on-site reflect varying degrees of incision and continued degradation. Bank erosion will continue contributing sediment to areas downstream of the project site and will cause widening of the stream. Restoration and enhancement measures will help to stabilize the channel, halt incision and widening, and significantly diminish bank erosion.

The accompanying plans depict the proposed restoration measures. The application of these measures are described below according to reach location.

<u>Sink Hole Creek (Reach 1)</u>

Priority I restoration of Reach 1 of Sink Hole Creek will address prior manipulation of the reach by recreating a slightly more sinuous channel and step-pool morphology. The reconstruction of the stream will facilitate the removal of the existing headcuts propagating up the channel, improve floodplain connectivity and eliminate the presence of vertical and eroding banks. Vertical and lateral stability will be achieved with meandering riffle-pool sequences and with a series of small grade drops. Grade control structures installed will aid in dissipating streamflow energy, decrease pool-to-pool spacing and improve the quality of pool habitat present. In areas, the existing channel alignment will be adjusted; new channel segments will be constructed to achieve the pattern and profile desired for Reach 1. A vegetated riparian buffer will also be restored along Reach 1 of Sink Hole Creek. These efforts will restore grade control, lateral stability, and habitat features to the reach improving both its health and function as well as that of receiving waters.

<u>Sink Hole Creek (Reach 2)</u>

In this lower portion of the project, Sink Hole Creek becomes severely impacted by channelization and manmade levy creation. The valley is narrow and grade is controlled by bedrock outcroppings. This reach will be restored using a Priority II approach. Modifications to the cross-sectional dimension will be made to improve floodplain connectivity. Restoration of the floodplain will involve the removal of the manmade levies. Restoration will involve slight meandering in areas not heavily influenced by bedrock; elsewhere, energy dissipation will primarily be achieved through a step-pool morphology. This approach will decrease pool-to-pool spacing and maintain pools created by incorporating grade-control features with small amounts of vertical drop to scour out fine sediments from the pools. Throughout the reach, patches of invasive species will be removed or treated and a wide buffer of native vegetation will be established.

UT1 (Reach 1)

This reach, located above an in-line pond, will be placed under preservation status. Reach 1 is forested and is relatively stable with good access to its floodplain.

UT1 (Reach 2)

UT1 is the largest of the tributaries on-site; its confluence with Sink Hole Creek is located at UT1 Station 4+94. A Priority II restoration approach will be used to address head-cutting and a lack of grade control currently present in this section of UT1. Grade control structures as well as constructed riffle-pool sequences will be made to improve the profile. Modifications to the cross-sectional dimension will also be made to correspond with other B-type streams of this size. The lack of a riffle – pool sequence can be mostly attributed to the historical straightening of the stream. Invasive vegetative species removal efforts and reforestation of the riparian buffer with native species will complement the channel restoration.

UT2 (Reach 1)

Reach 1 of the headwater tributary UT2 has no buffer from its source to its confluence with UT3. It is bordered on either side by pasture and is impacted by sloughing banks and cattle impacts. UT2 emanates from approximately two springs at the head of the project reach. A Priority 1 restoration approach will be used in this reach to raise the channel elevation and improve access to its floodplain. This approach will create a stable, A-type headwater channel. The project will eliminate erosion and replace what is essentially a ditch with a step-pool channel that will effectively dissipate energy and maintain scour pools for habitat. The creation of a well vegetated riparian buffer will also significantly reduce the impacts from the adjacent pasture.

UT2 (Reach 2)

A Priority I restoration approach will be used to reconstruct Reach 2 of UT2. A new channel alignment will start at the beginning of the reach at the confluence with UT3. This new alignment will eliminate the vertical, eroding banks by restoring a stable dimension to the tributary. The new stream design will be a step-pool channel with abundant grade control to eliminate the possibility of future down-cutting, provide energy dissipation and create pool habitat below the grade control features. The channel is mostly bordered by pasture with some exotic invasive vegetation; the corridor will be revegetated with a native riparian buffer. The new channel and buffer will eliminate the siltation that is currently clogging the stream bottom. Proposed efforts will restore grade control, lateral stability, and habitat features to the reach improving both its health and function and that of the downstream system.

UT3

Like the UT2 Reach 1, a Priority I approach is proposed for UT3. The headwater tributary UT3 has no buffer from its source to its confluence with UT2. It is bordered on either side by pasture and is impacted by sloughing banks and prior manipulation. The beginning of the reach is where the stream emanates from a spring. Using techniques described for the upper reach on UT2, this stream will undergo extensive transformation into a new, more stable A-type headwater channel. Dimension adjustments and the implementation of a series of grade control measures will eliminate erosion and replace what is essentially a ditch with a step-pool channel that will effectively dissipate energy and maintain scoured pools for habitat, and restore the riparian buffer to a natural state. The buffer will significantly reduce the impacts from the adjacent pasture.

7.2 Design Criteria Selection for Stream Restoration

A number of analyses and data were incorporated in the development of site-specific natural channel design approaches. Among these are hydraulic and sediment analyses, existing site conditions data collection, incorporation of reference reach databases, regime equations, and evaluation of results from past projects.

Design criteria are dependent on the general restoration approach determined to be a best fit for the Sink Hole Creek restoration site (Table 7.1). The approach for restoration was based on an assessment of each reach and its potential. After selection of the general restoration approach, specific design criteria were developed so that the plan view layout, cross-section dimensions, and profile could be described for each reach. These criteria are presented in the construction documents.

Assigning an appropriate stream type for the corresponding valley that accommodates the existing and future hydrologic and sediment contributions was considered conceptually prior to selecting reference reach streams. Design criteria for the proposed stream concept were selected based on the range of the reference data and the desired performance of the proposed channel.

Following initial application of the design criteria, detailed refinements were made to accommodate the existing valley morphology, to work around project constraints, to minimize unnecessary disturbance of the riparian area, and to allow for natural channel adjustment following construction. The construction documents have been tailored to produce a cost and resource efficient design that is constructible, using a level of detail that corresponds to the tools of construction. The design also reflects a philosophy that the stream will adapt to the inherent uniformity of the restoration project and be allowed to adjust over long periods of time under the processes of flooding, re-colonization of vegetation, and local topographic influences.

Table 7.1 Project Design Stream Types
Sink Hole Creek Restoration Plan

Stream	Reach	Proposed Stream Type	Rationale
Sink Hole Creek Mainstem	1	B/C	Priority I restoration will be used to recreate a slightly more sinuous channel and step-pool morphology. The reconstruction of the stream will facilitate the removal of the existing headcuts propagating up the channel, improve floodplain connectivity and eliminate the presence of vertical and eroding banks. Meandering riffle-pool sequences and a series of small grade drops will be used to aid in dissipating streamflow energy, decrease pool-to-pool spacing and improve the quality of pool habitat present. In areas, the existing channel alignment will be adjusted; new channel segments will be constructed to achieve the pattern and profile desired for Reach 1. Native re-vegetation of buffers will also improve habitat and stabilize the banks.
	2	B	This reach will be restored using a Priority I approach. Modifications to the cross-sectional dimension will be made to improve floodplain connectivity. Restoration will involve slight meandering in areas not heavily influenced by bedrock; elsewhere, energy dissipation will primarily be achieved through a step-pool morphology. This approach will decrease pool-to-pool spacing and maintain pools created by incorporating grade-control features with small amounts of vertical drop maintain pool habitat quality.
UT1	1	B/C	Priority II restoration will be used to restore channel dimension and profile. The new stream design entails a step-pool channel design with abundant grade control to eliminate the possibility of future down-cutting. The channel design will also provide energy dissipation and create pool habitat below the grade control structures.
UT2	1	Aa+	Priority I restoration will be used to raise the bed elevation and allow reconnection of the channel and floodplain downstream for the first 595 LF. A series of grade control structures will be installed for energy dissipation and improvements to bedform diversity and habitat.
	2	A	Priority I restoration will involve creating a new alignment to restore stable dimension to the tributary, thereby eliminating the vertical, eroding banks currently present. The new stream design also entails a step-pool channel design with abundant grade control to eliminate the possibility of future down-cutting. The channel design will also provide energy dissipation and create pool habitat

Table 7.1 Project Design Stream Types Sink Hole Creek Restoration Plan			
Stream	Reach	Proposed Stream Type	Rationale
			below the grade control structures.
UT3	1	B	Priority I restoration will be used to raise the bed elevation and allow reconnection of the channel and floodplain downstream for the first 586 LF. A series of grade control structures will be installed for energy dissipation and improvements to bedform diversity and habitat.
Notes:			

7.3 Stream Project Design & Justification

The primary objective of the restoration design is to construct a stream with a stable dimension, pattern, and profile that has access to its floodplain at bankfull flows while enhancing riparian and aquatic habitat. The philosophy applied by Baker to the Sink Hole Creek project consisted of creating more stable A, B, or Cb-type channels with the potential to naturally adjust into A, B, or Eb-type channels. The proposed design parameters for each of the reaches are detailed in Table 7.2.

The design rationale and design parameters for all of the design reaches are presented below.

Dimension

Throughout the entire proposed design, the channel dimensions were adjusted to reduce velocities and near-bank shear stress. The selected design parameters eliminate incision and restore access to the floodplain, increasing the entrenchment ratio. Due to the size of the channels, it was necessary to use a width to depth ratio at the lower end of the range for C-type channels. It is expected that these channels may narrow to an E-type morphology over time. E-type channels are difficult to construct due to high instability from the lack of established vegetation immediately after construction. A low bank height ratio (BHR) of 1.0 was chosen to develop a channel with access to its floodplain for relief during events having flows in excess of bankfull. Typical cross-sections are shown on the plan sheets.

Pattern

The existing pattern of these project streams is representative of stream channelization and relocation. In general, the proposed channels have been designed to dissipate energy vertically rather than through meandering. This step-pool morphology is most appropriate for streams that have slopes in excess of 2% as is the case on all of the reaches in this project. Changes to the channel alignment in the restoration reaches are meant to modify the sinuosity of these channels to a value of 1.1 to nearly 1.2, typical of natural step-pool systems. Where applicable and feasible, the new channel alignment locations also attempt to bring the channel away from the valley wall to allow for overbank flow on both sides of the stream.

The sinuosity of Sink Hole Creek and its tributaries will not dramatically increase based on the naturally steep channel slopes present on-site. The pattern at an overly sinuous section in Reach 2 of Sink Hole Creek will be decreased whereas slight increases in sinuosity will be added elsewhere in the Reach to achieve an overall sinuosity of 1.1 to 1.2 on Sink Hole Creek. The sinuosity of project reaches on the unnamed tributaries will remain approximately 1.1.

In the upper tributaries, the streams have very minimal meander width ratios which is a function of their location in the valley. They are fairly straight, occupying the low point in the valley. In areas where the valley narrowed, the meander width ratio approaches the minimum range of 2.1 times the bankfull width. In these areas, energy is dissipated through step pools or elevation changes. These ratios are still limited by the valley width and step-pool systems are, in general, not meandering systems. Higher meander width ratios are present where the valley widens and are intended to allow for lateral dissipation of energy and provide a floodplain sufficient for future natural channel development. Plan views of the main channel and unnamed tributaries are shown on the attached plan sheets.

While radius of curvature is not a primary feature of step-pool channels, some pattern was used in areas where the floodplain width increased and the floodplain topography flattened. Aside from reaches that are confined, the radius of curvature ratio falls into the range of approximately 2.5 to 3.5.

Profile/Bedform

Although moderately functional and somewhat stable, the channel profile of the existing mainstem of Sink Hole Creek is lacking woody debris and overall bedform diversity. The profile of the existing tributaries lack vertical grade control, woody debris, and overall bedform diversity. With the exception of off-line channel segments proposed, initial construction on project reaches will consist of restoring connectivity between channels and the floodplain. This will be followed by development of a step-pool system mimicking those characteristic of the reference reaches. Grade control structures placed according to the pool-to-pool spacing range as well as the natural tendency of the stream, dictate where pools will be located in sections of the stream with lower sinuosity. The average channel slope proposed for Sink Hole Creek Reaches 1 and 2 will remain approximately 3%. The average channel slope for Reach 1 of UT2 and UT3 will remain approximately 11%. The average channel slope for Reaches 2 of UT1 and UT2 is slightly less steep and will maintain its existing channel slope as well (4-6%).

Riffles throughout the design reaches will typically be 1.5 and 2 times the average slope of the channel while there is no slope from the head to tail of the pools. The proposed maximum pool depth will be approximately 1.8 to 3.0 feet on the mainstem of Sink Hole Creek with pool to pool spacing ranging from 18 to 65 lf. Pool to pool spacing on Reach 2 of UT1 is expected to range from 11 to 37 lf with a maximum pool depth of 0.9 to 1.5 feet. The uppermost reach of UT2 and UT3 have a designed pool spacing of 6 to 30 lf. Pools that develop in these reaches as a result of restoration activities are expected to have a maximum depth between 0.7 to 1.0 feet. Efforts were made to maximize diversity while designing a channel with adequate sediment transport capacity within the profile constraints.

Table 7.2 Geomorphic Characteristics of the Proposed Sink Hole Creek Restoration Plan Sink Hole Restoration Plan	Sink Hole Creek Mainstem			
	Reach 1 Sta. 0+00 to 11+14		Reach 2 Sta. 11+14 to 21+74	
	Min	Max	Min	Max
1. Stream Type	B-Cb		B	
2. Drainage Area – mi^2	.72		.84	
3. Bankfull Width (w_{bkf}) – ft	12.3		13.0	
4. Bankfull Mean Depth (d_{bkf}) – ft	1.0		1.1	
5. Width/Depth Ratio (w/d ratio)	12.0		12.0	
6. Cross-sectional Area (A_{bkf}) – ft^2	12.6		14.0	
7. Bankfull Mean Velocity (v_{bkf}) - ft/sec	6.7		6.0	
8. Bankfull Discharge (Q_{bkf}) – ft^3/sec	84		85	
9. Bankfull Max Depth (d_{mbkf}) - ft	1.4		1.4	
10. d_{mbkf} / d_{bkf} Ratio	1.3		1.3	
11. Low Bank Height to d_{mbkf} ratio	---		---	
12. Floodprone Area Width (w_{fpa}) – feet	70	100	70	100
13. Entrenchment Ratio (ER)	5.7	8.1	5.4	7.7
14. Meander Length (L_m) – ft*	N/A		N/A	
15. Meander Length to Bankfull Width (L_m/w_{bkf})*	N/A		N/A	
16. Radius of Curvature (R_c) – ft*	N/A	N/A	N/A	N/A
17. Radius of Curvature to Bankfull Width (R_c / w_{bkf})*	N/A	N/A	N/A	N/A
18. Belt Width (w_{blt}) – ft*	N/A	N/A	N/A	N/A
19. Meander Width Ratio (w_{blt}/W_{bkf})*	N/A	N/A	N/A	N/A
20. Sinuosity (K) (Stream Length / Valley Length)	1.1	1.2	1.1	1.2
21. Valley Slope	.0280	.0300	.0280	.0300
22. Average Channel Slope (S_{bkf})	.0250	.0255	.0250	.0255
23. Pool Slope (s_{pool})	.0050	.0051	.0050	.0051
24. Pool Slope to Average Slope (S_{pool} / S_{bkf})	.20		.20	
25. Maximum Pool Depth (d_{pool}) – ft	1.8	2.9	1.9	3.0
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	1.8	2.8	1.8	2.8
27. Pool Width (w_{pool}) – ft	13.5	18.4	14.3	19.5
28. Pool Width to Bankfull Width (w_{pool} / w_{bkf})	1.1	1.5	1.1	1.5
29. Pool Area (A_{pool}) – ft^2	---		---	
30. Pool Area to Bankfull Area (A_{pool}/A_{bkf})	---		---	
31. Pool-to-Pool Spacing (p-p) – ft	18	62	20	65
32. Pool-to-Pool Spacing to Bankfull Width (p-p/w_{bkf})	1.5	5.0	1.5	5.0
33. Riffle Slope (s_{riffle})	.0382	.0500	.0382	.0500
34. Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	1.5	2.0	1.5	2.0

Table 7.2 (Cont.) Geomorphic Characteristics of the Proposed Sink Hole Creek Restoration Plan-Unnamed Tributaries Sink Hole Creek Restoration Plan	UT1		UT2				UT3	
	Reach 2 Sta. 0+00 to 4+94		Reach 1 Sta. 0+00 to 5+95		Reach 2 Sta. 5+95 to 14+88		Reach 1 Sta. 0+00 to 5+86	
	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	B-C		Aa+		A		B	
2. Drainage Area- mi^2	.09		.02		.08		.02	
3. Bankfull Width (w_{bkf}) – ft	7.4		4.0		6.0		4.0	
4. Bankfull Mean Depth (d_{bkf}) – ft	.6		.4		.5		.4	
5. Width/Depth Ratio (w/d ratio)	12.0		10.8		11.4		10.8	
6. Cross-sectional Area (A_{bkf}) – ft^2	4.6		1.5		3.2		1.5	
7. Bankfull Mean Velocity (v_{bkf}) - ft/sec	4.4		3.3		4.8		3.3	
8. Bankfull Discharge (Q_{bkf}) – ft^3/sec	20		5		15		5	
9. Bankfull Max Depth (d_{mbkf}) - ft	.8		.5		.7		.5	
10. d_{mbkf} / d_{bkf} Ratio	1.3		1.3		1.4		1.3	
11. Low Bank Height to d_{mbkf} ratio	---		---		---		---	
12. Floodprone Area Width (w_{fpa}) – feet	70	100	70	100	70	100	70	100
13. Entrenchment Ratio (ER)	9.5	13.5	17.4	24.8	11.7	16.7	17.4	24.8
14. Meander Length (L_m) – ft*	N/A		N/A		N/A		N/A	
15. Meander Length to Bankfull Width (L_m/w_{bkf})*	N/A		N/A		N/A		N/A	
16. Radius of Curvature (R_c) – ft*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17. Radius of Curvature to Bankfull Width (R_c / w_{bkf})*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18. Belt Width (w_{blt}) – ft*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19. Meander Width Ratio (w_{blt}/W_{bkf})*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20. Sinuosity (K) (Stream Length / Valley Length)	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.2
21. Valley Slope	.0280	.0300	.1000		.0590	.0590	.1000	
22. Average Channel Slope (S_{bkf})	.0375	.0546	.1050	.1077	.0375	.0546	.1050	.1077
23. Pool Slope (s_{pool})	.0050	.0051	.0167	.0182	.0098	.0107	.0167	.0182
24. Ratio of Pool Slope to Average Slope (S_{pool} / S_{bkf})	.20	.20	.20	.20	.20	.20	.20	.20
25. Maximum Pool Depth (d_{pool}) – ft	1.1	1.7	.7	1.0	.9	1.5	.7	1.0
26. Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	1.8	2.8	1.8	2.8	1.8	2.8	1.8	2.8
27. Pool Width (w_{pool}) – ft	8.1	11.1	4.4	6.0	6.6	9.0	4.4	6.0
28. Pool Width to Bankfull Width (w_{pool} / w_{bkf})	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5
29. Pool Area (A_{pool}) – ft^2	---	---	---	---	---	---	---	---
30. Pool Area to Bankfull Area (A_{pool}/A_{bkf})	---	---	---	---	---	---	---	---
31. Pool-to-Pool Spacing (p-p) – ft	11	37	6	20	9.0	30.0	6	20
32. Pool-to-Pool Spacing to Bankfull Width ($p\text{-}p/w_{bkf}$)	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0
33. Riffle Slope (s_{riffle})	.0382	.0500	.1364	.1667	.0805	.0983	.1364	.1667
34. Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	1.5	2.0	1.5	2.0	1.5	2.0	1.5	2.0
Notes: * These parameters are typically applied to meandering streams, not A or B-type streams.								

