Puzzle Creek Restoration Plan
Rutherford County, North Carolina
EEP Project No. D06027-C

Prepared For

North Carolina Ecosystem Enhancement Program
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Puzzle Creek Stream Restoration Plan
Rutherford County, North Carolina

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EXECUTIVE SUMMARY

Baker Engineering NY, Inc. (hereafter referred to as Baker), proposes to restore 4,840 linear feet (LF) of stream along Puzzle Creek and an unnamed tributary in Rutherford County, NC. The streams are located near the Washburn Community approximately three miles northeast of Bostic, NC (Figure 1.1 Project Location Map). The unnamed tributary flows west then northwest from the upstream end of the Schafer property boundary to the confluence with Puzzle Creek. Reach 1 of Puzzle Creek begins where the creek passes under Piney Mountain Church Road (SR 1007) and flows southwest to the confluence with the unnamed tributary. Reach 2 of Puzzle Creek flows northwest from this confluence to the Schafer property boundary. The project site lies in the Broad River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-08-02 and United States Geologic Survey (USGS) hydrologic unit 03050105070050.

The goals for the restoration project are as follows:

- Improve hydrologic connections between creeks and floodplains.
- Improve the water quality in the Puzzle Creek watershed.
- Improve aquatic and terrestrial habitat along the project corridor.
- Create geomorphically stable conditions on the project reaches.

To accomplish these goals, we propose the following:

- Remove anthropogenic impacts from the stream corridor and rehabilitate the existing incised and eroding streams by creating stable channels with sufficient floodplain access.
- Improve water quality by improving buffers for nutrient removal from runoff and by stabilizing stream banks to reduce bank erosion and sediment contribution to creek flows.
- Improve in-stream habitat by providing more stable and diverse channel features such as depositional riffles and bars, creating deeper pools and areas of water re-aeration, providing woody debris for habitat, and reducing sedimentation from bank erosion.
- Improve terrestrial habitat by permanently establishing riparian areas characterized by native vegetation, organic debris, and bi-annual flooding.
- Establish native stream bank and floodplain vegetation in a permanent conservation easement to improve bank stability, provide shading to decrease water temperature and provide cover, and improve wildlife habitat.

Table ES.1
Puzzle Creek Restoration Overview

Project Feature	Existing Condition	Design Condition	Approach
Puzzle Creek	1,623.5 LF	1,594.5 LF	Priority I & Priority II Restoration
Unnamed Tributary	3,123.5 LF	3,245.5 LF	Priority I & Priority II Restoration; Enhancement I & Enhancement II
Total Stream Work	**4,747 LF**	**4,840 LF**	

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1.0 PROJECT SITE IDENTIFICATION AND LOCATION

1.1 Brief Project Description and Location

Baker proposes to restore and enhance 4,840 linear feet (LF) of stream on Puzzle Creek and an unnamed tributary.

The Puzzle Creek restoration site is located approximately three miles northeast of Bostic in Rutherford County, NC, as shown on Figure 1.1 Project Location Map. Reach 1 of the unnamed tributary (UT 1) flows west then northwest from the upstream end of the Schafer property boundary to a break in the easement. Reach 2 of the unnamed tributary continues northwest from the break in the easement to its confluence with Puzzle Creek. Reach 1 of Puzzle Creek begins above Piney Mountain Church Rd (SR 1007) and continues southwest to where it meets UT1. Reach 2 of Puzzle Creek is located above Reach 1 and continues northwest to the end of the property boundary. The project site is accessible from Piney Mountain Church Rd. and Washburn Rd.

Puzzle Creek and the unnamed tributary are “blue-line” streams, as shown on the USGS topographic quadrangle for the site (Figure 1.2 Site Topographic Map). The site is located in United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 03050105070050. Puzzle Creek is listed by the North Carolina Division of Water Quality (NCDWQ) in the Broad River Basin 03-08-02. Figure 2.1 depicts the basin boundaries for the project reach.

Sections of Puzzle Creek have recently been utilized for pasture and are frequently mowed. The remainder of the site is wooded, with acreage being managed for timber production and also as a wildlife sanctuary and hunting grounds. The primary causes of impairment found within the project reaches include previous efforts to channelize the streams, logging activities, an abundance of unstable log jams resulting in erosion, and the presence of non-native vegetation. The total current length of stream on the project reach is 4,747 LF.

