Logan Creek Stream Restoration Plan
Jackson County, North Carolina
EEP No. D06046-A

Prepared For

North Carolina Ecosystem Enhancement Program
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Logan Creek Stream Restoration Plan - Draft
Jackson County, North Carolina

Report Prepared and Submitted by Baker Engineering NY, Inc.

Baker

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EXECUTIVE SUMMARY

Baker Engineering NY, Inc. (Baker) proposes to restore, enhance, and preserve nearly 8,131 linear feet (LF) of stream along Logan Creek. In addition, 1.71 acres of existing wetlands will be preserved within the easements that will be established; no mitigation credit will be sought for protecting these wetlands. The project site is located in Jackson County, approximately three miles east of Cashiers. The project site is on property owned by the Lonesome Valley Company, Inc. and was previously held by a single family for many years. The lands along the stream and in the surrounding area were logged 60 to 80 years ago. Since that time various agricultural enterprises were conducted, including an apple orchard, trout farming, mink farming and livestock grazing; however, most of the land has been maintained as a forest. Cow Rock and Laurel Knob are sheer granite cliffs that create a box canyon that surrounds this property. The present landowners are actively developing the property as an exclusive, "environmentally friendly", low density residential development.

Logan Creek is a low gradient, gravel bed stream that supports a good trout population. Logan Creek is within the Savannah River Watershed and is also within the N. C. Ecosystem Enhancement Program (EEP) targeted local watershed 10020, the Horsepasture River basin. There are sections of Logan Creek that are highly sinuous and other reaches that appear to have been straightened in the past. The channel is eroding its banks in many locations where woody vegetation has been removed and a grass field developed. There are other areas where dense stands of rhododendron have shaded out deep rooted tree species producing unstable, eroding banks and an over-wide condition. In stream habitat is primarily composed of woody debris and a few scattered bedrock outcroppings.

The goals for the restoration project are as follows:

- Create geomorphically stable conditions on the Logan Creek project site.
- Protect stable, well vegetated reaches of six tributaries to Logan Creek.
- Improve the water quality in the Logan Creek watershed.
- Improve aquatic and terrestrial habitat along the project corridor.

To accomplish these goals, we are proposing to do the following:

- Restore the existing eroding or over-wide stream reaches by creating a stable channel with access to the floodplain.
- Preserve well-functioning tributaries.
- Improve in-stream habitat by providing a more diverse bedform with riffles and pools, creating deeper pools, providing woody debris for habitat, and reducing bank erosion.
- Establish native stream bank and floodplain vegetation to increase storm water runoff filtering capacity, improve bank stability, provide shading to decrease water temperature, provide cover, improve wildlife habitat and protect this area with a permanent conservation easement.
- Improve terrestrial habitat by increasing the density of tree species that root deeply, by thinning the thick stands of rhododendron within the easement area and planting a more diverse native plant community.

Table ES.1 Logan Creek Restoration Overview			
Project Feature	**Existing Condition (Linear Feet or Acres)**	**Design Condition (Linear Feet or Acres)**	**Approach**
Logan Creek reach 1	450	450	Enhancement I
Logan Creek reach 2	3,445	3,140	Restoration
Logan Creek reach 3	1,000	1,000	Enhancement I
Logan Creek (upstream of reach 1)	1,510	1,510	Preservation
UT1	65	65	Preservation
UT2	170	170	Preservation
UT3	305	305	Preservation
UT4	300	382	Preservation/Restoration
UT5	975	975	Preservation
Wetlands	1.71	1.71	Preservation

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1.0 PROJECT SITE IDENTIFICATION AND LOCATION

1.1 Brief Project Description and Location

Baker proposes to restore, enhance, and preserve 8,131 linear feet (LF) of stream along Logan Creek and five of its tributaries, in Jackson County, North Carolina. Included within the easement area to be preserved are nine wetland areas totaling 1.71 acres.

The Logan Creek restoration site is located approximately three miles northeast of Cashiers in Jackson County, North Carolina, as shown on Figure 1.1. The project site extends south from the confluence of Logan Creek and an unnamed tributary downstream to immediately upstream of a culvert at US 64. Stream names used in this report follow those used by the Division of Water Quality; however, locally Logan Creek is known as West Fork Logan Creek and Right Prong Logan Creek is known only as Logan Creek. The site is accessible from US 64 at the Lonesome Valley Company, Inc. development.

The Logan Creek watershed lies in the Savannah River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-13-02 and USGS hydrologic unit 03060101010020.

The recent land use of the site has been open hay fields and forestry. Historically, the site was used for pasture, timbering, trout farming and as a mink farm. Past land uses created conditions that today are causing the degradation of on-site streams.

Logan Creek through the project site is a "blue-line" stream, as shown on the USGS topographic quadrangle for the site. Based on field evaluations using NCDWQ stream assessment protocols, all of the stream channels proposed for restoration, enhancement, or preservation are perennial as shown in Appendix A.

2.0 WATERSHED CHARACTERIZATION

2.1 Watershed Delineation

The Logan Creek site is located in the Savannah River Basin as illustrated in Figure 1.1. The project reach watershed is delineated on Figure 2.1. The total drainage area for the entire project reach is 2.67 square miles at the downstream end. The project begins at the confluence of Logan Creek, which has a drainage area of 1.08 square miles, and Right Prong Logan Creek which has a drainage area of 1.0 square mile.

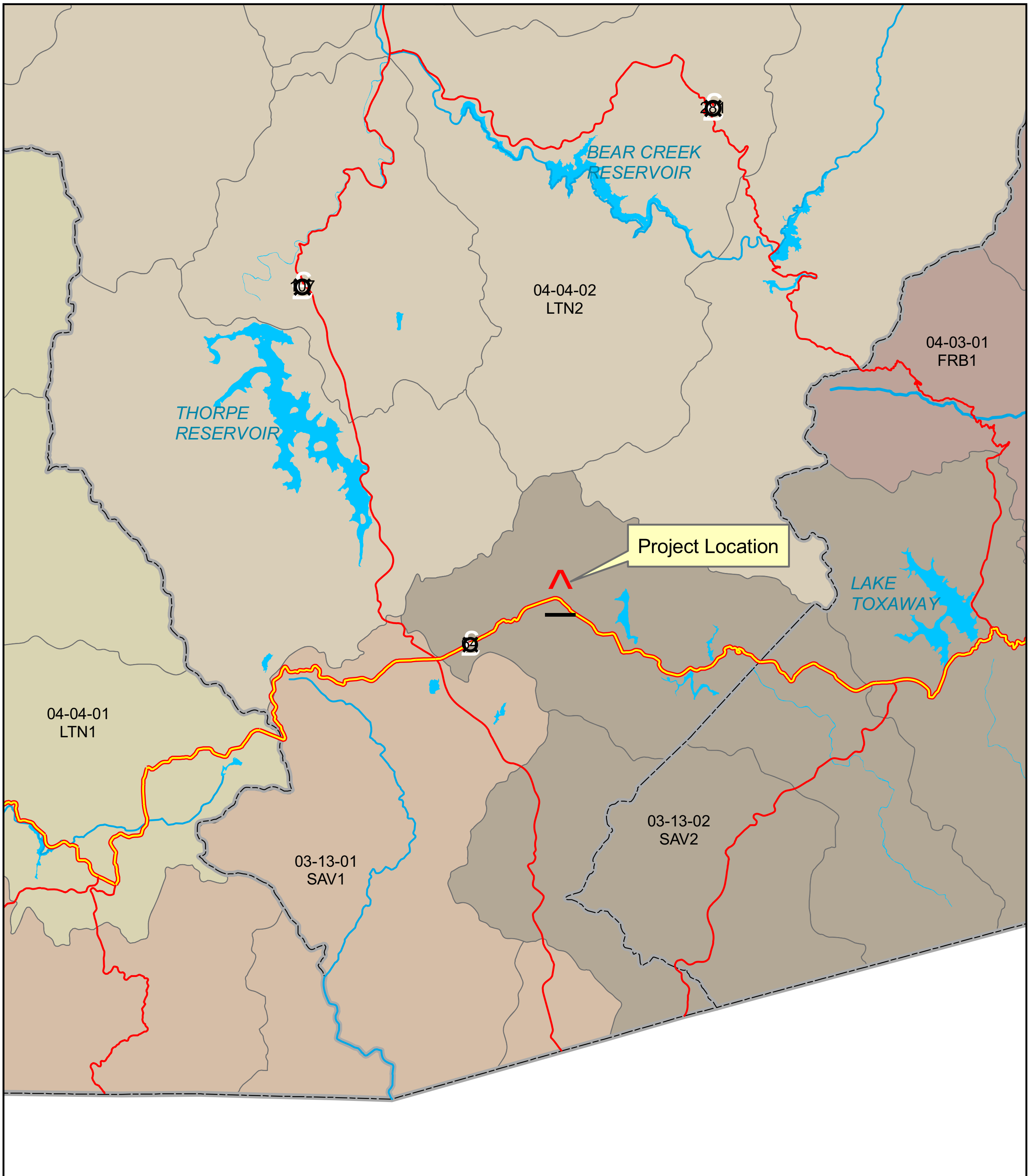
2.2 Surface Water Classification/ Water Quality

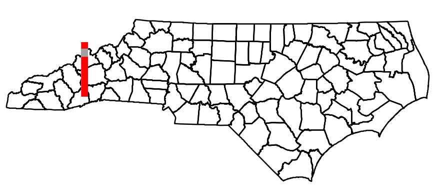
NCDWQ designates surface water classifications for water bodies such as streams, rivers, and lakes. Classifications define the best uses for these waters (e.g., swimming, fishing, and drinking water supply). These classifications are associated with a set of water quality standards to protect their uses. All surface waters in North Carolina must at least meet the standards for Class C (fishable/swimmable) waters. Other primary 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. Logan Creek [NCDWQ Index No. 3-13-2] has the primary classification Class C water and the supplemental classifications of Tr for trout waters and HQW for high quality waters. 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. The HQW supplemental classification is intended to preserve a high level of existing water quality that exceeds state water quality standards. There are both wastewater treatment standards and development controls enforced by NCDWQ on these streams. Logan Creek carries the HQW designation because it is a tributary to the Horsepasture River which is designated as HQW.

2.3 Physiography, Geology and Soils

The project site lies within the Blue Ridge Belt of the Blue Ridge physiographic province of western North Carolina. According to the 1985 North Carolina Geological Survey Map and a 1 degree by 2 degree geologic map of the Knoxville Quadrangle prepared by the USGS (Hadley, and Nelson, 1971, Map I-654), the project site is underlain by an intrusive igneous formation of quartz diorite and grandiorite that are middle Paleozoic Era, late Devonian in age. This rock unit is described as gray or white, medium to coarse-grained, generally foliated rock composed dominantly of plagioclase feldspars, muscovite, biotite, quartz, hornblende, plagioclase feldspars and xenocrysts.

This rock unit along with other rock types of the geographic area (amphibolite and biotite gneiss), weather to form clay-rich saprolite, generally a soft, friable material that often contains relict structures and mineral assemblages from the parent rock material. Due to faster weathering rates on rock in topographically low areas and increased erosion rates in topographically high areas, saprolite in the area tends to be thickest in valley and small coves around Cashiers and thins out as the topography rises to hilltops and ridges. Additional soil characteristics of the site were determined using the Natural Resources Conservation Service (NRCS) Soil Survey data for Jackson County, along with preliminary on-site evaluations to determine any hydric soil areas (USDA 1975). A map depicting the boundaries of each soil type is presented in Figure 2.2. There are four general soil types found within the project boundaries. A discussion of each soil type and its locations given by the NRCS is presented in Table 2.1. Table 2.2 identifies characteristics of each soil series located on the project site and will be referenced in conjunction with the soils descriptions to select appropriate seeding mixes and other vegetative cover.





Counties
NCDWQ Sub-basin
USGS Hydrologic Unit

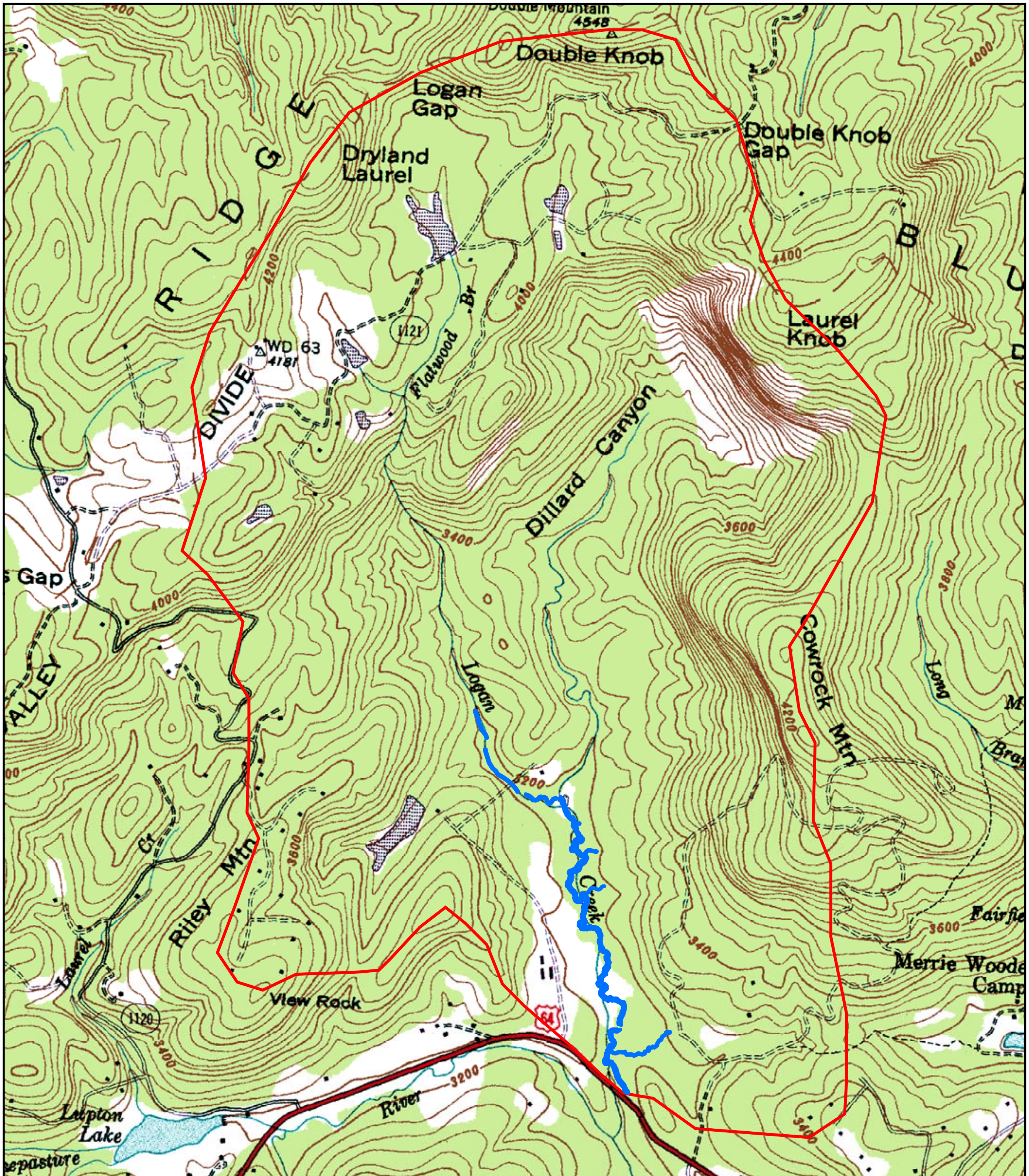
0 1 2 3 Miles

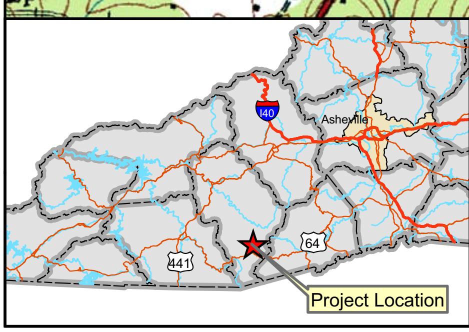
Fig 1.1 Project Location Map

Logan Creek Stream Restoration

Ecosystem Enhancement Program

Baker





Legend

- Existing Alignment
- Watershed Boundary

0 1,000 2,000 Feet

N

Fig 2.1 Watershed Basin Map

Logan Creek Stream Restoration

Soils within the proposed stream restoration areas are primarily mapped as the Nikwasi series by the NRCS in Jackson County. The Nikwasi fine sandy loam is found along the floodplain of Logan Creek and the lower ends of the tributary valleys. The Whiteside-Tuckasegee complex is mapped along the upland Logan Creek Valley, upstream of the proposed restoration reach. The steep slopes along the edges of the downstream Logan Creek valley, just upstream of US 64, are mapped as the Saunook gravelly loam. Soils along the UT5 valley are mapped as Cullowhee fine sandy loam. Bedrock was observed in a few isolated locations in the Logan Creek bed, and numerous outcroppings are visible along the valley walls. Generally, the depth to bedrock appears to be at least three feet in the Logan Creek floodplain. In areas where shallow bedrock is encountered, the restoration plan will incorporate this bedrock as in-situ grade control.

