

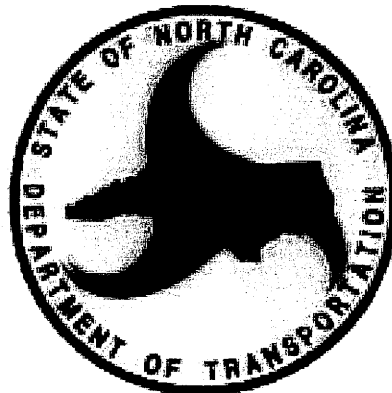
# **STREAM MITIGATION PLAN**

## **US HIGHWAY 19, R-2518B ON-SITE MITIGATION YANCEY COUNTY, NORTH CAROLINA**

WBS ELEMENT: 34445.3.1  
LSC NUMBER: 6300013251  
TIP NUMBER: R-2518WM

Prepared for:

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION  
PROJECT DEVELOPMENT AND ENVIRONMENTAL  
ANALYSIS BRANCH  
RALEIGH, NORTH CAROLINA



**FEBRUARY 2007**

## TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	GOALS AND OBJECTIVES.....	1
3.0	LOCATION INFORMATION.....	2
4.0	GENERAL WATERSHED INFORMATION.....	9
5.0	EXISTING CONDITIONS.....	10
6.0	FEDERALLY PROTECTED SPECIES.....	11
7.0	STREAM REFERENCE RESTORATION STUDIES.....	12
8.0	STREAM MITIGATION PLAN.....	14
9.0	STREAM PERFORMANCE CRITERIA AND MONITORING PLAN.....	16
10.0	MITIGATION SUMMARY.....	16
11.0	REFERENCES.....	16

## FIGURES

FIGURE 1.	VICINITY MAP
FIGURE 2A.	SOIL MAP SITE 1
FIGURE 2B.	SOIL MAP SITE 3
FIGURE 2C.	SOIL MAP SITE 4
FIGURE 2D.	SOIL MAP SITE 8
FIGURE 2E.	SOIL MAP SITE 11
FIGURE 2F.	SOIL MAP SITE 12
FIGURE 3.	COMPARISON OF REGIONAL CURVE INFORMATION FOR PROJECT REACHES

## TABLES

TABLE 1.	STREAM INFORMATION
TABLE 2.	SITE LOCATION INFORMATION
TABLE 3.	DRAINAGE AREAS FOR PROJECT REACHES
TABLE 4.	FEDERALLY PROTECTED SPECIES FOR YANCEY COUNTY
TABLE 5.	MITIGATION SUMMARY

## APPENDICES

APPENDIX A.	REFERENCE REACH STREAM DATA
APPENDIX B.	MORPHOLOGICAL CHARACTERISTICS OF PROPOSED STREAMS
APPENDIX C.	SEDIMENT TRANSPORT CALCULATIONS
APPENDIX D.	RIPARIAN PLANTING PLAN AND SPECIFICATIONS
APPENDIX E.	PHOTOGRAPHS

## 1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) plans to use on-site stream mitigation to offset unavoidable impacts to existing streams from the widening and relocation of US Highway 19 (R-2518B) in Yancey County. The mitigation project will provide approximately 85 linear meters (279 linear feet) of stream restoration, and 1,564 linear meters (5,131 linear feet) of stream enhancement in the French Broad River Basin.

The project involves six sites as shown in Figure 1. Twelve potential sites were initially identified during the project feasibility study; however, six of the sites were not pursued due to site limitations. The six remaining sites (Sites 1, 3, 4, 8, 11, and 12) are described in this document. The sites are located along the US Highway 19 corridor in Yancey County, between the Madison-Yancey County line at Ivy Gap east to Burnsville. The sites lie in the French Broad River watershed within North Carolina Division of Water Quality (NCDWQ) sub-basin 04-03-07. Sites 1, 3, 4 and 8 lie within US Geological Survey (USGS) hydrologic unit (HU) 06010108080020, while sites 11 and 12 lie within USGS HU 06010108070010.

All of the stream sites are shown as perennial blue-line streams on the USGS topographic quadrangle. The total existing length of project stream reaches is approximately 1,649 meters (5,410 feet). A summary of the stream locations, mitigation approaches, and lengths are provided in Table 1.

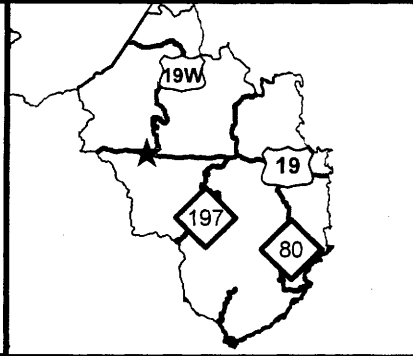
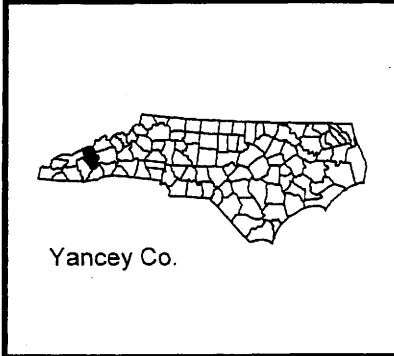
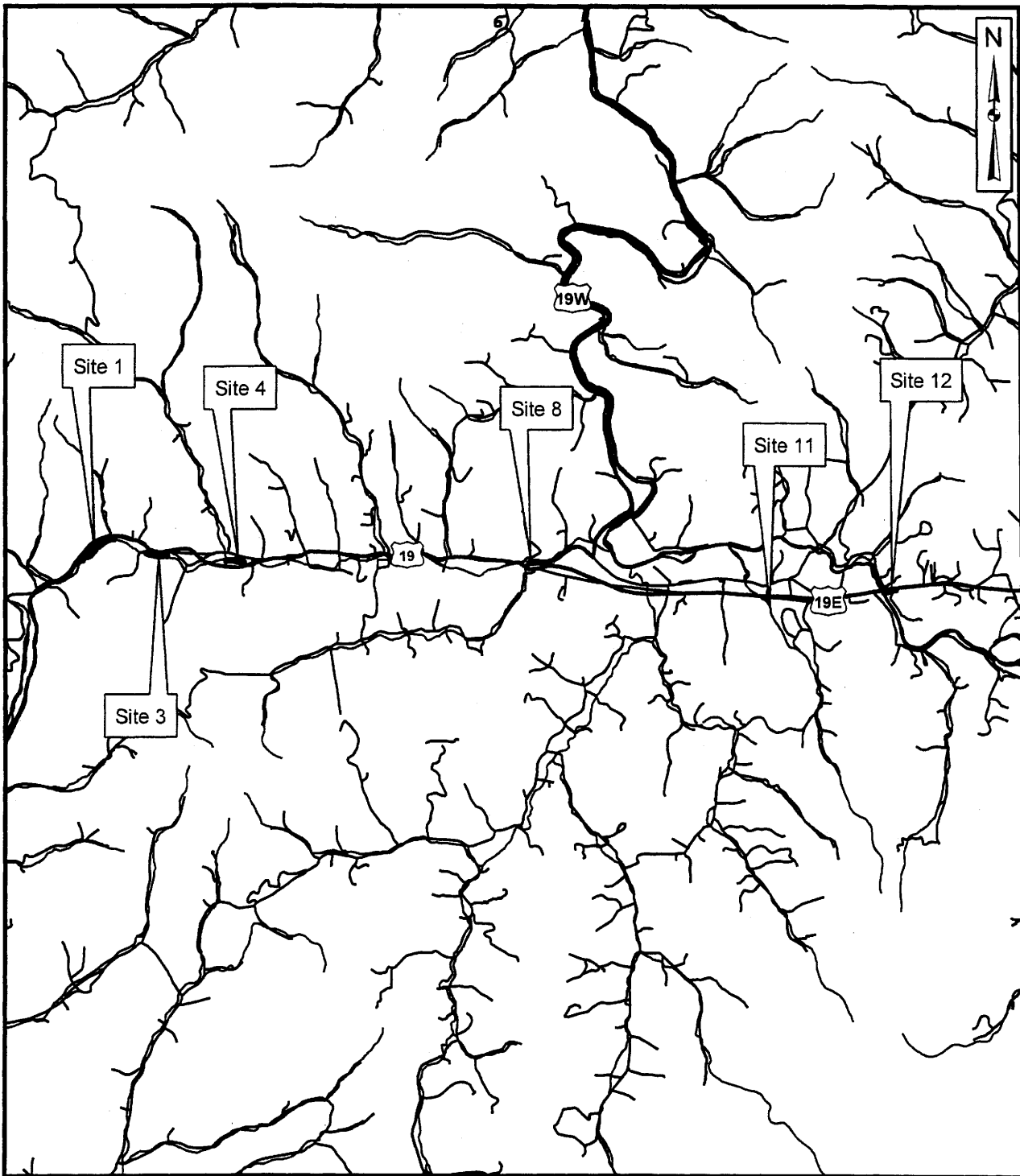
**TABLE 1. STREAM INFORMATION**

Mitigation Site	Approximate Road Stationing	Mitigation Type	Length (ft)
Site 1	114+50 to 120+10	Enhancement	533 (1,749)
Site 3	124+43 to 127+18	Enhancement	301 (987)
Site 4	135+60 to 138+05	Enhancement	248 (814)
Site 8	175+65 to 178+50	Enhancement	304 (997)
Site 11	207+64 to 208+50	Restoration	85 (279)
Site 12	223+66 to 225+46	Enhancement	178 (584)

## 2.0 GOALS AND OBJECTIVES

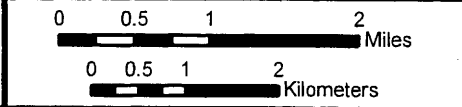
The specific goals for the R-2518B mitigation project are as follows:

















- Restore and/or enhance 1,649 meters (5,410 feet) of stream.
- Improve floodplain function by matching floodplain elevation with bankfull stage.
- Establish native stream bank and floodplain vegetation.
- Improve water quality in the French Broad River watershed by reducing sediment and nutrient inputs.
- Improve aquatic and riparian habitat by creating deeper pools and areas of re-aeration, planting a riparian buffer, and reducing bank erosion.