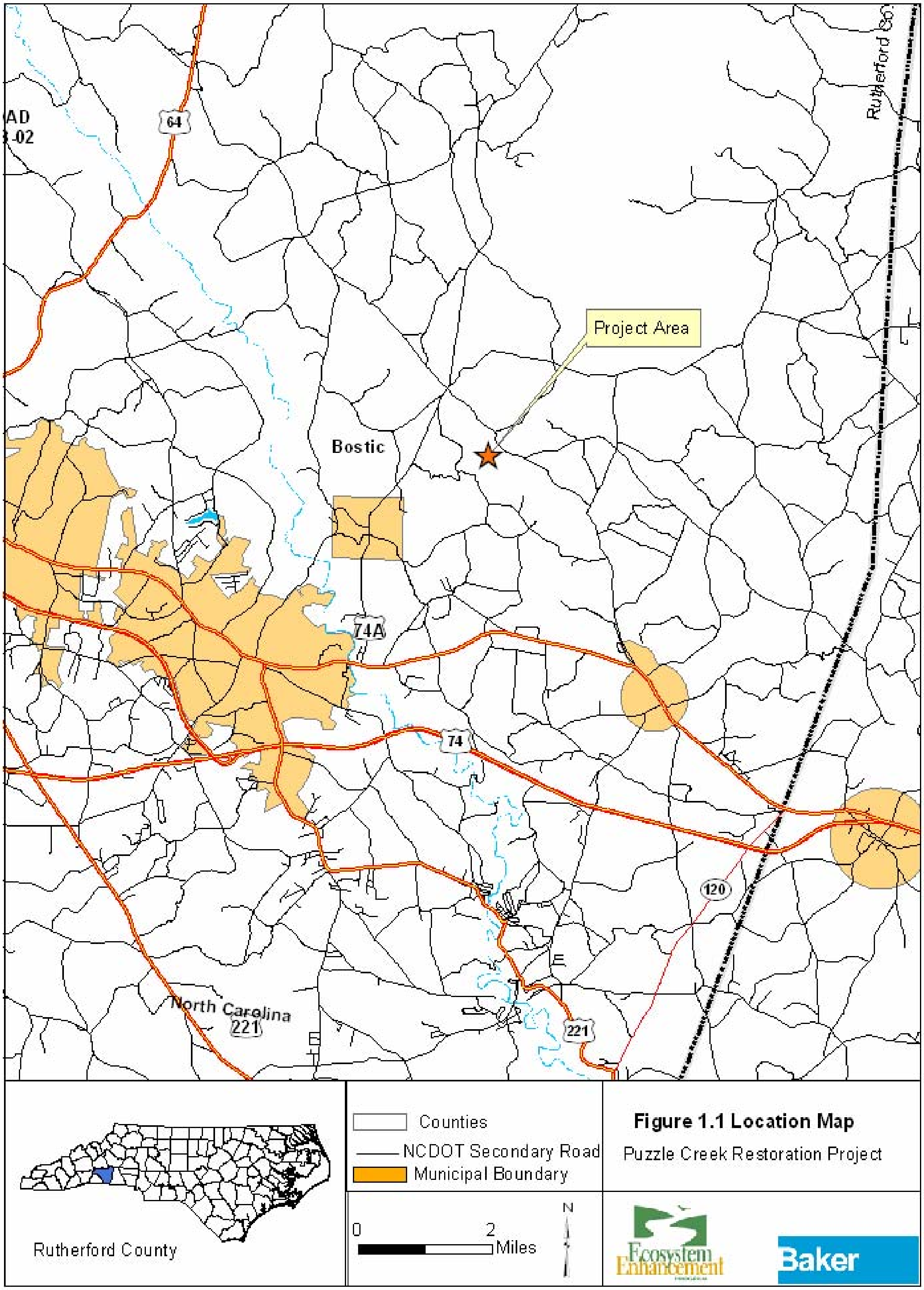


Figure 1.1 Location Map
Puzzle Creek Restoration Project

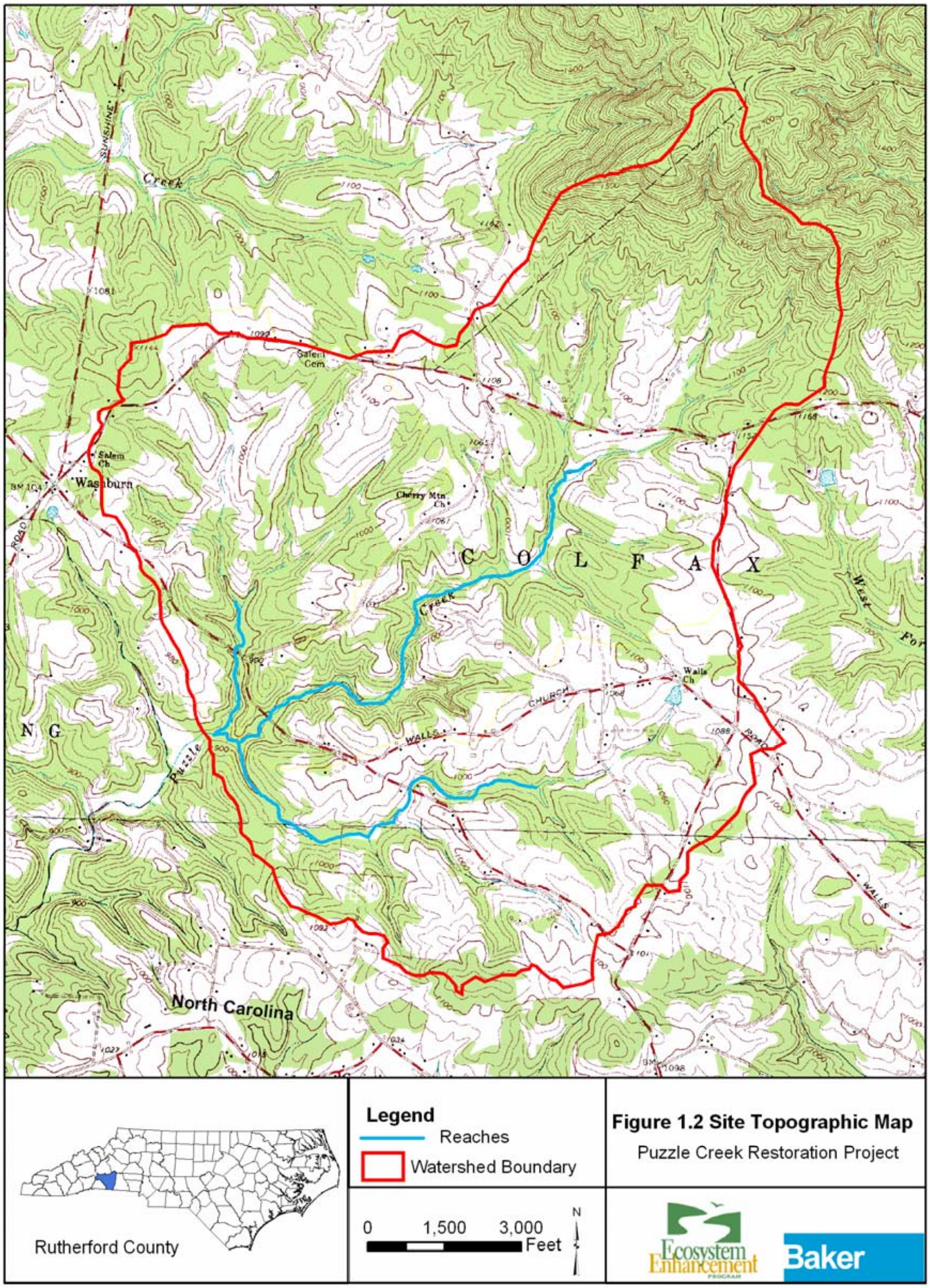


Figure 1.2 Site Topographic Map

Puzzle Creek Restoration Project

2.0 WATERSHED CHARACTERIZATION

2.1 Watershed Delineation

The Puzzle Creek site is located in Rutherford County, in the Broad River Basin as illustrated in Figure 2.1. The total drainage area for Puzzle Creek at the downstream project limit is 5.5 square miles; the unnamed tributary contributes 1.6 square miles.

2.2 Surface Water Classification/ Water Quality

The NCDWQ designates surface water classifications for water bodies such as streams, rivers, and lakes which define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications are associated with a set of water quality standards to protect those uses. All surface waters in North Carolina must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). Class WS waters are protected for Class C uses as well as a source of potable water. Puzzle Creek and the unnamed tributary are both listed as Class WS-V waters within the project limits [DWQ Index No. 9-41-19]. This classification indicates that the streams are considered to support aquatic life and secondary recreational uses and are not listed with any categorical restrictions on watershed development or treated wastewater discharges.

2.3 Geology and Soils

The Puzzle Creek project site is located in the Inner Piedmont belt of the Piedmont physiographic province approximately 4.5 miles upstream of its confluence with the Second Broad River, in eastern Rutherford County. According to the 1 degree by 2 degree geologic map of the Charlotte Quadrangle prepared by the U.S. Geological Survey (Goldsmith et al., 1988, Map I-1251-E), the geologic formations underlying the site consist of a metamorphosed formation of sillimanite-mica schist with inclusions of biotite gneiss that are late Proterozoic in age. In this section