Table 2.1
Project Soil Types and Descriptions

Soil Name	Location	Description
Nikwasi	Floodplain	The Nikwasi series consists of poorly drained and very poorly drained, moderately rapidly permeable soils on flood plains in the Blue Ridge (MLRA 130). These soils formed in recent alluvium consisting of loamy material that is moderately deep to strata of sand, gravel, and/or cobbles. Slope ranges from 0 to 3 percent.
Whiteside-Tuckasegee	Upland valley	The Whiteside series consists of very deep, moderately well drained, moderately permeable soils on colluvial toe slopes, benches, and fans in coves in the Southern Appalachian Mountains. These soils formed in colluvium and alluvium derived from materials weathered from felsic to mafic crystalline rocks such as granite, mica gneiss, and hornblende gneiss. The Tuckasegee series consists of very deep, well drained soils on gently sloping to very steep benches, foot slopes, toe slopes, drainageways, and fans in coves in the Southern Appalachian Mountains. These soils formed in colluvium derived from materials weathered from igneous and metamorphic crystalline rocks such as granite, mica gneiss, hornblende gneiss, and schist.
Saunook		The Saunook series consists of very deep, well drained, moderately permeable soils on benches, fans, and toe slopes in coves in the Blue Ridge (MLRA 130). They formed in colluvium derived from materials weathered from felsic to mafic, igneous and high-grade metamorphic rocks. Slope ranges from 2 to 60 percent.
Cullowhee	Valley	The Cullowhee series consists of somewhat poorly drained, moderately rapidly permeable soils on flood plains in the Southern Appalachian Mountains. They formed in recent alluvium that is loamy in the upper part and is moderately deep to sandy strata that contain more than 35 percent by volume rock fragments. They are very deep to bedrock. Slope ranges from 0 to 3 percent.

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

Table 2.2 Project Soil Type Characteristics					
Series	**Max Depth (in)**	**% Clay on Surface**	**Erosion Factor K**	**Erosion Factor T**	**OM %**
Nikwasi Fine (NkA)	30"	11.50	0.20	4	10.00
Whiteside-Tuckasegee Complex (WtB)	>60"	16.00	0.24	5	9.50
Saunook Gravelly Loam (SaC)	> 60"	13.50	0.24	5	6.50
Cullowhee Fine (CwA)	40"	11.50	0.20	3	6.50
Source: **NRCS, USDA. Official Soil Series Descriptions** (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx) (http://soildatamart.nrcs.usda.gov/Default.aspx)					

2.4 Historic Land Use and Development Trends

Except for low density residential development and portions of land in agricultural use, the Logan Creek watershed is primarily forested. Less than 10% of land in the Logan Creek drainage is in development while approximately 87% remains forested as shown in Table 2.3. The Logan Creek drainage has experienced varying degrees of agricultural and aquaculture development for the past 60 to 80 years. The Logan Creek watershed was logged in the 1920's to 1940's as much of the southern Appalachians were at the time. Since then, portions of the project area have supported apple orchards and livestock as well as a trout hatchery and mink farm. Currently the project site is being developed as an eco-friendly development. This includes large lots and a significant amount of green-space. The developers are maintaining a 25 foot buffer on all streams outside of those included in this project.

Table 2.3 Logan Creek Watershed Land Use/ Land Cover		
Land Use Category[1]	**Area (acres)**	**Percent Area**
Streams/Wetlands	6.23	<1% (.40)
Low Density Residential	40.26	2.4%
High Density Residential	.92	<1% (.05)
Bare Rock/Sand/Clay	32.02	1.9%
Pasture Lands	78.46	4.6%
Grasslands	12.78	<1% (.80)
Forested:		
Deciduous Forest	1293.77	76%
Evergreen Forest	135.36	8%
Mixed Forest	39.99	2.4%
Shrub/Scrub	57.55	3.4%
Note: 1. The above was gathered from 2001 U.S. Geological Survey land cover data. *Source: http://seamless.usgs.gov/*		

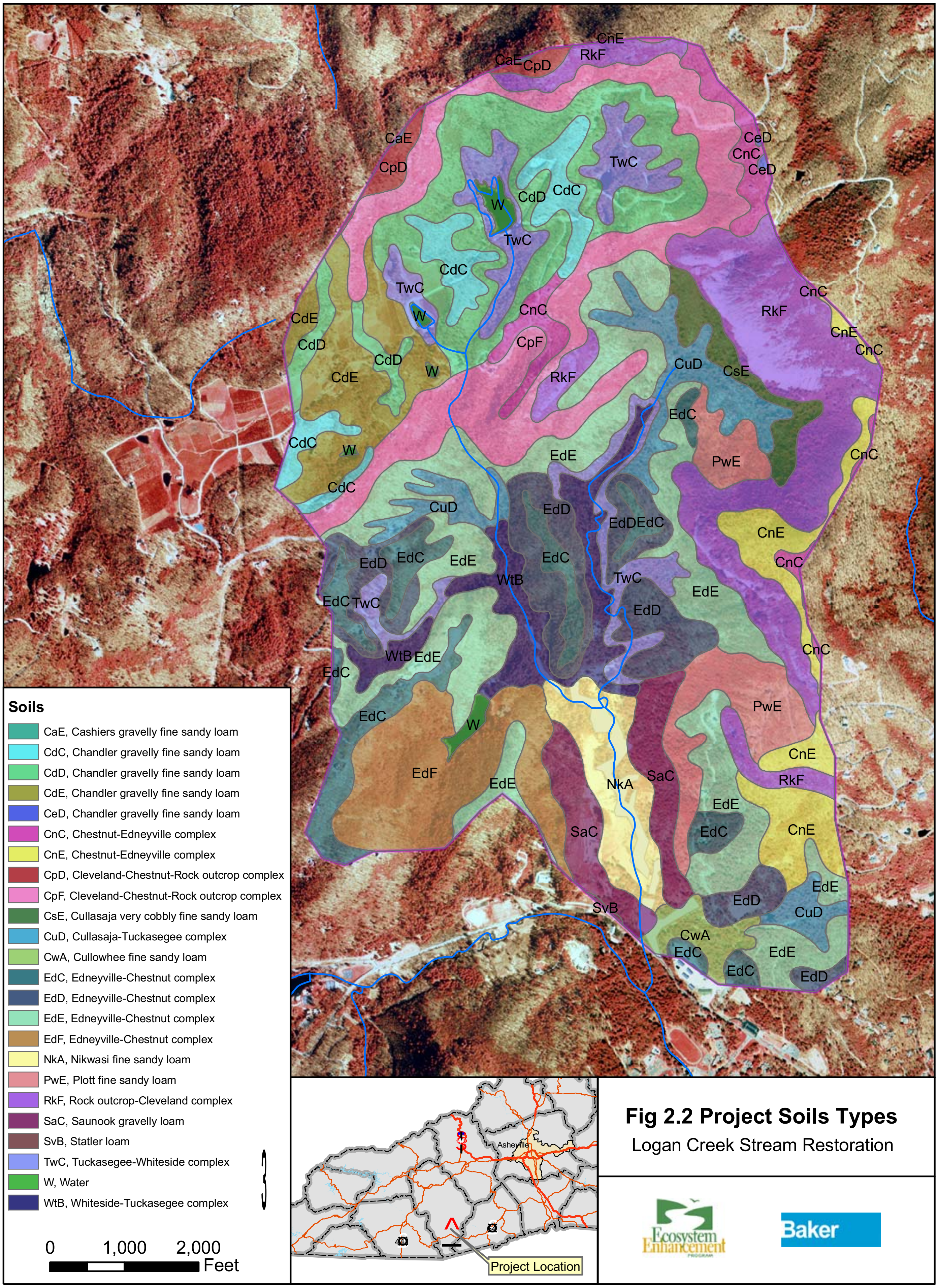


Fig 2.2 Project Soils Types
Logan Creek Stream Restoration

2.5 Endangered/Threatened Species

Some populations of plants and animals are declining as a result of either natural forces or their own difficulties in competing with humans for resources. Plants and animals with a federal classification of Endangered (E), Threatened (T), Proposed Endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. Seven species that the North Carolina Natural Heritage Program (NHP) lists under federal protection for Jackson County as of March 1, 2007 are listed in Table 2.4. A brief description of the characteristics and habitat requirements of the species under federal protection follows in Table 2.4, along with a conclusion regarding potential project impact.

Table 2.4 Species Under Federal Protection in Jackson County

Family	Scientific Name	Common Name	Federal Status	State Status	Habitat Present / Biological Conclusion
Vertebrates					
Emydidae	*Clemmys muhlenbergii*	Bog Turtle	T(S/A)	N/A	Yes/No effect
Sciuridae	*Glaucomys sabrinus coloratus*	Carolina Northern Flying Squirrel	E	E	No/No effect
Vespertilionidae	*Myotis sodalit*	Indiana Myotis (bat)	E	E	No/No effect
Invertebrates					
Unionidae	*Alasmidonta raveneliana*	Appalachain elktoe	E	E	No/No effect
Plants					
Orchidaceae	*Isotoria medeoloides*	Small whorled pogonia	T	E	Yes/No effect
Liliaceae	*Helonias bullata*	Swamp pink	T	T-SC	Yes/No effect
Lichen					
Cladoniaceae	*Gymnoderma lineare*	Rock Gnome Lichen	E	T	No/No effect

Notes:

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

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).

T Threatened

T(S/A) Threatened due to similarity of appearance. A species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.

The U.S. Fish and Wildlife Service (USFWS) was most recently contacted August 1, 2006 regarding protected species on the project site. A response was received February 21, 2007 from the USFWS concurring with a finding of "no effect" for project impacts to federally listed species located in Jackson County. As a precautionary measure, Baker will consider the effects of construction activities on species listed in Table 2.4 and take reasonable measures to avoid direct and indirect impacts during the project. A copy of the correspondence from USFWS is included in Appendix B.

2.5.1 Federally Protected Vertebrates

2.5.1.1 *Clemmys muhlenbergii* (Bog Turtle)

The Bog Turtle is among the smallest turtles of North America at only 3-4.5 inches in length and 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 include 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. Suitable habitat was found for the bog turtle in the larger wetland areas located adjacent to Logan Creek. However, no examples of this species were observed during pedestrian surveys of the site on May 18 and 24, 2005 and on September 28, 2005

Biological Conclusion: No Effect

Project design for Logan Creek will be such that minimal land disturbing activities will take place in the wetland areas identified. By avoiding adverse impacts to potential habitat to the greatest extent possible, and referencing a lack of bog turtle observations, a "no effect" determination was assigned.

2.5.1.2 *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.

Biological Conclusion: No Effect

The Carolina northern flying squirrel prefers the ecotone between coniferous and mature northern hardwood forests usually above 4,500 feet. The project area consists of floodplain with maximum elevations of approximately 3,500 feet. Due to the lack of suitable habitat on the project site, a "no effect" determination was made for the Carolina northern flying squirrel.

2.5.1.3 *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 (Nature Serve Explorer, 2006).

Biological Conclusion: No Effect

Riparian corridors adjacent to Logan Creek may provide suitable summer foraging habitat for the Indiana bat; however USFWS records indicate that Jackson County N.C. records of this species have all been winter records. No winter hibernation habitat was observed on the project site. Therefore a “no effect” determination was made.

2.5.2 Federally Protected Invertebrates

2.5.2.1 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 mussel’s life span is unknown.

Biological Conclusion: No Effect

The Appalachian elktoe prefers morphologically stable stream reaches with no silt accumulation or heavily shifting substrate, which does not currently exist on the site. Given the degraded conditions on Logan Creek a “no effect” determination was made.

2.5.3 Federally Protected Plants

2.5.3.1 *Isotria medeoloides* (Small Whorled Pogonia)

Small whorled pogonia is a small, perennial member of the Orchidaceae. These plants arise from long slender roots, with hollow stems terminating in a whorl of five or six light green leaves. The single flower is approximately one inch long, with yellowish-green to white petals and three longer green sepals. This orchid blooms in late spring, from mid-May to mid-June. Populations of this plant are reported to have extended periods of dormancy and to bloom sporadically. This small spring ephemeral orchid is not observable outside of the spring growing season. When not in flower, young plants of Indian cucumber-root (*Medeola virginiana*) also resemble small whorled pogonia; however, the hollow stout stem of *Isotria* separates it from the genus *Medeola*, which has a solid, more slender stem (U.S. Fish and Wildlife Service County Listing, 2007).

Small whorled pogonia may occur in young as well as maturing forests, but typically grows in open, dry, deciduous woods and areas along streams with acidic soil. It also grows in rich, mesic woods in association with white pine and rhododendron.

The primary threat to small whorled pogonia is habitat destruction resulting from residential or commercial development or forestry. Other threats, such as recreational use of habitat and inadvertent damage from research activities, have also been identified.

Biological Conclusion: No Effect

Second-Third growth upland forest in the vicinity of the project area was found to contain suitable habitat for the small whorled pogonia. However, no small whorled pogonia was observed during on-site surveys conducted May 18, and May 24, 2005. Lack of observations as well as limited disturbance activities within the habitat area resulted in a “no effect” determination.

2.5.3.2 *Helonias bullata* (Swamp Pink)

A perennial, the Swamp Pink usually is one of the first wildflowers to bloom in the spring. The plant usually blooms from March to May. Its fragrant flowers are pink and occur in a cluster of 30 to 50. Its dark evergreen, lance-shaped, and parallel-veined leaves form a basal rosette which arises from a stout, hollow stem. This stem can grow from a height of 2 to 9 decimeters during flowering, and to 1.5 meters during seed maturation (U.S. Fish and Wildlife Service 1990). The plant's stout rootstock has many fibrous rootlets. During the winter, the leaves often turn reddish brown and will lie flat on, or slightly raised, from the ground. These winter leaves are often hidden by leaf litter, but a visible large button, in the center of the leaves, represents next season's flowerhead. The plant produces three-lobed fruit of an inverted heart shape. Each fruit has many ovules; each ovule opens into six lobes which release linear shaped seeds with appendages on both ends.

Biological Conclusion: No Effect

Larger wetland areas adjacent to Logan Creek contain suitable habitat for swamp pink. However, no species were located during on-site surveys conducted May 18 and May 24, 2005. In addition, no ground disturbing activities will occur in these wetlands areas. Therefore, a “no effect” determination was issued.

2.5.4 Federally Protected Lichen

2.5.4.1 *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 between 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 (2.4 square yards). Most populations are 1 meter (3.3 feet) or less in size.

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 1,524 meters (5,000 feet).

Biological Conclusion: No Effect

The project area is in a broad valley setting of mixed meadows and forested areas and does not meet the habitat criteria for the rock gnome lichen. A Biological Conclusion of No Effect is expected from the proposed project construction.