7.3.1 Sediment Transport Analysis

As discussed in the channel stability assessment, Lane (1955) describes a generalized relationship of stream stability wherein the product of sediment load and sediment size is proportional to the product of stream slope and discharge. But whereas sediment size, stream slope, and stream discharge can be assessed in a straight-forward manner, sediment load is difficult to quantify because of the numerous processes controlling sediment delivery and movement within the stream system.

Sediment transport is typically assessed by computing channel competency, capacity, or both. Sediment transport competency is a measure of force (lbs/ ft^2) that refers to the stream's ability to move a given grain size. Quantitative assessments include shear stress, tractive force, and critical dimensionless shear stress. Since these assessments help determine a size class that is mobile under certain flow conditions, they are most important in gravel bed studies in which the bed material ranges in size from sand to cobble (of which only a fraction are mobile during bankfull conditions). Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross-section per unit of time, expressed in pounds/second or tons/year. In these headwater streams, sediment supply is likely to be a limiting factor in sediment transport capacity. In order to compensate for this condition, larger colluvial particles may protect smaller particles from movement. This armoring effect limits the potential down-cutting of the stream. The newly constructed channel will be constructed with an engineered bed material that will include colluvial-size particles in order to recreate the natural armoring present in a developed channel.

7.3.1.1 Methodology

To conduct the sediment competency analyses, pavement, subpavement, and pebble count sediment samples were taken; typically two sets in each reach. The sediment samples were weighed to generate cumulative frequency plots. Project reaches have median particle sizes in the range of small to large gravel. No sampling was conducted for UT2 and UT3 since these systems will be redesigned as step-pool channels whose particles are predominantly immobile based on a critical shear stress analysis.

As described earlier, a HEC-RAS model was created for the various reaches. This model was used to provide a reach-wide view of the magnitude of the shear stresses that exist in the existing channel at the proposed design bankfull flow. At cross-sections where the existing channel is relatively stable, the bankfull shear stress was compared against the design channel shear stress in order to assess the relative competency of the design channel to existing stable cross-sections. In addition, the shear stress at unstable cross-sections and reach minimums and maximums were used for comparative purposes. Aside from these comparisons, it should be noted that, where incised, the existing channel will have a shear stress that continues to increase markedly until the discharge is sufficient to overtop of the banks. For all discharges greater than the bankfull discharge, the shear stress in the design channel may be significantly less than in the existing incised reaches. Due to the relief provided by the more accessible floodplain in the design channel, there is a flattening in the slope of the stage discharge curve at all flows above bankfull (resulting in a lower stage occurring in the design channel for all discharges in excess of this flow, and therefore a lower shear stress).

7.3.1.2 Sediment Transport Analysis Discussion

The sediment samples were used to determine the dimensionless critical shear stress and corresponding slope and depth required to move the largest particle size. For Sinkhole reaches 1 and 2, the design bankfull depth and slope was capable of moving particles in the size range of the D100 particle of the subpavement sample, 67 mm and 55 mm, respectively. The corresponding D100 pavement particle size for these reaches is 128 mm and 109 mm, respectively. The design shear stress for reach 1 is 1.9 lb/sq ft and for reach 2, 1.5 lb/sq ft. Shear stresses of this magnitude move particles through both suspended load and bedload transport and, based on other bedload data sets, may move particles that range in size from 50 mm to 150 mm in size (Colorado Bedload Data, Natural Channel Design (In-house) Workshop, 2006). This is interpreted to mean that the design bankfull flow may move the D100 particle in these reaches if conditions are right. Counteracting this is the step-pool nature of the design, which provides grade-control to significantly reduce, or eliminate, the possibility of riffle degradation. Additionally, the effects of stream vegetation in a channel of this size are significant with respect to flow velocities and channel evolution through sediment transport and deposition. If existing conditions are any indication, streamside vegetation is expected to result in sediment desposition on the newly constructed banks and result in channel narrowing towards a lower width to depth ratio. The increased roughness from vegetation is counteracted by a more efficient (from a sediment transport perspective) E-type channel. It is also true, as evidenced by the HEC-RAS model, that the bankfull flow in the existing channel yields a comparable competency to the design at existing cross-sections of relative stability. The fact that these cross-sections are not significantly degraded or otherwise compromised supports a design that yields a capacity of this magnitude.

In Reach 2 of UT1, the critical dimensionless shear was again considered. Again, the design depth and slope was capable of moving the D100 particle size. The design channel average shear stress was calculated to be 1.5 lb/sq ft. Based on other bedload data sets, this may move particles that range in size from 50 mm to 100 mm in size. The D100 from the subpavement sample is 64mm and from the pavement sample, 90 mm. Based on this, the same interpretation as above is applicable. A step-pool design similar to the mainstem is being proposed; this approach will reduce transport and prohibit down-cutting. This reach has an energy grade line slope of about 4.0%, steeper than the 2.5-3% typical of mainstem reaches 1 and 2. This yields a much higher shear stress for the same channel size. To counteract the steep nature of this reach, energy dissipation in the form of pools will be spaced at short intervals, slope will be taken out of the riffles by using the grade control structures to drop elevation (effectively reducing the slope), and the design will use the sediment competency data to develop a sediment gradation for the design channel that will be less susceptible to transport. Since the reach is located below a pond that acts like a sediment sink, the reach will be designed for minimal transport (by using large cobble and boulders in the design) to counteract the lack of sediment supply.

Sediment capacity was not a significant consideration in the design, except to consider its minimal level in the headwater reaches or in UT1 below the pond. Evidence of aggradation in the system, or a known significant sediment load, might be cause for an in-depth sediment capacity assessment. For this project, a limited sediment transport capacity check using stream power as a surrogate for capacity was deemed sufficient for Sinkhole Creek reaches 1 and 2. The sediment capacity of the proposed reaches is comparable to the capacity of the existing stable channel segments for reaches 1 and 2. For UT1, UT2 and UT3, no sediment capacity check was performed as these steep headwater tributaries are degradational systems by nature and they are being built primarily out of colluvial material that is designed to be immobile. This design technique, to be used throughout the project, protects smaller particles from movement. This armoring effect limits the potential down-cutting of the stream. Newly constructed channel segments will be constructed with an engineered bed material that will include poorly sorted medium to larger-sized particles to recreate the natural armoring present in developed channels elsewhere within the project area.

7.3.2 HEC-RAS Analysis

7.3.2.1 Preliminary Modeling and Hydrologic Trespass

Sink Hole Creek is a low order tributary to the North Toe River. It is not necessary to conduct a flood study based on the following information: according to the FEMA Flood Insurance Rate Map (FIRM) for Mitchell County, NC (Panel Numbers 0852 and 0862), the project is not within a regulated floodplain. Flood modeling is not required for non-regulatory floodplains. Furthermore, any change in the 100-year water surface is expected to be minimal and to be contained within the conservation easement.

7.4 Site Construction

7.4.1 Site Grading, Structure Installation, and Other Project Related Construction

7.4.1.1 Narrative

A construction sequence is provided below and can be found within the accompanying restoration plan set for the Sink Hole Creek project.

1. Equipment and materials shall be mobilized to the site.

2. The contractor shall have all underground utilities within the project limits located and marked prior to beginning construction.

3. A gravel "construction entrance" that consists of class A stone, at least 50 feet in length, shall be incorporated into every access point that connects to a public road.

4. Temporary and permanent stream crossings and temporary check dams shall be installed as shown in the plan set. Temporary check dams shall be removed when grading work upstream has been completed.

5. Construction shall proceed upstream to downstream. Grading of bankfull benches within a work area shall be done before new channels are graded.

6. Temporary sand bag coffer dams shall be installed upstream of each work area and flow in the work reach shall be diverted by pumping and piping around the work area. The length of each diversion shall be approximately 300 to 500 linear feet. Pumping will be done when work is required in a channel where the stream is flowing.

7. The limited clearing and grubbing required within the grading limits shall be performed so as to limit sediment migration off-site. Logs and root wads from trees larger than 10 inches in diameter shall be stockpiled for use as in-stream structures. Salvageable native vegetation (black willow, tag alder, silky dogwood, etc.) shall be harvested for transplanting or for cutting and live-staking materials.

8. The new channel sections shall be stabilized with in-stream structures, erosion control matting, seed, and transplants before turning water into these sections. Compacted soil channel plugs shall be installed in areas where the new channel diverges from the original channel, and the original, abandoned channel sections will be backfilled.

9. Dewatering of off-line sections shall be diverted through a sediment filter before being discharged into the downstream reach.

10. Earthwork shall be staged such that no more channel will be disturbed than can be stabilized by the end of the work day or before flow is diverted into a new channel segment.

11. Excess soil materials shall be stockpiled in designated staging and stockpile areas, with silt fence installed on the stream side(s) of the base of the stockpiles and maintained when sediment

has accumulated above one third of the height of the silt fence and/or the silt fence has failed. Excess soil shall be hauled outside the conservation easement before demobilization.

12. The flow diversions and temporary stream crossings shall be removed when no longer needed and the banks in these areas stabilized with seeding and matting.

13. Bank and floodplain vegetation, including brush materials and live stakes, are preferably installed during the dormant season, November to April.

14. Construction entrances, staging and stockpile areas, and silt fences shall be removed and ground shall be repaired to its original conditions once planting is complete or once they are no longer needed.

7.4.1.2 In-stream Structures and other construction elements

A variety of in-stream structures are proposed for the Sink Hole Creek site. Structures such as constructed riffles, log vanes, log rollers and boulder steps will be used to stabilize the newly-restored stream. This project will primarily utilize those structures which provide grade control and enhance pool habitat as “A” and “B” type streams make up the project site. Wood structures will alternate with boulder structures on this site because of the material observed in the existing system. A certain amount of wood will be generated through the construction of this project. Table 7.3 summarizes the use of in-stream structures at the site.

Table 7.3 Proposed In-Stream Structure Types and Locations
Sink Hole Creek Restoration Plan

Structure Type	Location
Constructed Riffle	Through straight, steeper sections to provide grade control.
Log Vane	In meander bends to turn water.
Log Roller	In steep channels to control grade and maintain step-pool system.
Boulder Step Structure	In steep channels to control grade and maintain step-pool system.

Constructed Riffle

A constructed riffle consists of the placement of coarse bed material in the stream at specific riffle locations along the profile. A buried log or rocks at the upstream and downstream end of riffles may be used to control the slope through the riffle in steeper sections. The purpose of this structure is to provide grade control and establish riffle habitat. Constructed riffles will be placed throughout all reaches. In the higher slope reaches, the constructed riffles and cross vanes will be intermixed to provide diversity of structure and in-stream habitat.

Rock or Log Vane

A rock or log vane is used to protect the stream bank. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes are located either upstream or downstream along a meander bend and function to initiate or complete the redirecting of flow energies resulting in reduced near bank shear stress and alignment maintenance. Vanes are located just downstream of the point where the stream flow intercepts the bank at acute angles. These vanes may also be used outside of meanders on moderate to steep channel gradients for grade control, a primary concern in this restoration project. Logs and or boulders may be used to construct vanes.

Log Roller

Log rollers are logs that are usually placed in a series and at opposing angles and slopes. These structures are used in riffles to create small meanders within the riffle, diversifying habitat.

Boulder Step Structure

Boulder step structures consist of boulders placed in the channel in a U-shape constructed similarly to a cross-vane. These structures provide grade control in steep channels, direct high velocity flows to the center of the channel, and promote diverse habitat through the creation of plunge pools immediately downstream of the structure.

7.4.2 Natural Plant Community Restoration

Native riparian vegetation will be established in the restored stream buffer. Any areas of invasive vegetation such as Chinese privet and Japanese honeysuckle will be removed so as not to threaten the newly-established native plants within the conservation easement. Known invasive species to be treated include multiflora rose, chinese privet and japanese honeysuckle.

7.4.2.1 Soil Preparation and Amendments

Soil amendments will be prepared according to the dominant soil types present within the floodplains for Sink Hole Creek and its unnamed tributaries. Application of soil amendments will occur as site stabilization measures are implemented and during installation of permanent bank and riparian vegetation.

7.4.2.2 Stream Buffer Vegetation

Bare-root trees, live stakes, and permanent seeding will be planted within designated areas of the conservation easement. A preferred 30-foot buffer measured from the top of banks (sometimes slightly less and quite often, substantially more) will be established along the restored stream reaches. In the preservation reach, the combined buffer width for left and right banks will be approximately 100 feet. Bare-root vegetation will be planted at a target density of 680 stems per acre, or an 8-foot by 8-foot grid. The proposed species to be planted are listed in Table 7.4. Planting of bare-root trees and live stakes will be conducted during the first dormant season following construction. If construction activities are completed in summer/fall of a given year, all vegetation will be installed prior to the start of the growing season of the following calendar year.

Species selection for re-vegetation of the site will generally follow those suggested by Schafale and Weakley (1990) and tolerances cited in the USACE Wetland Research Program (WRP) Technical Note VN-RS-4.1 (1997). Tree species selected for stream restoration areas will generally be weakly tolerant to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive in soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997).

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

Live stakes will be installed two to three feet apart using triangular spacing or at a density of 160 to 360 stakes per 1,000 square feet along the stream banks between the toe of the stream bank and bankfull elevation. Site variations may require slightly different spacing.

Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 7.5 lists the species, mixtures, and application rates that will be used. A mixture is provided for floodplain wetland and floodplain non-wetland areas. Mixtures will also include temporary seeding (rye grain during cold season or browntop millet during warm season). The permanent seed mixture specified for floodplain areas will be applied to all disturbed areas outside the banks of the restored stream channel and is intended to provide rapid growth of herbaceous ground cover and biological habitat value. The species provided are deep-rooted and have been shown to proliferate along restored stream channels, providing long-term stability.

Temporary seeding will be applied to all disturbed areas of the site that are susceptible to erosion. These areas include constructed stream banks, access roads, side slopes, and spoil piles. If temporary seeding is applied from November through April, rye grain will be used and applied at a rate of 130 pounds per acre. If applied from May through October, temporary seeding will consist of browntop millet, applied at a rate of 45 pounds per acre.

Table 7.4 Proposed Bare-Root and Live Stake Species (may also include species to be seeded or installed as container plantings)
Sink Hole Creek Restoration Plan

Common Name	Scientific Name	% Planted by Species	Wetness Tolerance
Riparian Buffer Plantings			
Trees Overstory			
Sycamore	*Platanus occidentalis*	8	FACW-
River Birch	*Betula nigra*	7	FACW
White Oak	*Quercus alba*	5	FACU
Red Maple	*Acer rubrum*	10	FAC
Tulip Poplar	*Liriodendron tulipifera*	5	FAC
Yellow Birch	*Betula alleghaniensis (lutea)*	5	FACU+
Black (Sweet) Birch	*Betula lenta*	5	FACU
Northern Red Oak	*Quercus rubra*	5	FACU
Sugar Maple	*Acer saccharum*	5	FACU-
Mockernut Hickory	*Carya alba (tomentosa)*	3	N/A
Scarlet Oak	*Quercus coccinea*	2	N/A
Trees Understory			
Black Willow	*Salix nigra*	4	OBL
Ironwood	*Carpinus caroliniana*	7	FAC
Witch Hazel	*Hamamelis virginiana*	4	FACU
Sourwood	*Oxydendrum arboreum*	7	FACU
Flowering Dogwood	*Cornus florida*	6	FACU
Rhododendron	*Rhododendron maximum*	7	FAC-
Tag Alder	*Alnus serrulata*	10	
Redbud	*Cercis canadensis*	6	FACU
Shrubs			
Rivercane (giant cane)	*Arundinaria gigantea*	15	FACW
Spicebush	*Lindera benzoin*	15	FACW

Deerberry	*Vaccinium stamineum*	10	FACU
Eastern Sweetshrub, Sweetshrub	*Calycanthus floridus, Calycanthus spp.*	10	FACU
Sweetpepperbush	*Clethra spp.*	15	N/A
Winterberry	*Ilex verticillata*	10	FACW
Virginia Sweetspire	*Itea virginica*	15	FACW+
Chokeberry	*Photinia*	5	N/A
Alternate Species			
Blight-resistant American Chestnut	*Castanea dentata*	N/A	N/A
Dog Hobble	*Leucothoe fontanesiana (axilarris var. editorum)*	N/A	N/A
Mountain Laurel	*Kalmia latifolia*	N/A	FACU
American Hazelnut	*Corylus americana*	N/A	FACU
Blue Ridge Blueberry	*Vaccinium pallidum*	N/A	N/A
Riparian Livestake Plantings			
Ninebark	*Physocarpus opulifolius*	10	FAC-
Elderberry	*Sambucus canadensis*	20	FACW-
Buttonbush	*Cephalanthus occidentalis*	10	OBL
Silky Willow	*Salix sericea*	35	OBL
Silky Dogwood	*Cornus amomum*	25	FACW+
Note: Species selection may change due to refinement or availability at the time of planting.			

Table 7.5 Proposed Permanent Seed Mixture
Sink Hole Creek Restoration Plan

Common Name	Scientific Name	% Planted by Species	Density (lbs/ac)	Wetness Tolerance
Creeping Bentgrass	*Agrostis stolonifera*	10%	1.5	FACW
Big Bluestem	*Andropogon gerardii*	2%	0.3	N/A
Devil's Beggartick	*Bidens frondosa (or aristosa)*	3%	0.45	FACW
Northern Long Sedge	*Carex folliculata*	2%	0.3	N/A
Nodding Sedge	*Carex gynandra*	5%	0.75	N/A
Upright Sedge	*Carex stricta*	2%	0.3	OBL
Lance-leaved Tick Seed	*Coreopsis lanceolata*	3%	0.45	N/A
Virginia Wildrye	*Elymus virginicus*	15%	2.25	FAC
Soft Rush	*Juncus effusus*	2%	0.3	FACW+
Tioga Deer Tongue	*Panicum clandestinum*	10%	1.5	FACW
Switch Grass	*Panicum virgatum*	15%	2.25	FAC+
Pennsylvania Smartweed	*Polygonum pensylvanicum*	5%	0.75	FACW
Broadleaf Arrowhead	*Sagittaria latifolia var. pubescens*	1%	0.15	OBL
Little Bluestem	*Schizachyrium scoparium*	5%	0.75	FACU
Roundleaf Goldenrod	*Solidago patula*	3%	0.45	OBL
Indian Grass	*Sorghastrum nutans*	10%	1.5	FACU

Eastern Gamma Grass	*Tripsacum dactyloides*	5%	0.75	FAC+
Joe Pye Weed	*Eupatorium fistulosum*	2%	0.3	N/A
	Total	100	15	
Note: Species selection may change due to refinement or availability at the time of planting.				

7.4.2.3 On-site Invasive Species Management

The site has some infestation of Chinese privet (Ligustrum sinense), multiflora rose (Rosa multiflora), and Japanese honeysuckle (Lonicera japonica). These areas will be treated and monitored so that the invasive species do not threaten the newly-planted riparian vegetation.