of the Inner Piedmont belt, sillimanite-mica schist is variably garnetiferous, locally pyretic and when weathered, appears, white, pale purple, yellow or a reddish orange. It consists primarily of lenses of biotite gneiss (metawacke), and subordinate quartz schist, micaceous quartzite, and calc-silicate rock. Inclusions of biotite gneiss in the project area appear gray to dark-gray, and consists of variably layered biotite quartz-feldspar gneiss, in part garnetiferous. Interlayered in the biotite gneiss are calc-silicates, sillimanite-mica schist, mica schist, amphibolite and inclusions that may contain granite.

Soils within the proposed stream restoration areas are primarily mapped as the Chewacla, Pacolet, and the Pacolet-Bethlehem series by the Natural Resources Conservation Service (NRCS) for Rutherford County (Figure 2.2 Project Soil Types). The Chewacla and Pacolet-Bethlehem series are the predominant soils found along the floodplain areas of Puzzle Creek and the tributary. Chewacla soils are described as nearly level, very deep, somewhat poorly drained soils found on floodplains. Soils that make up the Pacolet-Bethlehem complex are described as very deep, poorly drained soils found on moderate slopes in the floodplain. Soft bedrock is within 20 – 40 inches of the surface. The Pacolet soil series is a very deep, well drained, erodible soils located on eroded uplands. Pacolet soils are found only for a short section in the middle of the tributary reach. On-site observations of soil conditions do not indicate any limitations to performing the work described in this proposal. However, the presence of shallow bedrock in some areas may limit the depth to which excavation can be done. A map depicting the boundaries of each soil type is presented in Figure 2.2. There are three general soil types found within the project boundaries. A summary of each soil type and its locations given by the NRCS is presented in Table 2.1.