2.6 Cultural Resources

A letter was sent to the North Carolina State Historic Preservation Office (SHPO) and Eastern Band of Cherokee Indians’ Tribal Historic Preservation Office (THPO), August 1, 2006, requesting a review and comment for the potential of cultural resources in the vicinity of the Logan Creek restoration site. A response was received on August 30, 2006, from the SHPO with a recommendation that a comprehensive survey be conducted due to the project site landscape and proximity to two previously recorded archaeological sites and one architectural site. The THPO also submitted a letter requesting they be contacted for further consultation should further cultural resources data be obtained for the project site. Subsequently, an archaeological survey was completed by Archaeological Consultants of the Carolinas, Inc. in which no significant archeological or architectural resources were located within the project boundaries. Camp Merrie Woode, which is listed on the National Register of Historic Places (NRHP), is located approximately 1.6 km from the Logan Creek project area. However no adverse impacts to the camp are anticipated from the project. On December 1, 2006, the archaeological survey report was submitted to the SHPO and THPO for review. On January 12, 2007, Baker received a letter from the SHPO concurring with findings from the archaeological survey that no further archaeological investigation be conducted in connection with this project. The THPO submitted a concurrence letter on January 24, 2007. A copy of the SHPO and THPO correspondence is included in Appendix C.

2.7 Potentially Hazardous Environmental Sites

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

2.8 Potential Constraints

Baker assessed the Logan Creek project site in regards to potential site constraints. No fatal flaws have been identified during project design development.

2.8.1 Property Ownership and Boundary

Baker has obtained a conservation easement from Cow Rock Mountain, Inc., for the Logan Creek project area. The easement has been approved by the N. C. State Property Office (SPO) and recorded at the Jackson County Courthouse. Final copies of the easement and plat have been provided to SPO and to EEP. The easement will allow Baker to proceed with the restoration project and restricts the land use in perpetuity. The landowner will retain the right to establish and maintain a trail for non-motorized use that will pass through the easement in a few areas. The trail base will be maintained with a natural, pervious material such as mulch and shall conform to easement guidelines. The easement area lost to this trial is compensated for by the fact that the easement will average approximately 45 feet in width.

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

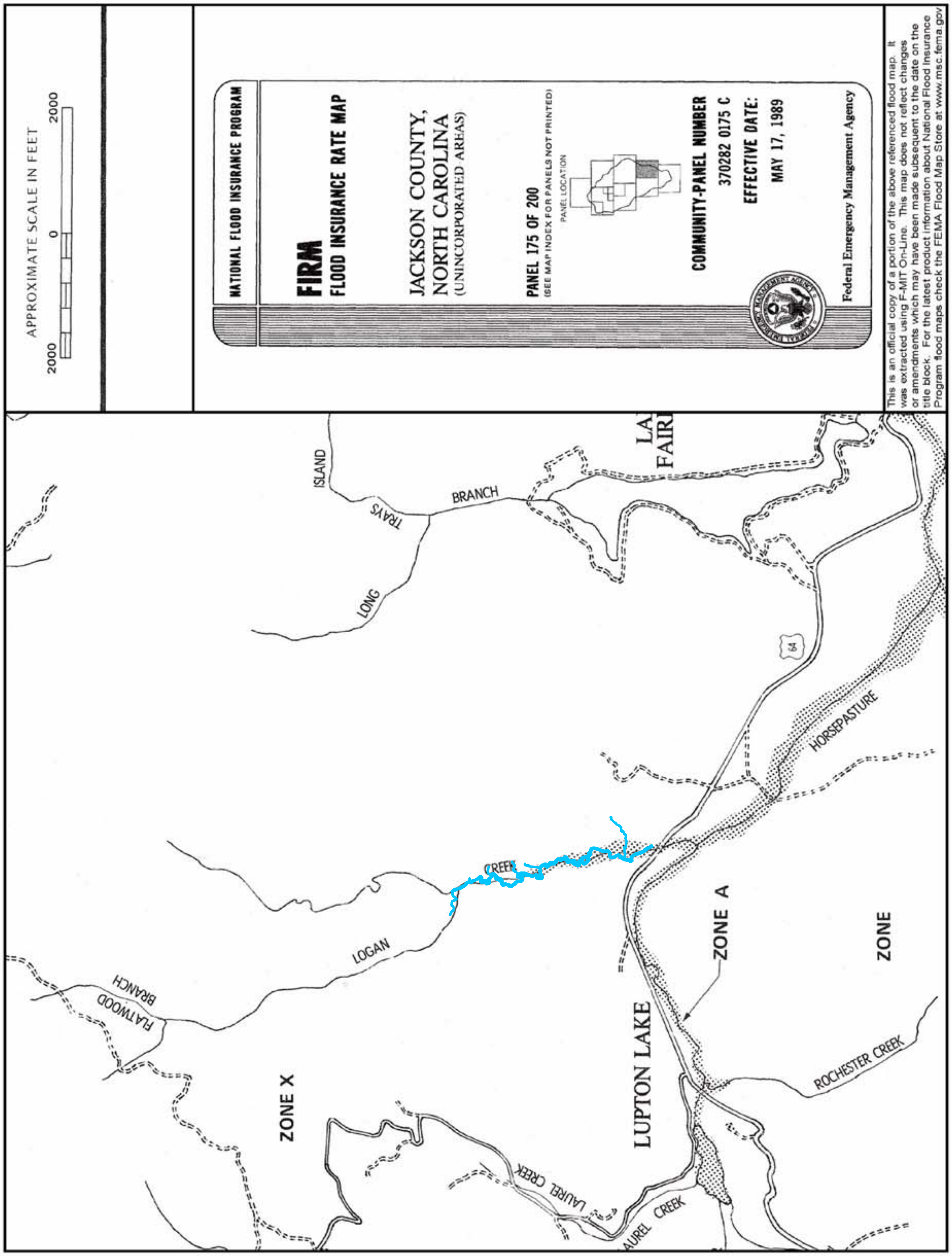
2.8.2 Utilities

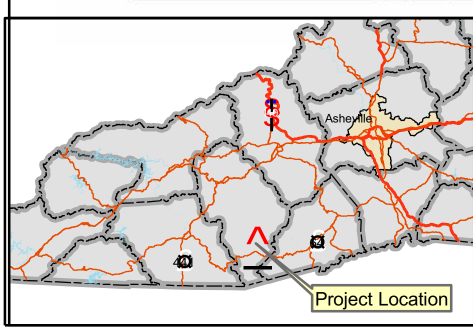
No utility easements are present within the conservation easement. There are at least two 100 foot diameter, circular easements that protect wells that adjoin the proposed easement lines. These will not infringe on the conservation easement since for the most part these easement areas will be maintained in a natural condition. There is one existing waterline pipe that crosses the stream at the upstream end of the project reach, in the area of the pond. This waterline was part of the old trout hatchery infrastructure and is no longer functioning. It will be removed during construction.

2.8.3 Hydrologic Trespass and Floodplain Characterization

The FEMA Flood Insurance Rate Map (FIRM) for Jackson County, NC, (Panel Number 3702820175C) indicates that the project is located within a regulatory floodplain, zone A. Figure

2.3 illustrates the FEMA mapping near the site. No flood study is planned as a part of this project and we don't anticipate any change to the present flood elevations as a result of this project. Baker will perform hydraulic modeling of the final design to compare pre and post-project flood elevations, with results to be placed in the project file for future reference. The county floodplain manager will be contacted and advised of this project.





Legend

Project Stream

Fig 2.3 FEMA Floodplain Map

Logan Creek Stream Restoration

Ecosystem Enhancement Program

Baker

3.0 PROJECT SITE STREAMS (EXISTING CONDITIONS)

3.1 Existing Channel Geomorphic Characterization and Classification

Baker performed representative longitudinal profile and cross-section surveys of the existing stream reaches to assess the current condition and overall stability of the channels. Baker also collected substrate samples to characterize stream sediments. Figure 3.1 illustrates the locations of cross-section surveys on the project reaches. The following sections of this report summarize the survey results for the mainstem reaches. Surveyed cross sections and profiles are included in Appendix E. Results of sediment sampling and analysis are included in Appendix G.

3.1.1 Logan Creek Mainstem

Table 3.1 summarizes the geomorphic parameters of the mainstem downstream of the confluence with Right Prong Logan Creek. In general, the bedform diversity of Logan Creek is fair with some pool habitat in existing meanders and around woody debris. Most pools are scour features associated with woody debris laying over or in the channel and debris buried in the substrate. Most of the stream bed is shallow and is best described as a riffle with a few runs. Low velocity areas of the channel are primarily composed of large sand particles and small gravel. Higher velocity pools and runs have some small cobble and gravel. The project reach can be described as a gravel bed stream based on stream bed sampling at Logan Creek. Table 3.2 lists substrate data.

Logan Creek flows through a locally broad, alluvial floodplain characteristic of a Rosgen Valley Type VIII. Alluvial terraces typically present in a Valley Type VIII are low elevation rises and are observed in a few places along Logan Creek; however historic agricultural manipulation of the floodplain has likely altered the topography. The overall valley slope is 0.0045 ft/ft.

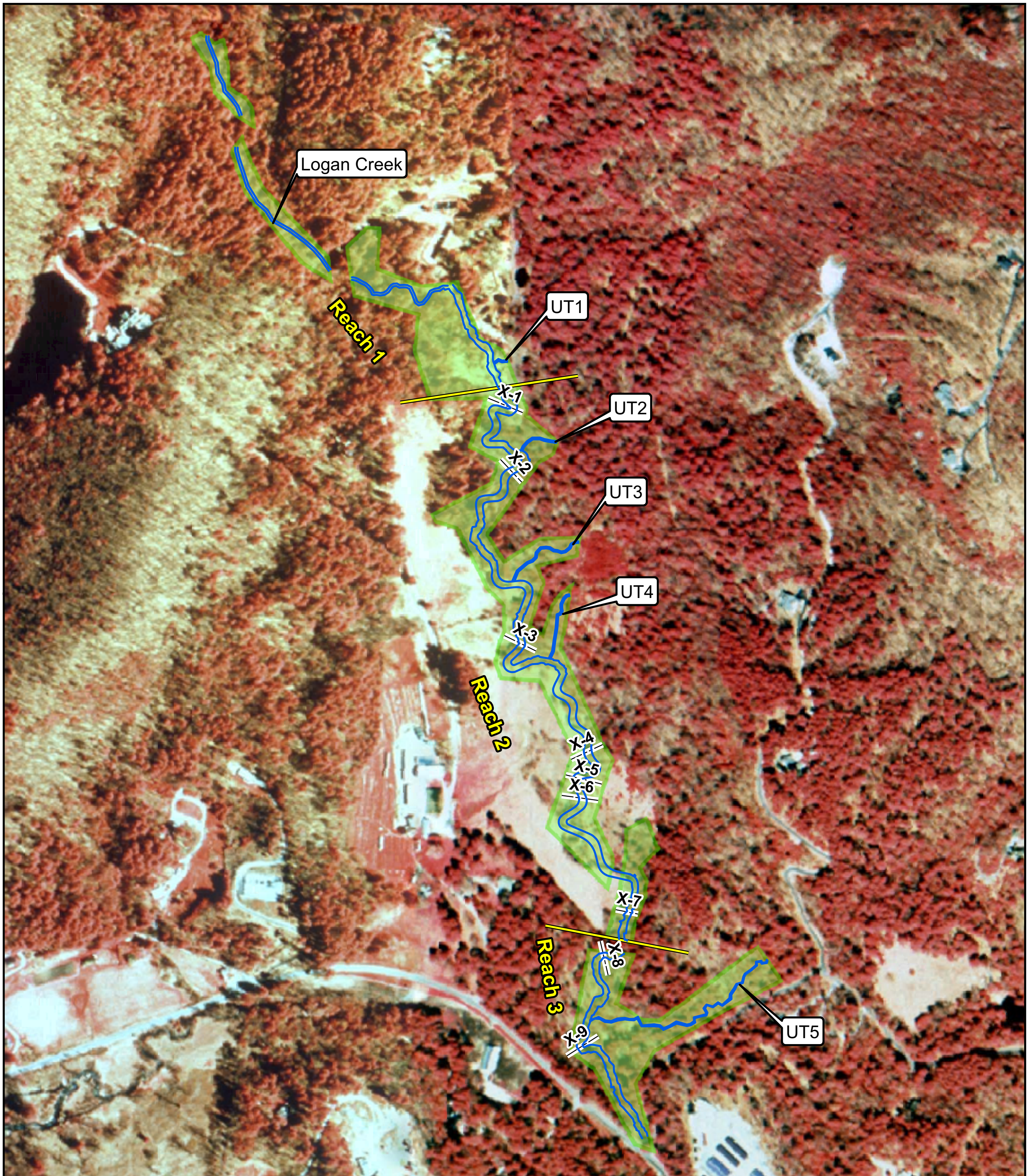
Within the project limits, Logan Creek is predominately classified as a Rosgen stream type C4. However, some areas of the channel demonstrate Rosgen stream type E4 characteristics and indicate that the stream either was an E in the past or is evolving into this stream type. Existing natural and anthropogenic impacts have caused a shift away from the more stable E channel.

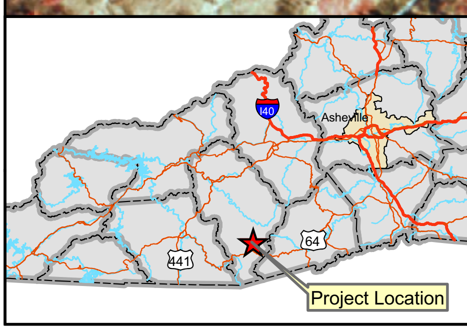
Table 3.1 Representative Geomorphic Data for Logan Creek – Stream Channel Classification Level II					
Parameter	**Value**				**Units**
	Reach 2, XS2 Sta. 11+10	**Reach 2 , XS4 Sta. 29+25**	**Reach 2, XS5 Sta. 30+00**	**Reach 3, XS9 Sta. 46+05**	
Feature Type	Riffle	Run	Riffle	Pool	
Bankfull Width (W_{bkf})	38.7	36.0	34.9	80.96	Feet
Bankfull Mean Depth (d_{bkf})	1.51	1.55	1.56	1.6	Feet
Cross-Sectional Area (A_{bkf})	58.4	55.8	54.2	55.8	Sq. ft.
Width/Depth Ratio (W/D ratio)	25.7	23.2	22.4	23.2	
Bankfull Max Depth (d_{mbkf})	3.42	2.94	2.3	2.9	Feet
Floodprone Area Width (W_{fpa})	>150	122	74.0	>150	Feet
Entrenchment Ratio (ER)	>5	3.4	2.12	>5	
Bank Height Ratio (BHR)	1.45	1.6	1.86	1.1	
Water Surface Slope (S)	.0032	.0012	.0026	.0002	Feet per foot
Channel Sinuosity (K)	1.16	1.25	1.25	1.60	
Rosgen Stream Type	C4	C4	C4	C4	

Table 3.2 Particle Size Distribution from different sediment samples of Logan Creek				
	Channel materials			
Particle Size (mm)	**Pebble Count**	**Pavement**	**Subpavement**	**Bar Bulk Sample**
D16 =	0.8	16.8	0.6	0.7
D35 =	5.8	19.9	2.1	2.0
D50 =	12.4	32.2	8.1	2.5
D84 =	35.4	43.0	19.8	10.5
D95 =	169.6	54.2	33.3	19.5
D100 =	> 2048	45 - 64	52.0	16 - 22.6

The mainstem project reach of Logan Creek between the confluence with Right Prong Logan Creek and US 64 has been divided into three reaches which are described in Table 3.3. Reach divisions were based on an assessment of need and the proposed actions being either Restoration or Enhancement I. Stationing is based on the proposed channel and does not align with the existing thalweg. In the following description reference is made to stationing on the proposed alignment and locations on the existing channel are approximate.