Fields within the easement boundaries are predominantly planted in fescue. Fescue will be treated by physical and chemical means in order to reduce competition for native grasses.

The most appropriate means of treating invasive grasses growing in the creek and on the margins of the channel will be assessed and implemented prior to vegetation removal. In many cases, building a new offline channel will reduce or eliminate this issue and the long-term development of a forested creek will shade out this and other invasive grasses.

These areas will be treated and monitored so that the invasive species do not threaten the newly-planted riparian vegetation.

8.0 PERFORMANCE CRITERIA

Baker has been involved in obtaining recent approvals from the regulatory agencies for a series of mitigation and restoration plans for NCEEP full-delivery projects. The stream restoration success criteria for the project site will follow accepted and approved success criteria presented in recent restoration and mitigation plans developed for these full delivery projects. These plans were based on the Stream Mitigation Guidelines issued in April 2003 by the USACE and NCDWQ. Specific success criteria components are presented below.

8.1 Stream Monitoring

Channel stability and vegetation survival will be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to evaluate the effectiveness of the restoration practices. Monitored stream parameters include stream dimension (cross-sections), pattern (longitudinal survey), profile (profile survey), and photographic documentation. The methods used and related success criteria are described below for each parameter.

8.1.1 Bankfull Events

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

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

8.1.2 Cross-sections

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

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

8.1.3 Longitudinal Profile

A longitudinal profile will be surveyed immediately after construction and annually thereafter for the duration of the five-year monitoring period. The as-built survey will be used as the baseline for year one monitoring. Based on project length, the entire project reach on Sink Hole Creek, UT2 and UT3 will be surveyed. The restoration reach on UT1 will also be surveyed. Measurements will include thalweg, water surface, bankfull, and top of low bank. Each of these measurements will be taken at the head of each feature (e.g., riffle, pool) and at the maximum pool depth. The survey will be tied to a permanent benchmark.

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

8.1.4 Bed Material Analyses

Pebble counts will be conducted for at least six permanent cross-sections (100-counts per cross-section) across the Sink Hole Creek project site. Pebble counts will be conducted immediately after construction and annually thereafter at the time the cross-section and longitudinal surveys are performed during the five year monitoring period. These samples will reveal any changes in sediment gradation that occur over time as the stream adjusts to upstream sediment loads. Significant changes in sediment gradation will be evaluated with respect to stream stability and watershed changes.

8.1.5 Photo Reference Sites

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

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

Structure photos. Photographs will be taken of grade control structures along the restored stream, and will be limited to boulder and log steps. Photographers will make every effort to consistently maintain the same area in each photo over time.

Photographs will be used to evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures subjectively. Lateral photos should not indicate excessive erosion or continuing degradation of the banks. A series of photos over time should indicate successive maturation of riparian vegetation.

8.2 Storm Water Management Monitoring

No storm water BMPs are proposed at the Sink Hole Creek restoration project site.

8.3 Wetland Monitoring

No wetland enhancement or restoration activities are proposed in the Sink Hole Creek project area.

8.4 Vegetation Monitoring

Successful restoration of the vegetation on a 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. The NCEEP's methodology for determining the number of vegetation plots required per mitigation site will be used to figure the number of quadrants needed for the Sink Hole Creek project. The size of individual quadrants will vary from 100 square meters for tree species to 1 square meter for herbaceous vegetation.

Vegetation monitoring will occur in spring, after leaf-out has occurred. Individual quadrant data will be provided and will include diameter, height, density, and coverage quantities. Relative values will be calculated, and importance values will be determined. Individual seedlings will be marked to ensure that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living, planted seedlings and the current year's living, planted seedlings.

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

Specific and measurable success criteria for plant density on the project site will be based on the recommendations found in the WRP Technical Note and past project experience.

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

8.5 Benthic Monitoring

If required by the NCDWQ as part of the permitting requirements of the project, benthic macroinvertebrate sampling will be conducted at the restored site prior to construction. Sampling will then occur annually following construction during the five-year monitoring period. Appropriate sampling methodologies will be based on current sampling protocols approved by the NCDWQ.

8.6 Schedule/Reporting

Annual monitoring reports containing the information defined herein will be submitted to NCEEP by December 31 of the year during which the monitoring was conducted. Project success criteria must be met by the fifth monitoring year, or monitoring will continue until all success criteria are met.

9.0 PRELIMINARY MONITORING

Once construction is complete, geomorphic data collected during the design phase will be compared to post-construction survey data to evaluate the success of restoration measures implemented. Other preliminary monitoring data which may be collected includes benthic macroinvertebrate data if required by the NCDWQ.

10.0 SITE PROTECTION AND ADAPTIVE MANAGEMENT STRATEGY

The Sink Hole Creek restoration project area will be protected by a permanent conservation easement that will be held by the state. Baker will monitor the project site for a minimum of five years following construction. Post-construction monitoring activities will be conducted to evaluate site performance, to identify maintenance and/or repair concerns, and to maintain the integrity of the project boundaries. If during the post-construction monitoring period it is determined project compliance is jeopardized, the Baker shall take the necessary action to resolve the project concerns and bring the project back into compliance. If maintenance or site repairs become necessary, Baker will evaluate the level of response required, secure a contractor to make the repairs and monitor the work performed by the construction contractor.

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

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

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. The conditions listed above and any other factors that may have necessitated maintenance will be discussed. If more substantial repair work is required Baker will coordinate with the NCEEP and regulatory agencies to determine whether work performed merits an extended monitoring period. At the conclusion of the post-construction monitoring period the project shall be transferred to the NCDENR Division of Natural Resource Planning and Conservation Stewardship Program for long-term management and stewardship.

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APPENDIX A. NCDWQ Stream Identification Forms

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

Date: 10/12/06	Project: SINK HOLE	Latitude: 035°58'26" N
Evaluator: AB	Site: Main Stem	Longitude: 082°10'39" W
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30* 47.5	County: Mitchell	Other *e.g. Quad Name:* Micaville

A. Geomorphology (Subtotal = 32)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3 ✓	

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

B. Hydrology (Subtotal = 8)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel -- dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 7.5)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians frogs	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

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

Sketch:

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

Date: 8/22/06	Project: LOWER SNK TR	Latitude:
Evaluator: EAM	Site: B UT1 REACH 1	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30* 20.75	County: Moore	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 10.0)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

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

B. Hydrology (Subtotal = 5.0)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel – dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 5.75)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

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

- DEPRESSION
- W/L PLANTS IN STREAM
- GOOD SUBSTRATE SORTING

Sketch:

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

Date:	8/22/06	**Project:**	LOWER SINK [illegible]	**Latitude:**	
Evaluator:	EAM	**Site:**	A UT1 REACH 2	**Longitude:**	
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	32.5	**County:**	MITCHELL	**Other** *e.g. Quad Name:*	

A. Geomorphology (Subtotal = 16.5)

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

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

B. Hydrology (Subtotal = 7.5)

14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, <u>or</u> Water in channel – dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 8.5)

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

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

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

- GOOD SUBSTRATE SORTING
- FORESTED
- HEADH2O WETLANDS

Sketch:

16.5
7.5
8.5
32.5

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

Date:	8/22/06	**Project:**	UPPER SINKHOLE	**Latitude:**	
Evaluator:	EAM	**Site:**	B UT2	**Longitude:**	
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	32.25	**County:**	MITCHELL	**Other** *e.g. Quad Name:*	

A. Geomorphology (Subtotal = 15.0)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank INCISED 4-5 FT.	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural levees	0	1	2	3
10. Headcuts UPSTREAM	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

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

B. Hydrology (Subtotal = 8.5)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel – dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 8.75)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians TOADS	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

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

- SPRING FEED CHANNEL
- CHANNEL INCISED – 4'-5'
- W/L VEGETATION UPSTREAM INCLUDES – JUNCUS, CARDINAL FLOWER, LADY'S THUMB, CAREX
- FLOWS THROUGH STEEP PASTURELAND
- POOR BIOLOGY COMPONENT

Sketch:

15.0
8.5
8.75
32.25

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

Date: 8/22/08		Project: UPPER SINK HOLE		Latitude:	
Evaluator: EAM		Site: A UT 3		Longitude:	
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	20.75	County: MITCHELL		Other *e.g. Quad Name:*	

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

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

B. Hydrology (Subtotal = 8.0)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel -- dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 9.25)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians TOADS	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

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

Sketch:

- OLD PASTURE
- WEAK BIOLOGY COMPONENT
- SPRING FEED
- W/L VEG INCLUDE JUNCUS, CAREX, NY IRONWEED
- MAY BE INTERMITTENT IN DRY YEARS

APPENDIX B. Regulatory Correspondence

EEP Floodplain Requirements Checklist

This form was developed by the National Flood Insurance program, NC Floodplain Mapping program and Ecosystem Enhancement Program to be filled for all EEP projects. The form is intended to summarize the floodplain requirements during the design phase of the projects. The form should be submitted to the Local Floodplain Administrator with three copies submitted to NFIP (attn. Edward Curtis), NC Floodplain Mapping Unit (attn. John Gerber) and NC Ecosystem Enhancement Program.

Project Location

Name of project:	Sinkhole Creek Restoration
Name if stream or feature:	Sinkhole Creek and UT's near intersection of NC Highway 80 and Water Street (NC Highway 1182)
County:	Mitchell County (floodmap overlaps into Yancey County)
Name of river basin:	French Broad River Basin- North Carolina Division of Water Quality (NCDWQ) sub-basin 04-03-06 and United States Geologic Survey (USGS) local watershed unit 06010108040010
Is project urban or rural?	Rural
Name of Jurisdictional municipality/county:	Mitchell County
DFIRM panel number for entire site:	0852, 0862
Consultant name:	Michael Baker Engineering, Inc.
Phone number:	828-350-1408 x2007
Address:	797 Haywood Road Suite 201 Asheville, NC 28806

Design Information

Provide a general description of project (one paragraph). Include project limits on a reference orthophotograph at a scale of 1" = 500".
(See attached figures at end of form, scale slightly different than specified)

Baker proposes to restore or enhance 2,098 linear feet (LF) of Sink Hole Creek and complete 2,572LF of channel restoration or enhancement along three unnamed perennial/intermittent tributaries (UT1, UT2, and UT3) to Sink Hole Creek, in Mitchell County, NC. Additionally, this plan proposes 1,076 LF of preservation in the headwaters of UT1. Sink Hole Creek is a tributary to the North Toe River approximately one mile below the project site. The nearest town, Bakersville, is approximately four miles northeast of the Sink Hole Creek Project site. The site lies in the French Broad River Basin within North Carolina Division of Water Quality (NCDWQ) sub-basin 04-03-06 and local watershed unit 06010108040010.

Summarize stream reaches or wetland areas according to their restoration priority.

Table ES.1 Restoration Plan Overview Sink Hole Creek Restoration Plan		
Project Feature	Design Condition (LF)	Approach
Sink Hole Creek		
Reach 1	1,036	Priority I Restoration
Reach 2	1,062	Priority I Restoration
UT1		
Reach 1	1,076	Preservation
Reach 2	489	Priority II Restoration
UT2		
Reach 1	595	Priority I Restoration
Reach 2	902	Priority I Restoration
UT3		
Reach 1	586	Priority I Restoration
Total Stream Work	5,746 LF	Variable

Floodplain Information

Is project located in a Special Flood Hazard Area (SFHA)?

☐ Yes ☒ No

If project is located in a SFHA, check how it was determined: **Not Applicable**

☐ Redelineation

☐ Detailed Study

☐ Limited Detail Study

☐ Approximate Study

☐ Don't know

List flood zone designation: **Zone X (Unmapped)**

Check if applies:

☐ AE Zone

- ○ Floodway
- ○ Non-Encroachment
- ◉ None

☐ A Zone

- ○ Local Setbacks Required
- ○ No Local Setbacks Required

If local setbacks are required, list how many feet: **Project not in a Zone A**

Does proposed channel boundary encroach outside floodway/non-encroachment/setbacks?

○ Yes ◉ No

Land Acquisition (Check)

☐ State owned (fee simple)

☐ Conservation easment (Design Bid Build)

☑ Conservation Easement (Full Delivery Project)

Note: if the project property is state-owned, then all requirements should be addressed to the Department of Administration, State Construction Office (attn: Herbert Neily, (919) 807-4101)

Is community/county participating in the NFIP program?

◉ Yes ○ No

Note: if community is not participating, then all requirements should be addressed to NFIP (attn: Edward Curtis, (919) 715-8000 x369)

Name of Local Floodplain Administrator: **Keynan Phillips**
Phone Number: **828.688.4771, k.phillips@mitchellcounty.org**

Floodplain Requirements

This section to be filled by designer/applicant following verification with the LFPA

- [x] No Action
- [ ] No Rise
- [ ] Letter of Map Revision
- [ ] Conditional Letter of Map Revision
- [ ] Other Requirements

List other requirements:
None

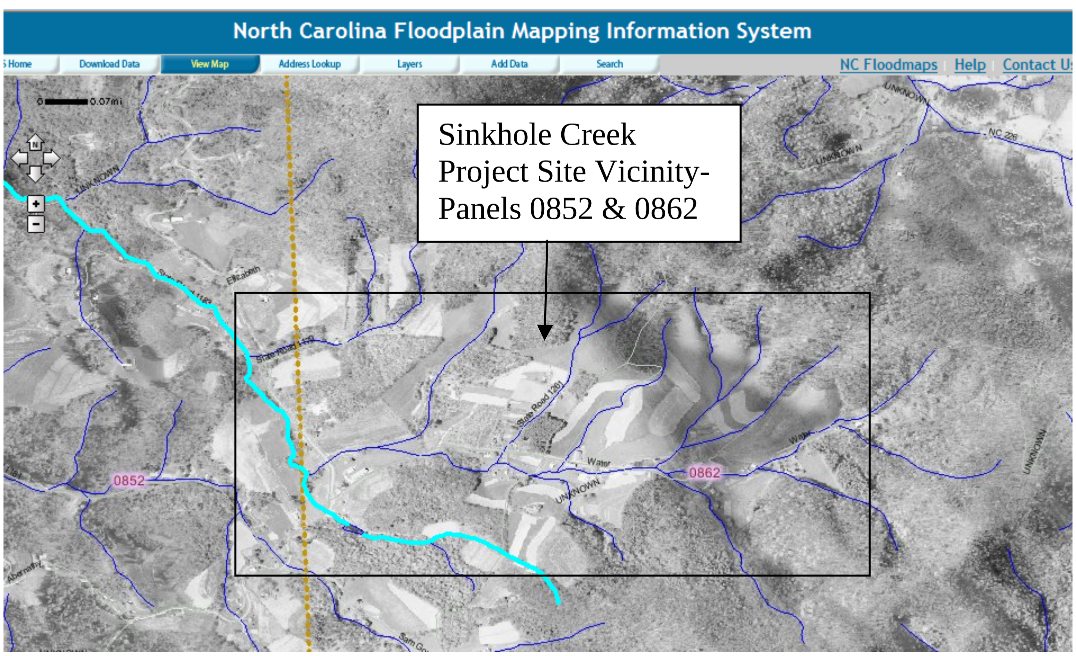
Comments:
The stream is an unmapped Zone X. It does not involve disturbance to more than 5 acres of land. No federal or state FEMA requirements apply.

Name: Jake McLean

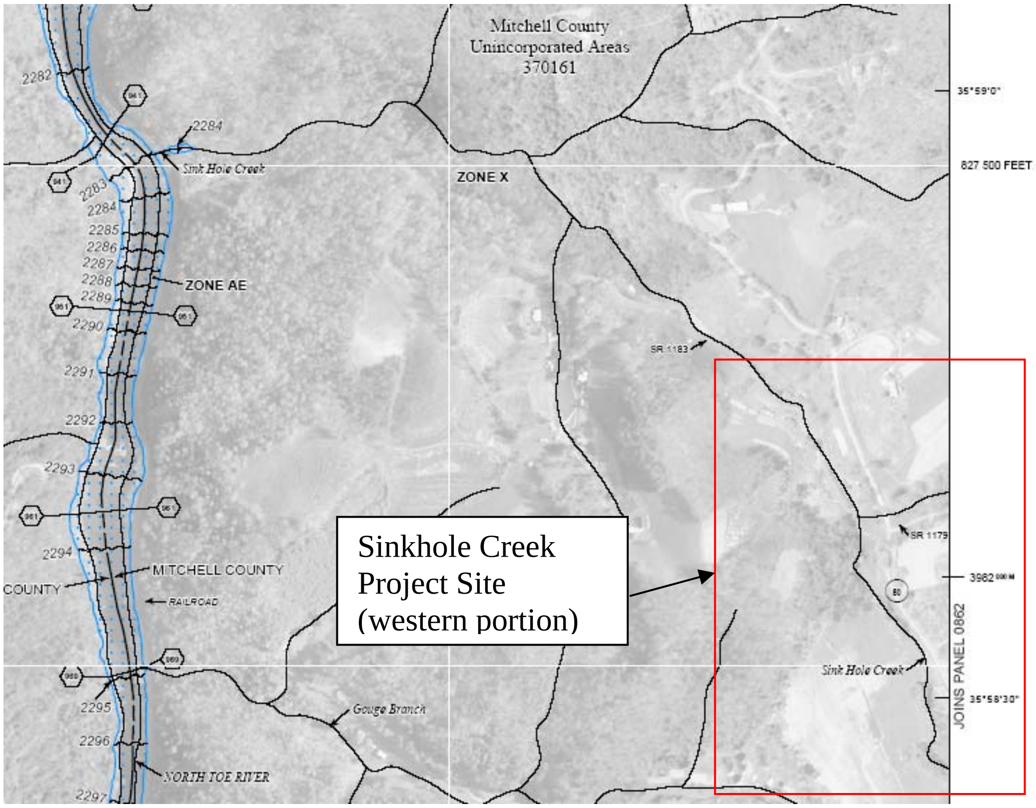
Signature: Jacob P. McLean

Title: Professional Engineer, NC

Date: 5/27/2009



Panel 0852



(Panel 0862 not available for download from state website at time of investigation (5/28/09))