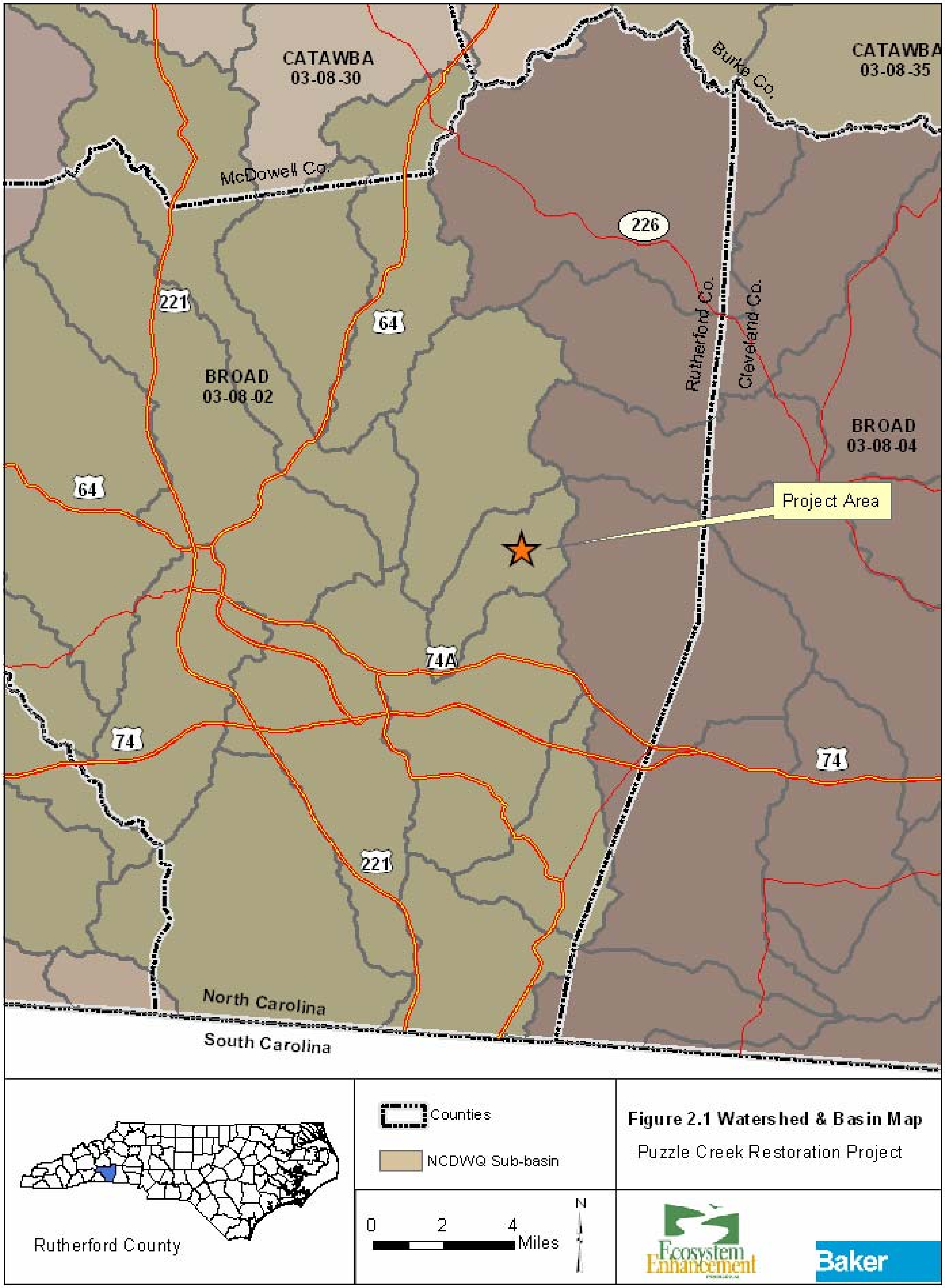


Figure 2.1 Watershed & Basin Map

Puzzle Creek Restoration Project

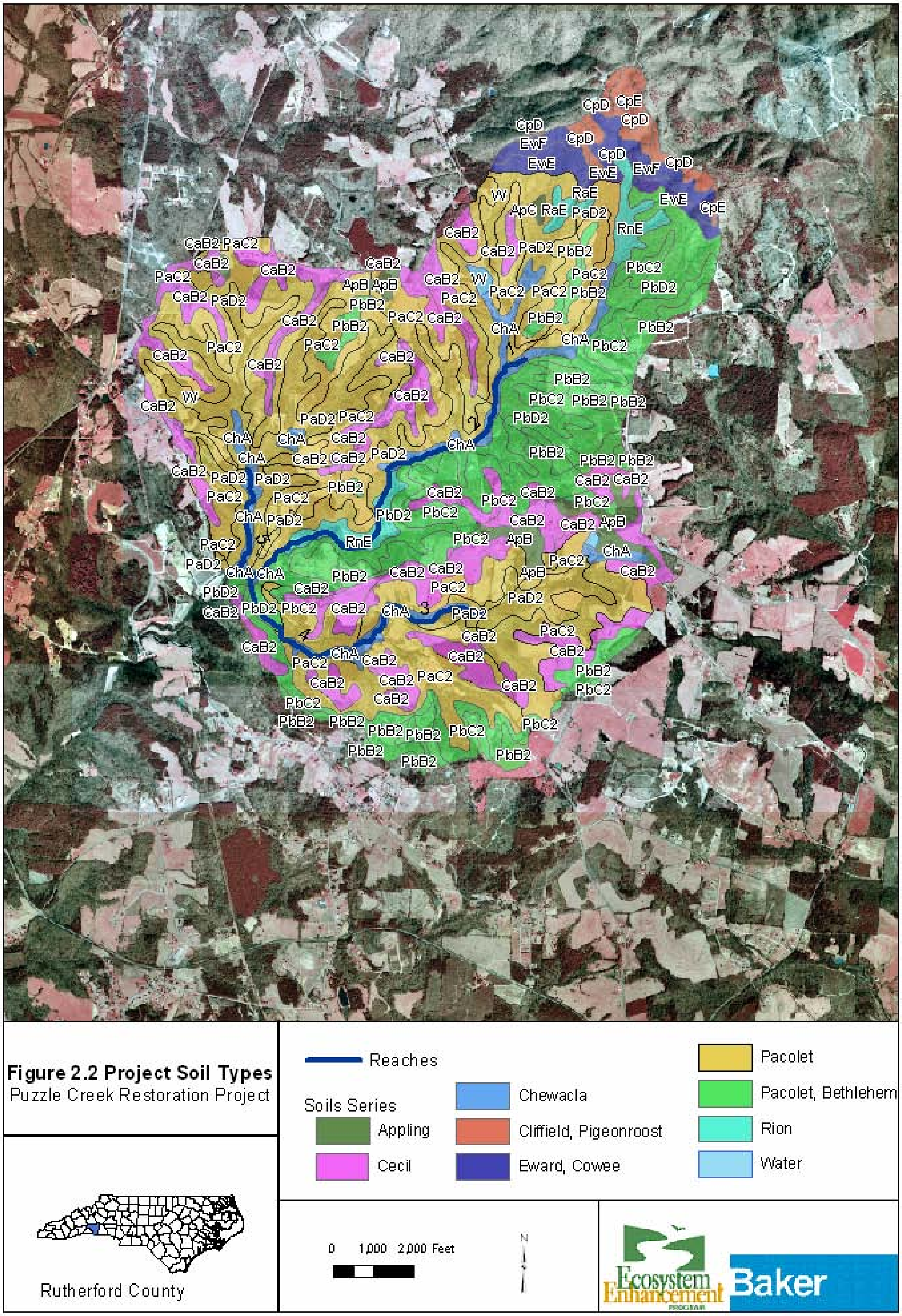


Figure 2.2 Project Soil Types
Puzzle Creek Restoration Project

Table 2.1 Project Soil Types and Descriptions		
Soil Name	**Location**	**Description**
Chewacla	Floodplain	The Chewacla series is composed of very deep, somewhat poorly-drained soils. These soils are on flood plains and have slopes ranging from 0 to 2 percent.
Pacolet	Uplands	The Pacolet series is composed of very deep, well drained, erodible soils. These soils are on uplands and have slopes ranging from 8-15 percent.
Pacolet-Bethlehem	Floodplain	The Pacolet-Bethlehem series is composed of very deep poorly drained soils. These soils are found on floodplains and have slopes ranging from 15-25 percent.
Note: **NRCS, USDA. Official Soil Series Descriptions** (http://soils.usda.gov/soils/technical/classification/osd/index.html) USDA- NRCS Rutherford County Soil Survey (http://soils.usda.gov/survey/)		

Table 2.2 Project Soil Type Characteristics					
	Max Depth (in)	**% Clay on Surface**	**Erosion Factor K**	**Erosion Factor T**	**OM%**
Chewacla Loam (ChA)	61”	22.5	0.32	5	2.5
Pacolet Sandy (PaC2)	62”	27.5	0.2	5	0.75
Pacolet Bethlehem (PbD2) -Pacolet -Bethlehem	62" 33"	27.5	0.2	3	2
Source: **NRCS, USDA. Official Soil Series Descriptions** (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx) (http://soildatamart.nrcs.usda.gov/Report.aspx?Survey=NC161&UseState=NC) USDA- NRCS Rutherford County Soil Survey (http://soils.usda.gov/survey/)					

2.4 Historic Land Use and Development Trends

The Puzzle Creek restoration project area drains agricultural and forested land, as well as a small amount of surrounding residential areas. The area is distant from major population centers, is rural in character, and is not likely to change significantly in the foreseeable future.