Logan Creek above the confluence with Right Prong Logan Creek is in good condition. This section has a thick forest buffer and minimal instability. Future development by Lonesome Valley is planned for this watershed and could impact the existing high quality. However, they are committed to





Proposed Design
Easement
Cross-Sections
Project Reaches

0 250 500 Feet

N

Fig 3.1 Project Reaches and Surveyed Cross-Sections

Logan Creek Stream Restoration

maintaining the 25 foot buffer in a natural condition and areas within the project limits will have a 30 foot buffer.

Table 3.3
Logan Creek mainstem Reach Descriptions

Reach	Station Location	Reach Length * (LF)	Watershed Size at Downstream End of Reach (square miles)
Reach 1	Sta. 0+00 to 4+50	450	2.18
Reach 2	Sta. 4+50 to 35+90	3,140	2.42
Reach 3	Sta. 36+50 to 46+50	1,000	2.67
Total Existing Stream Length		4,590	
***Reach lengths are approximate and based on proposed alignment.**			

3.1.1.1 Reach 1

Reach 1 begins at the confluence of Logan Creek and Right Prong Logan Creek and extends downstream to station 4+50. The right bank is forested down to station 2+50 were a large wetland area drains into Logan Creek. The delineated wetland boundaries are 20 to 40 feet away from the top of the bank, except for the channel through which the wetland drains. On the left bank is a large pond and the stream bank between 1+75 and 2+25 is the emergency spillway for the pond. At this point a past bank slump has caused a diversion of the stream flow into the toe of the bank at the emergency overflow section. The left bank below the pond is vegetated by shrubs and herbaceous species with a few trees. The reach is unusually straight and may have been straightened in the past to develop the trout hatchery facility which was in the area of the pond. This reach is being impacted by beavers and a number of beaver dams have been built in this reach over the past few years. This has caused the channel to erode in a number of places, resulting in an over-wide condition and the channel continues to be diverted into the bank between stations 4+50 and 5+10. The slope over this reach is .0029.

3.1.1.2 Reach 2

Reach 2 extends approximately 3,140 LF downstream from the end of Reach 1 at station 4+50 to station 35+90. The slope across this reach is steeper than the other two reaches at 0.0040 ft/ft. The steepest slope (.0064 ft/ft) within the reach is across the upper 800 LF. This relative steepness reflects a profile of debris jams, over-widening and aggradation punctuated by short, steep drops at the downstream ends of the debris jams. The banks are eroding between station 4+50 and 7+75. In part this is due to an unstable pattern and over-wide cross-section, and these conditions are exacerbated by log jams and past beaver activity. Similar problems are also causing degradation and bank erosion between stations 9+00 and 13+00. Within this reach the channel is exceptionally over-wide and a large log jam has formed at approximately station 12+20. This appears to back water up during storm flows causing the channel to aggrade. Much of the woody debris associated with these blockages is rhododendron branches that have fallen in or entire plants that have been washed out of the bank. Between station 7+00 and 13+00 rhododendron plants are so thick that they have limited germination of tree species. Because rhododendrons are not deeply rooted and shade out herbaceous species, they do not stabilize the stream bank and allow for rapid erosion during storm flows.

Beginning at approximately station 13+00 the right bank is a grass meadow with a few trees. The left bank continues to have thick rhododendron down to station 26+00 where it is also a grassed meadow with a few trees along the edge of the stream. At two sites along this reach (Station 15+25 and 18+50) the stream is overly sinuous. In each of these cases the stream is flowing up-valley, resulting in excessive erosion and setting up an avulsion situation. Between stations 21+50 and 29+50 the channel appears to be straighter than one would expect given the low slope. It may be that in the past, the stream was straightened over this length to increase farming opportunities in the adjoining fields. Just downstream of station 30+50 (on existing channel) the existing channel flows into and along a steep, eroding right bank. Downstream of this bank the channel is a long riffle to the end of Reach 2 at station 35+90. The channel bed particle size through this reach is similar to the reach wide description in Section 3.1.1; however, there are areas within this reach were bedrock is exposed. Four unnamed tributaries (UT2 through UT5) enter Logan Creek along this reach.

3.1.1.3 Reach 3

Reach 3 extends 1,000 LF downstream from the end of Reach 2 and ends at station 46+50, just above a culvert crossing under US64. The slope of this reach is the lowest of the three reaches at .0021. This relative flatness appears to be related to log jams through the reach that have caused aggradation of the stream bed. Sand is the primary particle size in this reach, though gravel and bedrock are present. Aggradation appears to have caused the bed to rise and bank heights to lower. Thick stands of rhododendron are present at two locations along this reach but in general the vegetation of this reach is more diverse than what is seen upstream. Bank erosion is a problem between station 39+00 and 40+50 due to a log jam diverting water into the bank and in the area of station 41+75 where the channel meanders against a steep bank. Between stations 40+25 and 45+75 the channel becomes over-wide in three different locations. This appears to be associated with log jams that have caused erosion of the banks. In these areas the water is very shallow and provides little habitat value. Between station 35+90 and 36+50 an area has been excluded from the easement for a bridged stream crossing that spans the channel. The largest tributary within the project reach (UT6) enters Logan Creek at station 40+50.

3.1.1.4 Logan Creek Upstream of Station 0+00

Approximately 1,550 linear feet of Logan Creek upstream of station 0+00 will be included in the project. These reach is heavily forested and has not been disturbed by past development. The channel bed is composed of gravel and small cobble and has good aquatic habitat. Thirty foot buffers have been established along this entire reach within the conservation easement.

3.1.1.5 Unnamed Tributaries

Along the project reach near stations 3+75, 8+50, 16+00, 20+75 and 40+50 five unnamed tributaries enter Logan Creek. These tributaries range in drainage area size from 0.025 sq. mi. to 0.20 sq. mi and range in length within the easement from 65 LF to 975 LF. All of these tributaries are less than 3 feet in bankfull width but all are perennial within the project area and all have bed material of silt or sand and are well forested

3.2 Channel Stability Assessment

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

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

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

Figure 3.2 illustrates the six steps of the Simon Channel Evolution Model.

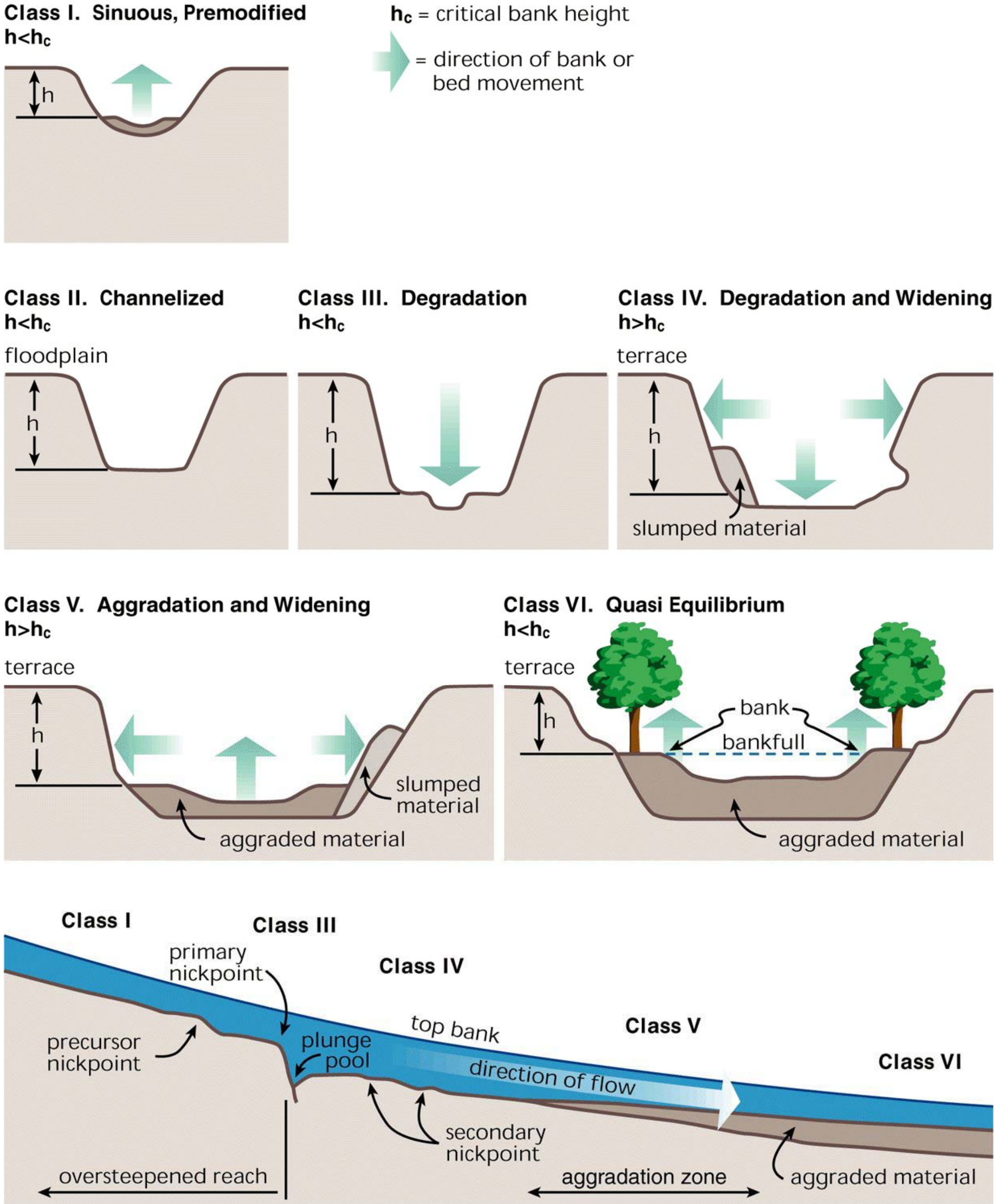
The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads 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).

The mainstem channel within the project area is a perennial stream with sections that appear to have been channelized in the past. Other sections of the stream flow through forest areas that were probably clear cut in the past, allowing thick stands of pioneering rhododendron to become established and to limit the density of other woody species. This watershed carries a high load of large grained sand and small gravels. The channel has a number of reaches within the forested sections that are impacted by debris jams that have caused erosion and channel over-widening. The straightened sections are eroding banks in order to reestablish a stable pattern of meandering. Some stable cross-sections within the project reach indicate that when deeply rooted vegetation is allowed to grow along the banks the stream takes on characteristics of an E channel. Table 3.4 summarizes the geomorphic parameters related to channel stability.

Table 3.4 Stability Indicators – Logan Creek			
Parameter	**XS2** **Sta. 9+30**	**XS4** **Sta. 25+50**	**XS5** **Sta. 28+00**
Stream Type	C	C	C
Riparian Vegetation	Wide buffer of mature rhododendron plants with some mature trees scattered within the stand on the left bank. On the right bank is a thin forest of mixed trees, shrubs and herbaceous veg.	Wide buffer of mature rhododendron plants with some mature trees scattered within the stand on the left bank. The right bank has only fescue grass and this is mowed.	The right and left banks are fields of fescue grass that is mowed. There are a few scattered trees on each bank.
Channel Dimension			
Bankfull Area (SF)	58.4	55.8	54.2
Width/Depth Ratio	25.7	23.2	22.4
Channel Pattern			
Meander Width Ratio	1.5	1.7	1.7
Sinuosity	1.16	1.25	1.25
Vertical Stability			
Bank Height Ratio (BHR)	1.45	1.6	1.86
Entrenchment Ratio (ER)	>5.0	3.4	2.12
Evolution Scenario	E-G-F-C-E	E-G-F-C-E	E-G-F-C-E
Simon Evolution Stage[1]	V	IV	IV
Notes: 1. Simon Channel Evolution see Figure 3.2.			

3.3 Bankfull Verification

Baker applied several methods to verify the bankfull stage and discharge of the restoration reach of Logan Creek. Field-identified physical indicators were collected during the topographic survey; these indicators were used in conjunction with hydraulic modeling and discharge information from regional curve data and the USGS rural regression equations to evaluate bankfull estimates for consistency and accuracy.



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

Figure 3.2
Simon Channel Evolution Model
Logan Creek Restoration Plan

Source: Simon, 1989

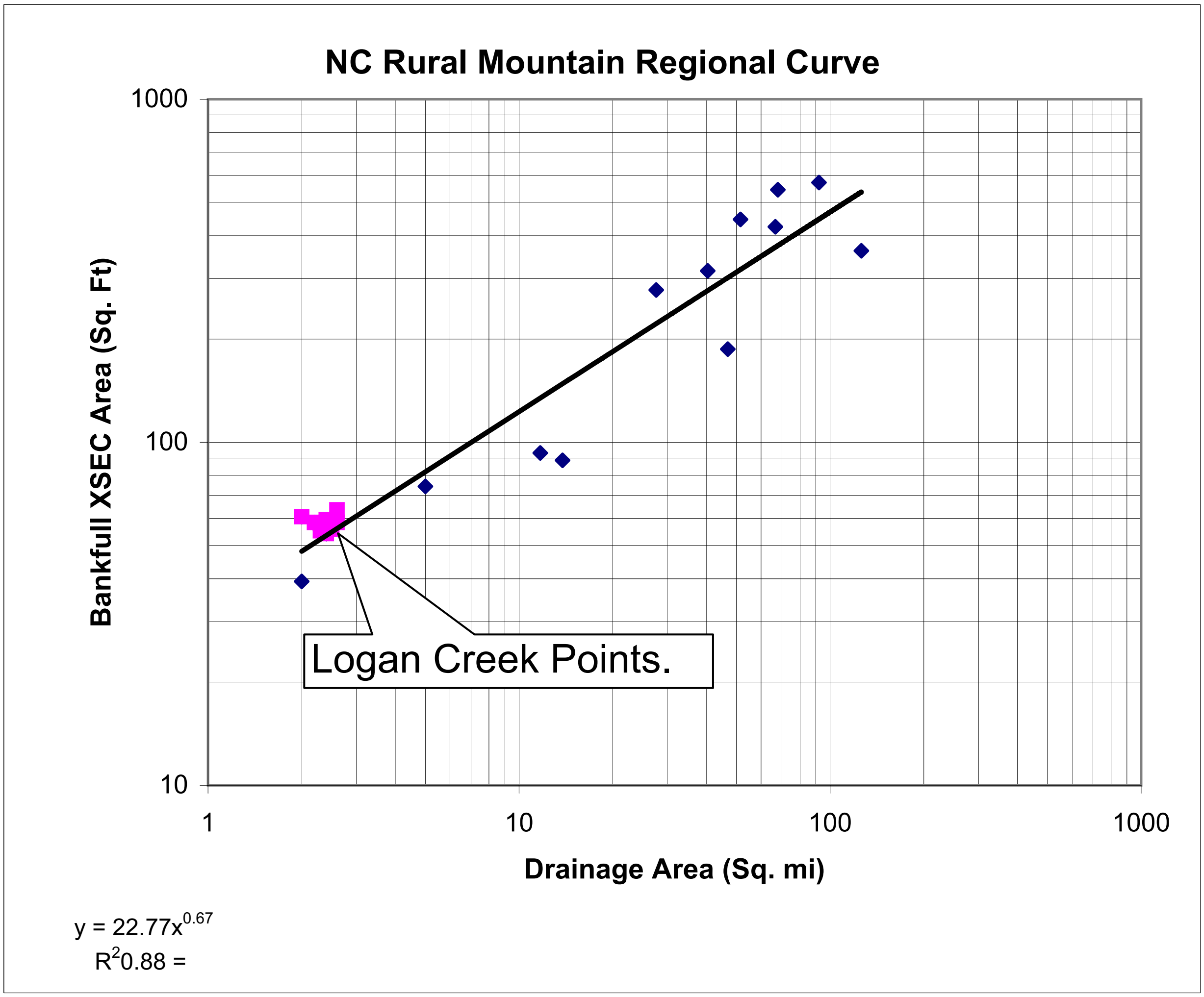


Figure 3.3 A plot of bankfull indicators at Logan Creek relative to the North Carolina Mountain Regional Curve.