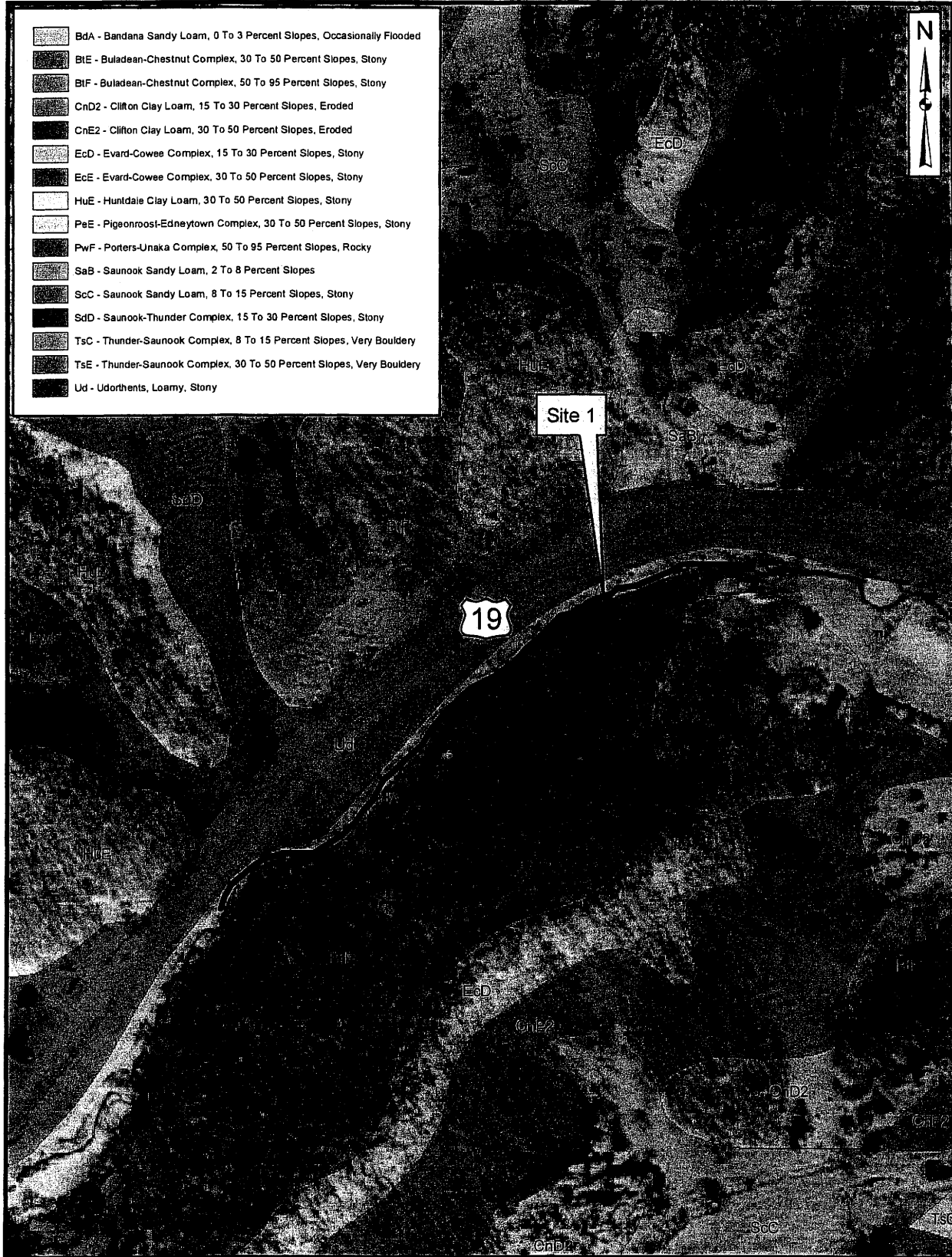



 Project Development and  
 Environmental Analysis Branch

Figure 1. Project Vicinity Map  
R-2518B



-  BdA - Bandana Sandy Loam, 0 To 3 Percent Slopes, Occasionally Flooded
-  BtE - Buladean-Chestnut Complex, 30 To 50 Percent Slopes, Stony
-  BtF - Buladean-Chestnut Complex, 50 To 95 Percent Slopes, Stony
-  CnD2 - Clifton Clay Loam, 15 To 30 Percent Slopes, Eroded
-  CnE2 - Clifton Clay Loam, 30 To 50 Percent Slopes, Eroded
-  EcD - Evard-Cowee Complex, 15 To 30 Percent Slopes, Stony
-  EcE - Evard-Cowee Complex, 30 To 50 Percent Slopes, Stony
-  HuE - Huntdale Clay Loam, 30 To 50 Percent Slopes, Stony
-  PeE - Pigeonroost-Edneytown Complex, 30 To 50 Percent Slopes, Stony
-  PwF - Porters-Unaka Complex, 50 To 95 Percent Slopes, Rocky
-  SaB - Saunook Sandy Loam, 2 To 8 Percent Slopes
-  ScC - Saunook Sandy Loam, 8 To 15 Percent Slopes, Stony
-  SdD - Saunook-Thunder Complex, 15 To 30 Percent Slopes, Stony
-  TsC - Thunder-Saunook Complex, 8 To 15 Percent Slopes, Very Bouldery
-  TsE - Thunder-Saunook Complex, 30 To 50 Percent Slopes, Very Bouldery
-  Ud - Udorthents, Loamy, Stony



Project Development and  
Environmental Analysis Branch

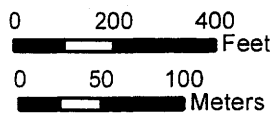
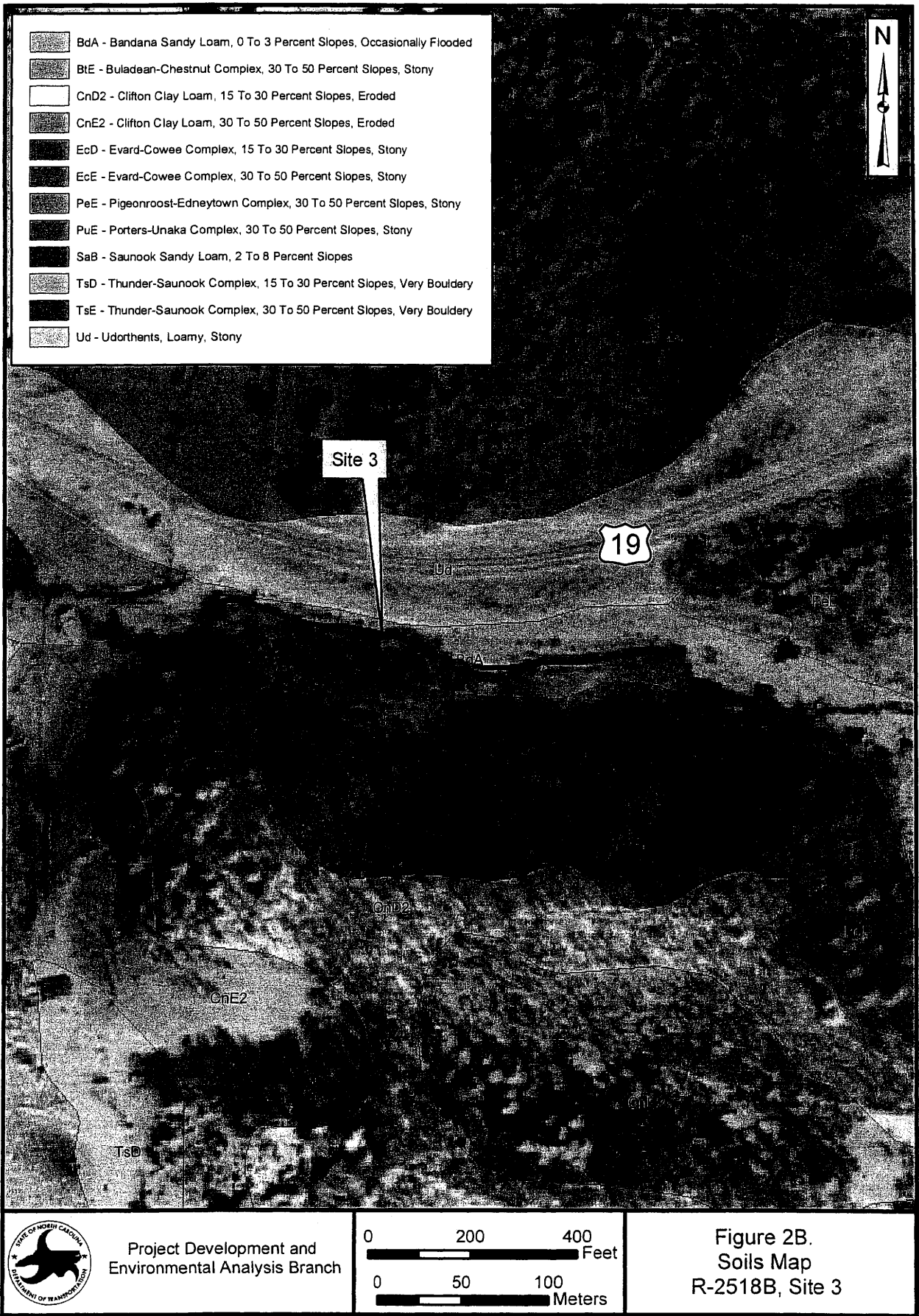
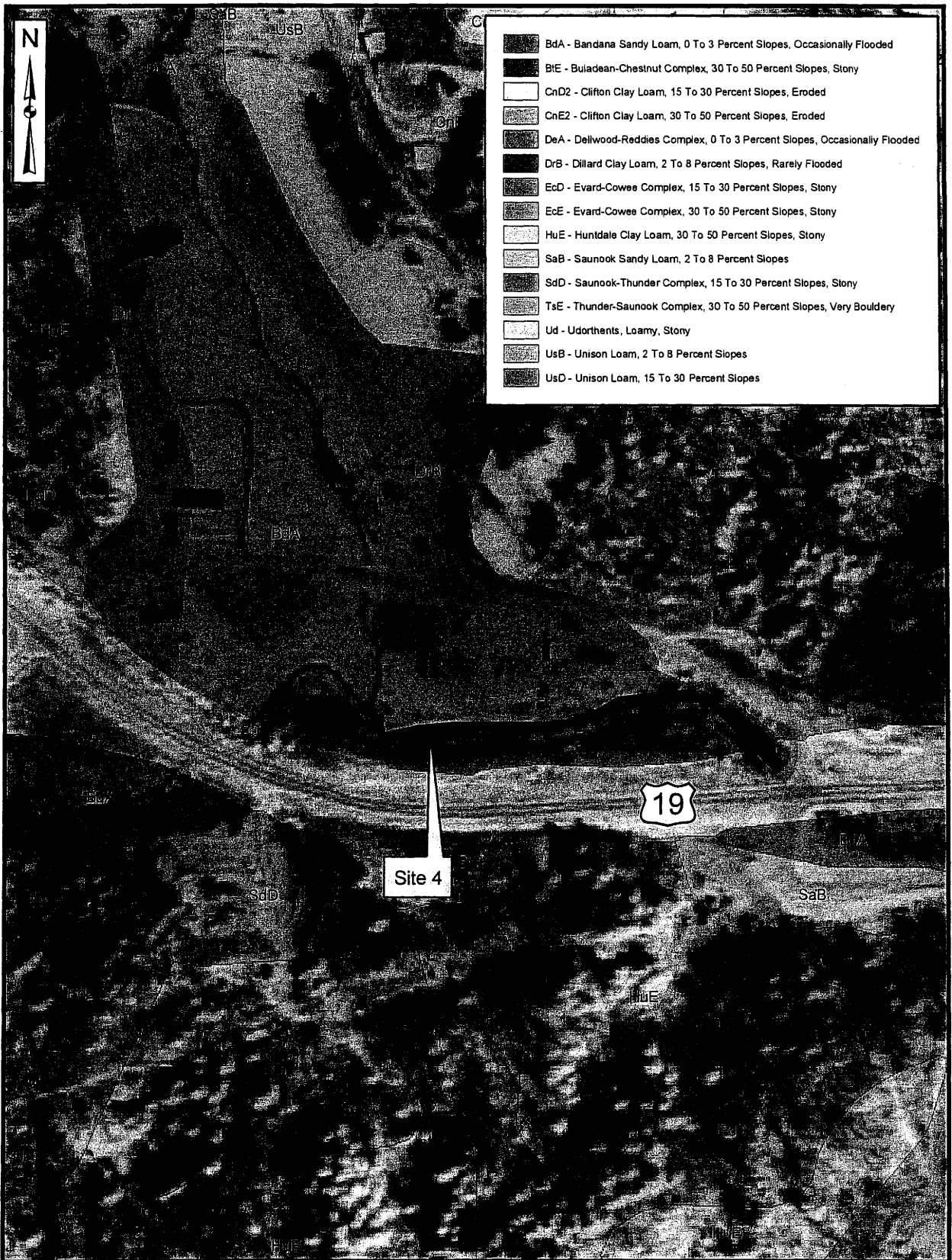



Figure 2A.  
Soils Map  
R-2518B, Site 1





- BdA - Bandana Sandy Loam, 0 To 3 Percent Slopes, Occasionally Flooded
- BiE - Buladean-Chestnut Complex, 30 To 50 Percent Slopes, Stony
- CnD2 - Clifton Clay Loam, 15 To 30 Percent Slopes, Eroded
- CnE2 - Clifton Clay Loam, 30 To 50 Percent Slopes, Eroded
- DeA - Dellwood-Reddies Complex, 0 To 3 Percent Slopes, Occasionally Flooded
- DrB - Dillard Clay Loam, 2 To 8 Percent Slopes, Rarely Flooded
- EcD - Evard-Cowee Complex, 15 To 30 Percent Slopes, Stony
- EcE - Evard-Cowee Complex, 30 To 50 Percent Slopes, Stony
- HuE - Hunt Dale Clay Loam, 30 To 50 Percent Slopes, Stony
- SaB - Saunook Sandy Loam, 2 To 8 Percent Slopes
- SdD - Saunook-Thunder Complex, 15 To 30 Percent Slopes, Stony
- TsE - Thunder-Saunook Complex, 30 To 50 Percent Slopes, Very Boulderly
- Ud - Udorthents, Loamy, Stony
- UsB - Unison Loam, 2 To 8 Percent Slopes
- UsD - Unison Loam, 15 To 30 Percent Slopes