The Puzzle Creek watershed continues to support low density residential areas as well as a portion of lands in agriculture. The largest percentage of land use in the watershed currently is in forested cover for wildlife habitat and hunting as well as timber production. The percentage of land in the watershed available to agriculture is 27% with over 60% of the watershed remaining as forest land as reflected in Table 2.3. Orthophotography maps from the 1930's show residential and agricultural land use altering the Puzzle Creek watershed. Many streams were channelized to help mark property boundaries and to drain low lands for farming. Anthropogenic land use alteration and channelization of streams introduced instablilities from which the streams are still recovering. Incision, bank erosion, meander cutoffs, lateral bar formation, debris jams, and other ongoing stream processes typical of adjusting streams are found in the project reach. Segments of the unnamed tributary have achieved a degree of relative stability due to the presence of heavily wooded banks, developing floodplains which have been active in recent years, and bedrock that has prevented incision from becoming the driving factor in channel geomorphic development.

Table 2.3

Puzzle Creek Major Watershed Land Uses

Land Use Category[1]	Area (acres)	Percent Area
Forest	1639	61%
Shrub	315	12%
Pasture	724	27%
Water	12	0.45%

Note:
1. USGS Land use data from 2001.

2.5 Endangered/Threatened Species

Some populations of plants and animals are declining because of either natural forces or their inability to compete for resources with the encroachment of humans. The North Carolina Natural Heritage Program (NHP) and United States Fish and Wildlife Service (USFWS) composed a list of rare and protected animal and plant species that contains five federally listed species known to exist in Rutherford County (USFWS, 2006 and NCNHP, 2006).

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

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

Species that the USFWS lists under federal protection Rutherford County as of August 1, 2006 are listed in Table 2.4. A brief description of the characteristics and habitat requirements of the federally protected species is included in the following section, along with a conclusion regarding potential project impacts.

Table 2.4
Species of Federal and State Status in Rutherford County

Family	Scientific Name	Common Name	Federal Status	State Status	Habitat Present / Biological Conclusion
Vertebrates					
Vespertilionidae	*Myotis sodalis*	Indiana Bat	E	E	No/No Effect
Vascular Plant					
Aristolochiaceae	*Hexastylis naniflora*	Dwarf-flowered Heartleaf	T	T	Yes/Not Effect
Orchidaceae	*Isotria medeoloides*	Small Whorled Pogonia	T	E	No/No Effect
Iridaceae	*Sisyrinchium dichotomum*	White Irisette	E	E	Yes/No Effect
Lichen					
Cladoniaceae	*Gymnoderma lineare*	Rock Gnome Lichen	E	T	No/No Effect

Notes:
E An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.
T Threatened
SC A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations Adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).

A pedestrian survey of the project area was conducted on August 1, 2006 for these species. One federal protected species, the Dwarf-flowered heartleaf (*Hexastylis naniflora)*, was observed in the project area during the field survey.

The USFWS was notified of the project on October 19, 2006 regarding the findings of the potential *Hexastylis naniflora*. Baker also sent them an email on October 27, 2006, requesting their review and comment on the issue and again on November 30, 2006. USFWS staff indicated they would like to see protective measures in the design plans and design narrative to ensure proper planning has occurred with respect to such considerations as avoidance of the plant during staging activities, and procedures for enhancing the riparian corridor. During discussions with the USFWS since that time, it has been determined that the construction corridor will not encompass the area in which the *Hexastylis naniflora* was found. However, given its proximity to the project area and the potential for canopy alteration during the course of the project, additional steps have been taken to ensure canopy alterations resulting from the project will not adversely impact the plant. Avoidance measures as discussed between the USFWS and Baker personnel will be identified on plan sets and submitted to the USFWS and US Army Corps of Engineers during the permitting stage for any further comment. If Baker does not receive comment from the USFWS at the time of the US Army Corps of Engineers' issuance of permitting for restoration activities, Baker will commence with project plans that include avoidance measures as currently outlined in the project plan sheets. Agency comments have been incorporated and correspondence on this issue is included in Appendix A. No additional federally listed species of concern have been identified in Rutherford County since the time initial pedestrian surveys were performed for this project.

2.5.1 Federally Listed Threatened or Endangered Species

2.5.1.1 Vertebrates

2.5.1.1.1 *Myotis sodalis* (Indiana Myotis)

The Indiana bat is 3.5 inches long, with mouse-like ears, plain nose, dull, grayish fur on the back, and lighter, cinnamon-brown fur on the belly. Its "wingspread" ranges from 9.5 to 10.5

inches. From early October until late March and April, Indiana bats hibernate in large clusters of hundreds or even thousands in limestone caves and abandoned mines, usually near water. During summer, females establish maternity colonies of two dozen to several hundred under the loose bark of dead and dying trees or shaggy-barked live trees, such as the shagbark hickory. Hollows in live or dead trees are also used. Most roost trees are usually exposed to the sun and are near water. Males and non-reproductive females typically roost singly or in small groups. Roost trees can be found within riparian areas, bottomland hardwoods, and upland hardwoods (Nature Serve Explorer, 2006).