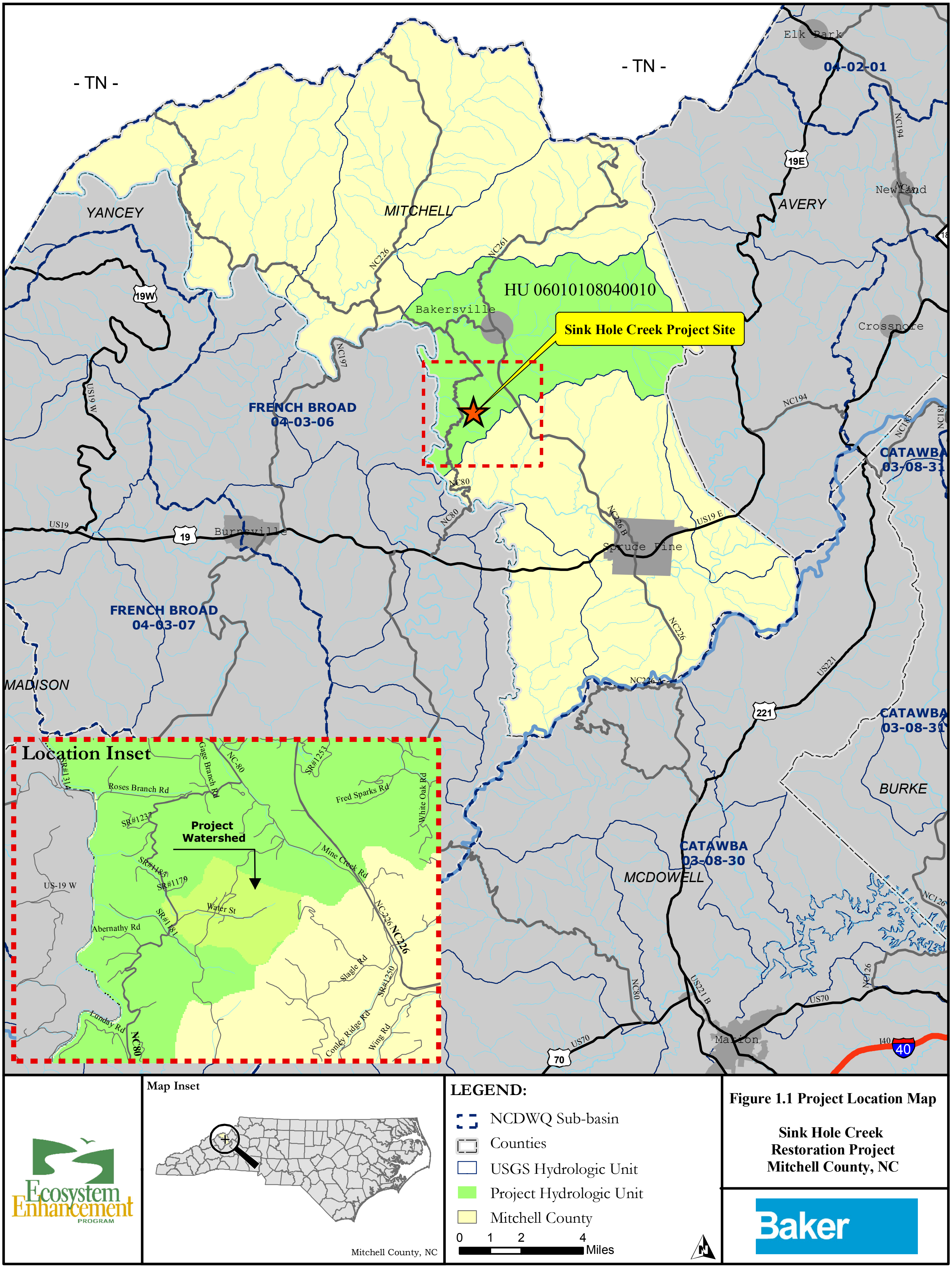


Figure 1.1 Project Location Map

Sink Hole Creek Restoration Project Mitchell County, NC

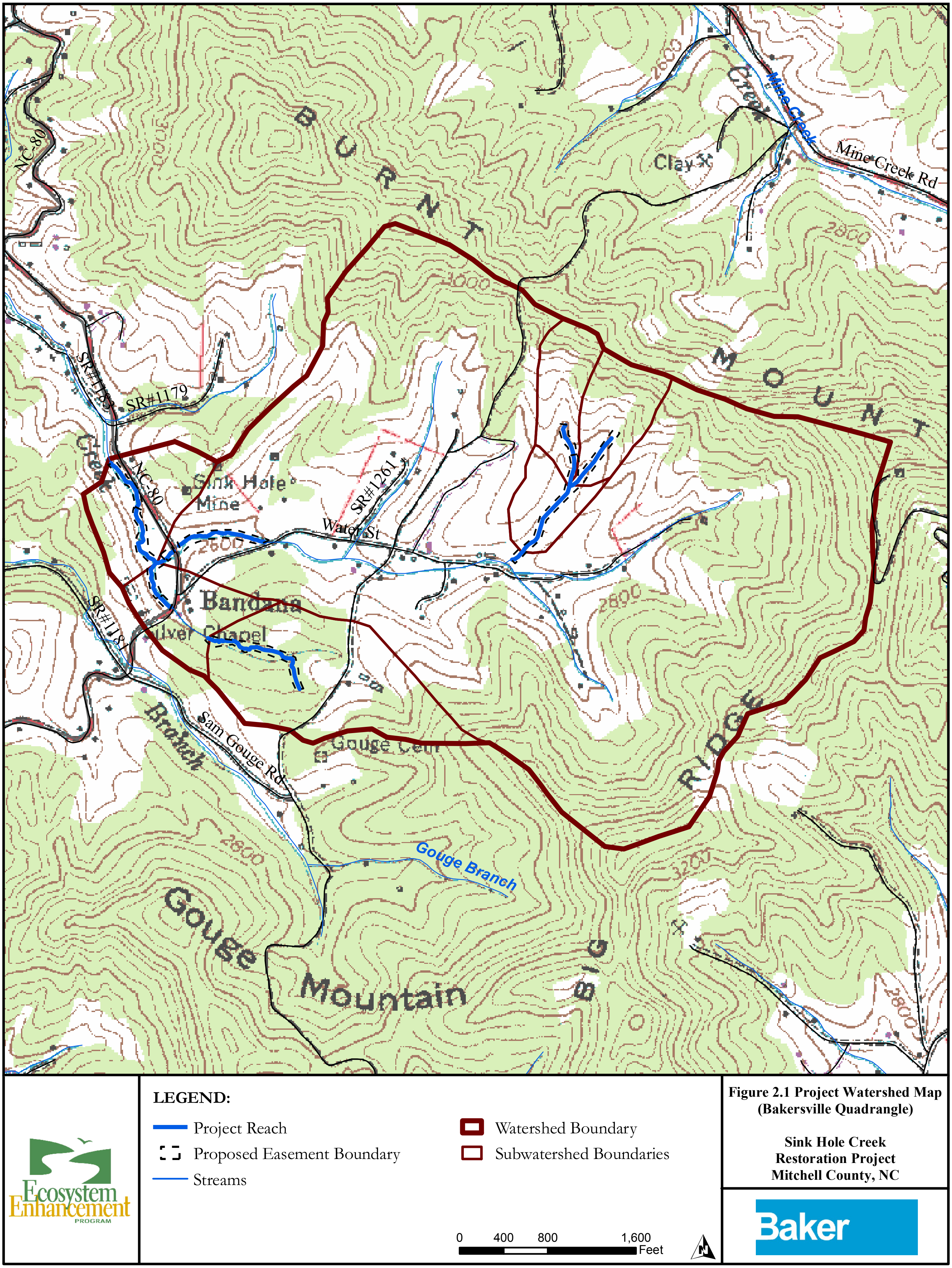
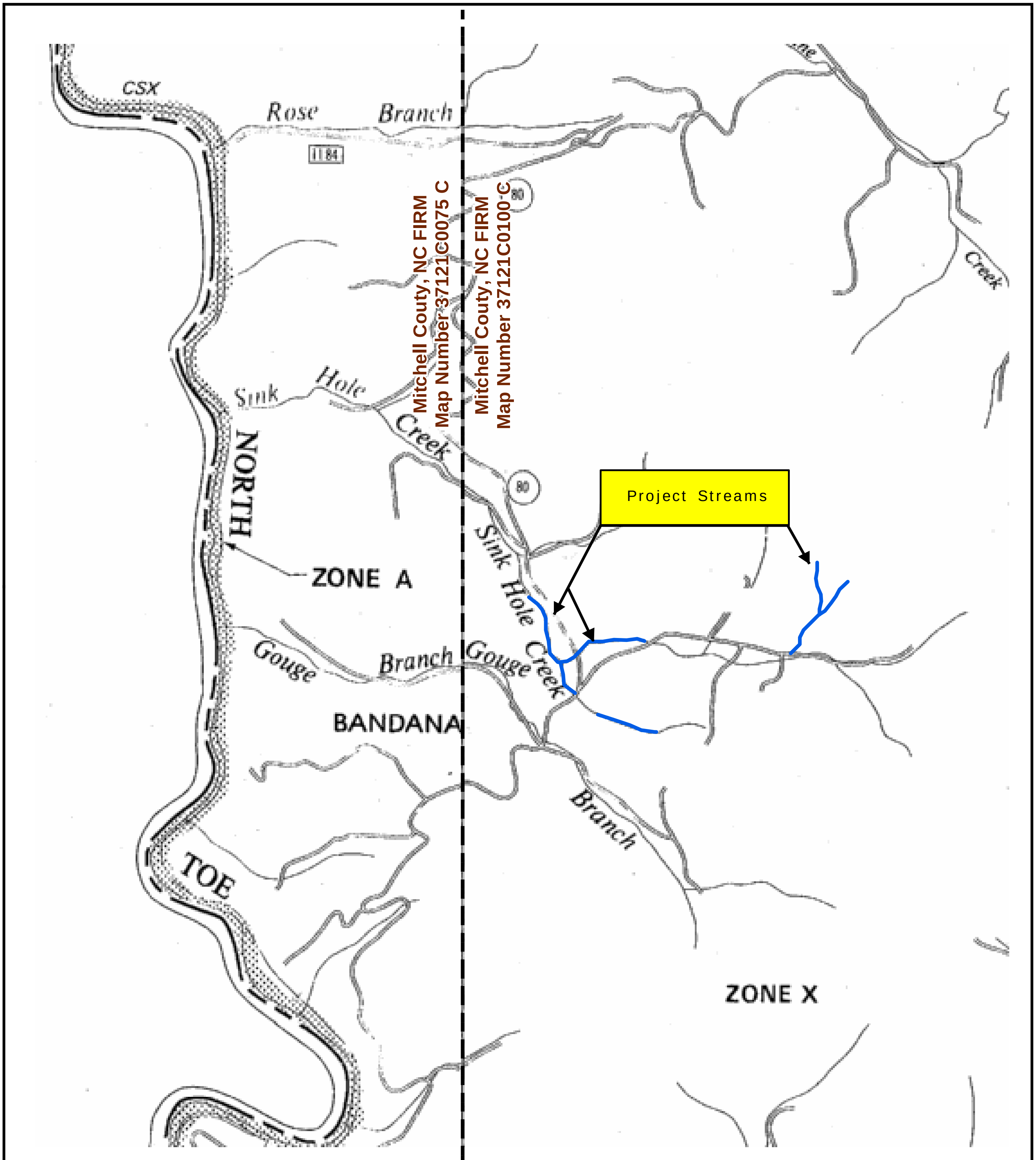


Figure 2.1 Project Watershed Map (Bakersville Quadrangle)

Sink Hole Creek Restoration Project Mitchell County, NC

Ecosystem Enhancement PROGRAM

Baker



LEGEND:

Project Reach

*Figure Not to Scale

Figure 3.1 FEMA Floodplain Map
Flood Insurance Rate Map

Sink Hole Creek
Restoration Project
Mitchell County, NC

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

April 9, 2007

Renee Gledhill-Earley
State Historic Preservation Office
4617 Mail Service Center
Raleigh, NC 27699-4617

Subject: North Carolina Ecosystem Enhancement Program,
Sink Hole Creek Stream Restoration Project,
Mitchell County, NC

Dear Ms. Gledhill-Earley,

The Ecosystem Enhancement Program (EEP) requests review and comment on any possible issues that might emerge with respect to archaeological or cultural resources associated with a potential stream restoration project on the attached site (a vicinity map, USGS site map with areas of potential ground disturbance, and a soils map are enclosed).

The Sink Hole Creek site has been identified for the purpose of providing in-kind mitigation for unavoidable stream channel impacts. The project will involve the restoration of Sink Hole Creek and two unnamed tributaries in the French Broad River Basin, which include sections of channel that are identified as significantly degraded. Project goals include the restoration or enhancement of approximately 4,806 linear feet of stream for the purpose of obtaining stream mitigation credit in the French Broad River Basin.

No architectural structures or archeological artifacts have been observed or noted during preliminary surveys of the site for restoration purposes. In addition, these channels have been relocated in the past and the ground disturbed through clearing and cattle grazing. As the enclosed aerial photograph shows, the majority of the area within the construction limits of the site consists of floodplain, farmland, or straightened stream channel.

We ask that you review this site based on the attached information to determine the presence of any historic properties. Thank you in advance for your timely response and cooperation. Please feel free to contact us with any questions that you may have concerning the extent of site disturbance associated with this project.

Sincerely,

Andrea M. Spangler
Baker Engineering NY, Inc.

North Carolina Department of Cultural Resources
State Historic Preservation Office
Peter B. Sandbeck, Administrator

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

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

April 30, 2007

Andrea M. Spangler
Baker Engineering
1447 South Tryon Street
Charlotte, NC 28203

Re: EEP, Sink Hole Creek Stream Restoration, Mitchell County, ER 07-0777

Dear Ms. Spangler:

Thank you for your letter of April 9, 2007, concerning the above project.

There are no known recorded archaeological sites within the project boundaries. However, the project area has never been systematically surveyed to determine the location or significance of archaeological resources. Based on the topographic and hydrological situation, and the documented prehistoric activity in the vicinity, there is a high probability for the presence of prehistoric or historic archaeological sites.

We recommend that a comprehensive survey be conducted by an experienced archaeologist to identify and evaluate the significance of archaeological remains that may be damaged or destroyed by the proposed project. Potential effects on unknown resources must be assessed prior to the initiation of construction activities.

Two copies of the resulting archaeological survey report, as well as one copy of the appropriate site forms, should be forwarded to us for review and comment as soon as they are available and well in advance of any construction activities.

A list of archaeological consultants who have conducted or expressed an interest in contract work in North Carolina is available at www.arch.dcr.state.nc.us/consults.htm. The archaeologists listed, or any other experienced archaeologist, may be contacted to conduct the recommended survey.

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

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763 ext. 246. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

Peter Sandbeck

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

April 4, 2007

Tyler Howe
Eastern Band of Cherokee Indians
Tribal Historic Preservation Office
P.O. Box 455
Cherokee, NC 28719

Subject: North Carolina Ecosystem Enhancement Program,
Sink Hole Creek Stream Restoration Project,
Mitchell County, NC

Dear Mr. Howe:

The Ecosystem Enhancement Program (EEP) requests review and comment on any possible issues that might emerge with respect to archaeological or religious resources associated with a potential wetland and stream restoration project on the attached site (a vicinity map and a USGS site map with approximate areas of potential ground disturbance are enclosed).

A similar letter has been sent to the North Carolina State Preservation Office for compliance with Section 106 of the Historic Preservation Act.

The Sink Hole Creek site has been identified for the purpose of providing in-kind mitigation for unavoidable stream channel impacts. The project will include restoration, enhancement, and preservation on Sink Hole Creek and two unnamed tributaries. No architectural structures or archeological artifacts have been observed or noted during preliminary surveys of the site for restoration purposes. In addition, the majority of the site has historically been disturbed due to agricultural purposes such as straightening, tilling, and cattle grazing.

We ask that you review this site based on the attached information to determine if you know of any existing resources that we need to know about. In addition, please let us know the level your future involvement with this project needs to be (if any).

We thank you in advance for your timely response and cooperation. Please feel free to contact the below referenced EEP Project Manager with any questions that you may have concerning the extent of site disturbance associated with this project.

Sincerely,

Andrea M Spangler

Andrea Spangler
704-319-7884

cc: Donnie Brew
EEP FHWA Liason
1652 Mail Service Center
Raleigh, NC 27699

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

April 4, 2007

Marella Buncick
US Fish and Wildlife Service
Asheville Field Office
160 Zillicoa Street
Asheville, NC 28801

Subject: North Carolina Ecosystem Enhancement Program (NCEEP)
Sink Hole Creek Stream Restoration Project, Mitchell County, NC

Dear Ms. Buncick,

The Sink Hole Creek site has been identified for the purpose of providing in-kind mitigation for unavoidable stream channel impacts. The project will include restoration, enhancement, and preservation on Sink Hole Creek and two unnamed tributaries. This stream restoration site was selected based on its probability to restore high quality stream habitat where it has ceased to exist.

We have obtained an updated species list for Mitchell County from your web site (http://nc-es.fws.gov/es/countyfr.html). The threatened or endangered species for this county are: bog turtle (*Clemmys muhlenbergii*), Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*), Appalachian elktoe (*Alasmidonta raveneliana*), spruce-fir moss spide (*Microhexura montivaga*), roan mountain bluet (*Hedyotis purpurea var. montana*), spreading avens (*Geum radiatum*), and Virginia spirea (*Spirea virginiana*). We are requesting that you please provide any known information for each species in the county. The USFWS will be contacted if suitable habitat for any listed species is found or if we determine that the project may affect one or more federally listed species or designated critical habitat.

Please provide comments on any possible issues that might emerge with respect to endangered species, migratory birds or other trust resources from the construction of a wetland and stream restoration project on the subject property. A vicinity map, USGS map, and a soils map of the project site have been enclosed.

If we have not heard from you in 30 days we will assume that our species list is correct, that you do not have any comments regarding associated laws, and that you do not have any information relevant to this project at the current time.

We thank you in advance for your timely response and cooperation. Please feel free to contact us with any questions that you may have concerning the extent of site disturbance associated with this project (704-319-7884).

Sincerely,

Andrea M Spangler

Andrea Spangler
Baker Engineering NY, Inc.

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

April 5, 2007

Mr. Cliff Vinson
District Conservationist
11943 South 226 Highway, Suite C
Spruce Pine, NC 28777-3423

Subject: North Carolina Ecosystem Enhancement Program,
Sink Hole Creek Stream Restoration Project,
Mitchell County, NC

Dear Mr. Vinson:

The purposed of this letter is to request your assistance in completing a Farmland Conversion Impact Rating form for the subject site. Enclosed please find a copy of the form, vicinity map, USGS topographic map, and soils map of the project site. The project will include restoration, enhancement, and preservation on Sink Hole Creek and two unnamed tributaries. The project area includes 5.0 acres of Bandana sandy loam, 4.5 acres of Dillsboro clay loam, 8-15% slopes, 1.1 acres of Saunook-Thunder complex, 0.8 acres of Pigeonroost-Edneytown complex, 0.7 acres of Udorthents, 0.7 acres of Dillsboro clay loam 2-8% slopes, 0.5 acres of Watauga sandy loam, 0.4 acres of Dellwood-Reddies complex, and 0.3 acres of Clifton clay loam 8-15% slopes.. Based on our evaluation, we estimate that no Prime Farmland will be converted to nonagricultural use by this action.

We know that you have more familiarity with the region and we will be happy to make any changes to the form that you deem appropriate. Please return the form to us with your determinations and we will fill out the remainder of the form if you determine there is Prime Farmland on the site. Our Fax number is (704) 334-4492.

If you have any questions, please feel free to contact me at (704) 319-7884 or aspangler@mbakercorp.com. Thank you for your assistance in this matter.

Sincerely,

Andrea Spangler
Baker Engineering NY, Inc.

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

May 3, 2007

Mr. M. Kent Clary
Area Resource Soil Scientist
Natural Resources Conservation Service
589 Raccoon Road, Suite 246
Waynesville, NC 28786

Subject: Prime and Important Farmlands
North Carolina Ecosystem Enhancement Program,
Sink Hole Creek Stream Restoration Project,
Mitchell County, NC

Dear Mr. Clary:

Thank you for your assistance in completing a Farmland Conversion Impact Rating form for the subject site. Enclosed please find a copy of the completed form.