 Project Development and  
 Environmental Analysis Branch

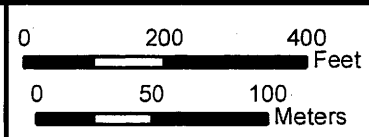
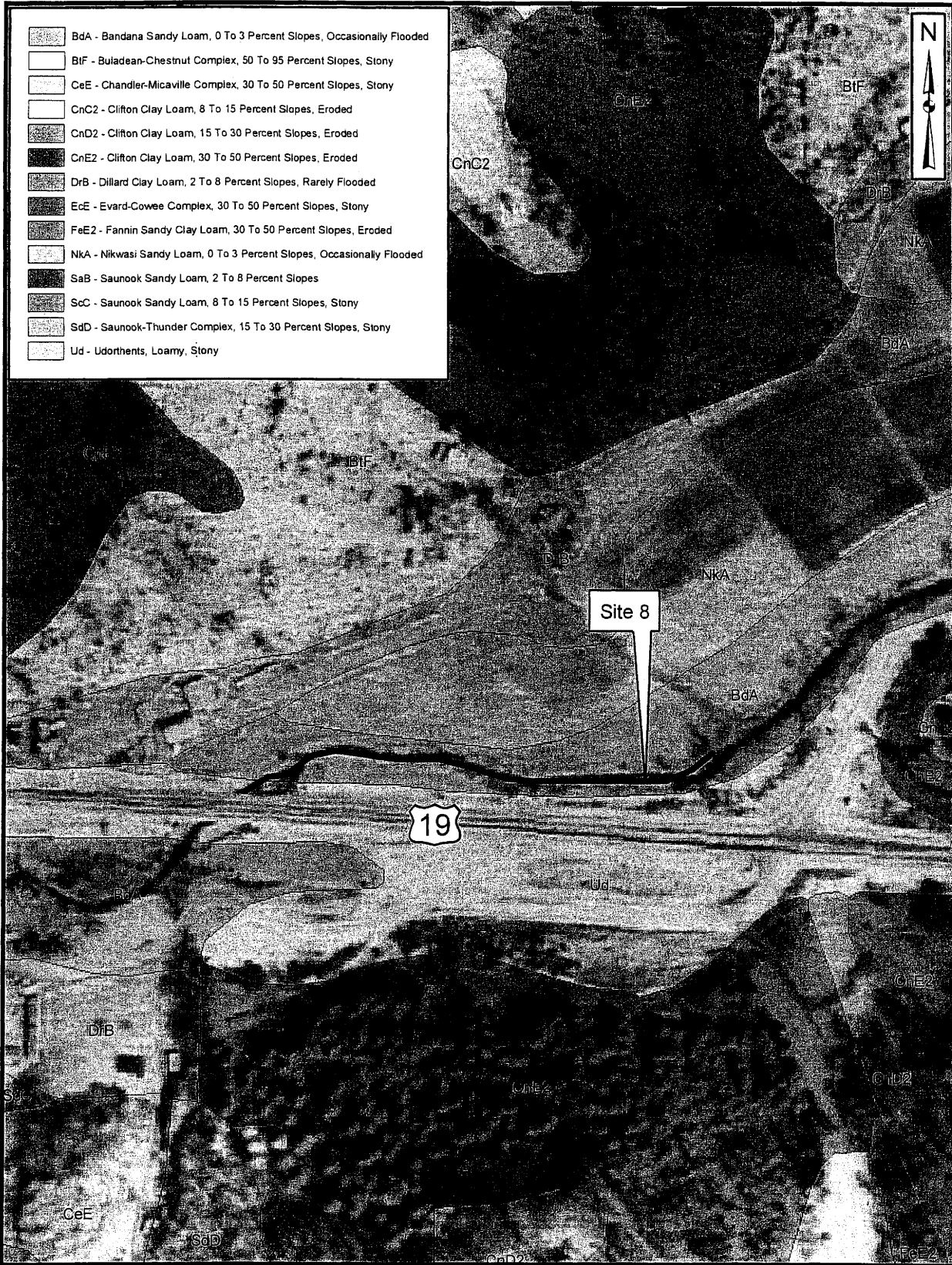
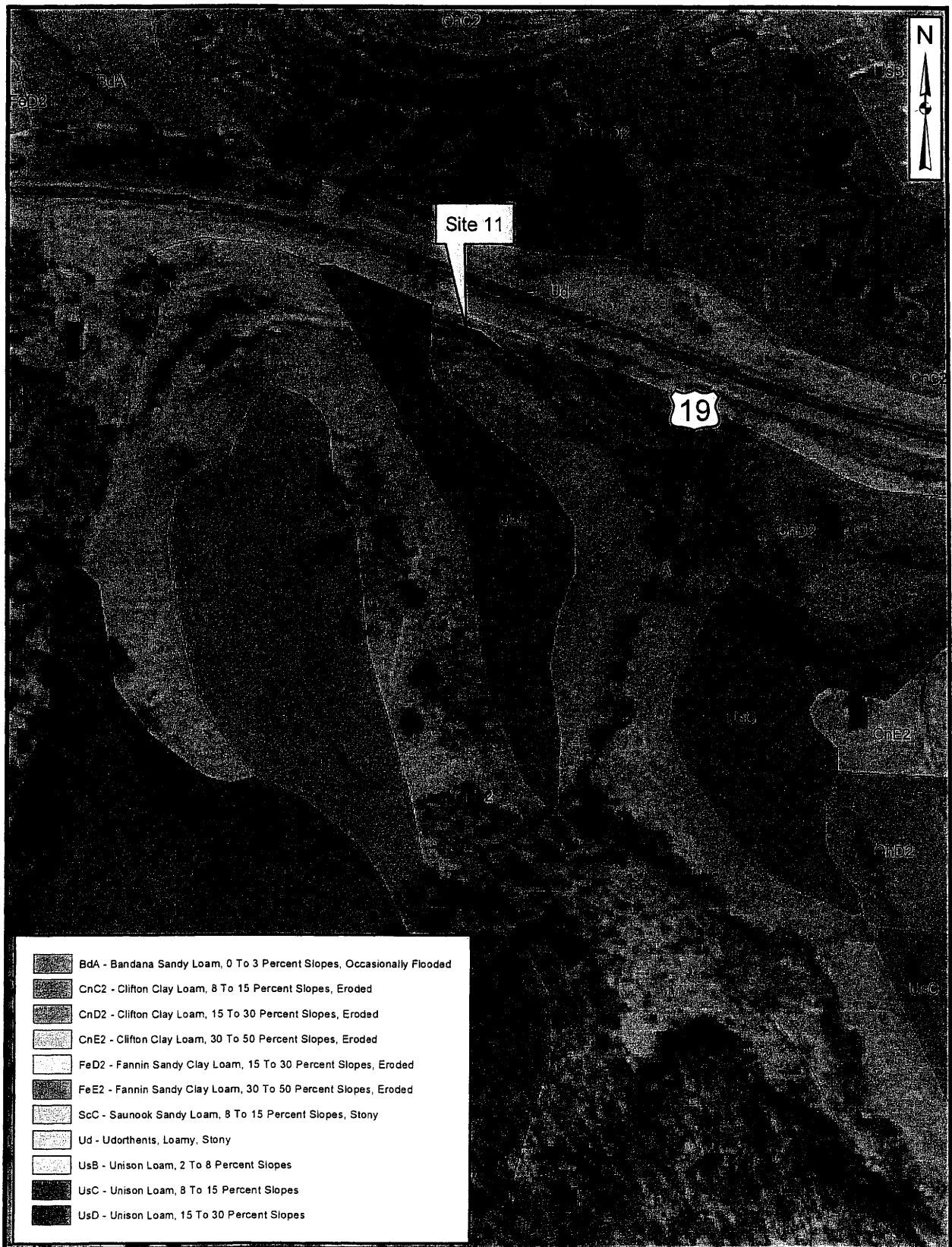













Figure 2C.  
 Soils Map  
 R-2518B, Site 4







-  BdA - Bandana Sandy Loam, 0 To 3 Percent Slopes, Occasionally Flooded
-  CnC2 - Clifton Clay Loam, 8 To 15 Percent Slopes, Eroded
-  CnD2 - Clifton Clay Loam, 15 To 30 Percent Slopes, Eroded
-  CnE2 - Clifton Clay Loam, 30 To 50 Percent Slopes, Eroded
-  FeD2 - Fannin Sandy Clay Loam, 15 To 30 Percent Slopes, Eroded
-  FeE2 - Fannin Sandy Clay Loam, 30 To 50 Percent Slopes, Eroded
-  ScC - Saunook Sandy Loam, 8 To 15 Percent Slopes, Stony
-  Ud - Udorthentis, Loamy, Stony
-  UsB - Unison Loam, 2 To 8 Percent Slopes
-  UsC - Unison Loam, 8 To 15 Percent Slopes
-  UsD - Unison Loam, 15 To 30 Percent Slopes



Project Development and  
Environmental Analysis Branch

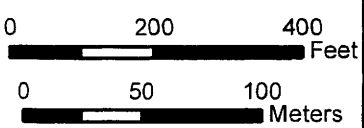

















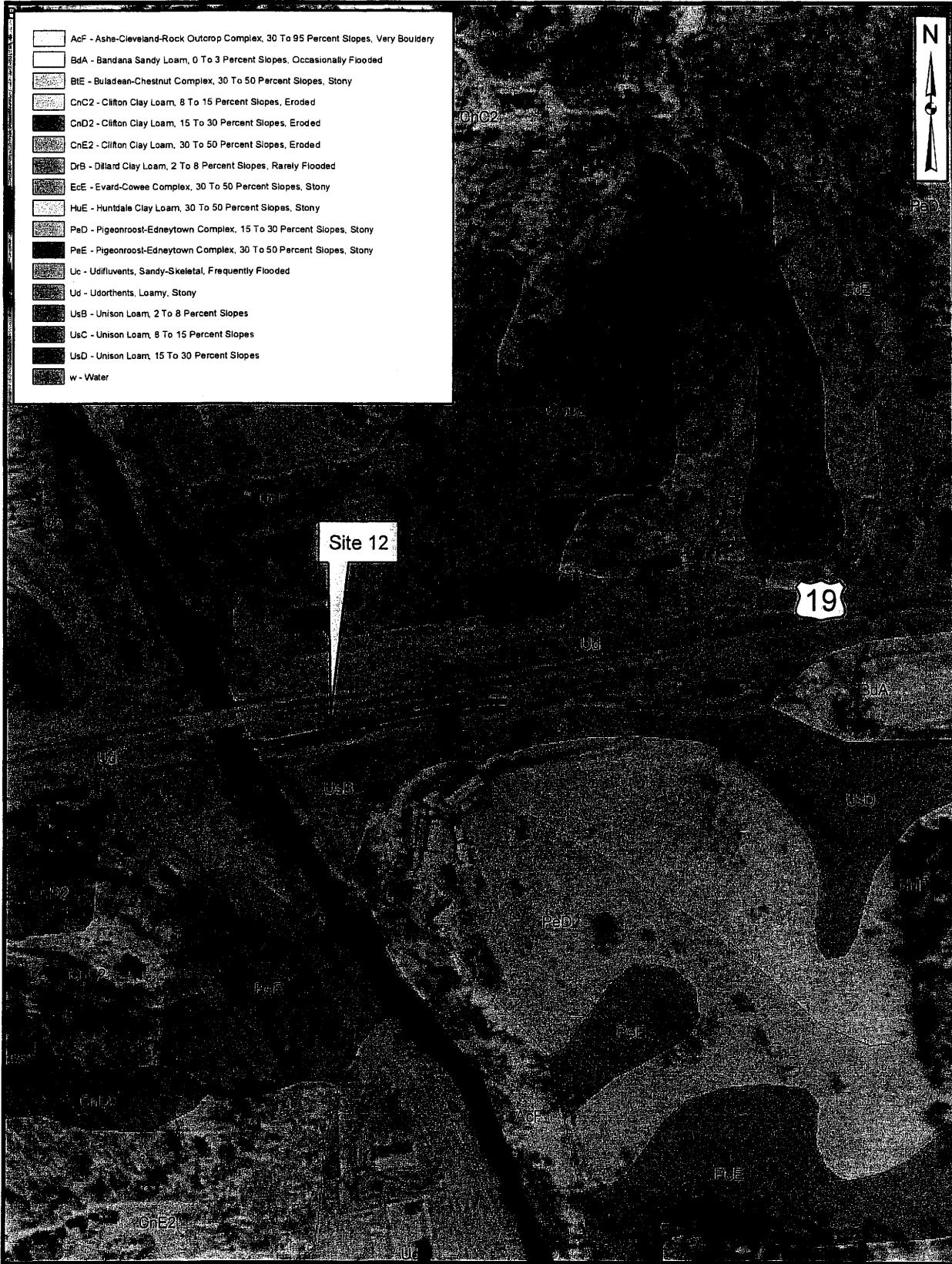


Figure 2E.  
Soils Map  
R-2518B, Site 11

-  AcF - Ashe-Cleveland-Rock Outcrop Complex, 30 To 95 Percent Slopes, Very Bouldery
-  BdA - Bandana Sandy Loam, 0 To 3 Percent Slopes, Occasionally Flooded
-  BIE - Buldean-Chestnut Complex, 30 To 50 Percent Slopes, Stony
-  CnC2 - Clifton Clay Loam, 8 To 15 Percent Slopes, Eroded
-  CnD2 - Clifton Clay Loam, 15 To 30 Percent Slopes, Eroded
-  CnE2 - Clifton Clay Loam, 30 To 50 Percent Slopes, Eroded
-  DrB - Dillard Clay Loam, 2 To 8 Percent Slopes, Rarely Flooded
-  EcE - Evard-Cowee Complex, 30 To 50 Percent Slopes, Stony
-  HuE - Hunt Dale Clay Loam, 30 To 50 Percent Slopes, Stony
-  PeD - Pigeonroost-Edneytown Complex, 15 To 30 Percent Slopes, Stony
-  PeE - Pigeonroost-Edneytown Complex, 30 To 50 Percent Slopes, Stony
-  Uc - Udifluvents, Sandy-Skeletal, Frequently Flooded
-  Ud - Udorthents, Loamy, Stony
-  UsB - Unison Loam, 2 To 8 Percent Slopes
-  UsC - Unison Loam, 8 To 15 Percent Slopes
-  UsD - Unison Loam, 15 To 30 Percent Slopes
-  w - Water



Project Development and  
Environmental Analysis Branch

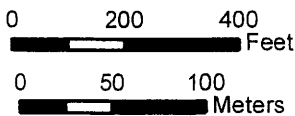


Figure 2F.  
Soils Map  
R-2518B, Site 12

### 3.0 LOCATION INFORMATION

The R-2518B mitigation sites are located along the US Highway 19 corridor in Yancey County, between the Madison-Yancey County line at Ivy Gap east to Burnsville. The sites lie in the French Broad River watershed within NCDWQ sub-basin 04-03-07. Sites 1 through 8 lie within USGS HU 06010108080020, while sites 11 and 12 lie within USGS HU 06010108070010. Figure 1 shows the site locations for the various project reaches. Table 2 provides the NCDWQ Stream Classifications of the proposed mitigation reaches.

