Chapel Creek Stream Restoration Project
Orange County, North Carolina
SCO ID#050645701

Restoration Plan
August 31,2006

Prepared for:
North Carolina Department of Environment and Natural Resources
Ecosystem Enhancement Program
Parker Lincoln Building
2728 Capital Boulevard, Suite 1H-103
Raleigh, NC **27606**

Chapel Creek Stream Restoration
Chapel Hill, North Carolina
Orange County

Restoration Plan Prepared By:

Ward Consulting Engineers, P.C.
Project Manager: Becky Ward, P.E.
1512 Eglantyne Court
Raleigh, NC 27613
Ph: 919-7870-5359

NORTH CAROLINA PROFESSIONAL SEAL 13344 ENGINEER BECKY LYNNE WARD

Becky L. Ward August 31, 2006

Vegetation and Soils Investigations Provided by:
The Catena Group, Inc.
410-B Millstone Drive
Hillsborough, NC 27278
Ph: 919-732-1300
Fax: 919-732-1303

Field surveys Provided by:
Riley Surveying, P.A.
95 East Lakeview Drive
Durham, NC 27707
Ph: 919-677-0742
Fax: 919-402-0234

Executive Summary

The North Carolina Ecosystem Enhancement Program (EEP) will complete a stream restoration project along approximately 1,500 linear feet of Chapel Creek, located on University of North Carolina property in Chapel Hill, Orange County, North Carolina. The drainage area for Chapel Creek is approximately 0.42 square miles at the downstream limit of the project where a drainage channel through the A.E. Finley Golf Course flows into Chapel Creek. The land use in the watershed consists of University of North Carolina facilities, single family residential, elementary schools, roadways, and forested land.

The goals of the restoration project are to improve water quality in Chapel Creek and the Cape Fear river basin by:

- Channel restoration of pattern, profile, and dimension for approximately 1,000 linear feet of Chapel Creek.
- Channel enhancement/stabilization for approximately 600 feet with a Priority Two restoration approach, bankfull bench and stream bank repairs.
- Restore reach to a stable stream channel, capable of transporting flows and sediment load efficiently.
- Improve aquatic habitat by planting trees along the banks in the cleared section to increase shade and adding more sinuosity to create more pool and riffle sections.
- Reduce sediment inputs to the stream from bank erosion by re-vegetating the banks.

There are two distinct types of channels within the project limits of Chapel Creek. The upper reach, existing of the first 957 feet of stream from Highway 15/501 heading southeast, is in a cleared area that was once used as part of the A.E. Finley Golf Course and was regularly mowed and maintained. The lower reach, existing of the last 557 feet of stream, is in a wooded section where trees and other plants provide more bank stabilization and the floodplain has been less disturbed. The design for the upper reach includes approximately 1,000 linear feet of stream relocation. The design for the lower reach includes benching areas where the stream is entrenched and sloping the banks where possible to give the stream better access to its floodplain for an approximate length of 600 feet.

Table of Contents

11.0 Appendices

Appendix 1. Restoration Site Photographs
Appendix 2. Restoration Site NCDWQ Stream Classification Forms
Appendix 3. Reference Site Photographs
Appendix 4. Reference Site NCDWQ Stream Classification Forms
Appendix 5. HEC-RAS Analysis
Appendix 6. Restoration Site Soil Boring Location Map and Logs
Appendix 7. Cultural Resources

1.0 Project Site Identification and Location

The North Carolina Ecosystem Enhancement Program (EEP) will complete a stream restoration project along approximately 1,500 linear feet of Chapel Creek, located on University of North Carolina property in Chapel Hill, Orange County, North Carolina. The project begins at the downstream face of the existing culvert under Highway 15/501 (Fordham Boulevard). The existing culvert is located approximately 1,200 feet south of the interchange of Highway 15-501 and Highway 54 (Raleigh Road). The study area for Chapel Creek extends downstream from the culvert approximately 1,500 linear feet to just downstream of where a drainage feature that runs south through the golf course merges with Chapel Creek. The stream runs through an abandoned fairway of the A.E. Finley Golf Course. Chapel Creek is subject to the zoning restrictions of the Town of Chapel Hill.

1.1 Directions to Project Site

From Raleigh take I-40 west to Exit 273, Highway 54 (Raleigh Road) towards Chapel Hill. At the intersection of Highway 54 and Highway 15-501 (Fordham Boulevard), stay on Highway 54 West towards Carrboro; this merges with 15-501 South. Take a left at the first traffic light onto Mason Farm Road. Take the very first left onto Highland Woods. The trail head is approximately 400 feet from the intersection on the left hand side of the road. The trail can be walked to Chapel Creek approximately 1,500 linear feet north.

1.2 USGS Hydrologic Unit Code (8- and 14- digit codes)

The United States Geological Survey (USGS) uses a multi-tiered system to divide and sub-divide the country's watersheds into successively smaller hydrological units. Each hydrologic unit is identified by a unique hydrologic unit code (HUC), consisting of various numbers of digits depending on the level of classification within the hydrologic unit system. Under the USGS system, the Cape Fear River basin contains seven 8-digit hydrologic units (New, Haw, Deep, Upper Cape Fear, Lower Cape Fear, Northeast Cape Fear, and Black). The Chapel Creek Project Site is located in the Haw Basin, HUC 03030002 (USGS 2005).

The 8-digit units are further sub-divided into smaller 14-digit hydrologic units that are used for smaller scale planning. The Project Site is located in the 14-digit HUC 03030002060080.

1.3 NC DWQ River Basin Designations

The North Carolina Division of Water Quality (NCDWQ) uses a two-tiered system to divide the state into watershed units. The state is divided into seventeen major river basins with each basin further subdivided into sub-basins (NCDWQ 6-digit sub-basins). The project area is located within sub-basin 03-06-06 of the Cape Fear River Basin (DWQ 2000). This area is part of USGS Hydrologic Unit 03030002 of the South Atlantic/Gulf Region. This river basin covers 9,393 square miles (24,328 square kilometers) and 24 counties (DWQ 2000).

1.4 Project Vicinity Map

The project vicinity map is included in Section 9.0, Figure 1.

2.0 Watershed Characterization

2.1 Drainage Area

The drainage area for Chapel Creek is approximately 0.42 square miles at the downstream limit of the project where the drainage channel through the golf course flows into Chapel Creek. The drainage area at the upstream limits of the project, at the downstream edge of the 7'x7' box culvert under Fordham Boulevard, is approximately 0.38 square miles. The watershed boundary follows the ridgeline around Chapel Creek, with roads along the ridges forming most of the boundaries (Section 9.0, Figure 2).

The watershed boundary is defined by the following physical features: the northern watershed boundary starts where Fordham Boulevard meets Arrowhead Road and heads west along Arrowhead Drive. Approximately 270 feet before Arrowhead Road ends at Greenwood Road, the boundary heads north, parallel to Greenwood Road, for approximately 450 feet, then turns in a general westward direction along the ridge line towards Gimghoul Road. The line passes over the historic Gimghoul Castle, and then follows Gimghoul Road west until it ends at Country Club Drive. The boundary then follows the ridge line southeast along Country Club Road, crosses over Raleigh Road, and then heads south for about 1,050 feet, with the boundary line approximately 100 to 150 feet east of Ridge Road. The boundary then turns in a general southeast direction and follows Laurel Hill Road for approximately 2,000 feet. At this point Laurel Hills Road turns south while the watershed boundary line turns southeast towards Fordham Boulevard, passing just northeast of the end of St. James Place, and heading towards Highland Woods Road. The boundary line then follows the southern portion of Highland Woods Road heading east. When Highland Woods Road turns north, the boundary line turns slightly northeast towards the confluence of Chapel Creek and the tributary that merges with Chapel Creek approximately 1,400 feet southeast of Fordham Boulevard. The boundary line then heads northwest between the drainage channel through the golf course to Chapel Creek and Glenwood Elementary School until it reaches Preswick Road, where it turns west and follows Preswick Road until it reaches the exit ramp from Fordham Boulevard to N.C. Highway 54 east. The boundary line follows the exit ramp north, crosses over Highway 54, and then continues north along the entrance ramp from Highway 54 west onto Highway 15-501 north. It then heads west to meet with Arrowhead Road.

The watershed boundaries are mainly composed of roadways, some with curb and gutter and others with ditches along the sides. The roads with ditches are often located on the ridge line with one side of the road draining down one side of the ridge and the other side draining down the other side. The roads with ditches that are not located along ridge lines, such Greenwood Road, have pipes that go under the road at certain intervals along the road. A large drain pipe goes under Raleigh Road approximately 600 feet west of Greenwood Road that drains that portion of the watershed north and west of the pipe. There is a 7' x 7' box culvert under Fordham Boulevard where Chapel Creek goes under the roadway, including the water from the watershed that has reached Chapel Creek at this point. This accounts for approximately 70% of the watershed.

2.2 Surface Water Classification/Water Quality

Best Usage Classifications are ranks assigned to each surface water body by the NCDWQ in accordance with *Procedures for Assignment of Water Quality Standards* (15A NCAC 2B .0100) and *Classifications and Water Quality Standards Applicable to the Surface Waters of North Carolina* (15A NCAC 2B .0200). These classifications serve to protect water quality by governing the uses of the water resource.

Chapel Creek is the only perennial stream located within the project area (DWQ Stream Index Number 16-41-2-8), (Section 9.0, Figure 4). DWQ classifies Chapel Creek as **WS-IV; NSW**. The "**WS-IV**" classification indicates waters used for drinking, culinary, or food processing purposes, where a WS-I, WS-II, or WS-III classification is not feasible. WS-IV waters are generally located within moderately to highly developed watersheds. The "**NSW**" classification denotes nutrient sensitive waters that need additional nutrient management. Chapel Creek leaves the project area and flows into Morgan Creek, which continues into Jordan Lake approximately 1.4 river miles (RM) downstream.

A stream evaluation of Chapel Creek determined it to be a perennial stream (Appendix 2). Therefore, surface waters within the embankments of Chapel Creek are subject to jurisdictional consideration under Section 404 of the Clean Water Act as waters of the U.S. (33 CFR Section 328.3).

2.3 Physiography, Geology and Soils

The slopes within Chapel Creek's watershed range from approximately 1% to greater than 18%. The northwestern portion of the watershed is much steeper than the southeastern portion. The northwestern portion has elevations around 487 feet above mean sea level while the southeastern portion has an elevation at the confluence of the drainage ditch from the golf course and Chapel Creek of around 256 feet above mean sea level, for a difference of 231 feet. The watershed shape is roughly oval with a northwest to southeast orientation. The restoration site is within the flatter southeastern portion of the watershed with a general elevation difference of 16 feet over the 1, 400 feet of stream, for a slope of around 1.2%. The western portion of the watershed has a much greater elevation difference of about 213 feet from the top near Country Club Road and Laurel Hill Road to the bottom near the culvert under Fordham Boulevard, for an average slope of around 6%, but there are localized slopes within the western portion of the watershed that are greater than 18%. The valley slope on average is 2%. This is a steep slope compared to the average slope of 1% for streams in North Carolina.

The geology of this area is characterized by two different soil systems that are dominated by their major kinds of bedrock (Daniels, Buol, Kleiss, & Ditzler, 1999). The eastern 40% or so of the watershed has the soils and landform characteristics to indicate it is located within the Triassic Basin, with the western 60% or so of the watershed exhibiting characteristics that indicate it is located within the Felsic Crystalline System. The study area of Chapel Creek, consisting of the 1,500 linear feet southeast of Fordham Boulevard, is within the Triassic Basin. The areas within the Triassic Basin are lower in elevation than the surrounding landscape and their local relief is less than most Piedmont areas (Daniels et al, 1999). The Triassic rocks are shales, dark and light colored sandstones, mudstones, siltstones and conglomerates. Triassic rocks apparently are easier to erode than the surrounding crystalline and metamorphic rocks. The three main soil series within the Triassic Basin include Mayodan, Creedmoor, and White Store (Daniels et al, 1999). The Triassic Basin occupies only about 5% of the North Carolina Piedmont and is not used extensively for agricultural production. Urban and industrial development requires attention to the hydrologic properties of the subsoil and underlying geologic materials (Daniels et al, 1999).

The felsic crystalline system has bedrock consisting of granite, granite gneiss, mica gneiss and mica schist (Daniels et al, 1999). The topography of this system varies from broad, gently sloping uplands to moderately to steeply sloping areas with narrow convex ridges and steep valley slopes (Daniels et al, 1999). The main soil series in the eastern portion of the felsic crystalline system include Cecil, Appling, Pacolet, Wedowee, Saw and Wake (Daniels et al, 1999).

Streams within the felsic crystalline terrain have narrow valleys and floodplains that widen abruptly upon entering the Triassic Basin. This is evident in Chapel Creek's watershed, where the western and southern portions have steep slopes that widen towards the eastern part of the watershed.

NRCS maps the soil on site as part of the Chewacla soil series (Section 9.0, Figure 3), (NRCS 1977). Multiple soil borings were conducted and this series was confirmed to generally occur throughout the study area except for the abandoned green area of Hole 14 (Appendix 6). This disturbed area was dominated by severely altered soil conditions; generally 18 inches of sand over gravel.

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates (Soil Conservation Service, 1986). Soils are classified into four hydrologic soil groups (A, B, C, and D) according to their minimum infiltration rate. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates (Soil Conservation Service, 1986). Chapel Creek has soils in hydrologic groups B, C, and D. Group B soils have moderate infiltration rates when thoroughly wetted and consist mainly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 – 0.30 in/hr). Group C soils have low infiltration rates and consist mainly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 – 0.15 in/hr). Group D soils have high runoff potential. They have very low infiltration rates and consist mainly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 – 0.05 in/hr).

Group B soils dominate the southwestern portion of the Chapel Creek watershed, which is the portion within the felsic crystalline soil system with the broad, gently sloping uplands to moderately to steeply sloping areas. The Group B soils exist along the ridges, the slopes, and the valleys beneath. The soil series' present in this area consist mainly of Appling and Wedowee soils. The Appling series consists of gently sloping and sloping, well-drained soils on uplands. The landscape is characterized by rounded divides. These soils formed under forest vegetation, in residuum derived from acidic crystalline rock (United States Department of Agriculture, 1977). The Wedowee series consists of strongly sloping and moderately steep, well-drained soils on uplands. The landscape is characterized by rounded divides on steep slopes. These soils formed under forest vegetation, in residuum from granite, gneiss, and other acidic rock (United States Department of Agriculture, 1977). In both series' permeability is moderate, available water capacity is medium, shrink-swell potential is low. These areas with Group B soils have most of their development along the ridges with the slopes remaining forested. This will facilitate water infiltration and lesson erosion as water moves down the slopes and into the valleys. With the increased development along the ridges in the past 60 years, less water is infiltrating into the soil along the ridges and more water is being discharged down the slopes, resulting in more water and sediment entering Chapel Creek compared to 60 years ago, causing the channel to become entrenched and incised as it is trying to accommodate the increased load.

Group C soils exist primarily along Chapel Creek and its floodplain, and consist of the Chewacla series. The Chewacla series consists of nearly level, somewhat poorly drained soils on flood plains. The soils formed in fine loamy material washed from soils on uplands (United States Department of Agriculture, 1977). These soils are flooded very frequently for very brief periods, their permeability is moderate, and available water capacity is high. Other pockets of Group C soils exist in the northwestern corner and in the southeastern corner of the watershed, with both of these pockets consisting of the Augusta soil series with a very small amount of the Creedmoor soil series. The Augusta series consists of nearly level and gently sloping soils that are deep and somewhat poorly drained. These soils are on low stream terraces near the large streams. These soils are frequently flooded, but the floodwaters remain for only a short period of time. They have formed in alluvial deposits under forest. Permeability is moderately slow, and the available water capacity is medium. The shrink-swell potential is moderate. The Creedmoor Series consists of gently sloping and sloping, moderately well drained soils on uplands. The landscape is characterized by rounded divides. These soils formed under forest vegetation, in residuum from Triassic Mudstone. Permeability is very slow, and available water capacity is medium (United States Department of Agriculture, 1977).

Group D soils exist primarily in the northern and eastern portions of the watershed and consist entirely of the White Store soil series. The White Store series consists of nearly level to moderately steep, moderately well drained soils on uplands. The landscape is characterized by rounded divides and steep side slopes. These soils formed under forest vegetation, in material weathered from Triassic Mudstone (United States Department of Agriculture, 1977).

2.4 Historical Land Use and Development Trends

In the early part of the 1900's, a portion of the watershed west of Fordham Boulevard was partly owned by the Chapel Hill Country Club (Jean O'Daniel, 1/5/2006). The Club was incorporated in 1922 and consisted of a club house, a 4-hole golf course, a small pool, and a tennis court. The golf course was later expanded to include 9 holes. At the location of Hole #2, there was a pond and a fairway that was reportedly wet for long periods during the year. This area is still fairly wet. The pond is still in existence. The club house was located on Country Club Road, at the current home of the University of North Carolina's Law School building, Van Hecke-Wettach Hall. Before the University bought the building it was home to the Mormon Church for a few years. The Chapel Hill Country Club moved from its original location on Country Club Road to its current location on Lancaster Drive in Chapel Hill in 1978.

In 1950 the University of North Carolina built the Finley Golf Course, an 18-hole public course. In the early to mid-1980's, the University took back some of the land in the golf course, specifically where holes 14 through 18 were located, for athletic fields. The Golf Course rebuilt those holes starting where the Chapel Creek restoration site is located, then curving the course along the southeast side of Fordham Boulevard heading south to the current location of the Ronald MacDonald House along Mason Farm Road (Ross Fowler, 1/5/2006 & 1/18/2006). Hole #14 was built where the Chapel Creek Restoration Site is located. Then in late 1998 or early 1999, the entire golf course was redesigned and these new holes were abandoned. The course was redesigned to better fit in with the existing land and topography (Mark Steffer, 1/3/2006). After holes 14 – 18 were abandoned the UNC cross country practice track was built around hole #14, including two bridges, bridges #1 and #5 on Figure 10, that cross the creek.

It is believed that when the Golf Course built hole #14, they did not use any fill material to construct the fairway. The land was only graded due to budget constraints. They used native soil which was quite rocky (Ross Fowler, 1/5/2006).

The State of North Carolina owns approximately 75 acres of land in the western part of the watershed that includes the current location of the Frisbee golf course (which was the location of the golf course used by the old Chapel Hill Country Club) and the tennis complex. The Frisbee golf course and the tennis complex are both located off of Country Club Road in the vicinity of the old Chapel Hill Country Club. The Administration Building is owned by the University of North Carolina and is located at the corner of Highway 15-501 south/Highway 54 west and Raleigh Road. The Frisbee golf course is also accessible from the parking lot behind the Administration Building. The University is currently building a women's softball complex west of the Administration building. The University of North Carolina also owns approximately 21.75 acres southeast of Fordham Boulevard, which includes the study area along Chapel Creek, as well as just over 21 acres in the center of the watershed. The University of North Carolina owns approximately 20% of the watershed, with the State of North Carolina owning approximately 28% of the watershed.

Other land uses in the watershed include single-family residential neighborhoods with houses built primarily from the 1930's to the 1960's, mostly on lots of half an acre to an acre in size. These residential areas are mostly along the northern, western, and southern boundary of the watershed, along the ridge line. Residential areas within the watershed account for approximately 40% of the land use. There is little to no development on the steep slopes in the western portion of the watershed. Two schools exist in the watershed. The land for the St. Thomas Moore School was bought in 1990 by the Roman Catholic Diocese, and occupies approximately 7% of the watershed. This is located along Fordham Boulevard, directly south of Chapel Creek. The land for the Greenwood Elementary School, which borders the study area of Chapel Creek to the north, was bought in 1989 and occupies about 4% of the watershed. Other land uses in the watershed include roadways and forested land.

Future land uses in the watershed may consist of the University improving some of the undeveloped land it owns with facilities for the university, especially around the Administration Building where there is some flat land that is currently part of the Frisbee golf course. The State of North Carolina also owns some undeveloped lots in the northern part of the watershed off of Greenwood Road, a residential neighborhood that could be developed.

2.5 Endangered/Threatened Species

Plants and animals with federal classifications of Endangered, Threatened, Proposed Endangered, and Proposed Threatened are protected under provisions of Sections 7 and 9 of the Endangered Species Act of 1973, as amended. There are four federally protected species listed for Orange County (Table 1).

Table 1: Federally endangered species, Orange County, North Carolina (02/25/2003)

Common Name	Scientific Name	Status
Red-cockaded woodpecker	*Picoides borealia*	Endangered**
Dwarf wedgemussel	*Alasmidonta heterodon*	Endangered
Michaux's sumac	*Rhus michauxii*	Endangered
Smooth coneflower	*Echinacea laevigata*	Endangered*

* Historic Record: the species was last observed in the county more than 50 years ago.
** Obscure Record: the date and/or location of observation is uncertain.

2.5.1 Species Description and Biological Conclusion

Red-cockaded woodpecker (*Picoides borealis*)
Family: Picoidae
Endangered
Date Listed: October 13, 1970

About the size of the common cardinal, the red-cockaded woodpecker (RCW) is approximately 7 inches (18 to 20 centimeters) long with a wingspan of about 15 inches (35 to 38 centimeters). Its back is barred with black and white horizontal stripes. The red-cockaded woodpecker's most distinguishing feature is a black cap and nape that encircle large white cheek patches.

This bird's range is closely tied to the distribution of southern pines. Historically, the red-cockaded woodpecker occurred from East Texas and Oklahoma, to Florida, and North to New Jersey. The present distribution is similar, except the species has been extirpated from Missouri, Maryland, and New Jersey.

The red-cockaded woodpecker makes its home in mature pine forests. Longleaf pines (*Pinus palustris*) are preferred, but other species of southern pine are also acceptable. Nest cavities are constructed in the heartwood of living pines, generally older than 70 years that have been infected with red-heart disease. While other woodpeckers bore out cavities in dead trees where the wood is rotten and soft, the red-cockaded woodpecker is the only one which exclusively excavates cavities in living pine trees. Development of a thick understory may result in abandonment of cavity trees (USFWS 2003).

BIOLOGICAL CONCLUSION: NO EFFECT

No suitable habitat in the form of old-growth pine dominated communities for red-cockaded woodpecker occurs within the project area. Based on NCNHP records, this species has not been documented to occur within 1 mile (1.6 kilometer) of the study area. Consequently, the proposed stream restoration will have "No Effect" on red-cockaded woodpeckers.

Dwarf wedgemussel (*Alasmidonta heterodon*)
Family: Unionidae
Endangered
Date Listed: March 14, 1990

The dwarf-wedge mussel is relatively small, rarely exceeding 1.5 inches in length. The shell's outer surface (periostracum) is usually brown or yellowish brown in color, with faint green rays that are most noticeable in young specimens. Unlike some mussel species, the male and female shells differ slightly, with the female being wider to allow greater space for egg development. A distinguishing characteristic of this mussel is its dentition pattern; the right valve possesses two lateral teeth, while the left valve has only one. This trait is opposite of all other North American species having lateral teeth (Clark 1981).

The dwarf wedge mussel is limited in distribution to the Tar and Neuse River basins where it inhabits creeks and rivers with slow to moderate current and a sand, gravel, or muddy bottom. Toxic effects from industrial, domestic and agricultural pollution are the primary threats to this mussel's survival (USFWS 1993).

BIOLOGICAL CONCLUSION: NO EFFECT

The dwarf wedgemussel is not known to occur in the Cape Fear River Basin.

Additionally, the unstable conditions of Chapel Creek would likely preclude this species, and thus no suitable habitat for dwarf wedgemussel occurs within the project area. Based on NCNHP records, this species has not been documented to occur within 1 mile (1.6 kilometer) of the study area. Consequently, the proposed stream restoration will have "No Effect" on this species.

Michaux's sumac (*Rhus michauxii*)
Family: Anacardiaceae
Endangered
Date Listed: September 28, 1989

Michaux's sumac, a densely hairy shrub with erect stems 1 to 3 feet (0.3 to 0.9 meters) in height, grows in sandy or rocky open woods in association with basic soils. Michaux's sumac has compound leaves which are narrowly winged at the base, dull on the top, and veiny and slightly hairy on the bottom. Each leaf is finely toothed on its edges. Most plants are unisexual; however, more recent observations have revealed plants with both male and female flowers on one plant. The flowers are small, borne in a terminal, erect, dense cluster, and colored greenish yellow to white. Flowering usually occurs from June to July; while the fruit, a red drupe, is produced through the months of August to October.

Michaux's sumac survives best in areas that are open due to some form of disturbance such as roadside rights-of way, artificially maintained clearings, or in areas with periodic fires. It was once found in Georgia, South Carolina, and North Carolina but now only has viable populations North Carolina. Just four plants still survive in one county (down from five counties) in Georgia. In South Carolina, two populations of the plant were historically known; now, the plant is considered extirpated from that State. Currently, the plant survives in the following North Carolina Counties: Richmond; Hoke; Scotland; Franklin ; Davie ; Robeson ; and Wake). It has been eliminated from Durham, Moore, Orange, Randolph, Wilson, Lincoln, and Mecklenburg counties. Of the 15 existing populations in North Carolina, nine have less than 100 plants each, and three of these have less than a dozen plants each (USFWS 1993).

BIOLOGICAL CONCLUSION: NO EFFECT

Michaux's sumac is known historically from, but is considered to have been extirpated from in Orange County. Additionally, no suitable habitat for Michaux's sumac occurs in the project area as the maintained / disturbed area is mowed periodically throughout the year. Based on NCNHP records, this species has not been documented to occur within 1 mile (1.6 kilometer) of the study area. Consequently, the proposed stream restoration will have "No Effect" on Michaux's sumac.

Smooth coneflower (*Echinacea laevigata*)
Family: Asteraceae
Endangered
Date Listed: October 8, 1992

Smooth coneflower is a rhizomatous perennial herb that grows up to 4.9 feet (1.5 meters) tall. The stem is smooth. Basal leaves are smooth to slightly rough and are the largest, reaching 7.9 inches (20 centimeters) in length and 2.9 inches (7.5 centimeters) in width. They have long stems, and are elliptical to broadly lanceolate, tapering to the base. Midstem leaves have shorter stems or no stems and are smaller in size than the basal leaves. Flower heads are usually solitary with drooping petals light pink to purplish in color and 1.9 to 3.1 inches (5 to 8 centimeters) long. Flowering occurs from May through July. Smooth coneflower is usually found in open woods, cedar barrens, roadsides, clearcuts, dry limestone bluffs, and power line rights-of-way, usually on magnesium- and calcium-rich soils associated with limestone (in Virginia), gabbro (in North Carolina and Virginia), diabase (in North Carolina and South Carolina), and marble (in South Carolina and Georgia). Smooth coneflower is found in areas with abundant sunlight and few competitors which are usually associated with periodic disturbances such as fire (USFWS 1995).

BIOLOGICAL CONCLUSION: NO EFFECT

No suitable habitat for smooth coneflower occurs within the project area as the maintained / disturbed area is mowed periodically throughout the year. Based on NCNHP records, this species has not been documented to occur within 1 mile (1.6 kilometer) of the study area. Consequently, the proposed stream restoration will have "No Effect" on smooth coneflowers.

2.5.2 Federal Designated Critical Habitat

Letters were sent to United States Fish and Wildlife Service (USFWS) and the North Carolina Wildlife Resource Commission (NCWRC) on December 27, 2005, requesting information concerning endangered species and any other wildlife matters at the project site. Additionally, a search of the North Carolina Natural Heritage Program (NCNHP) database of rare plants, animals and natural areas was conducted on January 19, 2006, and no records of federally designated habitat were found. No response was received from USFWS or NCWRC within 30 days of mailing.

2.6 Cultural Resources

Letters were sent to State Historic Preservation Office (SHPO) and the Eastern Band of Cherokee Indians (EBCI) on December 27, 2005, requesting information concerning significant cultural resources on the project site (Appendix 7). Multiple site visits were made and no evidence of significant cultural resources was noted. No response was received from EBCI within 30 days of mailing. SHPO responded on both March 8, 2006, and May 16, 2006, with both maps and information indicating a number of archaeological sites present within the project boundaries (Appendix 7). After reviewing the maps of the planned areas of ground disturbance for the proposed stream restoration, SHPO concluded that no archaeological sites of concern would be impacted. Potential Constraints

2.6.1 Property Ownership and Boundary

Chapel Creek is located on a 21.75-acre tract of land owned by the University of North Carolina at Chapel Hill (UNC), Orange County Pin Number 9798149225. The property boundary is approximately 170 feet south of the stream and 285 feet to the north. The project limits begin at the western property boundary with Highway 15/50 (Fordham Boulevard) and ends on the property boundary with another parcel of land approximately 189 acres in size, also owned by UNC and currently used as the A.E. Finley Golf Course, Orange County Pin Number 9798326854.

2.6.2 Site Access

Entry to the site will be through an existing gravel cross country trail accessed through a clearing off of Preswick Road just east of Hamilton Road. Hamilton Road connects with NC 54 just East of the intersection of NC 54 and Fordham Boulevard in Chapel Hill. A temporary construction road will be constructed through the existing clearing to tie into the existing gravel trail. The trail is a gravel path approximately 10 feet in width. The existing trail will provide access for construction equipment. The trail, which is substantially clear through out the 1500-foot length to the project area, will require minimal tree removal for construction equipment passage. This segment of the trail may need to be temporarily closed to foot traffic during any hauling activities if required as a part of the construction contract for safety.

The existing trail has two additional access locations, one that is located behind the maintenance buildings for the sports fields that are along Old Mason Farm Road and a second location with access to Highland Woods Road. These two access locations will not be used for construction access to the site.

2.6.3 Utilities

The North Carolina Department of Transportation (NCDOT) Right-of-Way is the western property line on the project site. The NCDOT ROW occurs along Highway 15/501 (Fordham Boulevard) and is variable in width. The ROW boundary crosses Chapel Creek just downstream of the 80" culvert under Highway 15/501. The stream restoration project begins on the University property below the NCDOT ROW. Construction activities proposed a the beginning of this project will include the removal of a segment of an existing 30" DIP storm drainage pipe that has separated from the line that currently extends too far into the stream within the drainage easement. Two utility lines, overhead power and sanitary sewer, are both located in the lower section of the project limits within a 30 foot maintained Duke Power Corridor. All of the utilities in the Town of Chapel Hill were at one time owned by the University and therefore when the utility companies took over operation, easements may not have been recorded. In conversations with Mr. Steve Small with Duke Power Engineering Division there may not be a recorded distribution line easement on the University Property, which he is currently investigating. The overhead power lines provide the main power feed to the sanitary sewer treatment plant located off of Mason Farms Road. The Duke Power corridor crosses chapel Creek approximately 250 linear feet along the stream from the beginning of the project limits, or approximately 600 linear feet north of the gate along the edge of the sports fields. An existing power pole is located just north of the stream bank of

Chapel Creek within this corridor. Mr. Ted Blake from OWASA stated that most likely no easement agreement exists on the University property for the Sanitary Sewer line but only a license agreement, which allows OWASA to own, operate and maintain sanitary sewer lines on the University property. The sanitary sewer line crosses Chapel Creek with a ductile iron pipe aerial crossing supported with concrete pedestals within the stream channel. Construction activities in adjacent to this sanitary sewer line will include stream bank stabilization and the placement of additional riprap to repair existing erosion around one of the concrete aerial supports. The sewer and power utilities are owned by Orange County Water and Sewer Authority (OWASA) and Duke Power respectively. Any work adjacent to the Duke Power, OWASA, and NCDOT will be approved by the respective organizations. The overhead power lines, sanitary sewer line, and storm drainage pipes are shown on plan sheet 4, of the construction drawings.

2.6.4 FEMA/Hydrologic Trespass

The North Carolina Flood Mapping Program completed and released in January of 2006 mapping changes to the FEMA flood maps in Orange County, North Carolina. Chapel Creek was part of the mapping changes in which streams with a drainage area from 0.5 to 1.0 square miles were evaluated and mapped with a limited detailed study. Previously Chapel Creek, which has a drainage area of approximately 1.0 square mile to its tie in location with Morgan Creek, did not have an established 100-year regulated floodplain. Since Chapel creek is located within the large floodplain of Morgan Creek, the100-year floodplain limits were shown on the previous maps based on the backwater elevations on the Morgan Creek Channel. These backwater limits extended up into Chapel Creek to within a short distance of the existing lower trail bridge at stream station 2319. With the new mapping revisions a HEC-RAS analysis was established for Chapel Creek defining the 100-year floodplain and floodway limits. The limited detailed study begins at the backwater limits for Morgan Creek, which is at Chapel Creek stream station 2282.3. The new FEMA regulated stream 100-year floodplain boundary was delineated with the established floodplain elevations from the HEC-RAS model imposed on topographic information generated from Lidar data. A no impact report will be submitted to the Town of Chapel Hill for their concurrence showing that no hydrologic trespass will occur on adjacent properties as a result of the construction work being completed on Chapel Creek. A Letter of Map Revision will be completed for this project upon completion of construction. The floodplain requirement were confirmed with Ms. Sue Burke, Floodplain Manager, with the Town of Chapel Hill, 209 N. Columbia Street Chapel Hill North Carolian 27514, 919-969-7246.

3.0 Project Site Streams (Existing Conditions)

3.1 Channel Classification

There are two distinct types of channels within the project limits of Chapel Creek. The upper reach, consisting of the first 957 feet of stream, is in a cleared area that was once used as part of the A.E. Finley Golf Course and was regularly mowed and maintained. The lower reach, consisting of the last 557 feet of stream, is in a wooded section where trees and other plants provide more bank stabilization and the floodplain has been less disturbed.

3.1.1 Upper Reach

Throughout most of the upper reach, the floodplain on both sides of Chapel Creek was utilized as a fairway for the Finley Golf Course. Maintenance on the fairway included mowing up the stream bank leaving only a small vegetated buffer which averages in width approximately 5 feet. The vegetation established on the banks consists of mostly small shrubs and invasive species. Few trees are located on the banks to provide shade or roots to help in bank stabilization, therefore this reach is more incised and exhibits less sinuosity than the lower section. This section of Chapel Creek classifies as a "G4" channel. The "G" or "gully" stream type is an entrenched, narrow, and deep, step/pool channel with a low to moderate sinuosity. The "G" stream types have very high bank erosion rates and a high sediment supply (Rosgen, 1996).

1.1.2 Lower Reach

Within the lower reach the floodplain is wooded and the disturbance to the stream, stream bank, and the floodplain surrounding the stream is significantly less than that on the upper reach. This reach is less incised and has more sinuosity. This section classifies as a "C4"-"G4" channel. The "C" stream types are located in narrow to wide valleys, constructed from alluvial deposition, have a well developed floodplain (slightly entrenched), and are relatively sinuous (Rosgen, 1996). Stream types classified as "G" have entrenched, narrow, and deep, step/pool channel with a low to moderate sinuosity. (Rosgen, 1996)

3.2 Discharge (bankfull, trends)

The drainage area to the end of the project limits is approximately 0.42 square miles and consists of fairly steep terrain in the western part of the watershed. The estimated bankfull discharge is approximately 160 cubic feet per second (cfs). The stream discharge was predicted with a HEC-1 analysis, TR-55, and the Rational methods that evaluate the watershed and the discharge amounts. The predicted discharge was then compared to discharges generated from field surveyed bankfull cross section areas. Bankfull is located at the top of the incised channel in the upper reach. Bankfull is located at the top of the channel on at least one bank or in a recovering floodplain bench in the upper portion of the wooded reach. In the majority of the wooded 600 linear feet of stream, bankfull is located within the incised channel banks.

3.3 Channel Morphology (pattern, dimension, profile)

The morphological characteristics of the seven (7) cross sections surveyed on the upper and lower reaches of Chapel Creek are shown in Table 5. The table compares the upper and lower reaches on Chapel Creek along with the morphological characteristics of the reference reach.

The upper reach of Chapel Creek is located within the abandoned fairway and is largely not vegetated. The lower reach is located within the established wooded area of the stream. The existing upper reach of Chapel Creek exhibits low entrenchment ratios, high bank heights to maximum depth bankfull, high erosion rates, low width to depth ratios, narrow bankfull width, and bedform features in inconsistent locations along the stream profile typical of a "G" type stream. The lower reach in the wooded buffer segment shows the channel dimensions and profile are consistent with a incised stream that is starting to recover from an "F" type to a "C" type streamin some areas. The channel banks in this area however remain incised with bank height ratios of 2.0 or greater. As the channel extends deeper into the wooded buffer it becomes more incised. The wooded reach of the channel currently has no or very little access to its floodplain.

3.4 Channel Stability Assessment

The channel stability was assessed with observations made in evaluating bank erosion potential with the Rosgen method of completing a Bank Erosion Hazzard Index (BEHI). BEHI indexes were completed on stream channel cross sections located in the upper and lower reaches of Chapel Creek. The upper reach in the abandoned fairway showed an index in the range of very high to moderate bank erosion potential. Visual observations of this reach indicate that most of this incised reach, which has minimal vegetation protection, and high steep banks is actively eroding. The lower reach had a low bank erosion potential. Visual observations and computed BEHI's of the lower reach show that the majority of this reach has good root depth and density, moderate bank slopes, and good vegetative surface protection. The channel stability assessment for Chapel Creek is listed in Table 6.

3.5 Bankfull Verification

Bankfull verification on Chapel Creek was completed with a comparison of field surveyed cross sections along the stream to typical bankfull width, area, depth and discharge relationships. The watershed predicted discharges were compared with the bankfull channel capacities as well for verification. The Rural Peiedmont and Urban Regional Curves developed by the North Carolina State University (NCSU) Water Quality Group, were used to verify acceptable limits of morphological characteristics based on a hydro-physiographic region and drainage area. The average cross sectional areas for Chapel Creek fell within the confidence limits on the regional curves. The bankfull area, width, and depth fell within the upper limits of the Rural Curves and the Lower limits of the Urban Curves.

3.6 Bridge and Sewer Crossing Conditions

Existing Bridge #1

Existing bridge #1 is located at the near the top of Chapel Creek approximately 120 feet of the Box Culvert under Fordham Boulevard. This bridge is fabricated of wood and is approximately 23.5 feet long. It has a total width of 9.5 feet and a usable width of 7.5 feet. It is set on abutments of used railroad ties that are embedded in the soil on either side of the stream. Three 12-inch diameter telephone poles span between the abutments. It appears that both the railroad ties and telephone poles are creosoted. The bridge deck consists of 2 x 6 foot boards that have been pressure treated with a wood preservative. The deck is nailed to the telephone poles. On either side is an 8 inch high rub rail constructed of treated 4 x 4's. There is a 4 x 8 foot sheet of plywood nailed to the decking at one end that appears to be a repair to the decking. There are existing 6 x 6 foot posts at each end of each side of the bridge. These have also been pressure treated with a wood preservative. A nylon rope runs along the side of the bridge between the posts to serve as a hand rail. Because the wood used in this bridge has been treated with preservative, there is little or no visible rot or decay in the structure. However, the structural strength of the bridge is questionable since it flexes under the weight of just one person. In addition the stream banks have eroded to within 2.5 to 3 feet of the abutments. The rope handrails serve more to visually identify the sides of the bridge than to prevent a pedestrian from stepping off the sides, since the rope will stretch far enough to allow stepping off the edges of the bridge.