We know that you have more familiarity with the site, so we will be happy to make any changes to the form that you deem appropriate. Please return the form to us if changes are needed. Our Fax number is (704) 334-4492. Otherwise we will send a copy of the completed form to NCEEP as part of the categorical exclusion document.

If you have any questions, please feel free to contact me at (704) 319-7884 or aspangler@mbakercorp.com. Thank you for your assistance in this matter.

Sincerely,

Andrea Spangler

Andrea Spangler
Baker Engineering

United States Department of Agriculture

NRCS
Natural Resources Conservation Service
589 Raccoon Road, Suite 246
Waynesville, NC 28786
Phone 828 456-6341 ext. 5 FAX 828 452-7031

April 26, 2007

Andrea Spangler
Baker Engineering
1447 S. Tryon Street
Charlotte, NC 28203

Re: USDA Farmland Conversion Impact Rating Form (AD-1006)
Sink Hole Creek Stream Restoration--Mitchell County, NC

Ms. Spangler:

Attached you will find two copies of the completed AD-1006. Based on the maps that you provided, it appears that 5.7 acres of prime farmland and 0.7 acres of state-wide important farmland will be impacted by the proposed stream restoration project.

If I can be of further assistance, please feel free to contact me.

M. Kent Clary

M. Kent Clary
Area Resource Soil Scientist
USDA-NRCS

RECEIVED
MAY 03 2007
BUCK ENGINEERING

cc: Cliff Vinson, District Conservationist, USDA-NRCS, Spruce Pine, NC

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I *(To be completed by Federal Agency)*	Date Of Land Evaluation Request 4/5/07
Name Of Project Sink Hole Creek	Federal Agency Involved FHWA/EEP
Proposed Land Use Stream Restoration	County And State Mitchell County, NC
PART II *(To be completed by NRCS)*	Date Request Received By NRCS 4/12/07

Does the site contain prime, unique, statewide or local important farmland? *(If no, the FPPA does not apply – do not complete additional parts of this form).*	Yes ☑ No ☐	Acres Irrigated —	Average Farm Size 73 AC
Major Crop(s) HAY, TOBACCO	Farmable Land In Govt. Jurisdiction Acres: 23,494 % 16.5	Amount Of Farmland As Defined in FPPA Acres: 8430 % 6.6	
Name Of Land Evaluation System Used Mitchell CALES	Name Of Local Site Assessment System	Date Land Evaluation Returned By NRCS 4/26/07	

PART III *(To be completed by Federal Agency)*	Maximum Points	Alternative Site Rating Site A	Site B	Site C	Site D
A. Total Acres To Be Converted Directly		~~0.0~~ 14.0			
B. Total Acres To Be Converted Indirectly		0.0			
C. Total Acres In Site		~~0.0~~ 14.0	0.0	0.0	0.0
PART IV *(To be completed by NRCS)* Land Evaluation Information					
A. Total Acres Prime And Unique Farmland		5.7			
B. Total Acres Statewide And Local Important Farmland		0.7			
C. Percentage Of Farmland In County Or Local Govt. Unit To Be Converted		<.01			
D. Percentage Of Farmland In Govt. Jurisdiction With Same Or Higher Relative Value		2.2			
PART V *(To be completed by NRCS)* Land Evaluation Criterion Relative Value Of Farmland To Be Converted *(Scale of 0 to 100 Points)*		78			
PART VI *(To be completed by Federal Agency)* Site Assessment Criteria *(These criteria are explained in 7 CFR 658.5(b)*	Maximum Points				
1. Area In Nonurban Use	15	15			
2. Perimeter In Nonurban Use	10	10			
3. Percent Of Site Being Farmed	20	17			
4. Protection Provided By State And Local Government	20	20			
5. Distance From Urban Builtup Area	15	15			
6. Distance To Urban Support Services	15	10			
7. Size Of Present Farm Unit Compared To Average	10	10			
8. Creation Of Nonfarmable Farmland	10	0			
9. Availability Of Farm Support Services	5	5			
10. On-Farm Investments	20	15			
11. Effects Of Conversion On Farm Support Services	10	0			
12. Compatibility With Existing Agricultural Use	10	0			
TOTAL SITE ASSESSMENT POINTS	160	0 117	0	0	0
PART VII *(To be completed by Federal Agency)*					
Relative Value Of Farmland *(From Part V)*	100				
Total Site Assessment *(From Part VI above or a local site assessment)*	160	0	0	0	0
TOTAL POINTS *(Total of above 2 lines)*	260	0	0	0	0

Site Selected:	Date Of Selection	Was A Local Site Assessment Used? Yes ☐ No ☐

Reason For Selection:

Baker

1447 S. Tryon St.
Charlotte, NC 28203
704-334-4454
FAX 704-334-4492

April 4, 2007

Shannon Deaton,
North Carolina Wildlife Resource Commission
Division of Inland Fisheries
1721 Mail Service Center
Raleigh, NC 27699

Subject: North Carolina Ecosystem Enhancement Program (NCEEP)
Sink Hole Creek Restoration Project
Mitchell County, NC

Dear Ms. Deaton,

The purpose of this letter is to request review and comment on any possible issues that might emerge with respect to fish and wildlife issues associated with a stream restoration project on the attached site (a vicinity map and a USGS site map with approximate areas of potential ground disturbance are enclosed).

The Sink Hole Creek site has been identified for the purpose of providing in-kind mitigation for unavoidable stream channel impacts. The project will include restoration, enhancement, and preservation on Sink Hole Creek and two unnamed tributaries. This stream restoration site was selected based on its probability to restore high quality stream habitat where it has ceased to exist.

We have enclosed a copy of the vicinity map and USGS topo map that includes the proposed stream restoration project site. We ask that you review this site based on the USGS topo map in your office to determine the presence of any constraints concerning trout waters or protected species.

We thank you in advance for your timely response and cooperation. Please feel free to contact us with any questions that you may have concerning the extent of site disturbance associated with this project (704-319-7884).

Sincerely,

Andrea Spangler
Baker Engineering NY, Inc.

ChallengeUs.

North Carolina Wildlife Resources Commission

Richard B. Hamilton, Executive Director

April 18, 2007

Ms. Andrea Spangler
Baker Engineering
1447 S. Tryon Street
Charlotte, North Carolina 28203

RE: Sink Hole Creek Restoration Project, North Carolina Ecosystem Enhancement Program (NCEEP), Mitchell County

Dear Ms. Spangler:

This correspondence is in response to your letter of April 4, 2007 requesting information pursuant to possible Fish and Wildlife Coordination Act concerns at the site indicated above. Biologists with the North Carolina Wildlife Resources Commission (NCWRC) are familiar with habitat values in the area. The NCWRC is authorized to comment and make recommendations which relate to the impacts of this project on fish and wildlife pursuant to Clean Water Act of 1977, North Carolina Environmental Policy Act, US National Environmental Policy Act, Endangered Species Act (16 U. S. C. 1531-1543; 87 Stat 884), the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-667d) and/or Federal License of Water Resource Project Act (Federal Power Act-16 U.S.C. 791a et seq.) as applicable.

The site is located near Bakersville, North Carolina and upstream of the North Toe River, a Significant Natural Heritage Area that supports listed species. The stream basin indicated for restoration is known for its Bog turtle, *Glyptemys muhlenbergii* (NCT, FT S/A) habitat. The Appalachian elktoe, *Alasmidonta raveneliana* (NCE/FE) and wavy-rayed lampmussel, *Lampsilis fasciola* (NCSC) are present within a mile of the project area in the North Toe River. The Sharphead darter, *Etheostoma acuticeps* (FSC, NCT) and blotched chub, *Erimystax insignis* (FSC, NCSR) are present in the North Toe River watershed. Hellbender, *Cryptobranchus alleganiensis* (NCSC, FSC) and the Olive darter, *Percina squamata* (NCSC, FSC) are known for the larger watershed. To our knowledge, trout are not known for Sink Hole Creek.

Based on the information provided and our in-office data review, the site appears to have sufficient ecosystem opportunities that warrant habitat improvements. Prior to site planning and construction, breeding season Bog turtle surveys should be accomplished by knowledgeable biologists if suitable habitats are present in or near the work area. During construction, stringent erosion control measures should be installed where soil is disturbed and maintained until project completion. Sediment and erosion control measures should adhere to the design standards for sensitive watersheds (15A NCAC 4B .0024).

Mailing Address: Division of Inland Fisheries • 1721 Mail Service Center • Raleigh, NC 27699-1721
Telephone: (919) 707-0220 • **Fax:** (919) 707-0028

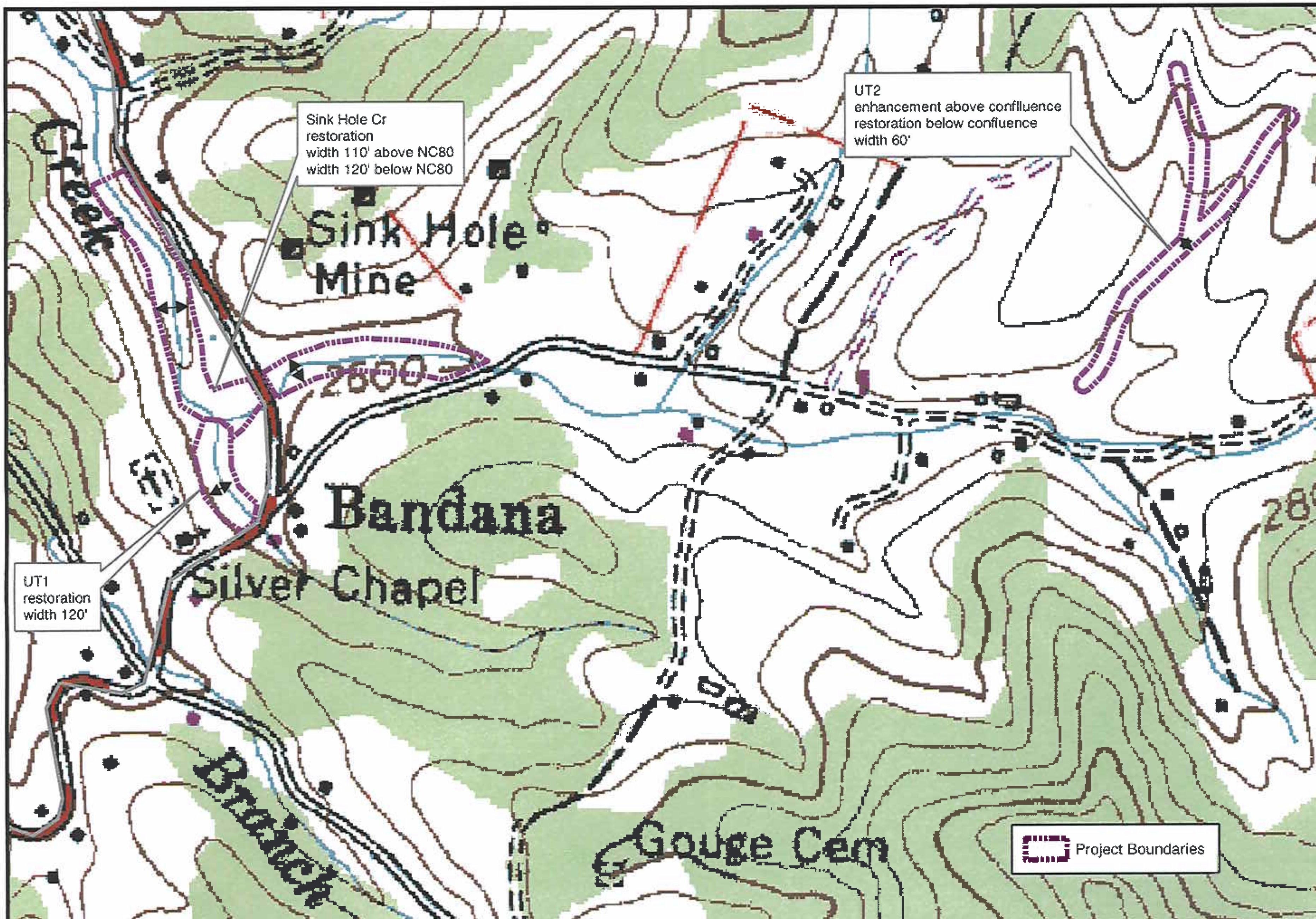
This office only reviews for animal species. In order to determine if plants and additional animals could be present, you should contact the NC Natural Heritage Program and the US Fish and Wildlife Service.

Thank you for the opportunity to comment on your proposed project during its early planning stages. If you have any questions regarding these comments, please contact me at 336-769-9453.

Sincerely,

Ron Linville
Regional Coordinator
Habitat Conservation Program

E-copy: Bryan Tompkins, USFWS
Sarah McRae, NHP



Baker

0 500 1,000 Feet

N

Figure 2.
USGS Topographic Map
Sink Hole Creek
Stream Restoration Project

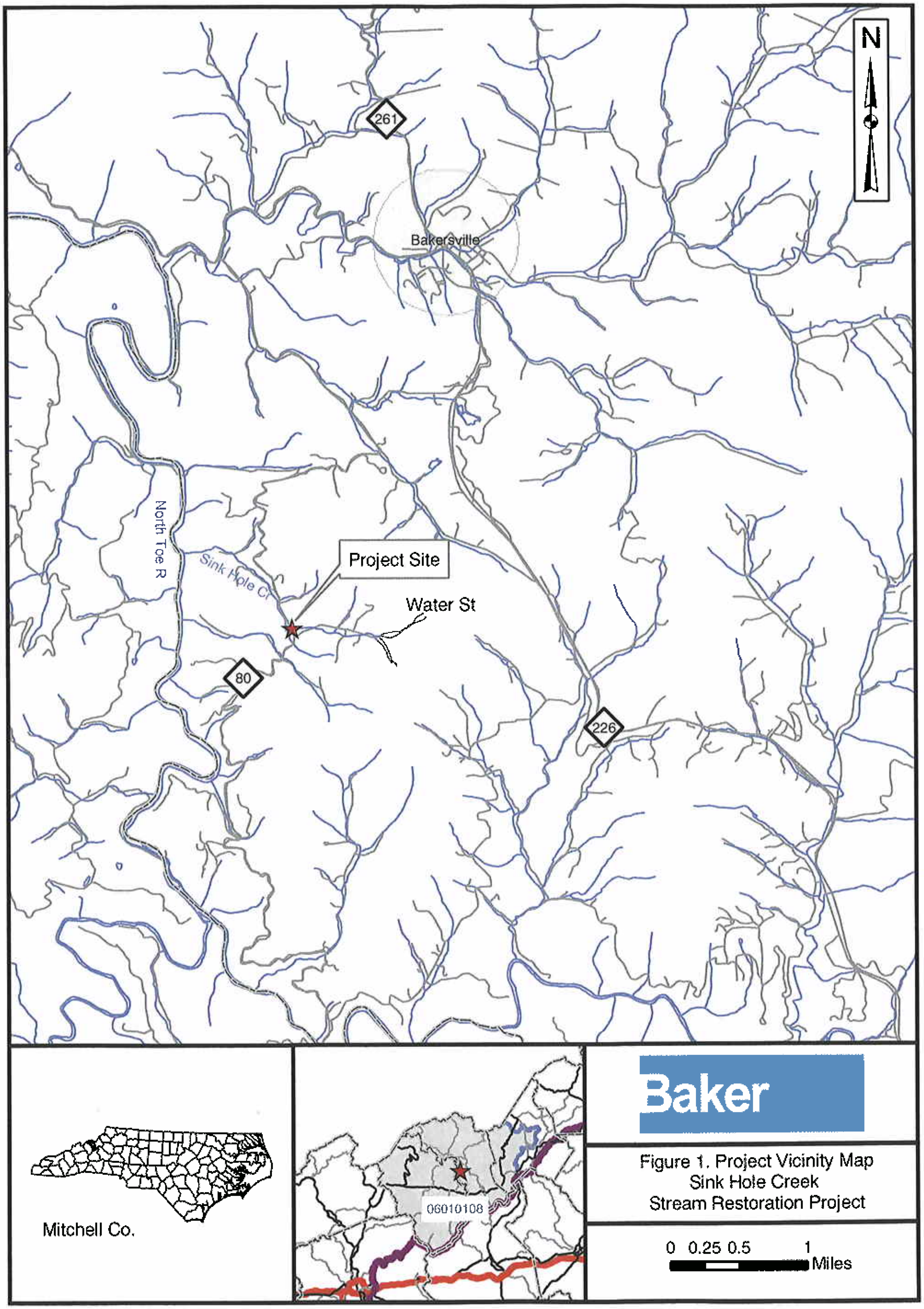
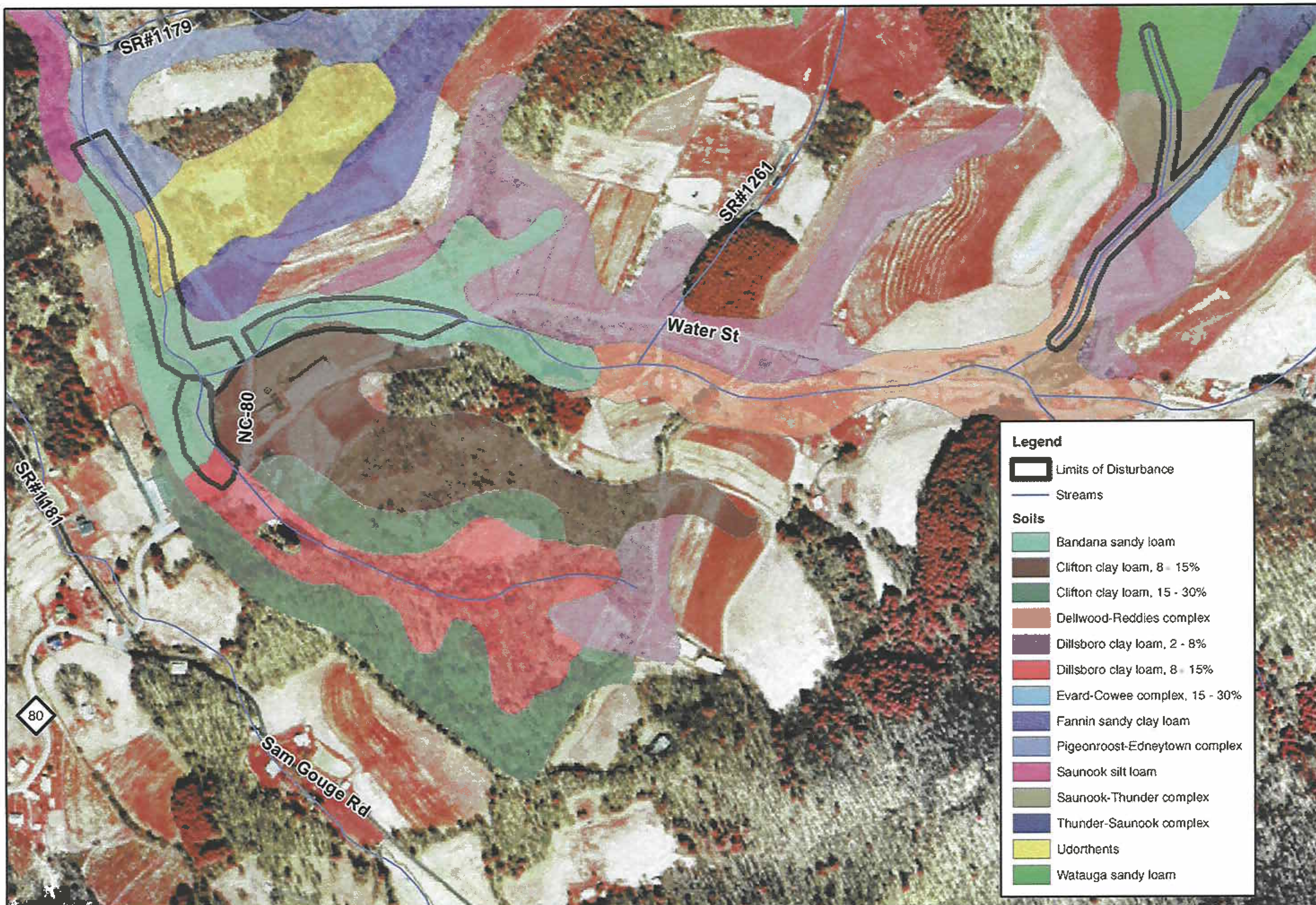