Drainage Area (Sq Mi)	Q (cfs)	Gage #	Description
2.6	264	-	LOGAN CK 2-YR USGS REGRESSION EQUATION
2.6	160	-	LOGAN CK DESIGN Q
6.5	356	Reference Reach	Upper Mitchell River (Headwaters)
7.18	253.7	0214253830	Norwood Creek near Troutman, NC
9.6	507.2	02121180	North Pott's Creek near Linwood, NC
15.5	655.3	02101800	Tick Creek near Mt. Vernon Springs, NC
31.8	1041	02144000	Long Creek Gage near Bessemer City
42.8	2236	02114450	Little Yadkin River at Dalton, NC

Bankfull geometric data, and its source, plotted on the mini-curve below.

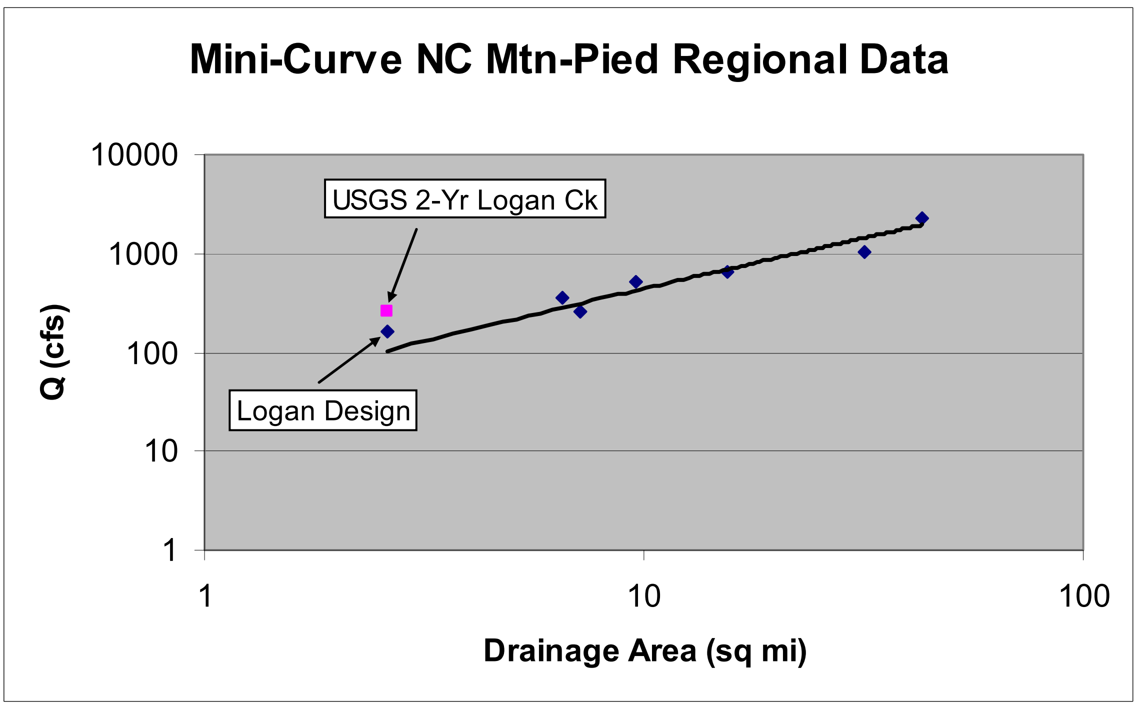


Figure 3.4. Mini-Curve Data from Mountain and Piedmont Streams with Logan Creek Data Included

Bankfull indicators on the mainstem channel were identified in the field; indicators include a break in slope, an intermittent flat depositional feature, and a consistent scour line. Depth and area measurements of stable cross-sections with bankfull indicators were compared to regional curve data to verify the quality of the indicators. Surveyed cross sections with bankfull indicators were plotted on the regional curve yielding estimates of cross-sectional area shown in Figure 3.3. Logan Creek data points plotted on or near the North Carolina Mountain Rural Regional Curve (Harman et al, 2000); indicating that the bankfull stage selected in the field was comparable with that of other Mountain streams of similar drainage area.

Using cross-sections extracted from the detailed topographic survey of the stream and floodplain, Baker prepared a HEC-RAS hydraulic model (US Army Corps of Engineers 2002) with cross-sections spaced every 20 to 40 feet. Water surface elevations in the riffle and run cross-sections were used to determine which discharge most consistently hit bankfull indicators throughout the project reach. Pool sections were excluded from the analysis because enlarged cross-sectional area typical of pools would overestimate conveyance area in the channel. This method was effective in determining a small range of bankfull discharges that would serve for choosing a reliable "effective" discharge for design.

For comparison and verification, a curve of the most geographically- and size- relevant regional curve data was used to create a mini-curve for discharge. The chosen design value and the 2-year USGS rural regression flow were plotted with the mini-curve in Figure 3.4.

In accordance with observed bankfull recurrence intervals between 1-2 years (and commonly in the 1.2-1.5 year range), the 2-year USGS flow plots just above the mini-curve. Furthermore, the design flow rate plots well with existing regional curve data providing collaborative evidence for better confidence in the methods used.

3.4 Discharge

Due to lack of gage data on Logan Creek, exhaustive efforts were made in an attempt to determine an appropriate design discharge. The strongest evidence came from HEC-RAS modeling which was produced from the existing conditions survey data. This data was used to create a surface model in AutoCAD, from which cross-sections were exported to HEC-RAS at intervals of 20 to 40 feet. Appropriate Manning's n values, slopes, and other model conditions were applied to provide a reliable backwater model. Flow rates, including the USGS regression flows, NC regional curve flow rates, and regional normalized flow duration curve flows from USGS gages in adjacent and regionally relevant gages, were modeled in HEC-RAS in order to assess what flow or flows produce flooding or inundation of the top of the bank and/or other floodplain formation (bankfull) features such as benches in stable or stabilizing sections of the project reach.

Since the project is located in an area of extremely high rainfall with significant fluctuations both within basins and between adjacent basins in the region, the HEC-RAS model was able to provide confidence in the design discharge that could not otherwise be achieved. We estimate the design bankfull discharge downstream of the confluence at the uppermost end of the restoration reach to be 180 cfs. Despite an increase in drainage area from the Right Prong Logan Creek confluence to the end of the project, this discharge consistently hit bankfull indicators and the top of the bank in stable areas throughout the restoration reach. This is thought to be a result of the diffuse nature of the flow paths and high occurrence of wetlands in this lower portion of the valley. As a result, this discharge was used for sediment transport and corresponding channel cross-section design throughout the project reach.

3.5 Vegetation and Habitat Descriptions

The habitat within and adjacent to the proposed project area consists of a Montane Alluvial Forest and a Montane Oak-Hickory Forest as described by Schafale and Weakley (1990). The riparian areas ranged from relatively disturbed to very disturbed. A general description of each community follows.

3.5.1 Montane Alluvial Forest

This ecological community covers approximately 85% of the project area and is located on large alluvial floodplains adjacent to Logan Creek. The riparian buffer varied from narrow corridors of 5 to 15 feet in width at mid-reach to broad corridors exceeding 50 feet in width at the upstream and downstream project limits. The dominant canopy species of the montane alluvial forest area included eastern hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), white oak (*Quercus alba*), northern red oak (*Quercus rubra*), white pine (*Pinus strobus*), and tulip poplar (*Liriodendron tulipifera*). Understory and shrub species consisted of rhododendron (*Rhododendron* spp.), mountain laurel (*Kalmia latifolia*), sourwood (*Oxydendrum arboretum*), black cherry (*Prunus serotina*), witch-hazel (*Hamamelis virginiana*), brook-side alder (*Alnus serrulata*), fetterbush (*Leucothoe fontanesiana*), elderberry (*Sambucus canadensis*), broad-leaved viburnum (*Viburnum cassinoides*), and yellow-root (*Xanthorhiza simplicissima*). Herbaceous species consisted of Christmas fern (*Polystichum acrostichoides*), woodfern (*Dryopteris* spp.), wild hydrangea (*Hydrangea arborescens*), golden-rod (*Solidago* spp.), smartweed (*Polygonum* spp.), trillium (*trillium* spp.), violets (*Viola* spp.), and club moss (*Lycopodium* spp.).

3.5.2 Montane Oak-Hickory Forest

This ecological community is located on the steep hillsides along the left bank of Logan Creek, and is an upland transition from the Montane Alluvial Forest. This ecological community covers approximately 15% of the project area. The dominant canopy species included white oak (*Quercus alba*), northern red oak (*Quercus rubra*), chestnut oak (*Quercus montana*), mockernut hickory (*Carya alba*), pignut hickory (*Carya glabra*), mountain maple (*Acer spicatum*), white pine (*Pinus strobus*), yellow birch (*Betula alleghaniensis*), and eastern hemlock (*Tsuga canadensis*). Understory and shrub species consisted of American chestnut (*Castanea dentata*), rhododendron (*Rhododendron* spp.), mountain laurel (*Kalmia latifolia*), sourwood (*Oxydendrum arboretum*), flowering dogwood (*Cornus florida*), American holly (*Ilex opaca*), witch-hazel (*Hamamelis virginiana*), viburnum (*Viburnum cassinoides*), huckleberry (*Gaylussacia* spp.), blueberry (*Vaccinium* spp.), and yellow Bakereye (*Aesculus octandra*). Herbaceous vegetation is generally sparse and included Christmas fern (*Polystichum acrostichoides*), New York fern (*Thelypteris noveboracensis*), hayscented fern (*Dennstaedtia punctilobula*), wild hydrangea (*Hydrangea arborescens*), golden-rod (*Solidago* spp.), galax (*Galax aphylla*), and club moss (*Lycopodium* spp.).

3.5.3 Swamp Forest Bog Complex

This wetland habitat type is classified by the NC Natural Heritage Program *as (S3) Rare or uncommon in North Carolina* and consists of a somewhat open tree canopy with a dense shrub layer. Within this shrub layer small open boggy areas containing sphagnum are located within depressions. These boggy areas are permanently saturated and contain hydric soils. In addition, the boggy areas are less than 1-acre in size. The bogs located within easement area of Lonesome Valley are surrounded by Cove Forest. Tree species are generally found along the perimeter of the bogs and may include red maple (*Acer rubrum),* yellow poplar (*Liriodendron tulipifera)*, and hemlock (*Tsuga Canadensis)*. The shrub layer consists of Rosebay (*Rhododendron maximum)* and dog hobble (*Leucothoe fonenesiana)*. Herbaceous species within the open boggy areas may include Cinnamon Fern (*Osmunda cinnamomea)*, Turtlehead (*Chelone* sp).,Netted Chainfern (*Woodwardia areolata),* Bluet (*Houstonia* sp.), club moss (*Lycopodium lucidulum)*, *sphagnum*, and various *carex* species.

3.5.4 Southern Appalachian Bog

This wetland habitat type is classified by the NC Natural Heritage Program as (S1S2) *critically impaired in North Carolina because of extreme rarity or otherwise vulnerable to extirpation in the state* and consists of various zones of shrubs and herbaceous areas containing *sphagnum*. These bogs are generally larger with a more open canopy than areas within the swamp forest bog complex. They generally contain a larger, (> 1 acre) interior herbaceous layer. Species within this habitat are similar to those of the Swamp Forest Bog Complex. Tree species are generally limited to the outer margins of the bog. Dominant trees include red maple, yellow poplar, and hemlock. Shrubs include spicebush (*Lindera benzoin*), elderberry (*Sambucus canadensi*s), and Rose (*Rosa* sp). Herbaceous species here are dominated by various *carex* species.

3.5.5 Disturbed Areas

At mid-reach of the project area, degraded riparian areas are present and consist of buffer widths ranging from 0 to 15 feet. A mowed lawn is adjacent to the riparian areas and herbaceous plant species consist of fescue (*Fescue* spp.), lamb's ear (*Stachys lanata*), arrow-leaf sida (*Sida rhombifolia*), buttercups (*Ranunculus* spp.), clovers (*Trifolium* spp.), and fennel (*Foeniculum* spp.). Some invasive species in and around the riparian buffer consisted of multi-flora rose (*Rosa muliflora*), and Japanese honeysuckle (*Lonicera japonica*).

4.0 REFERENCE STREAMS

In an effort to determine suitable reference data for the design we employed the NCDOT reference reach database, identified a reference reach within the watershed and collected dimensional data from stable cross sections within the project reach. Reference reach geomorphic data is summarized below in Table 4.1.

One undisturbed reference reach was found within the same watershed as the project site and surveyed for reference conditions. Additionally, the NCDOT database was reviewed for applicable reference reach streams. No existing reference reach steams exist in this database for the Savannah drainage, so we evaluated those sites that were closest to the project site. Two additional sites with streams of similar type and substrate were chosen as appropriate reference reaches for the Logan Creek Restoration.

The Right Prong reach is approximately .5 miles upstream of the project reach and has a watershed of .83 square miles. It is similar in slope, stream type, substrate and riparian vegetation. Baker conducted a survey of approximately 150 LF encompassing one pool and one riffle cross section. Surveyed cross sections and profile data are included in Appendix F.

Table 4.1
Reference Reach Geomorphic Parameters

	Right Prong Logan Jackson Co.		Big Branch Surry Co		Basin Creek Wilkes Co		On-site Stable Dimension Data	
	Min	Min	Max	Max	Min	Max	Min	Max
1. Stream Type	C4		E4		C4		E4	
2. Drainage Area – square miles	.83		1.9		7.2		2.08	2.67
3. Bankfull Width (w_{bkf}) – feet	16.7		18.5		29.5		22.6	
4. Bankfull Mean Depth (d_{bkf}) – feet	1.06		2.8		2.2		2.43	
5. Width/Depth Ratio (w/d ratio)	15.76		6.6		13.4		9.3	
6. Cross-sectional Area (A_{bkf}) – SF	17.7		51		64.9		54.8	
7. Bankfull Mean Velocity (v_{bkf}) - fps	3.55		-		5.5		3.28	
8. Bankfull Discharge (Q_{bkf}) – cfs	97.6		-		375		180	
9. Bankfull Max Depth (d_{mbkf}) - feet	1.54		3.5		3.2		3.5	
10. d_{mbkf} / d_{bkf} ratio	1.5		1.25		1.45		1.44	
11. Low Bank Height to d_{mbkf} Ratio	1.2		-				1.1	
12. Floodprone Area Width (w_{fpa}) – feet	35		130		329		323	
13. Entrenchment Ratio (ER)	2.0		7.0		11.2		14.3	
14. Meander length (L_m) – feet	150		185	260	350		-	
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	9.0		10.0		11.9		-	
16. Radius of curvature (R_c) – feet	23		42.3	63.1	40.1	69.3	-	
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	1.38		2.29	3.41	1.36	2.35	-	
18. Belt width (w_{blt}) – feet	80		30.5	44	59	75	-	
19. Meander Width Ratio (w_{blt}/W_{bkf})	4.8		1.65	2.38	2.00	2.54	-	
20. Sinuosity (K) Stream Length/ Valley Distance	2.01		1.1		-		1.38	
21. Valley Slope – feet per foot	.0160		-		-		..0045	
22. Channel Slope ($s_{channel}$) – feet per foot	.0079		0.009		.0144		.0033	
23. Pool Slope (s_{pool}) – feet per foot	.0033		-		.0019		-	
24. Ratio of Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	2.01		-		-		-	
25. Maximum Pool Depth (d_{pool}) – feet	2.28		3.5	4.1	2.2	2.8	4.2	
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	2.15		1.25	1.46	1.00	1.27	1.73	
27. Pool Width (w_{pool}) – feet	15.88		18.5	19.7	35	68	27.9	
28. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	.95		1.00	1.06	1.19	2.31	1.23	

Table 4.1
Reference Reach Geomorphic Parameters

	Right Prong Logan Jackson Co.		Big Branch Surry Co		Basin Creek Wilkes Co		On-site Stable Dimension Data	
	Min	**Min**	**Max**	**Max**	**Min**	**Max**	**Min**	**Max**
29. Pool Area (A_{pool}) – square feet	20.11		51	54.5	89.3	132.5	58.1	
30. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.14		1.00	1.07	1.38	2.04	1.06	
31. Pool-to-Pool Spacing – feet	75		97.5	179.8	271	334	-	
32. Ratio of Pool-to-Pool Spacing to Bankfull Width ($p\text{-}p/w_{bkf}$)	4.5		5.3	9.7	9.2	11.3	-	
33. Riffle Slope [4((s_{riffle}) – feet per foot	0.019		0.015	0.019	0.020		-	
34. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	1.188		1.7	2.1	1.4		-	
Particle Size Distribution of Riffle Material								
Material (d_{50})								
d_{16} – mm	-		0.13		0.17		-	
d_{35} – mm	-		0.3		29		-	
d_{50} – mm	-		1.9		58		-	
d_{84} – mm	-		50		180		-	
d_{95} – mm	-		100		300		-	

- : data not available

5.0 PROJECT SITE WETLANDS

5.1 Jurisdictional Wetlands

It is likely that much of the project area once existed as a wetland ecosystem, as evidenced by hydric soil areas across the floodplain of the site. Wetland areas that once existed on the site were drained and manipulated to promote past land use. Sections of the stream may have been channelized within the project area to improve surface and subsurface drainage and to decrease flooding.

