NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

STREAM MITIGATION PLAN

BEAR CREEK (PHILLIPS PROPERTY)
CHATHAM COUNTY, NORTH CAROLINA

January 2003

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PREPARED BY:

HDR ENGINEERING, INC. OF THE CAROLINAS

HABITAT ASSESSMENT AND RESTORATION PROGRAM

TABLE OF CONTENTS

APPENDICES

STREAM MITIGATION PLAN
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1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) has identified one reach of Bear Creek and one reach of a tributary to Bear Creek on the Phillips property in Chatham County, North Carolina as having potential for stream mitigation. There are approximately 2,374 linear feet (LF) of Bear Creek and approximately 1,744 LF of the unnamed tributary (UT) to Bear Creek located on the Phillips property. Based on initial field surveys, there are approximately 884 LF of Bear Creek and 1,744 LF of the UT to Bear Creek that likely meet the criteria for full stream mitigation credit and are located in settings under which a restoration would be practical. This report provides a summary of the field activities and analyses used to develop a preliminary stream mitigation plan for these two impaired reaches located on the Phillips property.

1.1 Project Description

The two reaches of interest on the Phillips property are located in Chatham County, North Carolina, west of the town of Bear Creek, approximately 2.5 miles north of Harpers Cross Roads, just off of SR 1006 (Siler City-Glendon Road). The primary reach is a third order segment of Bear Creek, a tributary to Deep River (USGS Hydrologic Unit 03030003). The secondary reach is a second order tributary to Bear Creek. The 129 acre tract of land owned by the Phillips includes: 1) an approximately 682 LF segment of Bear Creek (upper reach segment labeled A in Appendix B Figure) that flows through an open pasture with no trees or other woody shrub along the banks; 2) a lower approximately 1127 LF segment of Bear Creek (Segments B and E in Appendix B Figure) that flows within a wooded area with sparse under story vegetation, also used for cattle grazing; and 3) an UT to Bear Creek that drains lands to the west. The UT is divided for the purposes of this assessment into an upper and lower segment, both within open pasture. The upper segment is located west of SR 1007 (Segment C of Appendix B Figure) and the lower segment is located east of SR 1007 and discharges into Bear Creek (Segment D of Appendix B Figure). The UT includes approximately 1866 LF of stream.

1.2 Goals and Objectives

The goals of the mitigation plan for both sections are to:

- Restore these impaired segments of Bear Creek and of the unnamed tributary to Bear Creek to a stable dimension, pattern and profile that can transport the watershed's water and sediment load;
- Improve habitat through enhancement of the riparian zone and provision of a vegetated buffer; and
- Improve water quality by fencing livestock out of stream
- Replace culvert under Siler City/Glendon Road

1.3 Methodology

Additional field investigations were conducted on the above referenced sections of Bear Creek and the tributary to Bear Creek as part of this project. Preliminary field investigations were also

conducted on a preliminary reference reach for the Bear Creek segment located in Chatham County and on a preliminary reference reach for the UT to Bear Creek located in Randolph County, North Carolina as part of this project. Data on existing plan, profile and cross-sectional area were collected for use in Rosgen-based stream classification method, Levels I and II. Drought conditions prohibited collection of sediment transport data typically collected as part of these preliminary field investigations. Therefore, these data will be collected in the next phase of data collection or prior to the finalization of this report.

2.0 EXISTING CONDITIONS

2.1 Watershed

The Site is located in the Piedmont physiographic province. The landscape is characterized by gently rolling, well-rounded hills and long, low ridges that form a transition area between the Blue Ridge Mountains and the Atlantic Coastal Plain. Elevation within the Piedmont ranges from 300 to 1,500 feet (91.44 to 457.20 m) above sea level. The Site includes Bear Creek, a third order stream, as well as one second order tributary to Bear Creek. All waterways within the Site flow into the Rocky River (Figure 1).

Water resources within the Study Area are located in the Deep River Basin of the Cape Fear River watershed (USGS Hydrologic Unit 03030003, NCDWQ Subbasin 03-06-12). Streams have been assigned a best usage classification by the North Carolina Department of Water Quality (NCDWQ) that reflects water quality conditions and potential resource usage. The classification for Bear Creek (NCDWQ Index No. 17-43-16, 04/01/59) is Class C. Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses. Secondary recreation involves human body contact with water (wading, boating, etc.), which occurs in an infrequent, unorganized, or incidental manner.

The Cape Fear River watershed that surrounds the Site supports a drainage basin of approximately 9,322 square miles (24,144 km2). The Cape Fear River Subbasin 03-06-12, near Siler City, drains approximately 243 square miles (629.37 km2). Land within the watershed is approximately 68.9 percent forested/wetland habitat, 29.3 percent agricultural land, 1.3 percent urban areas, and the remaining land is surface water (NCDENR, 2000).

2.1.1 Soils

Based on the 1937 Department of Agriculture Soil Survey for Chatham County, the surface soils in the project area are mainly Alamance gravelly silt loam. The Alamance soils have been derived from the underlying rock formations of the Carolina Slate Belt. The predominant rocks in this belt have a very fine texture, slaty structure. Some of the rocks are coarse in texture and some contain embedded gravel.

2.1.2 Land Use and Zoning

Aerial photographs of the area were used to determine current and potential future land use. Inspection of USGS maps (Bear Creek, Bennett, and Siler City quadrangles) and 1999 high altitude IR photography indicates that the watershed includes rural lands with a preponderance of forest (approximately 70 percent) with subordinate open farmland (approximately 30 percent).

2.2 Project Site

2.2.1 General Description

Bear Creek has approximately 4 square miles of contributing watershed to the north and northwest (Figure 1). The streams have headwaters at peak elevations of approximately 550 feet above sea level, and fall to elevations of 490 feet above sea level at the Phillips property. The upper watershed of Bear Creek is composed of first to third order streams with gradients of approximately 0.005 (ft/ft). This gradient decays to approximately 0.003 (ft/ft) within the Phillips reach.

The UT to Bear Creek drains approximately 0.85 square miles from the west and is a first order stream. The gradient in the upper source region is approximately 0.016 (ft/ft) which decays to 0.005-0.007 (ft/ft) on the Phillips Tract.

Inspection of USGS maps and 1999 high altitude IR photography indicates that the Bear Creek watershed includes rural lands with a preponderance of woods (approx. 70 percent) with subordinate open farmland (30 percent). The unnamed tributary to Bear Creek has principally wooded lands in the upper watershed and pasture in the lower portions. Photography of the Site and both Bear Creek and its UT within the Site are included in Appendix A.

2.2.2 Soils

Soil mapping units are based on the NRCS soil survey for the County (USDA, 2002). The Site encompasses 0.21 square miles (0.55 km^2) and is mapped as Riverview (*Fluventic Dystrudepts*), Callison-Lignum complex (*Aquic Hapludults*), and Callison-Misenheimer complex (*Aquic Hapludults* and *Aquic Dystrudepts*).

Riverview soils are frequently flooded and nearly level. This soil type is found mainly in the floodplains along major rivers and streams throughout the County. Within the Site, Riverview soils are found along Bear Creek on slopes ranging from 0 to 3 percent. Permeability is moderate, and available water capacity is high to very high. These soils are well drained, and the surface runoff is slow. Although Riverview soils are not hydric, they do contain hydric inclusions of Chewacla and Wehadkee soils (USDA, 2002).

Callison-Lignum complex soils are found on ridges, broad inter-stream divides, drainage ways, and heads of drainage ways. This complex consists of approximately 55 percent Callison soils, 27 percent Lignum soils, and 18 percent dissimilar soils. Within the Site, Callison-Lignum soils are found near the two tributaries to Bear Creek on slopes of two to six percent. Callison soils have a moderately slow permeability, while Lignum soils have a very slow permeability. This complex is somewhat poorly to moderately well drained and has moderate to high water capacity and slow to medium surface runoff (USDA, 2002).

Callison-Misenheimer complex soils are found on ridges, broad inter-stream divides, drainage ways, and heads of drainage ways. The complex consists of approximately 51 percent Callison soils, 35 percent Misenheimer and similar soils, and 14 percent dissimilar soils. Within the Site, Callison-Misenheimer soils are found along the second order tributary to Bear Creek on slopes ranging from 6 to 10 percent. Callison soils have a moderate to high water capacity and moderately slow permeability, while Misenheimer

soils have a low water capacity and moderately rapid permeability. This soil complex is somewhat poorly drained to moderately well drained and has medium surface runoff (USDA, 2002).

The banks of Bear Creek along the Phillip's Property did not reveal clear profiles of alluvial soils, but these are likely to exist in sporadic pockets within the floodplain to Bear Creek. The dominance of silty soils throughout the upper Bear Creek Watershed may in part be a causative factor in the rapidly changing stream dimensions noted in the cross sections for both the UT and Bear Creek on the Phillip's tract.

2.2.3 Terrestrial Plant Communities

The project area included on the Phillips Tract is composed of primarily open pasture with the usual complement of pasture graminoid species. Along the banks of Bear Creek, there is a small strip of riparian shrub and tree vegetation that includes Sweetgum (*Liquidambar styraciflua*), Oaks (*Quercus* spp.), Box elder (*Acer negundo*), Tag alder (*Alnus serrulata*), Winged Elm (*Ulmus alata*), American elm (*U. americana*), Hackberry (*Celtis laevigatus*), blackberry (*Rubus* sp.) and other herbaceous species such as Rushes (*Juncus* spp.) and sedges (*Carex* spp.).

The second order tributary is found mostly in open field; however, the upper 500 ft. is located in a mixed Pine/Hardwood forest.

2.2.4 Rare and Protected Species

Species with the Federal Classification of Threatened (T), Endangered (E), or Federal Species of Concern (FSC) are protected under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). An "Endangered Species" is defined as "any species which is in danger of extinction throughout all or a significant portion of its range," and a "Threatened Species" is defined as "any species which is likely to become an Endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532).

The Federally protected species for the County are shown in the following table (NHP, 2003). Although the Bald eagle is currently listed as threatened, it has been proposed for delisting (PD).

Federally Protected Species
Chatham County, NC

Common Name	Scientific Name	Federal Status	Potential Habitat
Red-cockaded woodpecker	*Picoides borealis*	E	No
Cape Fear shiner	*Notropis mekistocholas*	E	No
Harperella	*Ptilimnium nodosum*	E	No
Bald eagle	*Haliaeetus leucocephalus*	T-PD	No

The Site does not provide potential habitat for any of these species. The Critical Habitat, as defined by the US Fish and Wildlife Service, for the Cape Fear shiner (*Notropis mekistocholas*) is found several miles downstream near the Bear Creek confluence with the Deep River. Habitat is not likely to extend up into the upper portion of the watershed based on observations on its current distribution in this and neighboring watersheds. Restoration activities may potentially improve downstream habitat.

3.0 REFERENCE REACHES

3.1 Unnamed Tributary to Bear Creek

An unnamed tributary to Bear Creek, located several miles downstream from the Phillips property in Chatham County, was used as a preliminary reference reach for the impaired Bear Creek reach (Figure 2). The reach surveyed to provide preliminary reference reach data included approximately 300 LF of the stream just north of the bridge crossing along NC 902, approximately 3/4 mile southeast of the Chatham County High School. The reference reach has approximately 6.6 square miles of drainage, slightly larger than the impaired section of Bear Creek on the Phillips tract. A meeting has been scheduled for January 2003 to discuss NCDWQ approval for this reference reach.

The reference reach and its contributing watershed is located within the same topography, geology and soil types that dominate the upper portions of Bear Creek that drain to the impaired reaches along the Phillips Tract. The soils are the gray silty loam Almacene soils derived from the largely fine-grained rocks of the underlying Paleozoic formations of the Carolina Slate Belt. Here, as well as in the Phillips tract, the steam bed includes exposures of interbedded, steeply dipping, strongly cleaved, and moderately fractured meta-sandstone, meta-siltstone and slate.

The stream is surrounded by a mature hardwood forest that is composed of typical Piedmont riparian/upland forest tree species. Species include Tulip poplar (*Liriodendron tulipifera*), Sweetgum, American elm, Red maple (*Acer rubrum*), Oaks and Hackberry. The understory also includes Flowering dogwood (*Cornus florida*), Ironwood (*Carpinus caroliniana*) and Paw-paw (*Asimina triloba*).

Land use in this watershed is estimated as 30 percent open rural farmland (mostly pasture) and 70 percent second growth timber. The amount of roads and buildings is less than 1 percent of the entire watershed. Historical information suggests that most of the county was cleared at one time for agriculture uses. However, before the advent of readily available fertilizer, many areas were abandoned due to depleted nature of the soils. These lands, once abandoned, returned to woods. The reference reach is located within a second growth hardwood stand, with sizable found trees along both banks. The base of the stream is more than 60 percent bedrock and lag stones, which are boulder to cobble-sized fractured or unconnected bedrock.

Stream morphologic information was collected from available topographic and photographic maps and by field surveys.

The reach is believed to provide a reasonable preliminary reference reach to the impaired section of Bear Creek due to:

1. Similarity of topography and climatic setting.
2. Similarity of land use.
3. Similarity of watershed area.

4. Similarity of geology and soils.
5. Existence of bedrock or large lag stones in 60 percent of streambed.
6. Existence of wooded riparian areas with mature large trees along both banks.
7. A planform exhibiting significance natural meander components.

The banks along this reach showed some signs of localized instability, and there is some possibility that this reach may have a slope somewhat steeper than that of Bear Creek in the upper portions of the Phillips reach. More detailed topographic information should be collected on the impaired and reference reaches to establish a longer, more reliable, baseline for stream or water slope before finalizing any design from this reference reach. Also of some concern in the application of this stream as a reference reach was the dry condition of the stream during the survey. The stream consisted of dry rock and boulder (with limited gravel) riffle areas, and stagnant pools coated with organic sediment over bedrock and boulder pavements. The lack of flowing water prevented the collection of a water slope and any direct calculation of riffle or pool slopes in the stream. Estimates are included in Table 1 using the assumptions that streambed slopes from riffle crest to riffle crest provide an average stream water slope, and the riffle bed slope approximates the riffle water slope. Finally, the accumulation of organic mud in all pool areas and presence of bedrock and large lag boulders and cobbles in the riffle areas prevented a standard pebble count from being conducted during the initial survey.

Table 1 summarizes the fluvial morphologic data collected from this reference reach. Appendix A includes some photographs of typical field conditions seen along the reach. Appendix C includes the tabulated field data for cross section and longitudinal profiles, along with graphical plots of the data annotated with fluvial dimensions, and some of the dimensionless ratios.

The reference reach classes are on the boundary limits, by definition, for two of the morphologic parameters for Rosgen Class C streams. First, it has a sinuosity of 1.2, which is at the lower limit for Class C Rosgen streams. Second, the width/depth ratio of 12.7 is at the lower limit for a C stream, basically transitional to a G. The bed of the stream transitions from bedrock (C1) to gravely sand (C5). As bedrock and lag stone can not be incorporated into a grain size average for the stream bottom, a grain average, based on the bar deposits, would be transitional from a C5 to C4 (as can be seen in the Appendix A).

3.2 Unnamed Tributary to Sandy Creek, Randolph County

An unnamed tributary to Sandy Creek located in Randolph County was used as a preliminary reference reach for the impaired unnamed tributary located on the Phillips property (Figure 3). The reference reach is located on the Acher's tract, along the north side of Old Liberty Road, approximately 3.5 miles west of US 421 and 5 miles west of Liberty. The reach joins another tributary just before the bridge on Old Liberty Road.

The drainage area to this reference reach is approximately 1.1 square miles. The land use is estimated to be 57 percent woods and 43 percent open farmland. There are three small ponds that capture approximately 0.29 square miles of upland runoff.

The underlying bedrock at this location is granite or granitic gneiss of probably Paleozoic age. There are two areas of bedrock exposure along the creek reference reach, but otherwise the creek rests on a sand and gravel base.

The soils locally developed along the creek vary from sandy to silty loam. These types of soils are consistent with the presence of granitic rocks at depth. However, small areas of faint alluvial

deposit layering along the creek banks suggest that the floodplain at this location is partially underlain by alluvial sediments.