Figure 1. Project Vicinity Map
Sink Hole Creek
Stream Restoration Project



Baker

Soils Map
Sink Hole Creek
Stream Restoration Project
Mitchell County, NC

APPENDIX C. EDR Report

The EDR Radius Map
with GeoCheck®

Sink Hole Creek Restoration Project
Mitchell County
Bakersville, NC 28705

Inquiry Number: 01897517.1r

April 06, 2007

EDR® Environmental Data Resources Inc

The Standard in Environmental Risk Information

440 Wheelers Farms Road
Milford, Connecticut 06461

Nationwide Customer Service

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

TABLE OF CONTENTS

SECTION **PAGE**

GEOCHECK ADDENDUM

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

EXECUTIVE SUMMARY

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

TARGET PROPERTY INFORMATION

ADDRESS

MITCHELL COUNTY
BAKERSVILLE, NC 28705

COORDINATES

Latitude (North):	35.975800 - 35˚ 58' 32.9''
Longitude (West):	82.171300 - 82˚ 10' 16.7''
Universal Tranverse Mercator:	Zone 17
UTM X (Meters):	394396.5
UTM Y (Meters):	3981698.0
Elevation:	2666 ft. above sea level

USGS TOPOGRAPHIC MAP ASSOCIATED WITH TARGET PROPERTY

Target Property Map:	35082-H2 MICAVILLE, NC
Most Recent Revision:	1978

TARGET PROPERTY SEARCH RESULTS

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

DATABASES WITH NO MAPPED SITES

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

FEDERAL RECORDS

NPL	National Priority List
Proposed NPL	Proposed National Priority List Sites
Delisted NPL	National Priority List Deletions
NPL RECOVERY	Federal Superfund Liens
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERC-NFRAP	CERCLIS No Further Remedial Action Planned
CORRACTS	Corrective Action Report
RCRA-TSDF	Resource Conservation and Recovery Act Information
RCRA-LQG	Resource Conservation and Recovery Act Information

EXECUTIVE SUMMARY

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

STATE AND LOCAL RECORDS

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

TRIBAL RECORDS

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

EDR PROPRIETARY RECORDS

Manufactured Gas Plants	EDR Proprietary Manufactured Gas Plants

SURROUNDING SITES: SEARCH RESULTS

Surrounding sites were identified in the following databases.

EXECUTIVE SUMMARY

Elevations have been determined from the USGS Digital Elevation Model and should be evaluated on a relative (not an absolute) basis. Relative elevation information between sites of close proximity should be field verified. Sites with an elevation equal to or higher than the target property have been differentiated below from sites with an elevation lower than the target property.
Page numbers and map identification numbers refer to the EDR Radius Map report where detailed data on individual sites can be reviewed.

Sites listed in ***bold italics*** are in multiple databases.

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

FEDERAL RECORDS

Mines: Mines Master Index File. The source of this database is the Dept. of Labor, Mine Safety and Health Administration.

A review of the MINES list, as provided by EDR, and dated 11/15/2006 has revealed that there is 1 MINES site within approximately 0.75 miles of the target property.

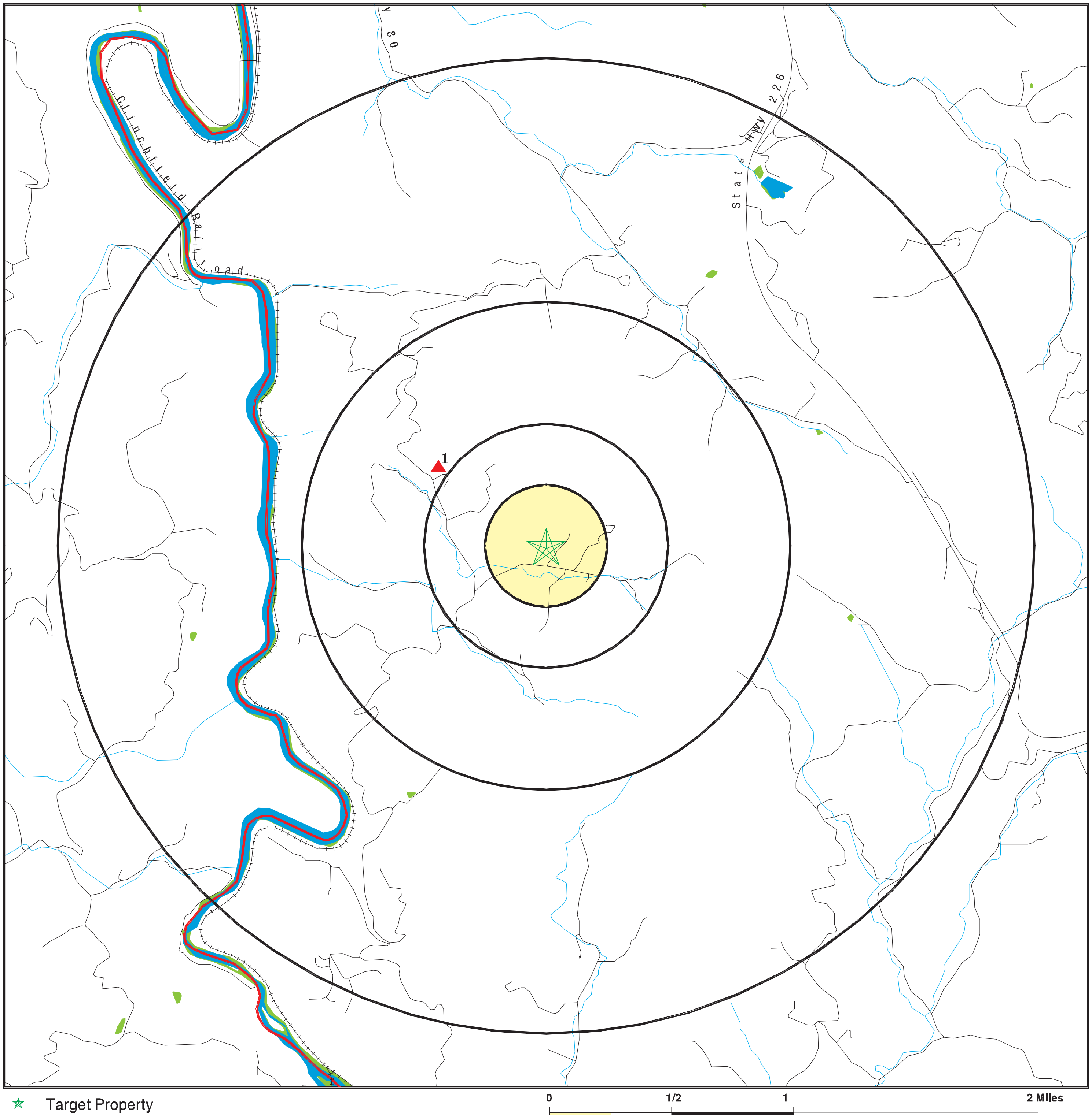
Equal/Higher Elevation	Address	Dist / Dir	Map ID	Page
POWHATAN MINING CO		1/2 - 1 NW	1	6

EXECUTIVE SUMMARY

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

Site Name	Database(s)
GLEN AYRE GROC & HARDWARE	LUST, UST, IMD
ROAN VIEW GROC.	LUST, UST, IMD
BAKERSVILLE TEXACO QUICK MART	LUST, UST, IMD
BOWMAN MIDDLE SCHOOL	LUST, UST, IMD
THOMAS GROCERY	UST
STEVE'S EXXON	UST
MILLER BROTHERS EXXON	UST
LEDGER GROCERY	UST
MITCHELL CO. AMBULANCE SERVIC	UST
WAYNE TIPTON GROCERY	UST
GATEWAY MARKET	UST
HOPSON GRO & SERVICE 23732	UST
MOUNTAINEER TIRE	UST
MITCHELL COUNTY JAIL	UST
SNOW HILL GENERAL STORE	UST
BULADEAU ELEMENTARY SCHOOL	UST
TIPTON HILL ELEMENTARY	UST
BEAR CREEK BAPTIST CHURCH	FINDS
BEAR CREEK CHURCH PARSONAGE	FINDS
CANE CREEK FWB CHURCH	FINDS
SPRING CREEK BAPTIST	FINDS
HENRY BOONE PROPERTY	IMD
MORGAN OIL-BAKERSVILLE	IMD
318 MINE CREEK RD	US CDL

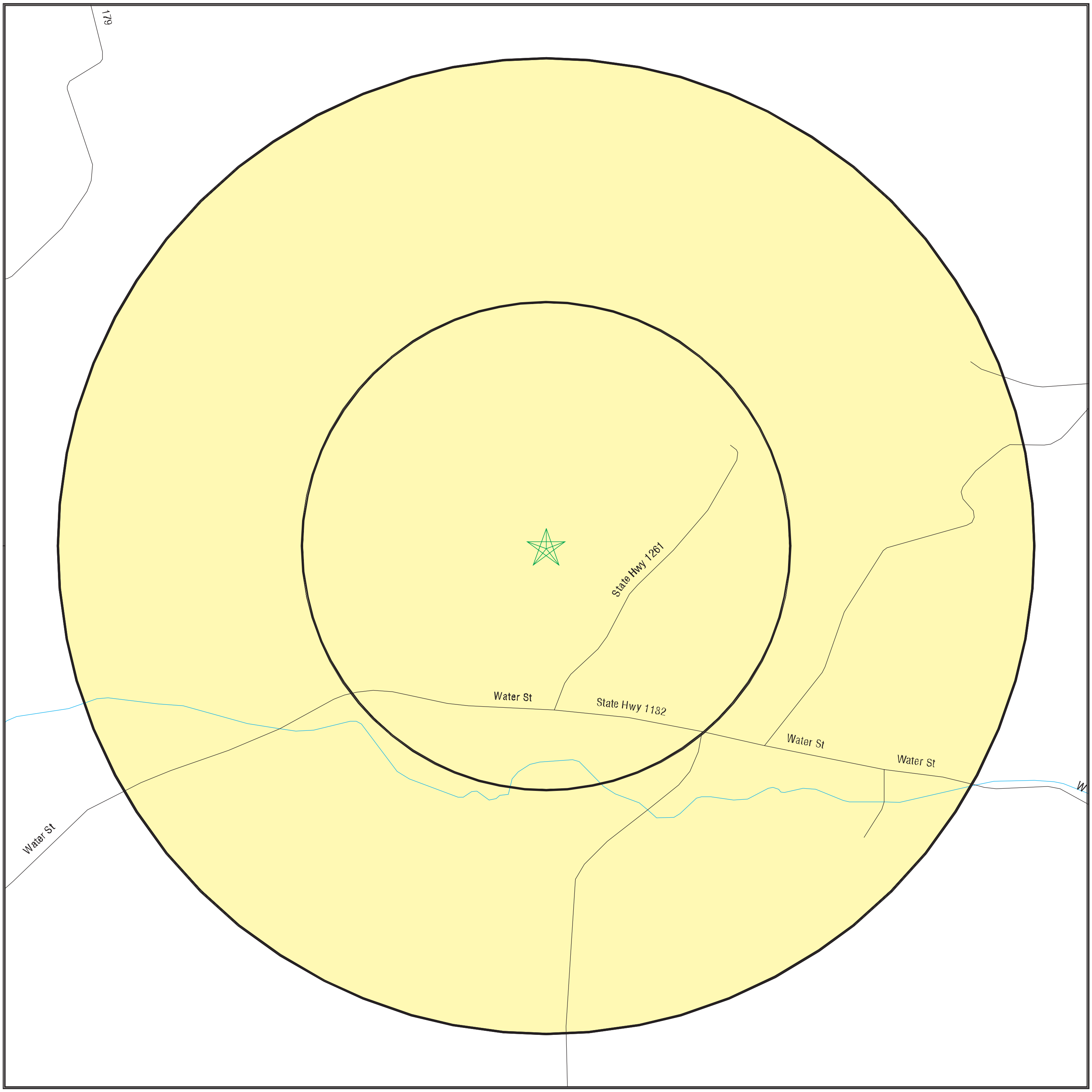
OVERVIEW MAP - 01897517.1r



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

SITE NAME: Sink Hole Creek Restoration Project ADDRESS: Mitchell County Bakersville NC 28705 LAT/LONG: 35.9758 / 82.1713	CLIENT: Buck Engineering CONTACT: Andrea Spangler INQUIRY #: 01897517.1r DATE: April 06, 2007 4:55 pm

DETAIL MAP - 01897517.1r



Target Property

Sites at elevations higher than or equal to the target property

Sites at elevations lower than the target property

Manufactured Gas Plants

Sensitive Receptors

National Priority List Sites

Landfill Sites

Dept. Defense Sites

0 1/16 1/8 1/4 Miles

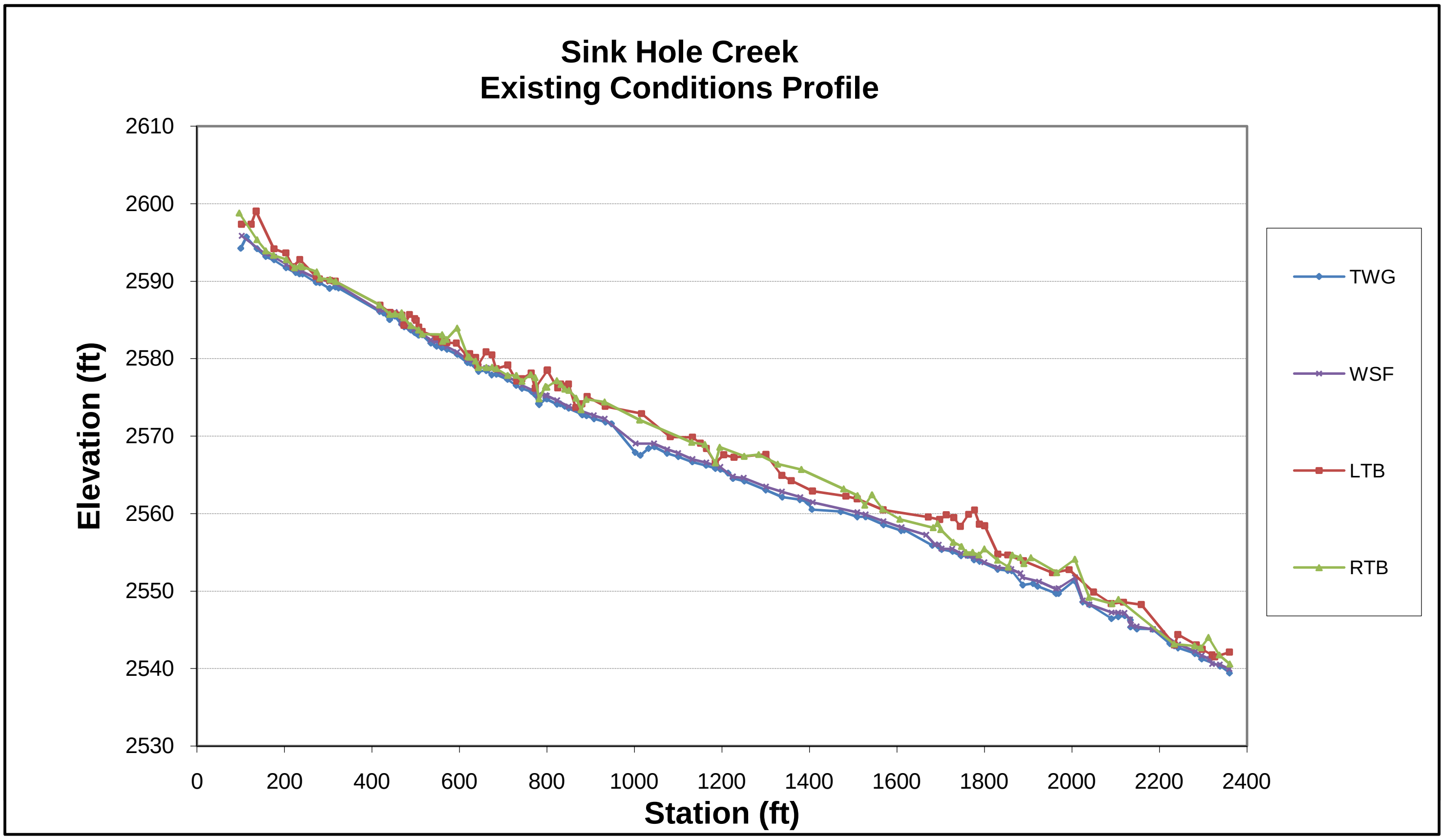
Indian Reservations BIA

Oil & Gas pipelines

Hazardous Substance Disposal Sites

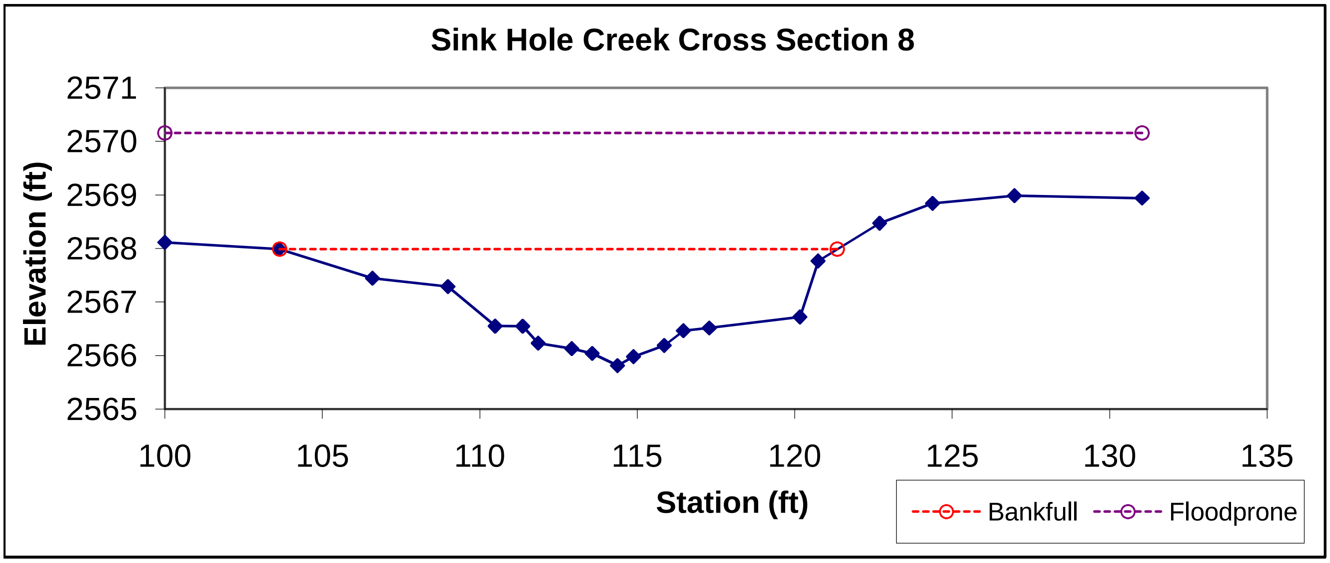
SITE NAME:	Sink Hole Creek Restoration Project	CLIENT:	Buck Engineering
ADDRESS:	Mitchell County	CONTACT:	Andrea Spangler
	Bakersville NC 28705	INQUIRY #:	01897517.1r
LAT/LONG:	35.9758 / 82.1713	DATE:	April 06, 2007 4:55 pm