In general, the bridge has served its purpose as a pedestrian crossing, but is only marginally adequate structurally, is subject to erosion of the abutments as upstream areas develop and generate increased runoff, and is unsafe due to inadequate handrails. This bridge will be removed and replaced with a relocated bridge just south of the existing structure in the proposed design.

Existing Bridge #2

Bridge #2 is located at the lower end of the project within the wooded buffer area of Chapel Creek, approximately 1,100 linear feet downstream of The culvert under Fordham Boulevard. The bridge is part of the UNC existing cross country trail. This bridge is fabricated of wood and is approximately 50 feet long. It has a total width of 12 feet and a usable width of 10.5 feet. It appears this bridge was constructed at the same time and in the same general manner as bridge #1. Bridge #2 is also set on abutments of used railroad ties that are embedded in the soil on either side of the stream. In addition, there are intermediate supports that provide increased structural strength. Three 18-inch diameter telephone poles span between the abutments and across the vertical supports. Once again it appears that both the railroad ties and telephone poles are creosoted. The bridge deck consists of 2 x 6 foot boards that have been pressure treated with a wood preservative. The deck is nailed to the telephone poles. On either side is a 4-inch high rub rail constructed of treated 2 x 6 foot decking planks that run perpendicular to the decking. There are existing 6 x 6 foot posts at each end of each side of the bridge and at the intermediate support. These have also been pressure treated with a wood preservative. A nylon rope runs along the side of the bridge between the posts to serve as a hand rail.

Because the wood used in this bridge has been treated with preservative, there is little or no visible rot or decay in the structure. Due to the intermediate support and the increased diameter of the telephone poles, this bridge is much more rigid than bridge #1 and cannot be made to flex under the weight of one person. Its increased length keeps the stream banks at least twice as far from the abutments. Unfortunately, like bridge #1, the rope handrails serve more to visually identify the sides of the bridge than to prevent a pedestrian from stepping off the sides, since the rope will stretch far enough to allow stepping off the edges of the bridge. The bridge is adequate as a pedestrian crossing. This bridge will remain undisturbed by the proposed stream construction work.

Existing Bridge #3

Bridge #3 is located approximately 200 feet upstream of Bridge #2. The bridge is no longer in use and has partially fallen into the stream. This bridge was inspected to determine if it is feasible to relocate it to the site of the new bridge that will replace existing bridge #1. It is similar in design and construction to existing bridges #1 and #2. Bridge #3 is located in a heavily wooded area and is no longer is use as it has fallen in on the northern side of the stream due to erosion of the abutment on this side. Subsequent twisting, due both to its weight and the force of the water flowing against it, has resulted in structural damage that renders it unusable at any other site without considerable reworking. It addition, any attempt to remove this bridge will result in significant damage to the wooded area along the stream banks with subsequent stream bank re-stabilization required. This bridge will be removed as part of the proposed construction design.

Existing Concrete Slab Crossings

The existing two reinforced concrete slab crossings were originally used for foot traffic crossings for the golf course. These concrete crossings are located between existing bridges #1 and #3 in the upper reach of Chapel Creek. Each crossing consists of two 18 – 24 inch reinforced concrete slabs, 4 – 6 inches thick, set next to each other and on the existing ground at each side of the stream. These crossings are not used in use and are in a state of disrepair. The slabs have fallen into the stream and are separated from each other, thus forming an unstable and hazardous crossing. In addition, the presence of these slabs in the flow path of the stream is creating increased erosion of the banks due to the impounding flow and subsequent turbulence.

It is recommended that the concrete slab crossings be removed. With proper soil backfilling, these slabs could be disposed of as part of the filling used in the existing relocated stream.

Existing Sanitary Sewer Crossing

There is an existing gravity sanitary sewer line crossing approximately 180 feet downstream of existing bridge #2. This crossing is in the flow path of the stream and consists of a 16-inch ductile iron pipe set on concrete piers. The crossing is in good shape with some slight erosion between the far stream bank and the concrete pier where the stream is forced to turn. It is recommended that rip rap or other stream bank stabilization be applied at that area to prevent undermining the pier and stopping further erosion of the bank.

3.7 Vegetation

Plant community classifications follow those presented by Schafale and Weakly (1990) where possible (Section 9.0, Figure 5). The dominant flora observed, or likely to occur, in each community are described and discussed. Scientific nomenclature and the common names (when applicable) are provided. Plant taxonomy typically follows Radford et al. (1968) with adjustments for updated nomenclature (Kartesz 1998). All subsequent references to the same organism will include the common name only. Published range distributions and habitat analysis are used in estimating fauna expected to be present within the project area.

Piedmont/Low Mountain Alluvial Forest
This community occurs on both sides of Chapel Creek for the first 130 feet downstream of the 80" culvert under Highway 15/501, from 880 feet downstream of culvert to the end of the project limits on the south side of the stream, and from 1,030 feet downstream of the culvert to the end of the project limits on the north side.

This plant community is described by Schafale and Weakly (1990) as occurring in river and stream floodplains in the Piedmont and lower elevation Mountain zones. The Chapel Creek site has not yet reached its climax community, but is still in an early successional stage (Figure 4). The canopy is dominated by sweet gum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), and red maple (*Acer rubrum*), with musclewood (*Carpinus caroliniana*), winged elm (*Ulmus alata*), water oak (*Quercus nigra*), Virginia pine (*Pinus virginiana*), and sycamore (*Platanus occidentalis*) also present to a lesser extent. The understory consists of blackjack oak (*Quercus marilandica*), white oak (*Quercus alba*), river birch (*Betula nigra*), eastern red cedar (*Juniperus virginiana*), American beech (*Fagus grandifolia*), smooth alder (*Alnus serrulata*), Chinese privet (*Ligustrum sinense*), cherrybark oak (*Quercus pagoda*), Southern wax myrtle (*Myrica cerifera*),and silverling (*Baccharis halimifolia*). Vines in this community include green briar (*Smilax* sp.), Japanese honeysuckle (*Lonicera japonica*), and muscadine grape (*Vitis rotundifolia*). The herbaceous layer is dominated by Christmas fern (*Polystichum acrostichoides*), poison ivy (*Toxicodendron radicans*), and brambles (*Rubus* sp.).

Maintained / Disturbed Land
This community type occurs from 130 feet to 530 feet downstream of the culvert under Highway 15/501 on the north side of the stream and from 130 feet to 880 feet downstream of the culvert on south side of stream.

Vegetation is maintained through infrequent mowing which has allowed woody species to begin to establish. This community supports Bermuda grass (*Cynodon dactylon*), rushes (*Juncus* sp.), fescue (*Festuca* sp.), dandelion (*Taraxacum officinale*), smartweed (*Polygonum* sp.), horseweed (*Conyza canadensis*), broomsedge (*Andropogon virginicus*), dog fennel (*Eupatorium capillifolium*), poison ivy, goldenrod (*Solidago* sp.),multiflora rose (*Rosa multiflora*), brambles, Japanese honeysuckle, Southern wax myrtle, Japanese mahonia (*Mahonia japonica*), Russian olive (*Elaeagnus angustifolia*), black willow (*Salix nigra*), tulip poplar (*Liriodendron tulipifera*), and sycamore.

Pine Plantation / Disturbed Land
This community type occurs from 530 feet to 1030 feet downstream of the culvert under Highway 15/501 on north side of the stream. This community is a natural regeneration, early successional forest community. The natural climax community type for this area is a Piedmeont Alluvial Forest per Schafale and Weakley. Currently this area contains most of the plant species typical for a Piedmont Alluvial Forest, except the shrubby species such as black willow and Russian olive, found in the maintained / disturbed land in addition to many loblolly pine (*Pinus taeda*) saplings ranging from 5-10 years in age.

4.0 Reference Stream

4.1 Watershed Characterization

The reference reach for this project is an unnamed tributary to Cabin Branch located in the northern part of the City of Durham, Durham County, North Carolina (Section 9.0, Figure 6). The reach is located at the end of Earl Road, a dead end road off of Goodwin Road, approximately 1.14 miles east of Roxboro Road. The drainage area is approximately 1.27 square miles and consists mostly of residential land uses, with a few commercial uses in the western part of the watershed along Roxboro Road (Section 9.0, Figure 7). The soils surrounding Cabin Branch consist mostly of the Chewacla & Wehadkee Soils and Nason Silt Loam. Chewacla soils were described earlier in Section 2.3. Nason Silt Loam is described as a well-drained soil on side slopes adjacent to major drainageways on uplands. Infiltration is moderate and runoff is rapid (NRCS, 1971). Other soils present in the watershed include Herdon Silt Loam, Goldston Slaty Silt Loam, and Mayodan Sandy Loam (Section 9.0, Figure 8). Cabin Branch is located on the edge of the Triassic Basin and the Carolina Slate Belt, and has a similar slope to that of Chapel Creek.

4.2 Channel Classification

The UT to Cabin Branch is located in a wooded area that is residential in nature. The stream classifies as a C4/E4 stream type. The C-type stream types occur generally in wide valleys, constructed from alluvial deposition. They have a well developed floodplain that is slightly entrenched, are relatively sinuous with a channel slope of 2% or less and a bedform morphology indicative of a riffle/pool configuration. The C-type streams also exhibit a sequencing of steeps (riffles) and flats (pools) that are linked to the meander geometry of the river where the riffle/pool sequence or spacing is approximately 5-7 bankfull channel widths. The primary morphological features of the "C" stream type are the sinuous, low relief channel, the well developed floodplains built by the river, and characteristic "point bars" within the active channel. The channel ggradation/degradation and lateral extension processes, notably active in "C" stream types, are dependent on the natural stability of streambanks, the existing upstream watershed conditions and flow and sediment regime. These channels can be significantly altered and rapidly de-stabilized when the effects of imposed changes in bank stability, watershed condition, or flow regime are combined to cause an exceedance of a channel stability threshold (Rosgen, 1996).

The "E" stream type represents the developmental "end-point" of channel stability and fluvial process efficiency for certain alluvial streams undergoing a natural dynamic sequence of system evolution. These stream types are slightly entrenched, exhibit very low channel width/depth ratios, and display very high channel sinuosities which result in the highest meander width ratio values and the highest number of pools per unit distance of channel of all the other stream types. The "E" type streams usually occur in alluvial valleys that exhibit low elevational relief characteristics. These systems, while considered highly stable systems (provided the floodplain and the low channel width/depth characteristics are maintained), are very sensitive to disturbance and can be rapidly adjusted and converted to other stream types in relatively short time periods (Rosgen, 1996).

4.3 Discharge (bankfull, trends)

The drainage area at the downstream limit of the reference reach is approximately 1.27 square miles and the discharge is approximately 167 cfs. The stream discharge was predicted with at least two methods that evaluate the watershed and these discharge amounts were compared to discharges generated from field surveyed bankfull cross section areas. Bankfull is located at the top or very close to the top of the channel.

4.4 Channel Morphology (pattern, dimension, profile)

The morphological characteristics of the eight (8) cross sections surveyed on the UT to Cabin Branch are shown in Table 5 with those from Chapel Creek. Cabin Branch is a C4/E4 stream type. The stream is located in the same physiographic region, Slate Belt-Triasic Basin, as Chapel Creek. The channel has a high bankfull width/depth ratio and a low bank height allowing floodwaters to access the floodplain. The profile consists of a well-developed riffle pool sequence located appropriately within the stream's sinuous pattern.

4.5 Channel Stability Assessment

The channel stability was assessed with observations made in evaluating bank erosion potential with the Rosgen method of completing a Bank Erosion Hazard Index (BEHI). BEHI indexes were completed on stream channel cross sections on Cabin Branch. Visual observations and computed BEHI's of Cabin Branch show that the stream has good root depth and density, moderate bank slopes, low bank heights, and good vegetative surface protection. The channel stability assessment for Cabin Branch is low bank erosion potential.

4.6 Bankfull Verification

Bankfull verification on Cabin Branch was completed with a comparison of field surveyed stream cross-sections typical bankfull width, area, depth and discharge relationships. The watershed predicted discharges were compared with the bankfull channel capacities generated from field cross sections for verification. The Rural Peiedmont and Urban Regional Curves developed by the North Carolina State University (NCSU) Water Quality Group, were used to verify acceptable limits of morphological characteristics based on a hydro-physiographic region and drainage area. The average cross sectional areas for Cabin Branch fell within the confidence limits on the regional curves. The bankfull area, width, and depth fell within the upper limits of the Rural Curves and the Lower limits of the Urban Curves.

4.7 Vegetation

Mesic Mixed Hardwood Forest – Piedmont Subtype

The vegetative community at the reference site, UT to Cabin Branch, can be classified as Mesic Mixed Hardwood Forest – Piedmont Subtype (Section 9.0, Figure 9). This vegetative community occurs on lower slopes, steep north-facing slopes, ravines, and occasionally well-drained small stream bottoms, on acidic soils (Schafale and Weakly 1990). The canopy is dominated by tulip poplar, white oak, sweet gum, and American beech with Virginia pine, loblolly pine, black gum (*Nyssa sylvatica*), and red oak (*Quercus rubra*) also present. The understory is dominated by American beech saplings and musclewood with red maple also present. The shrub layer is dominated by pinxter flower (*Rhododendron nudiflorum*), Chinese privet, Eastern red cedar saplings, smooth alder, arrow-wood (*Viburnum dentatum*), strawberry bush (*Euonymus americana*), and witch hazel (*Hamamelis virginiana*) also present. The vine layer consists of green briar and Japanese honeysuckle. The herbaceous layer includes Christmas fern, Eastern bottlebrush (*Elymus hystrix*) and brambles.

5.0 Project Site Restoration Pan

5.1 Restoration Project Goals and Objectives

The goals of the restoration project are to improve water quality in Chapel Creek and the Cape Fear river basin by:

- Channel restoration of pattern, profile, and dimension for 1,000 linear feet of Chapel Creek.
- Channel enhancement/stabilization for 600 feet with a Priority Two restoration approach, bankfull bench.
- The preservation of any existing wetland areas and the creation of additional wetland pockets or features where possible to enhance stream and buffer credits.
- Restore reach to a stable stream channel, capable of transporting flows and sediment load efficiently.
- Improve aquatic habitat by planting trees along the banks in the cleared section to increase shade and adding more sinuosity to create more pool and riffle sections.
- Reduce sediment inputs to the stream from bank erosion by re-vegetating the banks.

5.1.1 Designed Channel Classification (narrative)

Chapel Creek will be restored with a Priority Level I restoration approach for approximately 1000 linear feet within the abandoned fairway. The classification of the proposed stream is a C4 stream type. The currently incised stream will be reconnected to its floodplain. The stream pattern, profile, and dimension will be adjusted to allow the stream to efficiently transport its water and sediment load through a combination of changes to the channel dimension, pattern, and bedform. In addition the installation of structures and vegetation will be an important part of the restoration plan to lend long-term stabilization.

The lower reach of Chapel Creek will be enhanced with bankfull benches on one side of the stream to allow flood flows greater than bankfull to expand onto the floodplain. Stream bank locations along the lower reach that are currently showing signs of erosion will be repaired by creating a stable slope, stabilizing the slope with erosion control matting and re-vegetating. Additional stabilization will be placed around one of the existing sanitary sewer concrete supports that is currently showing signs of erosion at its base within the stream. The proposed stream restoration plans are included in Section 10 Design Plan Sheets. The plan sheets include the plan and profile for the priority one restoration and show the enhancement benching in plan view and cross sections. The location of the proposed benches minimizes he loss of existing buffer trees.

5.1.2 Target Buffer Communities

The plant community types within the project study area are a piedmont alluvial forest, a naturally regenerating pine plantation, and a maintained/disturbed area which is a relic fairway of the UNC Finley Golf Club. One goal of this project is to restore the natural community type within the project study area. The target community for this project is the Piedmont alluvial forest with the incorporation of a low lying depressional area in the old channel for the purposes of vegetation diversity. The existing pine plantation will remain intact where possible to continue providing good wildlife cover. The restoration plan consists of three planting zones: Zone 1 (Depressional Area), Zone 2 (Riparian buffer), and Zone 3 (Stream bank).

5.2 Sediment Transport Analysis

5.2.1 Methodology

A stable stream has the capacity to move its sediment load without aggrading or degrading. The total load of sediment can be divided into wash load and bed load. Wash load is normally composed of fine sands, silts and clay and transported in suspension at a rate that is determined by availability and not hydraulically controlled by the size and nature of the bed material and hydraulic conditions (Hey 1997).

The critical shear stress for the proposed channels has to be sufficient to move the particle size diameter value at the 84^{th} percentile (D84) of the bed material. Shear stress was computed using the shear stress equation below and compared to the Shield's Curve of the threshold of grain diameter motion.

$$\tau = \gamma Rs$$

Where:
τ= shear stress (lb/sqft)
γ= specific gravity of water (62.4 lb/cubic ft.)
R = hydraulic radius (ft)
s = water surface slope (ft/ft)

Additional sediment transport analysis was completed using the Rosgen method of using bed materials and sub surface material D50 particle sizes to determine the critical dimensionless shear stress. The critical shear stress along with the channel slope and largest sub-pavement moving particle made available by the watershed as measured on a depositional feature were used to predict the mean depth for the design channel at bankfull. If the channel design depth is too small the channel sediment will be deposited. If the depth is too large the channel will need energy deposition.

$$\Upsilon ci = 0.0834\left(\frac{di}{D^{\wedge}50}\right)^{\wedge} -0.872$$

$$Depth = \frac{(Tci)\ 1.65\ (D)}{slope}$$

Where: *Tci* = critical shear stress (lb/sqft)
di = D50 pavement bed material
d^50 = D50 sub-pavement
D = Largest sub-pavement particle (ft)
Depth = Mean depth at bankfull (ft)
Slope = Average water surface slope at bankfull (ft/ft)

5.2.2 Calculations and Discussion

The lower reach of Chapel Creek will only involve bank repairs and benching, therefore no sediment transport analysis was conducted for the lower reach. The proposed modifications make no changes to slopes or profiles. Therefore the proposed repairs will have no effect in the sediment transport through the lower segment of Chapel Creek.

The shear stress calculated for sediment samples in the existing upper reach of Chapel creek (0.98 lb/sq ft) when entered into Shield's Curve, predicted a range of particle motion of 120 mm (small cobble). The D84 in Chapel Creek is small cobble and therefore will move as bed load. The existing stream shows evidence of down cutting over time to the current stream slope. The existing stream slope average is 0.0128 ft/ft in a valley slope of 0.0136 ft/ft. The stream slope includes existing rock grade control structures that drop the elevation several feet at the upper end of the project. Below the rock control structure the stream has incised to slopes that are currently effectively passing their sediment. The proposed project will reconnect the existing channel with its floodplain and in doing so will increase the channel length. The proposed channel relocation in the upper segment of Chapel Creek will increase in overall elevation change but with the increased channel length the resulting proposed slope will be 0.011 ft/ft. The lower segment of Chapel Creek will have no change in its current slope. The lower segment of Chapel Creek is currently effectively passing its sediment.

The Rosgen analysis showed that with the mean channel depth designed, a particle between four and one half to five inches approximately 114 to 130 mm (Small Cobble) will pass through the system. This is consistent with the shields diagram analysis of the range of particle motion in the system of small cobbles. The bankfull depth of 1.59 feet for the proposed stream was designed to pass the small cobble sediment that is moving through Chapel Creek.

5.3 HEC-RAS Analysis

5.3.1 No-rise, LOMR, CLOMR

The effective FEMA HEC-RAS models were obtained from the North Carolina Flood Mapping program for Chapel Creek. The effective model was copied to a corrected effective file and modified to include the two existing pedestrian bridges crossing Chapel Creek, existing FEMA cross sections were modified to reflect surveyed topographic information, and the culvert at Fordham Boulevard elevations were adjusted to field survey data. The corrected effective model was copied to a pre-project model and was further modified to include additional cross sections at selected locations to represent the benching and stream relocation that will occur in the post project model. The post-project model for Chapel Creek reflects the project after construction is completed based on the design information for the project. The post-project model includes the bridge replacement at stream cross section 3291, stream channel relocation, fill of the existing channel, and the stream benching in the wooded lower reach. The existing FEMA 100-year storm event floodplain and proposed floodplain limits are shown in Figure 10. The preliminary HEC-RAS analysis data and output summary tables are included in Appendix 5.

The results of the hydraulic HEC-RAS analysis shows that the post-project 100-year floodplain will be located entirely on the project property owned by the University of North Carolina. A rise in water surface elevations will occur on the project property due to the construction work, however no impacts will occur on adjacent properties. The proposed channel work will not effect the 100-year flood elevations upstream of Fordham Boulevard. Additional mapping changes will be required upstream of Fordham Boulevard, however they are only due to incorrect invert elevations on the culvert under Fordham Boulevard in the Effective model. A preliminary HEC-RAS analysis report will be submitted to the town of Chapel Hill for their review and concurrence prior to construction. After construction is complete a LOMR will be submitted to the North Carolina Flood Mapping Program based on as-built information for 100-year storm event elevation changes, floodway relocation, and 100-year floodplain mapping changes.

5.3.2 Hydrologic Trespass

As a result of the stream channel relocation and benching the water surface elevations predicted by the effective FEMA model will rise at some locations. The rise in water surface elevation will be contained on the project property owned by the University of North Carolina. No hydrologic trespass of floodwaters will occur on adjacent properties due to the proposed stream improvements.

5.4 Natural Plant Community Restoration

Vegetation will be established with the restoration of 3.34 acres of stream buffers and 1300 linear feet of stream bank.

5.4.1 Narrative & Plant Community Restoration

Riparian vegetation plays a crucial role in maintaining bank stability and control of bed erosion in streams and can be directly linked to water quality issues. The amount of sediment and associated pollutants entering the stream are reduced by adequately vegetating the stream. Research suggests that stream and riverbanks that are sparsely vegetated erode at a much higher rate than those banks that are densely vegetated. A well-vegetated streambank is resistant to streambank erosion due to the extra stability provided by the roots and other plant material, and because it can reduce flow velocity at the edges of the stream. Riparian vegation also plays a role in increasing biodiversity and serves to provide habitat for native fauna.

The objective of the revegetation plan in to plant a variety of native species that will maximize stream buffer functions. The plants chosen were based on their facultative status, professional judgment, and reference species. Each species is native to the Piedmont/Low Mountain Alluvial Forest. Proposed tree species for Zone 1 consist of tag alder (*Alnus serrulata*), silky dogwood (*Cornus ammomum*), and bladdernut (*Staphlea trifolia*). Proposed shrub species include swamp marshmallow (*Hibiscus moscheutus*), swamp rose (*Rosa palustris*), Southern wild raisin (*Viburnum cassinoides*), yellow root (*Xanthorhiza simplicissima*), and swamp azalea (*Rhododendron viscosum*). These species were chosen due to the higher moisture content that will be present in the low lying depressional area. Proposed tree and shrub species of the riparian buffer include species typically found in a piedmont alluvial forest such as sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), ironwood (*Carpinus caroliniana*), and hackberry (*Celtis laevigata*). Proposed shrub species include spice bush (*Lindera benzoin*), arrowwood (*Viburnum cassinoides*), sweet shrub (*Calycanthus floridus*), and deciduous holly (*Ilex verticillata*). Small tree species and shrubs are proposed for the stream bank zone. Due to the small nature of the proposed channel, the smaller tree and shrub species were chosen. The smaller species will allow pedestrians using the trail to observe wildlife and the stream itself. Proposed tree species of the stream bank zone tag alder, silky dogwood, elderberry (*Sambucus canadensis*), and downy serviceberry (*Amelanchier arborea*). Proposed shrub species include highbush blueberry (*Vaccinium corymbosum*), buttonbush (*Cephalanthus occidentalis*), yellowroot, and hazelnut (*Corylus americana*). The woody vegetation to be restored to the buffer will be planted on a 7 foot spacing. Stream bank plants will be spaced 3 foot on center. The schedule of restoration Vegetation is listed in Table 8.

Permanent seeding will be required in all planting zones. The permanent seed mixture will be a combination of grasses and herbs native to the piedmont area. Typical grasses that will comprise 65 to 75 percent of the seed mix are Panicum clandestinum, Deertongue, Panicum virginicus, switch grass, Andropogon gerardii, Big bluestem, and Arustuda structa, Wiregrass. Herbs will make up 25 to 35 percent of the permanent seed mix which would include Eupatorium fistulosum, Joe-Pye Weed and Bidens aristosa Bur-marigold. The final seed mix will be determined as the construction plans are completed and input is received from the North Carolina Botanical Gardens staff.

5.4.2 On-site Invasive Species Management

A variety of plant species inhabit the project study area. While the majority of those species are native to the region there are a few invasive exotic species found within the project study area. Within the project study area, there are 6 invasive exotic plant species; Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), Russian olive (*Elaeagnus angustifolia*), English ivey (*Hedera helix*), and tall fescue (*Lolium arundincaceum*). Where ground disturbing activities occur within the project study area, invasive exotic species management strategies should be conducted. Manual or mechanical removal of invasive exotic plants should always be considered as the first method of control where feasible. Alternative management strategies that are species specific are presented below.

Chinese privet: This shrub was introduced from China and Europe in the early to mid 1800's and used as an ornamental shrub and has spread throughout and invaded woodlands in the southeastern United States. This aggressive thicket forming shrub can out-compete native vegetation and become the dominant shrub layer of an invaded habitat resulting in a lower species composition and an alteration in the natural community structure. It can shade out the herbaceous layer of the community it inhabits. This evergreen shrub is shade tolerant and colonizes by root and stump sprouts and the seeds are spread widely by wildlife such as birds. It has commonly been used as a hedge and has escaped and invaded adjacent areas to form dense thickets. Control efforts during early stages of colonization have a higher potential for successful management. A foliar herbicidal application of glyphosate as a 3 percent solution in water should be applied between August to December. For stem to tall for a foliar spray, an application of Garlon 4 as a 20 percent solution in a basal oil, diesel fuel, or kerosene with a penetrant to the bark as a basal spray. The cut stump method, which entails cutting large stems and immediately treating the stumps with Velpar L as a 10 percent solution in water with a surfactant. This method may harm nontarget plants by root uptake. A safer method when considering surrounding vegetation is through treating the cut stump and stem with a glyphosate or Garlon 3A herbicide as a 20 percent solution in water with a surfactant.

Japanese Honeysuckle: Japanese honeysuckle occurs as dense infestations along forest margins, rights-of-ways, and under canopies. This vine is shade tolerant and spreads from a large root stock, rooting at vine nodes, and seeds are dispersed by animals. Manual or mechanical removal should be considered as the first step in eradication. Other control procedures to consider should include cutting the larger vines just above the soil surface and immediately treat the freshly cut stem with with a glyphosate herbicide or Garlon 3A as a 20 percent solution in water from July to October. Foliar treatments with a glyphosate herbicide as a 2 percent solution in water should be applied between July and October.

Multiflora rose: This shrub thrives in sunny locations and well drained soils. This shrub forms dense thickets that outcompete native herbaceous and shrub species. The seeds of this shrub are bird and mammal dispersed. Due to bird dispersal, this shrub can colonize the gaps in late-successional forests. It may not be a long-term threat in mature forests and may be likely to be shaded out by surrounding trees and shade tolerant shrubs. Recommended control procedures for this shrub include a foliar application of Arsenal AC as a 1 percent solution between August and October. This method may harm surrounding nontarget plants through root uptake. A less effective treatment of a glyphosate herbicide as a 4 percent solution in water with a surfactant should be applied from May to October. This method would have no soil activity to damage surrounding plants.

English Ivey: This vine grows well in moist open forests and is adaptable to a wide range of moisture and soil conditions. This shade tolerant vine can grow under dense canopy stands and can become adaptable to higher light levels as it matures. English ivy can cover and decrease vigor of native trees. It serves as a reservoir for bacterial leaf scorch that infects oaks (*Quercus* spp.), elms (*Ulmus* spp.), and maples (*Acer* spp.). It is spread by bird-dispersed seeds and colonizes by trailing and climbing vines that root at the nodes. A foliar herbicidal application of Garlon 3A of Garlon 4 as a 3-5 percent solution or a glyphosate herbicide as a 4 percent solution should be applied between July and October. Use a string trimmer to reduce growth layers and to injure the leaves to allow for improved herbicide uptake. For larger vines, cut and apply a 20 percent solution of Garlon 4 in a basal oil, diesel fuel, or kerosene with a penetrant.

Russian olive: This shrub is a fast growing weedy ornamental. It is tolerant to shade, drought, and salt, and is spread by animal dispersed seeds occurring in the open and under forest shade. Management strategies include a foliar herbicide such as Arsenal AC or Vanquish as a 1 percent solution in water with a surfactant. Nontarget plants may be injured by root uptake. An application of Garlon 4 as a 20 percent solution in a basal oil, diesel fuel, or kerosene with a penetrant to the bark as a basal spray between January to February or May to October. Other options include an application of glyphosate herbicide as a 20 percent solution in water to cut stumps or stems.

Tall fescue: This grass is found in the maintained/disturbed area of the project study area. Currently it is being maintained through mowing however post restoration management strategies will need to be implemented. This cool season grass is found in extensive colonies and can cause serious infestations. Control efforts include using a glyphosate herbicide a s a 0.5 precent solution in water in the spring.

Areas of the restoration site that are currently vegetated with native, non-invasive species will not be disturbed, outside the limits of necessary construction activities. Succession in these areas should be allowed to proceed naturally. In areas where exotic species are located removal should be undertaken by hand or by herbicide application It is especially important that these measures be taken to eradicate fescue grass (Festuca sp.) within the construction areas prior to planting.

6.0 Performance Criteria

To demonstrate mitigative success, baseline conditions will be established in the form of as-built drawings. The as-built drawings will include profile and plan views of the completed stream project. At the conclusion of the construction activities, the channel modifications and planted vegetation based on a 1.4 – 1.7 year bankfull return period will be monitored annually for a minimum of five years. Monitoring reports will be prepared at the end each year and made available to the resource agencies.

6.1 Streams

The proposed success criteria for stream mitigation will be based on the stability of the stream. The geomorphology of the stream will be monitored as follows:

- Dimension: Permanent cross sections (surveyed or GPS'd) will be established in the frequency of one for every 20 bankfull widths along the length of the reach. Cross section sites will be selected such that approximately half are placed in riffles and half placed in pools. Measurements of W/D ratio, entrenchment ratio, and low bank height ratio will be monitored yearly.
- Pattern: Pattern measurements will include sinuosity and meander width ratio and will be performed yearly. Measurements of radius of curvature will be monitored on newly constructed meanders for the first year only.
- Profile: Longitudinal profile will be surveyed and measurements collected on slope (average, pool, riffle) and pool-to-pool spacing.
- Materials: Pebble counts in pools and riffles will be measured. The D50 and D84 particle size diameter percentiles will be monitored to assure an increase in coarseness in riffles and an increase in fineness in pools.
- Photo Reference Points: Photo reference points will be established at all cross sections showing banks and channel. Additional photos will be taken at selected structures on the project to monitor their structural stability.

During the annual review the entire stream reach will be evaluated for any potential problem areas and photographs taken to document the degree and severity. Potential problem areas may include bank instability, in-stream structure failure or unsuccessful vegetation establishment. If a failure area is noted, corrective actions will be evaluated to resolve the problem. Remedial actions will be undertaken considering any seasonal limitations. Any remedial actions will be documented on the as-built plans.

6.2 Vegetation

The vegetation monitoring will be conducted according to the Carolina Vegetation Survey (CVS) – EEP protocol. Vegetation monitoring plots will be 100 square meters in size and will be conducted according to the Level I protocol which has a focus of planted stems only. The purpose of this level of monitoring is to determine the pattern of installation of plant material with respect to species, spacing, density, and to monitor the survival and growth of those installed species. The success criteria for the preferred species in the restoration areas will be based on annual and cumulative survival and growth over five (5) years. Survival on preferred species must be at a minimum 320 stems/acre at the end of the five years of monitoring. Determining sampling strategy for woody trees and shrubs depends on the size and uniformity of the plants. According to the CVS-EEP protocol, the total area of all the sampling plots must be equal to or greater than 5% of the total area of the mitigation site.

6.3 Schedule/Reporting

The Chapel Creek Stream Restoration Project will be determined to be successful once vegetation success criteria have been met within the restoration and enhancement areas. During vegetation monitoring, planted and volunteer stem densities will be measured in

Orange County North Carolina GIS Information

Radford, A.E., H.E. Ahles and G.R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press. Chapel Hill, North Carolina.

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

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina. Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, NCDEM. Raleigh, North Carolina.

Town of Chapel Hill. 2003. Land Use Management Ordinance. Chapel Hill, North Carolina.

U.S. Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1. US Army Engineer Waterways Experiment Station. Vicksburg, MS. 100 pp.

US Army Corps of Engineers, HEC-1 Flood Hydrograph Package, September 1990, Hydrologic Engineering Center.

US Geological Survey, Water-Resources Investigations Report 96-4084, Estimation of Flood-Frequency Characteristics of Small Urban Streams in North Carolina, 2001

U.S. Geological Survey (USGS). 1993. Northwest Durham quadrangle, North Carolina [map]. 1:24,000. 7.5 Minute Series. Washington D.C.

U.S. Geological Survey (USGS). 1978 [Photorevised 1981]. Chapel Hill quadrangle, North Carolina [map]. 1:24,000. 7.5 Minute Series. Washington D.C.

Urban Hydrology for Small Watersheds, Soil Conservation Services, June 1986, Technical Release 55

US Geological Survey, Water-supply Paper 1898-B. Determination of the Manning Coefficient From measured Bed Roughness in Natural Channels, 1970.

U.S. Geological Survey (USGS). 2005. Water Resources of the United States. Hydrologic Unit Maps. Available URL: http://water.usgs.gov/GIS/huc.html. [Accessed: January 31, 2006]

Wolman, M.G., 1954. A Method of Sampling Course River-Bed Material, Transactions of American Geophysical Union 35:951-956.