The reach has a limited wooded riparian fringe dominated by hardwoods and brush. Species here include Sweetgum, Hackberry, Oaks and Ironwood with a dense understory of vines such as Poison Ivy (*Toxicodendron radicans*) and Japanese honeysuckle (*Lonicera japonica*). While some of the trees along the stream banks had 8 to 14 inch diameters, other bank areas were lined with trees and shrubs with limited growth and maturity. Open fields are found within 30 to 165 feet of the creek on both sides. It is possible that the creek was located within a more cleared setting a few decades ago. The banks along this creek included some areas of moderate erosion on meander bend areas, but erosion has not exceeded rates of deposition on point bars, so a balance of erosion and deposition is still in effect.

Aerial photographs of the site were insufficient in detail to map the planform of this reach, so a tape and compass survey was added to the field assessment to establish the planform parameters. The overall alignment of the stream is fairly straight with small meanders superimposed (Appendix C). This could be the result of the stream having been straightened at one time in the past. However, the presence of bedrock in two areas along the creek argues against this interpretation. It is also common in granitic bedrock for streams to follow fracture trends in the otherwise homogeneous underlying granitic formations. Figure 3 indicates that the overall valley at this site has a North to North-Northeast narrow linear trend that basically parallels the reach alignment. Thus, the occurrence of bedrock in the channel bottom, and the co-alignment of the stream reference reach with a narrow linear topographic drainage argues for this reach not having been previously altered. Instead, the stream appears to be running a coarse dictated by the weaknesses in the underlying fractured granite or granitic gneiss.

The reach is considered to have sufficient indications of stability and comparative watershed characteristics to use as a preliminary design benchmark for the small UT to Bear Creek on the Phillips tract. The tract is in a similar topographic and climatic setting. The land use is comparable, although the presence of the three ponds likely has some impacts on storm flow and sediment transport. The drainage area is 1.1 square miles, which is close to the 0.8 to 0.9 square miles for the impaired unnamed tributary to Bear Creek. The soils are sandy to silty loam. The creek has some signs of instability, but it is reasonably consistent in cross section dimensions. The presence of bedrock leads to the conclusion that the morphologic dimensions are representative of a stream that is evolving within a stable set of morphologic parameters for its pattern, dimension and profile.

The stream classification for this reach is a Rosgen C5 stream (Table 1), with the exception of its W/D ratio of only 6.1. On the basis of this parameter, it would be a Rosgen G; however, the entrenchment ratio, which is greater here than 7, is inconsistent with a G. Both entrenchment ratio and W/D are parameters that are determined by the estimation of the Bankfull Stage, which can be somewhat debatable. Fundamentally the issue cannot be uniquely resolved without the construction of stream sediment rating curves to demonstrate the storm and storm return interval that moves the most sediment through the reach. The presence of deeply weathered rock in the North Carolina Piedmont favors low W/D ratios for a given valley slope, and as such may explain the C to G transitional nature of many of the Piedmont streams. Also, this stream is transitional in its sinuosity with steeper topographic stream classes (A or B); however, as noted earlier the reach is likely controlled by underlying bedrock fractures, thus the low sinuosity and meander belt width (Appendix C).

4.0 STREAM MITIGATION DESIGN

The Phillips tract includes a number of stream segments, which hold various possibilities for stream mitigation. These various segments are outlined on Figure 4. First, there are two areas that have reasonable pattern, dimension and profile, and adjustments to these areas are not needed (Segments B and E). However, these areas are impacted by farm practices, which have opened up bank areas and allowed grazing and animal access to the creek and creek banks. In these areas, the banks are susceptible to high rates of erosion, and degradation of water quality by sediment and bacteria sourced to domestic animals. Thus, these two areas are recommended for the establishment of a fenced conservation buffer with buffer plantings to preclude the need of future adjustments to pattern, dimension, and profile.

Second, along Bear Creek, for approximately 300 to 400 feet below the confluence with the UT, Bear Creek has an east bank with several areas lacking woody riparian bank protection and indications of rapid bank failure. These include rotational bank slumping and bank collapse associated with animal activity. These areas have enlarged channel dimensions, and a need for the re-establishment of bank and riparian areas with more deeply rooted vegetation to promote the stable evolution of the stream.

Finally, the remaining section of Bear Creek and the UT have a channelized planform and inappropriate dimension and longitudinal profile. It lacks significant wooded riparian buffers thus justifying full restoration efforts. The restoration of these two reaches are briefly discussed along parametric lines below, but are also outlined on Figure 4 and 5 in plan and cross section views, respectively.

4.1 Restoration components

4.1.1 Dimension

The preliminary design dimension for the restoration of Bear Creek comes from the reference reach data collected for the UT to Bear Creek located downstream along NC 902 northeast of Harper's Crossing. The watershed for the reference reach is slightly larger than that for the impaired reach, and until more detailed surveys are available for the Phillips tract, one cannot confirm that the two reaches have comparable average bankfull water slopes. The USGS topographic data suggests they have comparable valley settings, but the limited longitudinal data needs to be supplemented prior to final design. The final design dimensions should also be adjusted to accommodate the slight differences in watershed areas.

The preliminary design dimension for the restoration of the UT to Bear Creek comes from the reference reach data collected for the UT tributary to Sandy Creek located downstream along Old Liberty Road, 3.5 miles west of US 421. The watershed for the reference reach is slightly larger than that for the impaired reach (1.1 versus 0.8 to 0.9 square miles), and until more detailed surveys are available for the Phillips tract, the two reaches may not have comparable average bankfull water slopes. The longitudinal profile conducted for the impaired tributary yielded a very low slope (less than 0.001; sinuosity = 1.0). The longitudinal profile conducted for the reference tributary yielded a water slope of 0.006 to 0.007. The USGS topographic data suggests, however, that overall the impaired tributary has a comparable valley slope. The limited longitudinal data for the impaired reach will have to be supplemented prior to final design. The existing longitudinal profile came from the easternmost segment of the impaired tributary (east of SR 1006), and this segment may be running at an artificially low gradient due to conditions established when the culvert was put in on SR 1006. Should a low gradient be confirmed also for the impaired tributary segment west of SR 1006, additional reference

reach data will have to be obtained for lower slope first order streams in the areas to properly size the dimensions of the restored tributary. Finally, the final design dimensions should also be adjusted to accommodate the slight differences in watershed areas.

4.1.2 Pattern

The patterns shown on Figure 4 include meander belt widths, meander radii of curvature, channel sinuosity, and mean meander wavelengths determined from the two reference reaches assessed in this work. The parameters were adjusted to accommodate site constraints (e.g. road, bridge, and topographic information). The exact pattern for the restored stream reaches should not be finalized until more detailed topographic information is available for the proposed realignments. Field visual inspections on the extent of lateral bottomlands available to shift the centerline of the creek suggest that the new alignments are feasible, but the amount of cut and fill needed to carry out this plan can not be verified until more detailed surveys have been made. Also, the pattern determines the sinuosity and, together with the valley grade, the final stream grade. The proposed new stream sinuosity may impose too low a water slope on the restored stream to maintain its water and sediment transport characteristics, thus again the need to obtain more detailed site topographic information prior to final design.

4.1.3 Bedform

The final bedform of the stream will be determined once a final stream grade can be established. Neither a final riffle-pool structure nor the grain size characteristics can be determined until final grade information can be established. Due to the prolonged drought conditions in the area, information regarding grain size was unable to be determined. Additionally, vegetation overgrowth along the creek beds of Bear Creak and the UT severely limited the ability to obtain pebble counts to estimate grain size.

4.1.4 Structures

In addition to several natural bedrock nick points, a series of grade control (e.g. rock vanes and artificial nick point riffle areas) will likely be needed in both reaches to stabilize all pool areas. Meander bends are proposed to be kept to low arc lengths so that hard bank revetment can be avoided. Bridge and culvert areas will likely need some protection. Culvert protection can occur during culvert replacement. The stream should be dressed with a bed of transportable materials in pool areas to allow appropriate pool development. In the areas of bank stabilization downstream from the confluence with the unnamed tributary, toe protection will be needed (enhancement areas of Figure 4). In these areas, the meander bends have long arc lengths and are currently failing by rotation block slumps (triggered by erosion along the toe of existing banks). Footer stones will be needed to stabilize these bends and offer toe protection (particularly if alluvial soils underlie the adjacent floodplain). Root wads will also be placed in conjunction with the footer stones as habitat improvements. Upstream of these areas, either cross vanes or rock vanes will lower velocities and bed shear stresses in the near-bank flow regime. In addition, a December 27, 2002 meeting will finalize the location and type of livestock crossings. Potential livestock crossing sites are shown in Figure 4. A generalized planform for the Bear Creek section of the restoration can be seen in Figure 6.

4.2 Sediment Transport

Detailed sediment transport calculations have not been made at this point in the study. These calculations need to carefully consider final stream grades, which cannot be determined from the available site topographic information. Drought conditions also limited the ability to collect reliable streambed sediment data during this study.

4.3 Flooding Analysis

The USGS has developed regression curves to quantify periodic flood flows in small (0.04 to 41 square miles), ungauged streams in North Carolina (Gunter, et al., 1987). The regression curves were developed using stream flow and rainfall data from basins. The basins were further segregated into three hydrologic regions: Blue-Ridge Piedmont, Sand Hills, and Coastal Plain. The regional regression equations developed for North Carolina Blue-Ridge Piedmont, small urban streams were used to estimate the 2-, 5-, 10-, 25-, 50- and 100-year peak discharges for the 4.1 square mile watershed of the proposed Bear Creek restoration area and for the 0.9 square mile watershed of the proposed tributary to Bear Creek restoration. The regression equations are summarized in Appendix E.

The resulting estimated discharges (Q) for Bear Creek are:

Q2 = 382 cfs
Q5 = 638 cfs
Q10 = 854 cfs
Q25 = 1193 cfs
Q50 = 1454 cfs
Q100 = 1781 cfs

The resulting estimated discharges (Q) for the unnamed tributary to Bear Creek are:

Q2 = 132 cfs
Q5 = 229 cfs
Q10 = 308 cfs
Q25 = 431 cfs
Q50 = 537 cfs
Q100 = 665 cfs

The bankfull event is likely to lie between the 1 and 2 year return interval storm, thus the 2-year estimate in these regression calculations can be considered an upper bound to the bankfull discharge. For the small tributary, the estimate is 132 cubic feet per second (cfs), and it is 382 cfs for Bear Creek.

In addition to these calculations, a review of the NC USGS gauging data for stations showed similar settings. There are only two stations that come close to conditions seen in the impaired watersheds. These two stations have limited peak annual flow data, but the existing data is plotted on return interval probability curves in Appendix D. One station (Dutchman Creek with 3.44 square miles of drainage) yields a 1.5-year return interval storm with approximately 280 cfs; the other station, Rocky River (Chatham County) with 7.42 square miles of drainage, has a 1.5-year return interval discharge of approximately 200 cfs. There are no stations with appropriate characteristics for the smaller tributary. From this, and the regression curve estimates, the estimated bankfull discharge is likely to lie between 200 and 400 cfs. Additional hydraulic calculations should be completed prior to final design to compare bankfull discharge estimates between the reference reaches and impaired reach under anticipated design conditions.

4.4 Vegetative Planting

4.4.1 Stream Bank and Riparian Buffer Vegetation

Vegetative plantings would include the use of stream-adapted species to bioengineer the slopes of the new stream for stabilization and shade. A variety of species would be used to prevent a monoculture and provide for a greater diversity of wildlife resources. Tree species adapted for riparian conditions would be used to vegetate the buffer areas along the streams. The following table indicates the types and uses of species that would likely be incorporated into the design. Plantings will be bare root trees or live stakes, depending on availability.

Stream Bank and Riparian Buffer Vegetation Bear Creek		
Common Name	**Latin Name**	**Use**
Silky dogwood	*Cornus amomum*	Bank stability
Smooth alder	*Alnus serrulata*	Bank stability
Elderberry	*Sambucus canadensis*	Bank stability
Willow	*Salix* sp.*	Bank stability
American sycamore	*Platanus occidentalis*	Riparian buffer
Black gum	*Nyssa sylvatica*	Riparian buffer
Green ash	*Fraxinus pennsylvanica*	Riparian buffer
Oak	*Quercus* sp.**	Riparian buffer

* Likely Silky willow (*Salix cericea*), which is a streamside shrub, native to the Piedmont of the Carolinas.
** Can be any number of species including *Q. alba, Q. rubra, Q. michauxii, Q. lyrata, Q. falcata, Q. nigra* or *Q. phellos.* Final species selection is contingent upon landowner agreement.

5.0 MONITORING AND SUCCESS CRITERIA

The NCDOT will provide an "as-built" of the stream reach within 90 days after construction has been completed. The "as-built" will include profile and plan view of the completed stream project. The "as-built" will serve as the baseline during the monitoring period. The as-built will consist of "red line" design plans, which will also include the location of permanent photo points and vegetation plots.

The mitigation project will be monitored biannually for five years. The NCDOT recommends this "preventive" review in order to identify early the potential development of problem areas along the stream reach. As part of the biannual review, the entire stream reach will be visually monitored for stability and vegetation establishment. The NCDOT believes the walkthrough will ensure that the entire stream reach is in good condition and again provide a thorough preventive review of the stream. Permanent photo reference points along the stream will be established for the biannual monitoring.

During the biannual review of the stream, the entire stream reach will be evaluated for any potential problem areas such as stream bank instability, in-stream structure failure or unsuccessful vegetation establishment. Photographs of the good, stable sections of the stream as well as potential problem areas will be taken to document the stability of the stream and the severity of the potential problem area(s) encountered.

An annual report documenting the two yearly visits to the stream mitigation will be prepared. The report will contain photographs and documentation of the stream during the monitoring period.

If during the biannual review of the stream reach a failure area is noted, the area will be evaluated to determine the corrective actions that will be required to resolve the problem. The NCDOT will take cross sections in these areas where failure is occurring. These cross sections will be compared to the as-built. If remediation of an area is required, a proposal will be submitted for the needed work. Remedial actions will be undertaken considering any seasonal limitations at the site.

The NCDOT does not recommend taking cross sections in stable areas, which prevents unnecessary survey work. The NCDOT believes surveying cross sections and reviewing them in the office will not yield conclusive results about where sections of the stream may be failing. A field visit would have to occur in order to resolve whether the stream is actually failing.

Upon completion of monitoring the site for three successful growing seasons, a final report will be prepared and presented to the resource agencies prior to a "Final Review" of the project. If remedial actions to the stream have been required during the monitoring period, an updated "as-built" will be attached to the report. The stream mitigation site will be reviewed with the resource agencies for final acceptance of the stream reach. If the resource agencies require additional work to the stream, then the work will be performed considering the seasonal limitations of the site.

6.0 DISPENSATION OF PROPERTY

NCDOT will hold a conservation easement on the property until all mitigation activities are completed and the site is determined to be successful. Although no plan for dispensation of the Bear Creek mitigation site has been developed, NCDOT will likely transfer the easement to a resource agency (public or private) acceptable to the appropriate regulatory agencies. Covenants and/or restrictions on the deed will insure adequate management and protection of the site in perpetuity. NCDOT currently has an option of a conservation easement. The conservation easement will be signed upon completion of the design plans.

7.0 STREAM MITIGATION CREDIT

The Unnamed Tributary to Bear Creek and Bear Creek have been divided into Reaches A through E, as shown on the Planform Figure in Appendix B. The following table illustrates the proposed mitigation credits for each reach. The proposed reaches will be approximately 4,644 feet in length, which is 526 feet longer than the existing reaches. Final stream length will be determined during the design phase. Based on mitigation credit ratios available for each reach, the final credit is approximately 3,816 feet. As part of the stream restoration, a 50-foot vegetated buffer will be planted on each side of the stream channel (Figure 4). The total buffer acreage for reaches A through E will be approximately 10.7 acres.