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).

Wetland determinations were made by evaluating vegetation, soils and observable hydrologic indicators within the project reach. Wetland boundaries were subsequently delineated in winter 2005-2006. The limits were recorded by metes-and-bounds survey in 2006.

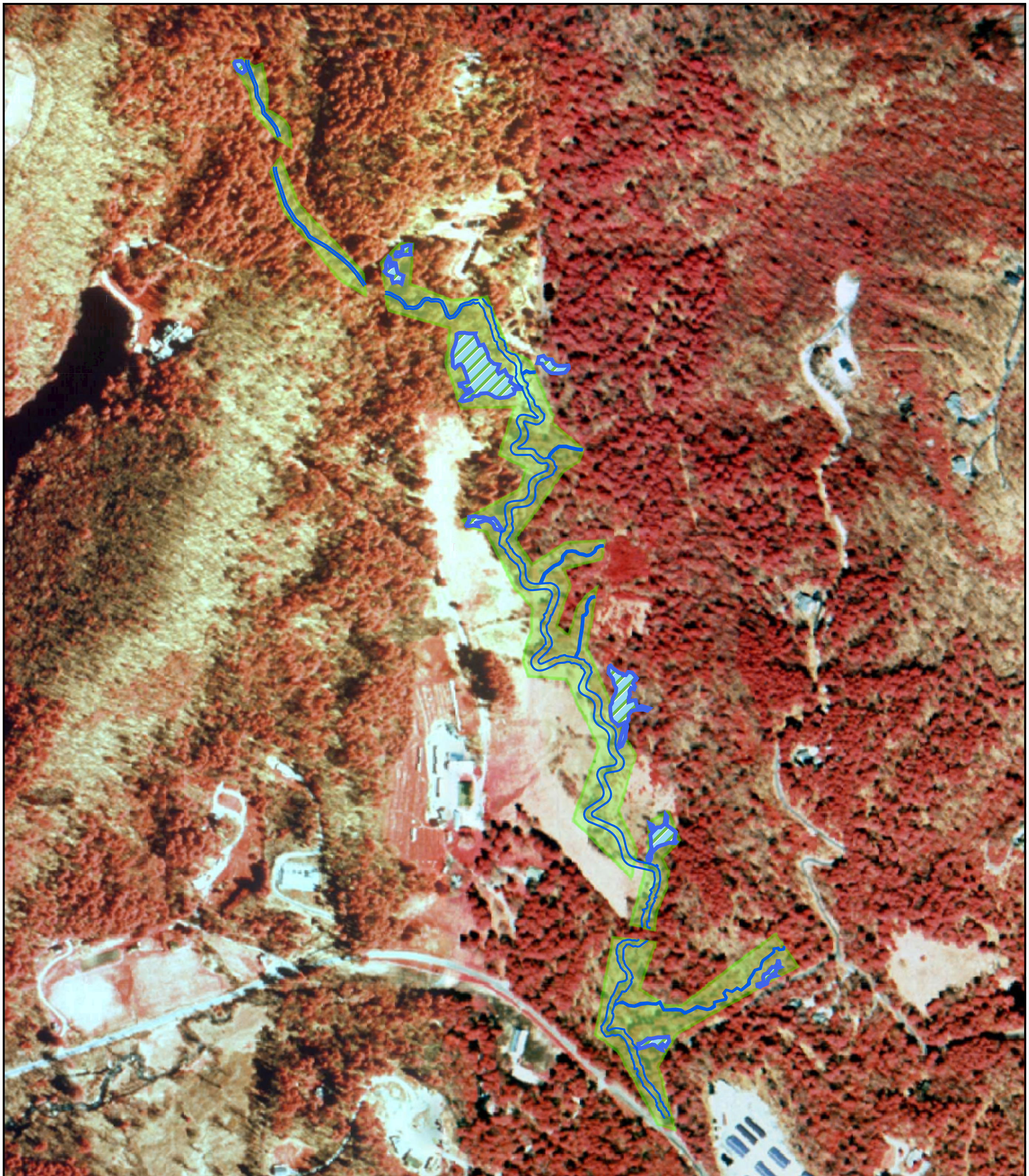
Less than 500 acres of mountain bogs exist within North Carolina, and the entire Appalachian Highlands, which includes the Appalachian Plateau, Ridge and Valley, and Blue Ridge provinces of Alabama, Georgia, Tennessee, North Carolina, Virginia and West Virginia, contain less than 6,175 acres (Moorhead and Rossell, 1998). Mountain bogs in North Carolina are generally small, isolated and rare wetlands largely concentrated in two areas: a band between Henderson and Clay counties in the southern mountains (including the Savannah River basin); and in Avery, Watuaga, Ashe and Alleghany counties in the northern mountains (Early, 1989).

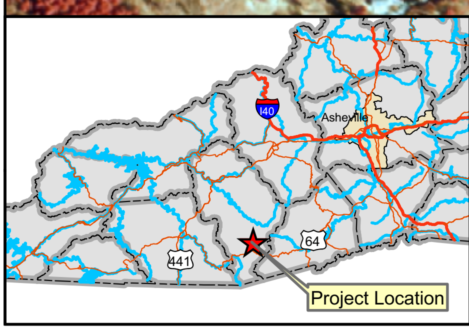
North Carolina's mountain bogs are known to host 77 species of rare, threatened or endangered plants such as the bunched arrowhead, swamp pink and Gray's lily. In addition to harboring important plant species, the state's mountain bogs also host five species of rare, threatened or endangered animals (Murdock, 1994), most notably the bog turtle (*Clemmys muhlenbergii*). Of the estimated 500 acres of mountain bogs in North Carolina, less than half support bog turtles (Herman, 1994).

Little research has investigated the hydrology of these bogs, but they may be found in four principle positions on the landscape: 1) headwater regions of mountain streams; 2) slopes intercepting the water table and subject to constant groundwater seepage; 3) stream valleys no longer subject to flooding; and 4) isolated systems over resistant rock strata (Walbridge, 1991; Weakley and Schafale, 1994). Although these wetlands are groundwater fed, technically called "fens" in classifications based on water source, they are locally known as bogs and have been called that in most publications within the state. The groundwater in fens tends to be acidic and nutrient poor, because of the rock and soil types it flows through. Groundwater in these areas of the Savannah River basin is less rich than is typical of most northern fens; therefore, the vegetation is more "bog-like" (Pohlman, September 2001).

Many bogs are privately owned and not actively managed or protected (Weakley and Moorhead, 1991). Historically ditched and drained for farms, ponds and pastures, mountain bogs today are also imperiled by development activities. Active management of some mountain bogs has focused on protecting or enhancing habitat for bog turtles or rare plants (Moorhead and Rossell, 1998).

Most wetlands found on the project site are hydrologically connected to Logan Creek through both natural and mechanically produced drain channels. Stream realignment and reconstruction will be designed to avoid wetland impacts to the greatest extent practicable. Nine wetlands, totaling 1.71 acres, were identified within the proposed easement boundary areas shown on Figure 5.1. These wetlands are in good condition and will be preserved within the easement being established to protect the stream restoration project. We are not requesting stream mitigation credit for the preservation of these wetlands.





Stream Design

Existing Wetlands

Easement

0 250 500

Feet

N

Fig 5.1 Existing Wetlands

Logan Creek Stream Restoration

Ecosystem Enhancement Program

Baker

6.0 PROJECT SITE RESTORATION PLAN

This section discusses the design criteria selected for stream restoration on the Logan Creek project site.

6.1 Restoration Project Goals and Objectives

This project site is an appropriate candidate for restoration because significantly more erosion will occur before the channel is able to achieve a stable, quasi-equilibrium state. Most of the project reach appears to have one of two problems: either over-widened with debris jams, aggradation and channel erosion or accelerated meandering and erosion due to a lack of vegetation. These two instability problems are contributing extensive sediment to the areas downstream of the project site. Restoration can help to stabilize the channel, halt over-widening, establish proper pattern and significantly diminish bank erosion.

This watershed is under pressure from development and other human impacts. Much of the stream length has eroding banks due to lateral migration of the channel. If left alone the development of a stable dimension and pattern at a new floodplain elevation would continue through erosion and aggradation. The restoration approach on the mainstem is targeted at moving the evolutionary process to a final stable condition. The over-wide channel condition and bank erosion on Reaches 1 and 3 will be addressed by the installation of wood based structures that will center the thalwag, improve sediment transport and stabilize failing stream banks. The unstable stream pattern and erosion on Reach 2 will be improved by grading a new sinuous pattern. Bank stability and habitat improvement will be accomplished by installing log structures in meanders and along riffles. Grading a new cross-section will improve sediment transport while providing improved trout habitat. Vegetation along all reaches will be modified to increase diversity by reducing the density of rhododendron and planting a mix of species that root deeply and provide higher quality biomass to the stream to support aquatic food chains. Invasive vegetative species removal efforts and reforestation of the riparian buffer with native species will complement the channel restoration.

6.2 Design Criteria Selection for Stream Restoration

Selection of natural channel design criteria is based on a combination of approaches including review of reference reach databases, hydraulic modeling, sediment transport predictions, and evaluation of results from past projects.

Selection of a general restoration approach was the first step in selecting design criteria at the Logan Creek site. The approach was based on the reach's potential for restoration, as determined during the site assessment. 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, for the purpose of developing construction documents. The design philosophy at the Logan Creek site is to use average values for the selected stream type when designing dimension and profile and to work within the ranges expected for the selected stream type with regards to pattern and instream structures used. This approach should allow for maximum diversity of pattern and habitat while maintaining stable pools and riffles. Extreme variation in form will develop over long periods of time under the processes of flooding, re-colonization of vegetation, and geologic influences.

After examining the existing conditions, recognizing the potential for restoration, and reviewing reference reach data, design criteria were developed. Assigning an appropriate stream type for the corresponding valley that will accommodate the existing and future hydrologic and sediment contributions was considered conceptually prior to selecting reference reach streams. Design criteria for the proposed stream 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, detail refinements were made to accommodate the existing valley morphology, to avoid encroachment of property boundaries and the valley wall, to minimize unnecessary disturbance of the existing large trees, and to promote natural channel adjustment following construction. The proposed design rationale for the project are summarized in Table 6.1.

Table 6.1
Project Design Stream Types and Rationale

Reach	Proposed Stream Type	Rationale
Reach 1	C4	An Enhancement I approach will be used to move slumped and aggraded sediment through the channel and to improve sediment transport through the reach. The thalweg will be centered using log structures to reduce erosion, address an over-wide area and to improve habitat. Use of the existing channel will limit grading and disturbance. Trees will be planted to provide bank stabilization, shading and vegetative diversity.
Reach 2	C4	A Restoration approach will be used to establish a stable, sinuous channel with greater pool habitat. Over-wide sections will be narrowed to improve depth and sediment transport. Eroding banks will be stabilized by correcting pattern and by installing log based structures that direct flow to the thalweg and improve aquatic habitat. Constructed channels will provide connectivity to floodplains. Forest diversity and bank stability will be improved by reducing the extent of rhododendron coverage, eliminating nonnative vegetation and planting diverse tree, shrub and herbaceous species.
Reach 3	C4	An Enhancement I approach will be used to move aggraded sediment through the channel and to improve sediment transport through the reach. The thalweg will be centered using log structures to reduce erosion, address several over-wide areas and improve habitat. Use of the existing channel will limit grading and disturbance. Where necessary, trees will be planted to provide bank stabilization, shading and vegetative diversity.

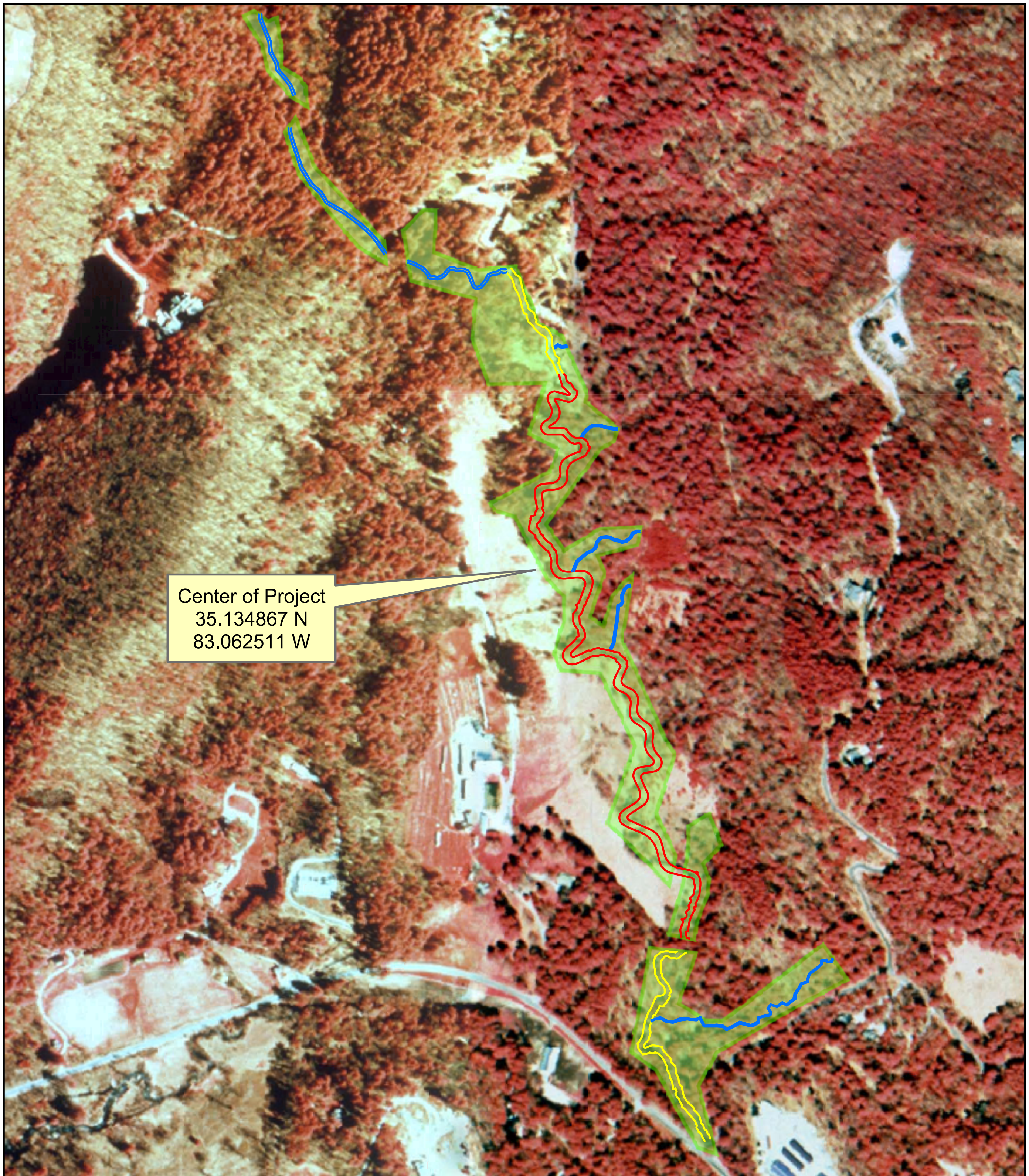
6.3 Design Parameters

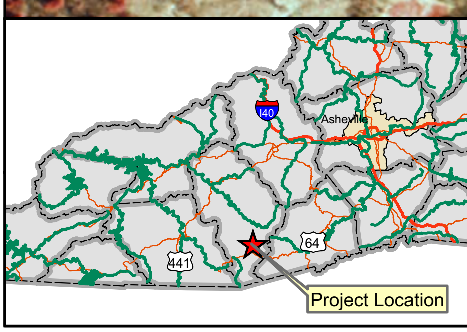
The primary objective of the restoration design is to construct a stream with a stable dimension, pattern, and profile that has access to its floodplain at bankfull flows while enhancing riparian and aquatic habitat. The philosophy applied by Baker through the Logan Creek project reach consisted of creating a low width-depth ratio C-type channel with the expectation that it will naturally adjust toward a narrower E-type channel over time as the riparian buffers become more established. The proposed design for the entire project reach is shown in Figure 6.1 and is presented in more detail on the plans.