8.0 Tables

Table 2: Chapel Creek Restoration Structure and Objectives

Restoration Segment ID	Station Range	Restoration Type	Priority Approach	Existing Linear Footage	Designed Linear Footage	Comment
Reach 1	15+94 – 6+00	Restoration	P1	957	994	Includes approx. 900 lf of channel relocation
Reach 2	6+00 – 0+00	Enhancement	P3	600	600	

Table 3: Drainage Areas

Stream	Drainage Area (Sq. Miles)
Chapel Creek	0.42
UT Cabin Branch (reference reach)	1.27

Table 4: Land Use of Watersheds

Land Use	Square Miles	Percentage
Open Space with grass cover > 75%	.036	9%
Parking lots, roads, roofs, driveways	.038	9%
Residential area with ½ acre lots	.032	8%
Residential area with 1 acre lots	.102	24%
Wooded area	.208	50%

Table 5: Morphological Table

Variables	Existing Channel Restoration Reach	Existing Channel Enhancement Reach	Proposed Restoration Reach	Cabin Branch Reference Reach
Stream type	G4	C4/G4	C4	C4/E4
Drainage Area (Sq. Mile)	0.42	0.42	0.42	1.27
Bankfull width (Wbkf)	12.7 (9.5 – 16.3)	16.2 (16-16.3)	17.5	16.7 (16.2-21.1)
Bankfull mean depth (dbkf)	1.7 (1.42 - 1.9)	1.43 (1.2 - 1.8)	1.59	1.63 (1.32-1.69)
Width/depth ratio (Wbkf/dbkf)	7.58 (5.01 – 9.1)	9.0	11	10.2 (9.56-16)
Bankfull Cross Sectional Area (Abkf)	21.57 (17.5 – 29.2)	29.5 (29.2 – 29.7)	27.8	27.5 (27.2-27.8)
Bankfull Mean Velocity (Vbkf)	6.83 (6.57 – 7.29)	5.4	5.8	5.3 (5.1-5.7)
Bankfull Discharge, cfs (Qbkf)	160	160	160	167
Bankfull Maximum depth (dmax)	3.2 (2.8 – 3.8)	2.83	2.38 (2.28 – 2.54)	2.3 (2.2 –2.47)
Max driff/dbkf ratio	1.58 (1.22 – 1.95)	0.53 (0.41 – 0.77)	1.5 (1.44 – 1.6)	1.5 (1.44 – 1.6)
Low Bank Height	4.41 (2.30 – 5.95)	2.69	3.8 (3.5 – 4.3)	2.49 (2.36 – 2.6)
Low bank Height to max dbkf	3.28 (1.71 – 4.43)	1.42	1.6 (1.54 – 1.7)	1.6 (1.54 – 1.7)
Width of flood prone area (Wfpa)	24.67 (18 – 35)	60	101.5 (61 – 126)	97 (58 – 120)

Entrenchment ratio (Wfpa/Wbkf)	2.06 (1.46 – 3.21)	6.32	5.8 (3.5 – 7.2)	5.8 (3.5 – 7.2)
Meander length (Lm)	58.33 (55 – 65)	70 (50 – 90)	120.4 (108.5 – 134.8)	125 (113 – 140)
Ratio of meander length to bankfull width (Lm/Wbkf)	2.96 (0 – 4.45)	3.16 (0 – 7.37)	6.88 (6.2 – 7.7)	6.88 (6.2 – 7.7)
Radius of Curvature (Rc)	23.37 (14.60 – 30.13)	27.03 (14.50 – 39)	19.25 (10.2 – 36.8)	20 (10.6 – 38.2)
Ratio of radius of curvature to bankfull width (Rc/Wbkf)	1.89 (1.18 – 2.44)	2.85 (1.53 – 4.11)	1.10 (0.58 – 2.1)	1.10 (0.58 – 2.1)
Belt width (Wblt)	17.67 (15 – 20)	22.33 (12 – 30)	27.6 (21.2 – 38.5)	28.7 (22 – 40)
Meander width ratio (Wblt/Wbkf)	1.43 (1.21 – 1.62)	2.35 (1.26 – 3.16)	1.58 (1.21 – 2.2)	1.58 (1.21 – 2.2)
Sinuosity (stream length /valley distance) (k)	1.06	1.05	1.14	1.14
Valley slope (ft/ft)	0.0136	.0017	0.0136	0.0137
Average slope Savg= (Svalley /k)	0.0128	.0016	0.011	0.012
Pool Slope (Spool)	.0036 (0 – 0.233)	.0098 (0 – 0.0556)	0.003 (0- 0.0021)	0.0003 (0 – 0.0021)
Ratio of pool slope to average slope (spool/Sbkf)	.39 (0 – 2.49)	.45 (0 – 2.54)	.03 (0 – 0.16)	0.03 (0 – 0.16)
Maximum pool depth (dpool)	2.71 (2.12 – 3.46)	1.52 (1.3 – 1.89)	3.16 (2.5 – 4.4)	3.04 (2.45 – 4.2)

Ratio of pool depth to average bankfull depth (dpool/dbkf)	1.84 (1.49 – 2.06)	.80 (.69 – 1)	1.99 (1.6 – 2.74)	1.99 (1.60 – 2.74)
Pool width (Wpool)	11.30 (11.10 – 11.50)	13	13.8 (12.8 – 16.1)	14.3 (13.2 – 16.8)
Ratio of pool width to bankfull width (Wpool/Wbkf)	.91 (.90 - .93)	1.37	0.79 (.73 - .92)	0.79 (0.73 – 0.92)
Pool Cross Sectional Area	24.45 (24.40 – 24.50)	22.21	30.58 (23.35 – 38)	27.37 (18.53 – 37.7)
Ratio of pool area to bankfull area	1.47 (1.47 – 1.47)	1.23	1.1 (.84 – 1.37)	1.1 (0.84 – 1.37)
Pool to pool spacing (p-p)	42.08 (16 – 91)	28 (8 – 48.50)	54.6 (39.5 – 75)	55.72 (41 – 78)
Ration of p-p spacing to bankfull width (p-p/Wbkf)	3.40 (1.29 – 7.36)	2.63	3.12 (2.26 – 4.29)	3.12 (2.26 – 4.29)

Table 6: BEHI Estimates for Chapel Creek

Time Point	Segment	Linear Footage	Extreme		Very High		High		Moderate		Low		Very Low	
Pre-Construction			Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%
	Upper Reach	950			150	16			200	21				
	Lower Reach	600									400	67		

Table 7: BEHI Estimates for Cabin Branch

Time Point	Segment	Linear Footage	Extreme		Very High		High		Moderate		Low		Very Low	
Pre-Construction			Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%
	Entire Reach	416									416	100		

Table 8: Schedule of Restoration Vegetation

Planting Density = approx. 640 stems/acre

Planting Zone 1 - (Depressional Area) 0.14 acre Total = 100 Stems

Quantity	Taxonomic Name	Common Name	Size	Type
5	*Cephalanthus occidentalis*	button bush	18" - 42"	seedling
15	*Hibiscus moscheutus*	swamp marshmallow	18" - 42"	seedling
10	*Rosa palustris*	swamp rose	18" - 42"	seedling
15	*Viburnum cassinoides*	southern wild raisin	18" - 42"	seedling
10	*Xanthorhiza simplicissima*	yellow root	18" - 42"	seedling
5	*Alnus serrulata*	tag alder	18" - 42"	seedling
5	*Cornus ammomum*	silky dogwood	18" - 42"	seedling
15	*Rhododendron viscosum*	swamp azalea	18" - 42"	seedling
10	*Staphlea trifolia*	bladdernut	18" - 42"	seedling
10	*Stewartia malacodendron*	silky camelia	18" - 42"	seedling

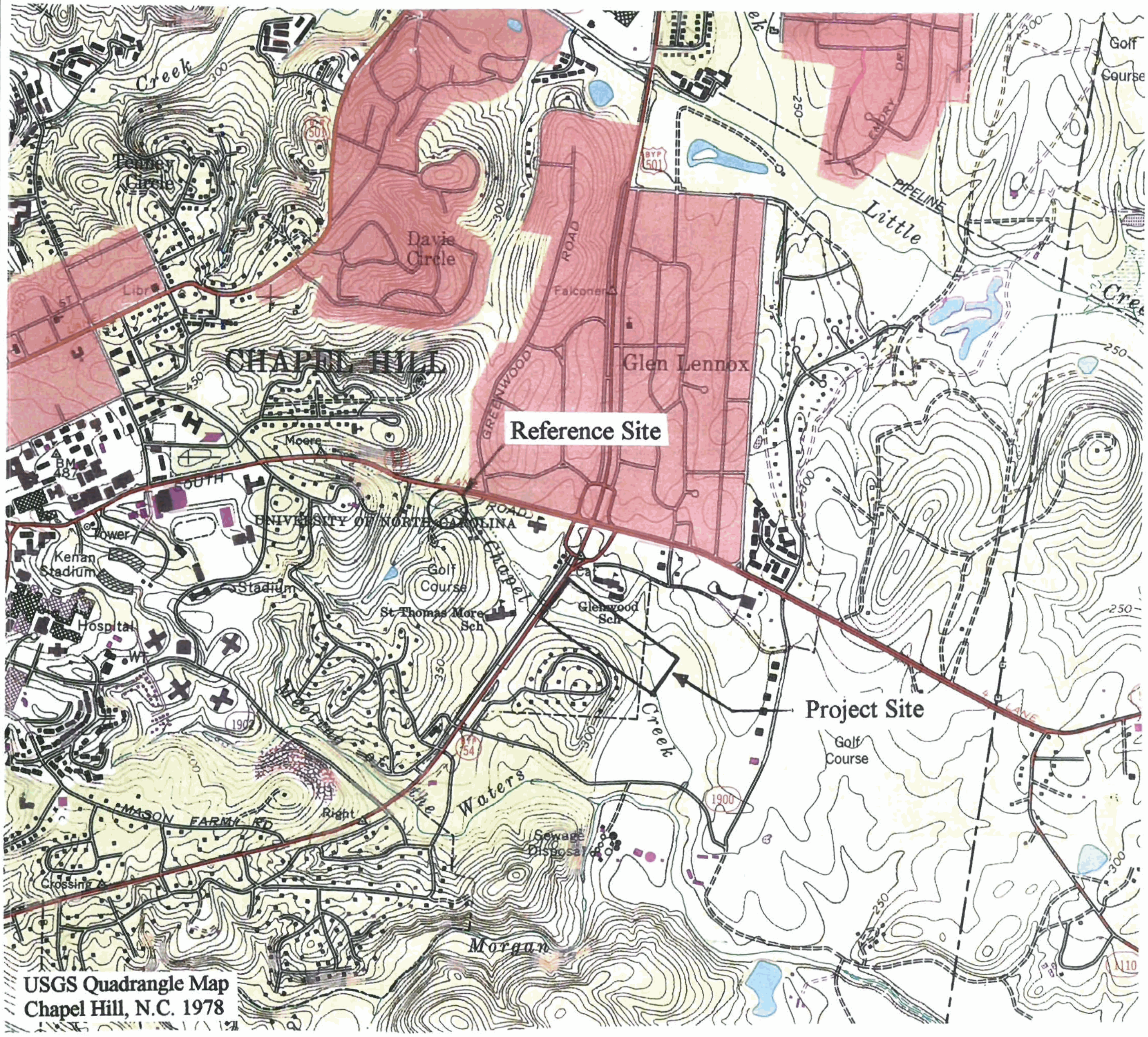
Planting Zone 2 (Riparian Buffer) - 3.2 acres Total = 2050 stems

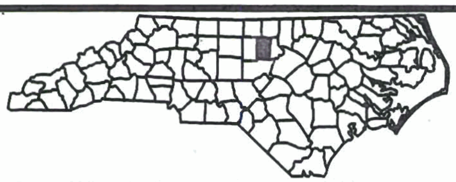
Quantity	Taxonomic Name	Common Name	Size	Type
307	*Platanus occidentalis*	sycamore	18" - 42"	seedling
307	*Fraxinus pennsylvanica*	green ash	18" - 42"	seedling
308	*Carpinus caroliniana*	ironwood	18" - 42"	seedling
308	*Lindera benzoin*	spice bush	18" - 42"	seedling
205	*Viburnum dentatum*	arrowwood	18" - 42"	seedling
205	*Calycanthus floridus*	sweet shrub	18" - 42"	seedling
205	*Ilex decidua*	deciduous holly	18" - 42"	seedling
205	*Celtis laevigata*	hackberry	18" - 42"	seedling

Planting Zone 3 (Stream Bank)- 2600 linear ft. Total = 1440 Stems

Quantity	Taxonomic Name	Common Name	Size	Type
216	*Amelanchier arborea*	downy serviceberry	12" - 24"	rooted plant plug
144	*Alnus serrulata*	tag alder	12" - 24"	rooted plant plug
216	*Vaccinium corymbosum*	highbush blackberry	12" - 24"	rooted plant plug
288	*Cephalanthus occidentalis*	buttonbush	12" - 24"	rooted plant plug
144	*Sambucus canadensis*	elderberry	12" - 24"	rooted plant plug
144	*Cornus ammomum*	silky dogwood	12" - 24"	rooted plant plug
144	*Corylus americana*	hazelnut	12" - 24"	rooted plant plug
144	*Xanthorhiza simplicissima*	yellowroot	12" - 24"	rooted plant plug

9.0 Figures





North Carolina – Ecosystem Enhancement Program

Ecosystem Enhancement PROGRAM

Chapel Creek Stream Reference Site
Orange County, North Carolina
SCO ID #050645701

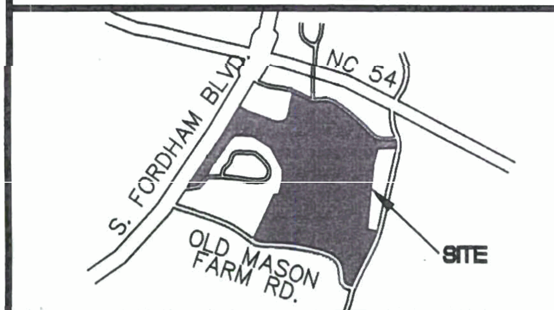


FIGURE 1
RESTORATION SITE
CHAPEL CREEK
VICINITY MAP

DATE: JULY 25, 2006

N

2000 1000 0 2000

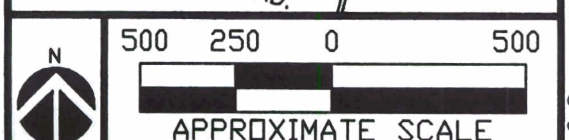
WARD CONSULTING ENGINEERS, PC
Water Management Engineering
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program

Chapel Creek Stream Reference Site
Orange County, North Carolina
SCO ID #050645701

FIGURE 1-A
RESTORATION SITE
CHAPEL CREEK
AERIAL VICINITY MAP

DATE: JULY 25, 2006



WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359

WARD CONSULTING ENGINEERS, PC
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

Ecosystem Enhancement PROGRAM

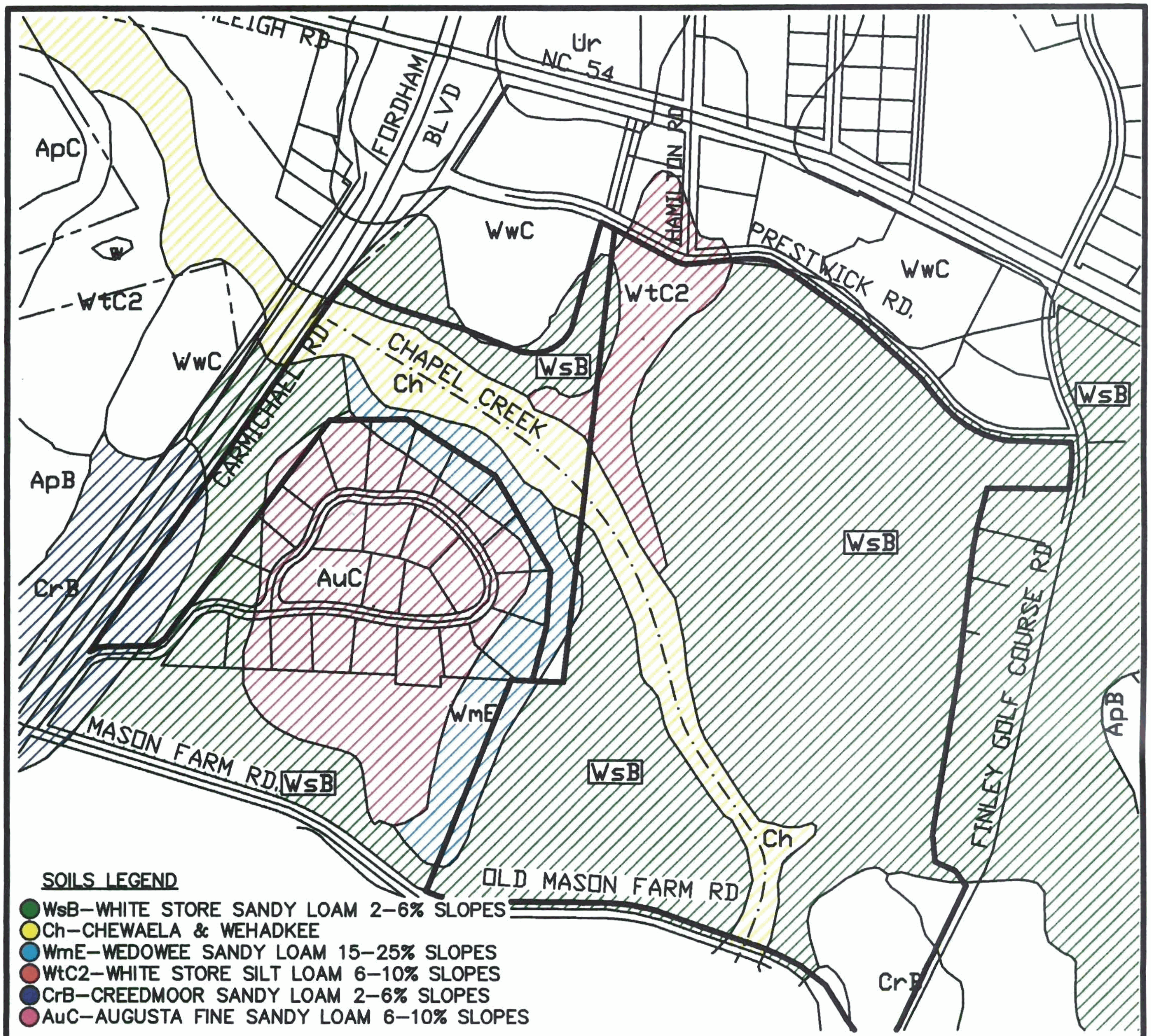
RESTORATION SITE
CHAPEL CREEK
WATERSHED MAP
ORANGE COUNTY, NORTH

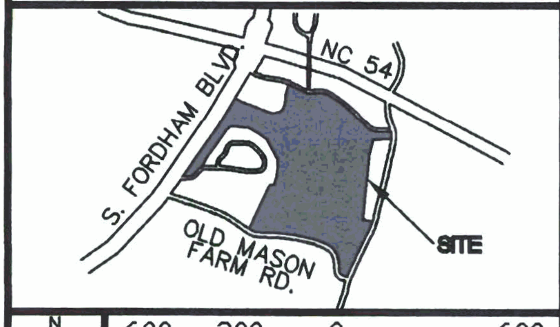
DATE: JULY 25, 2006

PROJ./DWG. NAME: CHAPEL CREEK cc-watershed

SCALE: 1"=600'

FIGURE 2





Ecosystem Enhancement PROGRAM

North Carolina – Ecosystem Enhancement Program

Chapel Creek Stream Reference Site
Orange County, North Carolina
SCO ID #050645701

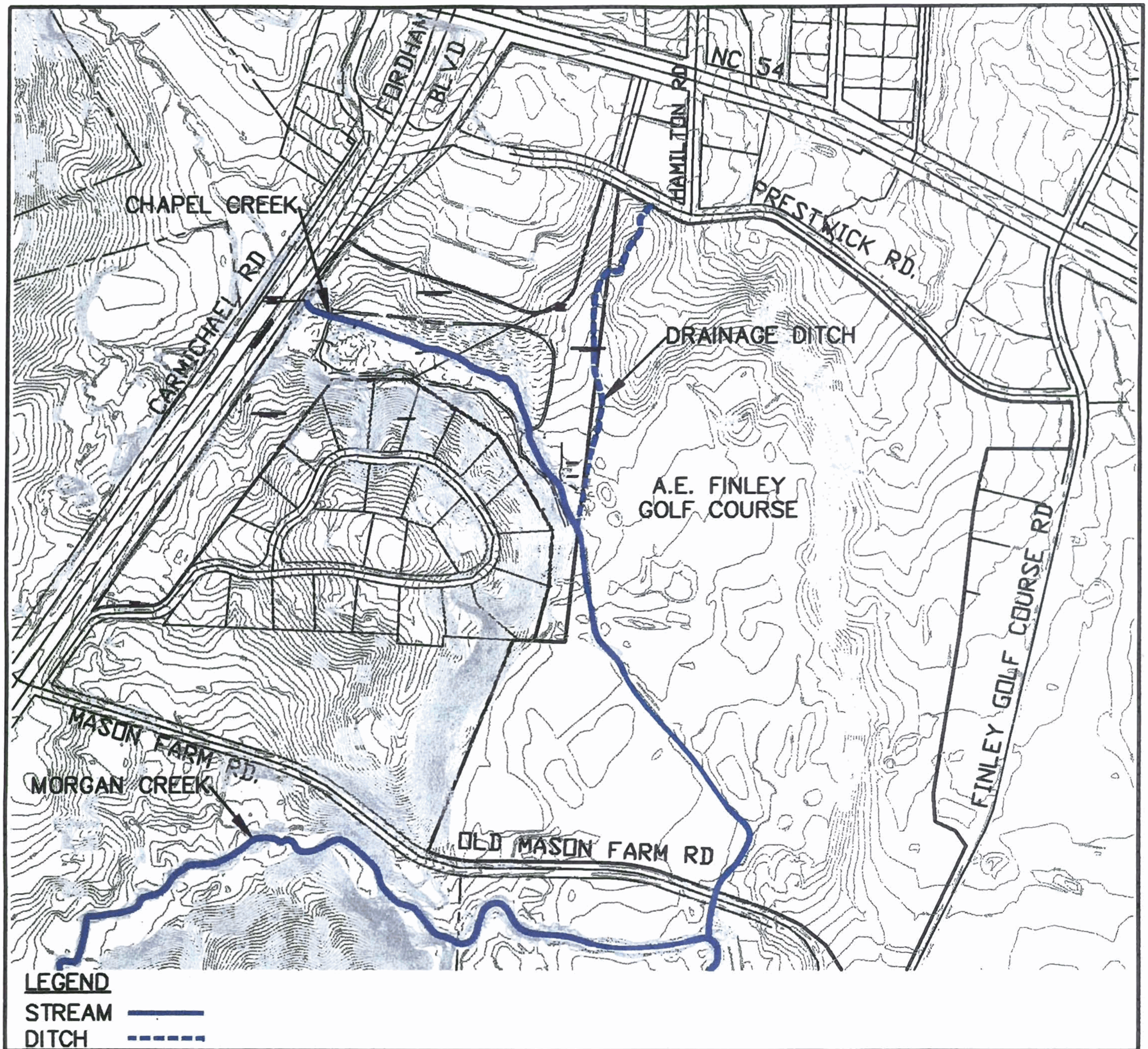
FIGURE 3
RESTORATION SITE
CHAPEL CREEK
NRCS SOILS SURVEY

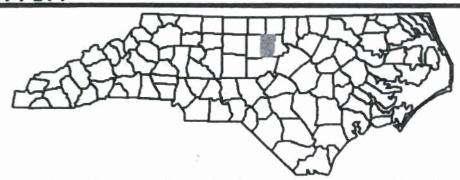
DATE: JULY 25, 2006

WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359





North Carolina – Ecosystem Enhancement Program

Chapel Creek Stream Reference Site
Orange County, North Carolina
SCO ID #050645701

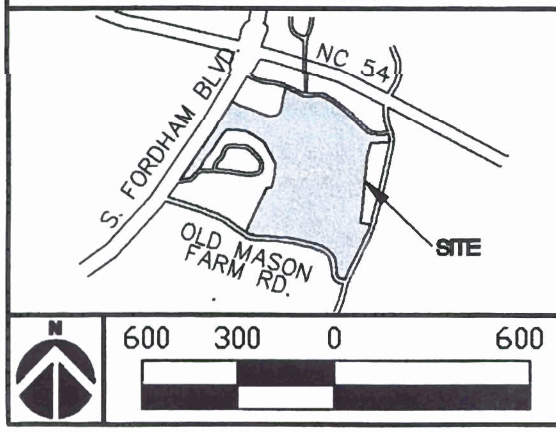


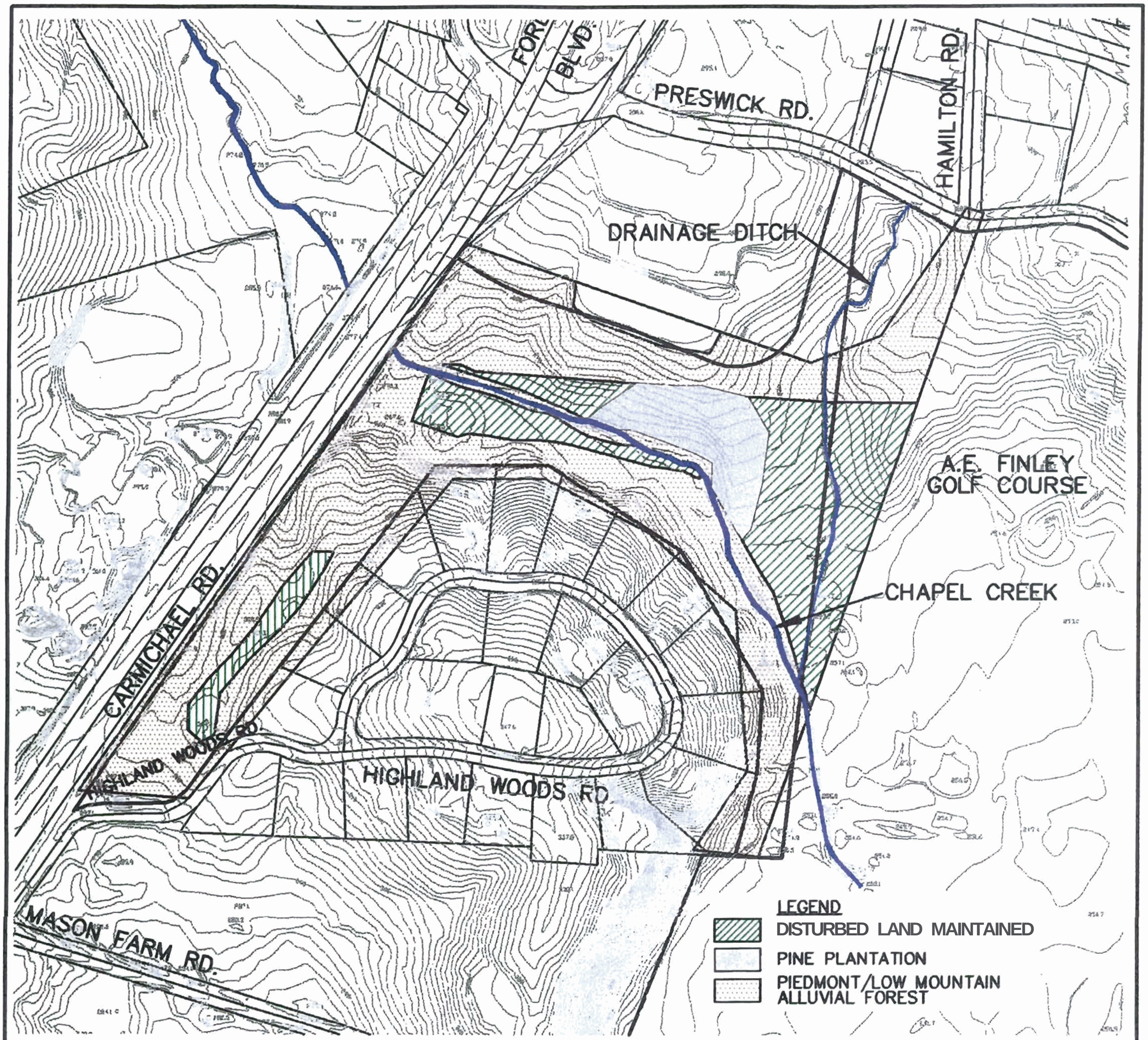
FIGURE 4
RESTORATION SITE CHAPEL CREEK HYDROLOGIC FEATURES

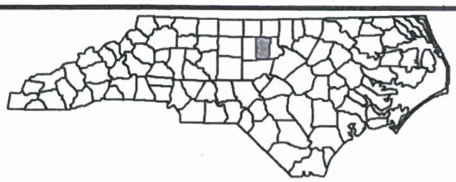
DATE: JULY 25, 2006

WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359





North Carolina – Ecosystem Enhancement Program

Ecosystem Enhancement PROGRAM

Chapel Creek Stream Reference Site
Orange County, North Carolina
SCO ID #050645701

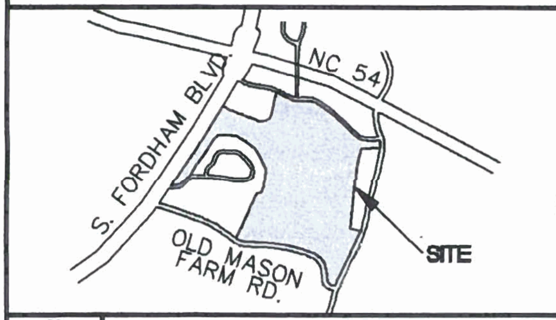


FIGURE 5
RESTORATION SITE
CHAPEL CREEK
VEGETATIVE COMMUNITIES MAP

DATE: JULY 25, 2006

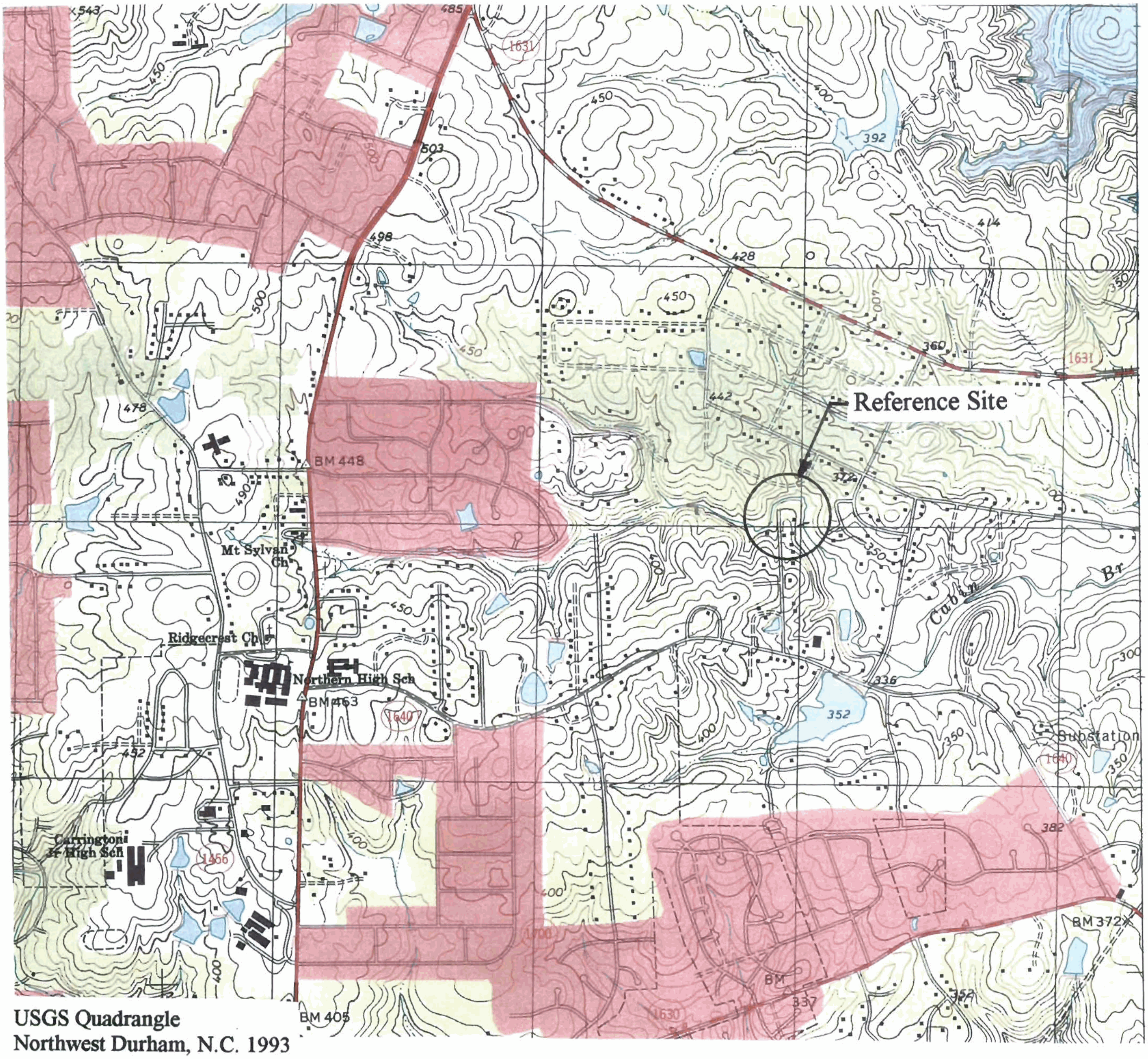
N

400 200 0 400

WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359



North Carolina – Ecosystem Enhancement Program

Ecosystem Enhancement PROGRAM

Chapel Creek Stream Reference Site
Durham County, North Carolina
SCO ID #050645701

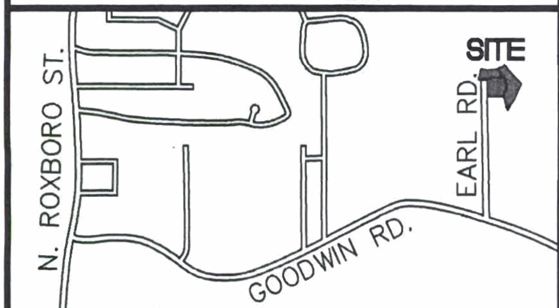
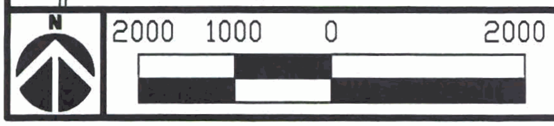


FIGURE 6
REFERENCE SITE
CABIN BRANCH
VICINITY MAP

DATE: JULY 25, 2006



WARD CONSULTING ENGINEERS, PC
Water Management Engineering
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

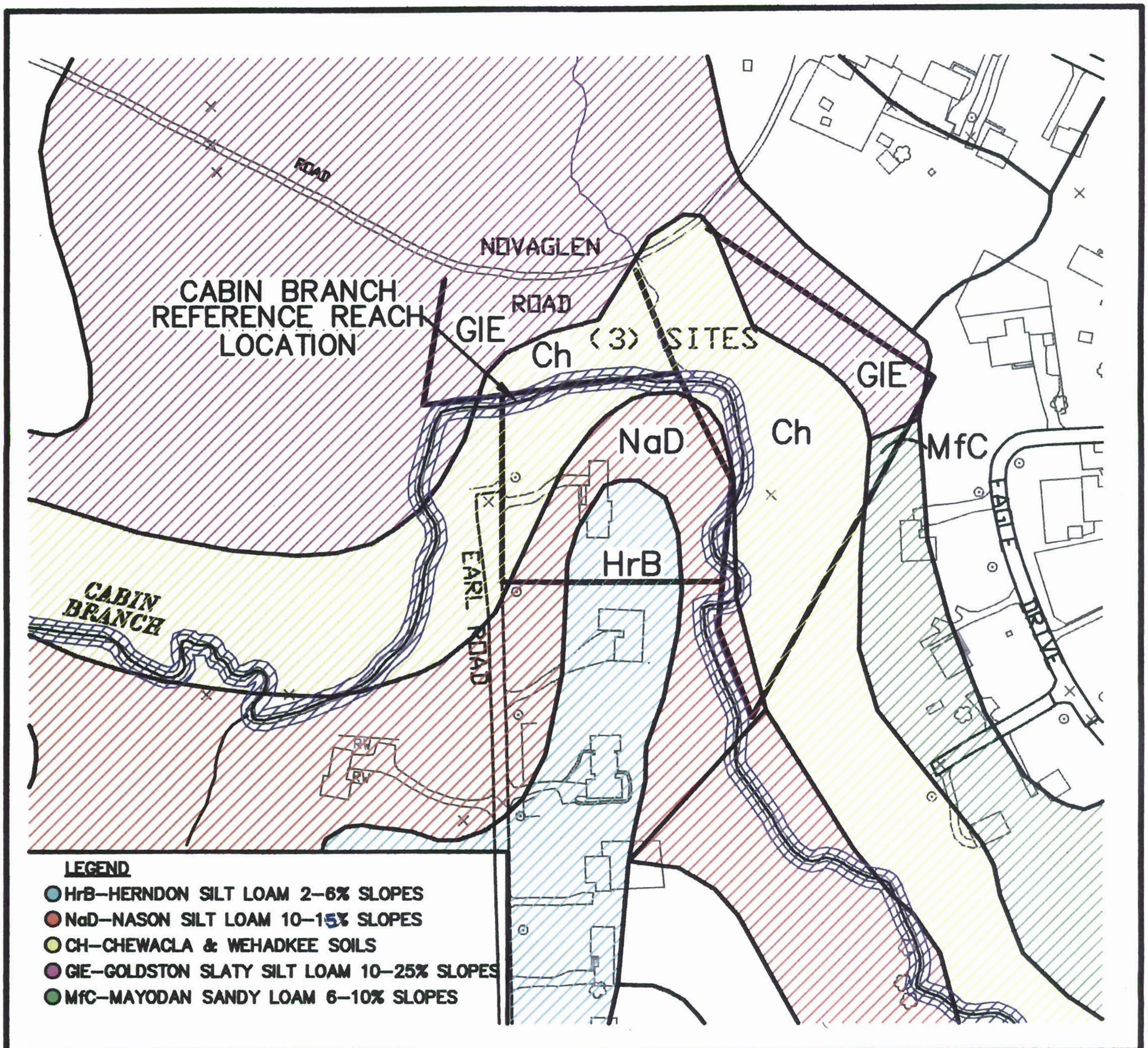
WARD CONSULTING ENGINEERS, PC
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

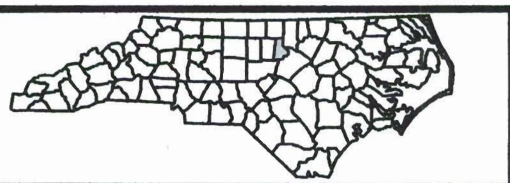
Ecosystem Enhancement PROGRAM

RESTORATION SITE
CABIN BRANCH
WATERSHED MAP
DURHAM COUNTY, NORTH CAROLINA

DATE: JULY 25, 2006
PROJ./DWG. NAME: CHAPEL CREEK
cb-watershed
SCALE: 1"=800'

FIGURE 7





Ecosystem Enhancement PROGRAM

North Carolina – Ecosystem Enhancement Program

Chapel Creek Stream Reference Site
Durham County, North Carolina
SCO ID #050645701

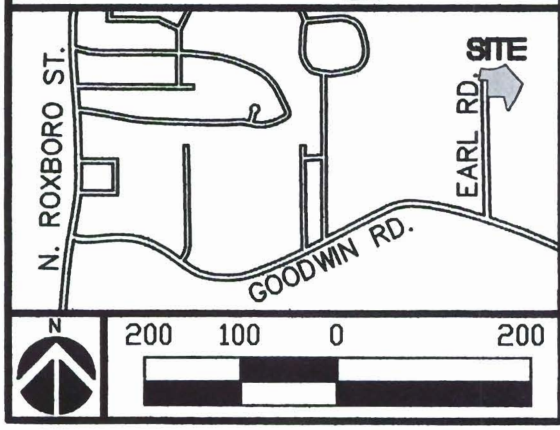


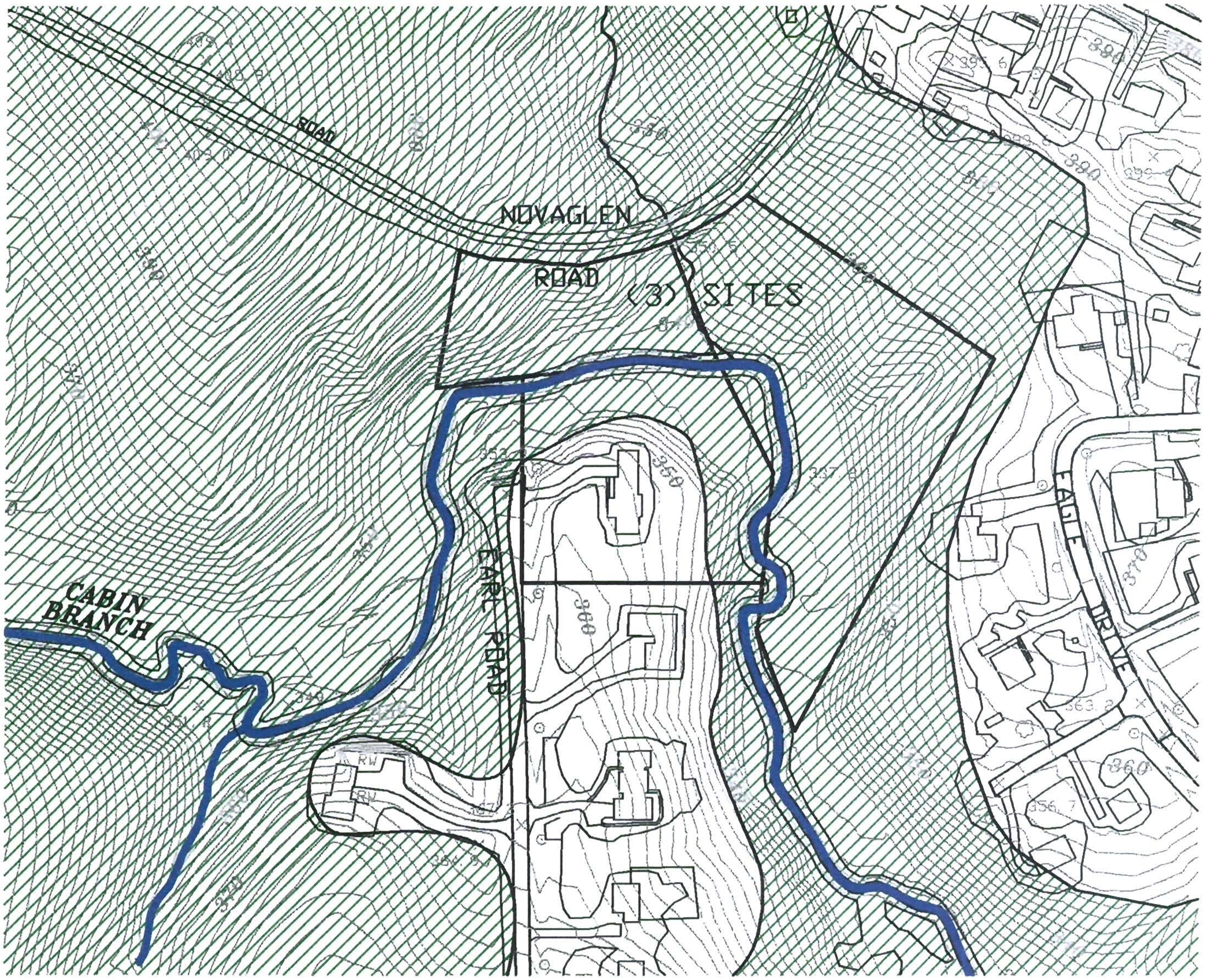
FIGURE 8
REFERENCE SITE
CABIN BRANCH
NRCS SOIL SURVEY