Biological Conclusion:

This project area is adjacent to old fallow agricultural fields. Larger trees on the project site tend to have smooth bark. A search of the NHP website on July 28, 2006 indicated no occurrence of this species in the project area. Therefore, it is anticipated that project construction will have "no effect" on the Indiana bat.

2.5.1.2 Vascular Plants

2.5.1.2.1 *Hexastylis naniflora* (Dwarf-flowered Heartleaf))

Dwarf-flowered heartleaf is a low-growing, spicy-smelling, evergreen, perennial herb. Leaves are heart-shaped, alternate, leathery, untoothed, and 1.6 to 2.4 inches wide. Each leaf is supported by a long, thin stalk that rises directly from the subsurface rhizome. This species has the smallest flowers of any North American plant in the genus *Hexastylis*. The solitary flowers are fleshy, firm, grow at the end of the short stalks, and are often found under forest litter and leaves near the base of the leafstalks. Every year, each rhizome section produces one leaf, one flower, and a leaf scale. The flowers are jug-shaped, less than 0.4 inches long, and have a narrow sepal tube, ranging in color from brown to greenish or purple. Flowering occurs from mid-March to early June; fruiting begins in late May.

This plant grows along bluffs and north-facing slopes, boggy areas along streams, and adjacent hillsides and ravines in rich, deciduous forests. It is usually associated with mountain laurel (*Kalmia latifolia*) or pawpaw (*Asimina triloba*) and requires acidic, sandy loam soils. The species needs Pacolet, Madison gravelly sandy loam, or Musella fine, sandy loam soils to grow and survive. Provided the soil type is right, the plant can survive in either dry or moderately moist habitat. For maximum flowering, the plant needs sunlight in early spring. Creek heads where shrubs are rare and bluffs with light gaps are the habitat types most conducive to flowering and high seed production. Seed output is lowest in bluff populations with a lot of shade (USFWS, 1992a).

Found in the upper Piedmont regions of South Carolina and North Carolina, this species has 24 known populations in an eight-county area. North Carolina has one population in Catawba County, two in Lincoln County, and three populations each in Rutherford, Cleveland, and Burke Counties. Rutherford County also supported another site, but it was reportedly eliminated by road construction. In addition to its known range, the plant may occur in isolated areas in northwestern Gaston County, western Iredell County, and Yadkin County, all in North Carolina (USFWS, 1992a).

Biological Conclusion:

Pacolet series soils are located within the project area, which is crucial habitat requirement for this species to grow and survive although no boggy areas were found along the corridor. A field survey for the dwarf-flowered heartleaf was conducted on August 1, 2006 for potential individuals throughout the project area and one potential population of dwarf-flowered heartleaf was identified along the right bank at mid-reach on the UT to Puzzle Creek. Although the dwarf-flowered heartleaf was located in the vicinity of an area slated for stream restoration, it was determined to exist on a steep hill slope outside of the construction corridor. Once identified, Baker staff took additional precaution to ensure any other potential habitat areas within the project boundaries were surveyed including access into and out of the site. Although the project area meets certain aspects of habitat needs for the dwarf flowered heartleaf such as soils, no boggy areas were identified near the project reach. Work outside of the stream channel will consist of buffer enhancement and sections of channel realignment as shown on the project plan sheets; disturbance to hill slopes, bluffs and ravines within the forested area in the vicinity of the project will be limited to site access. Access points were planned taking into consideration avoidance of potential habitat for the dwarf-flowered heartleaf. To avoid adverse impacts to the area in which the dwarf-flowered heartleaf was observed, measures have been incorporated into the planning and design layout to maintain similar canopy conditions in the project area post project completion. Because the restoration and enhancement work planned for Puzzle Creek falls outside of the area in which the dwarf-flowered heartleaf was identified, it is not expected that Baker will introduce additional competition from native and non-native plant species. Restoration and enhancement work performed at the toe of the bluff slope on which the dwarf-flowered heartleaf was found will actually provide benefits as the lower portion of the slope will be stabilized.

To avoid direct impacts to the area identified as supporting dwarf-flowered heartleaf, fencing will be installed around the site and maintained for the duration of restoration activity to avoid trampling by construction crews. A preconstruction conference will also be held with the construction contractor to review the plans and note any sensitive areas that will need to be avoided including the site where the dwarf-flowered heartleaf is located. With these precautionary measures in place, Baker feels the site potentially supporting dwarf-flowered heartleaf will not be adversely impacted.

2.5.1.2.2 *Isotria medeoloides* (Small Whorled Pogonia)

Small whorled pogonia is a small, perennial member of the Orchidaceae. These plants arise from long slender roots, with hollow stems terminating in a whorl of five or six light green leaves. The single flower is approximately one inch long, with yellowish-green to white petals and three longer green sepals. This orchid blooms in late spring, from mid May to mid-June. Populations of this plant are reported to have extended periods of dormancy and to bloom sporadically. This small spring ephemeral orchid is not observable outside of the spring growing season. When not in flower, young plants of Indian cucumber-root (*Medeola virginiana*) also resemble small whorled pogonia; however, the hollow stout stem of Isotria separates it from the genus Medeola, which has a solid, more slender stem (U.S. Fish and Wildlife Service County Listing, 2006).