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

Dimension

Throughout the entire proposed design, the cross-section dimensions were adjusted to reduce velocities and near-bank shear stress during storm flows. Channel width was designed to maintain velocities that will move small grain particles through the reach and avoid aggradation. The selected cross section dimensions provide access to the floodplain by storm flows greater than bankfull. The lower end of the width-depth ratio for an C-type channel was chosen (11.6) so that the channel may easily narrow to a lower width-depth E-type morphology over time. Low width-depth ratio channels maintain their steep banks by high root densities. They are difficult to construct due to having very little root mass immediately after construction, which results in high risk of instability in the short term. The proposed





Enhancement 1
Restoration
Preservation
Easement

0 300 600 Feet

N

Fig 6.1 Proposed Stream Design

Logan Creek Stream Restoration

Ecosystem Enhancement Program

Baker

channel has low sloping banks that are more stable and will allow for sediment build up and plant colonization, leading to a future low width-depth channel. A low bank height ratio (BHR) of 1.0 was designed so the channel has access to the floodplain during events having flows in excess of bankfull. Typical cross sections are shown on the attached plan sheets.

Pattern

The proposed channel alignment on Reach 2 will decrease the stream length and thus sinuosity slightly; the stream length in Reaches 1 and 3 will be essentially unchanged. This reduction in stream length represents pattern changes that remove overly sinuous meanders. Higher meander width ratios on the restored channel were intended to allow for lateral dissipation of energy and provide a floodplain sufficient for future natural channel development. A wide range of radii of curvature was utilized in the design to allow for connecting to sections of existing channel, to avoid as many large trees as possible and to provide diversity of pattern. Plan views of the main channel are shown on the attached plan sheets.

Profile/Bedform

Although moderately functional and somewhat stable, the channel profile of the existing mainstem is lacking sufficient overall bedform diversity. During the construction of the proposed channel, cross section dimensions will be achieved first, followed by structure placement and facet development to mimic characteristics of the reference conditions. Average channel slope for the total reach is .0035 which is a decrease from the existing reach-wide slope of .0047. This reflects the change in channel length. Riffles throughout the design reaches are between .6 and 2.0 times the average slope of the channel. The low riffle slopes are associated with connecting to existing ground sections were profile will not change. Design riffle slopes are usually between 1.5 and 2 times average slope. The maximum pool depth is proposed to be constructed from five feet upstream of the meander curve apex to a point 10 feet along the profile from the apex were a glide will begin to the head of the next riffle. Structural modifications to the existing profile will be done primarily with log structures rather than rock structures because large rock is fairly rare in this channel and large woody debris is common.

Design Reaches

A stable cross-section will be achieved by narrowing the channel where it is over-wide and laterally unstable and decreasing the width/depth ratio. In other sections stability will be enhanced by achieving a cross-section with banks that are low sloping to bankfull and the sinuosity will be increased by adding meanders to lengthen the channel and increase the area of deep water habitat. Grade control at the bed is not a major concern at this site due to the very low slope of the valley and the occasional presence of bedrock knick points. A variety of in-stream log structures will be used to enhance stability and improve habitat. These structures include log cross-vanes, log vanes, log step structures and randomly embedded logs. Bioengineering and in-stream structures will be used at the outside of meander bends (including root wads, vegetated geo-lifts, bunkers, log vanes and cover logs) to promote additional bank stability and improve habitat.

Reach 1, a 450-LF reach, is designed as a Rosgen C4 stream type, having a low slope and minimal meandering. Due to the constraints of the adjacent wetlands on the right bank and a hill slope on the left bank, pattern will not be changed through this reach. A variety of in-stream structures will be installed in this reach including log cross vanes, log vanes, and log steps that will serve to center the thalweg, improve sediment transport and improve habitat quality.

Reach 2 is approximately 3,140 LF in length (not including sections excluded from the easement) and begins at the point where Reach 1 ends. This reach, designed as an C4-type stream, involves Restoration level work with the construction of a new sinuous channel that meanders back and forth across the existing channel and utilizes short sections of the existing channel. Sinuosity through this reach was designed to avoid as many existing large trees as possible. At two different locations along the proposed channel the design alignment will abandon existing small radius meander bends that are flowing up-valley (area of 15+50 and 19+00). The plan also changes the alignment along a section (area of 30+50 to 32+00) that presently has flows against a steep and high (10 foot) right bank where erosion causes a constant sedimentation problem. Meanders through this reach will be stabilized using vegetated geo-lifts, rootwad revetments or bunkers. These structures may also include cover logs and transplanted vegetation on the banks. Riparian vegetation will be managed to improve diversity of deeply rooted species.

The final 1,000 LF of the project, Reach 3, begins below Reach 2 and an area excluded because of a road crossing and continues to the end of the project at US 64. The reach will be not have the pattern altered significantly. Alterations to dimension and profile will be those that reduce stream width, improve sediment transport and improve aquatic habitat. To this end a variety of in-stream structures will be installed in this reach including log cross vanes, log vanes, and a hanging cover log.

Table 6.2 presents the proposed stream restoration design criteria applied through the project reach.

Table 6.2
Design Parameters and Proposed Geomorphic Characteristics

	Design Reaches	
	Min	Max
1. Stream Type	E4	
2. Drainage Area – square miles	2.67	
3. Bankfull Width (w_{bkf}) – feet	26	
4. Bankfull Mean Depth (d_{bkf}) – feet	2.25	
5. Width/Depth Ratio (w/d ratio)	11.6	
6. Cross-sectional Area (A_{bkf}) – SF	58.5	
7. Bankfull Mean Velocity (v_{bkf}) - fps	3.08	
8. Bankfull Discharge (Q_{bkf}) – cfs	180	
9. Bankfull Max Depth (d_{mbkf}) - feet	4.0	
10. d_{mbkf} / d_{bkf} ratio	1.78	
11. Low Bank Height to d_{mbkf} Ratio	1.0	
12. Floodprone Area Width (w_{fpa}) – feet	150	
13. Entrenchment Ratio (ER)	5.8	
14. Meander length (L_m) – feet	118	236
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	4.54	9.1
16. Radius of curvature (R_c) – feet	27.5	75
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	1.06	2.88
18. Belt width (w_{blt}) – feet	65	140
19. Meander Width Ratio (w_{blt}/W_{bkf})	2.5	5.38
20. Sinuosity (K) Stream Length/ Valley Distance	1.30	
21. Valley Slope – feet per foot	.0047	
22. Channel Slope ($s_{channel}$) – feet per foot	.0035	
23. Pool Slope (s_{pool}) – feet per foot	.001	
24. Maximum Pool Depth (d_{pool}) – feet	6.0	
25. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	1.5	
26. Pool Width (w_{pool}) – feet	29	
27. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	1.12	
28. Pool Area (A_{pool}) – square feet	99	
29. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.13	
30. Pool-to-Pool Spacing – feet	94	165
31. Ratio of Pool-to-Pool Spacing to Bankfull Width (p-p/w_{bkf})	3.6	6.3
32. Riffle Slope [(4(] (s_{riffle}) – feet per foot	.003	.007
33. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	0.9	2.0

6.4 Sediment Transport

6.4.1 Methodology

The purpose of a sediment transport analysis is to ensure that the stream restoration design creates a stable channel that does not aggrade or degrade over time. The overriding assumption is that the project reach should be transporting all the sediment delivered from upstream sources, thereby being a "transport" reach.

Sediment transport is typically assessed by computing channel competency, capacity, or both. Sediment transport competency is a measure of force (lbs/ft2) that refers to the stream's ability to move a given grain size. Quantitative assessments include shear stress, tractive force, and critical dimensionless shear stress. Since these assessments help determine a size class that is mobile under certain flow conditions, they are most important in gravel bed studies in which the bed material ranges in size from sand to cobble (of which only a fraction are mobile during bankfull conditions). In most sand and small gravel-bed systems, all particle sizes have potential during bankfull flows; therefore, there is no need to determine the maximum particle size that the stream can transport. Comparing the design shear stress values for a project reach to those for the existing conditions in a system allows a quantitative determination of reduction of erosive forces.

6.4.2 Sediment Transport Analysis and Discussion

Existing channel form and sediment composition data, design data, hydraulic and sediment transport models, design spreadsheets, and best judgment were used to perform sediment transport analyses for Logan Creek. The small particle size makes sediment competence analysis secondary to sediment capacity.

Adequate sediment transport capacity analysis provides confidence in the capability of the design to transport a long-term balanced volumetric sediment load through all segments of the restoration reach. A design incorporating sediment transport results has a higher likelihood of maintaining its vertical stability while adjusting within stable limits to watershed and in-stream changes.

The existing project reach was modeled in HEC-RAS 4.0 (US Army Corps of Engineers 2006). The HEC-RAS sediment transport module incorporates sediment distribution data from field samples to estimate the concentration of sediment moving during design flow conditions based on the results of the water surface profile and velocities produced by the physical characteristics of the channel and floodplain. The result is a volumetric sediment discharge (or capacity) for the chosen design flow rate.

Subpavement (or bulk) samples from point bar and mid-channel bar locations were used to determine the sediment distributions for sediment transport (Table 3.2). Appendix G contains cumulative frequency graphs for all sediment samples used in the sediment transport analyses. Project reaches have median particle sizes ranging from fine to medium size gravel. Design sediment sizes used in transport capacity analyses were D_{16}=0.7 mm, D_{50}=2.7 mm, and D_{84}=14mm. The analyses were also checked for sensitivity to design sediment; transport capacity had an acceptably small sensitivity to the variations in distribution exhibited in the sediment samples.

Volumetric sediment discharge was analyzed at existing stable cross-sections in the project reach. These reference cross-sections are used to determine what the design sediment flow rate should be. The stable channel design module within HEC-RAS allows the modeler to incorporate design sediment discharge and design flow rate data in order to produce dimensions and energy slopes which will capably transport the sediment and water. Various combinations of channel cross-section and profile were assessed for their capability to move the design sediment discharge. These stable dimensions and slopes were incorporated into the typical riffle cross-section and design slope of the project.

While sediment competency is not considered to be a significant concern due to the presence of primarily sand and small gravel sediment sizes, a design depth capable of moving the largest sediment particles in the channel was determined. Sediment transport competency is measured in terms of the relationship between critical and actual depth at a given slope, and it occurs when the critical depth produces enough shear stress to move the largest (d_{100}) subpavement particle. As shown in Table 6.2, the critical design depth is 1.4 feet, and the critical slope is 0.00229 feet per foot. The design depth is 2.25 feet and the proposed slope is 0.0032 feet per foot. As a second check of sediment transport competency, boundary shear stress was plotted on Shield's curve to estimate the largest moveable particle. The Shield's curve predicts the mobility of particles larger than the d_{100} observed in the subpavement. Both of these sediment transport competency analyses confirm the ability of the design channel to transport the sediment load, not surprising for a sand and small gravel system

6.5 In-Stream Structures

A variety of in-stream structures are proposed for the Logan Creek site. Structures such as root wads, log cross-vanes and log vanes, and bioengineering measures such as geolifts will be used to stabilize the newly-restored stream. Wood (as opposed to rock)structures will primarily be used on this site because that is the material observed in the existing system and it is being generated by the development in the watershed and during the channel construction process. Table 6.3 summarizes the use of in-stream structures at the site.

Table 6.3
Proposed In-Stream Structure Types and Locations

Structure Type	Location
Log J-hook Vane	Riffles to turn water off of the stream bank and provide convergence for habitat improvement.
Log Step	Riffles for habitat diversity.
Root Wad	Outside bank of meander bends for stability and habitat.
Log Cross Vane	Straight sections to reduce stream width, center thalweg and improve habitat.
Hanging Cover Log	Riffles to create pool habitat.
Root Wad and Log Sill	Riffles for grade control and pool habitat.
Embedded Logs	Primarily riffles to improve habitat diversity.
Bunker	In meander bends for stability and habitat improvement
Vegetated Geo-lift	Outside meander bends for stability and vegetative cover.
Cover Log	In pools to provide habitat features.
Log Vane	In meander bends to turn water provide minimal pool habitat.

Log J-hook Vane

A log J-hook vane serves that same purposes and is constructed in the same manner as the log vane. The difference is that at the end of the vane arm a "comma" shaped series of rocks is placed in the channel to promote convergence of flow and scouring of the bed. This modification to the log vane promotes pool formation and habitat improvement. One of these structures will be constructed in Reach 2.

Log Step

A log step is used to enhance habitat and bed form diversity through longer riffle reaches. Log steps are constructed from 20-30 foot long logs with the rootwad attached. The length of a single log is laid across and upstream on the channel and spans the channel width. A series of two to four logs are installed to provide the bed diversity desired. A log step series is planned at one location on Reach 1, at two locations on Reach 2 and at 1 location on Reach 3.

Root Wad

Root wads are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also increase substate surface area for aquatic insects and other benthic organisms. Root wads will be placed throughout Reach 2 of the Logan Creek project and at one location on both Reach 1 and Reach 3.

Log Cross Vane

Cross vanes are used to provide grade control, keep the thalweg in the center of the channel, promote channel narrowing and protect the stream bank. A cross vane consists of two log vanes joined by a center structure installed perpendicular to the direction of flow. This centering structure sets the invert elevation of the stream bed. One of these structures will be placed in each of the project reaches to center the thalweg and promote stream narrowing.

Hanging Cover Log

This structure is new and is being tried at one location in Reach 3. It is designed to act like a tree that has fallen across the channel. It will be tied into the bank on one side of the channel and will rise to rest at bankfull on the far side of the channel. When a log hangs over the channel in this fashion it causes pressure and scour on the bed below the hanging cover log. This should help move sediment through this reach and create pool habitat in an area that now has a shallow sand bed.

Rootwad and Log Sill

Log sills consist of a footer log placed in the bed of the stream channel, perpendicular to stream flow. The logs extend into the stream banks on both sides of the structure to prevent erosion and bypassing of the structure. The logs are installed flush with the channel bottom upstream of the log. The footer log is placed to the depth of scour expected, to prevent the structure from being undermined. Rootwads are added into both left and right banks immediately below the sill to narrow the convergence zone, extend the pool and support the sill. Log sills provide bedform diversity, maintain channel profile, and provide pool and cover habitat. One of these structures will be installed in Reach 1 and two in Reach 3.

Embedded Logs

Embedded log placement is proposed in riffle areas throughout the project. Some specific sites have been identified for installation of these structures, but additional sites may be determined in the field as opportunities arise. The woody structure placement produces lateral and vertical flow diversity at low flows. At bankfull flows, the logs serve as energy dissipation features, adding to the overall bed roughness and providing local downstream eddy and scour pool microhabitat.