DATE: JULY 25, 2006

WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359



LEGEND

MESIC MIXED HARDWOOD FOREST (PIEDMONT SUBTYPE)

North Carolina – Ecosystem Enhancement Program

Ecosystem Enhancement PROGRAM

Chapel Creek Stream Reference Site
Durham County, North Carolina
SCO ID #050645701

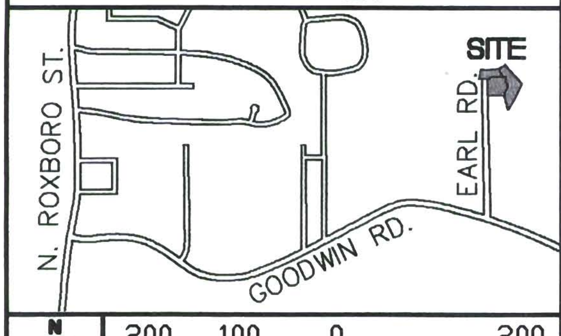


FIGURE 9
REFERENCE SITE
CABIN BRANCH
VEGETATIVE COMMUNITIES MAP

DATE: JULY 25, 2006

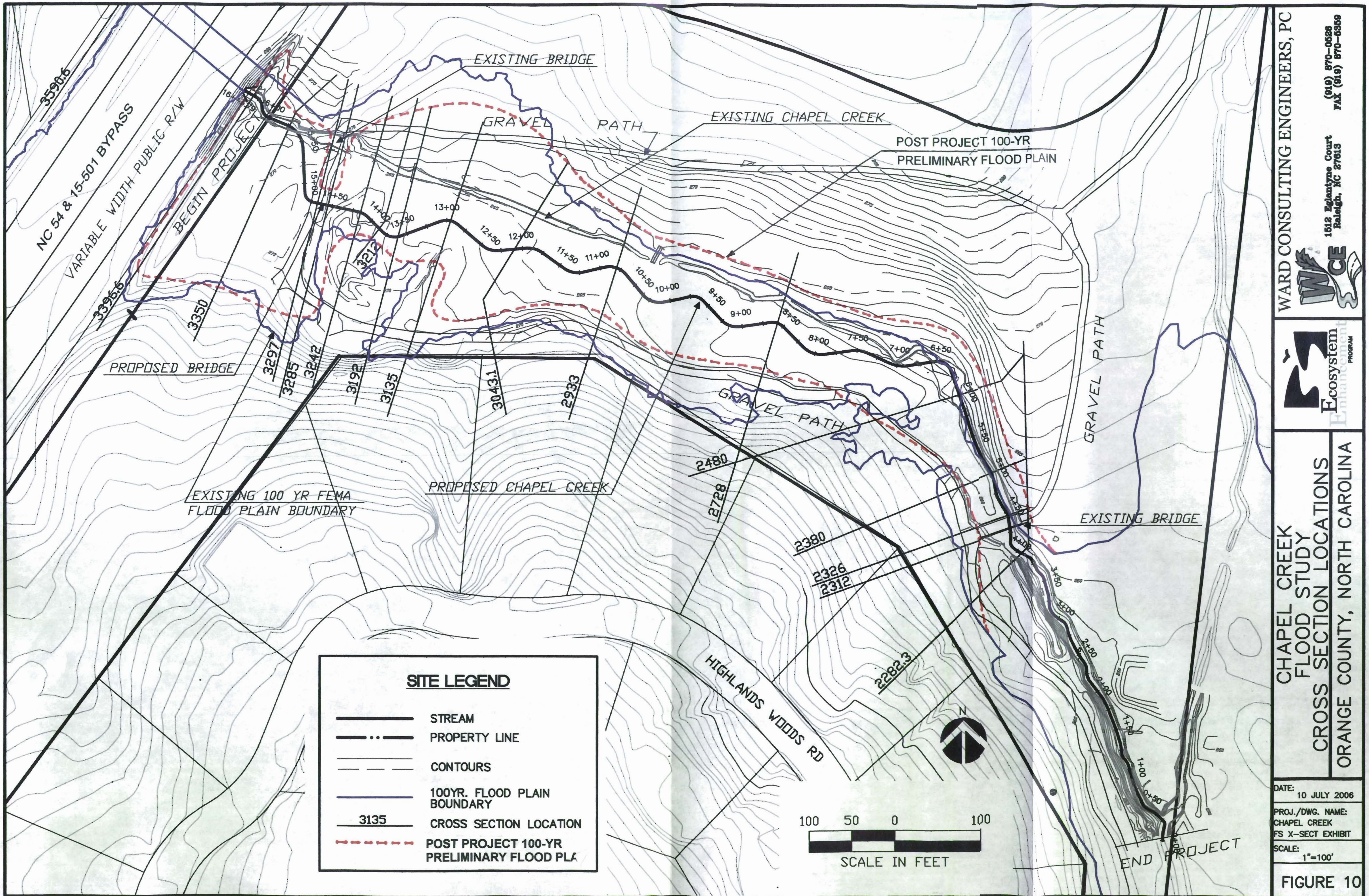
N

200 100 0 200

WARD CONSULTING ENGINEERS, PC

1512 Eglantyne Court
Raleigh, NC 27613

(919) 870-0526
FAX (919) 870-5359


EXISTING BRIDGE
EXISTING CHAPEL CREEK
GRAVEL PATH
POST PROJECT 100-YR
PRELIMINARY FLOOD PLAIN
NC 54 & 15-501 BYPASS
VARIABLE WIDTH PUBLIC R/W
BEGIN PROJECT
3590.6
3396.6
3350
3297
3285
3242
3212
3192
3135
3043.1
2933
2728
2480
2380
2326
2312
2282.3
PROPOSED BRIDGE
EXISTING 100 YR FEMA
FLOOD PLAIN BOUNDARY
PROPOSED CHAPEL CREEK
GRAVEL PATH
EXISTING BRIDGE
HIGHLANDS WOODS RD
END PROJECT
SITE LEGEND
STREAM
PROPERTY LINE
CONTOURS
100YR. FLOOD PLAIN BOUNDARY
3135
CROSS SECTION LOCATION
POST PROJECT 100-YR
PRELIMINARY FLOOD PLA
100 50 0 100
SCALE IN FEET
N
WARD CONSULTING ENGINEERS, PC
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359
Ecosystem Enhancement PROGRAM
CHAPEL CREEK
FLOOD STUDY
CROSS SECTION LOCATIONS
ORANGE COUNTY, NORTH CAROLINA
DATE: 10 JULY 2006
PROJ./DWG. NAME: CHAPEL CREEK FS X-SECT EXHIBIT
SCALE: 1"=100'
FIGURE 10

10.0 Design Plan Sheets

Sheet 1. Chapel Creek Title Sheet

Sheet 2. Chapel Creek Plan & Profile, Grading & Erosion Control Station **16+25** to **12+00**

Sheet 3. Chapel Creek Plan & Profile, Grading & Erosion Control Station **12+00** to **6+00**

Sheet 4. Chapel Creek Plan & Profile, Grading & Erosion Control Station 6+00 to **0+00**

Sheet 5. Chapel Creek Enhancement Cross Sections

Sheet 6. Chapel Creek Enhancement Cross Sections

Sheet 7. Chapel Creek Planting Plan

Sheet 8. Chapel Creek Staking Plan – to ***be completed during construction phase***

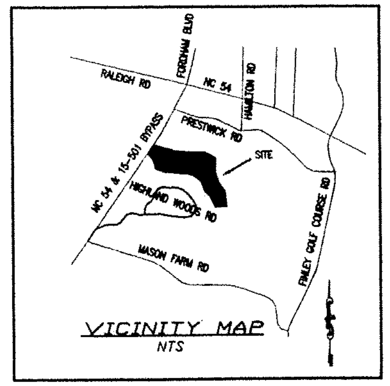
Sheet 9. Chapel Creek Details

Sheet 10. Chapel Creek Details

CHAPEL CREEK

STREAM, AND BUFFER RESTORATION, ENHANCEMENT, AND PRESERVATION

ORANGE COUNTY, NORTH CAROLINA



PROJECT RESTORATION/ENHANCEMENT AND PRESERVATION		
TYPE	AREA (ACRES)	DISTANCE (FEET)
STREAM RESTORATION	N/A	1000
STREAM ENHANCEMENT	N/A	600
STREAM BUFFER PRESERVATION	2.22	N/A

SHEET SCHEDULE

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program

Chapel Creek Stream & Buffer Restoration Enhancement and Preservation Orange County, North Carolina

Ecosystem Enhancement PROGRAM

SEAL:

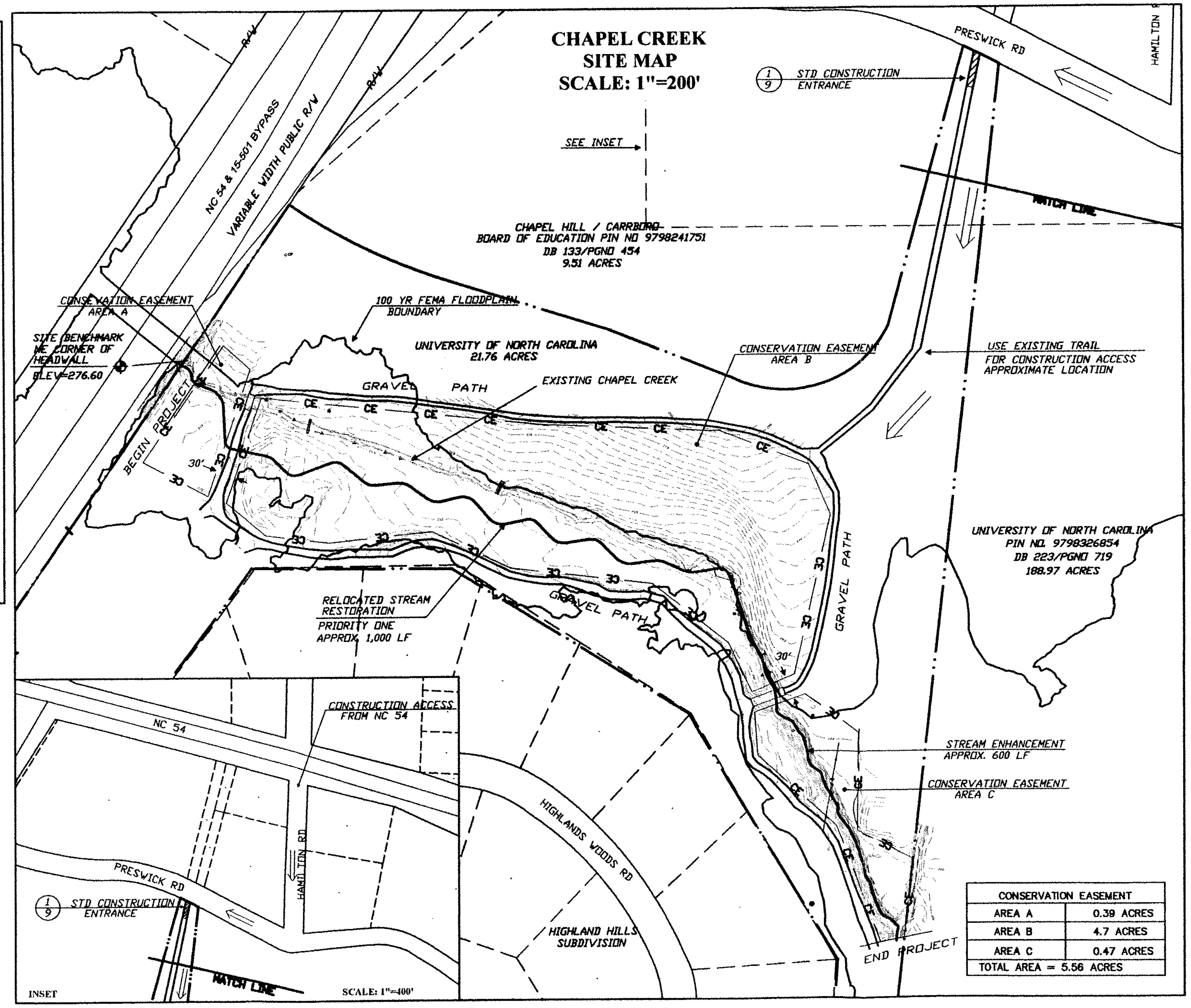
NORTH CAROLINA PROFESSIONAL SEAL 1334 ENGINEER BECKY LYNNE WARD

GENERAL NOTES

1. ALL SEDIMENTATION AND EROSION CONTROLS TO BE BUILT TO STATE OF NORTH CAROLINA STANDARDS.
2. ALL DISTURBED AREAS TO BE SEEDED TO SPECIFICATIONS UNLESS OTHERWISE NOTED.
3. ALL AREAS SHOWN OUTSIDE THE SHOWN DISTURBANCE LIMIT OR CONSERVATION EASEMENT TO REMAIN IN THEIR NATURAL CONDITION.
4. CONTRACTOR SHALL VERIFY ALL DIMENSIONS IN FIELD. ANY DISCREPANCIES THEREOF SHALL BE REPORTED TO THE OWNER AND ENGINEER, PRIOR TO PROCEEDING WITH THE WORK.
5. CONTRACTOR SHALL VERIFY LOCATIONS AND ELEVATIONS OF ALL EXISTING UTILITIES. (UTILITIES ONLY ANTICIPATED IN SMITH HUDSON ROAD ROW)
6. THE OWNER AND FINANCIALLY RESPONSIBLE PARTY FOR THIS RESTORATION PROJECT IS THE NC ECOSYSTEM ENHANCEMENT PROGRAM.
7. THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTENANCE OF ALL EROSION CONTROL MEASURES DURING CONSTRUCTION.
8. CONTRACTOR IS RESPONSIBLE FOR HAVING ALL UTILITIES LOCATED 48 HOURS PRIOR TO MOBILIZATION ON SITE. "CALL BEFORE YOU DIG" TOLL FREE NUMBER (800-698-4949).
9. BASE TOPOGRAPHIC AND PLANIMETRIC INFORMATION GENERATED FROM ORANGE COUNTY GIS DATA.
10. FIELD SURVEYS BY RILEY SURVEYING, PA. P.O. BOX 16459 CHAPEL HILL NC, 27516 (919) 667-0742, NOV. 2005.
11. ONE BENCHMARK SET ON PROJECT SITE BY RILEY SURVEY CREWS, SEE SITE MAP PLAN SHEET 1.
12. CONSTRUCTION EQUIPMENT LIMITED TO ACCESS THROUGH CONSERVATION EASEMENTS AS SHOWN ON TITLE SHEET.
13. ALL TREES AND DEBRIS TO BE MULCHED ON SITE. LARGE MATERIAL TO BE REMOVED FROM THE PROJECT SITE AND PROPERLY DISPOSED OF IN A LICENSED LANDFILL. REMAINING TREE STUMPS TO BE NO TALLER THAN 12" FROM EXISTING GROUND.
14. ALL CONSTRUCTION TO BE PERFORMED FROM TOP OF BANK NO EQUIPMENT WILL BE PERMITTED TO WORK FROM THE CHANNEL BED OR CROSS THE STREAMS EXCEPT AT DESIGNATED LOCATIONS AS SHOWN ON PLANS.

CONSTRUCTION SEQUENCE

1. CONTRACTOR TO INSTALL ALL EROSION CONTROL MEASURES AND TREE PROTECTION FENCING AS SHOWN OF THE PLANS PRIOR TO BEGINNING CONSTRUCTION.
2. INSTALL TEMPORARY STREAM CROSSINGS AS SHOWN ON PLANS.
3. PERFORM TREE REMOVAL OPPERATIONS FOR ACCESS TO THE SITE AND AS SHOWN ON THE PLANS, AS APPROVED BY THE ENGINEER AND OWNER. MULCH OR DISPOSE OF THE DEBRIS AS DESCRIBED IN THE PLANS.
4. REMOVE DEBRIS IN CHANNEL, CONCRETE BRIDGES, AND WOODEN BRIDGE AT STATION 6+50, AS SHOWN ON PLANS.
5. CONTRACTOR TO STOCK PILE MATERIALS IN ONLY THE LOCATIONS SHOWN ON THE PLANS UNLESS OTHERWISE APPROVED BY THE ENGINEER OR OWNER.
6. COMPLETE BENCHING ON LOWER REACH AND STOCK PILE SOILS IN UPPER REACH.
7. SEED AND STABILIZE DAILY AS CONSTRUCTION PROCEEDS DOWNSTREAM AND AS DIRECTED IN THE EROSION CONTROL AND VEGETATION SPECIFICATIONS.
8. COMPLETE STREAM ENHANCEMENT IN LOWER REACH.
9. CONSTRUCT NEW STREAM CHANNEL TO THE DIMENSIONS AND ELEVATIONS SHOWN ON THE PLANS WORKING FROM UPSTREAM TOWARDS THE DOWNSTREAM PROJECT LIMITS.
10. INSTALL NEW BRIDGE.
11. REROUTE WATER TO NEW CHANNEL AND FILL OLD CHANNEL COMPLETING GRADING.
12. PLANT AND MULCH VEGETATION IN THE BUFFER AND STREAM BANK AS AS SHOWN ON THE PLANTING PLAN.
13. SEED AND STABILIZE ALL DISTURBED AREAS REMAINING ON THE PROJECT SITE.
14. SEED AND STABILIZE CONSTRUCTION ACCESS. REPAIR ANY DAMAGE TO EXISTING TRAIL DUE TO CONSTRUCTION ACTIVITIES AS CONSTRUCTION OPERATIONS MOVE OUT.



CONSERVATION EASEMENT	
AREA A	0.39 ACRES
AREA B	4.7 ACRES
AREA C	0.47 ACRES
TOTAL AREA = 5.56 ACRES	

NATURAL SYSTEMS INVESTIGATION:
THE CATENA GROUP INC.
410-B MILLSTONE DRIVE
HILLSBORO, NC 27278
PH: 919-732-1300
FAX: 919-732-1303

SITE LEGEND

———	STREAM
—·—·—	PROPERTY LINE
- - - -	CONTOURS
— CE —	CONSERVATION EASEMENT
- - - - -	100YR. FLOOD PLAIN BOUNDARY
▨	TEMPORARY GRAVEL CONSTRUCTION ENTRANCE

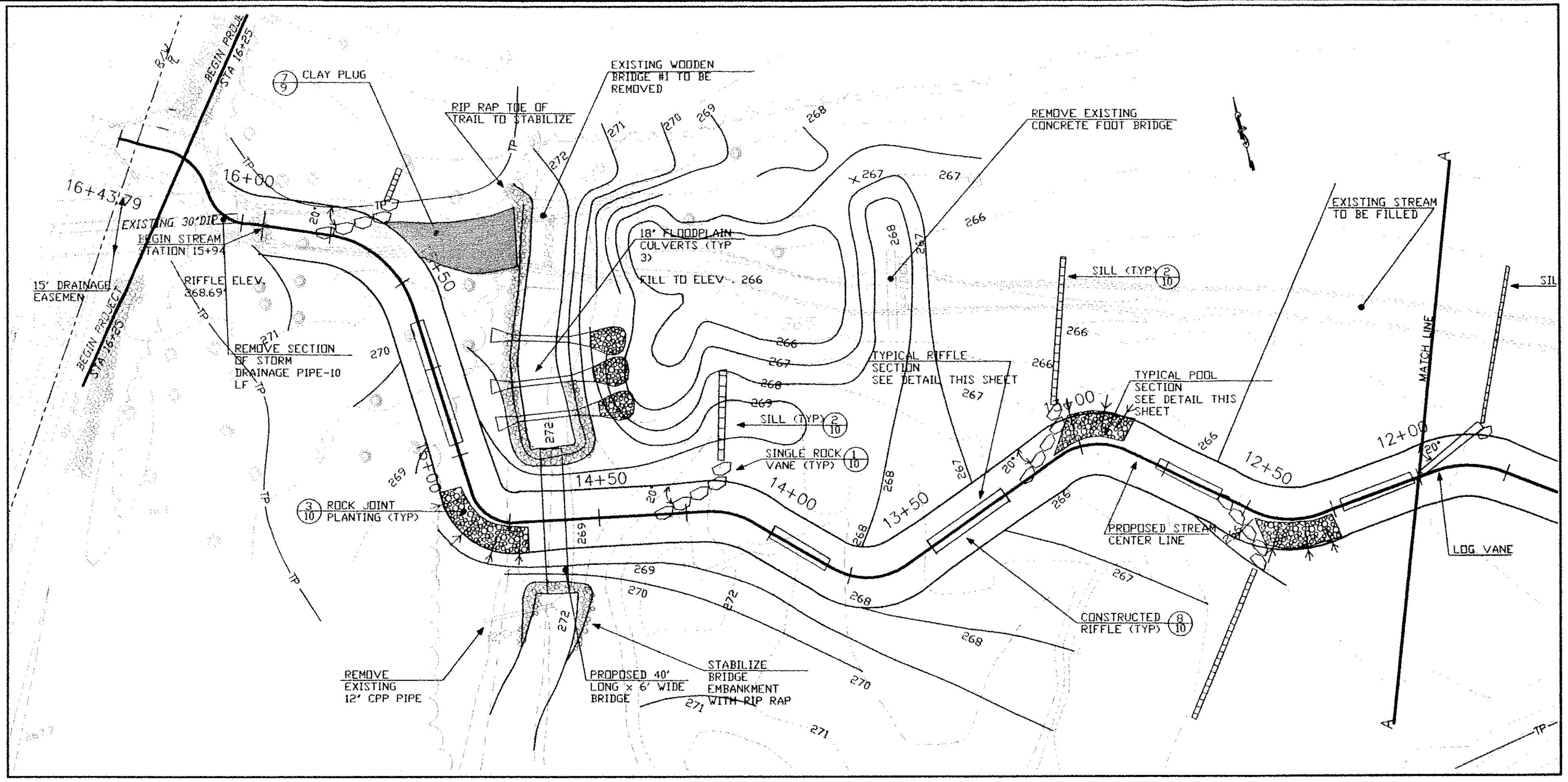
SITE DATA TABLE

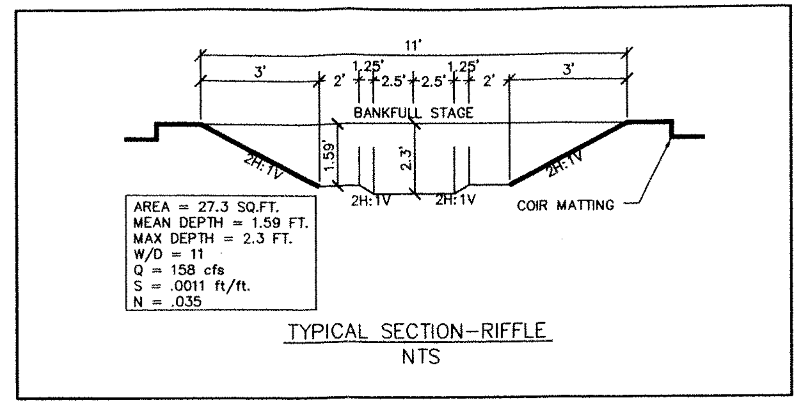
AREA:	21.76 ACRES
PROPERTY PIN NO.	9798149225
DEED BOOK & PAGE NUMBER:	130/530
OWNER:	UNIVERSITY OF NORTH CAROLINA
PROPERTY PHYSICAL ADDRESS:	CHAPEL HILL, NC 27514
PROJECT SPONSORED BY:	NC ECOSYSTEM ENHANCEMENT PROGRAM PARKER LINCOLN BUILDING 2728 CAPITAL BLVD. SUITE 1H-103 RALEIGH, NC 27606 919-715-0476
TYPE OF PROJECT:	STREAM, AND BUFFER RESTORATION ENHANCEMENT & PRESERVATION
TOTAL PROJECT DISTURBED AREA:	

CHAPEL CREEK
TITLE SHEET

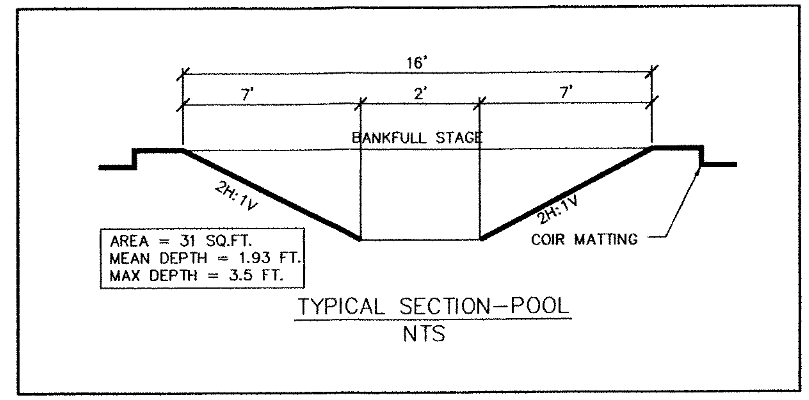
PRELIMINARY NOT FOR CONSTRUCTION

DATE:	10 JULY 2006
REVISIONS:	
PROJECT NAME:	CHAPEL CREEK
DWG NAME:	COVER
SCALE:	NTS
SHEET NO.	1 OF 10





TYPICAL SECTION-RIFFLE
NTS

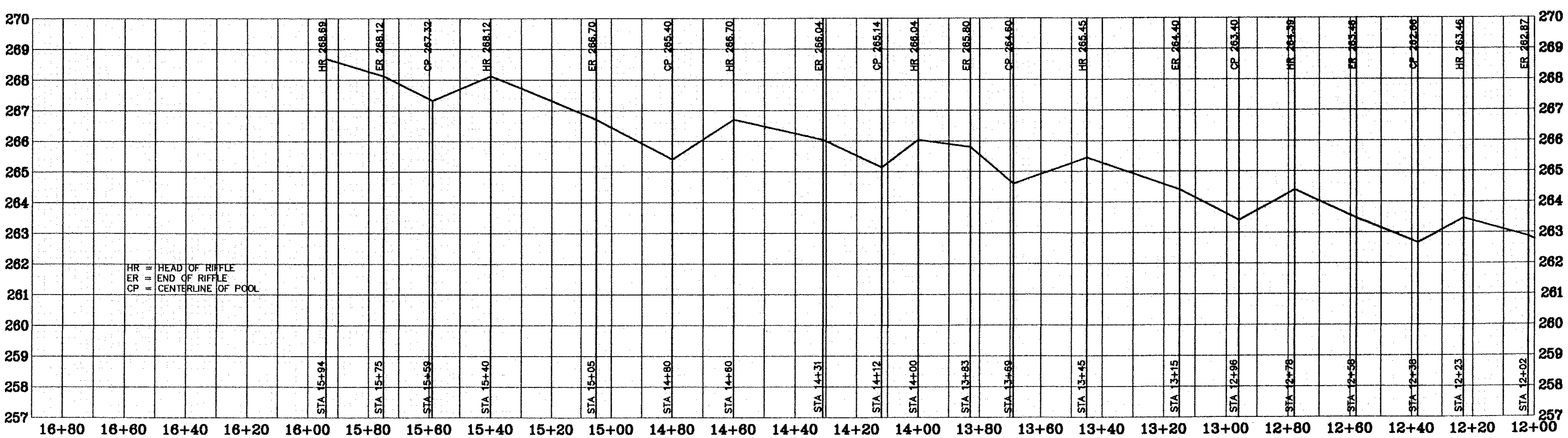


TYPICAL SECTION-POOL
NTS

DISTURBED AREA = ## ACRES

PROPOSED ℄ STREAM PLAN

SCALE IN FEET



PROPOSED ℄ STREAM PROFILE

LEGEND

PROPOSED 1' CONTOUR	CONSTRUCTED RIFFLE
EXISTING 1' CONTOUR	TREE PROTECTION FENCING
EXISTING 5' CONTOUR	SILT FENCING
TEMPORARY STREAM CROSSING	CLAY PLUG
BANK REPAIR	SILL
RIP RAP TOE TO BANKFULL	CROSS VANE
CONSTRUCTION ACCESS	SINGLE ROCK VANE
EXISTING TREE	ROCK JOINT PLANTING
EXISTING TREE TO BE REMOVED	ROOT WAD
LIMITS OF EXISTING TRAIL	LOG VANE

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

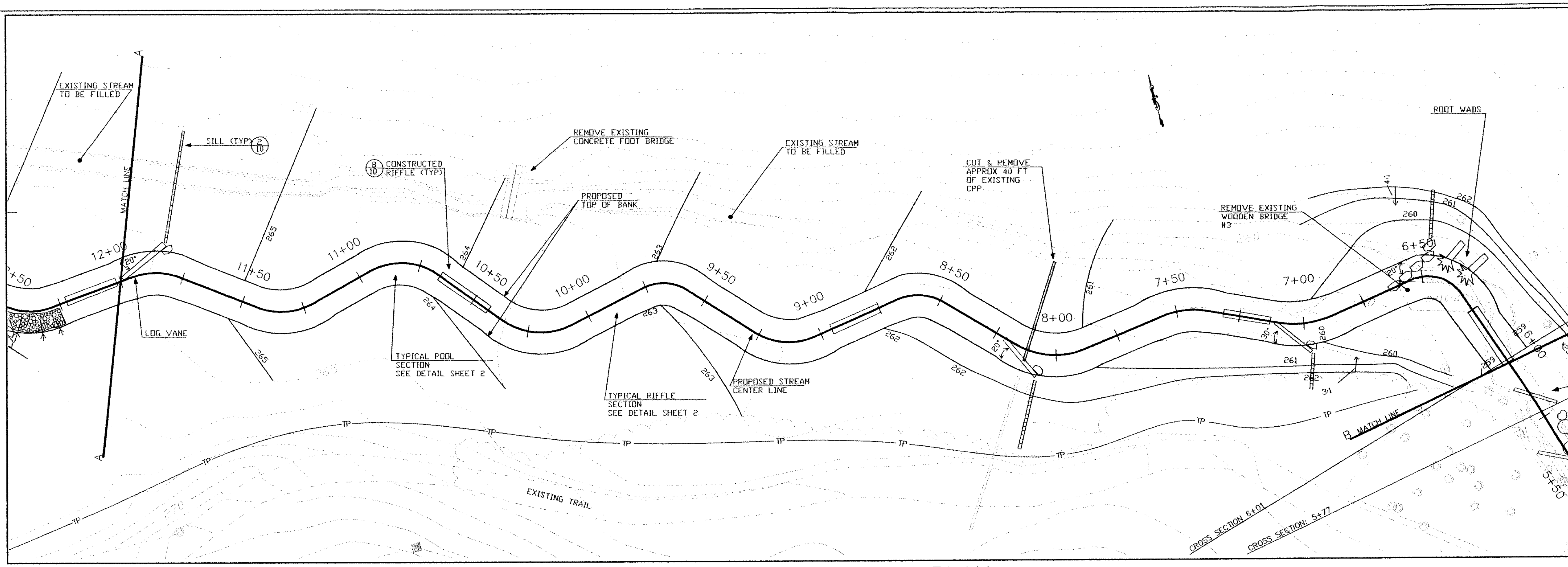
North Carolina - Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration
Enhancement and Preservation
Orange County, North Carolina

SEAL:

CHAPEL CREEK
PLAN & PROFILE, GRADING & EROSION CONTROL STA 16+25 TO 12+00

PRELIMINARY NOT FOR CONSTRUCTION

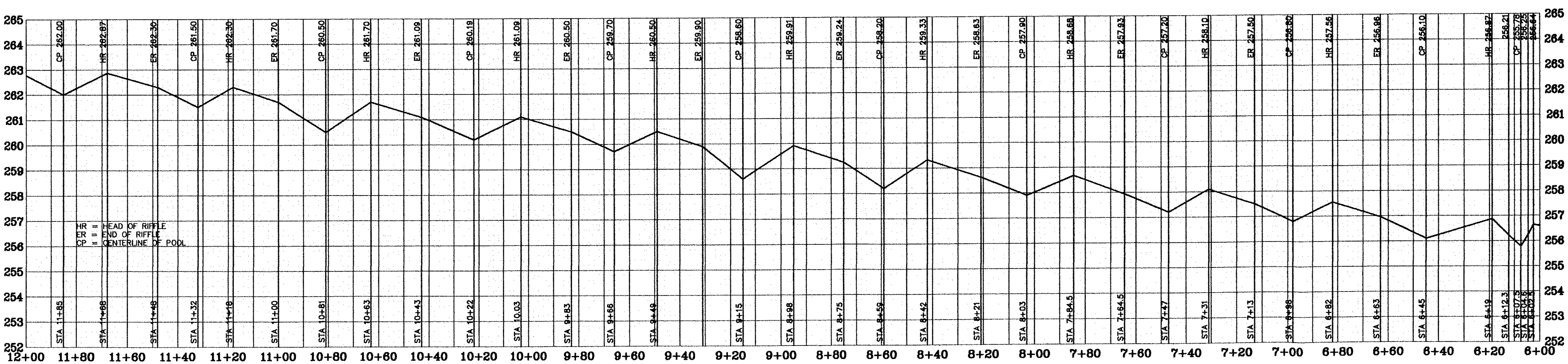
DATE: 10 JULY 2006
REVISIONS:
PROJECT NAME: CHAPEL CREEK
DWG NAME: GRADING
SCALE: 1" = 40'
SHEET NO. 2 OF 10



PROPOSED ℄ STREAM PLAN

DISTURBED AREA = ## ACRES

SCALE IN FEET



PROPOSED ℄ STREAM PROFILE

LEGEND

- PROPOSED 1' CONTOUR
- EXISTING 1' CONTOUR
- EXISTING 5' CONTOUR
- TEMPORARY STREAM CROSSING
- BANK REPAIR
- RIP RAP TOE TO BANKFULL
- CONSTRUCTION ACCESS
- EXISTING TREE
- EXISTING TREE TO BE REMOVED
- LIMITS OF EXISTING TRAIL
- CONSTRUCTED RIFFLE
- TREE PROTECTION FENCING
- SILT FENCING
- CLAY PLUG
- SILL
- CROSS VANE
- SINGLE ROCK VANE
- ROCK JOINT PLANTING
- ROOT WAD
- LOG VANE

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration Enhancement and Preservation
Orange County, North Carolina

SEAL: NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 1344 BECKY LYNNE WARD

CHAPEL CREEK
PLAN & PROFILE, GRADING & EROSION CONTROL STA 12+00 TO 6+00

PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006

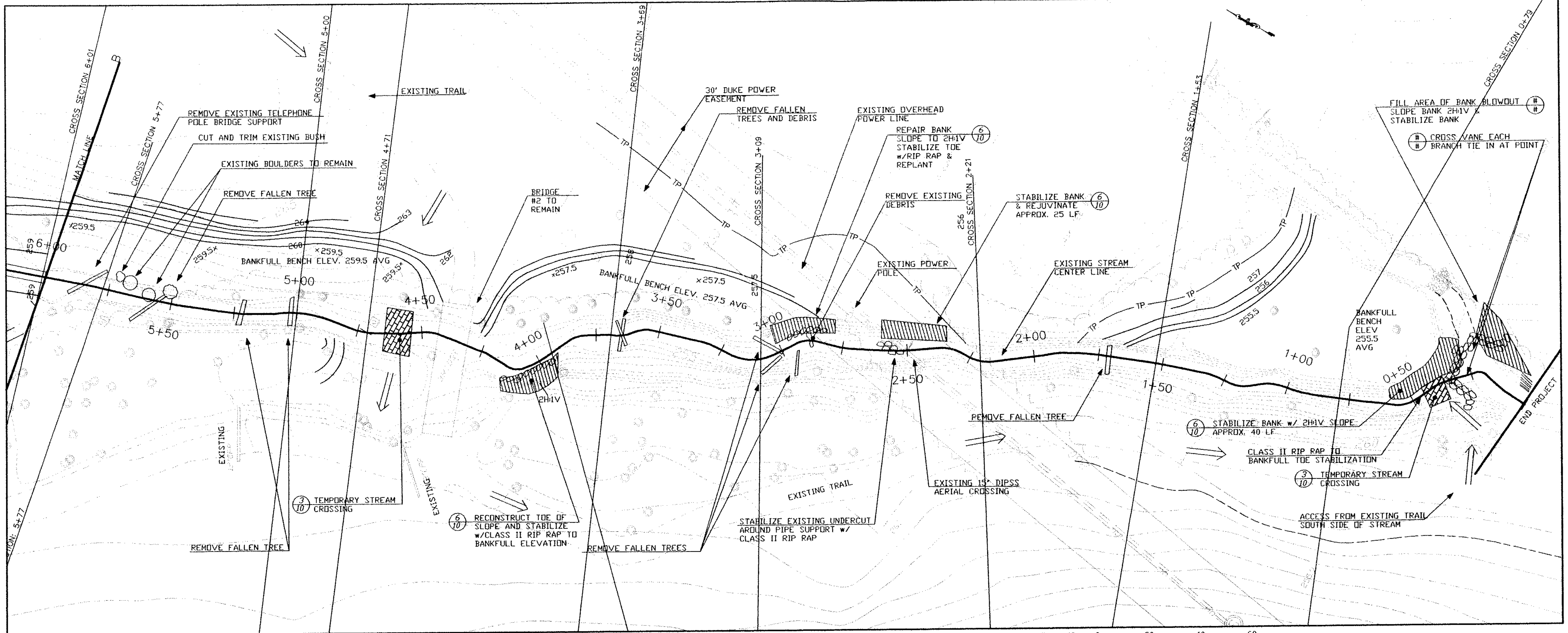
REVISIONS:

PROJECT NAME: CHAPEL CREEK

DWG NAME: GRADING

SCALE: 1" = 40'

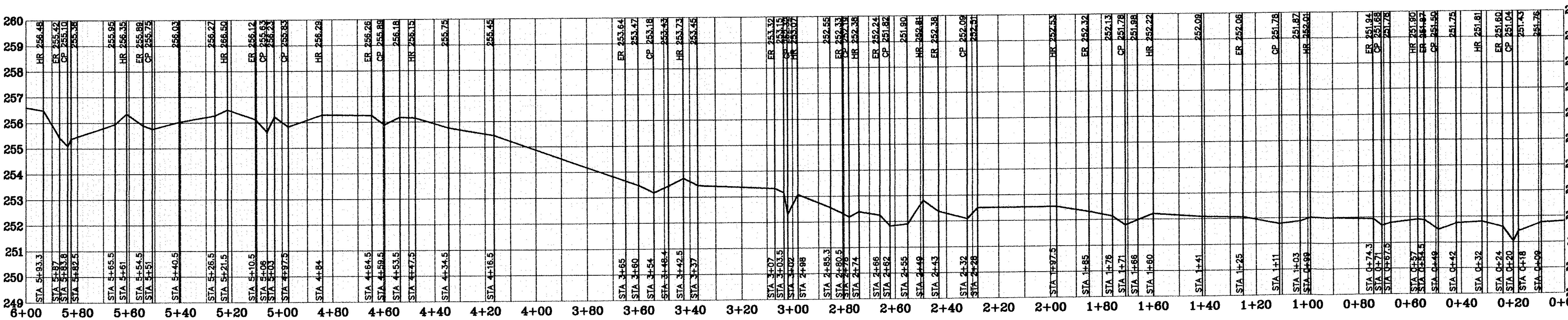
SHEET NO.