APPENDIX D. Existing Conditions Geomorphic Data

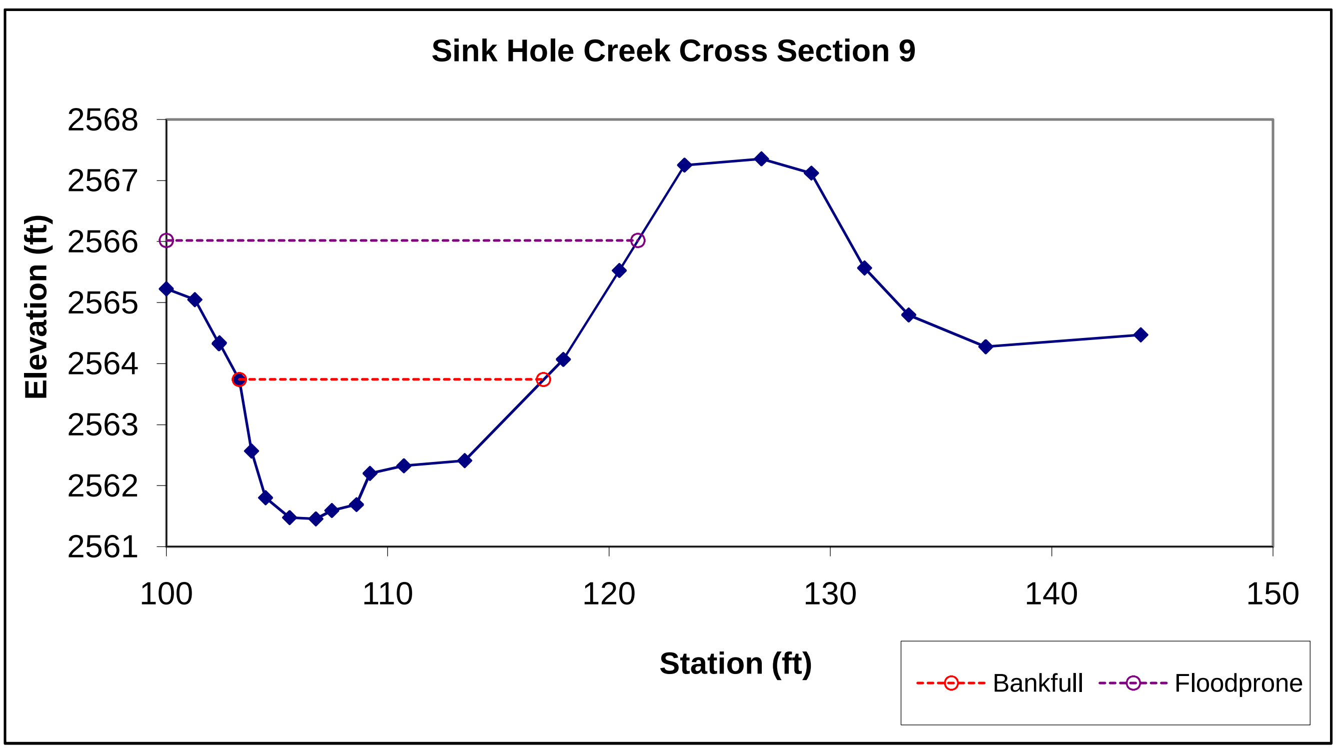


Sink Hole Creek
Existing Conditions Profile
Elevation (ft)
Station (ft)
2610
2600
2590
2580
2570
2560
2550
2540
2530
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
TWG
WSF
LTB
RTB

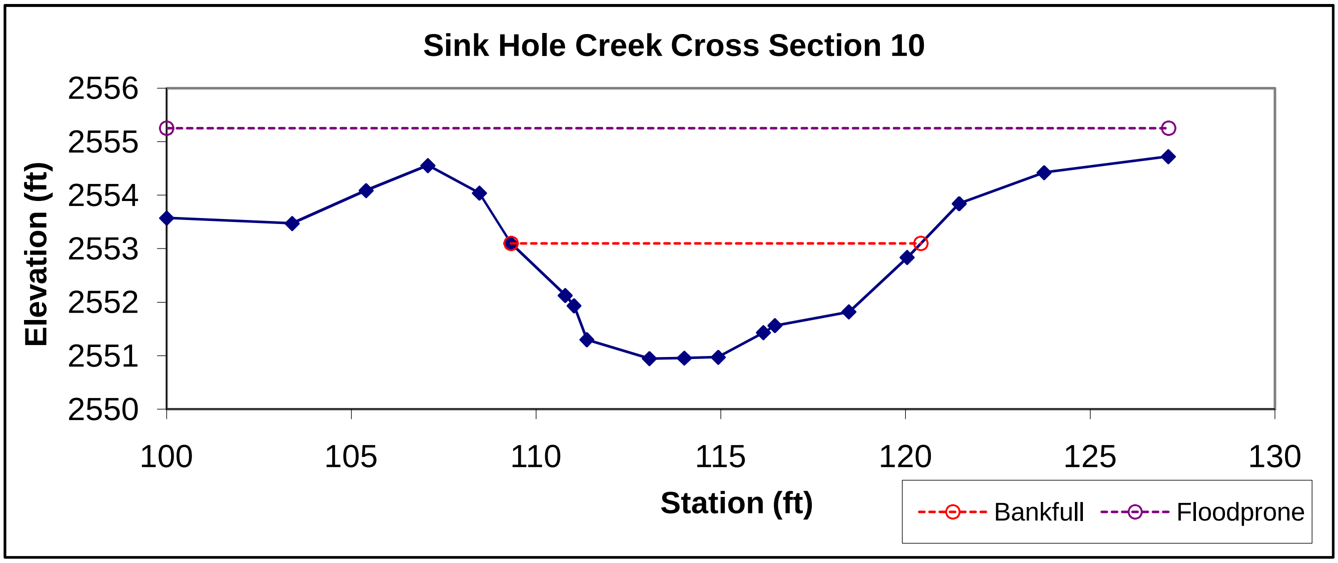
Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	20.3	17.71	1.15	2.18	15.42	1	1.8	2567.99	2567.99



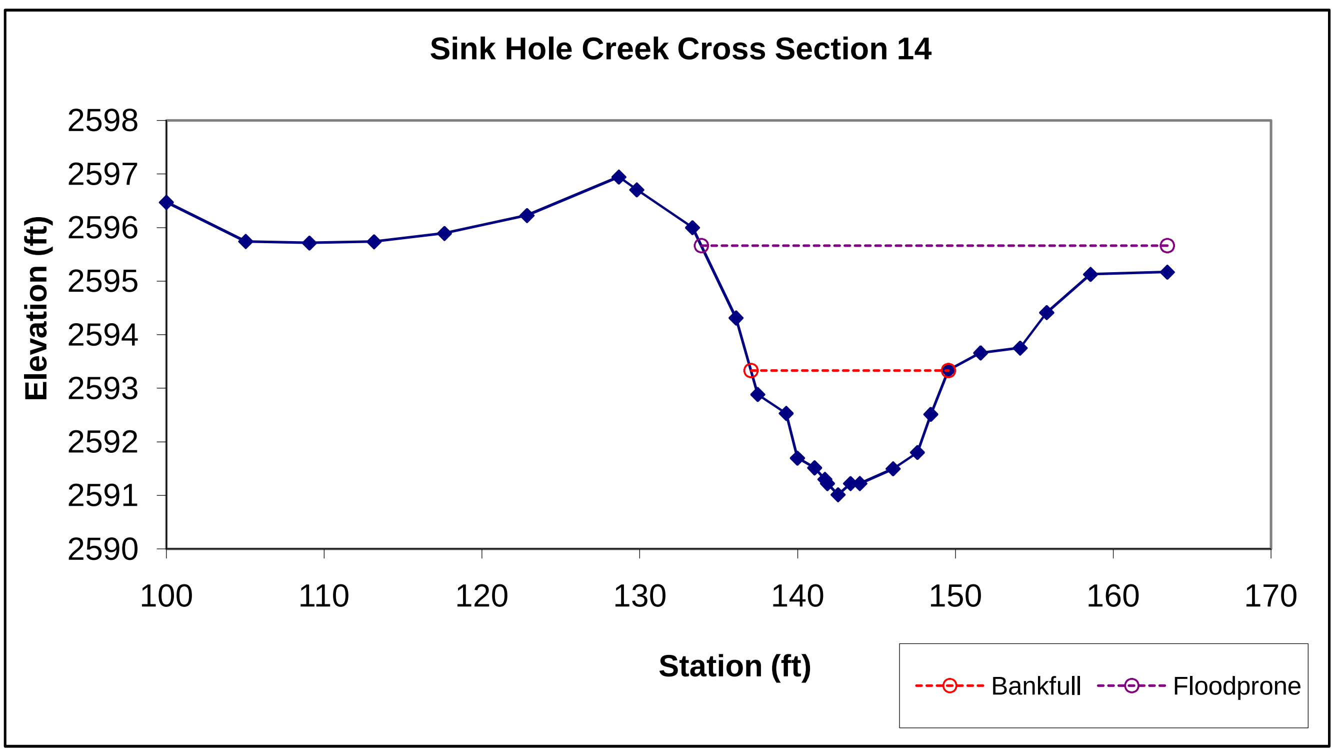
Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	19.7	13.76	1.43	2.28	9.6	1.6	1.5	2563.74	2565.05

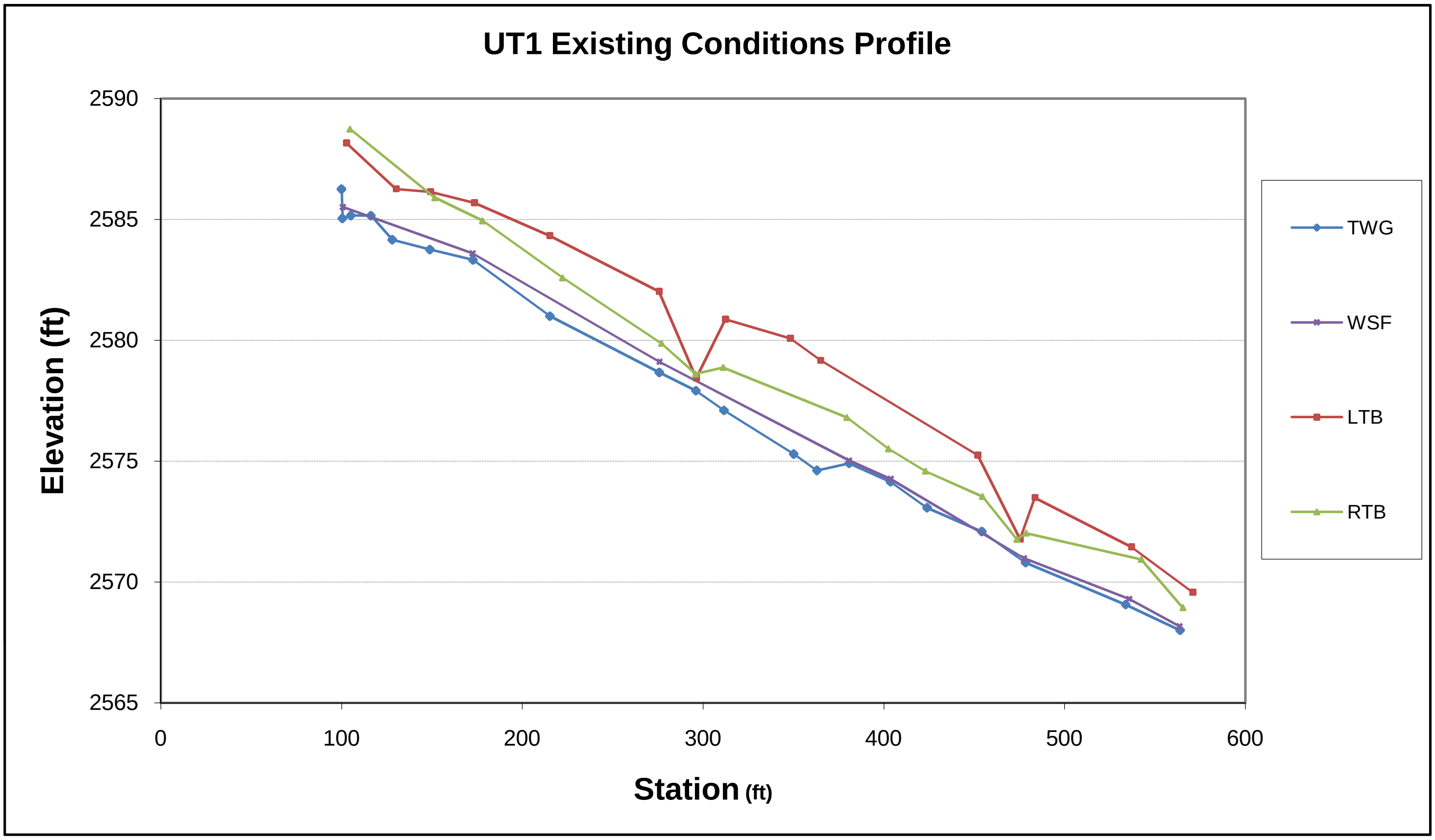


Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	15.7	11.1	1.42	2.15	7.83	1.6	2.4	2553.1	2554.42

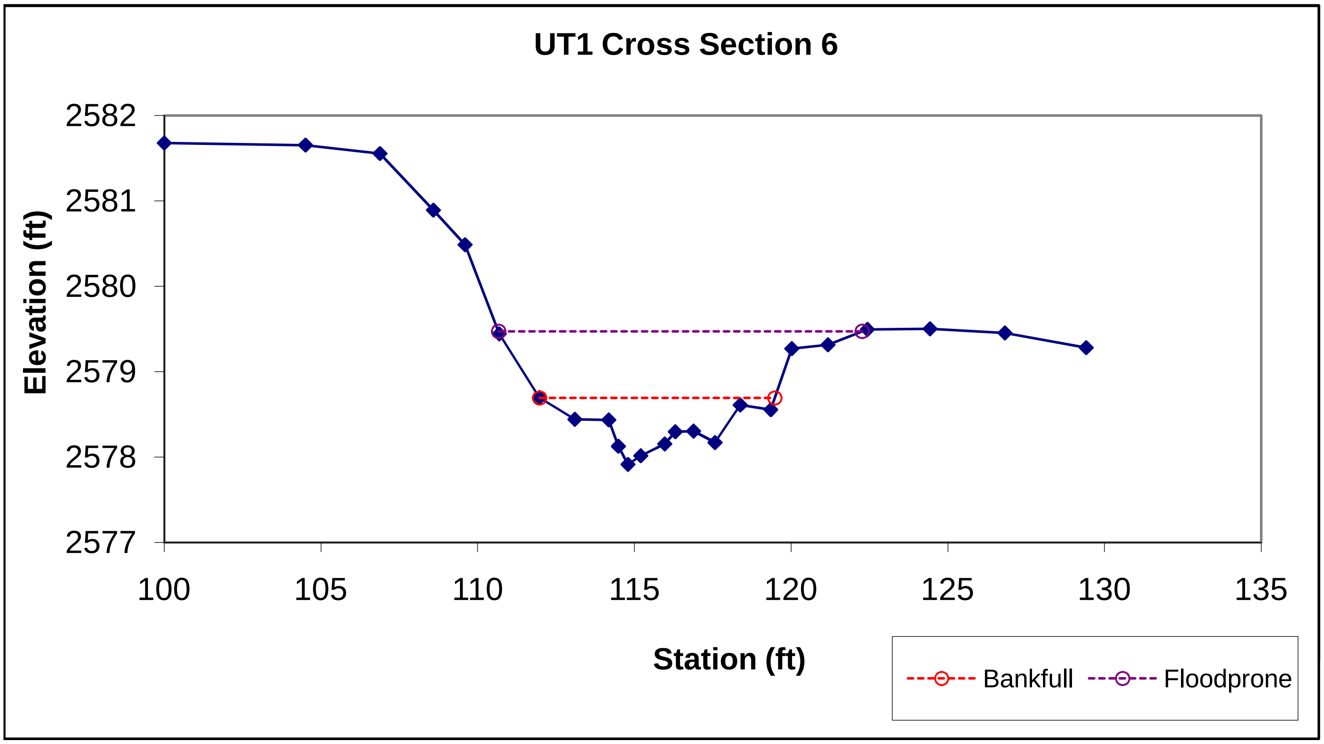


Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	18.3	12.52	1.46	2.32	8.57	1.8	2.4	2593.33	2595.13