NCDOT Proposed Mitigation Credit
Bear Creek and UT (Phillips Tract)

Reach	Initial Length (ft)	Proposed Length (ft)	Ratio	Restoration Parameters*	Final Credit (ft)
A	884	1,061	1:1	P, D, R, V, E	1,061
B	990	990	2:1	D, V, E	495
C	1,365	1,638	1:1	P, D, R, V, E	1,638
D	379	455	1:1	P, D, R, V, E	455
E	500	500	3:1	V, E	167
Total	**4,118**	**4,644**			**3,816**

* P = Pattern, D = Dimension, R = Profile, V = Vegetation (buffer), E = Livestock Exclusion

There are several benefits that can be obtained through the implementation of this Project. They include:

- Channel stabilization and in-stream sediment reduction
- Improved aesthetics
- Increased aquatic habitat
- Increased riparian habitat
- Improved water quality via livestock exclusion.

8.0 REFERENCES

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Table 1: Watershed and Stream Geomorphic Parameters, DOT Chatham Co. - Upper Bear Creek Watershed Project

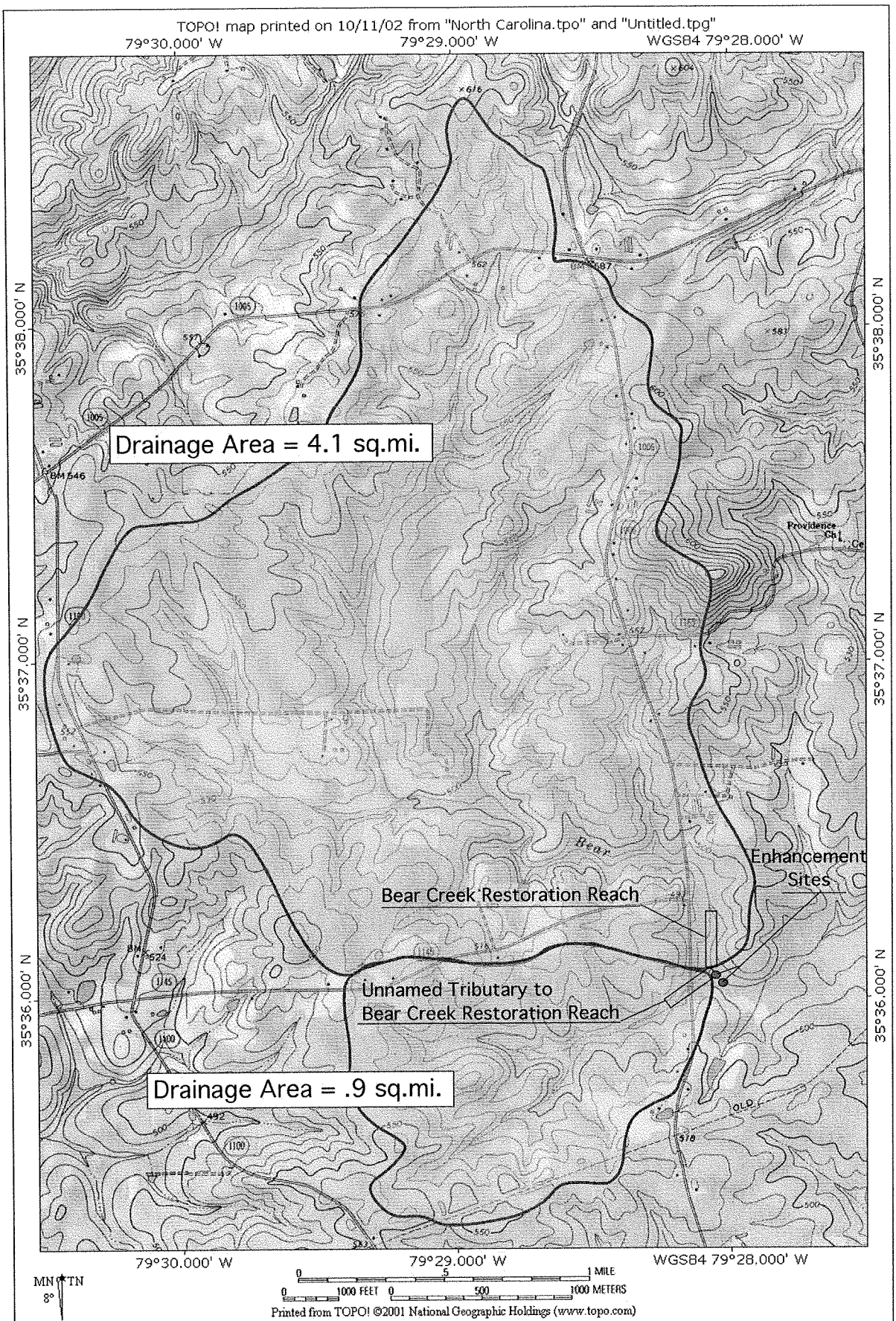
Parameters	Impaired Reaches*						Reference Reaches			
	Bear Creek Segment A		Bear Creek Segment B		Tributary to Bear Creek-1		Tributary to Bear Creek-2		Sandy Creek	
	English Units		*English Units*		*English Units*		*English Units*		*English Units*	
Watershed Area (sq mi & sq km)	4.1		5.0		0.9		6.6		1.0	
Bankfull Width (ft & m)	9.3		20.0		9.8 - 12.1		22.8		10.4	
Bankfull Area (sq. ft & sq. m)	16.0		50.4		11.0		41.7		17.6	
Avg. Bankfull Depth (ft & m)	1.7		2.5		.9 - 1.12		1.8		1.7	
Max. Depth (ft & m)	2.3		3.0		1.4		2.6		2.3	
Flood Prone Width (ft)	49.9		56.8		39.5 - 60.8		>70		> 74	
Entrenchment Ratio	5.4		2.8		4.03 - 5.02		>3.1		> 7.25	
Width/Depth Ratio	5.5		8.0		8.75 - 8.64		12.7		6.1	
Valley Slope	0.0022				0.001		0.0026-0.0033		0.0066	
Sinuosity	1.1		1.3		1.0		1.2		1.1	
Water Slope	0.002				0.001		0.0022-0.0029		0.006-0.007	
Pool/riffle Ratio							2.4		1.7	
Riffle Slope							0.003-0.022 (ave=0.009)		.003 - .14 (ave=.05)	
Pool Slope							<0.001		<0.001	
Ave. Riffle Spacing (ft)							120.0		16.7	
Pool to Pool (P-P) Spacing (ft)							153.0		26.0	
Pool Width (ft)							8 to 12		5 to 7	
Maximum Pool Depth (ft)							.9 (creek not flowing)		0.9	
Bed Material Grain Size (mm, *D50)										
Bed Material Grain Size (mm, *D84)										
Meander Radius of Curvature (ft)	50.0		50.0		33.0		105-411 (ave=228)		10-46 (ave=19.8)	
Meander Wave Length (ft)	245.0				150.0		249-947 (ave=423)		35.5-72.9 (ave=50.4)	
Meander Belt Width (ft)	67.0		197.0		47 - 88		234-323 (ave=278)		24.7	
Bankfull Discharge (cfs)										
Bankfull Est. Mean Velocity (ft/sec)										
Ratio of riffle slope to ave. slope							3.5		7.7	
Ratio of Meander Length to Bankfull Width							10.9-41.5 (ave=18.6)		3.9-8.0 (ave=5.5)	
Ratio of Radius of Curvature to Bankfull Width							4.6-18.0 (ave=10)		1.1-5.1 (ave=2.2)	
Ratio of Pool Width to Bankfull Width							0.43		0.57	
Ratio of P-P to Bankfull Width							6.7		2.5	
Rosgen Class	C5				C5		C5		C5	

Data not available. The Impaired Reaches and Tributary to Bear Creek-2 were dry during Data collection.

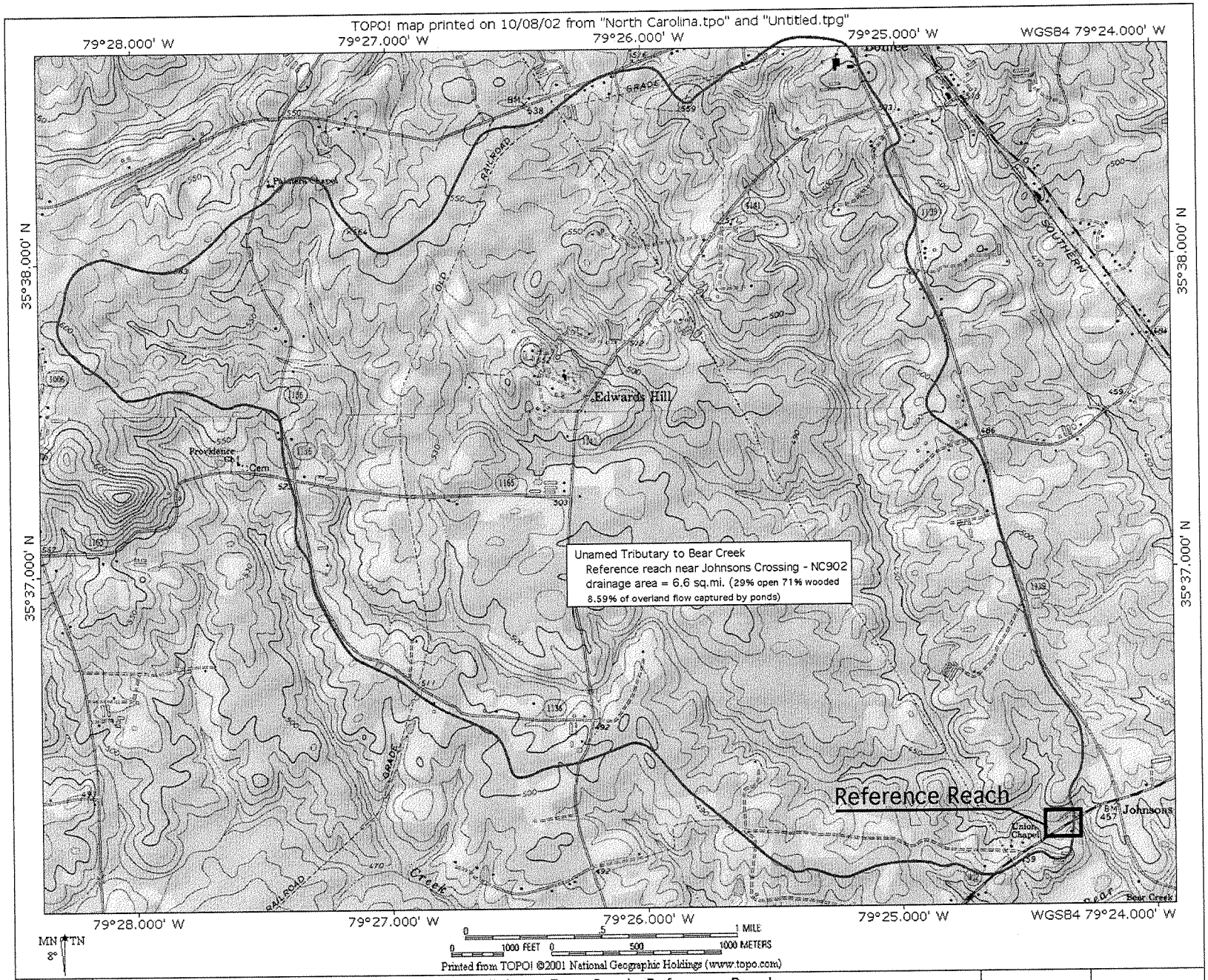
Metric units used on Regional Curves.

Bed material grain size data not collected at this time.

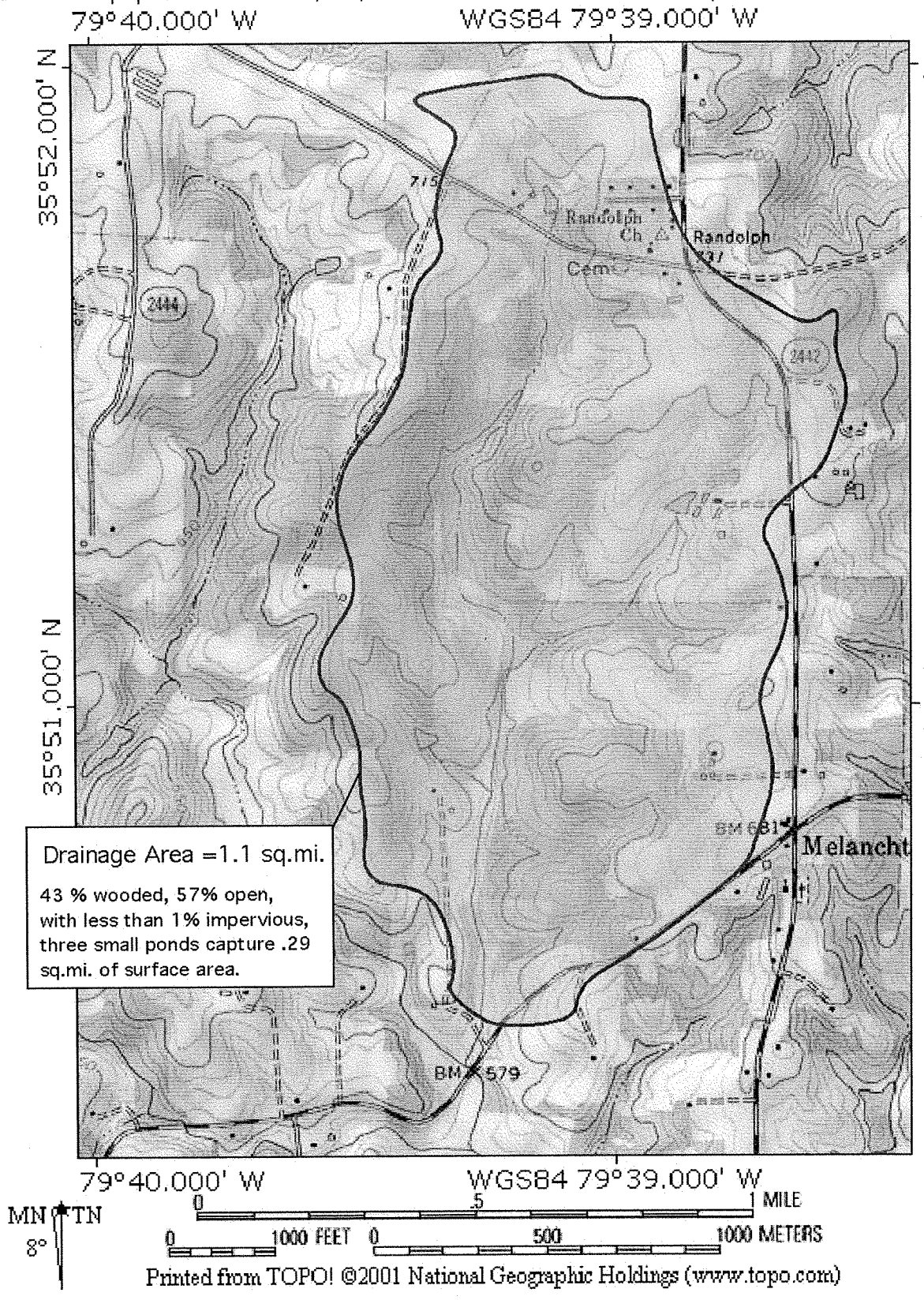
* morphologic data for the impaired streams have large uncertainties (e.g. poorly developed bankfull indicators) due to channel instability and drought conditions and should not be used as a design constraint.