DISTURBED AREA = ## ACRES

PROPOSED ℄ STREAM PLAN

SCALE IN FEET (20 10 0 20 40 60)



PROPOSED ℄ STREAM PROFILE

NOTES:
1. BENCHING TO BE CONSTRUCTED FROM N. SIDE OF STREAM
2. CONTRACTOR TO USE EXISTING TRAIL SOUTH SIDE OF STREAM TO ACCESS BANKFULL BENCH CONSTRUCTION STATION 0+00 TO 1+50
3. CONTRACTOR TO REMAIN OFF GOLF COURSE AT ALL TIMES

LEGEND

- PROPOSED 1' CONTOUR
- EXISTING 1' CONTOUR
- EXISTING 5' CONTOUR
- TEMPORARY STREAM CROSSING
- BANK REPAIR
- RIP RAP TOE TO BANKFULL
- CONSTRUCTION ACCESS
- EXISTING TREE
- EXISTING TREE TO BE REMOVED
- LIMITS OF EXISTING TRAIL
- CONSTRUCTED RIFFLE
- TREE PROTECTION FENCING
- SILT FENCING
- CLAY PLUG
- SILL
- CROSS VANE
- SINGLE ROCK VANE
- ROCK JOINT PLANTING
- ROOT WAD
- LOG VANE

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration Enhancement and Preservation
Orange County, North Carolina

SEAL

CHAPEL CREEK
PLAN & PROFILE, GRADING & EROSION CONTROL STA 6+00 TO 0+00

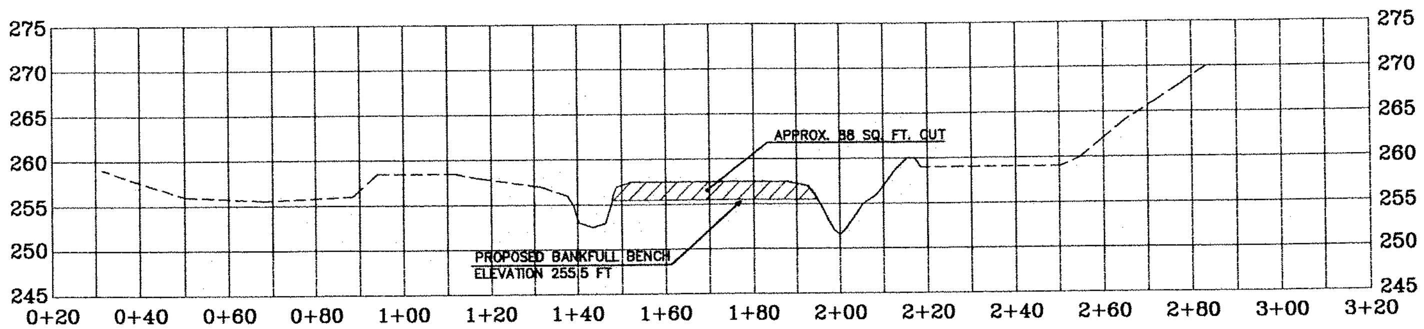
PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006
REVISIONS:

PROJECT NAME: CHAPEL CREEK
DWG NAME: GRADING
SCALE: 1" = 40'
SHEET NO.

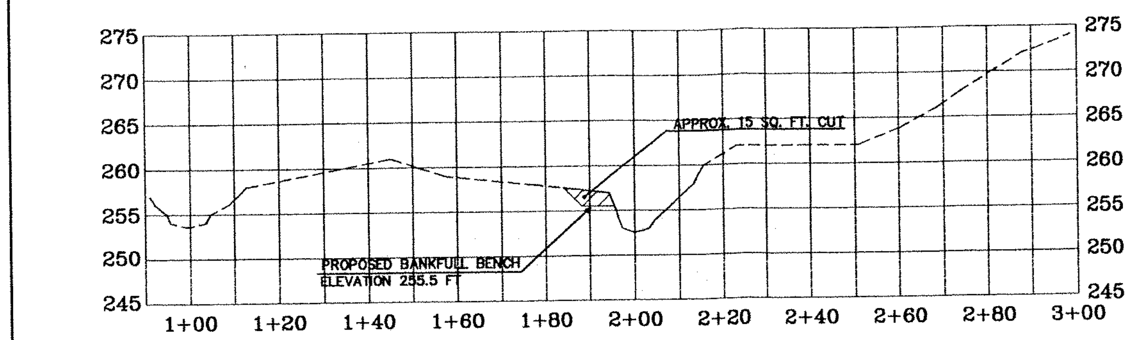
4 OF 10

NOTE: 1. ALL CROSS SECTIONS TAKEN FROM LEFT TO RIGHT LOOKING DOWNSTREAM.
2. CROSS SECTIONS LOCATED ON PLAN SHEET 4.



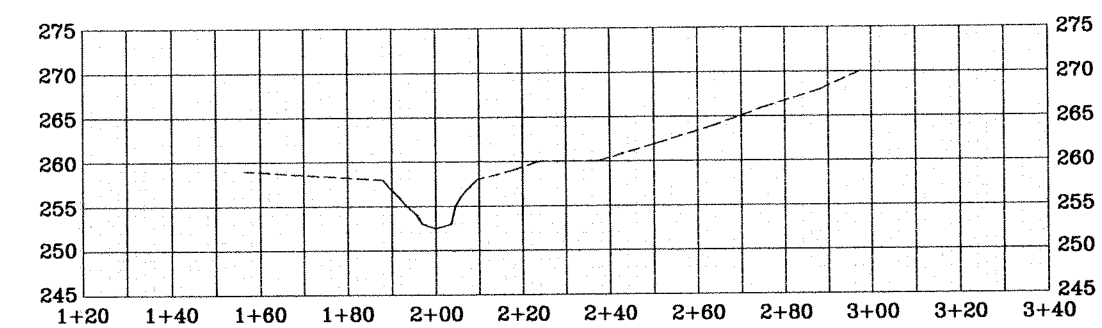
EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 0+79
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'



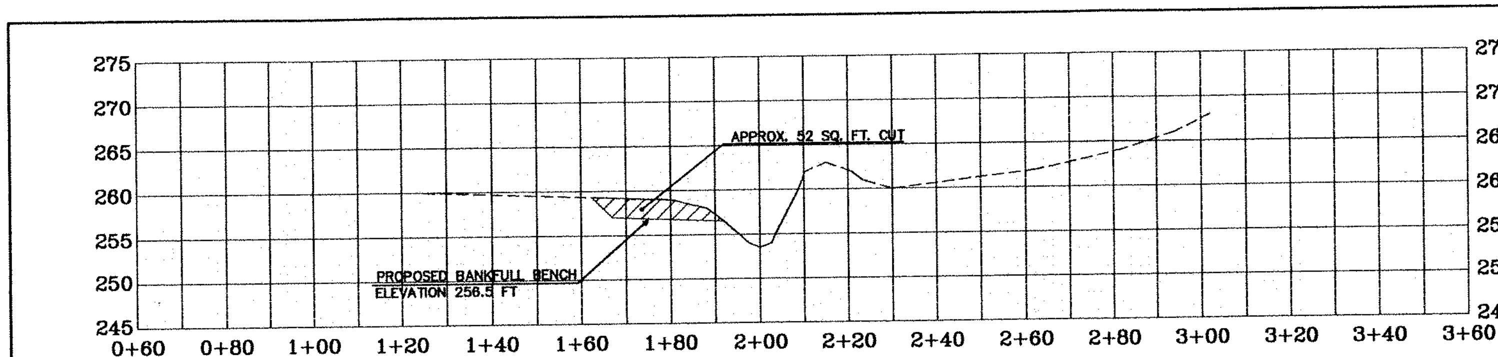
EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 1+53
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'



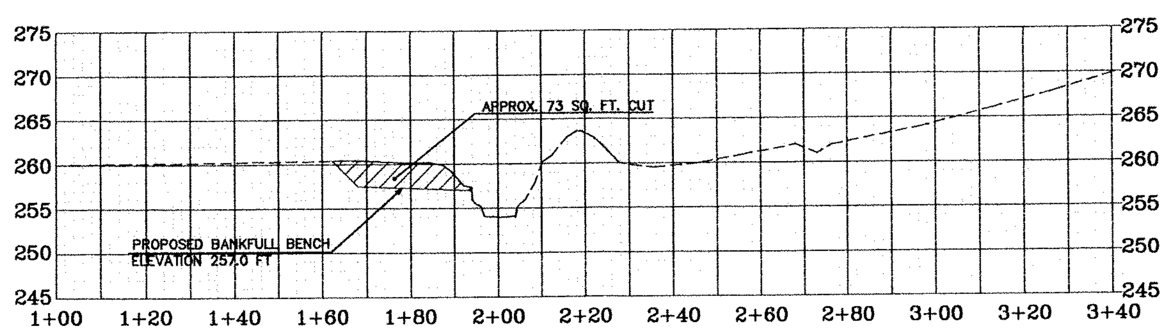
EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 2+21
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'



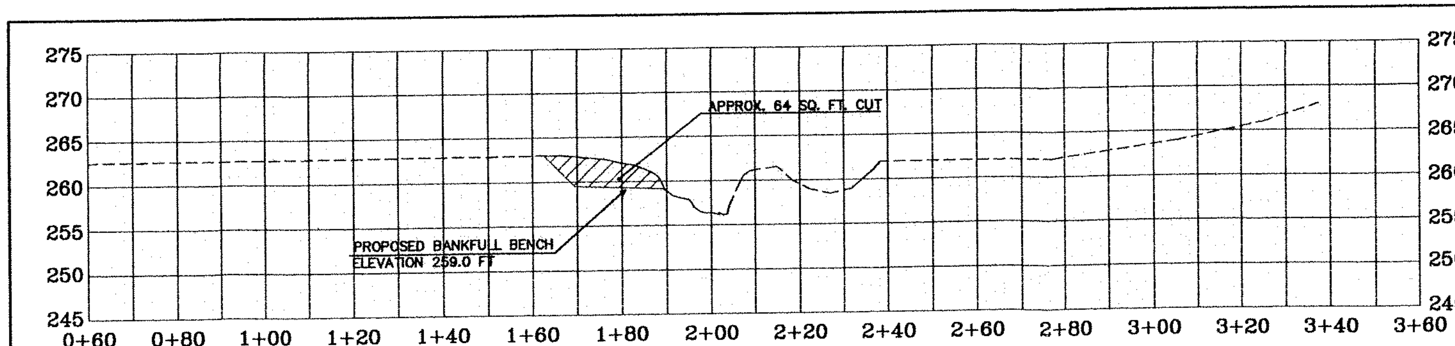
EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 3+09
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'



EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 3+69
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'



EXISTING SECTION
PROPOSED SECTION

CROSS SECTION 4+71
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'

20 10 0 20 40 60
SCALE IN FEET

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration
Enhancement and Preservation
Orange County, North Carolina

Ecosystem Enhancement PROGRAM

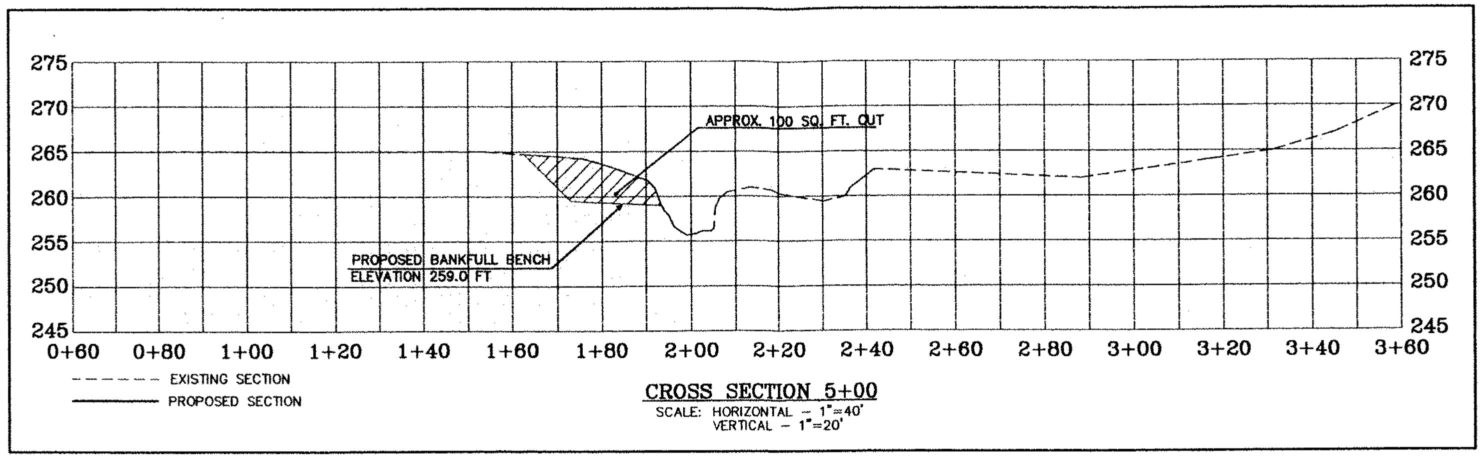
SEAL

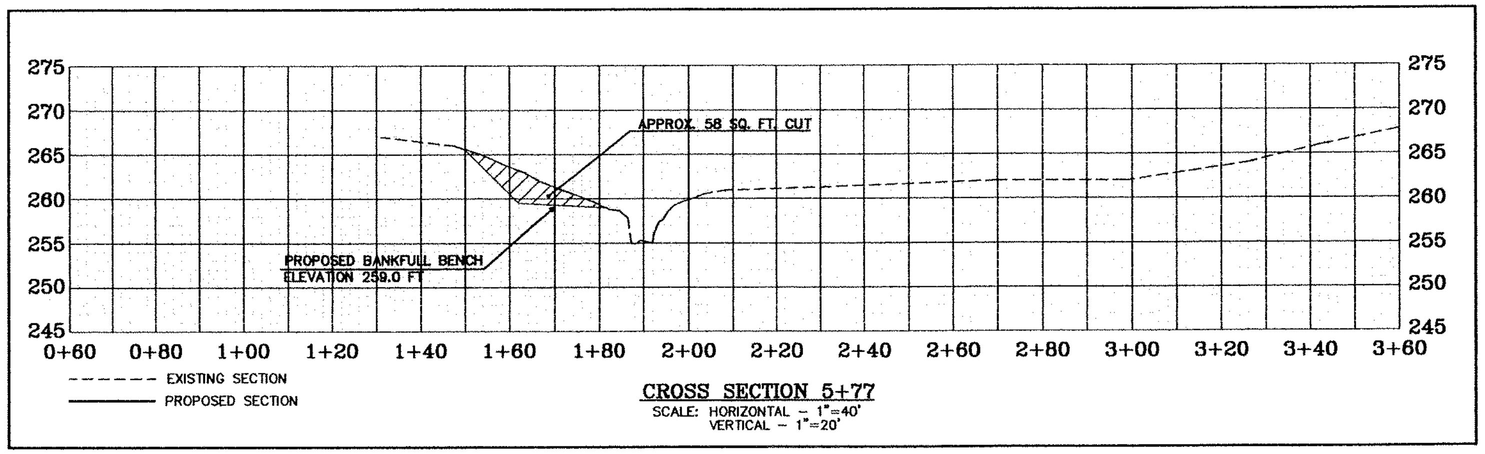
CHAPEL CREEK ENHANCEMENT CROSS SECTIONS

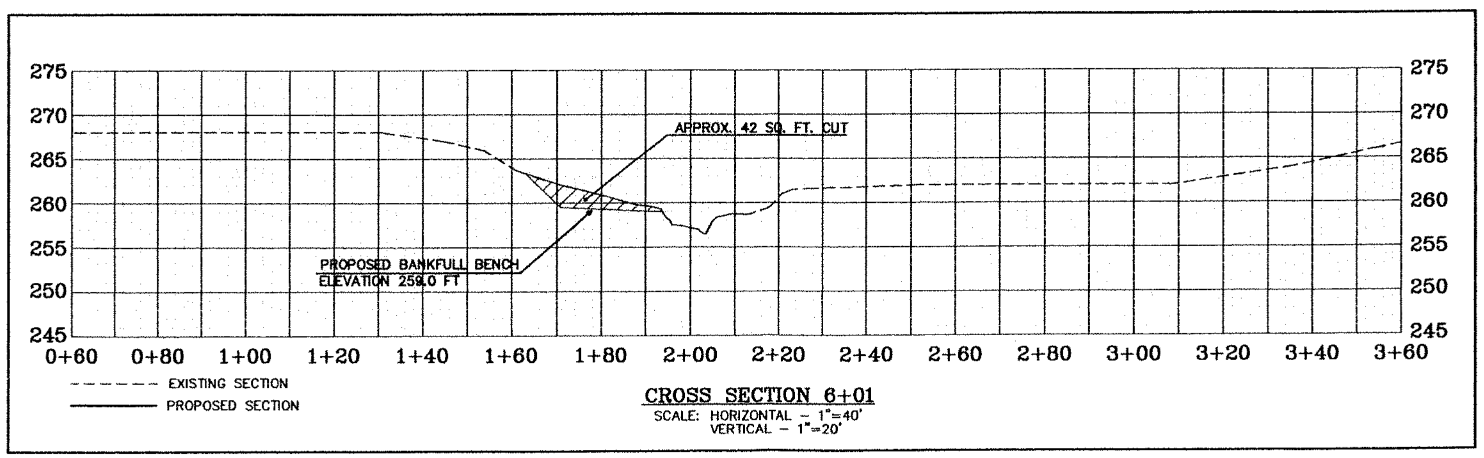
PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006
REVISIONS:
PROJECT NAME: CHAPEL CREEK
DWG NAME: CROSS SECTIONS
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'
SHEET NO.
5 OF 10

NOTE: 1. ALL CROSS SECTIONS TAKEN FROM LEFT TO RIGHT LOOKING DOWNSTREAM.
2. CROSS SECTIONS LOCATED ON PLAN SHEETS 3 & 4.







20 10 0 20 40 60
SCALE IN FEET

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration
Enhancement and Preservation
Orange County, North Carolina

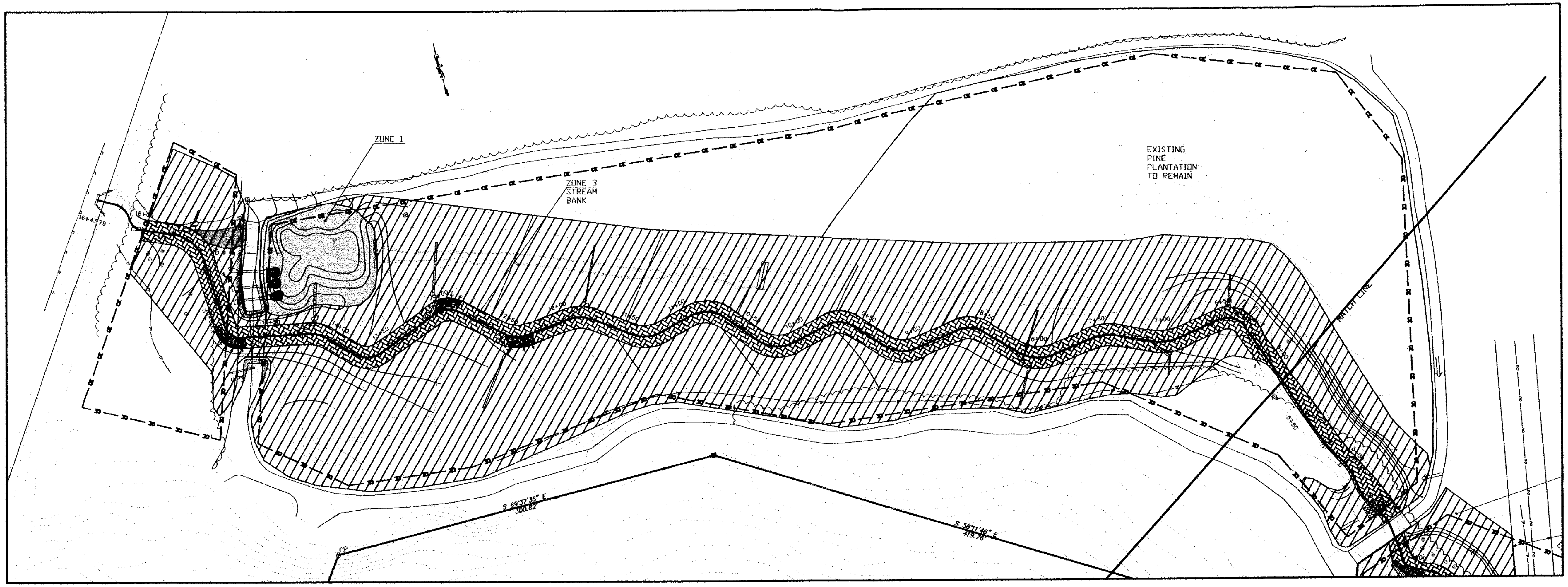
Ecosystem Enhancement PROGRAM

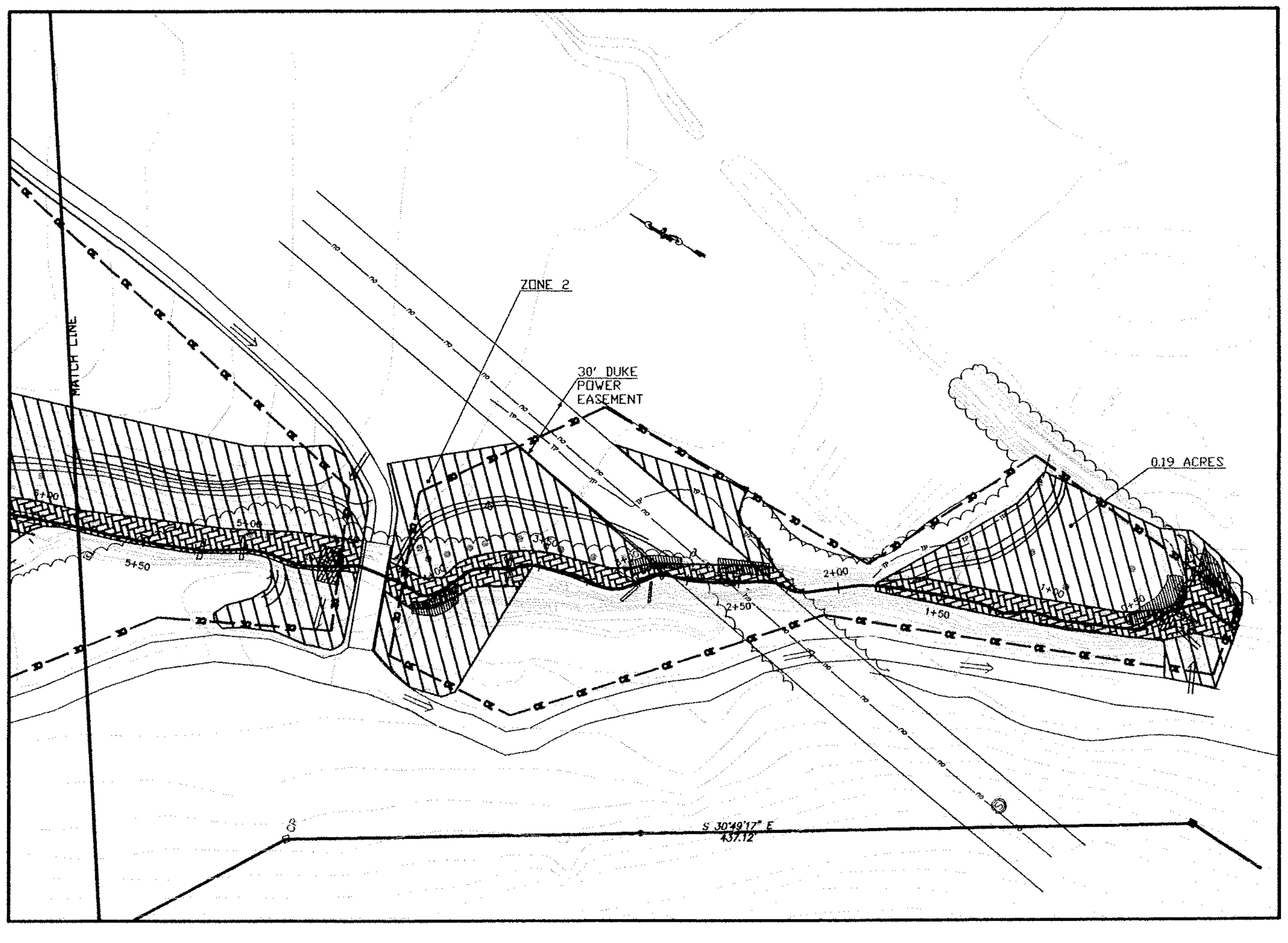
SEAL

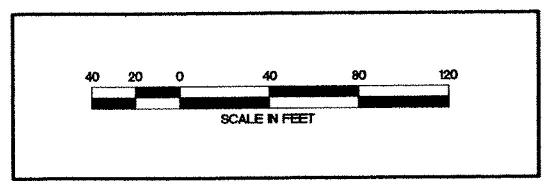
CHAPEL CREEK ENHANCEMENT CROSS SECTIONS

PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006
REVISIONS:
PROJECT NAME: CHAPEL CREEK
DWG NAME: CROSS SECTIONS
SCALE: HORIZONTAL – 1"=40'
VERTICAL – 1"=20'
SHEET NO.
6 OF 10







PLANTING PLAN LEGEND

- ZONE 1 DEPRESSIONAL AREA
- ZONE 2 RIPARIAN AREA
- ZONE 3 STREAM BANK
- PROPOSED 1' CONTOUR
- EXISTING 1' CONTOUR
- EXISTING 5' CONTOUR
- EXISTING TREE
- EXISTING TREE TO BE REMOVED
- PLANT COMMUNITY BORDER
- CONSERVATION EASEMENT

Planting Density = approx. 640 stems/acre

Planting Zone 1(DEPRESSIONAL AREA) – 0.14 acre — Total = 100 Stems

Quantity	Taxonomic Name	Common Name	Size/Height	Type
5	Cephalanthus occidentialis	Buttonbush	18" – 42"	seedling
15	Hibiscus moscheutus	Swamp Marshmallow	18" – 42"	seedling
10	Rosa palustris	Swamp Rose	18" – 42"	seedling
15	Viburnum cassinoides	Southern Wild Raisin	18" – 42"	seedling
10	Xanthorhiza simplicissima	Yellowroot	18" – 42"	seedling
5	Alnus serrulata	Tag Alder	18" – 42"	seedling
5	Cornus ammomum	Silky Dogwood	18" – 42"	seedling
15	Rhododendron viscosum	Swamp Azalea	18" – 42"	seedling
10	Staphlea trifolia	Bladdernut	18" – 42"	seedling
10	Stewartia malacodendron	Silky Camelia	18" – 42"	seedling

Planting Zone 2 (Riparian Buffer) – 3.2 acres — Total = 2050 stems

Quantity	Taxonomic Name	Common Name	Size/Height	Type
307	Platanus occidentalis	Sycamore	18" – 42"	seedling
307	Fraxinus pennsylvanica	Green Ash	18" – 42"	seedling
308	Carpinus caroliniana	Ironwood	18" – 42"	seedling
308	Lindera benzoin	Spicebush	18" – 42"	seedling
205	Viburnum dentatum	Arrowwood	18" – 42"	seedling
205	Calycanthus floridus	Sweet Shrub	18" – 42"	seedling
205	Ilex decidua	Deciduoud Holly	18" – 42"	seedling
205	Celtis laevigata	Hackberry	18" – 42"	seedling

Planting Zone 3 (Stream Bank)– 2600 linear ft. — Total = 1440 Stems

Quantity	Taxonomic Name	Common Name	Size/Height	Type
216	Amelanchier arborea	Downy Serviceberry	12" – 24"	rooted plant plug
144	Alnus serrulata	Tag Alder	12" – 24"	rooted plant plug
216	Vaccinium corymbosum	Highbush Blackberry	12" – 24"	rooted plant plug
288	Cephalanthus occidentialis	Buttonbush	12" – 24"	rooted plant plug
144	Sambucus canadensis	Elderberry	12" – 24"	rooted plant plug
144	Cornus ammomum	Silky Dogwood	12" – 24"	rooted plant plug
144	Corylus americana	Hazelnut	12" – 24"	rooted plant plug
144	Xanthorhiza simplicissima	Yellowroot	12" – 24"	rooted plant plug

NOTES:

1. SUMMARY OF PLANT QUANTITIES CHART SIZE REFERS TO THE SIZE OF THE PLANTS AT INSTALLATION.
2. THE SPACING OF THE PLANTS SHALL BE 3' ON CENTER FOR SMALL PLANTS, WETLAND FORBES, AND ON STREAM BANK ZONE 3. FOR TREES AND SHRUBS SPACING SHALL BE 6' ALONG ROWS WITH 10' ROW SPACING FOR TREES AND SHRUBS. PLANTING DENSITY IS TO BE 625 PLANTS/ACRE. PLANTS WILL BE KEPT SHADED AND WELL WATERED TO MAINTAIN HEALTHY, VIGOROUS CONDITION PRIOR TO PLANTING.
3. PERMANENT SEED MIX DESCRIBED IN THE SPECIFICATIONS. SPECIAL RIPARIAN AND WETLAND MIX REQUIRES ADVANCE PRE-ORDER AND SHIPMENT.
4. PRIOR TO THE INSTALLATION OF PLANT MATERIAL, THE CONTRACTOR SHALL ACCURATELY LOCATE ALL EXISTING UNDERGROUND UTILITIES. THE CONTRACTOR SHALL IMMEDIATELY NOTIFY THE ENGINEER OF ANY CONFLICT WITH UTILITIES PRIOR TO PLANTING.
5. THE LANDSCAPE CONTRACTOR SHALL COORDINATE HIS WORK WITH ALL OTHER TRADES ON THE SITE, ANY PLANTING AREAS DISTURBED AS A RESULT OF CONSTRUCTION ACTIVITY SHALL BE REPAIRED/REPLACED BY THE LANDSCAPE CONTRACTOR AT NO ADDITIONAL EXPENSE TO THE OWNER.
6. ALL PLANT MATERIAL SHALL CONFORM TO OR EXCEED THE AMERICAN STANDARD FOR NURSERY STOCK (LATEST EDITION) AS PUBLISHED BY THE AMERICAN ASSOCIATION OF NURSERYMEN.
7. EXISTING TOPO AT 1' CONTOUR INTERVALS.

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-5359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration
Enhancement and Preservation
Orange County, North Carolina

Ecosystem Enhancement PROGRAM

SEAL

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 13344 BECKY LYNNE WARD

CHAPEL CREEK PLANTING PLAN

PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006

REVISIONS:

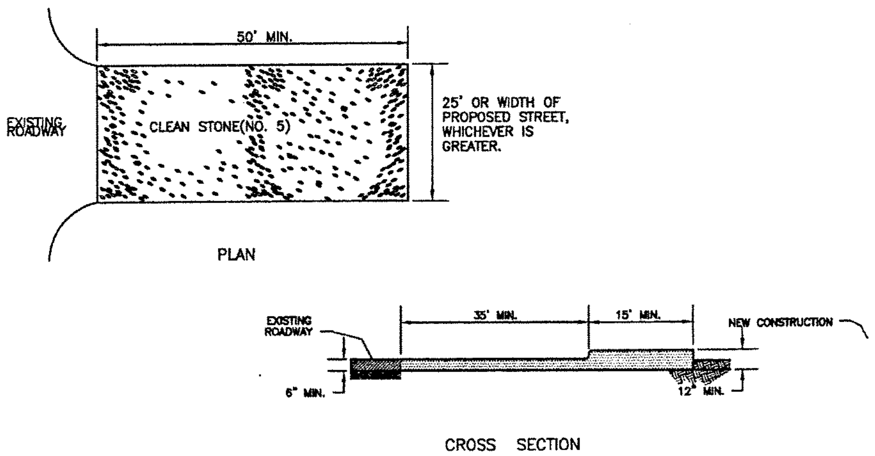
PROJECT NAME: CHAPEL CREEK

DWG NAME: PLANTING PLAN

SCALE: 1" = 80'

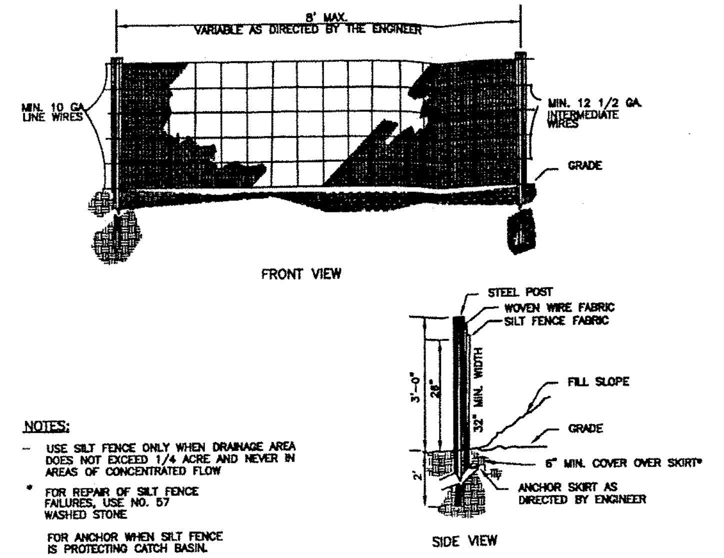
SHEET NO.

7 OF 10



1 CONSTRUCTION ENTRANCE

SCALE: NOT TO SCALE



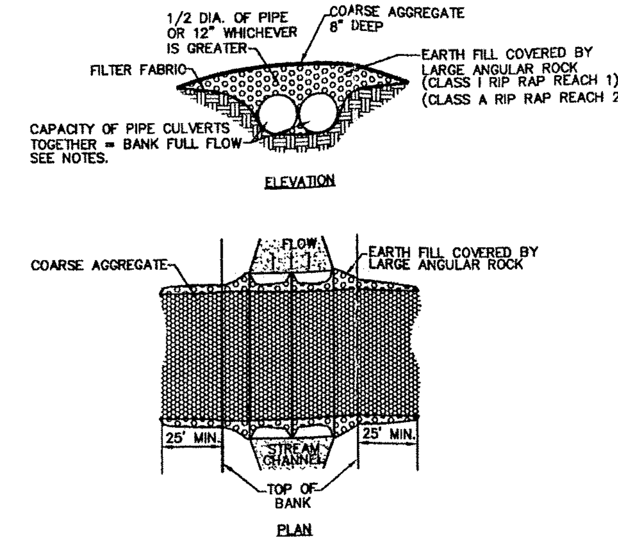
NOTES:

- USE SILT FENCE ONLY WHEN DRAINAGE AREA DOES NOT EXCEED 1/4 ACRE AND NEVER IN AREAS OF CONCENTRATED FLOW
- * FOR REPAIR OF SILT FENCE FAILURES, USE NO. 57 WASHED STONE.

FOR ANCHOR WHEN SILT FENCE IS PROTECTING CATCH BASIN.

2 STANDARD TEMPORARY SILT FENCE

SCALE: NOT TO SCALE



3 TEMPORARY STREAM CROSSING

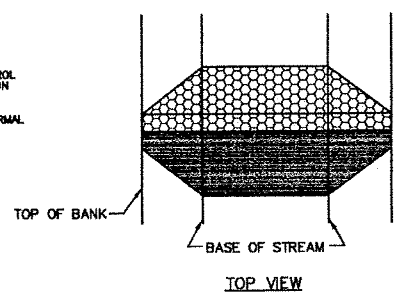
SCALE: NOT TO SCALE

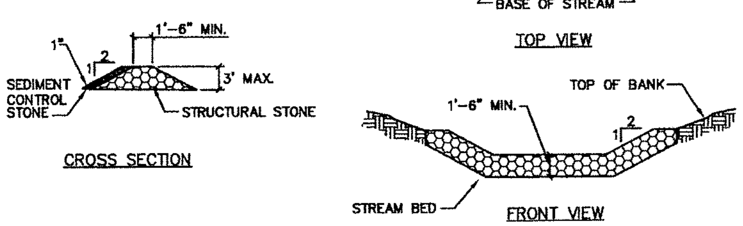
NOTES:

USE CLASS B STONE FOR STRUCTURAL STONE AND PAY FOR AT THE CONTRACT UNIT PRICE PER TON STONE FOR EROSION CONTROL, CLASS B.

USE NO. 5 OR NO. 57 STONE FOR SEDIMENT CONTROL AND PAY FOR AT THE CONTRACT UNIT PRICE PER TON SEDIMENT CONTROL STONE.

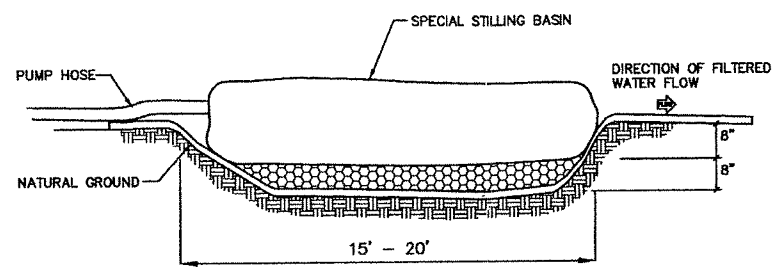
CONSTRUCT DAM A MAXIMUM OF 1 FOOT ABOVE NORMAL FLOW DEPTH.





4 ROCK SILT SCREEN

SCALE: NOT TO SCALE

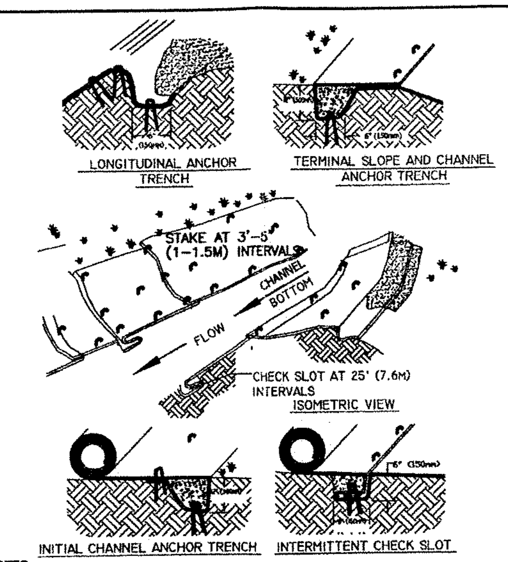


NOTE: PROVIDE STABILIZED OUTLET TO DRAIN TOWARDS STREAM.