**TABLE 2. SITE LOCATION INFORMATION**

Site Name	Approximate Roadway Station	Stream Name	Stream Classification	Stream Index Number
Site 1	114+50 to 120+10	Bald Creek	C	7-3-22
Site 3	124+43 to 127+18	Bald Creek	C	7-3-22
Site 4	135+60 to 138+05	Bald Creek	C	7-3-22
Site 8	175+65 to 178+50	Bald Creek	C	7-3-22
Site 11	207+64 to 208+50	Phipps Creek	C; Tr	7-3-20
Site 12	223+66 to 225+46	UT to Cane River	C; Tr	N/A

### 4.0 GENERAL WATERSHED INFORMATION

The watersheds for the project reaches are primarily rural, ranging from low density residential to agricultural land uses. The watersheds are estimated to be less than 15 percent residential and commercial development, with the remainder agriculture and forest. Few changes in land use are expected over the next 10 years. Watershed drainage areas are summarized in Table 3 for the project sites.

**TABLE 3. DRAINAGE AREAS FOR PROJECT REACHES**

Site Name	Stream Name	Drainage Area, km <sup>2</sup> (mi <sup>2</sup> )
1	Bald Creek	9.8 (3.8)
3	Bald Creek	10.9 (4.2)
4	Bald Creek	30.6 (11.8)
8	Bald Creek	44.3 (17.1)
11	Phipps Creek	3.6 (1.4)
12	UT to Cane River	1.8 (0.7)

## **5.0 EXISTING CONDITIONS**

A discussion of the existing conditions for each project stream site is provided in the sections that follow. Existing condition geomorphology parameters and measurements are provided in Appendix B.

### **5.1 SITE 1**

Bald Creek flows through Site 1 in a relatively straight pattern along the toe of a mountain slope. As a result, the right bank of the stream is very steep and wooded. The left bank of the stream ranges from steep and eroding in some localized areas (primarily at the beginning of the reach), to stable and vegetated with primarily herbaceous species. The stream is classified as a Rosgen B3 stream type through this reach and is relatively stable in most areas. The existing right-of-way fence runs along the left bank at a distance of 4.6 - 9 meters (15 - 30 feet) parallel to the stream.

Three ephemeral stormwater channels connect from drainage culverts beneath US Highway 19 to the existing stream from the left bank. The riffle/pool ratio of the stream is approximately 60/40 and the streambed consists mainly of silt, gravel and cobble.

### **5.2 SITE 3**

Bald Creek flows through Site 3 and is similar in nature to Site 1. Like Site 1, the stream is classified as a B3 stream type through this reach, is relatively stable in most areas, and is bounded by a mountain slope along the right bank. Much of the left bank is also a steep bank, with NC Route 1202 along the top of the slope. Cattle have had access to this reach in the past and, as a result, stream side vegetation has been cleared and impacted more than Site 1. Midway through the reach, there is a pinch point in the valley and rip-rap has been placed along the left bank to protect the slope. The stream is relatively stable, except for one bend near the end of the reach, where the stream has become overly wide and the right bank is unstable, most likely due to cattle access.

Some localized areas containing privet and multiflora rose were identified along the reach. The streambed consists mainly of gravel and cobble, with some fine sediment.

### **5.3 SITE 4**

Bald Creek flows through Site 4 and is less steep than Sites 1 or 3. The stream is classified as a C4 and is straight along the reach with the exception of one bend to the right near the end of the reach. Near the end of the reach, the stream becomes more confined by the valley and bedrock outcrops are evident and the stream type changes to a B4c. Along the upper portion of the reach, the stream is bordered by residential yards along the left bank. In this area, the stream has been channelized and appears to be overly wide. As a result, there are few deep pools in this reach. Streamside vegetation, especially along the left bank, is relatively sparse, with some alder clumps along the toe of the stream channel.

The riffle/pool ratio of Bald Creek is approximately 80/20 and the streambed consists mainly of gravel and cobble with fine sediment.

### **5.4 SITE 8**

Bald Creek flows through Site 8 which is bordered by a cultivated agriculture field on the left bank. Downstream of the US Highway 19 culverts at the beginning of the reach, the left bank is vertical and moderately unstable. Banks are relatively steep along the entire reach, with localized areas of bank instability. Streamside vegetation consists of sparse woody species and thick herbaceous vegetation. The stream is classified as an E4, however the reach is relatively straight due to past channelization.

The riffle/pool ratio for Bald Creek is approximately 70/30 and the streambed consists mainly of sand, gravel and cobble.

### 5.5 SITE 11

Phipps Creek flows through Site 11. The stream flows onto the proposed mitigation site from adjacent pasture land. The stream is highly incised and is classified as an E4b/G4, based on surveyed information. Streambanks along the reach are approximately 1.5 - 1.8 meters (5 - 6 feet) in height and generally unstable along most of the reach. The stream banks in this section contain very few trees and are mostly free of vegetation. Throughout the site there are relatively few pools and many riffles. The streambed consists mainly of silt, sand, and gravel.

### 5.6 SITE 12

An unnamed tributary to the Cane River flows through Site 12, parallel to US Highway 19. The stream has been channelized in the past; as a result the stream is classified as a straight B4/G4 stream type. While the banks of the stream are high, the stream is moderately stable. The stability is most likely due to the large amount of rock found in the stream on both banks, which appears to be a combination of natural material and rip rap which was applied to the banks in the past. A single line of trees is present along the left bank; however some of these trees have fallen into the channel, forming blockages and debris jams. The riffle/pool ratio for Site 12 is approximately 70/30 and the streambed consists mainly of sand, gravel and cobble. The pools in the reach are relatively shallow.

## 6.0 FEDERALLY PROTECTED SPECIES

There are ten federally threatened or endangered species identified for Yancey County, as listed in Table 4. Potential habitat does exist within the project area for Virginia spiraea and the Appalachian elktoe; however, these species are typically associated with stream systems larger than those proposed for mitigation practices in this document. Before in-stream work is conducted, surveys for these species will be conducted by NCDOT.

**TABLE 4. FEDERALLY PROTECTED SPECIES FOR YANCEY COUNTY**

Family	Scientific Name	Common Name	Federal Status	State Status	Biological Conclusion
Vertebrates					
Sciuridae	<i>Glaucomys sabrinus coloratus</i>	Carolina northern flying squirrel	E	E	No Effect
Vespertilionidae	<i>Corynorhinus townsendii virginianus</i>	Virginia big-eared bat	E	E	No Effect
Emydidae	<i>Glyptemys muhlenbergii</i>	Bog turtle	T(S/A)	T	Not Applicable
Felidae	<i>Puma concolor cougar</i>	Eastern cougar	E	E	No Effect

Vascular Plants					
Rosaceae	<i>Geum radiatum</i>	Spreading avens	E	E-SC	No Effect
Rubiaceae	<i>Houstonia montana</i>	Roan mountain bluet	E	E	No Effect
Rosaceae	<i>Spiraea virginiana</i>	Virginia spiraea	T	E	Not Likely to Adversely Affect / Unresolved
Non-Vascular Plants					
Cladoniaceae	<i>Gymnoderma lineare</i>	Rock gnome lichen	E	T	No Effect
Invertebrates					
Unionidae	<i>Alasmidonta raveneliana</i>	Appalachian elktoe	E	E	Not Likely to Adversely Affect / Unresolved
Dipluridae	<i>Microhexura montivaga</i>	Spruce-fir moss spider	E	SR	No Effect
<b>Notes:</b>					
<i>E</i>	<i>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.</i>				
<i>T</i>	<i>Threatened</i>				
<i>PE</i>	<i>Proposed Endangered</i>				
<i>PT</i>	<i>Proposed Threatened</i>				
<i>PD</i>	<i>These species have been proposed for delisting from the current status.</i>				
<i>FSC</i>	<i>Federal Species of Concern</i>				
<i>SC</i>	<i>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).</i>				
<i>SR</i>	<i>A Significantly Rare species is not listed as "E," "T," or "SC," but which exists in the state in small numbers and has been determined to need monitoring.</i>				

## 7.0 STREAM REFERENCE RESTORATION STUDIES

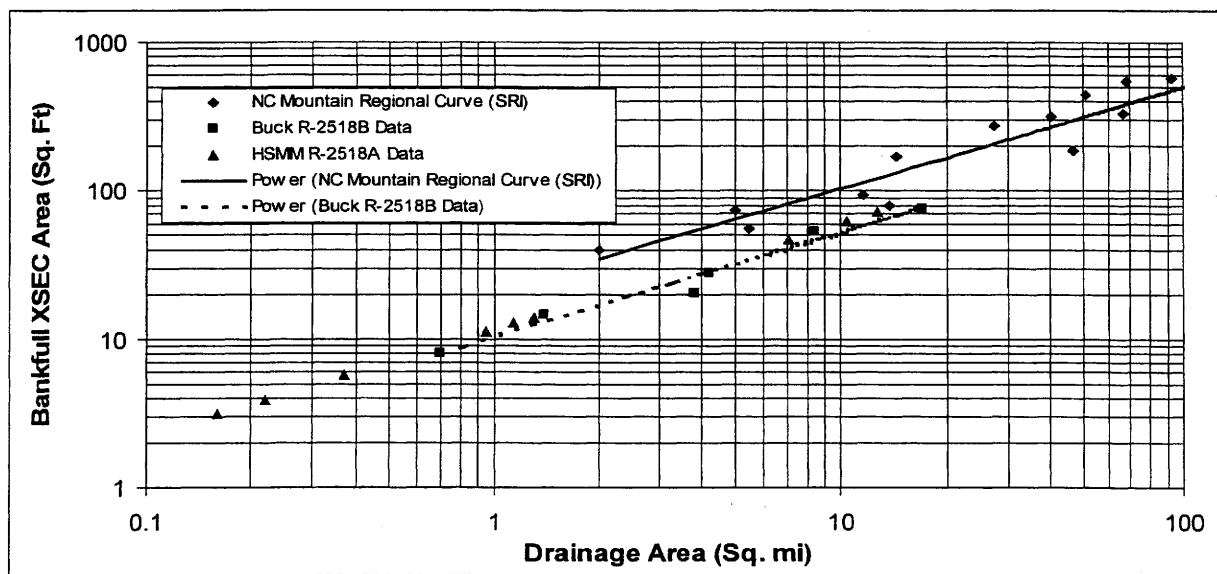
A reference reach is a stream segment that represents a stable channel within a particular valley morphology. A stable stream is defined as a stream, which over time and in the present climate transports the flows and sediment produced by its watershed in such a manner that the dimension, pattern, and profile are maintained without either aggrading or degrading (Rosgen, 1996, 1998).

The methodology used for the reference reach analysis consisted of the following tasks: (1) identify reference quality sections of the project reaches that could be used for dimension and/or pattern analysis, (2) identify nearby reference reaches that can be used to provide pattern data, if on-site reference reaches

cannot provide this data, (3) survey and classify the stream morphology for both on-site and off-site reference reaches, and (4) develop dimensionless ratios based on reference reach data and past project data under similar morphological conditions.

Several locations were identified within the project reaches where stable bankfull features had developed and provided information regarding bankfull dimension. These locations were identified by the presence of a consistent bankfull indicator, typically a well formed bankfull bench, and stable, vegetated stream banks. Cross-section surveys were conducted in these locations to evaluate stream dimension. The bankfull cross-section areas were then plotted versus drainage area and compared to published Mountain regional curve data, provided by the North Carolina Stream Restoration Institute (SRI).

The project site is located in a low rainfall hydrologic sub-region within the mountain physiographic province of western North Carolina. In a previous NCDOT mitigation report for project R-2518A, a project located several miles from the sites described here, Hayes, Seay, Mattern & Mattern, Inc. (HSMM) reported that streams within the area exhibited smaller bankfull cross-sectional areas than would be predicted by the SRI mountain regional curve. Data collected from the R-2518B site also follows the same trend indicated by the R-2518A report, as illustrated in Figure 3. Therefore, the curve developed with data from both the R-2518A and R-2518B projects (Figure 3) was used to predict and verify bankfull cross sectional areas of the proposed mitigation reaches.



**FIGURE 3. COMPARISON OF REGIONAL CURVE INFORMATION FOR PROJECT REACHES.**

The majority of the work proposed for this project will consist of enhancement approaches, with the exception of Site 11. For enhancement reaches, the work will consist primarily of installing in-stream structures to improve habitat and stability, conducting bank stabilization in areas of need, and planting riparian vegetation. The locations of structures in these reaches were determined by areas of degraded in-stream habitat or areas that require structures to aid in stabilization. Therefore, no reference reach information was required for these reaches.

For Site 11, the reach will be designed as a "B" channel, due to its relatively high slope (2.3 percent). The design width to depth ratio ( $W/D = 15$ ) is based on the width to depth ratios observed from relatively stable cross-sections on Sites 1 and 3, which are also "B" channels. The placement of grade control cross-vanes was based on the need to control stream gradient and provide appropriate in-stream habitat.