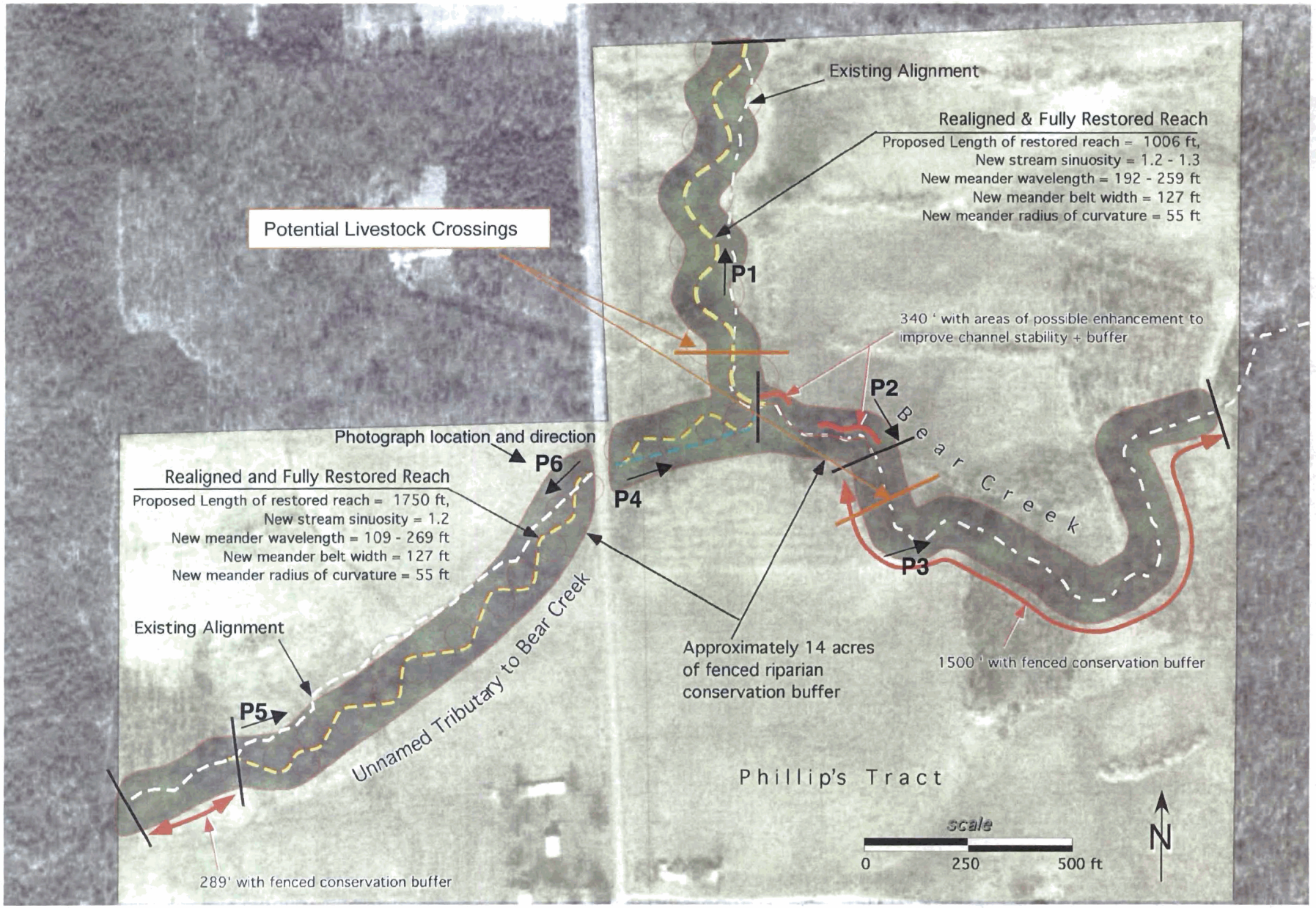
HDR/ HARP	Location Map and Watershed Areas of Bear Creek & Unnamed Trib. to Bear Creek, Impaired Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Figure 1



HDR/ HARP	Location Map and Watershed Area of Unnamed Trib. to Bear Creek, Reference Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Figure 2

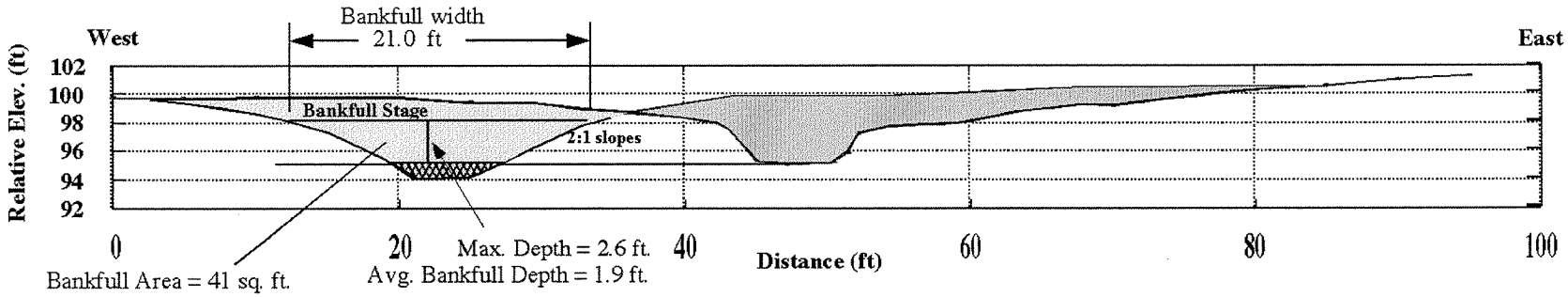


HDR/ HARP	Location Map and Watershed Area of Unnamed Tributary of Sandy Creek, Reference Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Figure 3



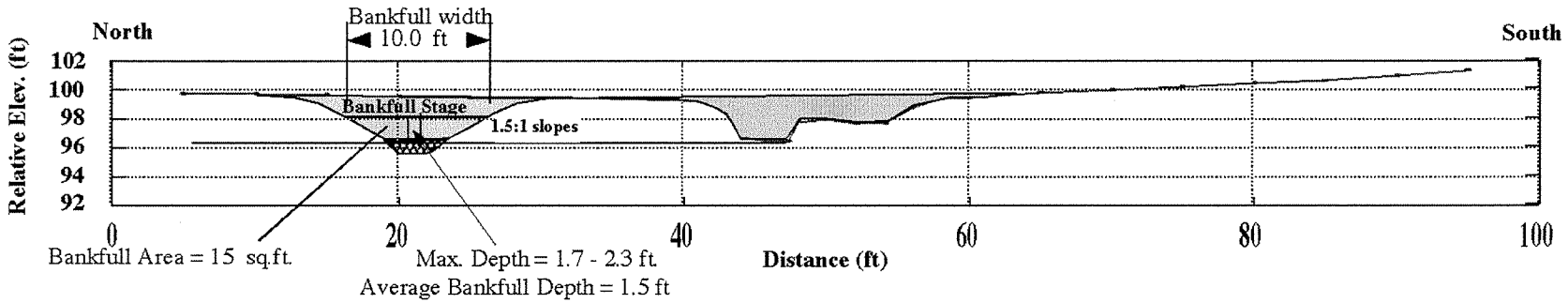
HDR/ HARP	Preliminary Proposed Mitigation Design Elements for Bear Creek and Unnamed Trib. To Bear Creek NCDOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Figure 4

Proposed Restoration Cross Section Segment A, Bear Creek



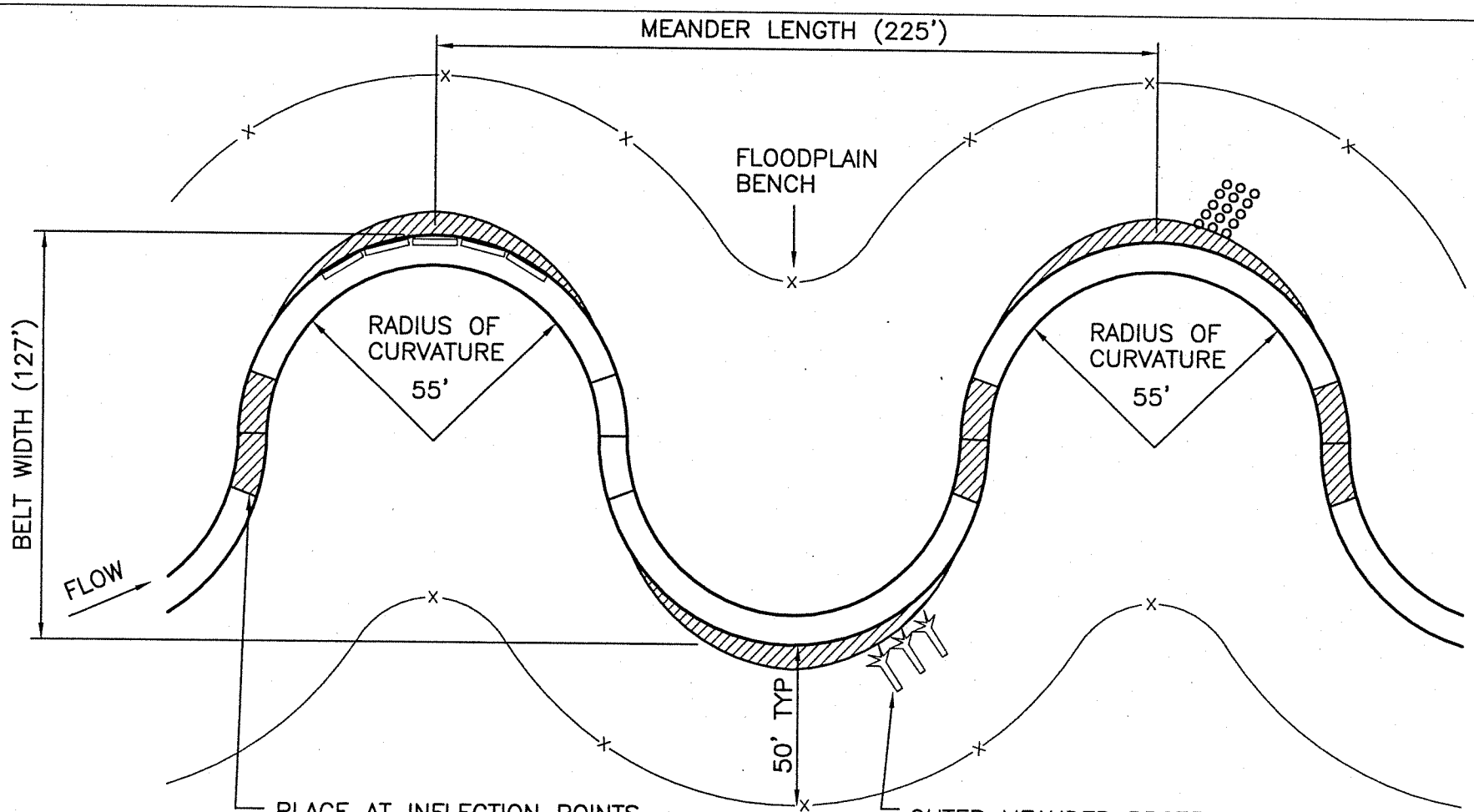
Cut section | Filled section | Channel bed material, sized for mobility

Proposed Cross Section, Segment D, Tributary to Bear Creek



HARP/ HDR	Proposed Preliminary Restoration Cross Sections for Bear Creek & Unnamed Tributary DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Figure 5

c:windm/00166101.018/typsection.dwg
12-20-02 SHANCOCK 14:27:28



NO SCALE

00166-101-018

HDR Engineering, Inc. of the Carolinas
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-6700

General Platform for Bear Creek
Upper Bear Creek Watershed Project

Chatham County, North Carolina

Date 12/2002

Figure 6

Picture location and direction are illustrated on Figure 4 using P1 through P6 annotations.

Photograph 1: View looking upstream along the upper 500 feet of Bear Creek on the Phillips property reach. The low cross section area of Bear Creek in this pasture setting is in marked contrast to the cross section area seen in the reach immediately downstream that has trees along its border.

Photograph 2: Bear Creek looking down stream on the Phillips property tract. Unstable east bank where pasture without shrub or trees along bank create conditions for rapid bank migration.

Photograph 3: Unstable east bank where pasture without shrub or trees along bank create conditions for rapid bank collapse and migration.

Photograph 4: View looking down stream along un-named tributary to Bear Creek that drains western portion of the Phillips property. Reach has a straight, channelized, planform, with undersized cross section. Confluence of un-named tributary with Bear Creek is at trees in background.

Photograph 5: Small dry storm run-off channels in woods along NW portions of Phillips property tract, which drain into Bear Creek during storms. Previously these channels have been suggested as evidence for past channelization of the un-named tributary, but no evidence of channelization of the stream was observed.

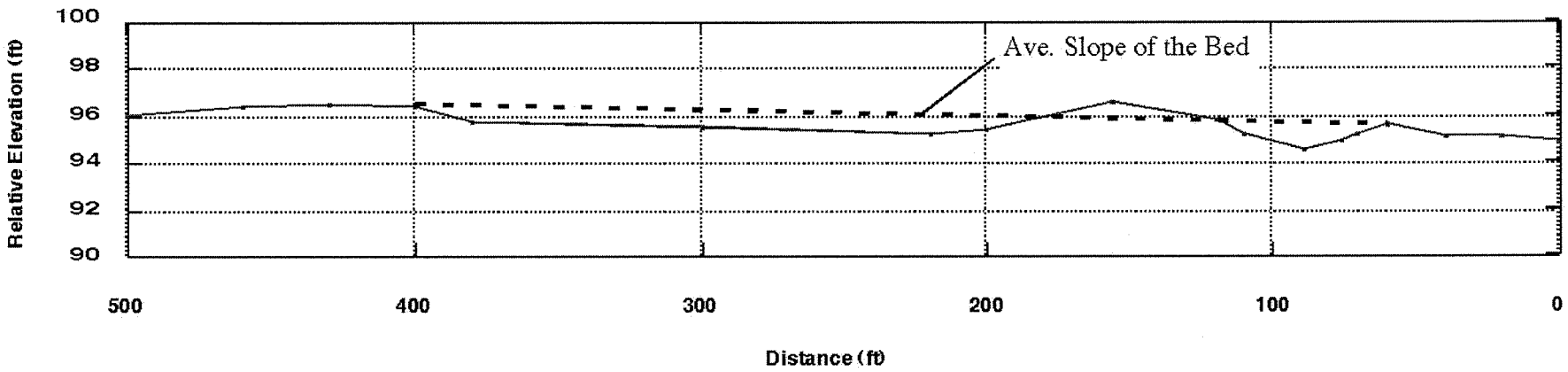
Photograph 6: View looking west up the un-named tributary that joins Bear Creek along the Phillips property reach from the Siler City – Glendon Road. The tributary has a low cross section area, common in pasture settings.

Longitudinal Profile of Bear Creek on Fannie Phillips Property, Segment A
DOT Chatham Co. - Upper Bear Creek Watershed Project

Distance (ft)	BS	HI	FS (ft)	FS (inches)	FS (ft)	Rel. Elevation (ft)	Notes
BM	4.54	104.54				100	
0			9	8.5	9.71	94.83	Top of pool, top of cow crossing area
20			9	5.5	9.46	95.08	
40			9	5.75	9.48	95.06	
60			8	11.25	8.94	95.60	
70			9	4	9.33	95.21	
76			9	7.5	9.63	94.92	Bottom of pool created by log jam, 2" of water
89			10	0	10.00	94.54	Deepest part of pool, WD=6"
110			9	4.5	9.38	95.17	Top of pool
120			8	8.5	8.71	95.83	
156			8	0	8.00	96.54	
200			9	2	9.17	95.37	Pool, WD=10"
220			9	4.5	9.38	95.17	WD=1'
300			9	0.5	9.04	95.50	Bottom of cow crossing, bedrock 237-254'
380			8	10	8.83	95.71	deepest part of pool at 350 (1.5'), bedrock 386-409', WD=8"
400			8	2	8.17	96.37	
430			8	0.5	8.04	96.50	bottom of pool
460			8	2	8.17	96.37	
500			8	6.25	8.52	96.02	WD=8"

No running water in creek, only standing pools
Top and bottom of pool locations based on current water levels, not necessarily representative of flowing water conditions.