NOTE: SPECIAL STILLING BASIN LOCATION TO BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

5 SPECIAL STILLING BASIN WITH ROCK PAD

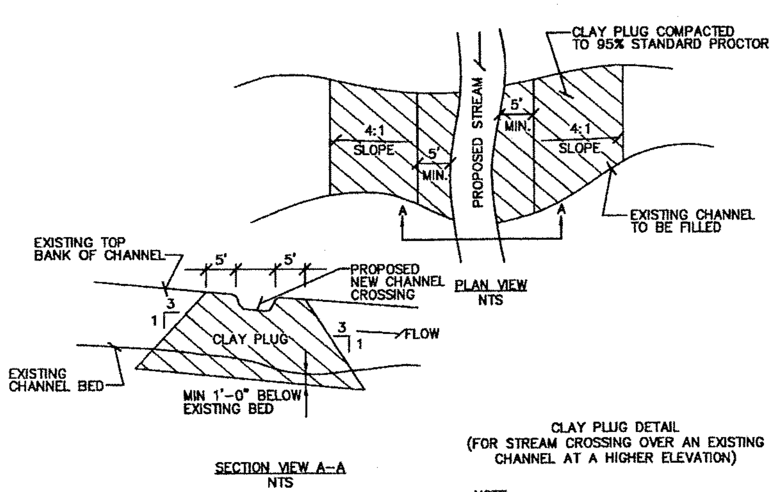
SCALE: NOT TO SCALE



NOTES:
1. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURERS SPECIFICATIONS.
2. STAKING OR STAPLING LAYOUT PER MANUFACTURERS SPECIFICATIONS.

6 COIR MATS - CHANNEL INSTALLATION

SCALE: NOT TO SCALE



CLAY PLUG DETAIL
(FOR STREAM CROSSING OVER AN EXISTING CHANNEL AT A HIGHER ELEVATION)

NOTE:
USE MINIMUM TOP WIDTH OF 10' WHERE CHANNEL IS TO THE SIDE OF THE CLAY PLUG AS SHOWN ON PLANS.

7 CLAY PLUG

SCALE: NOT TO SCALE

POSTS MAY BE EITHER 4" DIA. PINE, 2" DIA. OAK OR 1.33 LB/LF STEEL

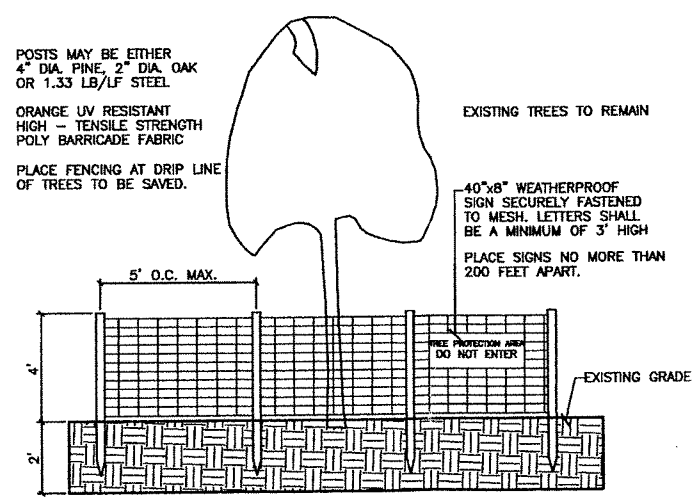
ORANGE UV RESISTANT HIGH – TENSILE STRENGTH POLY BARRICADE FABRIC

PLACE FENCING AT DRIP LINE OF TREES TO BE SAVED.

EXISTING TREES TO REMAIN

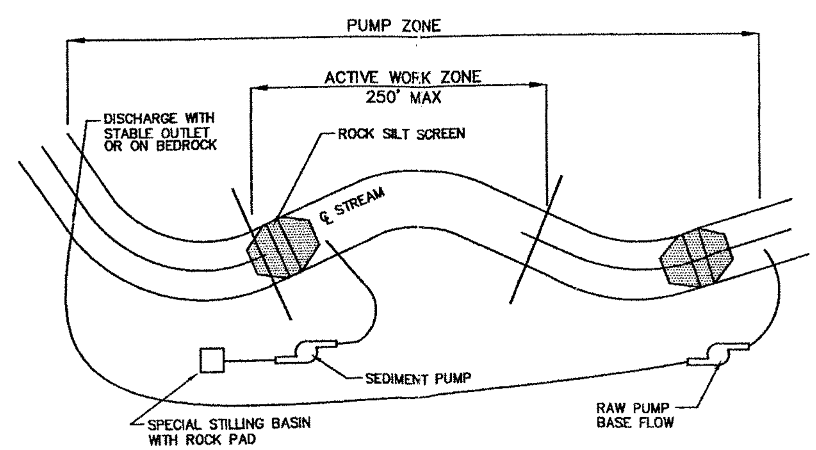
40"x8" WEATHERPROOF SIGN SECURELY FASTENED TO MESH. LETTERS SHALL BE A MINIMUM OF 3" HIGH

PLACE SIGNS NO MORE THAN 200 FEET APART.



8 TREE PROTECTION FENCE

SCALE: NOT TO SCALE



NOTE: WORK AREA TO BE STABILIZED AT THE END OF EACH WORK DAY.

9 TYPICAL PUMP AROUND OPERATION

SCALE: NOT TO SCALE

Ward Consulting Engineers, P.C.
1512 Eglantyne Court
Raleigh, NC 27613
(919) 870-0526
FAX (919) 870-6359

North Carolina – Ecosystem Enhancement Program
Chapel Creek Stream & Buffer Restoration Enhancement and Preservation
Orange County, North Carolina

Ecosystem Enhancement PROGRAM

SEAL:

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 1344 BECKY LYNNE WARD

CHAPEL CREEK DETAILS

PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006

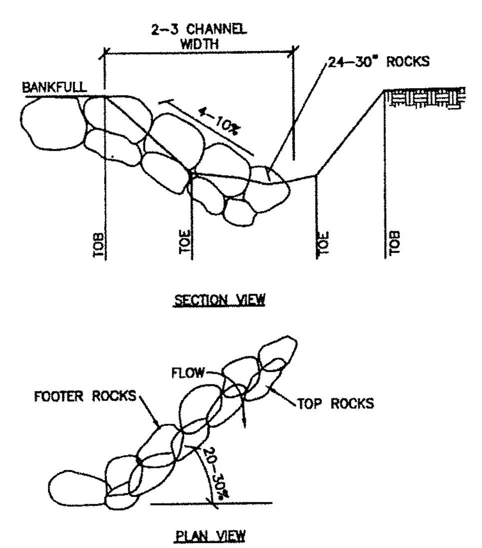
REVISIONS:

PROJECT NAME: CHAPEL CREEK

DWG NAME: DETAILS

SCALE: NTS

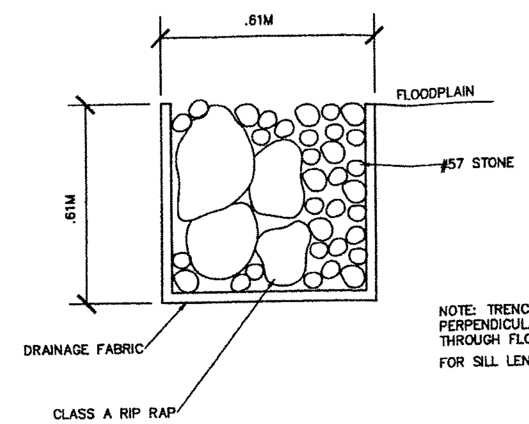
SHEET NO.



NOTES:
1. STRUCTURE SPANS 1/2 TO 2/3 OF STREAM WIDTH APPROXIMATE LENGTH = 12-15%.
2. LINE STRUCTURE UPSTREAM WITH FABRIC AND PACK ROCK VOIDS WITH #57 STONE.
3. STRUCTURES TYPICAL 25' LENGTH APPROXIMATE (20 ROCKS).

1 SINGLE ROCK VANE DETAIL

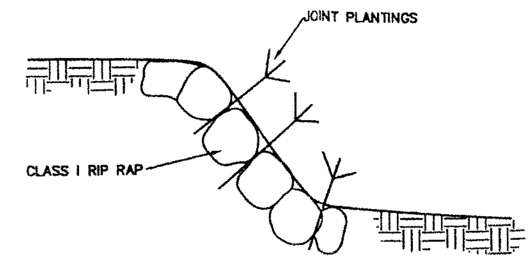
SCALE: NOT TO SCALE



NOTE: TRENCH EXCAVATED PERPENDICULAR TO CHANNEL THROUGH FLOOD PLAIN
FOR SILL LENGTH SEE PLANS.

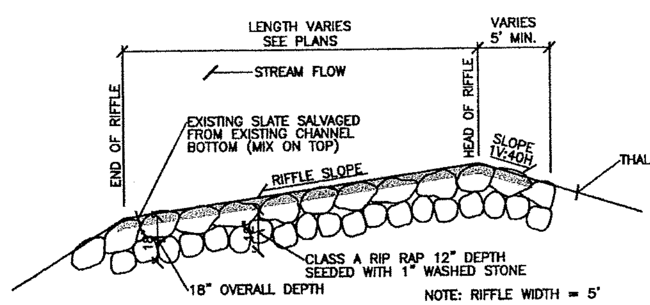
2 CROSS SECTION SILL

SCALE: NOT TO SCALE



3 ROCK JOINT PLANTING

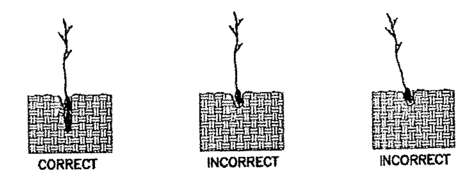
SCALE: NOT TO SCALE



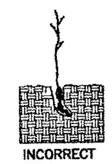
CONSTRUCTED RIFFLE

4 CONSTRUCTED RIFFLE

SCALE: NOT TO SCALE



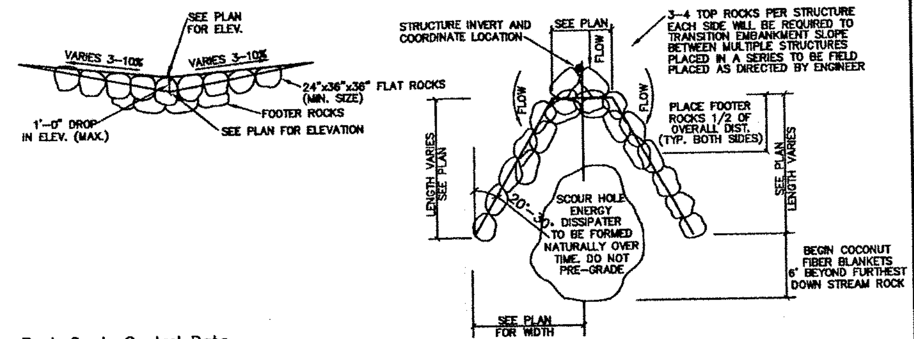
PLANT SEEDLINGS SO THAT ROOT COLLARIS JUST BELOW GROUND SURFACE. MAKE SURE TREES ARE NOT PLANTED TO DEEP OR TO SHALLOW.



ROOTS SHOULD BE STRAIGHT IN THE PLANTING HOLE. THEY SHOULD NOT BE "J" OR "U" SHAPED.

5 SEEDLING PLANTING

SCALE: NOT TO SCALE



Rock Grade Control Data

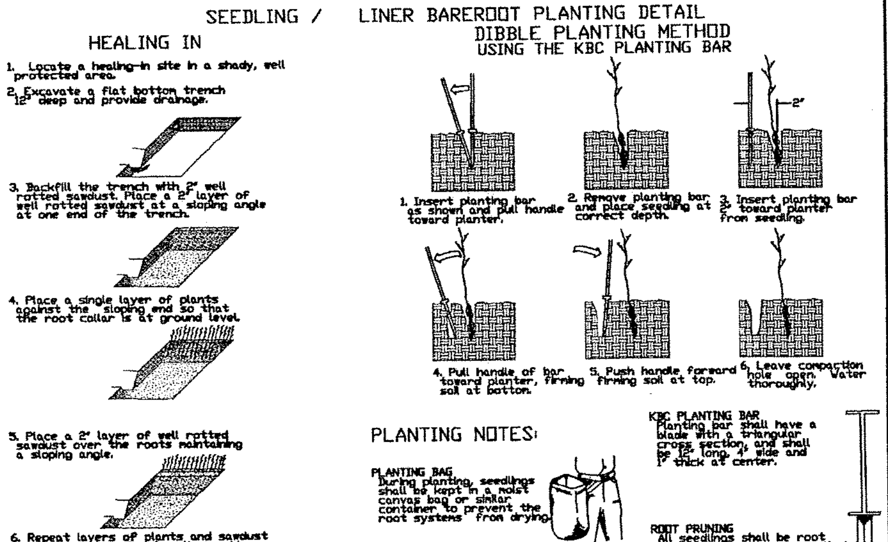
Structure Number	Coordinate		Invert Elevation (ft)	Arm Length (ft)	Arm Slope %	Minimum Boulder Size (ft)	Approx. Number Boulders/Rocks
	Northing	Easting					
#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#

6 TYPICAL ROCK GRADE CONTROL STRUCTURE

SCALE: NOT TO SCALE

PLANTING DETAILS

SEEDLING / LINER BAREROOT PLANTING DETAIL



7 REFORESTATION DETAIL

SCALE: NOT TO SCALE

Ward Consulting Engineers, P.C.

1512 Eglantyne Court
Raleigh, NC 27613

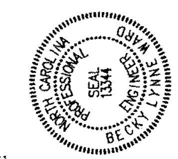
(919) 870-0526
FAX (919) 870-5359

North Carolina - Ecosystem Enhancement Program

Ecosystem Enhancement PROGRAM

Chapel Creek Stream & Buffer Restoration
Enhancement and Preservation
Orange County North Carolina

SEAL:



CHAPEL CREEK DETAILS

PRELIMINARY NOT FOR CONSTRUCTION

DATE: 10 JULY 2006

REVISIONS:

PROJECT NAME: CHAPEL CREEK

DWG NAME: DETAILS

SCALE: NTS

SHEET NO.

10 OF 10

11.0 Appendices

Appendix 1. Restoration Site Photographs

Appendix 1: Restoration Site Photographs

Chapel Creek in northern part of abandoned fairway section

Chapel Creek in southern portion of abandoned fairway section

Chapel Creek upstream of bridge #1

Chapel Creek lower section below abandoned fairway

Appendix 2. Restoration Site NCDWQ Stream Classification Forms

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

Date: 1-11-06	Chapel Crk		**Latitude:**
Evaluator: Kate Montieth	**Site:** Chapel Crk		**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30* 41.5	**County:** Orange		**Other** *e.g. Quad Name:*

A. Geomorphology (Subtotal = 21)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	F 1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural Levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley and drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

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

B. Hydrology (Subtotal = 9.5)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel -- dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 11)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	0.5	1	1.5
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

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

Sketch:

Appendix 3. Reference Site Photographs

Appendix 3: Reference Site Photograph

UT to Cabin Branch Reference Reach

Appendix 4. Reference Site NCDWQ Stream Classification Forms

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

Date: 1-11-06	**Project:** Chapel Creek	**Latitude:**
Evaluator: Chris Sheats	**Site:** Cabin Branch UT	**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30* 47	**County:** Durham	**Other** *e.g. Quad Name:*

A. Geomorphology (Subtotal = 25)	**Absent**	**Weak**	**Moderate**	**Strong**
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural Levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley and drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

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

B. Hydrology (Subtotal = 10.5)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, or Water in channel – dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = 11.5)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
a. Macrobenthos (note diversity and abundance)	0	0.6	1	1.5
27. Filamentous algae; periphyton	0	0.5	1	1.5
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

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

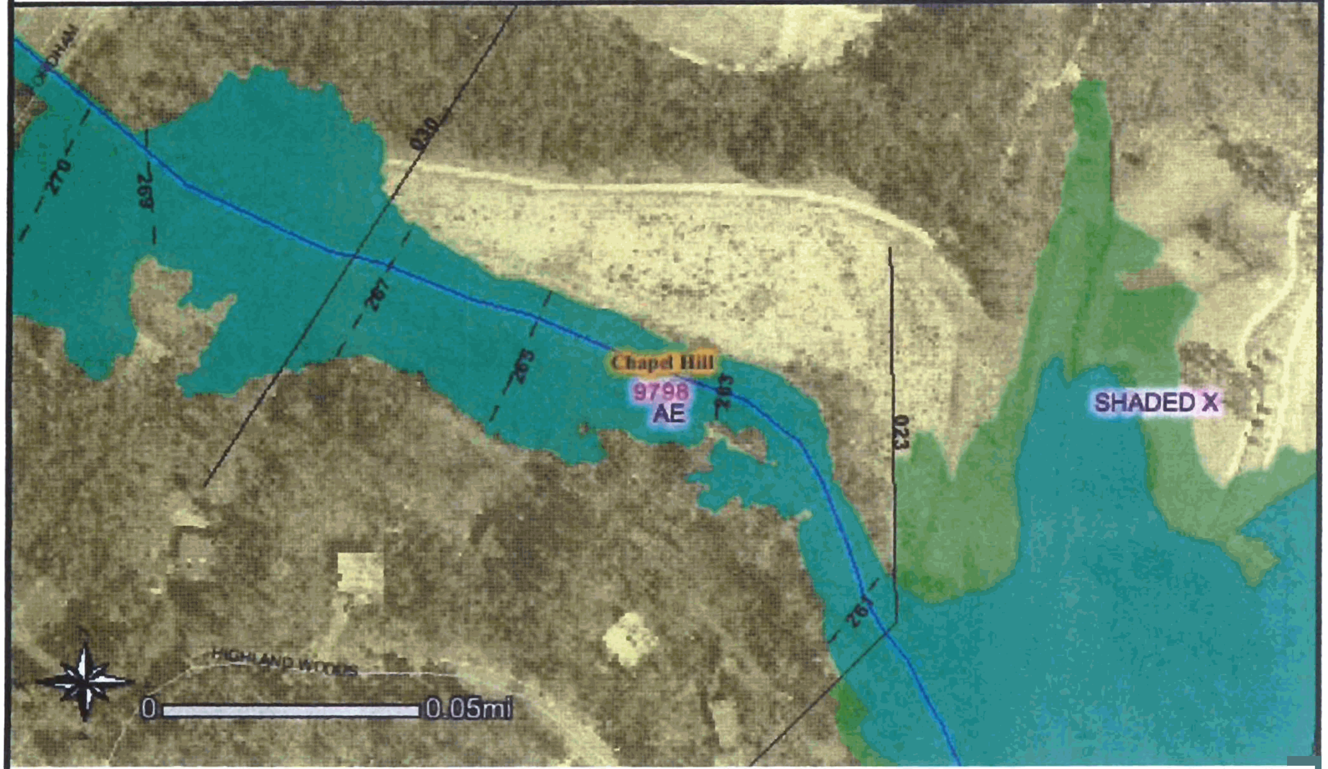
Notes: (use back side of this form for additional notes.)

Sketch:

Appendix 5. HEC-RAS Analysis

Chapel Creek Floodplain

Mon Jan 30 15:09:46 EST 2006



Legend

- DFIRM GRID
- DFIRM Available
- Elevation Data Grid
- Annotation Points
- DFIRM Label Leader Lines
- Base Flood Elevation (Symbol)
- Cross Sections
- Printed on DFIRM
- NHS Interstates
- NC Secondary Roads
- Railroads
- Roads
- Rivers and Streams
- Flood Hazard
- 100yr Flooding - No BFE's (A)
- 100yr Flood - Velocity Zone (V or VE)
- 100yr Shallow Flooding (AO or AH)
- 500yr Flooding (X or Shaded X)
- 100yr Flooding - Has BFE's (AE)
- 100yr FloodWay (AEFW)
- Municipal Boundary
- Sounds
- Water
- County Boundaries
- Aerial Photography

North Carolina Cooperating Technical State

FEMA'S COOPERATING TECHNICAL PARTNER

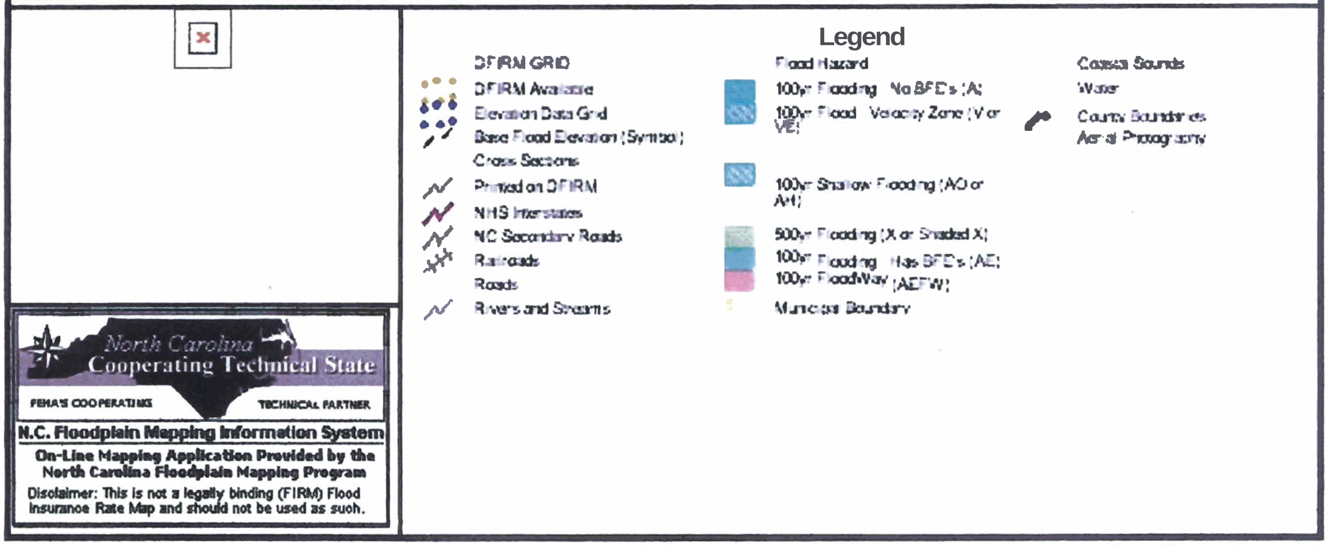
N.C. Floodplain Mapping Information System

On-Line Mapping Application Provided by the North Carolina Floodplain Mapping Program

Disclaimer: This is not a legally binding (FIRM) Flood Insurance Rate Map and should not be used as such.

Chapel Creek FEMA Floodplain

Mon Jan 30 15:06:06 EST 2006



HEC-RAS Plan: Postproj River: Chapel Creek Reach: Reach - 1

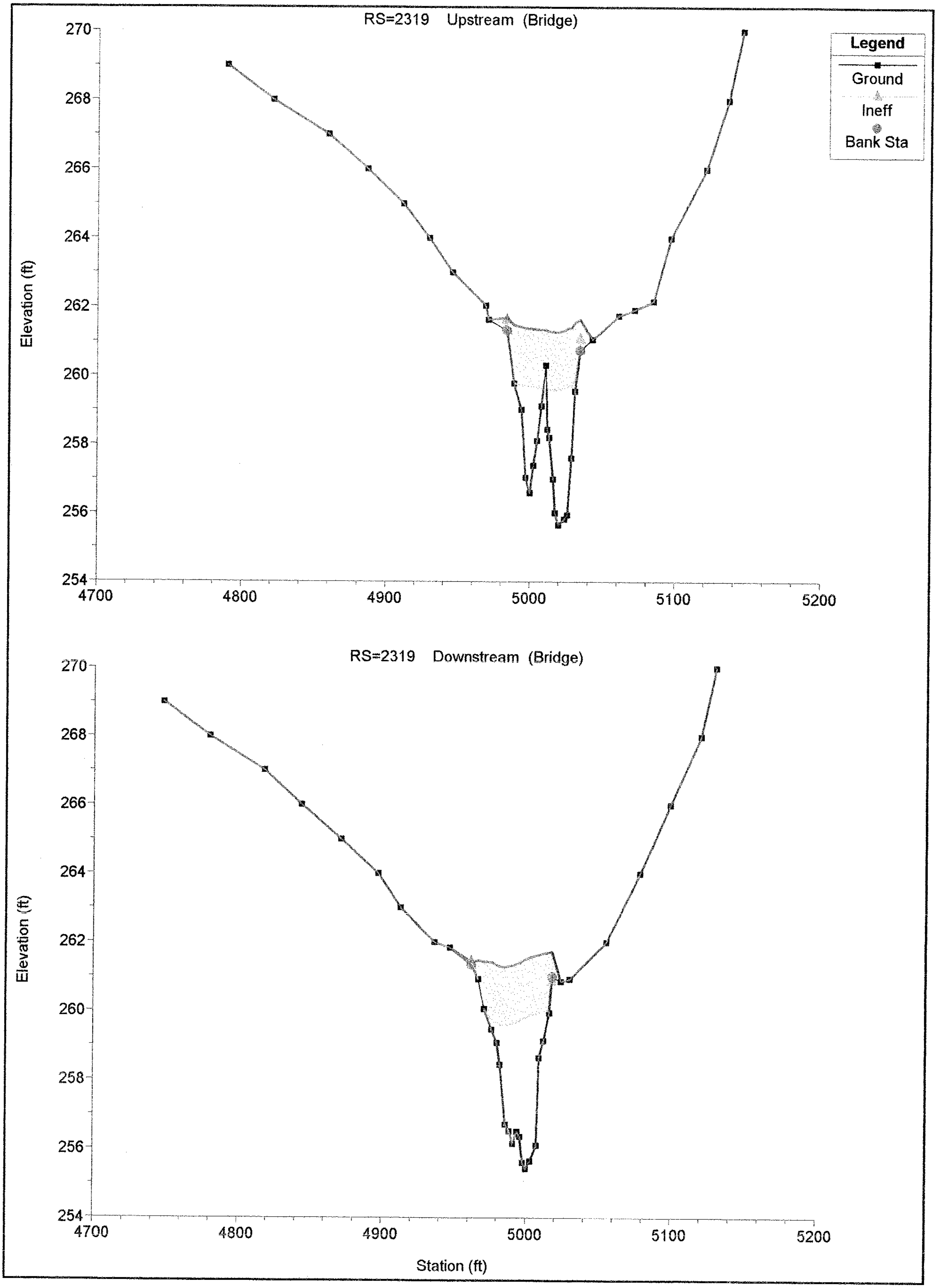
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach - 1	7543.5	100-Year	141.00	414.61	418.40	418.40	418.68	0.016496	5.87	80.02	136.15	0.54
Reach - 1	7543.5	100-yr FW	141.00	414.61	418.68	418.68	419.47	0.028309	8.08	30.39	19.83	0.72
Reach - 1	6962.0	100-Year	141.00	383.33	387.35	387.35	387.81	0.020540	6.82	50.31	55.31	0.61
Reach - 1	6962.0	100-yr FW	141.00	383.33	387.50	387.50	388.54	0.032798	8.84	24.25	13.60	0.78
Reach - 1	6479.3	100-Year	141.00	341.47	345.87	345.87	346.74	0.032976	8.18	28.79	21.68	0.70
Reach - 1	6479.3	100-yr FW	141.00	341.47	345.89	345.89	346.72	0.031588	8.03	29.14	20.00	0.69
Reach - 1	6219.4	100-Year	141.00	322.94	336.47	325.29	336.48	0.000033	0.87	249.73	103.62	0.04
Reach - 1	6219.4	100-yr FW	141.00	322.94	336.46	325.29	336.48	0.000043	0.99	216.80	20.00	0.05
Reach - 1	6179.4		Culvert									
Reach - 1	6139.4	100-Year	141.00	319.31	321.64	321.64	322.64	0.033609	8.00	17.63	9.11	1.01
Reach - 1	6139.4	100-yr FW	141.00	319.31	321.66	321.66	322.64	0.032732	7.92	17.80	9.14	1.00
Reach - 1	5936.1	100-Year	141.00	305.08	309.47	309.47	310.16	0.028449	7.58	36.06	32.02	0.65
Reach - 1	5936.1	100-yr FW	141.00	305.08	309.47	309.47	310.14	0.027749	7.49	35.58	28.00	0.64
Reach - 1	5463.2	100-Year	278.00	292.87	298.00	297.45	298.18	0.012277	5.55	141.16	93.96	0.44
Reach - 1	5463.2	100-yr FW	278.00	292.87	298.50	297.61	298.80	0.013671	6.25	96.18	35.00	0.47
Reach - 1	4991.7	100-Year	390.00	282.94	289.69		290.32	0.021203	8.81	144.38	159.65	0.61
Reach - 1	4991.7	100-yr FW	390.00	282.94	289.71	289.71	290.39	0.021891	8.97	116.18	70.00	0.62
Reach - 1	4581.9	100-Year	390.00	277.95	284.95		285.14	0.008001	5.55	180.09	82.46	0.37
Reach - 1	4581.9	100-yr FW	390.00	277.95	285.81		285.98	0.005492	4.98	156.79	35.00	0.32
Reach - 1	4067.5	100-Year	390.00	271.57	278.20	278.20	278.80	0.021109	8.68	122.63	89.57	0.60
Reach - 1	4067.5	100-yr FW	390.00	271.57	278.32	278.32	279.88	0.038684	11.90	56.79	18.00	0.82
Reach - 1	3590.6	100-Year	390.00	265.11	276.91	269.26	276.95	0.000184	1.97	340.11	611.40	0.11
Reach - 1	3590.6	100-yr FW	390.00	265.11	276.90	269.26	276.96	0.000217	2.14	339.89	40.00	0.11
Reach - 1	3493.6		Culvert									
Reach - 1	3396.6	100-Year	390.00	268.50	274.80	272.34	275.37	0.003426	6.20	70.02	314.42	0.45

HEC-RAS Plan: Postproj River: Chapel Creek Reach: Reach - 1 (Continued)

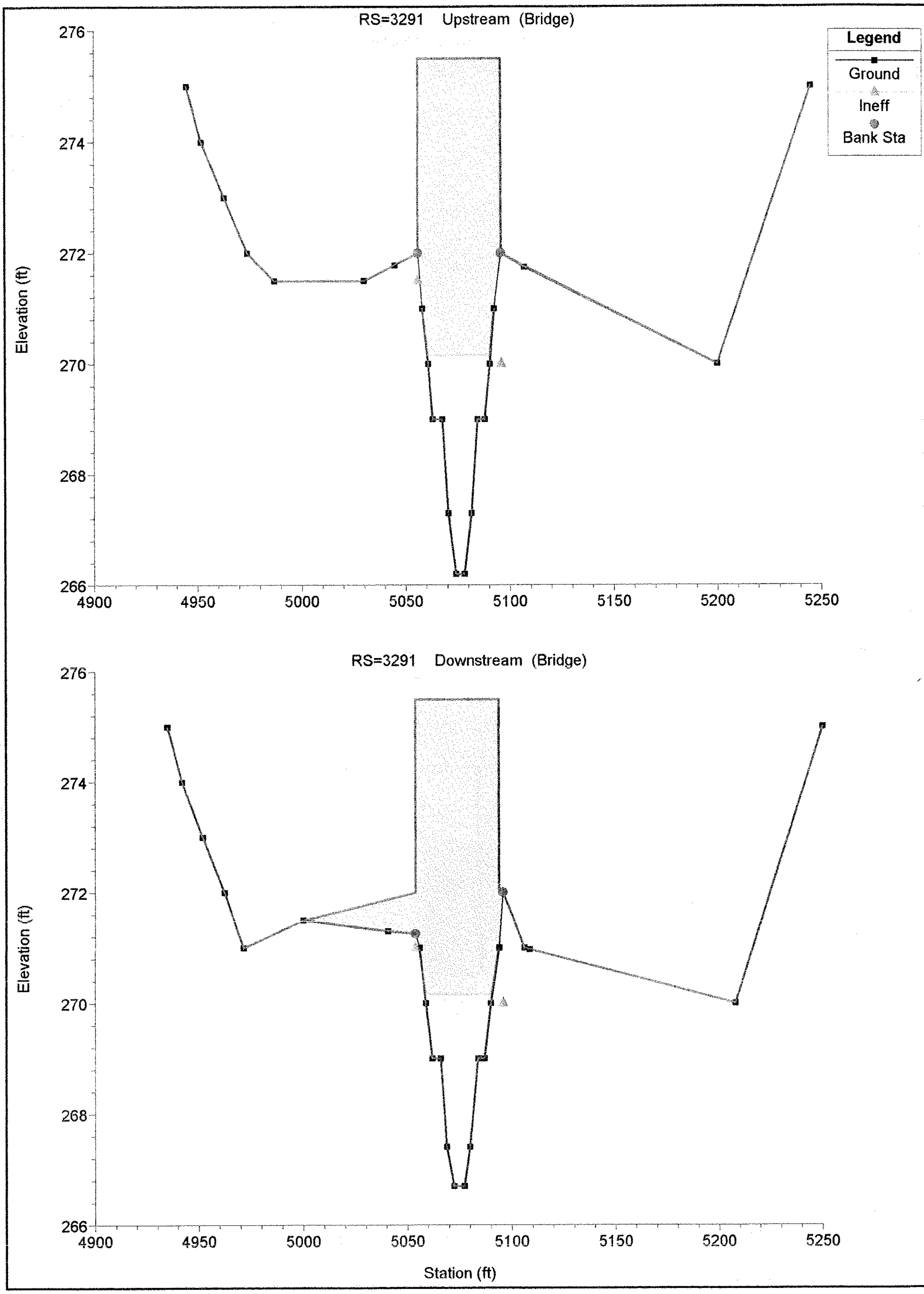
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach - 1	3396.6	100-yr FW	390.00	268.50	274.82	272.34	275.38	0.003391	6.18	70.24	40.00	0.45
Reach - 1	3350	100-Year	390.00	268.00	271.63	271.63	272.76	0.020506	8.65	53.06	219.66	0.89
Reach - 1	3350	100-yr FW	390.00	268.00	271.62	271.62	272.76	0.020924	8.71	52.59	31.83	0.90
Reach - 1	3297	100-Year	390.00	266.20	271.20	269.72	271.44	0.004023	3.97	142.91	110.07	0.42
Reach - 1	3297	100-yr FW	390.00	266.20	271.54	269.72	271.73	0.002901	3.52	110.67	37.41	0.36
Reach - 1	3291		Bridge									
Reach - 1	3285	100-Year	390.00	266.70	270.42	269.85	270.90	0.011233	5.55	79.99	80.27	0.68
Reach - 1	3285	100-yr FW	390.00	266.70	270.75	269.86	271.10	0.007356	4.76	81.98	36.26	0.56
Reach - 1	3242	100-Year	390.00	266.00	269.65	269.65	270.32	0.012902	7.11	97.51	135.61	0.75
Reach - 1	3242	100-yr FW	390.00	266.00	269.57	269.56	270.48	0.016664	7.93	68.01	50.00	0.85
Reach - 1	3212	100-Year	390.00	265.80	268.92		269.52	0.015663	7.14	110.94	160.65	0.81
Reach - 1	3212	100-yr FW	390.00	265.80	269.08	269.08	269.94	0.017653	7.91	73.62	50.00	0.87
Reach - 1	3192	100-Year	390.00	265.00	268.62	268.62	269.24	0.012293	6.91	108.36	182.08	0.73
Reach - 1	3192	100-yr FW	390.00	265.00	268.62		269.46	0.015078	7.65	71.18	50.00	0.81
Reach - 1	3135	100-Year	390.00	263.40	267.77		268.05	0.006336	5.21	177.96	193.24	0.53
Reach - 1	3135	100-yr FW	390.00	263.40	268.55		268.88	0.004463	5.09	127.39	50.00	0.46
Reach - 1	3043.1	100-Year	567.00	263.00	267.04		267.39	0.007827	6.11	263.89	228.40	0.60
Reach - 1	3043.1	100-yr FW	567.00	263.00	267.19		268.09	0.013453	8.26	108.36	50.00	0.79
Reach - 1	2933	100-Year	567.00	260.50	265.60		266.30	0.011843	7.68	156.70	117.09	0.73
Reach - 1	2933	100-yr FW	567.00	260.50	265.85		266.69	0.011722	8.00	112.29	50.00	0.73
Reach - 1	2728	100-Year	567.00	258.20	263.44		264.07	0.009867	7.28	159.54	102.93	0.67
Reach - 1	2728	100-yr FW	567.00	258.20	263.51		264.32	0.011340	7.90	115.00	50.00	0.72
Reach - 1	2480	100-Year	567.00	256.60	262.18		262.58	0.003769	5.60	199.29	137.84	0.45
Reach - 1	2480	100-yr FW	567.00	256.60	262.46		262.83	0.003219	5.37	169.40	50.00	0.42
Reach - 1	2380	100-Year	567.00	255.48	260.78	260.78	261.82	0.016753	8.92	100.40	59.21	0.82