Shear stresses were calculated for Site 11 to determine the particle size that will be mobilized by the stream. Sediment transport calculations were not completed for other reaches, since all other reaches will be addressed by enhancement approaches that will not affect the stream's ability to move sediment. The calculations for Site 11 are provided in Appendix C. The data show that the shear stresses for the proposed design will be able to move the bed material of the streams. Since the calculated critical shear and critical depths are less than those proposed for the design conditions, grade control structures will be incorporated into the design to ensure against downcutting of the streambed.

## **8.0 STREAM MITIGATION PLAN**

The stream mitigation plan for each of the six project sites is described in the sections that follow. Detailed plan sheets are being provided to NCDOT with the submittal of this report.

### **8.1 SITE 1**

The project reach for Site 1 is a fairly stable B3 channel; however, the reach is dominated by shallow riffles and pools. Enhancement of the reach will include the installation of several in-stream cross-vane structures to improve habitat diversity, and planting of the riparian buffer zone. Several areas of multiflora rose were noted along the reach and will be treated by NCDOT prior to construction.

The work described in this section and shown in the project plan sheets would qualify as Enhancement Level II under the April 2003 US Army Corps of Engineers (USACE) and NCDWQ *Stream Mitigation Guidelines*. Due to the width of the available right-of-way along the stream, buffer widths in excess of the required 9 meters (30 feet) will be established in many areas.

### **8.2 SITE 3**

The project reach is similar in comparison to Site 1. The reach is a relatively stable B3 channel. The reach can be addressed by the establishment of a buffer, stabilization of localized areas, placement of several in-stream structures to improve habitat, and exclusion of cattle. Near the middle part of the reach, there is a section of overly wide channel which will be narrowed and stabilized by channel reconfiguration and the placement of several cross-vanes. Several areas of privet and multiflora rose were noted along the lower portion of the reach. NCDOT will treat multiflora rose and privet areas prior to construction.

The work described in this section and shown in the project plan sheets would qualify primarily as Enhancement Level II under the April 2003 USACE and NCDWQ *Stream Mitigation Guidelines*. The middle portion of the reach, where channel dimension and profile will be addressed, would be considered as Enhancement Level I. Due to the width of the available right-of-way along the stream, buffer widths in excess of the required 9 meters (30 feet) will be established in many areas. A section of the right streambank from approximate station 12+10 to 13+01 will have a buffer width of approximately 8 to 9 meters (25 to 30 feet).

### **8.3 SITE 4**

Through Site 4, Bald Creek has less slope than the two upstream sites (Sites 1 and 3). The reach is characterized as a C4 channel in the upstream portions, and changes to a B4c near the downstream portion where the valley becomes more confined. This section of channel is relatively stable, but exhibits signs of past channelization and an overly wide channel dimension in many places. Pool habitat is lacking and will be improved with the installation of in-stream structures that will help narrow the channel and improve aquatic habitat and stability.



The work described in this section and shown in the project plan sheets would qualify primarily as Enhancement Level II under the April 2003 USACE and NCDWQ *Stream Mitigation Guidelines*. Minimum buffer widths on the right streambank will be in excess of 9 meters (30 feet). On the left streambank, buffer widths will be approximately 8 meters (26 feet) from station 10+00 to 11+80. All other areas will have buffers at least 9 meters (30 feet) in width.

#### **8.4 SITE 8**

This section of Bald Creek has been channelized and straightened in the past and, as a result, exhibits signs of instability along the project reach. Enhancement techniques will be used to stabilize the stream, including the excavation of bankfull benches and the installation of in-stream structures. In-stream structures, such as J-hooks and cross-vanes, will be used to stabilize channel pattern and improve bedform diversity and habitat.

The work described in this section and shown in the project plan sheets would qualify as Enhancement Level I under the April 2003 USACE and NCDWQ *Stream Mitigation Guidelines*. Minimum buffer widths on the right streambank will be in excess of 9 meters (30 feet) in all areas except near station 11+00, where the buffer will be approximately 6 meters (20 feet) in width. On the left streambank, buffer widths will be approximately 6 to 7 meters (20 to 23 feet) from station 10+40 to 10+60, and from station 11+50 to 13+07. All other areas will have buffers at least 9 meters (30 feet) in width.

#### **8.5 SITE 11**

The project reach is an unstable, relatively short section of Phipps Creek. The stream was most likely channelized in the past as a result of agricultural conversion of the surrounding land. The stream is deeply incised with actively eroding banks. The entire project reach will be restored through a Rosgen Priority Level II approach, where a bankfull bench is constructed along the left bank, and a new stream pattern is constructed within the excavated floodplain.

The work described in this section and shown in the project plan sheets would qualify as Restoration under the April 2003 USACE and NCDWQ *Stream Mitigation Guidelines*. A minimum buffer width of 9 meters (30 feet) will be established along the restored reach.

#### **8.6 SITE 12**

This project reach is relatively stable; however, in-stream habitat is limited due to the channelized nature of the reach and large amounts of fine sediment that are washed into the creek from an upstream cattle area. The project reach will be enhanced by the construction of a bankfull bench along the left bank of the project. Cross-vanes will be installed along the reach to improve overall aquatic habitat and protect against future down-cutting of the channel. Any trees that have fallen across the channel will be removed.

The work described in this section and shown in the project plan sheets would qualify as Enhancement Level I under the April 2003 USACE and NCDWQ *Stream Mitigation Guidelines*. Minimum buffer widths on the right streambank will be approximately 7 to 9 meters (23 to 30 feet) in width. On the left streambank, buffer widths will be approximately 5 to 6 meters (17 to 20 feet) in width along most of the reach.

## 9.0 STREAM PERFORMANCE CRITERIA AND MONITORING PLAN

An As-built will be submitted within 60 days of completion of the project. The As-built will document changes in the dimension, pattern, profile, vegetation plantings, and structures of the constructed channels.

The following components of Level 1 monitoring will be performed each year of the 5-year monitoring period: Reference photos, plant survival (i.e., identify specific problem areas (missing, stressed, damaged or dead plantings), estimated causes and proposed/required remedial action); visual inspection of channel stability. Physical measurements of channel stability/morphology will not be performed. A monitoring report will be submitted within 60 days after completing the monitoring.

## 10.0 MITIGATION SUMMARY

NCDOT has made an effort to restore and enhance approximately 1,649 meters (5,410 feet) of streams adjacent to the US 19 corridor to meet our mitigation requirements. The streams are being purchased as right-of-way for the roadway project. These sites will have controlled access to ensure they are protected from local landowner encroachment. Also, placing these streams and riparian buffers into right-of-way guarantees that no future impacts will occur directly to these channels due to commercial or residential development along the corridor.

We have protected extensive portions of the stream system from any future development. Based on the efforts to enhance the water quality adjacent to the roadway, NCDOT proposes the following credit ratios:

Restoration/Relocation	1:1
Enhancement	2:1

Using these ratios would yield the following:

**TABLE 5. MITIGATION SUMMARY**

Approach	Credit Ratio	Proposed Length	Proposed Credits
Restoration	1	85 meters	85 meters
Enhancement	2	1,564 meters	782 meters
		Total	867 meters
			(2,844 feet)

## 11.0 REFERENCES

Rosgen, D. L. 1996. Applied River Morphology. Wildland Hydrology Books. Pagosa Springs, CO.

Rosgen, D. L. 1998. The Reference Reach-a Blueprint for Natural Channel Design. Draft Presented at ASCE Conference on River Restoration. Denver, CO, March, 1998. ASCE. Reston, VA.

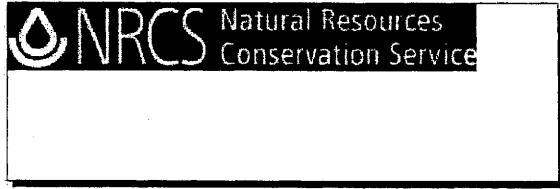
**APPENDIX A**

**REFERENCE REACH STREAM DATA**



# Reference Reach Database

Leilani Paugh, NCDOT  
 (919) 733-1194  
 lpaugh@dot.state.nc.us



Stream ID	<input type="text" value="1"/>
Stream Name	<input type="text" value="North Fork New River"/>
Contact	<input type="text" value="Angela Jessup"/>
Organization	<input type="text" value="NRCS"/>
Email	<input type="text" value="Angela.G.Jessup@usda.gov"/>
Date Surveyed	<input type="text"/>

Hydraulics	
Bankfull Discharge	<input type="text" value="1,000.0"/> (cfs)
Bankfull Velocity	<input type="text" value="5.9"/> (ft/s)
Manning's n	<input type="text"/>
Method of Calculating Manning's n	<input type="text"/>

Location	
River Basin	<input type="text" value="New"/>
8-digit HUC	<input type="text" value="05050001"/>
Location	<input type="text" value="NC Hwy 88 near Creston, NC"/>
Reach Description	<input type="text" value="Station 0+00 is at the head of the riffle above the first big bend on River Breeze Estates"/>
State	<input type="text" value="NC"/>
Latitude	<input type="text"/> (decimal degrees)
Longitude	<input type="text"/> (decimal degrees)
County	<input type="text" value="Ashe"/>
Physio. Region	<input type="text" value="Mountain"/> (coast, Piedmont, mtns)
Ecoregion	<input type="text"/>
Public/Private	<input checked="" type="checkbox"/> V
Right of Entry	<input type="checkbox"/> (check for yes)
USGS Quad	<input type="text" value="Baldwin Gap"/>

Channel Materials	
Percent Silt/Clay	<input type="text" value="2%"/>
Percent Sand	<input type="text" value="26%"/>
Percent Gravel	<input type="text" value="20%"/>
Percent Cobble	<input type="text" value="35%"/>
Percent Boulder	<input type="text" value="7%"/>
Percent Bedrock	<input type="text" value="10%"/>
D16	<input type="text" value="0.25"/> (mm)
D35	<input type="text" value="35"/> (mm)
D50	<input type="text" value="75"/> (mm)
D84	<input type="text" value="362"/> (mm)
D95	<input type="text" value="2600"/> (mm)

Note: 2,049 mm corresponds to BEDROCK



## Reference Reach Database

Leilani Paugh, NCDOT  
 (919) 733-1194  
 lpaugh@dot.state.nc.us

Stream ID	<input type="text" value="1"/>
Stream Name	<input type="text" value="North Fork New River"/>

Dimension Ratios	Mean	Minimum	Maximum
Bankfull Width: Depth Ratio	<input type="text" value="16.23"/>	<input type="text" value="13.53"/>	<input type="text" value="18.48"/>
Entrenchment Ratio	<input type="text" value="4.63"/>	<input type="text" value="2.26"/>	<input type="text" value="8.24"/>
Bank Height Ratio	<input type="text" value="1.00"/>	<input type="text" value="1.00"/>	<input type="text" value="1.00"/>
Pool width: Bankfull width*	<input type="text" value="0.97"/>	<input type="text" value="0.97"/>	<input type="text" value="0.97"/>
Max pool depth: Bankfull depth*	<input type="text" value="2.40"/>	<input type="text" value="2.32"/>	<input type="text" value="2.47"/>
Mean pool depth: Bankfull depth*	<input type="text" value="1.07"/>	<input type="text" value="0.84"/>	<input type="text" value="1.30"/>
Pool area: Riffle area*	<input type="text" value="1.03"/>	<input type="text" value="0.82"/>	<input type="text" value="1.25"/>

\* Ratio denominators are the riffle mean bankfull value.