Longitudinal Profile of Bear Creek



Average Slope of the Bed = 91.48'-90.29'/400'-60' = 0.002

Sinuosity approximately 1.07
Stream slope = .002; Valley slope = .0022

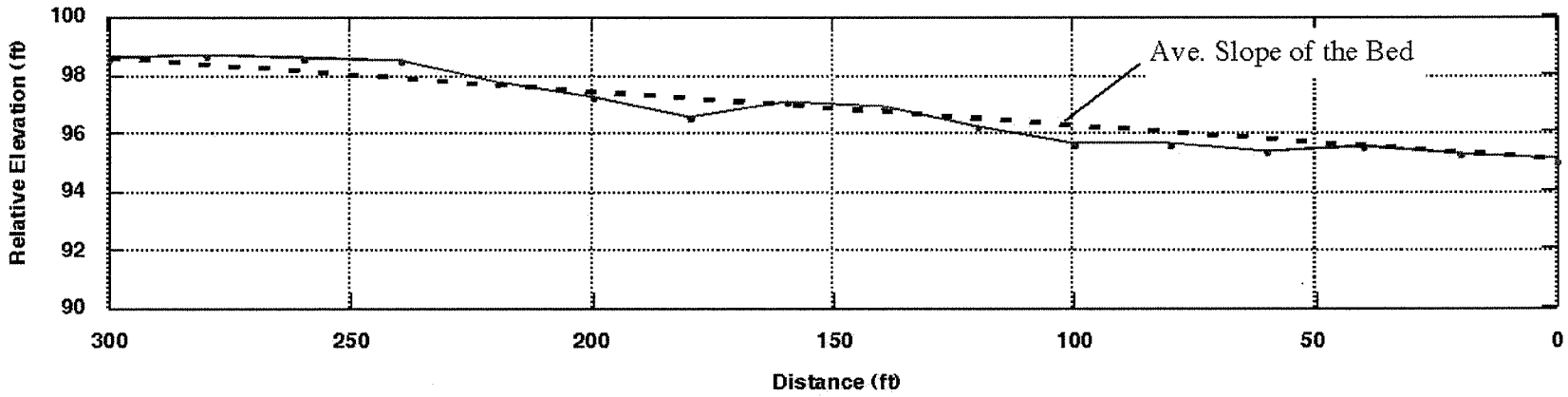
HARP/ HDR	Longitudinal Profile of Bear Creek, Impaired Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix B

Longitudinal Profile of Tributary to Bear Creek on Fannie Phillips Property, Segment D
DOT Chatham Co. - Upper Bear Creek Watershed Project

Distance (ft)	BS	HI	FS (ft)	FS (inches)	FS (ft)	Rel. Elevation (ft)	Notes
BM	4.54	104.54				100	
0			9	6	9.50	95.04	confluence with Bear Creek
20			9	3	9.25	95.29	
40			9	0.05	9.00	95.54	low bank at 7.25'
60			9	2.5	9.21	95.33	pool, WD=7"
80			8	11.5	8.96	95.58	top of pool, WD=2.5"
100			8	11.25	8.94	95.60	end of cow trampled path
120			8	4.25	8.35	96.19	top of cow trampled path
140			7	8.25	7.69	96.85	riprap in bottom of creek to road crossing
160			7	6	7.50	97.04	
180			8	0.5	8.04	96.50	170-180' = pool, WD=4"
200			7	4.25	7.35	97.19	splits into 2 channels below large rock
220			6	9.75	6.81	97.73	WD=1'
240			6	1.25	6.10	98.44	
260			6	0	6.00	98.54	260-280' has been filled in for cow crossing
280			5	10.75	5.90	98.64	290-280' = pool
300			6	0	6.00	98.54	

No running water in creek, only standing pools
Top and bottom of pool locations based on current water levels, not necessarily representative of flowing water conditions.

Longitudinal Profile of Tributary to Bear Creek



Average Slope of the Bed = 94.0'-90.5'/300'-0' = 0.01
Sinuosity = 1.02
Valley slope = .001

HARP/ HDR	Longitudinal Profile of Tributary to Bear Creek, Impaired Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix B

Bear Creek Cross Section -1, Segment A (Oct. 2002 Data)

DOT Chatham Co. - Upper Bear Creek Watershed Project

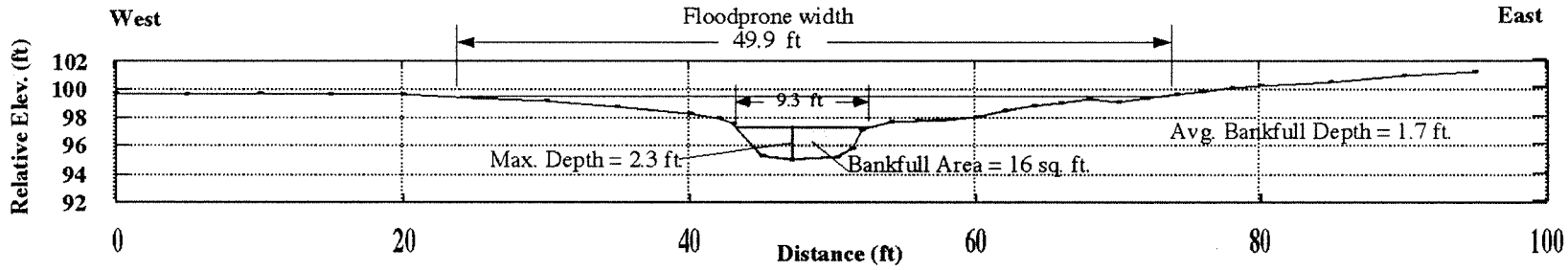
Distance (ft)	Depth		Depth (ft)	Relative	Notes
	Feet plus	Inches		Elevation (ft)	
BM					HI=103.02'
0	3	2.75	3.23	99.79	
5	3	4.25	3.35	99.67	
10	3	2.75	3.23	99.79	
15	3	4.25	3.35	99.67	
20	3	4.25	3.35	99.67	
25	3	6.75	3.56	99.46	
30	3	9.50	3.79	99.23	
35	4	2.25	4.19	98.83	
40	4	7.50	4.63	98.40	
42	5	0.50	5.04	97.98	
43	5	5.00	5.42	97.60	Top of Bank
45.1	7	8.50	7.71	95.31	Edge of Water
47.1	8	0.25	8.02	95.00	Center of Channel
50.4	7	9.50	7.79	95.23	
51.3	7	1.75	7.15	95.87	
52	5	10.00	5.83	97.19	
54	5	3.50	5.29	97.73	
56	5	2.00	5.17	97.85	
58	5	1.00	5.08	97.94	
60	4	11.00	4.92	98.10	
62	4	5.50	4.46	98.56	
64	4	2.00	4.17	98.85	
66	3	11.00	3.92	99.10	
68	3	8.25	3.69	99.33	
70	3	10.25	3.85	99.17	
72	3	7.50	3.63	99.40	
74	3	4.00	3.33	99.69	
76	3	1.50	3.13	99.90	
78	2	10.25	2.85	100.17	
80	2	8.00	2.67	100.35	
85	2	4.75	2.40	100.62	
90	2	0.50	2.04	100.98	
95	1	8.25	1.69	101.33	

File

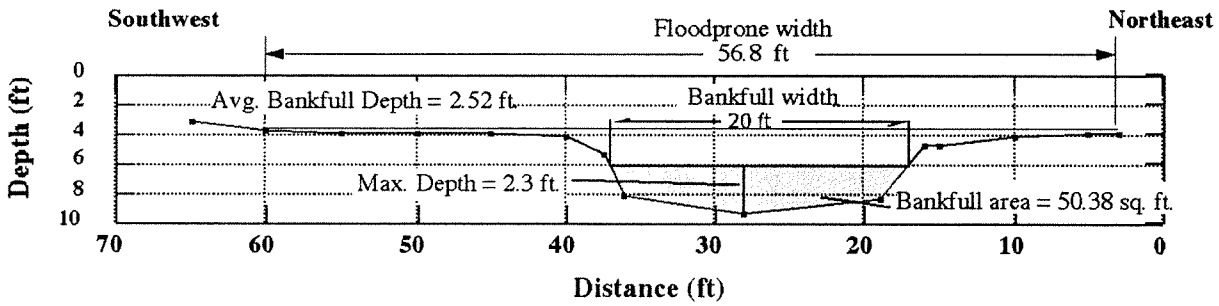
Bear Creek Cross Section -1, Segment B (Jan. 02 Data)
DOT Chatham Co. - Upper Bear Creek Watershed Project

Distance (ft)	Depth (ft)		Depth (ft)	Notes
	Feet plus	Inches		
3	4	0	4.00	
5	4	1	4.08	
10	4	2	4.17	
15	4	9	4.75	
16	4	9.5	4.79	Top of Bank
19	8	6	8.50	Edge of water
28	9	6	9.50	Middle of channel
36	8	3	8.25	Edge of water
37.4	5	6	5.50	
40	4	2	4.17	
45	4	0	4.00	
50	4	0	4.00	
55	4	0	4.00	
60	3	9.5	3.79	
65	3	3	3.25	

Bear Creek Cross Section - 1, Segment A



Bear Creek Cross Section-1, Segment B



Bankfull Indicators
24*
23
27
30
104 inches
Avg. Bankfull = 26 inches or 2.17 feet

*height above water surface

HARP/ HDR	Cross Sections of Impaired Bear Creek Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix B

Trib. to Bear Creek Cross Section -1, Segment D (Oct. 2002 Data)

DOT Chatham Co. - Upper Bear Creek Watershed Project

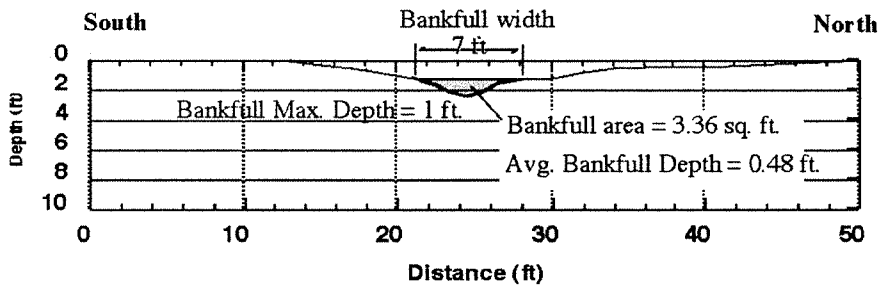
Distance (ft)	Depth		Depth (ft)	Relative Elevation (ft)	Notes
	Feet plus	Inches			
BM					HI=104.54, FS=4.94'
TP-1					BS=3.63', New HI = 103.23
5	3	5.00	3.42	99.81	
10	3	5.50	3.46	99.77	
15	3	7.00	3.58	99.65	
20	3	8.00	3.67	99.56	
25	3	9.00	3.75	99.48	
30	3	9.50	3.79	99.44	
35	3	9.75	3.81	99.42	
40	3	10.75	3.90	99.33	
41	4	0.00	4.00	99.23	Top of Bank
42	4	3.75	4.31	98.92	
43	4	10.50	4.88	98.36	Edge of Water
44	6	5.75	6.48	96.75	Center of Channel
46	6	9.50	6.79	96.44	
47.25	6	9.50	6.79	96.44	
48	5	5.50	5.46	97.77	
50	5	3.25	5.27	97.96	
52	5	6.25	5.52	97.71	
54	5	5.75	5.48	97.75	
56	4	5.25	4.44	98.79	
58	3	9.75	3.81	99.42	Top of Bank
60	3	8.25	3.69	99.54	
65	3	4.00	3.33	99.90	
70	3	2.00	3.17	100.06	
75	3	0.50	3.04	100.19	
80	2	9.25	2.77	100.46	
85	2	6.50	2.54	100.69	
90	2	2.50	2.21	101.02	
95	1	10.50	1.88	101.36	

Trib. to Bear Creek Cross Section -2, Segment D (Oct. 2002 Data)

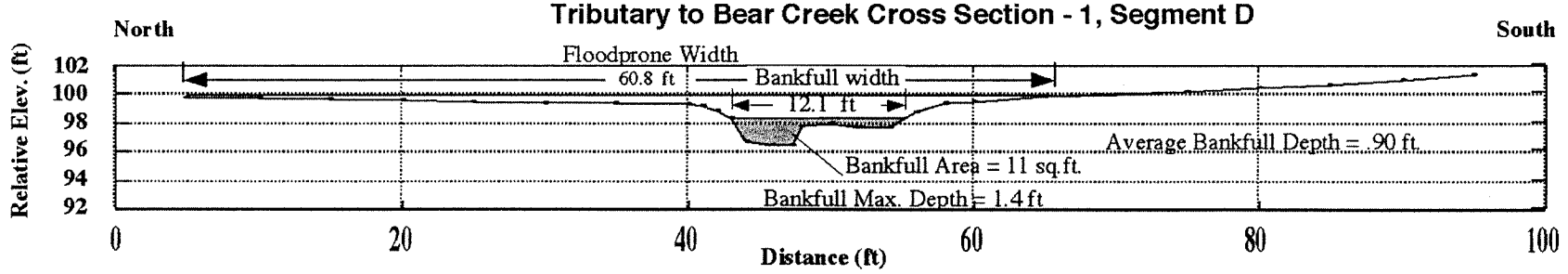
DOT Chatham Co. - Upper Bear Creek Watershed Project

Distance (ft)	Depth		Depth (ft)	Relative Elevation (ft)	Notes
	Feet plus	Inches			HI+103.45
0	3	7.25	3.60	99.85	
5	3	6.75	3.56	99.89	
10	3	4.75	3.40	100.05	
15	3	3.50	3.29	100.16	
20	3	4.50	3.38	100.08	
25	3	5.25	3.44	100.01	
30	3	7.00	3.58	99.87	
35	3	10.25	3.85	99.60	
39	4	3.75	4.31	99.14	Top of Bank
40	4	11.75	4.98	98.47	
42	5	0.00	5.00	98.45	
42.5	5	10.25	5.85	97.60	Edge of Water
44.5	6	1.75	6.15	97.30	Center of Channel
45.6	5	11.50	5.96	97.49	
46.5	5	7.75	5.65	97.80	
47.5	5	11.50	5.96	97.49	
48.5	5	4.50	5.38	98.08	
49	4	1.50	4.13	99.33	Top of Bank
50	4	1.00	4.08	99.37	
52	3	7.00	3.58	99.87	
54	3	2.75	3.23	100.22	
56	2	10.50	2.88	100.58	
60	2	8.00	2.67	100.78	
65	2	5.00	2.42	101.03	
70	2	3.25	2.27	101.18	
75	2	5.00	2.42	101.03	
80	2	4.00	2.33	101.12	
85	2	2.00	2.17	101.28	
90	1	10.25	1.85	101.60	

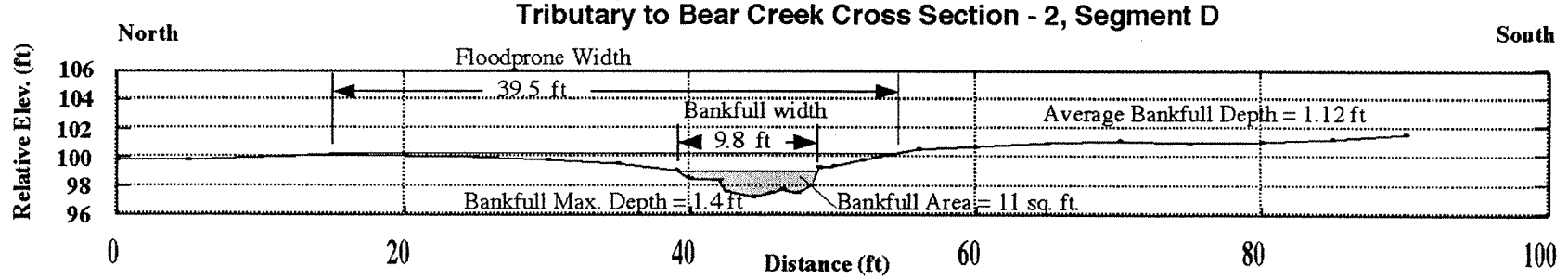
Tributary to Bear Creek Cross Section - 1, Segment C