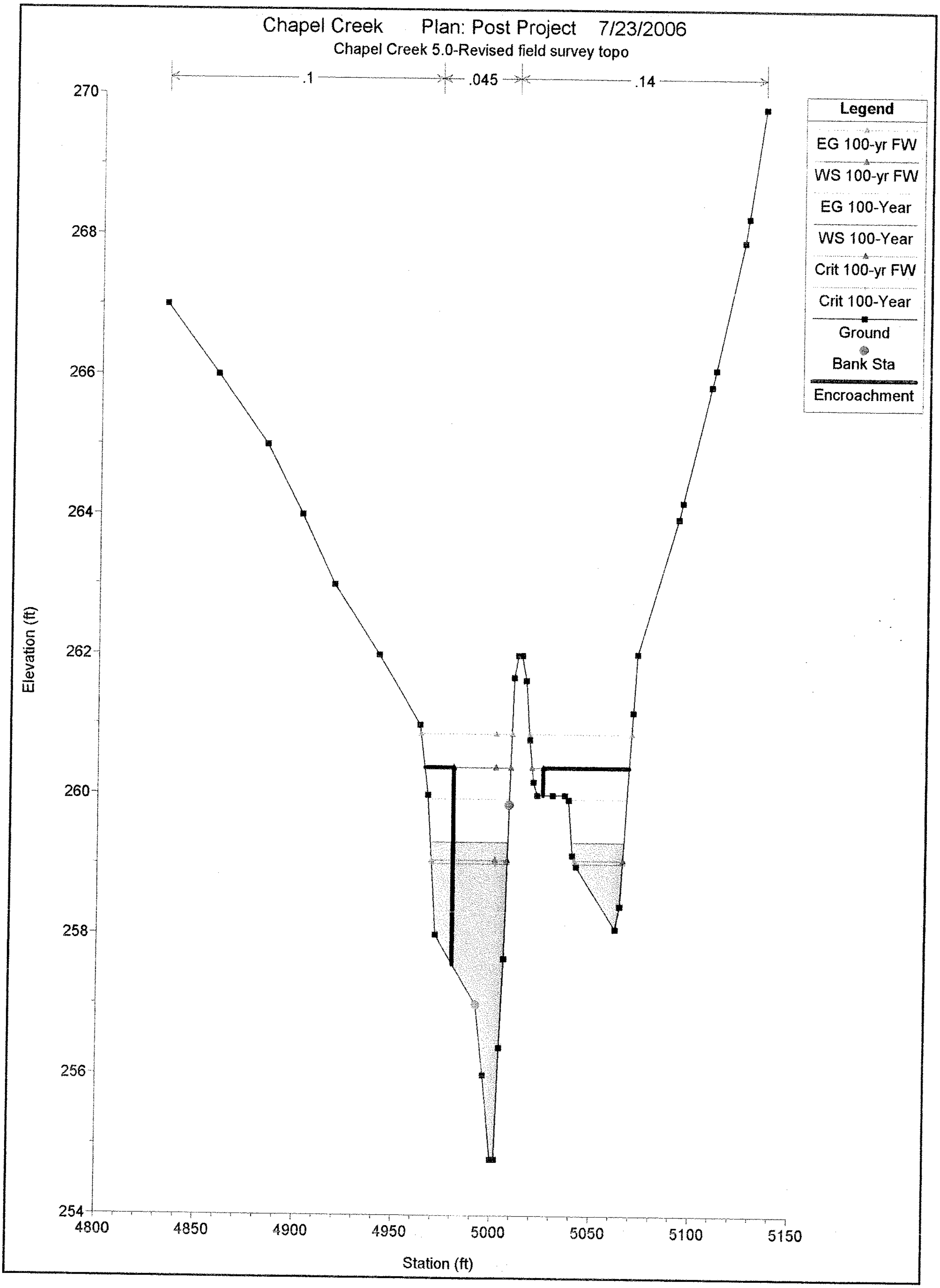
HEC-RAS Plan: Postproj River: Chapel Creek Reach: Reach - 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach - 1	2380	100-yr FW	567.00	255.48	261.69		262.33	0.007848	6.99	128.00	50.00	0.58
Reach - 1	2326	100-Year	567.00	255.66	260.47	259.29	260.82	0.006665	4.72	120.05	47.30	0.52
Reach - 1	2326	100-yr FW	567.00	255.66	261.76	259.29	261.91	0.001755	3.10	183.91	50.00	0.28
Reach - 1	2319		Bridge									
Reach - 1	2312	100-Year	567.00	255.42	259.77	258.81	260.27	0.009817	5.66	100.24	41.81	0.64
Reach - 1	2312	100-yr FW	567.00	255.42	260.85	258.81	261.07	0.003201	3.77	150.45	49.73	0.38
Reach - 1	2282.3	100-Year	567.00	254.80	259.32	259.02	259.93	0.011319	7.02	108.92	65.61	0.69
Reach - 1	2282.3	100-yr FW	567.00	254.80	260.39	259.06	260.87	0.005770	5.94	105.51	34.25	0.51

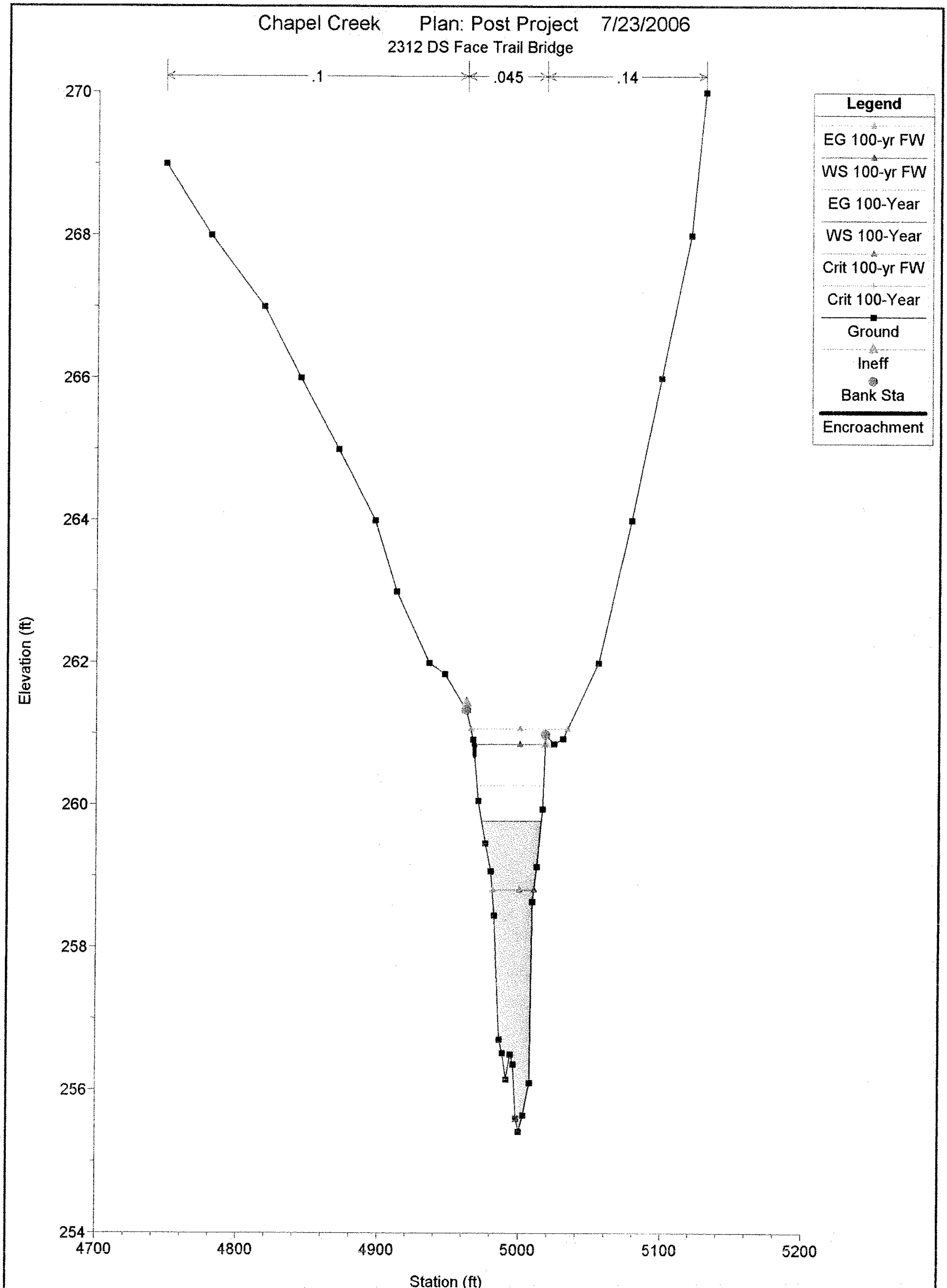


RS=2319 Upstream (Bridge)
Legend
Ground
Ineff
Bank Sta
Elevation (ft)
270
268
266
264
262
260
258
256
254
4700
4800
4900
5000
5100
5200
RS=2319 Downstream (Bridge)
Elevation (ft)
270
268
266
264
262
260
258
256
254
4700
4800
4900
5000
5100
5200
Station (ft)

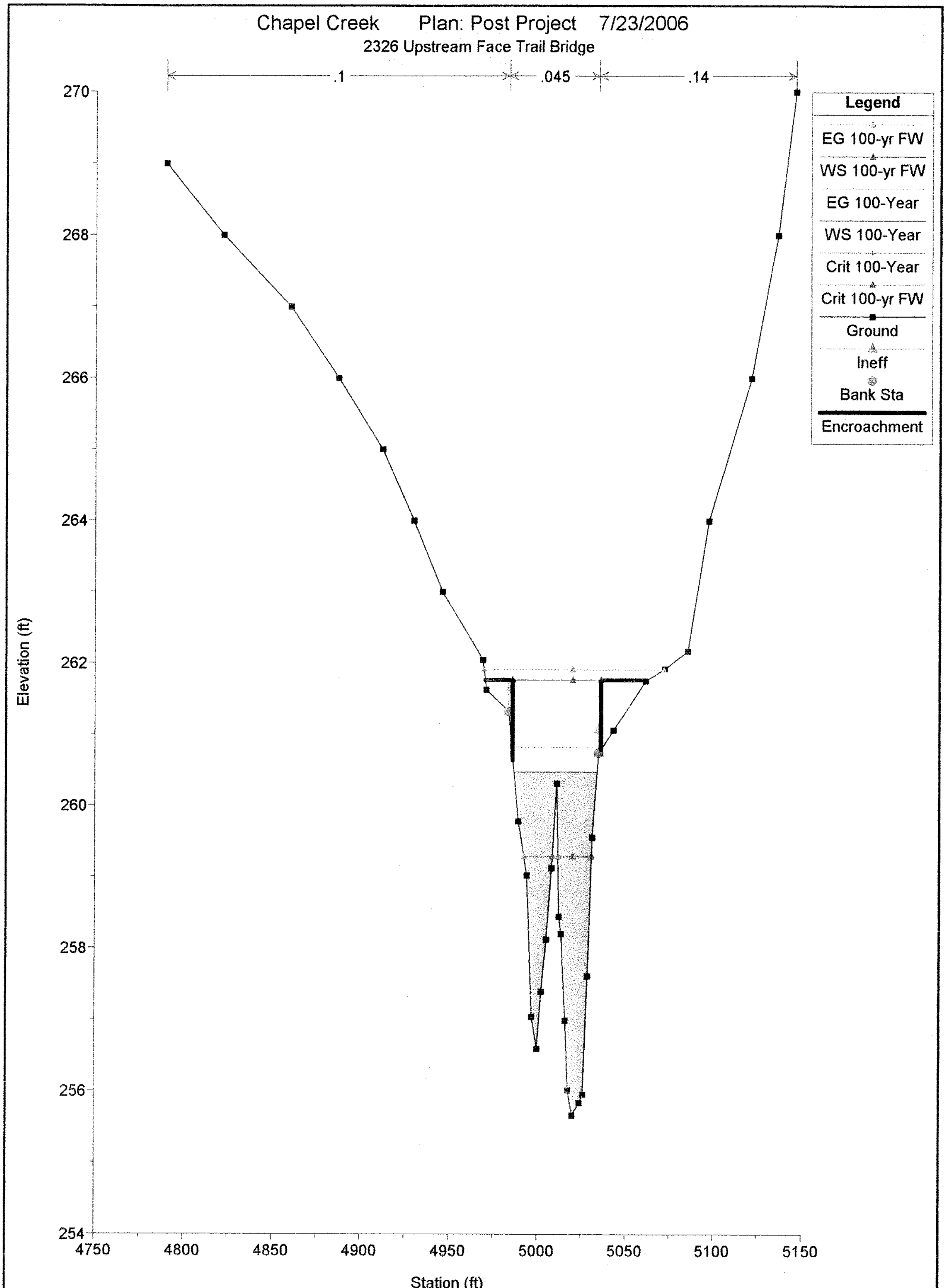

RS=3291 Upstream (Bridge)
Legend
Ground
Ineff
Bank Sta
Elevation (ft)
276
274
272
270
268
266
4900
4950
5000
5050
5100
5150
5200
5250
RS=3291 Downstream (Bridge)
Elevation (ft)
276
274
272
270
268
266
4900
4950
5000
5050
5100
5150
5200
5250
Station (ft)

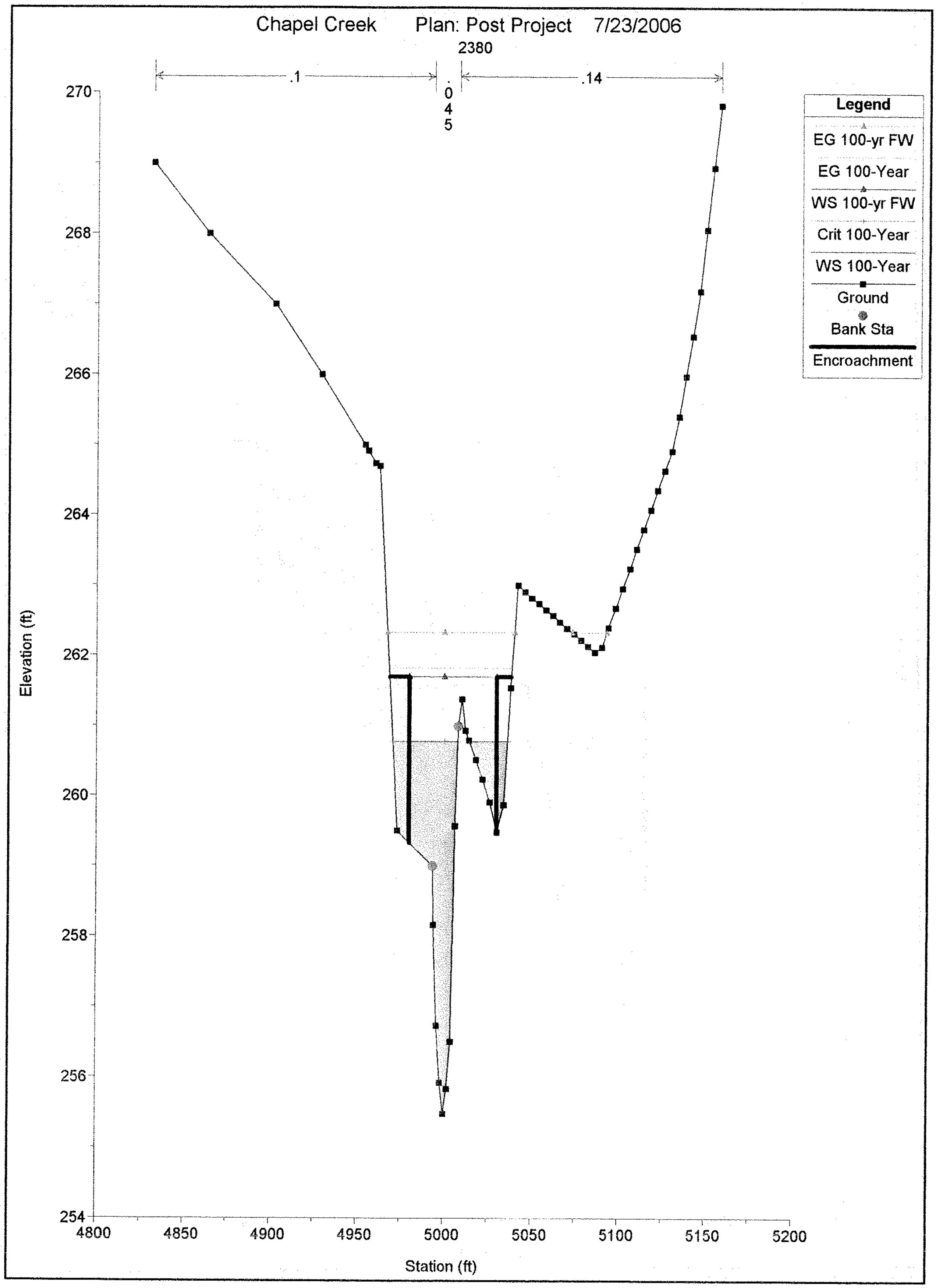


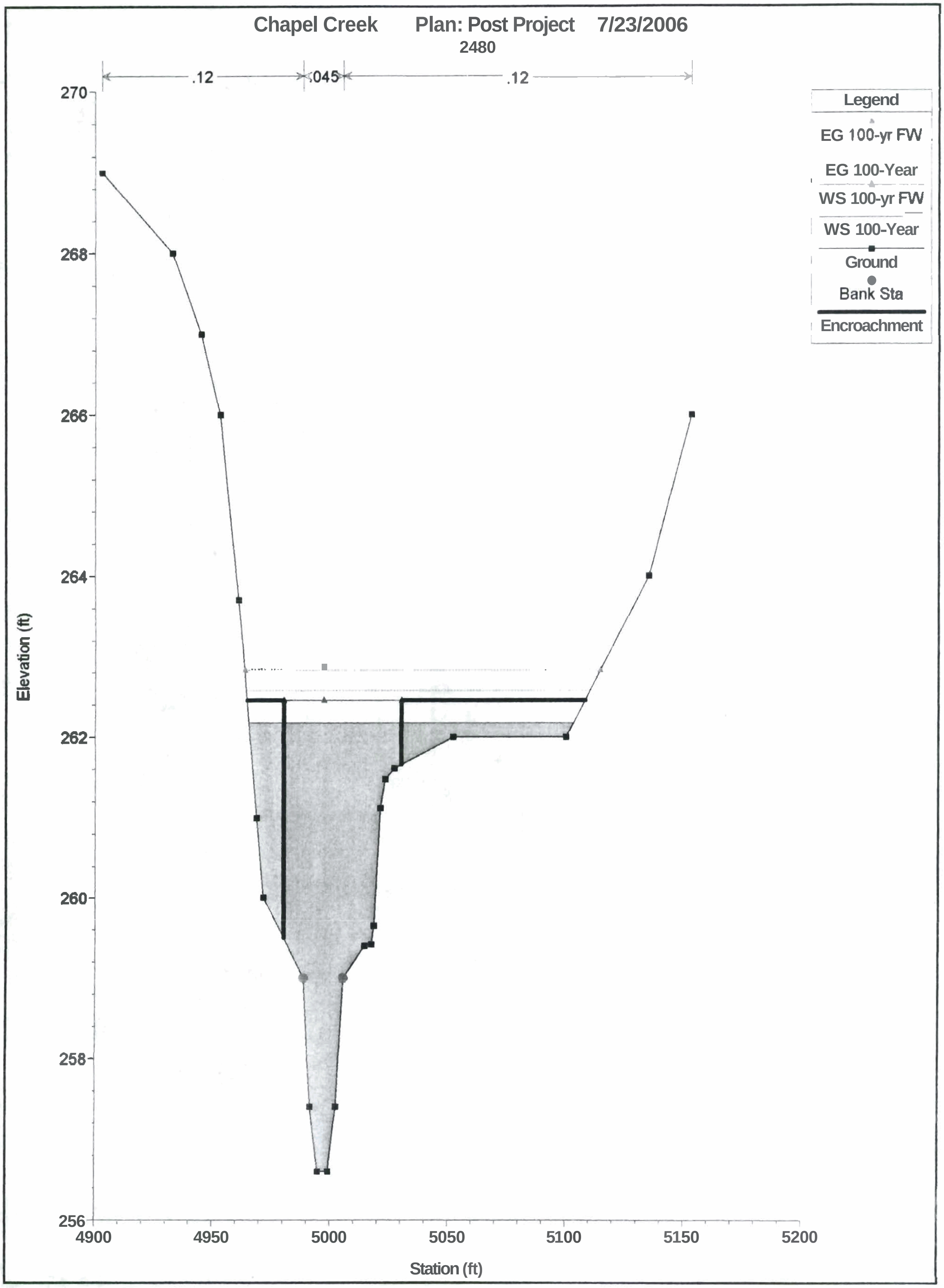
Chapel Creek Plan: Post Project 7/23/2006
Chapel Creek 5.0-Revised field survey topo
.1
.045
.14
Legend
EG 100-yr FW
WS 100-yr FW
EG 100-Year
WS 100-Year
Crit 100-yr FW
Crit 100-Year
Ground
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
270
268
266
264
262
260
258
256
254
4800
4850
4900
4950
5000
5050
5100
5150



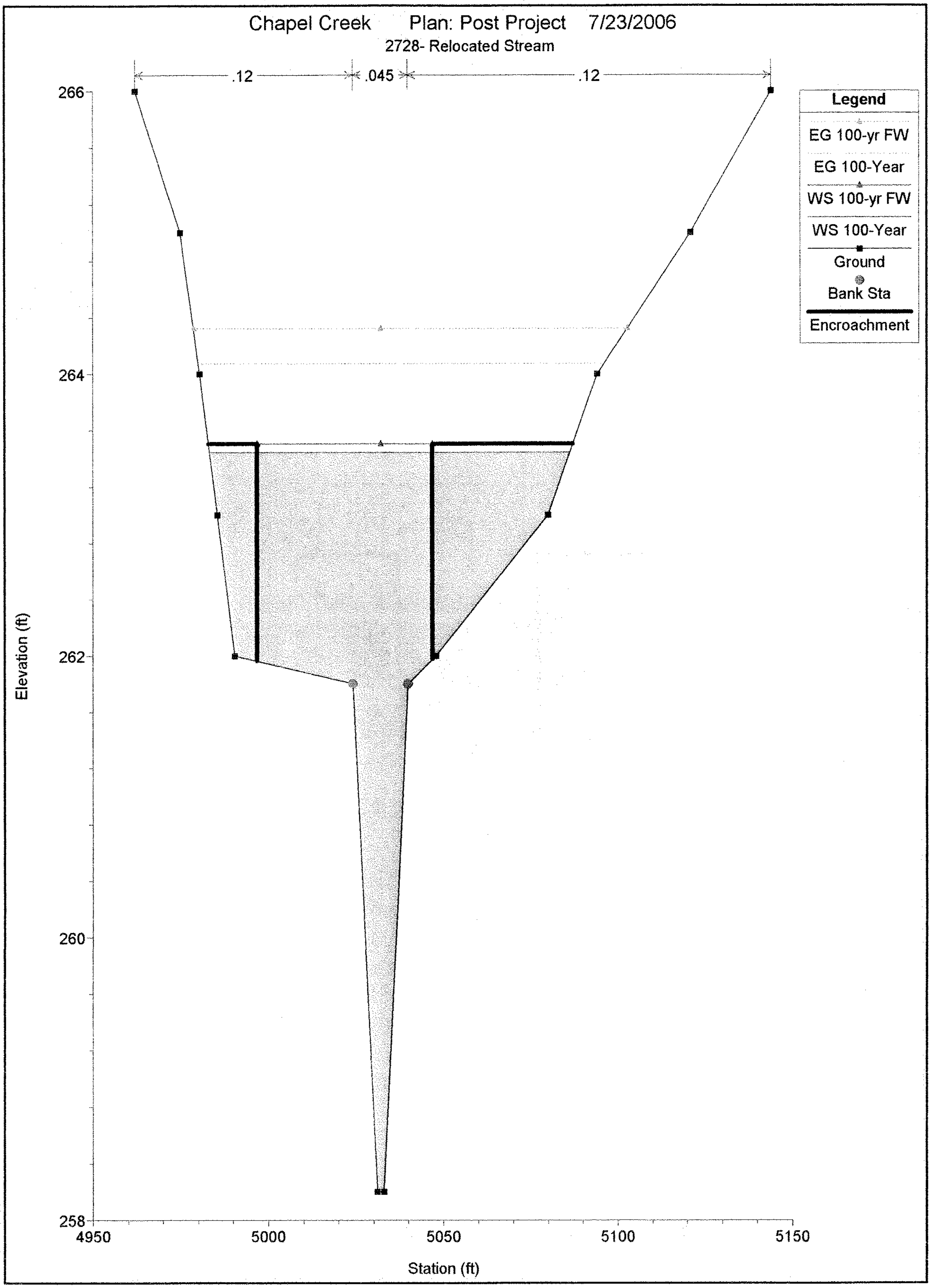
Chapel Creek Plan: Post Project 7/23/2006
2312 DS Face Trail Bridge
.1
.045
.14
Legend
EG 100-yr FW
WS 100-yr FW
EG 100-Year
WS 100-Year
Crit 100-yr FW
Crit 100-Year
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
270
268
266
264
262
260
258
256
254
Station (ft)
4700
4800
4900
5000
5100
5200


Chapel Creek Plan: Post Project 7/23/2006
2326 Upstream Face Trail Bridge
.1
.045
.14
Legend
EG 100-yr FW
WS 100-yr FW
EG 100-Year
WS 100-Year
Crit 100-Year
Crit 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
270
268
266
264
262
260
258
256
254
4750
4800
4850
4900
4950
5000
5050
5100
5150
Station (ft)

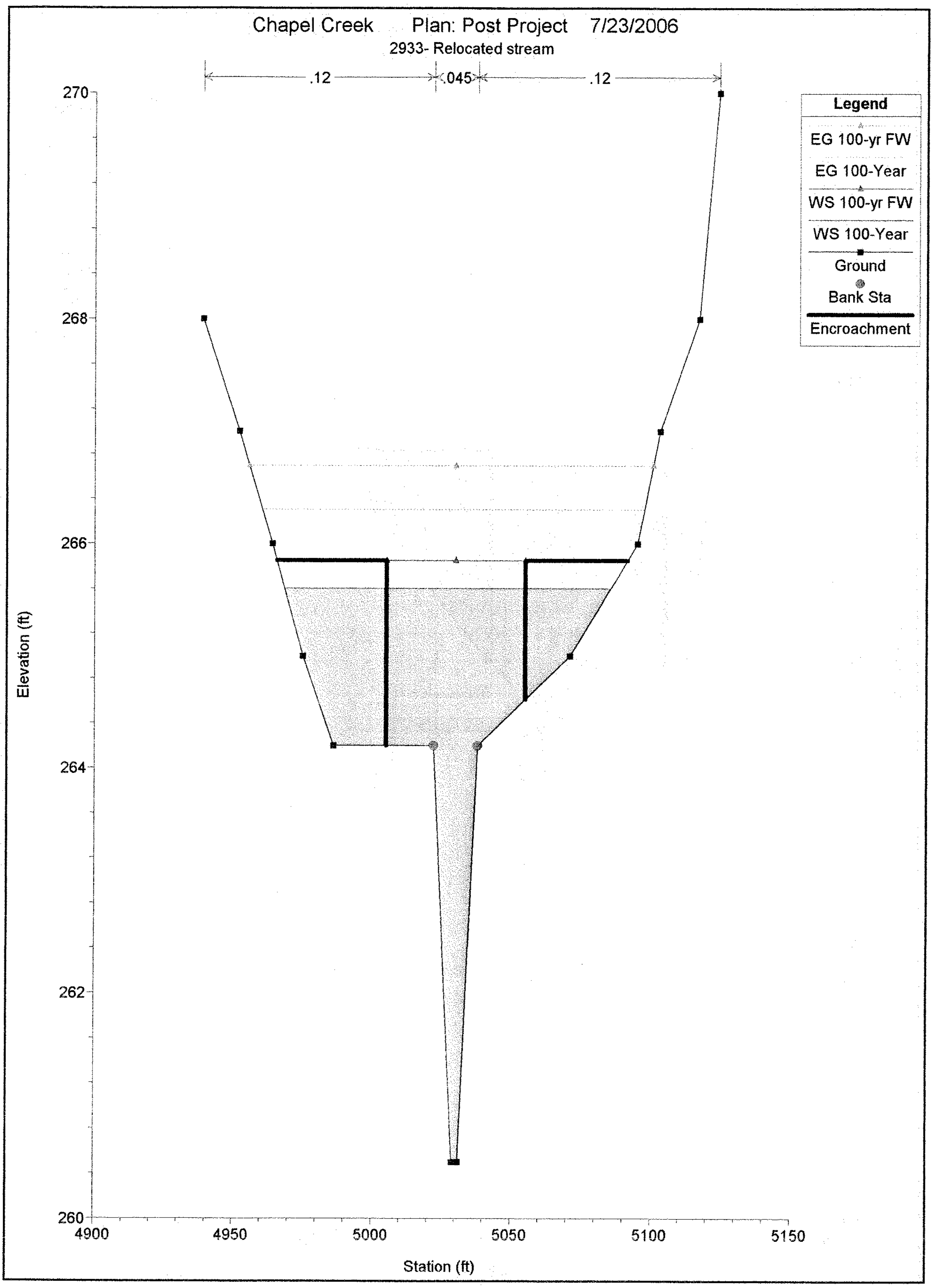

Chapel Creek Plan: Post Project 7/23/2006
2380
.1
.045
.14
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
Crit 100-Year
WS 100-Year
Ground
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
270
268
266
264
262
260
258
256
254
4800
4850
4900
4950
5000
5050
5100
5150
5200



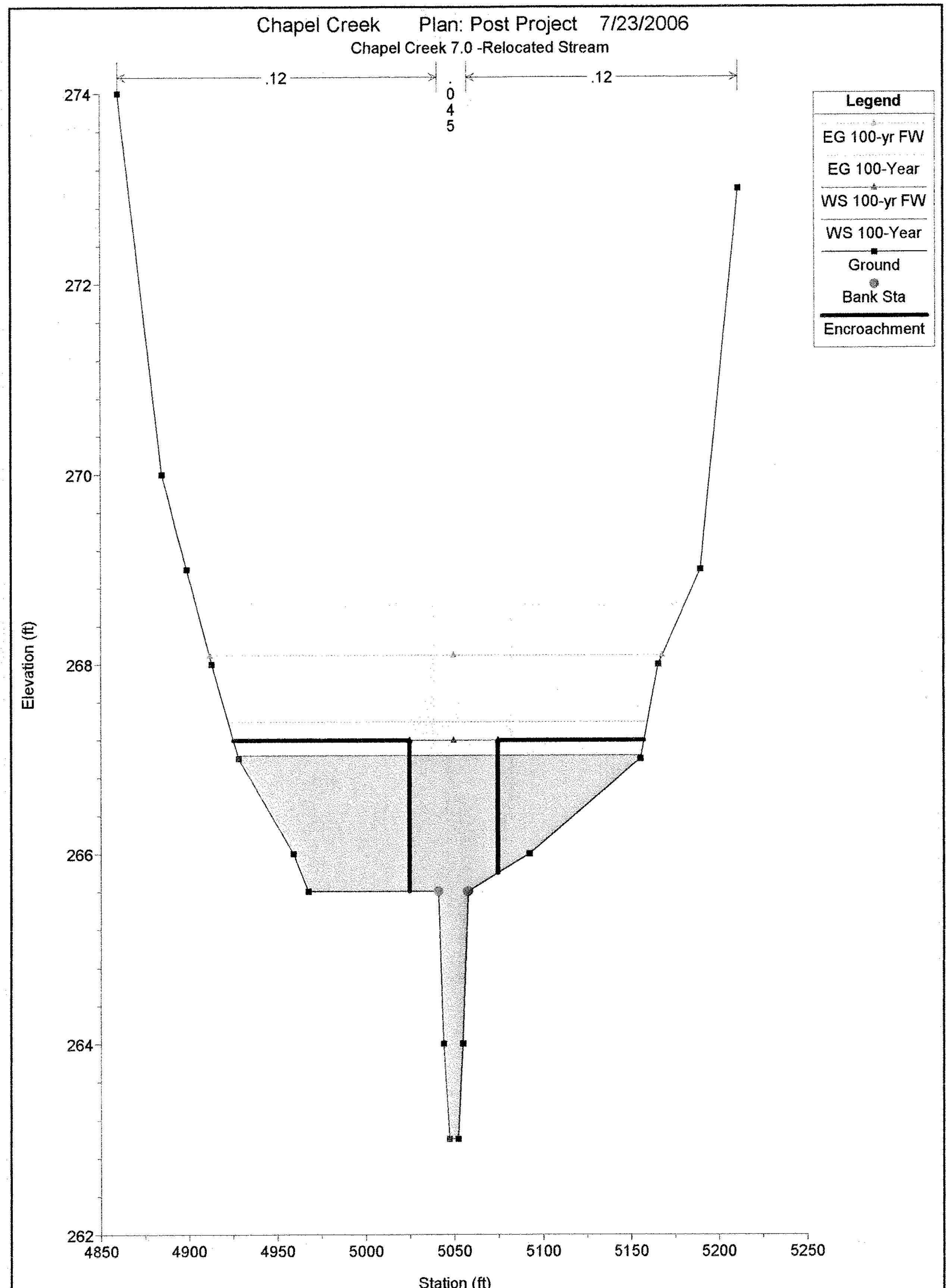
Chapel Creek Plan: Post Project 7/23/2006
2480
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Ground
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
270
268
266
264
262
260
258
256
4900
4950
5000
5050
5100
5150
5200



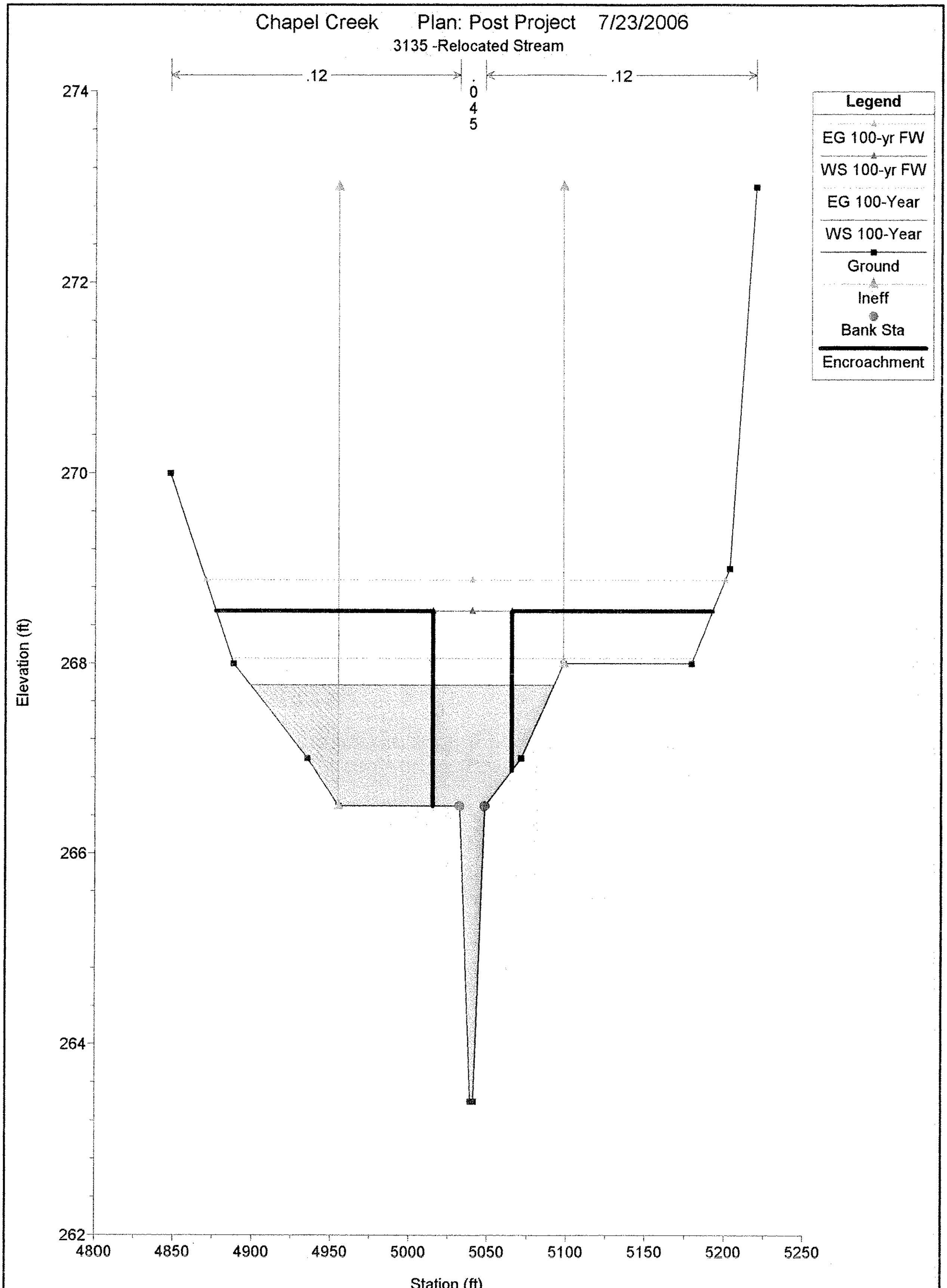
Chapel Creek Plan: Post Project 7/23/2006
2728- Relocated Stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Ground
Bank Sta
Encroachment
266
264
262
260
258
Elevation (ft)
4950
5000
5050
5100
5150
Station (ft)