Pattern Ratios	Mean	Minimum	Maximum
Pool to pool Spacing: Bkfl width	<input type="text" value="6.12"/>	<input type="text" value="4.24"/>	<input type="text" value="7.91"/>
Meander length ratio	<input type="text" value="19.20"/>	<input type="text" value="18.34"/>	<input type="text" value="20.06"/>
Radius of curvature ratio	<input type="text" value="1.02"/>	<input type="text" value="0.81"/>	<input type="text" value="1.31"/>
Meander width ratio	<input type="text" value="4.85"/>	<input type="text" value="3.67"/>	<input type="text" value="5.73"/>

Profile Ratios	Mean	Minimum	Maximum
Pool slope: Avg WS slope	<input type="text" value="-0.16"/>	<input type="text" value="-0.31"/>	<input type="text" value="0.00"/>
Riffle slope: Avg WS slope	<input type="text" value="1.92"/>	<input type="text" value="1.73"/>	<input type="text" value="2.02"/>
Glide slope: Avg WS slope	<input type="text" value="-0.56"/>	<input type="text" value="-0.56"/>	<input type="text" value="-0.56"/>
Run slope: Avg WS slope	<input type="text" value="1.17"/>	<input type="text" value="1.17"/>	<input type="text" value="1.17"/>



## Reference Reach Database

Lailani Paugh, NCDOT  
 (919) 733-1194  
 lpaugh@dot.state.nc.us

**NC STATE UNIVERSITY**

Stream ID	<input type="text" value="12"/>
Stream Name	<input type="text" value="Lost Cove Creek"/>
Contact	<input type="text" value="Dan Clinton"/>
Organization	<input type="text" value="NCSU"/>
Email	<input type="text" value="dan_clinton@ncsu.edu"/>
Date Surveyed	<input type="text" value="6/8/1998"/>

### Hydraulics

Bankfull Discharge	<input type="text"/>	(cfs)
Bankfull Velocity	<input type="text"/>	(ft/s)
Manning's n	<input type="text"/>	
Method of Calculating Manning's n	<input type="text"/>	

### Location

River Basin	<input type="text" value="Catawba"/>
8-digit HUC	<input type="text" value="03050101"/>
Location	<input type="text" value="Town of Edgemont, NC, within Pisgah National Forest"/>
Reach Description	<input type="text"/>
State	<input type="text" value="NC"/>
Latitude	<input type="text"/> (decimal degrees)
Longitude	<input type="text"/> (decimal degrees)
County	<input type="text" value="Avery"/>
Physio. Region	<input type="text" value="Mountain"/> (coast, Piedmont, mtns)
Ecoregion	<input type="text"/>
Public/Private	<input type="text" value="U"/>
Right of Entry	<input checked="" type="checkbox"/> (check for yes)
USGS Quad	<input type="text" value="Grandfather M"/>

### Channel Materials

Percent Silt/Clay	<input type="text" value="0%"/>
Percent Sand	<input type="text" value="18%"/>
Percent Gravel	<input type="text" value="5%"/>
Percent Cobble	<input type="text" value="48%"/>
Percent Boulder	<input type="text" value="18%"/>
Percent Bedrock	<input type="text" value="11%"/>
D16	<input type="text" value="1.4"/> (mm)
D35	<input type="text"/> (mm)
D50	<input type="text" value="144"/> (mm)
D84	<input type="text" value="512"/> (mm)
D95	<input type="text"/> (mm)

Note: 2,049 mm corresponds to BEDROCK



## Reference Reach Database

Lellani Paugh, NCDOT  
 (919) 733-1194  
 lpaugh@dot.state.nc.us

Stream ID	<input type="text" value="12"/>
Stream Name	<input type="text" value="Lost Cove Creek"/>

Dimension Ratios	Mean	Minimum	Maximum
Bankfull Width: Depth Ratio	<input type="text" value="18.59"/>	<input type="text" value="18.09"/>	<input type="text" value="19.09"/>
Entrenchment Ratio	<input type="text" value="4.02"/>	<input type="text" value="3.08"/>	<input type="text" value="4.96"/>
Bank Height Ratio	<input type="text"/>	<input type="text"/>	<input type="text"/>
Pool width: Bankfull width*	<input type="text" value="0.96"/>	<input type="text" value="0.96"/>	<input type="text" value="0.96"/>
Max pool depth: Bankfull depth*	<input type="text" value="2.30"/>	<input type="text" value="2.30"/>	<input type="text" value="2.30"/>
Mean pool depth: Bankfull depth*	<input type="text" value="1.25"/>	<input type="text" value="1.25"/>	<input type="text" value="1.25"/>
Pool area: Riffle area*	<input type="text" value="1.21"/>	<input type="text" value="1.21"/>	<input type="text" value="1.21"/>

\* Ratio denominators are the riffle mean bankfull value.

Pattern Ratios	Mean	Minimum	Maximum
Pool to pool Spacing: Bkfl width	<input type="text" value="3.05"/>	<input type="text" value="3.05"/>	<input type="text" value="3.05"/>
Meander length ratio	<input type="text" value="8.67"/>	<input type="text" value="8.67"/>	<input type="text" value="8.67"/>
Radius of curvature ratio	<input type="text" value="1.00"/>	<input type="text" value="1.00"/>	<input type="text" value="1.00"/>
Meander width ratio	<input type="text" value="8.03"/>	<input type="text" value="8.03"/>	<input type="text" value="8.03"/>

Profile Ratios	Mean	Minimum	Maximum
Pool slope: Avg WS slope	<input type="text" value="0.11"/>	<input type="text" value="0.11"/>	<input type="text" value="0.11"/>
Riffle slope: Avg WS slope	<input type="text" value="3.25"/>	<input type="text" value="3.25"/>	<input type="text" value="3.25"/>
Glide slope: Avg WS slope	<input type="text" value="0.19"/>	<input type="text" value="0.19"/>	<input type="text" value="0.19"/>
Run slope: Avg WS slope	<input type="text" value="1.43"/>	<input type="text" value="1.43"/>	<input type="text" value="1.43"/>

**APPENDIX B**  
**MORPHOLOGICAL CHARACTERISTICS OF**  
**PROPOSED STREAMS**



# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 1 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B3	B3
2. drainage area (sq. mi)	3.80	3.80
3. bankfull width (ft)	mean: 16.43 range: 15.48 - 17.39	mean: 16 range: --- - ---
4. bankfull mean depth (ft)	mean: 1.2 range: 1.16 - 1.23	mean: 1.23 range: --- - ---
5. width/depth ratio	mean: 13.8 range: 12.6 - 14.9	mean: 13 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 19.62 range: 19.01 - 20.23	mean: 19.7 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 4.7 range: --- - ---	mean: 4.7 range: --- - ---
8. bankfull discharge (cfs)	mean: 93 range: --- - ---	mean: 93 range: --- - ---
9. bankfull max depth (ft)	mean: 2.3 range: 2.2 - 2.39	mean: 1.8 range: --- - ---
10. width of floodprone area (ft)	mean: 28.93 range: 25.17 - 32.68	mean: 30 range: 25 - 35
11. entrenchment ratio	mean: 1.66 range: 1.45 - 1.87	mean: 1.6 range: 1.4 - 1.9
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.03 range: --- - ---	mean: 1.03 range: --- - ---
19. valley slope (ft/ft)	mean: 0.025 range: --- - ---	mean: 0.025 range: --- - ---
20. average slope (ft/ft)	mean: 0.024 range: --- - ---	mean: 0.024 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.04 range: --- - ---	mean: 0.04 range: --- - ---
23. maximum pool depth (ft)	mean: 2.5 range: 2.5 - 2.5	mean: 3 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: 2.1 range: 2.1 - 2.1	mean: 2.4 range: --- - ---
25. pool width (ft)	mean: 22.25 range: 22.25 - 22.25	mean: 19 range: --- - ---
26. ratio of pool width to bankfull width	mean: 1.4 range: 1.4 - 1.4	mean: 1.2 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.10 range: 1.00 - 1.20	mean: 1.00 range: 1.00 - 1.20

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B3	B3
2. drainage area (sq km)	9.84	9.84
3. bankfull width (m)	mean: 5.01 range: 4.72 - 5.30	mean: 4.88 range: --- - ---
4. bankfull mean depth (m)	mean: 0.37 range: 0.35 - 0.37	mean: 0.37 range: --- - ---
5. width/depth ratio	mean: 13.80 range: 12.60 - 14.90	mean: 13 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 1.82 range: 1.77 - 1.88	mean: 1.83 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.43 range: --- - ---	mean: 1.43 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 2.63 range: --- - ---	mean: 2.63 range: --- - ---
9. bankfull max depth (m)	mean: 0.70 range: 0.67 - 0.73	mean: 0.55 range: --- - ---
10. width of floodprone area (m)	mean: 8.82 range: 7.67 - 9.96	mean: 9.14 range: 7.62 - 10.67
11. entrenchment ratio	mean: 1.66 range: 1.45 - 1.87	mean: 1.6 range: 1.4 - 1.9
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.03 range: --- - ---	mean: 1.03 range: --- - ---
19. valley slope (m/m)	mean: 0.025 range: --- - ---	mean: 0.025 range: --- - ---
20. average slope (m/m)	mean: 0.024 range: --- - ---	mean: 0.024 range: --- - ---
21. Pool slope (m/m)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.04 range: --- - ---	mean: 0.04 range: --- - ---
23. maximum pool depth (m)	mean: 0.76 range: 0.76 - 0.76	mean: 0.91 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: 2.1 range: 2.1 - 2.1	mean: 2.4 range: --- - ---
25. pool width (m)	mean: 6.78 range: 6.78 - 6.78	mean: 5.79 range: --- - ---
26. ratio of pool width to bankfull width	mean: 1.4 range: 1.4 - 1.4	mean: 1.2 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.10 range: 1.00 - 1.20	mean: 1.00 range: 1.00 - 1.20

#### Notes

- \* Parameter was not estimated - stream is a step-pool system.
- Reference reach information not evaluated - design includes enhancement only.

# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 3 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B3	B3
2. drainage area (sq. mi)	4.20	4.20
3. bankfull width (ft)	mean: 21.26 range: 20.98 - 21.55	mean: 21 range: --- - ---
4. bankfull mean depth (ft)	mean: 1.62 range: 1.32 - 1.93	mean: 1.62 range: --- - ---
5. width/depth ratio	mean: 13.5 range: 11.2 - 15.9	mean: 13 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 34.6 range: 27.67 - 41.54	mean: 34 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 6.5 range: --- - ---	mean: 6.5 range: --- - ---
8. bankfull discharge (cfs)	mean: 226 range: --- - ---	mean: 226 range: --- - ---
9. bankfull max depth (ft)	mean: 2.71 range: 2.53 - 2.88	mean: 2.2 range: --- - ---
10. width of floodprone area (ft)	mean: 50.2 range: 29.47 - 70.94	mean: 50 range: 30 - 70
11. entrenchment ratio	mean: 1.45 range: 1.4 - 1.5	mean: 2.35 range: 1.4 - 3.3
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.04 range: --- - ---	mean: 1.04 range: --- - ---
19. valley slope (ft/ft)	mean: 0.032 range: --- - ---	mean: 0.032 range: --- - ---
20. average slope (ft/ft)	mean: 0.031 range: --- - ---	mean: 0.031 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.03 range: --- - ---	mean: 0.03 range: --- - ---
23. maximum pool depth (ft)	mean: --- range: --- - ---	mean: 3.5 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.2 range: --- - ---
25. pool width (ft)	mean: --- range: --- - ---	mean: 26 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.2 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.25 range: 1.00 - 1.50	mean: 1.00 range: 1.00 - 1.20

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B3	B3
2. drainage area (sq km)	10.88	10.88
3. bankfull width (m)	mean: 6.48 range: 6.39 - 6.57	mean: 6.40 range: --- - ---
4. bankfull mean depth (m)	mean: 0.49 range: 0.40 - 0.59	mean: 0.49 range: --- - ---
5. width/depth ratio	mean: 13.50 range: 11.20 - 15.90	mean: 13 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 3.21 range: 2.57 - 3.86	mean: 3.16 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.98 range: --- - ---	mean: 1.98 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 6.40 range: --- - ---	mean: 6.40 range: --- - ---
9. bankfull max depth (m)	mean: 0.83 range: 0.77 - 0.88	mean: 0.67 range: --- - ---
10. width of floodprone area (m)	mean: 15.30 range: 8.98 - 21.62	mean: 15.24 range: 9.14 - 21.34
11. entrenchment ratio	mean: 1.45 range: 1.40 - 1.50	mean: 2.35 range: 1.4 - 3.3
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.04 range: --- - ---	mean: 1.04 range: --- - ---
19. valley slope (m/m)	mean: 0.032 range: --- - ---	mean: 0.032 range: --- - ---
20. average slope (m/m)	mean: 0.031 range: --- - ---	mean: 0.031 range: --- - ---
21. Pool slope (m/m)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.03 range: --- - ---	mean: 0.03 range: --- - ---
23. maximum pool depth (m)	mean: --- range: --- - ---	mean: 1.07 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.2 range: --- - ---
25. pool width (m)	mean: --- range: --- - ---	mean: 7.92 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.2 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.25 range: 1.00 - 1.50	mean: 1.00 range: 1.00 - 1.20

#### Notes

- \* Parameter was not estimated - stream is a step-pool system.
- Reference reach information not evaluated - design includes enhancement only.

# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 4 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	C4	C4
2. drainage area (sq. mi)	8.40	8.40
3. bankfull width (ft)	mean: 25.58 range: 22.71 - 29.88	mean: 25.2 range: --- - ---
4. bankfull mean depth (ft)	mean: 1.67 range: 1.59 - 1.77	mean: 2 range: --- - ---
5. width/depth ratio	mean: 15.24 range: 14.28 - 16.84	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 43.03 range: 36.1 - 52.99	mean: 50 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 4.6 range: --- - ---	mean: 4.6 range: --- - ---
8. bankfull discharge (cfs)	mean: 241 range: --- - ---	mean: 241 range: --- - ---
9. bankfull max depth (ft)	mean: 3 range: 2.97 - 3.04	mean: 2.6 range: --- - ---
10. width of floodprone area (ft)	mean: > 50.0 range: --- - ---	mean: > 50.0 range: --- - ---
11. entrenchment ratio	mean: > 3.0 range: --- - ---	mean: > 3.0 range: --- - ---
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.11 range: --- - ---	mean: 1.11 range: --- - ---
19. valley slope (ft/ft)	mean: 0.013 range: --- - ---	mean: 0.013 range: --- - ---
20. average slope (ft/ft)	mean: 0.012 range: --- - ---	mean: 0.012 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.08 range: --- - ---	mean: 0.08 range: --- - ---
23. maximum pool depth (ft)	mean: --- range: --- - ---	mean: 4.5 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.3 range: --- - ---
25. pool width (ft)	mean: --- range: --- - ---	mean: 32 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.20 range: 1.00 - 1.30	mean: 1.00 range: 1.00 - 1.30

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	C4	C4
2. drainage area (sq km)	21.76	21.76
3. bankfull width (m)	mean: 7.80 range: 6.92 - 9.11	mean: 7.68 range: --- - ---
4. bankfull mean depth (m)	mean: 0.51 range: 0.48 - 0.54	mean: 0.61 range: --- - ---
5. width/depth ratio	mean: 15.24 range: 14.28 - 16.84	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 4.00 range: 3.35 - 4.92	mean: 4.65 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.40 range: --- - ---	mean: 1.40 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 6.82 range: --- - ---	mean: 6.82 range: --- - ---
9. bankfull max depth (m)	mean: 0.91 range: 0.91 - 0.93	mean: 0.79 range: --- - ---
10. width of floodprone area (m)	mean: > 15.2 range: --- - ---	mean: > 15.2 range: --- - ---
11. entrenchment ratio	mean: > 3.0 range: --- - ---	mean: > 3.0 range: --- - ---
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.11 range: --- - ---	mean: 1.11 range: --- - ---
19. valley slope (m/m)	mean: 0.013 range: --- - ---	mean: 0.013 range: --- - ---
20. average slope (m/m)	mean: 0.012 range: --- - ---	mean: 0.012 range: --- - ---
21. Pool slope (m/m)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.08 range: --- - ---	mean: 0.08 range: --- - ---
23. maximum pool depth (m)	mean: --- range: --- - ---	mean: 1.37 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.3 range: --- - ---
25. pool width (m)	mean: --- range: --- - ---	mean: 9.75 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.20 range: 1.00 - 1.30	mean: 1.00 range: 1.00 - 1.30

#### Notes

- \* Parameter was not estimated - stream is a step-pool system.
- Reference reach information not evaluated - design includes enhancement only.

# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 8 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	E4	E4/C4
2. drainage area (sq. mi)	17.10	17.10
3. bankfull width (ft)	mean: 25.12 range: 16.25 - 34.52	mean: 30 range: --- - ---
4. bankfull mean depth (ft)	mean: 2.95 range: 2.23 - 3.51	mean: 2.5 range: --- - ---
5. width/depth ratio	mean: 9.3 range: 4.6 - 15.4	mean: 12 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 70.13 range: 57 - 77.14	mean: 75 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 4 range: --- - ---	mean: 4 range: --- - ---
8. bankfull discharge (cfs)	mean: 279 range: --- - ---	mean: 279 range: --- - ---
9. bankfull max depth (ft)	mean: 4.22 range: 4.05 - 4.42	mean: 3.6 range: --- - ---
10. width of floodprone area (ft)	mean: > 80.0 range: --- - ---	mean: > 80.0 range: --- - ---
11. entrenchment ratio	mean: > 3.2 range: --- - ---	mean: > 3.2 range: --- - ---
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.03 range: --- - ---	mean: 1.03 range: --- - ---
19. valley slope (ft/ft)	mean: 0.006 range: --- - ---	mean: 0.006 range: --- - ---
20. average slope (ft/ft)	mean: 0.006 range: --- - ---	mean: 0.006 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.0001 range: --- - ---	mean: 0.0001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
23. maximum pool depth (ft)	mean: --- range: --- - ---	mean: 5.5 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.2 range: --- - ---
25. pool width (ft)	mean: --- range: --- - ---	mean: 40 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: 97.5 range: 75 - 120
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: 3.25 range: 2.5 - 4
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.00 range: 1.00 - 1.00	mean: 1.00 range: 1.00 - 1.20

Notes

\* Parameter was not estimated for existing condition - stream has been channelized.

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	E4	E4/C4
2. drainage area (sq km)	44.29	44.29
3. bankfull width (m)	mean: 7.66 range: 4.95 - 10.52	mean: 9.14 range: --- - ---
4. bankfull mean depth (m)	mean: 0.90 range: 0.68 - 1.07	mean: 0.76 range: --- - ---
5. width/depth ratio	mean: 9.30 range: 4.60 - 15.40	mean: 12.00 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 6.52 range: 5.30 - 7.17	mean: 6.97 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.22 range: --- - ---	mean: 1.22 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 7.90 range: --- - ---	mean: 7.90 range: --- - ---
9. bankfull max depth (m)	mean: 1.29 range: 1.23 - 1.35	mean: 1.10 range: --- - ---
10. width of floodprone area (m)	mean: > 24.4 range: --- - ---	mean: > 24.4 range: --- - ---
11. entrenchment ratio	mean: > 3.2 range: --- - ---	mean: > 3.2 range: --- - ---
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.03 range: --- - ---	mean: 1.03 range: --- - ---
19. valley slope (m/m)	mean: 0.006 range: --- - ---	mean: 0.006 range: --- - ---
20. average slope (m/m)	mean: 0.006 range: --- - ---	mean: 0.006 range: --- - ---
21. Pool slope (m/m)	mean: 0.0001 range: --- - ---	mean: 0.0001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
23. maximum pool depth (m)	mean: --- range: --- - ---	mean: 1.68 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.2 range: --- - ---
25. pool width (m)	mean: --- range: --- - ---	mean: 12.19 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: 29.72 range: 22.86 - 36.58
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: 3.25 range: 2.5 - 4
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 1.00 range: 1.00 - 1.00	mean: 1.10 range: 1.00 - 1.20

Notes

\* Parameter was not estimated for existing condition - stream has been channelized.

# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 11 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	E4b/G4	B4
2. drainage area (sq. mi)	1.40	1.40
3. bankfull width (ft)	mean: 8.97 range: --- - ---	mean: 14.5 range: --- - ---
4. bankfull mean depth (ft)	mean: 1.64 range: --- - ---	mean: 1 range: --- - ---
5. width/depth ratio	mean: 5.47 range: --- - ---	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 14.7 range: --- - ---	mean: 15 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 5.1 range: --- - ---	mean: 5.1 range: --- - ---
8. bankfull discharge (cfs)	mean: 75 range: --- - ---	mean: 75 range: --- - ---
9. bankfull max depth (ft)	mean: 2.2 range: --- - ---	mean: 1.3 range: --- - ---
10. width of floodprone area (ft)	mean: 21.11 range: --- - ---	mean: 43 range: --- - ---
11. entrenchment ratio	mean: 2.4 range: --- - ---	mean: 3 range: --- - ---
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.01 range: --- - ---	mean: 1.01 range: --- - ---
19. valley slope (ft/ft)	mean: 0.023 range: --- - ---	mean: 0.023 range: --- - ---
20. average slope (ft/ft)	mean: 0.023 range: --- - ---	mean: 0.023 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.04 range: --- - ---	mean: 0.04 range: --- - ---
23. maximum pool depth (ft)	mean: --- range: --- - ---	mean: 2.3 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.3 range: --- - ---
25. pool width (ft)	mean: --- range: --- - ---	mean: 18.8 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 2.00 range: 1.00 - 3.00	mean: 1.00 range: 1.00 - 1.20

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	E4b/G4	B4
2. drainage area (sq km)	3.63	3.63
3. bankfull width (m)	mean: 2.73 range: --- - ---	mean: 4.42 range: --- - ---
4. bankfull mean depth (m)	mean: 0.50 range: --- - ---	mean: 0.30 range: --- - ---
5. width/depth ratio	mean: 5.47 range: --- - ---	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 1.37 range: --- - ---	mean: 1.39 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.55 range: --- - ---	mean: 1.55 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 2.12 range: --- - ---	mean: 2.12 range: --- - ---
9. bankfull max depth (m)	mean: 0.67 range: --- - ---	mean: 0.40 range: --- - ---
10. width of floodprone area (m)	mean: 6.43 range: --- - ---	mean: 13.11 range: --- - ---
11. entrenchment ratio	mean: 2.4 range: --- - ---	mean: 3 range: --- - ---
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.01 range: --- - ---	mean: 1.01 range: --- - ---
19. valley slope (m/m)	mean: 0.023 range: --- - ---	mean: 0.023 range: --- - ---
20. average slope (m/m)	mean: 0.023 range: --- - ---	mean: 0.023 range: --- - ---
21. Pool slope (m/m)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.04 range: --- - ---	mean: 0.04 range: --- - ---
23. maximum pool depth (m)	mean: --- range: --- - ---	mean: 0.70 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.3 range: --- - ---
25. pool width (m)	mean: --- range: --- - ---	mean: 5.73 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 2.00 range: 1.00 - 3.00	mean: 1.00 range: 1.00 - 1.20

Notes

\* Parameter was not estimated - stream is a step-pool system.

# MORPHOLOGICAL MEASUREMENTS TABLE

## R-2518B On-Site Mitigation - Site 12 Parameters

### ENGLISH UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B4/G4	B4
2. drainage area (sq. mi)	0.70	0.70
3. bankfull width (ft)	mean: 8.26 range: 5.87 - 10.65	mean: 11.8 range: --- - ---
4. bankfull mean depth (ft)	mean: 1.36 range: 1.36 - 1.37	mean: 0.8 range: --- - ---
5. width/depth ratio	mean: 6.1 range: 4.3 - 7.8	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. ft)	mean: 11.24 range: 8.03 - 14.46	mean: 10 range: --- - ---
7. bankfull mean velocity (ft/sec)	mean: 4.3 range: --- - ---	mean: 4.3 range: --- - ---
8. bankfull discharge (cfs)	mean: 48 range: --- - ---	mean: 48 range: --- - ---
9. bankfull max depth (ft)	mean: 1.85 range: 1.76 - 1.95	mean: 1.1 range: --- - ---
10. width of floodprone area (ft)	mean: 13.89 range: 12.57 - 15.21	mean: 35 range: --- - ---
11. entrenchment ratio	mean: 1.75 range: 1.4 - 2.1	mean: 3 range: --- - ---
12. meander length (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.01 range: --- - ---	mean: 1.01 range: --- - ---
19. valley slope (ft/ft)	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
20. average slope (ft/ft)	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
21. Pool slope (ft/ft)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.05 range: --- - ---	mean: 0.05 range: --- - ---
23. maximum pool depth (ft)	mean: --- range: --- - ---	mean: 2 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.5 range: --- - ---
25. pool width (ft)	mean: --- range: --- - ---	mean: 15.3 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (ft) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 2.45 range: 1.00 - 3.90	mean: 1.00 range: 1.00 - 1.20

### METRIC UNITS

Variables	Existing Channel	Proposed Design
1. stream type	B4/G4	B4
2. drainage area (sq km)	1.81	1.81
3. bankfull width (m)	mean: 2.52 range: 1.79 - 3.25	mean: 3.60 range: --- - ---
4. bankfull mean depth (m)	mean: 0.41 range: 0.41 - 0.42	mean: 0.24 range: --- - ---
5. width/depth ratio	mean: 6.10 range: 4.30 - 7.80	mean: 14 range: --- - ---
6. bankfull cross-sectional area (sq. m)	mean: 1.04 range: 0.75 - 1.34	mean: 0.93 range: --- - ---
7. bankfull mean velocity (m/sec)	mean: 1.31 range: --- - ---	mean: 1.31 range: --- - ---
8. bankfull discharge (cu m/sec)	mean: 1.36 range: --- - ---	mean: 1.36 range: --- - ---
9. bankfull max depth (m)	mean: 0.56 range: 0.54 - 0.59	mean: 0.34 range: --- - ---
10. width of floodprone area (m)	mean: 4.23 range: 3.83 - 4.64	mean: 10.67 range: --- - ---
11. entrenchment ratio	mean: 1.75 range: 1.40 - 2.10	mean: 3 range: --- - ---
12. meander length (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
13. ratio of meander length to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
14. radius of curvature (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
15. ratio of radius of curvature to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
16. belt width (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
17. meander width ratio *	mean: NA range: --- - ---	mean: NA range: --- - ---
18. sinuosity (stream length/valley length)	mean: 1.01 range: --- - ---	mean: 1.01 range: --- - ---
19. valley slope (m/m)	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
20. average slope (m/m)	mean: 0.02 range: --- - ---	mean: 0.02 range: --- - ---
21. Pool slope (m/m)	mean: 0.001 range: --- - ---	mean: 0.001 range: --- - ---
22. Ratio of pool slope to average slope	mean: 0.05 range: --- - ---	mean: 0.05 range: --- - ---
23. maximum pool depth (m)	mean: --- range: --- - ---	mean: 0.61 range: --- - ---
24. ratio of pool depth to average bankfull depth	mean: --- range: --- - ---	mean: 2.5 range: --- - ---
25. pool width (m)	mean: --- range: --- - ---	mean: 4.66 range: --- - ---
26. ratio of pool width to bankfull width	mean: --- range: --- - ---	mean: 1.3 range: --- - ---
27. pool to pool spacing (m) *	mean: NA range: --- - ---	mean: NA range: --- - ---
28. ratio of pool to pool spacing to bankfull width *	mean: NA range: --- - ---	mean: NA range: --- - ---
29. ratio of lowest bank height to bankfull height (or max bankfull depth)	mean: 2.45 range: 1.00 - 3.90	mean: 1.00 range: 1.00 - 1.20

Notes

\* Parameter was not estimated - stream is a step-pool system.