Bunker

Bunkers are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. The base is constructed like a rootwad installation with the logs placed at or just below water level. Behind the rootwad and on the logs a deck is constructed of treated wood or small tree trunks. This is covered with a geo-textile and filled to the bankfull elevation. This structure provides an artificial undercut bank that benefits fisheries, particularly trout fisheries. Bunkers will be placed throughout Reach 2.

Vegetated Geolift

Soil lifts of 1.0 to 1.5 feet thick are constructed on a stone base. The lift is filled and compacted to the appropriate depth and is then wrapped with coir matting. A second layer of matting is laid down and fill is compacted on it to the appropriate depth and then wrapped. This continues until the desired elevation is reached. Vegetation can then be planted directly into the lifts as either live stakes or rooted material. Vegetated geolifts help to establish vegetation on the bank to secure the soil. Once the vegetation is established, the branches also provide cover and food for wildlife. Vegetated geolifts will be placed throughout Reach 2 of the Logan Creek project.

Cover Log

A cover log is placed in the outside of a meander bend to provide habitat in the pool area. The log is buried into the outside bank of the meander bend; the opposite end extends through the deepest part of the pool and may be buried in the inside of the meander bend, in the bottom of the point bar. The placement of the cover log near the bottom of the bank slope on the outside of the bend encourages scour in the pool. This increased scour provides a deeper pool for bedform variability. Cover logs will be used throughout Reach 2 in association with vegetated geolifts.

Log Vane

A 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 typically located just downstream of the point where the stream flow intercepts the bank at acute angles. Log vanes will be placed throughout the Logan Creek project.

6.6 Flood Modeling

A HEC-RAS model was built from the existing conditions survey to evaluate how bankfull indicators aligned with the bankfull discharge and to evaluate sediment transport as explained in sections 3.4 and 6.4. However, proposed conditions have not been modeled at this point in project planning to determine how the project might affect flooding. It is unknown whether further study will be required by the local floodplain manager, but Baker will be consulting with that office to determine what they will require.

According to the FEMA Flood Insurance Rate Map (FIRM) for Jackson County, NC, (Panel Number 3702820175C) the lower two thirds of the project reach is within a regulatory floodplain, zone A (Figure 2.3). While flood modeling is not required for zone A areas, Baker will use the proposed alignment and typical sections for modeling in HEC-RAS to determine what impact the proposed design may have on flooding. No insurable structures are in the area of the stream project and any change in the 100-year water surface is expected be minimal.

6.7 Natural Plant Community Restoration

Native riparian vegetation will be established in the restored stream buffer. Also, any areas of invasive vegetation such as multiflora rose and Japanese honeysuckle will be eradicated so as not to threaten the newly-established native plants within the conservation easement.

6.7.1 Rhododendron Control

The riparian buffer along the upper part of the Reach 2 has a very thick stand of *Rhododendron maximum.* The density of the 10 to 15 foot high shrubs is having an adverse impact on the riparian zone and stream channel of Logan Creek. The dense stands of evergreen rhododendron appear to be shading out small trees that attempt to germinate and grow under their canopy. This has resulted in a forest with a few large, older trees but few young trees to replace them. Aquatic populations depend on inputs of large woody debris so any factor that limits the growth of tree species is detrimental to the overall health of the system (Flebbe and Dolloff 1995). This has impacted the stability of the creek banks because rhododendrons are a shallow rooted species. They do not create the root mass needed to provide stability to the stream banks and they are out-competing more deeply rooted tree species. As limbs from the plants die and fall into the channel or when plants are washed out of the banks they form dense debris jams that further increase channel instability. Rhododendrons are also a less desirable stream side species because their leaves do not easily decompose, limiting their support of aquatic food chains.

Riparian buffer management along this reach will include reducing the density of rhododendron within 20 feet of the stream bank. We will cut back the existing plants within this area and mechanically remove unwanted plants. Many of these will be transplanted to other areas along the channel; however, some will be destroyed. Other more low growing species, such as yellow root and dog hobble, will be planted or transplanted to this area. We will also plant tree species that will grow to varying mature heights within this buffer area. The long-term goal of this management plan is to increase vegetative diversity within the buffer zone, increase stream bank stability with deeply rooted species and promote the growth of species that will provide shade, high quality leaf litter and terrestrial wildlife habitat.

6.7.2 Stream Buffer Vegetation

A 30-foot buffer measured from the top of banks (sometimes slightly less and quite often, substantially more, average 45 feet) will be established along the restored stream reaches. This buffer area will be protected by a conservation easement. Plantings in the buffer area will include bare-root, balled and burlap, seedlings and transplanted trees and shrubs. Vegetation will be planted at a target density of 500 stems per acre, with trees being planted on a minimum 10-foot spacing and shrubs on a 6-foot spacing. Live stakes will also be planted along the stream banks on a 3-foot spacing. The proposed species to be planted are listed in Table 6.4. 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 US Army Corps of Engineers (Corps) Wetland Research Program (WRP) Technical Note VN-RS-4.1 (1997). Tree species selected for stream restoration areas will be generally 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 at least three feet apart using triangular spacing at a density of 60 to 100 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. Transplanted material may be used in the place of live stakes when possible.

Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 6.5 lists the species, mixtures, and application rates that will be used. Mixtures will include temporary seeding (rye grain or browntop millet). The permanent seed mixture will be applied to all disturbed areas 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 streambanks, access roads, side slopes, and spoil piles. Temporary seeding will done with a millet species, most likely browntop, applied at a rate of 40 pounds per acre.

Table 6.4
Proposed Bare-Root and Live Stake Species

Common Name	Scientific Name
Stream Restoration and Enhancement Areas- Zone 1 (>15' from top of bank)	
Persimmon	*Diospyros virginiana*
Tulip Poplar	*Liriodendron tulipifera*
Green ash	*Fraxinus pennsylvanica*
Black walnut	*Juglans nigra*
Sycamore	*Platanus occidentalis*
Willow Oak	*Quercus phellos*
Swamp chestnut oak	*Quercus michauxii*
Blackgum	*Nyssa salvatica*
Alternate Species	
River Birch	*Betula nigra*
Sugarberry	*Celtis laevigata*
Redbud	*Cercis canadensis*
Flowering dogwood	*Cornus florida*
Southern red oak	*Quercus rubra*
Red Maple	*Acer rubrum*
Witch Hazel	*Hamamalis virginiana*
Alternate-leaved Dogwood	*Cornus alternifolia*
Stream Restoration Buffer- Zone 2 (<15' from top of bank)	
Redbud	*Cercis canadensis*
Silky dogwood	*Cornus amomum*
Flowering dogwood	*Cornus florida*
Tag alder	*Alnus serrulata*

Table 6.4 Proposed Bare-Root and Live Stake Species	
Common Name	**Scientific Name**
Paw paw	*Asimina triloba*
Silky willow	*Salix sericea*
Elderberry	*Sambucus canadensis*
Arrow-wood viburnum	*Viburnum dentatum*
Alternate Species	
Ninebark	*Physocarpus opulifolia*
Black haw viburnum	*Viburnum prunifolium*
Canada Hemlock	*Tsuga canadensis*
White Pine	*Pinus strobus*
White Oak	*Quercus alba*
Pignut Hickory	*Carya glabra*
Cherry Birch	*Betula lenta*
Black Cherry	*Prunus serotina*
Shrubs	
Possomhaw	*Viburnum cassinoides*
Black Huckleberry	*Gaylussacia baccata*
Mountain Holly	*Ilex Montana*
Buffalo Nut	*Pyrularia pubera*
Rosebay Rhododendron	*Rhododendron maximum*
Mountain Laurel	*Kalmia latifolia*
Dog Hobble	*Leucothoe fontanesiana*
Swamp Azalea	*Rhododendron viscosum*
Smooth Azalea	*Rhododendron arborescens*
Yellow Root	*Xanthorhyza simplicissima*
Cinnamon Clethra	*Clethra acumunata*
Mountain Hydrangea	*Hydrangea arborescens*
Southern Bush Honeysuckle	*Diervilla sessilifolia*
Hardhack	*Spirea tomentosa*
Streambanks (Live Stakes)	
Silky dogwood	*Cornus amomum*
Silky willow	*Salix sericea*
Elderberry	*Sambucus canadensis*
Note: Species selection may change due to availability at the time of planting.	

Table 6.5
Proposed Permanent Seed Mixture

Common Name	**Scientific Name**	**Percent of Mixture**
Bull Rush	*Scirpus cyperinus*	5%
Redtop	*Agrostis alba*	15%
Fox Sedge	*Carex vulpinoidea*	10%
Virginia Wild Rye	*Elymus virginicus*	20%
Soft Rush	*Juncus effisus*	5%
Deer Tongue	*Panicum clandestinum*	10%
Smartweed	*Polygonum pennsylvanicum*	5%
Beggers Ticks	*Bidens frondosa*	5%
Lance leafed Coreopsis	*Coreopsis lancolata*	15%
Partridge Pea	*Cassia fasciculata*	5%
Wingstem	*Verbesina alternifolia*	5%
Note: Species selection may change due to availability at the time of planting.		

6.7.3 On-site Invasive Species Management

The site has some limited stands of multiflora rose (*Rosa multiflora*), and Japanese honeysuckle (*Lonicera japonica*) on the floodplains along Logan Creek. These stands will be mechanically removed during construction and destroyed. These populations will be monitored to evaluate if they begin to reestablish. If these species persist after removal, individual plants will be treated with a direct application of herbicide and monitored to insure they are completely eradicated. Areas of infestation by these invasive species will be monitored to insure they do not threaten the newly-planted riparian vegetation by becoming reestablished.

7.0 PERFORMANCE CRITERIA

The Baker team has been involved in obtaining recent approvals from the regulatory agencies for a series of mitigation and restoration plans for wetland and stream 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 numerous NCEEP full deliver projects, as well as the Stream Mitigation Guidelines issued in April 2003. Specific success criteria components are presented below.

7.1 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 document project success.

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

7.1.1 Bankfull Events

The occurrence of bankfull events within the monitoring period will be documented by the use of a crest gage and photographs. The crest gage will be installed on the floodplain within 10 feet of the restored channel. The crest gage will record the highest watermark between site visits, and the gage will be checked 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.

7.1.2 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.

7.1.3 Longitudinal Profile

A longitudinal profile will be surveyed immediately after construction and once every year thereafter for the duration of the five-year monitoring period. The as-built survey will be used as the baseline for year one monitoring. Representative 3,000 LF segments of the restored Logan Creek project reach will 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.

7.1.4 Bed Material Analyses

Pebble counts will be conducted for at least six permanent cross-sections (100-counts per cross-section) for each project reach. Pebble counts will be conducted immediately after construction and at a two-year interval thereafter at the time the longitudinal surveys are performed (years three and five) throughout the five year monitoring period. Pebble count data will be plotted on semi-log paper and compared with data from pervious years.

7.1.5 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 at each grade control structure along the restored stream, limited to cross-veins and weir structures. Photographers should 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.

7.2 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 number of quadrants required will be based on the species/area curve method, with a minimum of three quadrants. 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.

7.3 Benthic Monitoring

If required by NC DWQ as part of the permitting requirements of the project, benthic macroinvertebrate sampling will be conducted on the restored site after one year of construction and every two years thereafter (years three and five) throughout the five year monitoring period. Appropriate sampling methodologies will be based on current sampling protocols approved by the NCDWQ.

7.4 Maintenance Issues

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

- Projects without established, woody floodplain vegetation are more susceptible to erosion from floods than those with a mature, hardwood forest.
- Projects with sandy, non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- 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.

7.5 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.

8.0 REFERENCES

Brinson, M. M. 1993. A hydrogeomorphic classification for wetlands. US Army Corps of Engineers, Waterways Exp. Stn. Tech. Rep. WRP-DE-4. Washington, DC. 79 pp. + app.

Copeland, R.R, D.N. McComas, C.R. Thorne, P.J. Soar, M.M. Jones, and J.B. Fripp. 2001. United States Army Corps of Engineers (USACOE). Hydraulic Design of Stream Restoration Projects. Washington, DC.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream corridor restoration: Principles, processes and practices. National Technical Information Service. Springfield, VA.

Flebbe, P.A., C.A. Dolloff. 1995. Trout Use of Woody Debris and Habitat in Appalachian Wilderness Streams of North Carolina. North American Journal of Fisheries Management. 15:579-590.

Goldsmith, R., Milton, D.J., and Horton, J.W. 1985. Geologic Map of the Charlotte 1° x 2° Quadrangle, North Carolina and South Carolina. USGS Map I-1251-E, 3p.

Hadley, J.B. and Nelson, A.E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-654, scale 1:250000. http://ngmdb.usgs.gov/Prodesc/proddesc_9432.htm

Harman, W.A., D.E. Wise, M.A. Walker, R. Morris, M.A. Cantrell, M. Clemmons, G.D. Jennings, D. Clinton, and J. Patterson. 2000. Bankfull regional curves for North Carolina mountain streams. In Proc. AWRA Conf. Water Resources in Extreme Environments, Anchorage, Alaska, ed. E.L. Kane, pp. 185-190. Middleburg, VA.: American Water Resources Association.

Lane, E. W. 1955. Design of stable channels. Transactions of the American Society of Civil Engineers. Paper No. 2776: 1234-1279.

North Carolina Geological Survey, 1985, Geologic map of North Carolina: North Carolina Department of Natural Resources and Community Development, scale 1:500000.

Reed, Jr., and Porter B. 1988. National List of Plant Species That Occur in Wetlands: National Summary. US Fish & Wildlife Service. Biol. Rep. 88(24). 244 pp.

Rosgen, D. L. 1994. A classification of natural rivers. *Catena* 22:169-199.

___. 1996. Applied River Morphology. Pagosa Springs, CO: Wildland Hydrology Books.

___. 1997. A geomorphological approach to restoration of incised rivers. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision. Wang, S.S.Y, E.J. Langendoen, and F.D. Shields, Jr., eds. 12-22.

___. 1998. The reference reach - A blueprint for natural channel design (draft). ASCE Conference on River Restoration. Denver CO. March, 1998. ASCE. Reston, VA.

___. 2001a. A stream channel stability assessment methodology. Proceedings of the Federal Interagency Sediment Conference. Reno, NV. March, 2001.

___. 2001b. The cross-vane, w-weir and j-hook vane structures…their description, design and application for stream stabilization and river restoration. ASCE conference. Reno, NV. August, 2001.

Schafale, M. P., and A. S. Weakley. 1990. Classification of the natural communities of North Carolina, third approximation. North Carolina Natural Heritage Program. Division of Parks and Recreation, NCDEHNR. Raleigh, NC.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. *Earth Surface Processes and Landforms* 14(1):11-26.

US Army Corps of Engineers. 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1. Environmental Laboratory. US Army Engineer Waterways Experiment Station. Vicksburg, MS.

US Army Corps of Engineers. 1997. Corps of Engineers Wetlands Research Program. Technical Note VN-rs-4.1. Environmental Laboratory. US Army Engineer Waterways Experiment Station. Vicksburg, MS.

U.S. Army of Corps of Engineers (2002). HEC-RAS Hydraulic Reference Manual, Version 3.1.0. Davis, CA: U.S. Army Corps of Engineers, Hydrologic Engineering Center.

US Department of Agriculture, Natural Resources Conservation Service (NRCS). 1997. Part 650, Chapter 19 of the NRCS Engineering Field Handbook: Hydrology Tools for Wetland Determination.

___. 1996. Field Indicators of Hydric Soils in the United States. G.W. Hurt, Whited, P.M., and Pringle, R.F., eds. Fort Worth, TX.

United States Department of Agriculture, Natural Resource Conservation Service (NRCS). Web Soil Survey of Rutherford County, North Carolina. http://websoilsurvey.nrcs.usda.gov/app/ WebSoilSurvey.aspx

Yang, C.T. 1973. "Incipient Motion and Sediment Transport," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 99, No HY10, October, 1973, pp 1679-1704.

Yang, C.T. 1984. "Unit Stream Power Equations for Gravel," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 110, No. 12, December, 1984, pp 1783-1797.

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Appendices