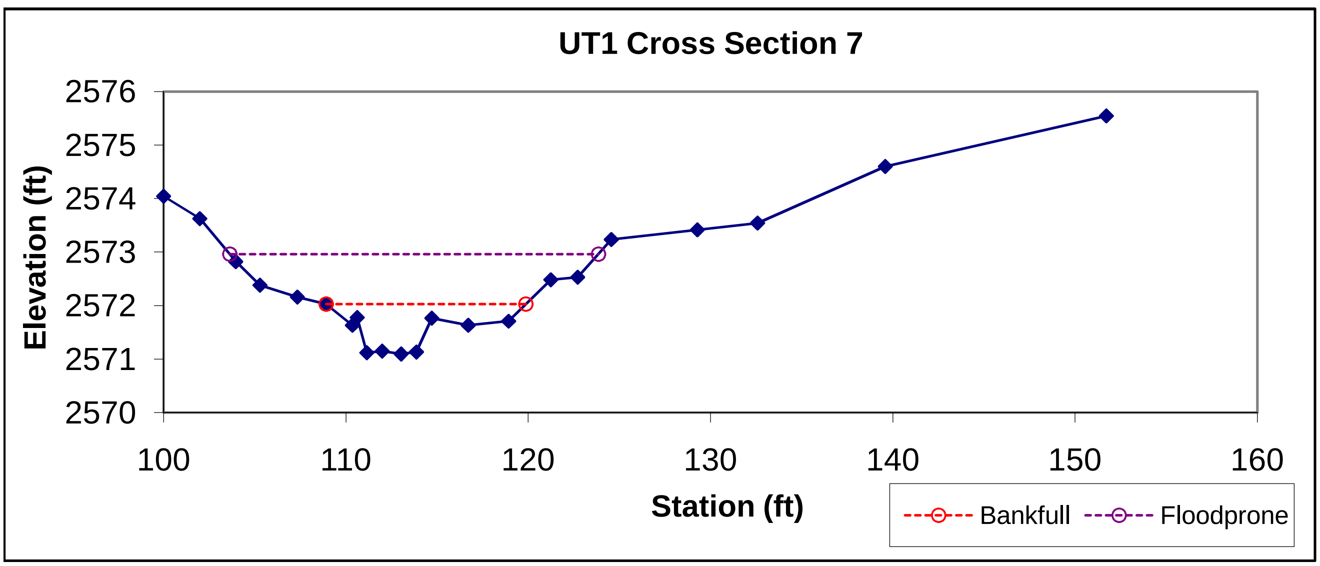


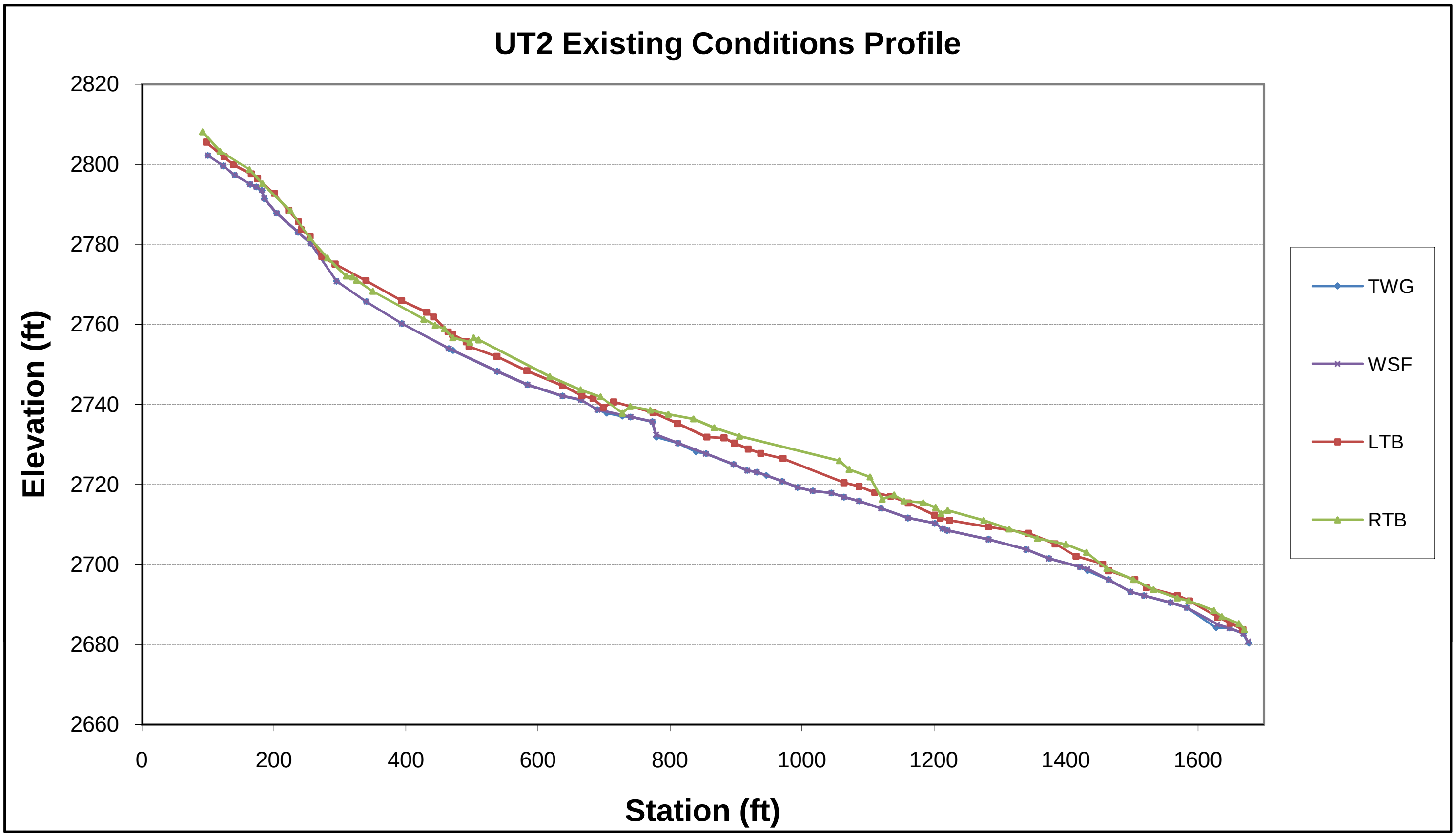

UT1 Existing Conditions Profile
Elevation (ft)
2590
2585
2580
2575
2570
2565
0
100
200
300
400
500
600
Station (ft)
TWG
WSF
LTB
RTB

Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	2.6	7.5	0.34	0.78	21.89	2.0	1.5	2578.69	2579.44

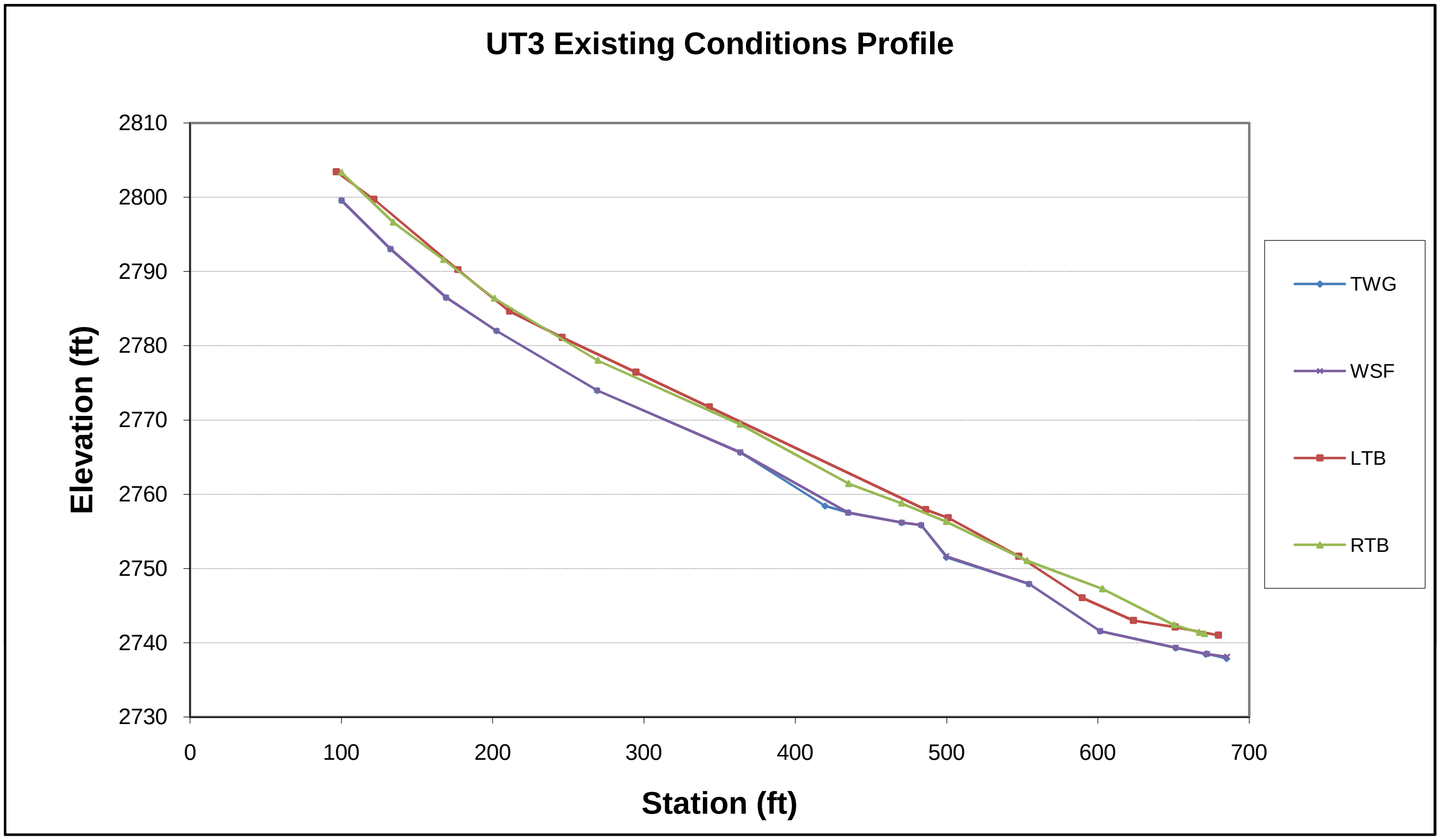


Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	5.2	10.96	0.48	0.93	23	2.3	1.8	2572.03	2573.23



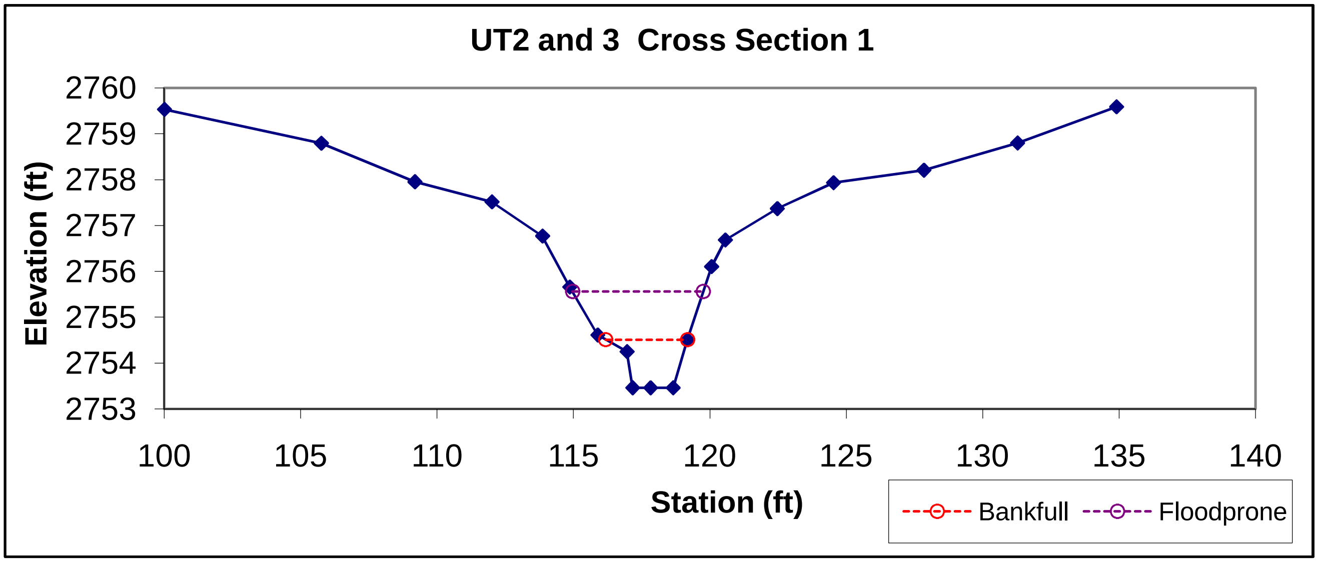


UT2 Existing Conditions Profile
2820
2800
2780
2760
2740
2720
2700
2680
2660
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
Station (ft)
TWG
WSF
LTB
RTB

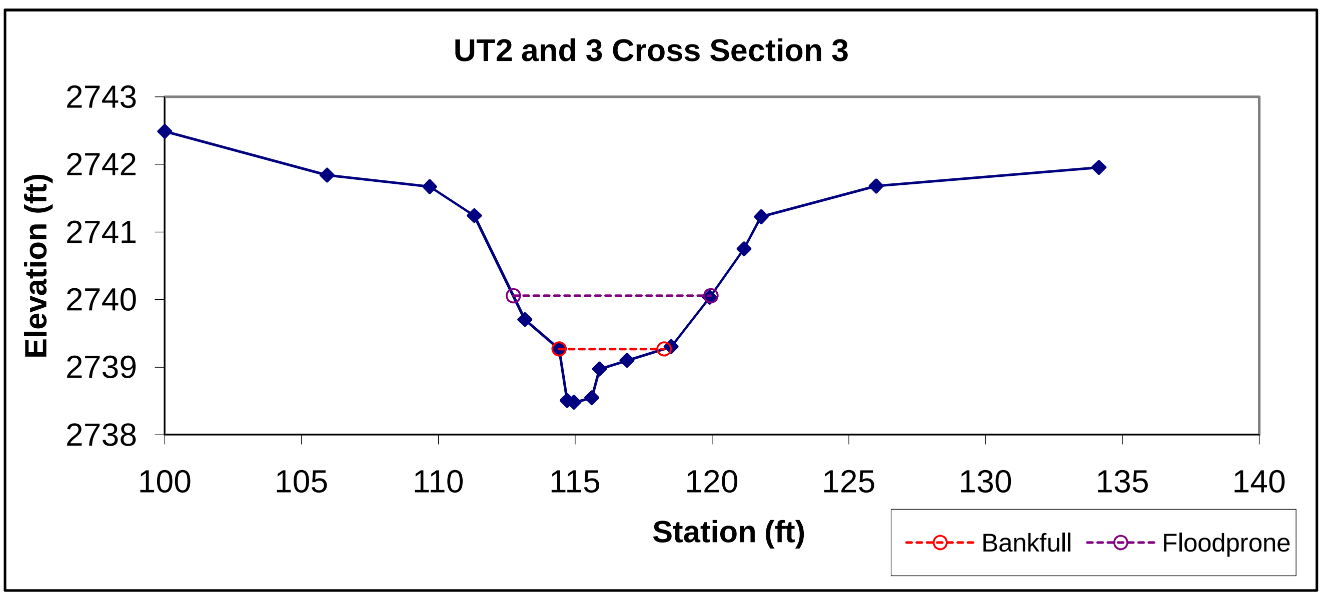


UT3 Existing Conditions Profile
Elevation (ft)
2810
2800
2790
2780
2770
2760
2750
2740
2730
0
100
200
300
400
500
600
700
Station (ft)
TWG
WSF
LTB
RTB

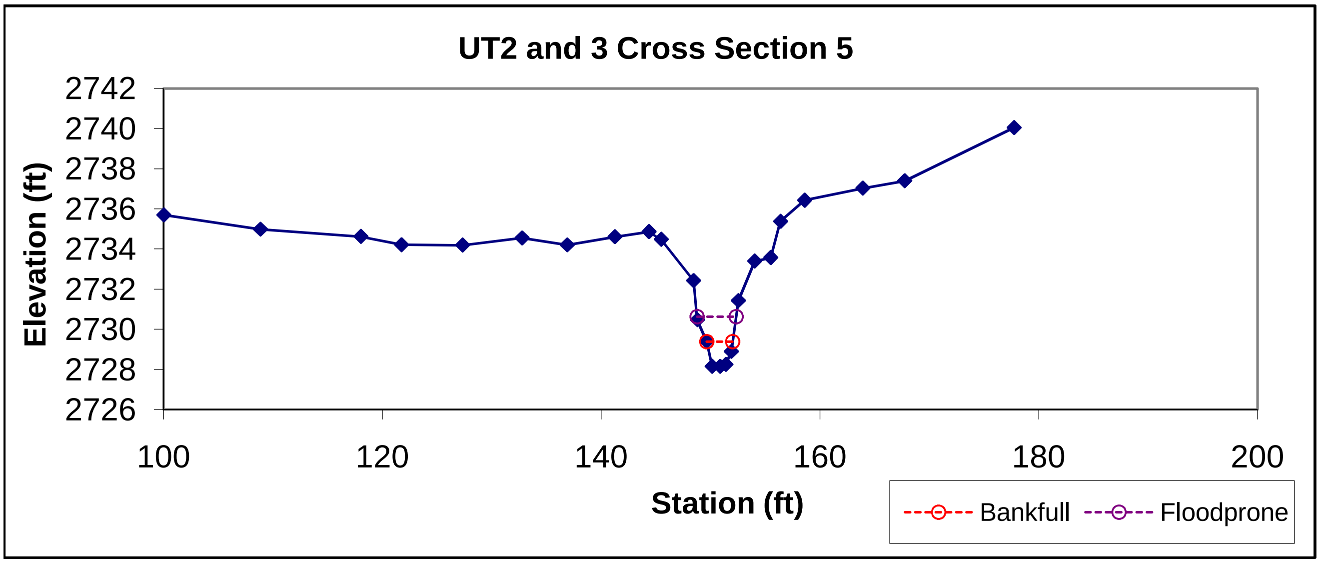
Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	2.1	2.99	0.69	1.05	4.33	3.1	1.6	2754.51	2756.68



Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	1.3	3.83	0.34	0.79	11.39	3.5	1.9	2739.27	2741.23



Feature	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	2.3	2.38	0.95	1.24	2.5	4.2	1.5	2729.39	2733.4



APPENDIX E. Existing Conditions Photo Log

Sink Hole Creek Reach 1

Upstream end of Sink Hole Reach 1 showing bank trampling by cattle and shearing

Sink Hole Creek Reach 1 berm formed by dredge spoils

Cast dredge spoils present on the banks of Sink Hole Creek Reach 1

Overly wide and aggradating section of Sink Hole Creek Reach 1 Downstream of Hwy 80

Sink Hole Creek Reach 1 channelized section through pasteur

Overwide section with bank trampling on Reach 1 of Sink Hole Creek

Sink Hole Creek Reach 2

Berm formed by dredge spoils on right bank of Sink Hole Creek Reach 2

Cattle have direct access to Sink Hole Creek Reach 2 along Hwy 80

Stream banks trampled by cattle on Sink Hole Creek Reach 2

Sink Hole Creek Reach 2 pushed against valley wall

Berm formed by dredge spoils on right bank of Sink Hole Creek Reach 2

Over widened and cattle trampled section of Sink Hole Creek Reach 2

Sink Hole Creek UT1 Preservation Reach

UT1 Preservation Reach flowing through forested area

UT1 Preservation Reach channel

Representative conditions on UT 1 Preservation Reach

UT1 Preservation Reach channel

UT1 Preservation Reach flowing through forested area

Sink Hole Creek UT1 Reach 2

Widening and aggradation on UT1 Reach 2 immediately below Hwy 80

UT1 Reach 2 trampled by cattle and pushed against hill slope

Stream banks are trampled by cattle, eroding, and lack woody vegetation along UT1 Reach 2

UT1 Reach 2 has been pushed against the hillslope as shown in the top of the photo

UT1 Reach 2 impacted by cattle and pushed against hill slope

Banks trampled by cattle along UT1 Reach 2

Sink Hole Creek UT2

Looking downstream at UT2 cattle impacts

Looking downstream at bank failure and incision on UT2

UT2 looking downstream from spring

UT2 looking upstream at end of reach

Cattle impacts on UT2

Headcut on UT2

Sink Hole Creek UT3

Pipe to be removed with incision and headcut on UT3

Lack of woody vegetation and cattle impacts causing bank failure on UT3

Incision on UT3