Reference reach information not evaluated - design includes enhancement only.

**APPENDIX C**

**SEDIMENT TRANSPORT CALCULATIONS**

Shear Stress Analysis Data	Site 11
Feature	Riffle
Bankfull Cross Sectional Area, Abkf (sq ft)	14.7
Bankfull Width, Wbkf (ft)	15.0
Bankfull Mean Depth, Dbkf (ft)	1.0
Width/Depth Ratio, W/D (ft/ft)	15.3
Wetted Perimeter, WP=W+2D (ft)	17.0
Hydraulic Radius, R=Abkf/WP (ft)	0.9
Average Channel Slope, Se (ft/ft)	0.02300
Boundary Shear Stress, $\tau$ (lb/sq ft)	1.41
Median Diameter of Pavement, D <sub>50</sub> (mm)	36.2
Median Diameter of Sub-pavement, D <sup>^</sup> <sub>50</sub> (mm)	13.7
Critical Dimensionless Shear Stress, $\tau_{ci}$	0.0357
Largest Particle from Sub-Pavement, D <sub>i</sub> (mm)	55
Largest Particle from Sub-Pavement, D <sub>i</sub> (ft)	0.18
Required Mean Bankfull Depth, Dr (ft)	0.5
Required Mean Bankfull Slope, Sr (ft/ft)	0.0109



**APPENDIX D**

**RIPARIAN PLANTING PLAN AND SPECIFICATIONS**

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize stream banks, creates habitat and food sources for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of this project will include live dormant staking of the stream banks, riparian buffer planting, invasive species removal, and seeding for erosion control. The stream banks and the riparian areas will be planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Planting the stream banks is a desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration. During high flows, plants lie flat, and stems and leaves shield and protect the soil surface from erosion.

### **Live Staking**

The installation of live stakes on the stream banks will serve to protect the banks from erosion while providing habitat, shade, and improved aesthetics. Live staking areas are indicated on the plan sheets. Live stakes will be installed in areas where banks are sloped or benched as part of the mitigation work. In some locations, live stakes may be installed along existing banks to improve streamside vegetation and stability. Live staking must take place during the dormant season (November to March). Live stakes may be gathered locally or purchased from a reputable, commercial supplier. Stakes should be at least ½ inches and no more than 2 inches in diameter, between 2 and 3 feet in length, and living, as evidenced by the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet. For hard ground or rocky sub-soil, holes for live stakes may be created in the soil by the use of a metal bar, provided that good soil contact is created between the walls of the hole and the inserted live stake.

### **Riparian Buffer Re-Vegetation**

Riparian buffers are naturally occurring ecosystems adjacent to rivers and streams and are associated with a number of benefits. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow groundwater flow. Buffers also provide habitat and travel corridors for wildlife populations and are an important recreational resource. It is also important to note that riparian buffer areas help to moderate the quantity and timing of runoff from the upland landscape and contribute to the groundwater recharge process.

The planting plans for the site (see plan sheets) indicate that bare-root trees will be planted within designated areas of the right-of-way easement. Efforts have been made to ensure at least 9 meters (30 feet) of buffer adjacent to project stream reaches; however, there are some areas where a 9-meter (30-foot) buffer is not possible due to the proximity of the right-of-way boundary. In many areas, the protected buffer area will exceed 9 meters (30 feet) in width. In general, bare-root vegetation will be planted to ensure survivability of at least 260 stems per acre five years after the completion of the work. Planting of bare-root trees will be conducted during the dormant season, with all trees installed prior to the beginning of the growing season.

Selected species for hardwood re-vegetation are presented in Table D.1. Temporary and permanent seed mixtures will be applied to all disturbed areas of the project site, including constructed stream banks, access roads, side slopes, spoil piles, etc.

**Table D.1**  
Proposed Bare-root and Live Stake Species

Common Name	Scientific Name	Percent Planted by Species
<b>Type II Streambank Reforestation – Bare Root Plantings</b>		
American Sycamore	<i>Platanus occidentalis</i>	20%
Green Ash	<i>Fraxinus pennsylvanica</i>	10%
River Birch	<i>Betula nigra</i>	20%
Southern Red Oak	<i>Quercus falcata</i> var. <i>falcata</i>	20%
White Oak	<i>Quercus alba</i>	10%
Yellow Poplar	<i>Liriodendron tulipifera</i>	20%
<b>Alternate Species</b>		
Northern Red Oak	<i>Quercus rubra</i>	n/a
Black Cherry	<i>Prunus serotina</i>	n/a
Black Walnut	<i>Juglans nigra</i>	n/a
<b>Type I Streambank Reforestation - Live Stakes</b>		
Black Willow	<i>Salix nigra</i>	50%
Silky Dogwood	<i>Cornus amomum</i>	50%



Site 1



Site 1



Site 1



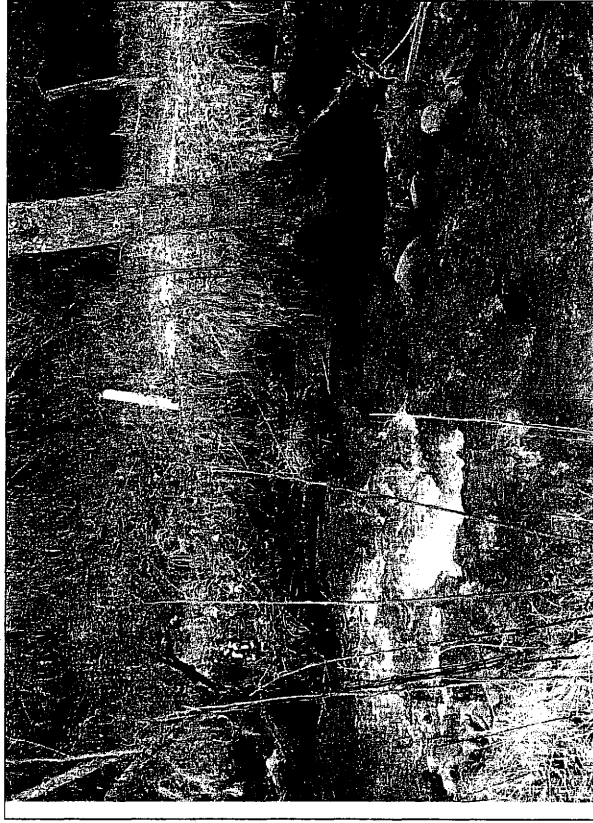
Site 1



Site 3



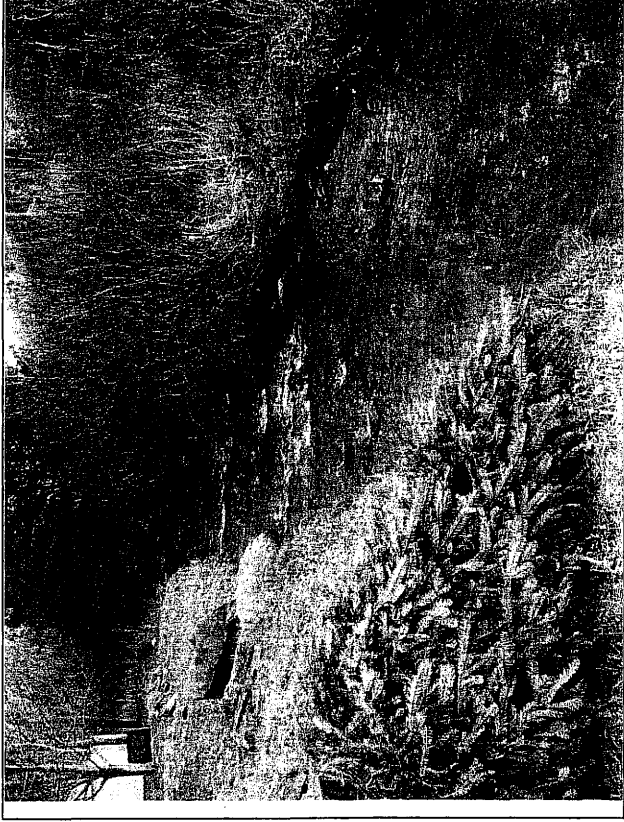
Site 3



Site 3



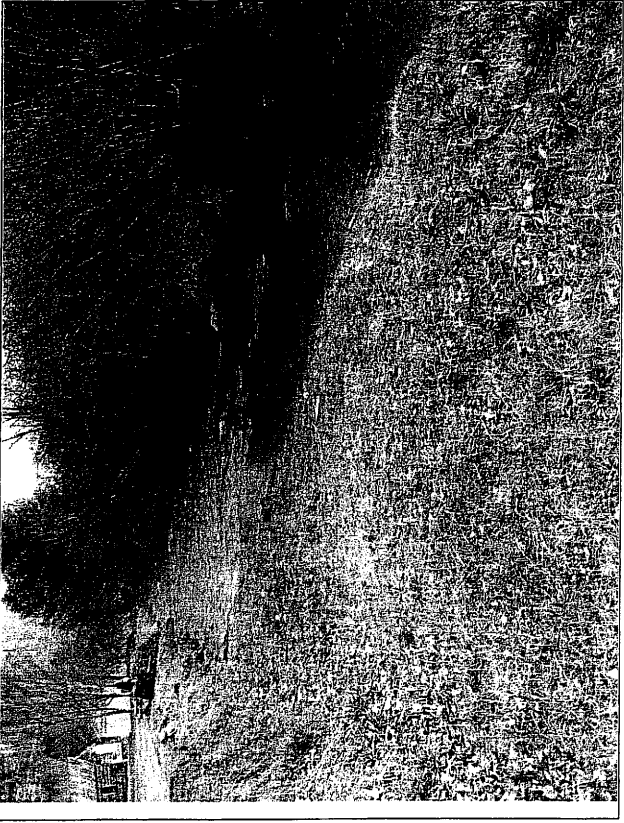
Site 3



Site 4



Site 4



Site 4



Site 4



Site 8



Site 8



Site 8



Site 8



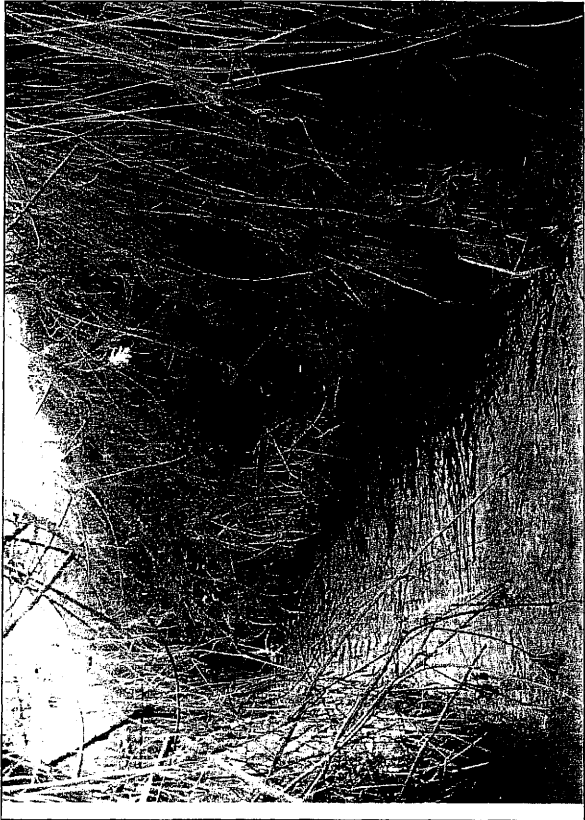
Site 11



Site 11



Site 11



Site 11





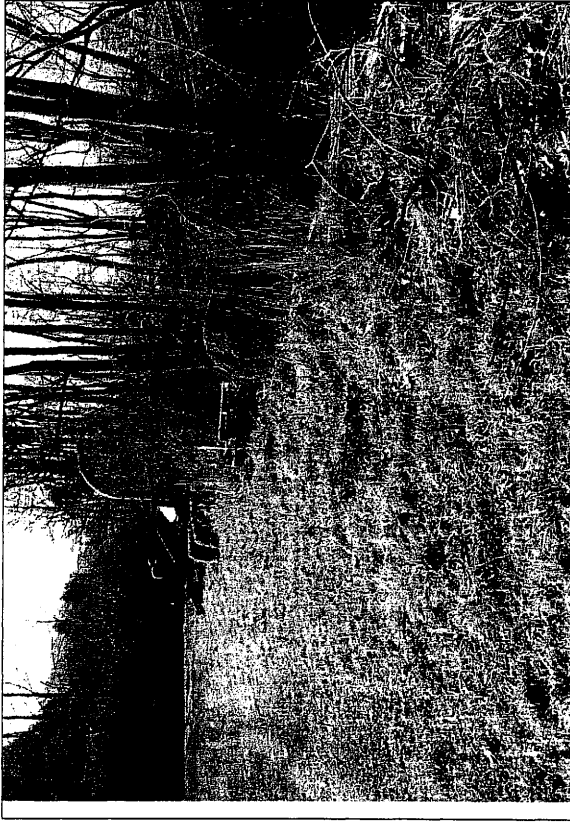
Site 12



Site 12



Site 12



Site 12