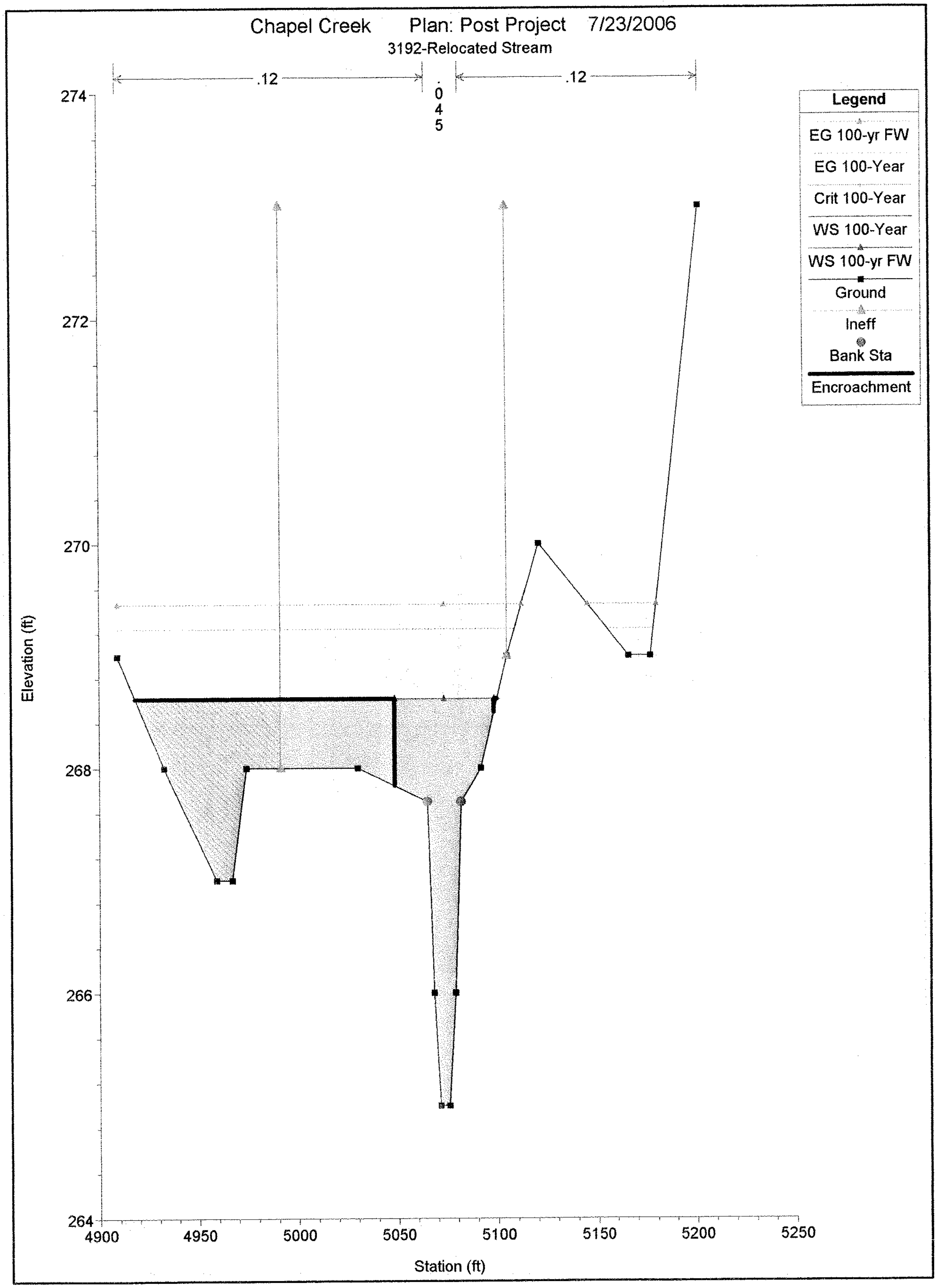


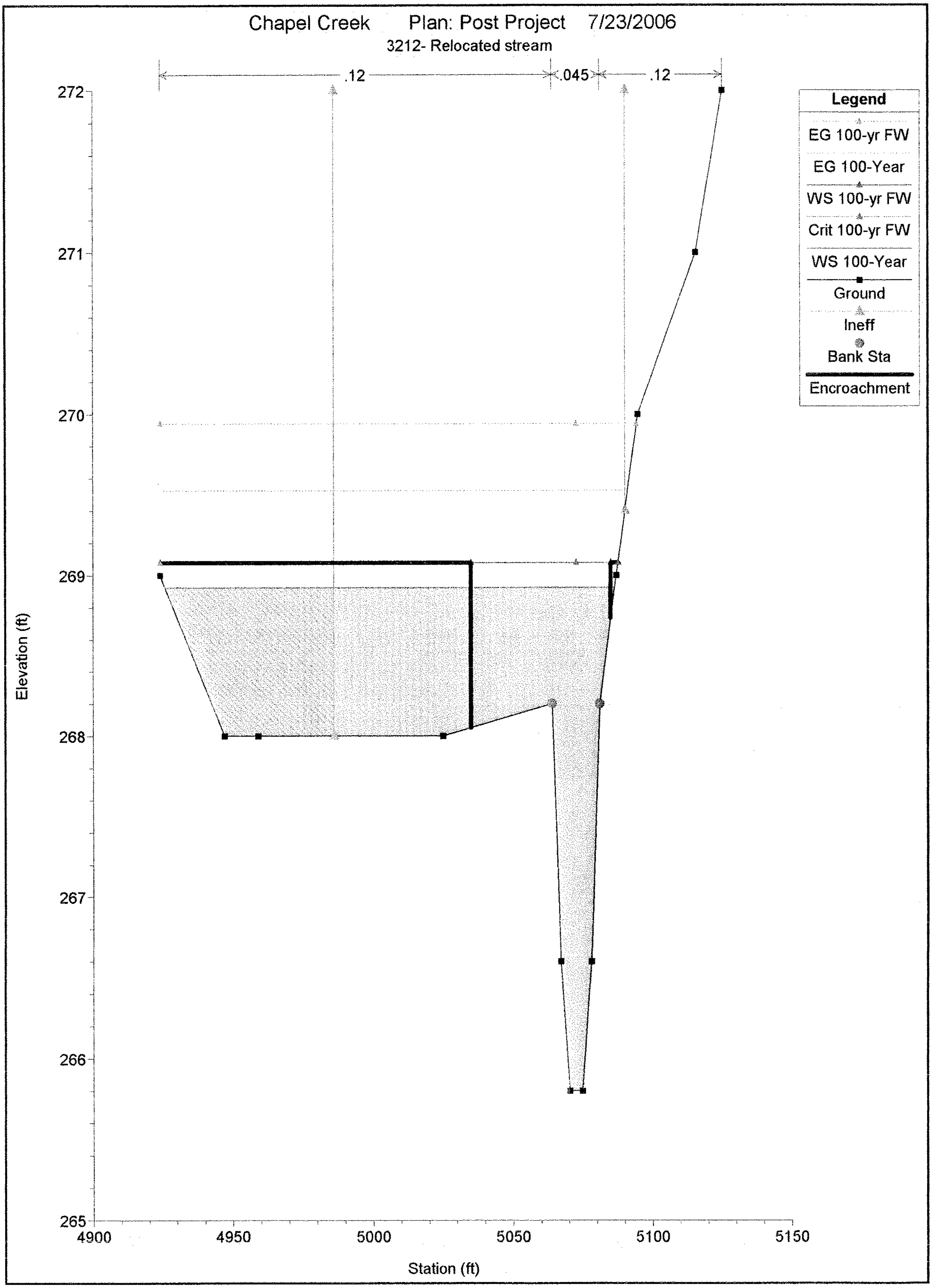
Chapel Creek Plan: Post Project 7/23/2006
2933- Relocated stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Ground
Bank Sta
Encroachment
Elevation (ft)
270
268
266
264
262
260
4900
4950
5000
5050
5100
5150
Station (ft)



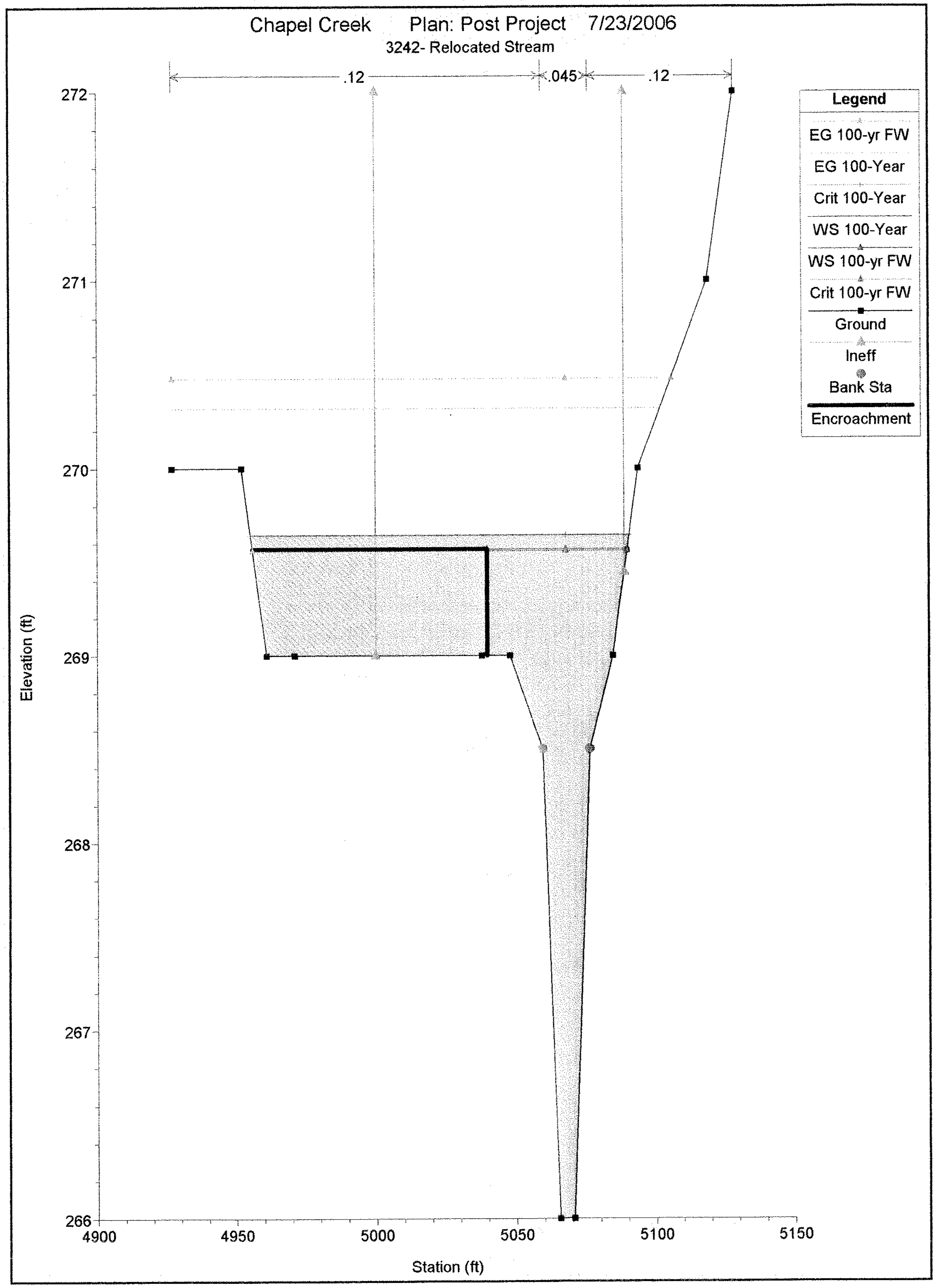
Chapel Creek Plan: Post Project 7/23/2006
Chapel Creek 7.0 -Relocated Stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Ground
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
274
272
270
268
266
264
262
4850
4900
4950
5000
5050
5100
5150
5200
5250

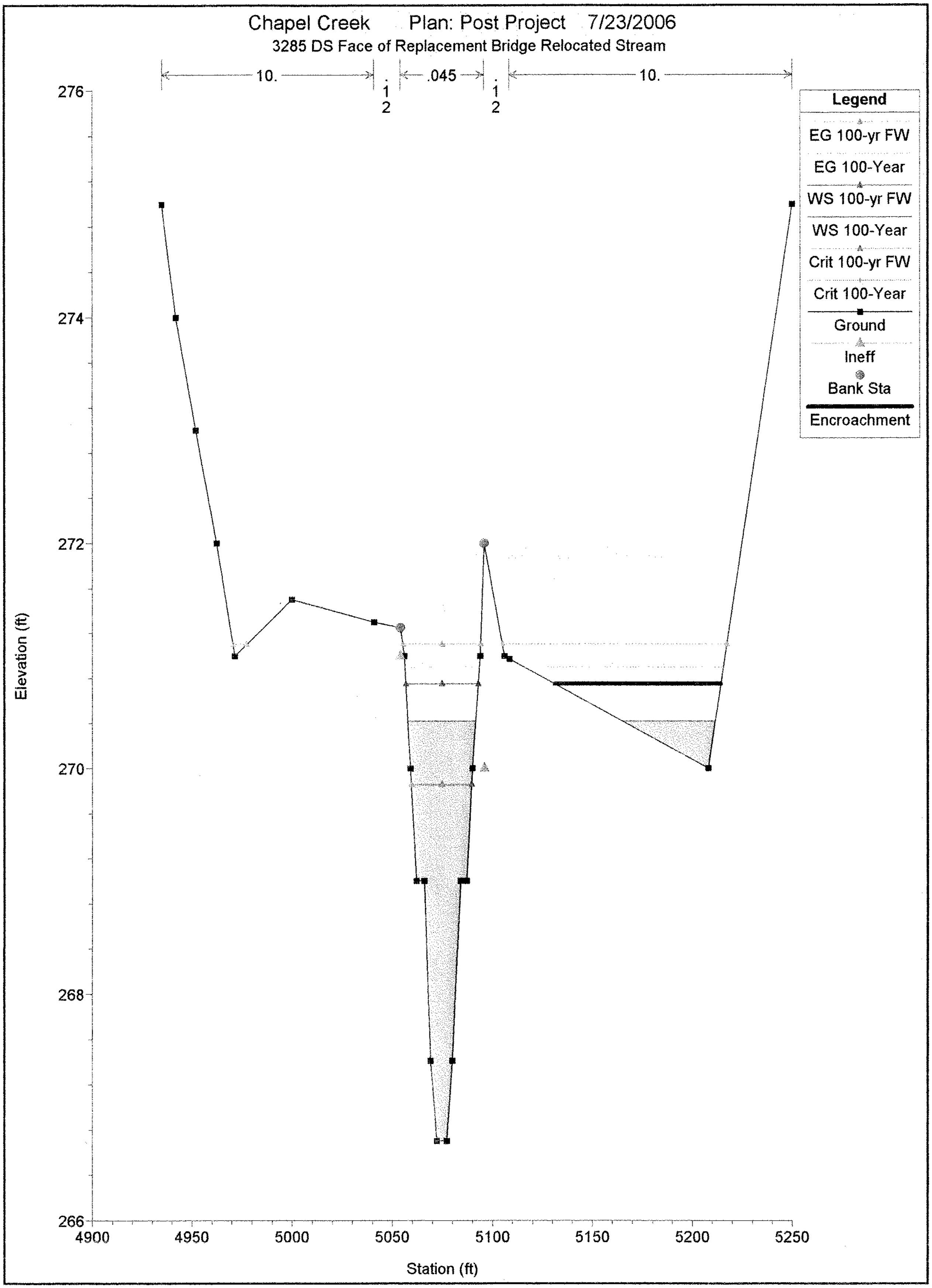

Chapel Creek Plan: Post Project 7/23/2006
3135 -Relocated Stream
.12
.045
.12
Legend
EG 100-yr FW
WS 100-yr FW
EG 100-Year
WS 100-Year
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
274
272
270
268
266
264
262
4800
4850
4900
4950
5000
5050
5100
5150
5200
5250
Station (ft)


Chapel Creek Plan: Post Project 7/23/2006
3192-Relocated Stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
Crit 100-Year
WS 100-Year
WS 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
274
272
270
268
266
264
Station (ft)
4900
4950
5000
5050
5100
5150
5200
5250

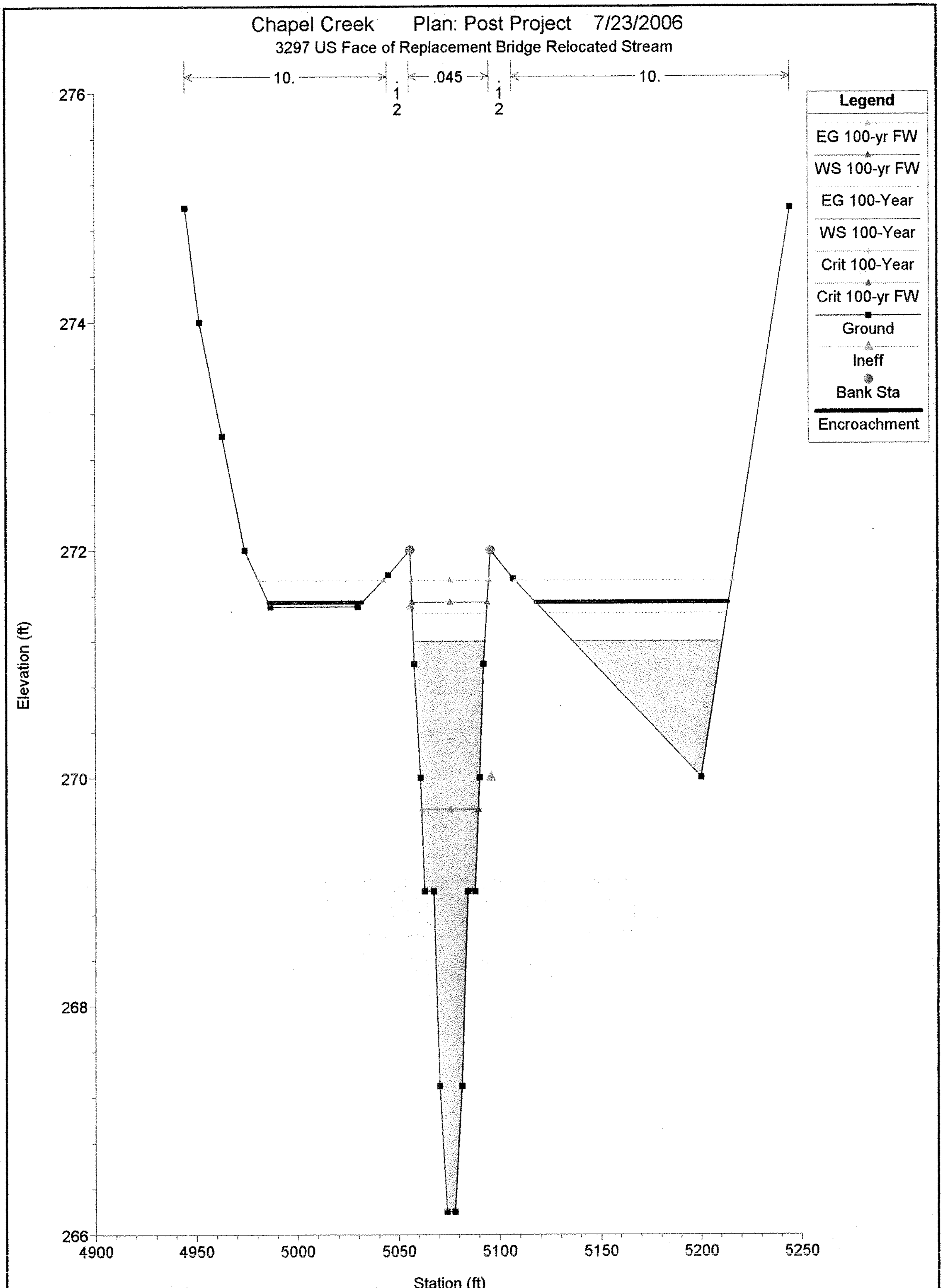


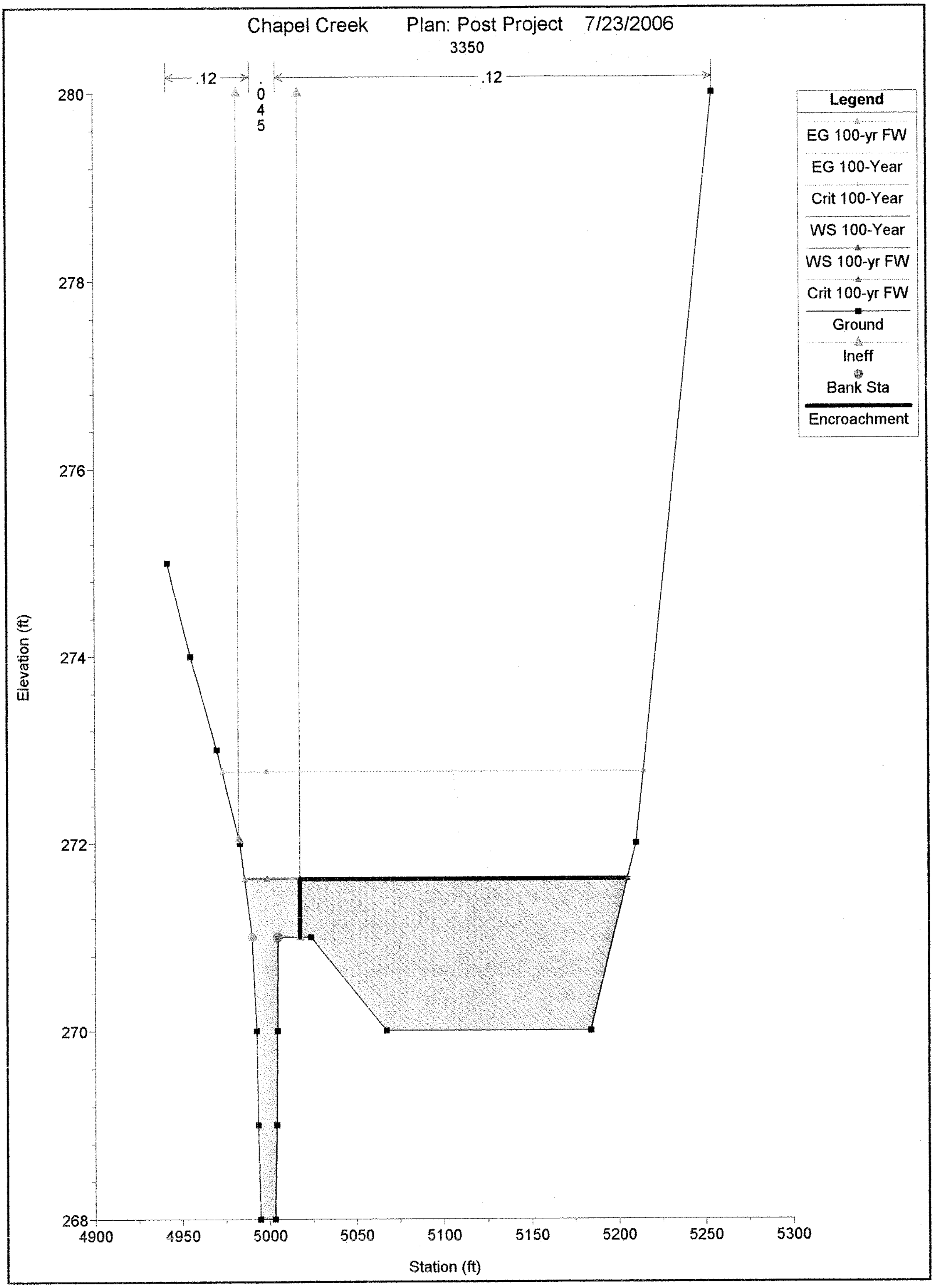
Chapel Creek Plan: Post Project 7/23/2006
3212- Relocated stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
Crit 100-yr FW
WS 100-Year
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
272
271
270
269
268
267
266
265
4900
4950
5000
5050
5100
5150
Station (ft)

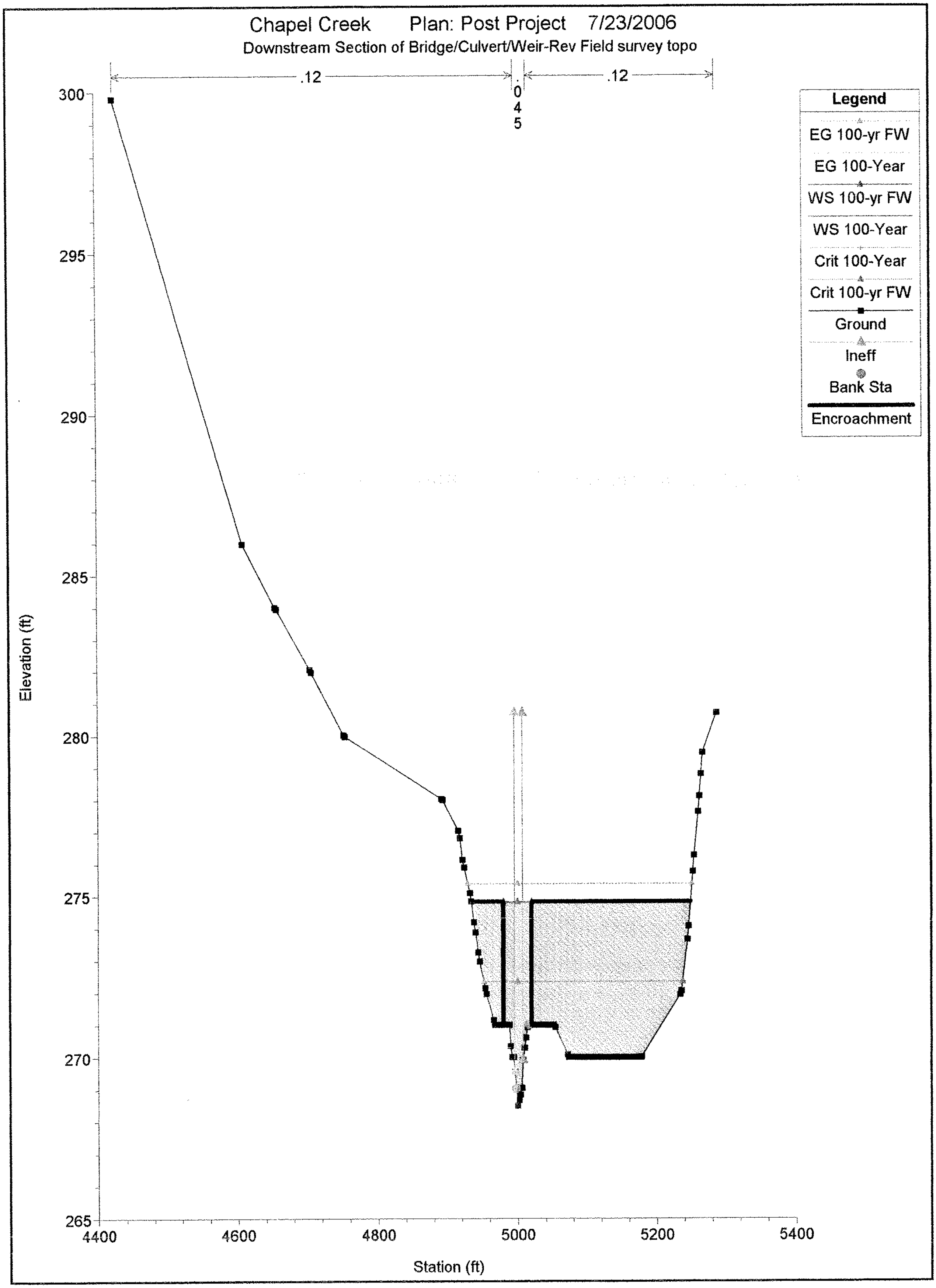

Chapel Creek Plan: Post Project 7/23/2006
3242- Relocated Stream
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
Crit 100-Year
WS 100-Year
WS 100-yr FW
Crit 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
272
271
270
269
268
267
266
4900
4950
5000
5050
5100
5150



Chapel Creek Plan: Post Project 7/23/2006
3285 DS Face of Replacement Bridge Relocated Stream
10.
.12
.045
.12
10.
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Crit 100-yr FW
Crit 100-Year
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
266
268
270
272
274
276
4900
4950
5000
5050
5100
5150
5200
5250

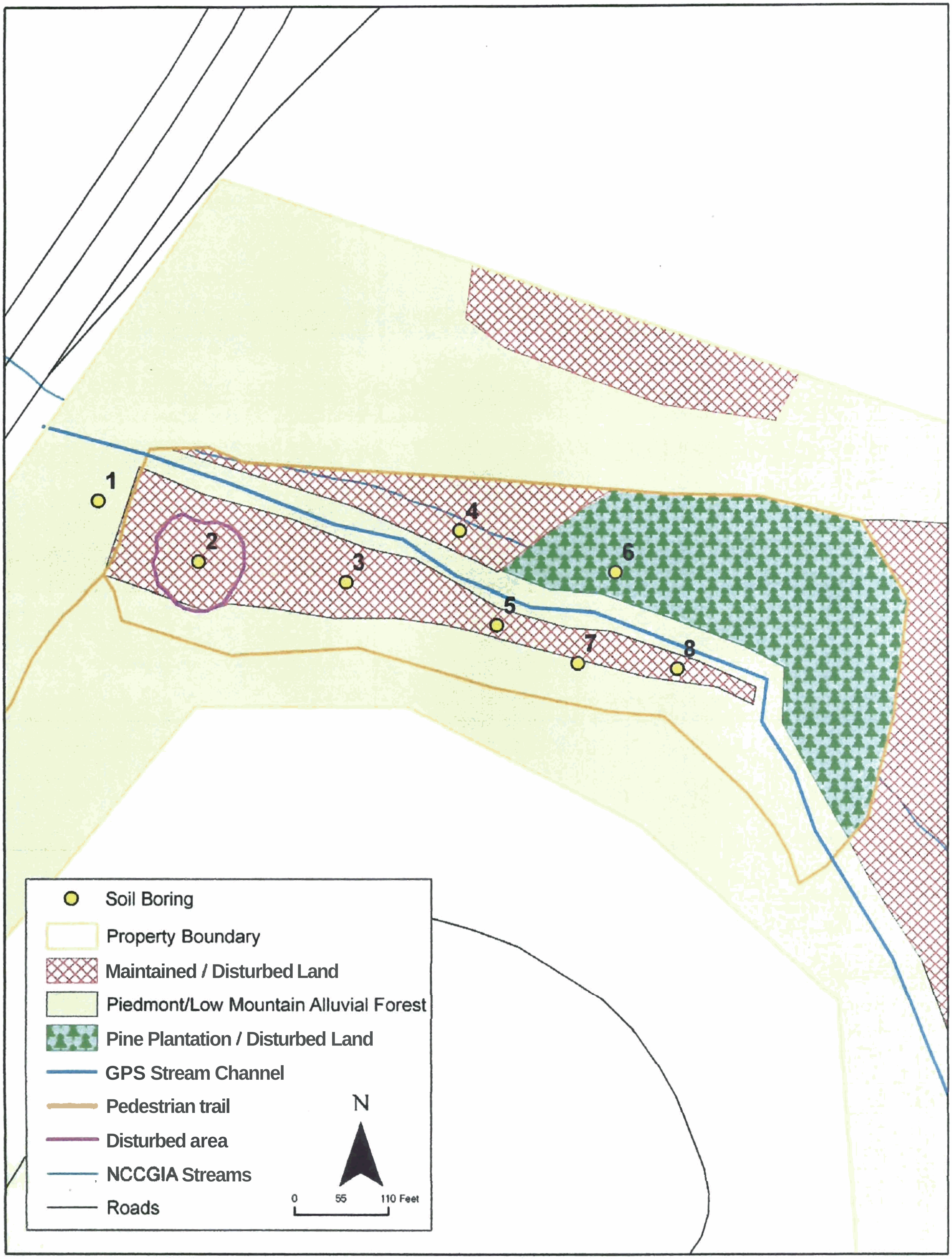

Chapel Creek Plan: Post Project 7/23/2006
3297 US Face of Replacement Bridge Relocated Stream
10.
.12
.045
.12
10.
Legend
EG 100-yr FW
WS 100-yr FW
EG 100-Year
WS 100-Year
Crit 100-Year
Crit 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
276
274
272
270
268
266
Station (ft)
4900
4950
5000
5050
5100
5150
5200
5250


Chapel Creek Plan: Post Project 7/23/2006
3350
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
Crit 100-Year
WS 100-Year
WS 100-yr FW
Crit 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
280
278
276
274
272
270
268
4900
4950
5000
5050
5100
5150
5200
5250
5300



Chapel Creek Plan: Post Project 7/23/2006
Downstream Section of Bridge/Culvert/Weir-Rev Field survey topo
.12
.045
.12
Legend
EG 100-yr FW
EG 100-Year
WS 100-yr FW
WS 100-Year
Crit 100-Year
Crit 100-yr FW
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
300
295
290
285
280
275
270
265
4400
4600
4800
5000
5200
5400
Station (ft)

Appendix 6. Restoration Site Soil Boring Location Map and Logs


1
2
3
4
5
6
7
8
Soil Boring
Property Boundary
Maintained / Disturbed Land
Piedmont/Low Mountain Alluvial Forest
Pine Plantation / Disturbed Land
GPS Stream Channel
Pedestrian trail
Disturbed area
NCCGIA Streams
Roads
N
0
55
110 Feet

PROJECT 1-1-05 DATE__________ COUNTY__________

PROPOSAL/LOT# [illegible]

Parent material (res/coll/all)__________ clay mineralogy:(sl.exp./exp.?)__________

	Boring # 1	Boring # 2	Boring # 3	Boring # 4
DEPTH HORIZON I	[illegible]	0-18"	0-14"	[illegible]
COLOR	[illegible]	[illegible]	10YR 5/3	[illegible]
TEXTURE	S	S	S.L	[illegible]
STRUCTURE	[illegible]	[illegible]	weak	[illegible]
CONSISTENCE	FR	[illegible]	FR	[illegible]
DEPTH HORIZON II	1-12"	[illegible]	14-18	[illegible]
COLOR	10YR 5/6	[illegible]	10YR [illegible]	[illegible]
TEXTURE	[illegible]		[illegible]	
STRUCTURE	[illegible]		[illegible]	
CONSISTENCE	[illegible]		FR	
%CLAY				[illegible]
[illegible] 5%	[illegible] 6/3	[illegible]	~~14-25~~	
DEPTH HORIZON III	12-24		14-25	
COLOR	mixed		10YR 5/6 → [illegible]	
TEXTURE	CL		LS	
STRUCTURE	[illegible]		SG	
CONSISTENCE	FR		VFR	
%CLAY				
[illegible]				
DEPTH HORIZON IV	24-32		25-34	
COLOR	[illegible]		[illegible] / 10YR 5/1	
TEXTURE	[illegible]		CL	
STRUCTURE	M		[illegible]	
CONSISTENCE	FR		FR	
[illegible]	[illegible]			
Soil Depth ? Restrict. Hor?				
Ld. pos.? Wet? % slope			[illegible]	
LTAR/soil group/ CLASSIFICATION (PS/U)			[illegible]	
			[illegible] 3/2	
Notes:				

Described by: __________

PROJECT [illegible] DATE 1-13-06 COUNTY

PROPOSAL/LOT#

Parent material (res/coll/all) clay mineralogy:(sl.exp./exp.?)

	Boring # 5	Boring # 6	Boring # 7	Boring # 7
DEPTH HORIZON I	[illegible] to 3	Non hydric	Sil [illegible]	0-24"
COLOR	Non Hydric	Chewacla	Chewacla	10YR 4/3
TEXTURE			Non hydric	SL
STRUCTURE				[illegible]
CONSISTENCE				f1 . VF1 [illegible]
				~~[illegible]~~ few mottles
				Non Hydric
DEPTH HORIZON II				
COLOR				
TEXTURE				
STRUCTURE				
CONSISTENCE				
%CLAY				
DEPTH HORIZON III				
COLOR				
TEXTURE				
STRUCTURE				
CONSISTENCE				
%CLAY				
DEPTH HORIZON IV				
COLOR				
TEXTURE				
STRUCTURE				
CONSISTENCE				
Soil Depth ? Restrict. Hor?				
Ld, pos.? Wet? % slope				
LTAR/soil group/ CLASSIFICATION (PS/U)				
Notes:				

Described by:

Appendix 7. Cultural Resources

Post-it® Fax Note 7671	Date 9/24	# of pages ▶ 5
To Becky Ward	From Kate	
Co./Dept.	Co. TCG	
Phone #	Phone # 919 7321300	
Fax # 919 8705359	Fax # 919 732 1303	

North Carolina Department of Cultural Resources

State Historic Preservation Office

Peter B. Sandbeck, Administrator

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

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

May 16, 2006

Kate Montieth
The Catena Group
410-B Millstone Drive
Hillsborough, NC 27278

Re: Chapel Creek Wetland and Stream Mitigation Project, Orange County, ER 06-0027

Dear Ms. Montieth:

Thank you for your letter of March 27, 2006 concerning the above project. We apologize for the delay in our response.

As noted in our letter of March 8, 2006, there are a number of archaeological sites on the Chapel Creek property within the project boundaries. Enclosed is a copy of your project map with the site locations added for your information. While most of these sites are not eligible for inclusion in the National Register of Historic Places, one of the sites may be eligible. Archaeological site 31OR472 is unassessed and testing has been recommended to determine its eligibility.

According to the map that accompanied your letter, it appears that 31OR472 is outside of the area proposed for ground disturbance. If any ground disturbing activities are planned in the future at the location of this site, additional archaeological investigation will be necessary. Plans for the remaining portion of the property should be forwarded to us for review prior to their implementation.

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

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

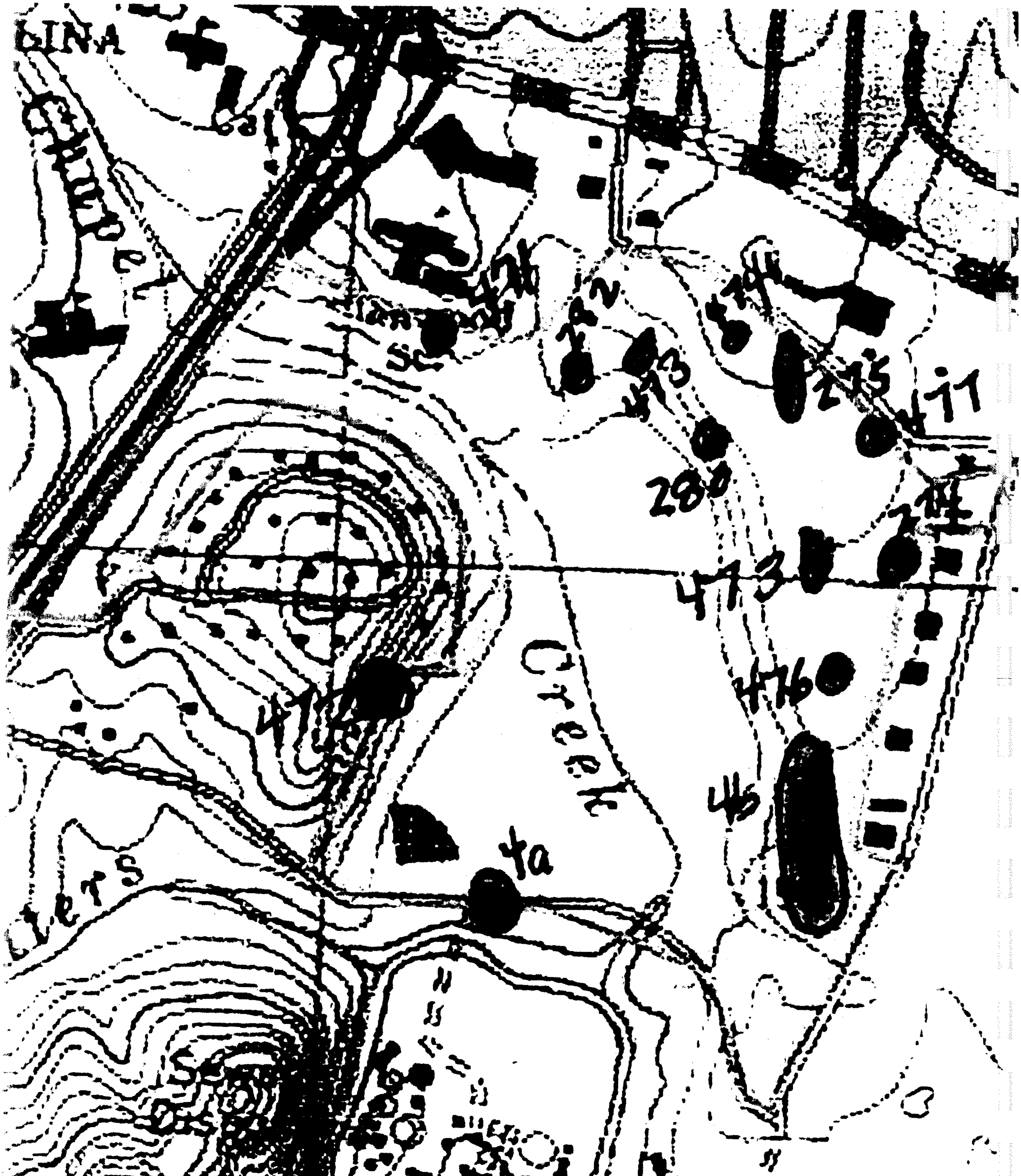
Sincerely,

Renee Gledhill-Earley

Peter Sandbeck

Enclosure

	Location	Mailing Address	Telephone/Fax
ADMINISTRATION	507 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-4763/733-8653
RESTORATION	515 N. Blount Street, Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6547/715-4801
SURVEY & PLANNING	515 N. Blount Street, Raleigh, NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919)733-6545/715-4801


Creek