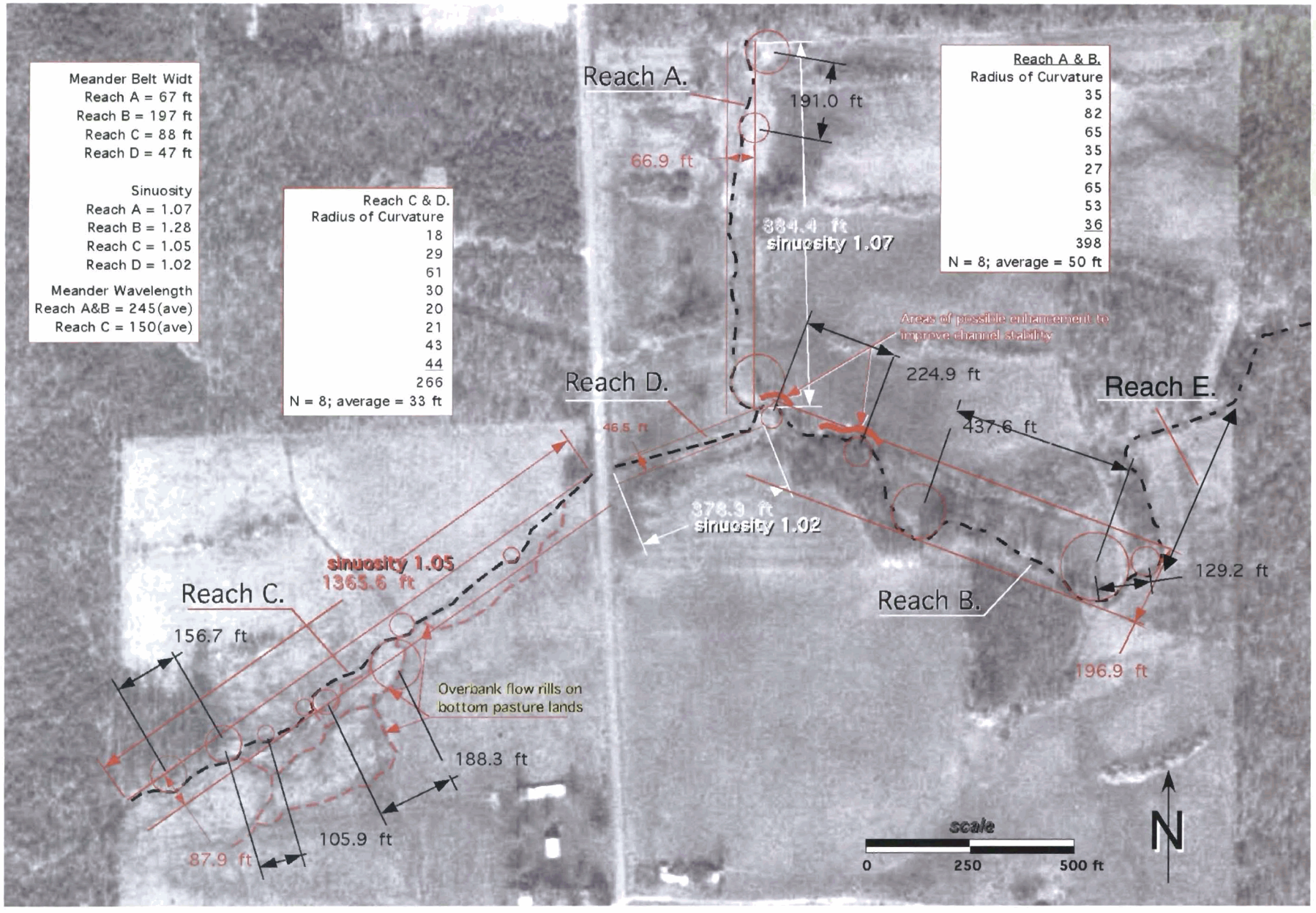
Tributary to Bear Creek Cross Section - 1, Segment D



Tributary to Bear Creek Cross Section - 2, Segment D



HARP/ HDR	Cross Sections of Impaired Bear Creek Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix B



HDR/ HARP	Planform of Bear Creek and Unnamed Trib. to Bear Creek, Impaired Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix B

Longitudinal Profile Data for Unnamed Tributary to Bear Creek, Reference Reach*

DOT Chatham Co. - Upper Bear Creek Watershed Project

St. No.	H.I.**	Bed + H.	Bed + H.I.	Bed Elev. (dec. ft.)	Water Depth	Water Surface E	Notes
-30	100.00	5	1.50	94.88	0	94.88	end of riffle
0	100.00	5	2.50	94.79	2.5	95.00	top of riffle
55	100.00	5	11.00	94.08	11	95.00	center of pool
95	100.00	4	11.25	95.06	0	95.06	end of riffle
136	100.00	4	10.00	95.17	0	95.17	top of riffle
200	100.00	5	7.75	94.35	10	95.19	center of pool
197	100.00	4	9.75	95.19			turning point FS
197	99.28	4	1.00	95.19			turning point BS
256	99.28	4	8.25	94.59	6	95.09	center of pool
300	99.28	5	1.00	94.19	11	95.11	center of pool
330	99.28	4	2.25	95.09	0	95.09	end of riffle
360	99.28	3	6.50	95.74	0	95.74	top of riffle

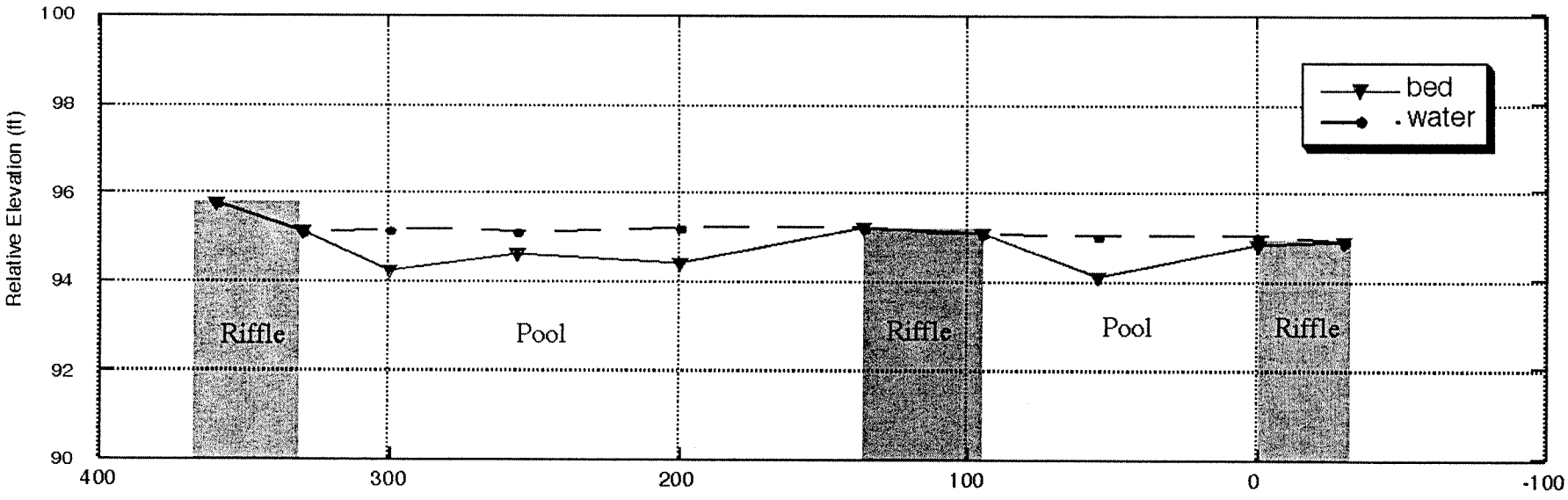
* The creek was not running, water ponded in pools, some upstream pools had water surfaces lower than down stream pools

** Arbitrary Datum Established for this Profile

Total drop along profiled reach = .86 ft; which using a sinuosity of 1.2 yields a stream slope of .0022, and valley slope of .0026.

USGS topo. maps suggest an average valley grade of .0033; which using a sinuosity of1.2 yields a USGS 1:24000-derived stream slope of .0027

Longitudinal Profile for Unnamed Tributary to Bear Creek Located near Johnson's Crossing NC 902



Stream Slope = .002
Sinuosity = 1.18
Valley Grade = .0026

Riffle Slopes
.022
.003
.003
.028

Average Riffle Slope = .009
Average Pool Slope < .001

Riffles
30
41
29
99 ft.

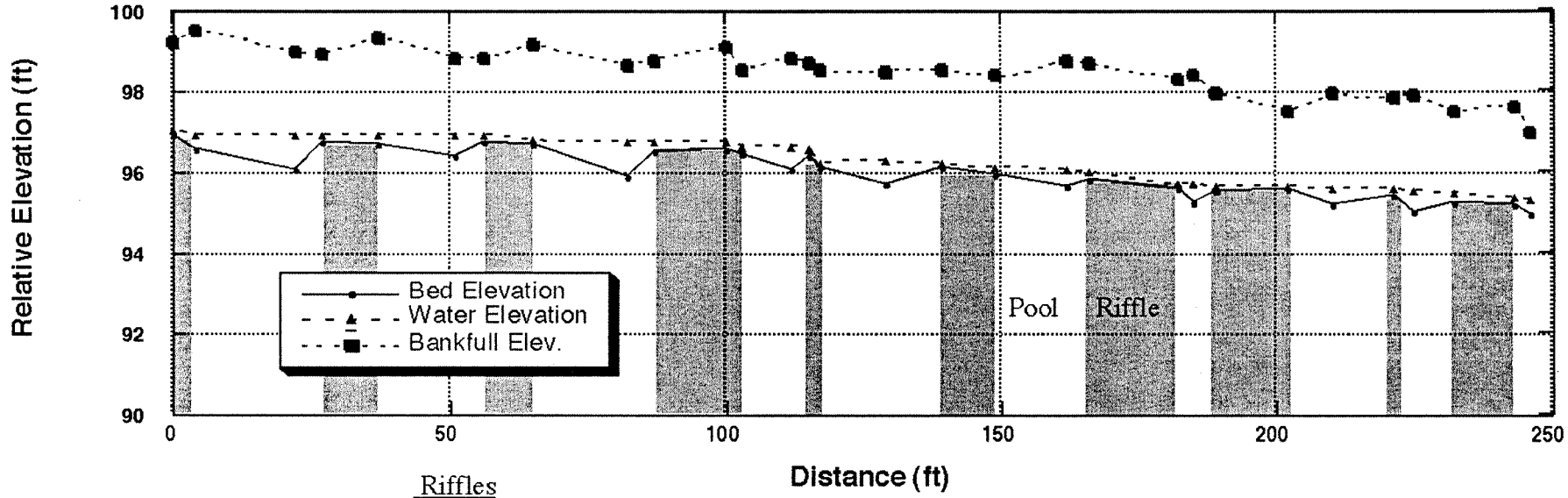
Average Riffle = 33 ft.
Pool:Riffle Ratio = 2.41
Ave. Pool - Pool Spacing = 153 ft.

HARP/ HDR	Longitudinal Profile of Unnamed Tributary to Bear Creek, Reference Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C

Longitudinal Profile of Trib. to Sandy Creek on Archer's Property, Randolph County, NC
DOT Chatham Co. - Upper Bear Creek Watershed Project

Distance (ft)	BS (ft)	BS (in)	BS (d-ft)	HI	FS (ft)	FS (inches)	FS (ft)	Bed Elevation (ft)	Water depth (in)	Water Elev.	Bankfull Height	Bankfull Elev	Notes
BM				100				100					
246					5	0	5.00	95.00	4.00	95.33	20.00	97.00	Pool center
243					4	9.5	4.79	95.21	2.00	95.38	27.00	97.63	Riffle end
232					4	9	4.75	95.25	3.00	95.50	24.00	97.50	Start of Riffle
225					4	11.5	4.96	95.04	6.00	95.54	28.00	97.88	Pool center
221					4	6.5	4.54	95.46	1.50	95.58	27.00	97.83	Center of 3' riffle
210					4	9.5	4.79	95.21	5.00	95.63	28.00	97.96	Pool center
202					4	5	4.42	95.58	1.00	95.67	22.00	97.50	Riffle end
189					4	5.5	4.46	95.54	1.50	95.67	27.00	97.92	Start of Riffle
185					4	9	4.75	95.25	5.50	95.71	32.00	98.38	Pool center
182					4	4.75	4.40	95.60	1.50	95.73	31.00	98.31	Riffle end
tp	4	8	4.66	100.97	3	8.25	3.69	96.31					.9725 ft diff
166					5	1.5	4.15	95.85	2.00	96.01	32.00	98.68	Start of Riffle
162					5	4	4.36	95.64	5.00	96.06	32.00	98.72	Pool center
163					3	1	2.11	97.89				97.89	inner berm
149					5	0.5	4.07	95.93	2.00	96.10	28.00	98.43	Riffle end
139					4	10.5	3.90	96.10	2.00	96.26	27.00	98.51	Start of Riffle
129					5	3	4.28	95.72	7.00	96.31	26.00	98.47	Pool center
117					4	10	3.86	96.14	1.50	96.26	27.00	98.51	Riffle end
115					4	6.5	3.57	96.43	2.00	96.60	25.00	98.68	Start of Riffle
112					4	11	3.94	96.06	7.00	96.64	26.00	98.81	Pool center
103					4	6.25	3.55	96.45	2.00	96.62	23.00	98.54	Riffle end
100					4	5	3.44	96.56	2.50	96.76	28.00	99.10	end of run
87					4	5.5	3.49	96.51	3.00	96.76	24.00	98.76	Start of Riffle
82					5	1	4.11	95.89	10.00	96.72	23.00	98.64	center of Pool
tp2	4		5 4.416	98.779	4	2		100.00					.2494 ft diff
65					4	6.5	3.32	96.68	1.50	96.81	28.00	99.14	Riffle end
56								100.00	3.00	95.92	23.00	97.84	Start of Riffle
51					4	9.5	3.57	96.43	5.50	96.89	23.00	98.81	center of Pool
37					4	6.5	3.32	96.68	2.50	96.89	29.00	99.31	Riffle end
27					4	6	3.28	96.72	2.50	96.93	24.00	98.93	Start of Riffle
22					5	2	3.94	96.06	10.25	96.91	25.00	98.99	center of Pool
4					4	8	3.44	96.56	4.50	96.93	31.00	99.51	Riffle end
0					4	4	3.11	96.89	1.50	97.01	26.00	99.18	Start of Riffle
											26.53	average	

Longitudinal Profile of Unnamed Tributary to Sandy Creek on Archer's Property, Randolph County, NC



Riffles
11
3
13
16
10
3
16
9
10
4
95 ft.

N = 10, average = 9.5 ft.

Ave. Pool - Pool Spacing = 26 ft.

Average Stream Slope = .006-.007
Sinuosity = 1.1
Valley slope = .0066

HARP/ HDR	Longitudinal Profile of Unnamed Tributary to Sandy Creek, Reference Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C

Trib. to Bear Creek, Reference Reach Cross Section -1, Riffle Section

DOT Chatham Co. - Upper Bear Creek Watershed Project

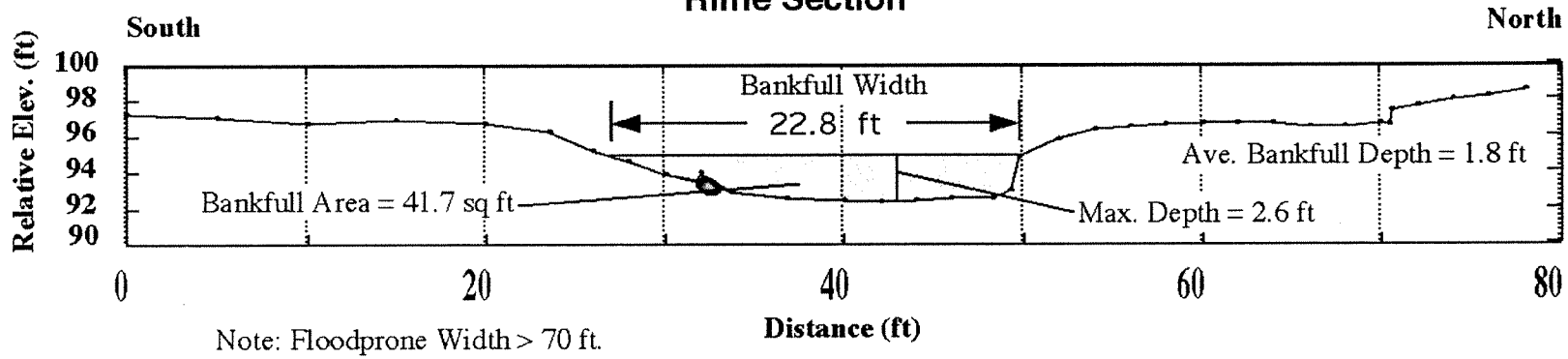
Distance (ft)	Depth		Depth (ft)	Relative Elevation (ft)	Notes
	Feet plus	Inches			
BM					HI=100'
0	2	8.50	2.71	97.29	
5	2	10.50	2.88	97.13	
10	3	2.00	3.17	96.83	
15	3	0.00	3.00	97.00	
20	3	2.50	3.21	96.79	
23.5	3	8.00	3.67	96.33	Top of Bank
26	4	9.00	4.75	95.25	
28	5	4.50	5.38	94.63	
30	6	1.00	6.08	93.92	
31.7	6	5.50	6.46	93.54	Base of Rock
32	5	11.25	5.94	94.06	Top of Rock
33.7	7	1.00	7.08	92.92	Base of Rock
36.8	7	4.50	7.38	92.63	Edge of Water
40	7	5.50	7.46	92.54	WD=1.5"
42	7	6.50	7.54	92.46	WD=2.25"
44	7	6.25	7.52	92.48	WD=2.25"
46	7	5.25	7.44	92.56	WD=1
48.25	7	4.50	7.38	92.63	Edge of Water
49.25	6	11.75	6.98	93.02	
49.7	5	1.50	5.13	94.88	
52	4	1.00	4.08	95.92	
54	3	7.00	3.58	96.42	
56	3	4.50	3.38	96.63	
58	3	4.00	3.33	96.67	
60	3	3.00	3.25	96.75	
62	3	2.00	3.17	96.83	
64	3	2.00	3.17	96.83	
66	3	4.25	3.35	96.65	
68	3	5.00	3.42	96.58	
70	3	3.00	3.25	96.75	
70.5	3	3.25	3.27	96.73	Base of Rock
70.6	2	5.50	2.46	97.54	Top of Rock
72	2	2.28	2.19	97.81	
74	1	10	1.83	98.17	
76	1	8.00	1.67	98.33	
78	1	4.00	1.33	98.67	

Trib. to Bear Creek, Reference Reach Cross Section -2, Pool Section

DOT Chatham Co. - Upper Bear Creek Watershed Project

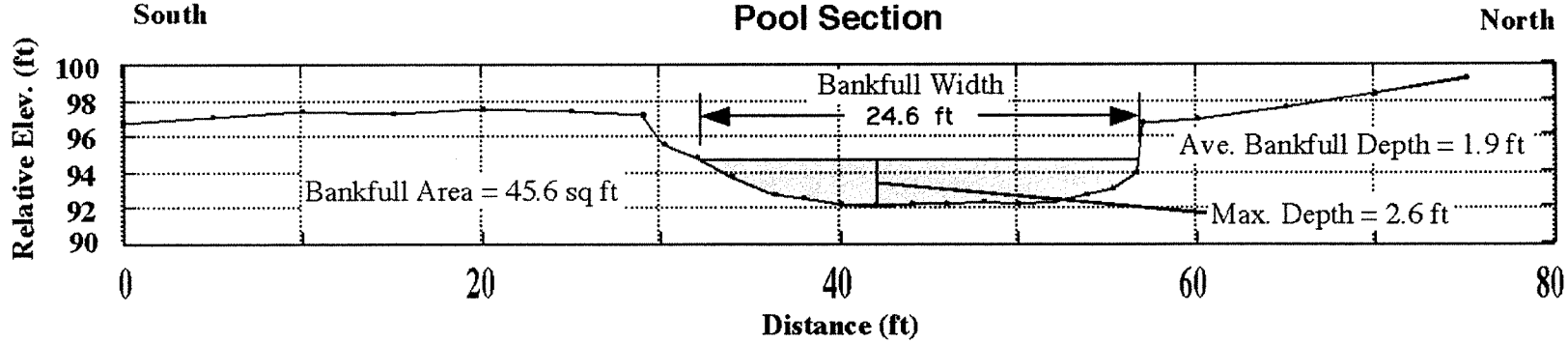
Distance (ft)	Depth		Depth (ft)	Relative Elevation (ft)	Notes
	Feet plus	Inches			
0	3	2.25	3.19	96.81	HI=100
5	2	10.50	2.88	97.13	
10	2	7.50	2.63	97.38	
15	2	8.25	2.69	97.31	
20	2	6.00	2.50	97.50	
25	2	6.25	2.52	97.48	
29	2	9.75	2.81	97.19	Top of Bank
30.25	4	4.75	4.40	95.60	
32	5	2.25	5.19	94.81	
34	6	3.25	6.27	93.73	
36.4	7	2.00	7.17	92.83	Edge of Water
38	7	4.50	7.38	92.63	WD=2.5"
40	7	8.25	7.69	92.31	WD=7"
42	7	10.00	7.83	92.17	WD=8"
44	7	8.25	7.69	92.31	WD=7"
46	7	8.25	7.69	92.31	WD=6.5"
48	7	7.75	7.65	92.35	WD=6.5"
50	7	8.25	7.69	92.31	WD=7"
52	7	7.00	7.58	92.42	WD=5"
53.8	7	2.25	7.19	92.81	Edge of Water
55.3	6	10.00	6.83	93.17	
56.6	6	0.25	6.02	93.98	At Undercut
57	3	3.00	3.25	96.75	Top of Bank
60	2	11.50	2.96	97.04	
65	2	4.00	2.33	97.67	
70	1	7.00	1.58	98.42	
75	0	9.50	0.79	99.21	

Unnamed Tributary to Bear Creek Cross Section - 1
Riffle Section



Note: Floodprone Width > 70 ft.

Unnamed Tributary to Bear Creek Cross Section - 2
Pool Section



HARP/ HDR	Cross Sections of Reference Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C

Trib. to Sandy Creek Cross Section-1, Reference Reach, Riffle Section

DOT Chatham Co. - Upper Bear Creek Watershed Project

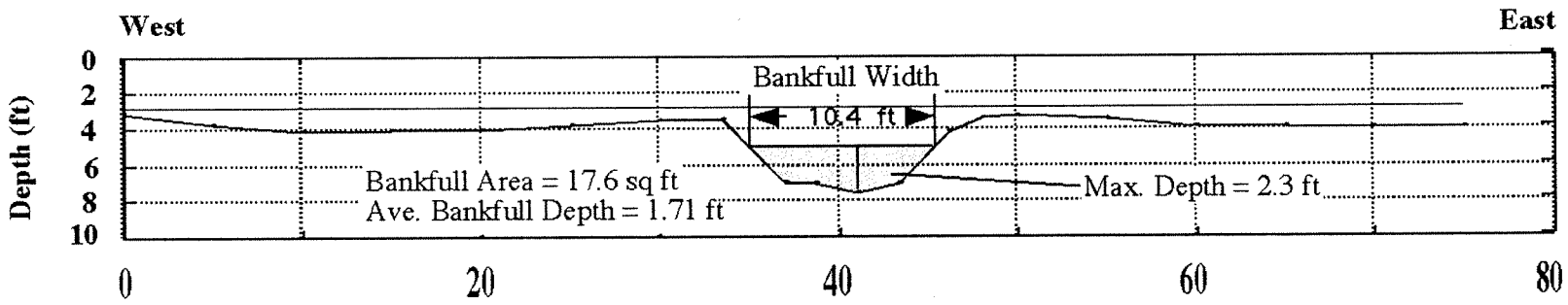
Distance (ft)	Depth		Depth (ft)	Relative Elevation (ft)	Notes
	Feet plus	Inches			
BM					HI=100'
0	3	1.25	3.10	96.90	West End
5	3	9.25	3.77	96.23	
10	4	1.50	4.13	95.88	
15	4	1.00	4.08	95.92	
20	4	0.50	4.04	95.96	
25	3	9.75	3.81	96.19	
30	3	6.25	3.52	96.48	
33.5	3	6.00	3.50	96.50	Top of Bank
37	6	11.50	6.96	93.04	Bottom of Bank
38.7	7	0.00	7.00	93.00	Edge of Water
41	7	6.50	7.54	92.46	Thalweg WD=6.5"
43.3	7	0.00	7.00	93.00	Edge of Water
46.2	4	2.00	4.17	95.83	Top of Bank
48	3	5.00	3.42	96.58	
50	3	3.75	3.31	96.69	
55	3	6.00	3.50	96.50	
60	3	11.25	3.94	96.06	
65	3	11.50	3.96	96.04	
70	4	0.00	4.00	96.00	
75	4	0.00	4.00	96.00	East End

Trib. to Sandy Creek Cross Section -2, Reference Reach, Pool Section

DOT Chatham Co. - Upper Bear Creek Watershed Project

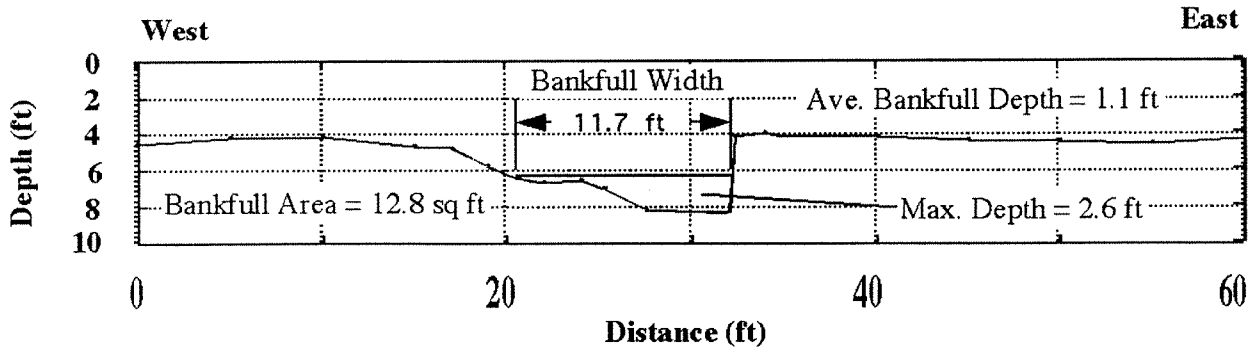
Distance (ft)	Depth		Depth (ft)	Relative	Notes
	Feet plus	Inches		Elevation (ft)	
BM					HI=100
0	4	6	4.50	95.50	West End
5	4	2.00	4.17	95.83	
10	4	1.50	4.13	95.88	
15	4	7.50	4.63	95.38	
17	4	9.25	4.77	95.23	Top of Berm
19	5	8.50	5.71	94.29	
20.5	6	5.00	6.42	93.58	Bankfull - Inner Edge of Lower Berm
22	6	8.00	6.67	93.33	
24	6	6.50	6.54	93.46	
25.3	6	11.50	6.96	93.04	
27.5	8	1.25	8.10	91.90	Edge of Water
30.8	8	3.50	8.29	91.71	Thalweg, WD=2"
32	8	3.50	8.29	91.71	Edge of Water
32.3	4	1.50	4.13	95.88	Top of Bank
34	3	11.50	3.96	96.04	
35	4	1.50	4.13	95.88	
40	4	1.50	4.13	95.88	
45	4	4.00	4.33	95.67	
50	4	4.50	4.38	95.63	
55	4	6.00	4.50	95.50	
60	4	2.00	4.17	95.83	

Unnamed Tributary to Sandy Creek Cross Section - 1
Riffle Section

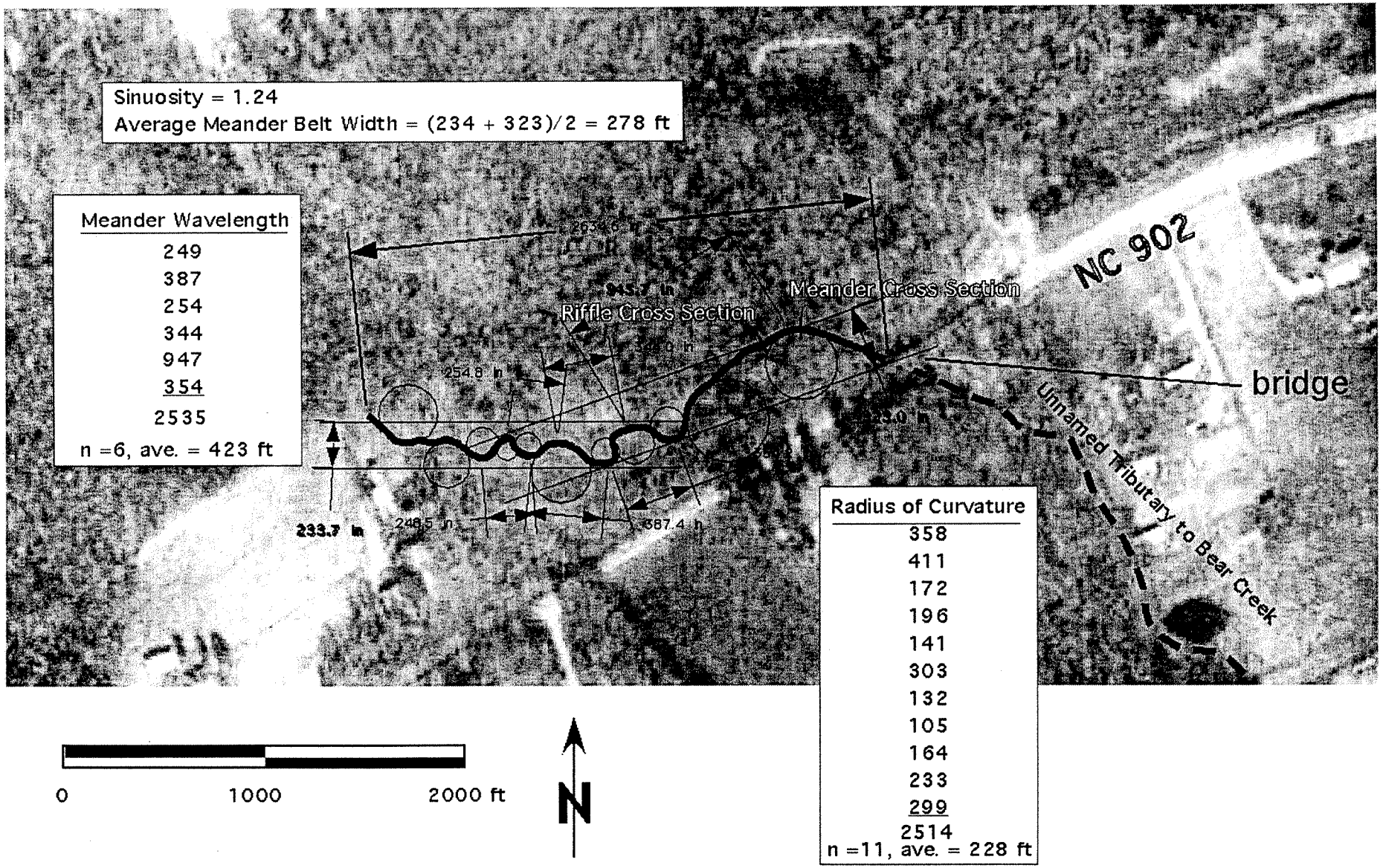


Note: Floodprone Width > 74.5 ft.

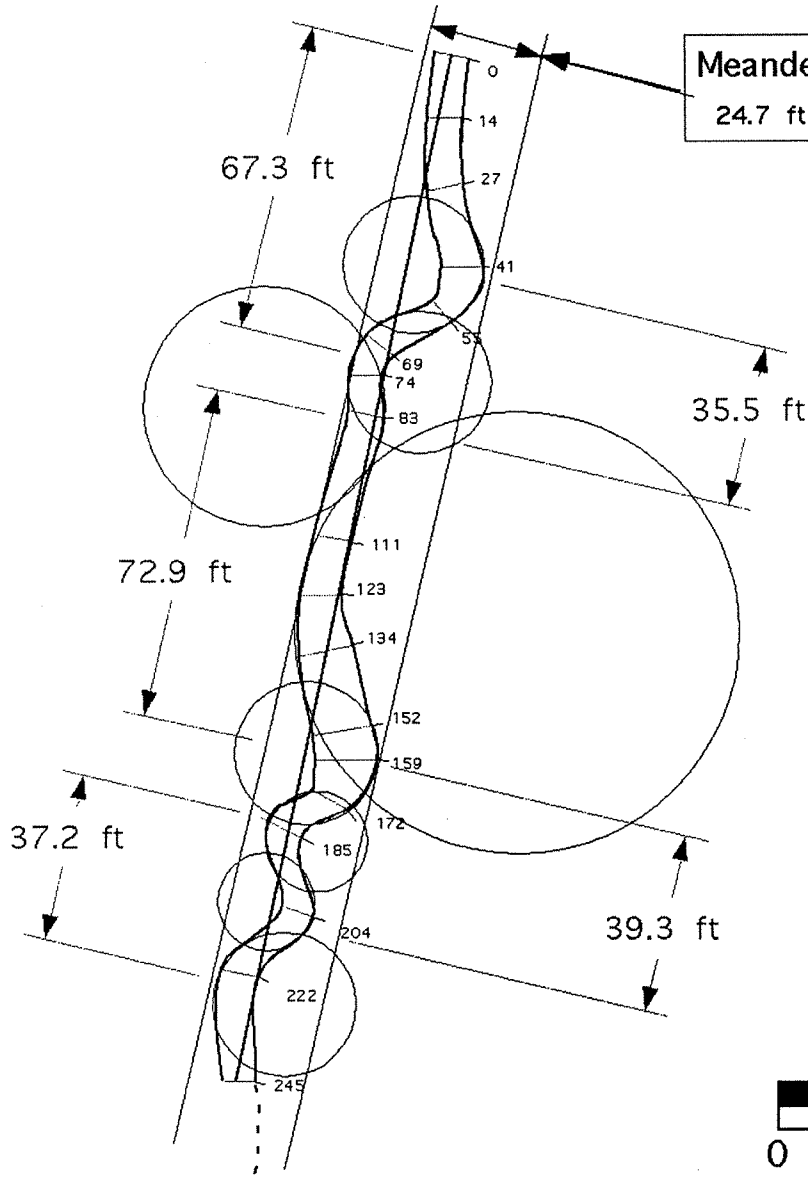
Unnamed Tributary to Sandy Creek Cross Section - 2
Pool Section



HARP/ HDR	Cross Sections of Reference Reaches DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C



HDR/ HARP	Planform of Unnamed Tributary to Bear Creek, Reference Reach DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C



Radii of Curvature
15
16
46
16
26
13
10
16
132 ft
n = 8, ave. = 19.75 ft

Meander Wavelength
67.3
72.9
37.2
39.3
35.5
252.2 ft
n = 5, ave. = 50.44 ft

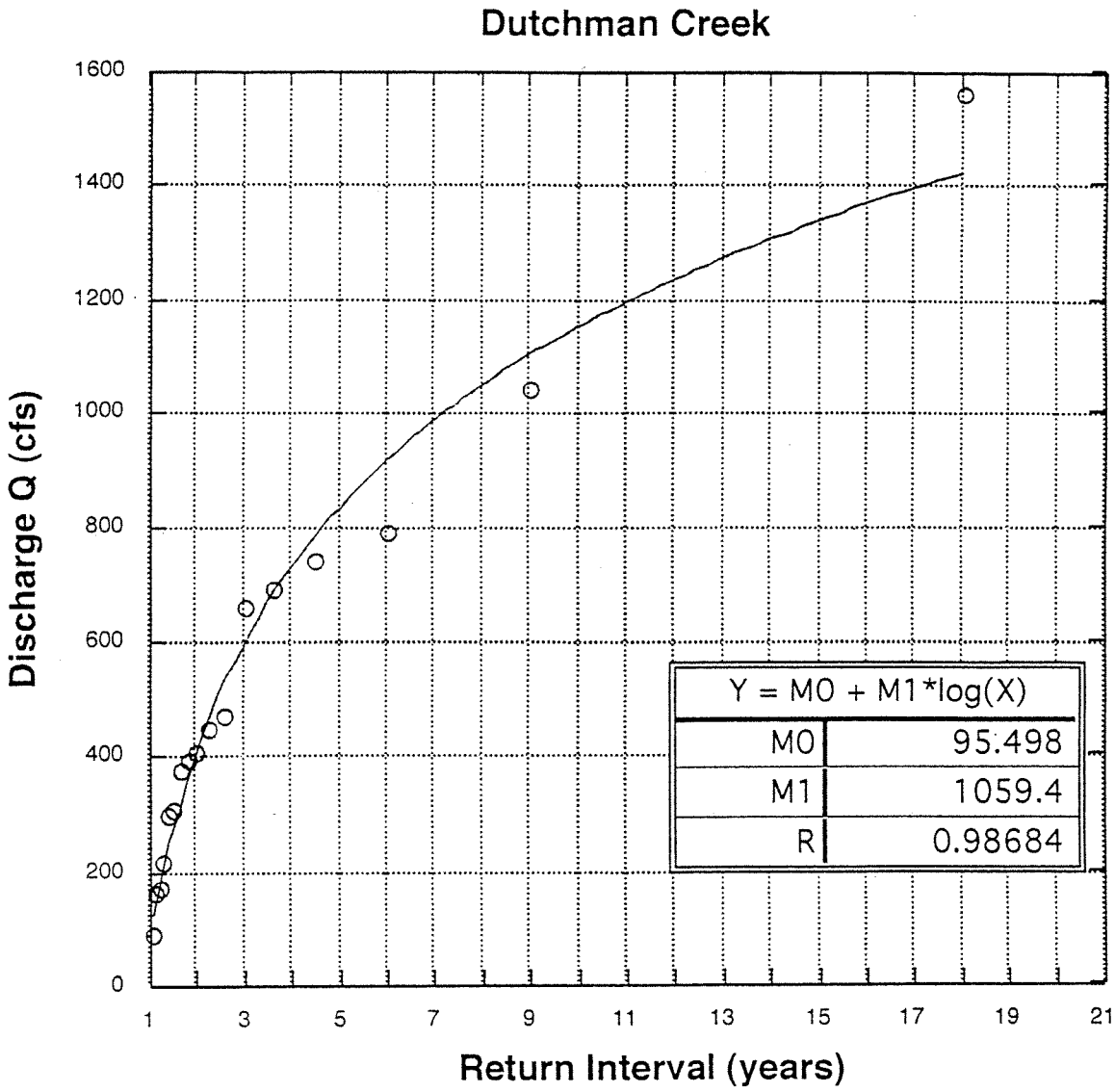
Sinuosity = 1.1

N

Scale

0 50 100 ft.

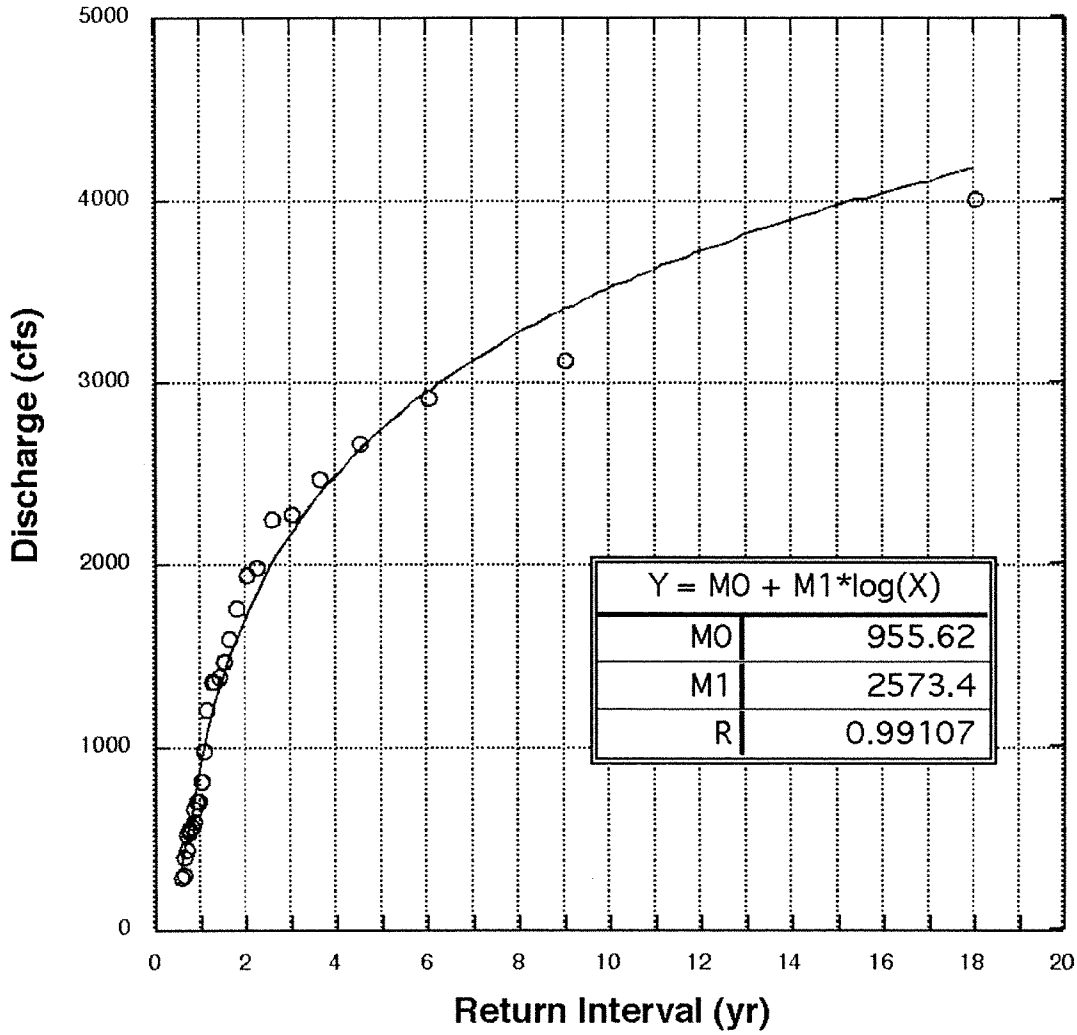
HDR/ HARP	Planform of Unnamed Tributary to Sandy Creek, Reference Reach Located Near Liberty, Randolph County, NC DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix C



Drainage Basin = 3.44 sq. miles
Located in Montgomery County
USGS Gaging Station No. 02123567

HDR/ HARP	USGS Return Interval Probability Curve for Dutchman Creek DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix D

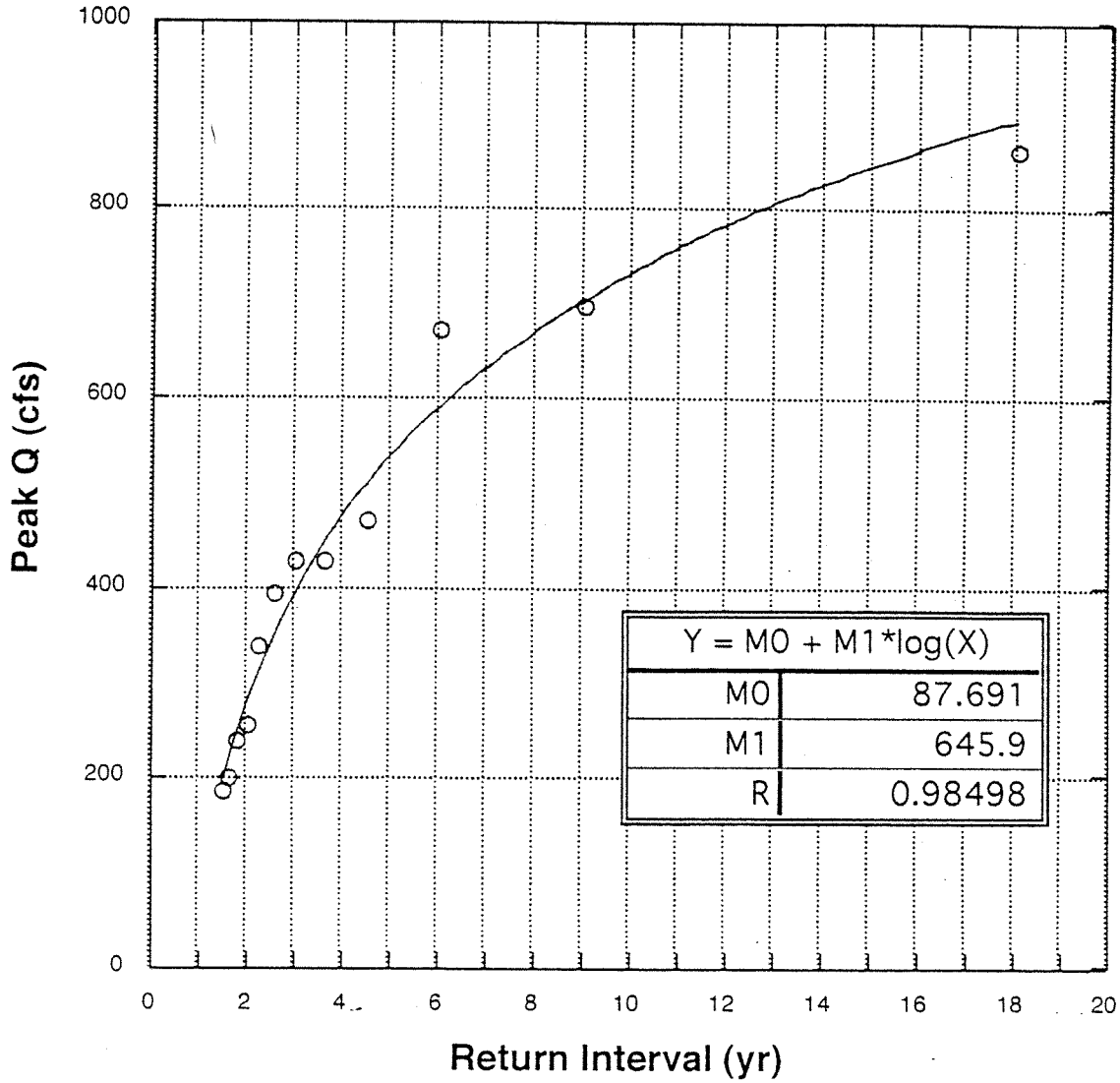
Tick Creek Annual Peak Flow Data (n = 30, 1959-2001)



Drainage Basin = 15.5 sq. miles
Located in Chatham County
USGS Gaging Station No. 02101800

HDR/ HARP	USGS Return Interval Probability Curve for Tick Creek DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix D

Rocky River Annual Peak Discharge Data (n=12, 1989-2001)



Drainage Basin = 7.42 sq. miles
Located in Chatham County
USGS Gaging Station No. 0210166029

HDR/ HARP	USGS Return Interval Probability Curve for Rocky River DOT Chatham Co. - Upper Bear Creek Watershed Project	Date: Oct. 2002	Appendix D

Estimation of Flood Frequency Magnitude for Bear Creek

North Carolina Rural Flood-Freq. Equation Parameters				
Flood Recurrence Interval (yrs.)	Blue-Ridge Piedmont Coeff_a	Drainage Area (sq. mi.)	Blue-Ridge Piedmont Coeff_b	Estimated Rural Discharge
2	144	4.1	0.691	381.77
5	248	4.1	0.670	638.29
10	334	4.1	0.665	853.59
25	467	4.1	0.665	1193.49
50	581	4.1	0.650	1453.74
100	719	4.1	0.643	1781.35

Estimation of Flood Frequency Magnitude for Trib. to Bear Creek

North Carolina Rural Flood-Freq. Equation Parameters				
Flood Recurrence Interval (yrs.)	Blue-Ridge Piedmont Coeff_a	Drainage Area (sq. mi.)	Blue-Ridge Piedmont Coeff_b	Estimated Rural Discharge
2	144	0.9	0.691	133.89
5	248	0.9	0.670	231.10
10	334	0.9	0.665	311.40
25	467	0.9	0.665	435.40
50	581	0.9	0.650	542.54
100	719	0.9	0.643	671.90

coeff_a x Drainage Area $^{coeff\_b}$ = Est. Rural Discharge

Reference: "Estimation of Flood Frequency Characteristics of Small Urban Streams in North Carolina", USGS WRIR 96-4084, 1996.