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

Biological Conclusion:

Most of the project area has been disturbed and does not meet the historic elevation requirements. In addition, areas were surveyed that possessed similar habitat conditions to those areas in which the pogonia has been identified in the southeast. A search of the NHP database of rare species and unique habitats, conducted on July 28, 2006, indicates no occurrences of this species in the project area. No impacts to this species are anticipated during the project construction.

2.5.1.2.3 *Sisyrinchium dichotomum* (White Irisette)

White irisette is a perennial herb with branching stems 4 to 8 inches tall. Leaves at the base of the plant are pale to bluish green and grow one-third to one-half the height of the plant. The flowers are tiny, occurring in clusters of four to six at the tops of winged stems.

Flowering occurs from late May to July. The fruit is a pale to medium brown capsule containing three to six rounded black seeds.

White irisette is endemic to the upper Piedmont of North and South Carolina. It is currently known from four populations in North Carolina and one in South Carolina. North Carolina's extant populations are in the following counties: Polk (six populations), Henderson (one population), and Rutherford (one population). The Greenville County, South Carolina, site is contiguous with one of the Polk County, North Carolina, sites. This species has apparently always been a narrow endemic, limited to an area in the Carolinas bounded by White Oak Mountain, Sugarloaf Mountain, Chimney Rock, and Melrose Mountain. Two of the remaining populations are within highway rights of way, and a third is inside a commercial recreation area (USFWS, 1995f).

White irisette occurs on rich, basic soils probably weathered from amphibolite. It grows in clearings and the edges of upland woods, where the canopy is thin, and often where down-slope runoff has removed much of the deep litter layer ordinarily present on these sites. The irisette is dependent on some form of disturbance to maintain the open quality of its habitat. Currently, artificial disturbances such as power line and right of way maintenance, when they do not involve herbicides or occur during the reproductive cycle of this species, are providing openings that may have been provided by native grazing animals and periodic, naturally-occurring fires (USFWS, 1995f).

Biological Conclusion:

The majority of the project area is in an alluvial floodplain area with moderately acidic soils that are prone to flooding. Potential habitat does occur along clearings and edges of upland woods. A survey for this plant was conducted on August 1, 2006 for potential individuals throughout the project area and none were identified. A search of the NHP database of rare species and unique habitats, conducted on July 28, 2006, shows no occurrences of this species in the project area. It is concluded that the project will not impact this endangered species.

2.5.1.3 Lichen

2.5.1.3.1 *Gymnoderma lineare* (Rock Gnome Lichen)

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

The rock gnome lichen is endemic to the southern Appalachian Mountains of North Carolina and Tennessee, where it is limited to 32 populations. Only seven of the remaining 32 populations cover an area larger than 2 square meters (2.4 square yards). Most populations are 1 meter (3.3 feet) or less in size (USFWS, 1997b).

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

Biological Conclusion:

Because this project involves degraded streams and lacks other habitat criteria necessary, this project is not likely to affect the threatened solitary rock gnome lichen populations. A Biological Conclusion of No Effect is expected from the proposed project construction.

2.6 Cultural Resources

Due the proximity of two previously recorded archaeological sites to the project area, an archaeological survey was completed for this project. In addition, a letter was sent to both the North Carolina State Historic Preservation Office (SHPO) and Eastern Band of Cherokee Indians' Tribal Historic Preservation Office (THPO), requesting a review and comment for the potential of cultural resources in the vicinity of the Puzzle Creek restoration site. Upon completion of the survey by Archaeological Consultants of the Carolinas, Inc. it was determined no significant archeological or architectural resources were located within the project boundaries. On December 1, 2006, the archaeological survey report was submitted to the SHPO and THPO for review. On January 12, 2007, Baker NY received a letter from the SHPO concurring with findings from the archaeological survey that no further archaeological investigation be conducted in connection with this project. The THPO submitted a concurrence letter on January 24, 2007. A copy of the SHPO and THPO correspondence is included in Appendix A.

2.7 Potential Constraints

2.7.1 Potentially Hazardous Environmental Sites

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

2.7.1.1 Property Ownership and Boundary

The two properties that encompass the Puzzle Creek Project Site are owned by Raymond G. and Katherine Schafer, and Charles William, Jr. and Pamela Philbeck. Baker has established a conservation easement on the two properties. The easement plat and deeds have been recorded at the Rutherford County courthouse and sent to the NC State Property office. This enables Baker to proceed with the project and to restrict the land-use in perpetuity through conservation easements.

2.7.1.2 Site Access

The site can be accessed for construction and post-restoration monitoring from the state road and from paths throughout both properties. Construction access and staging areas will be identified during final design.

2.7.1.3 Utilities

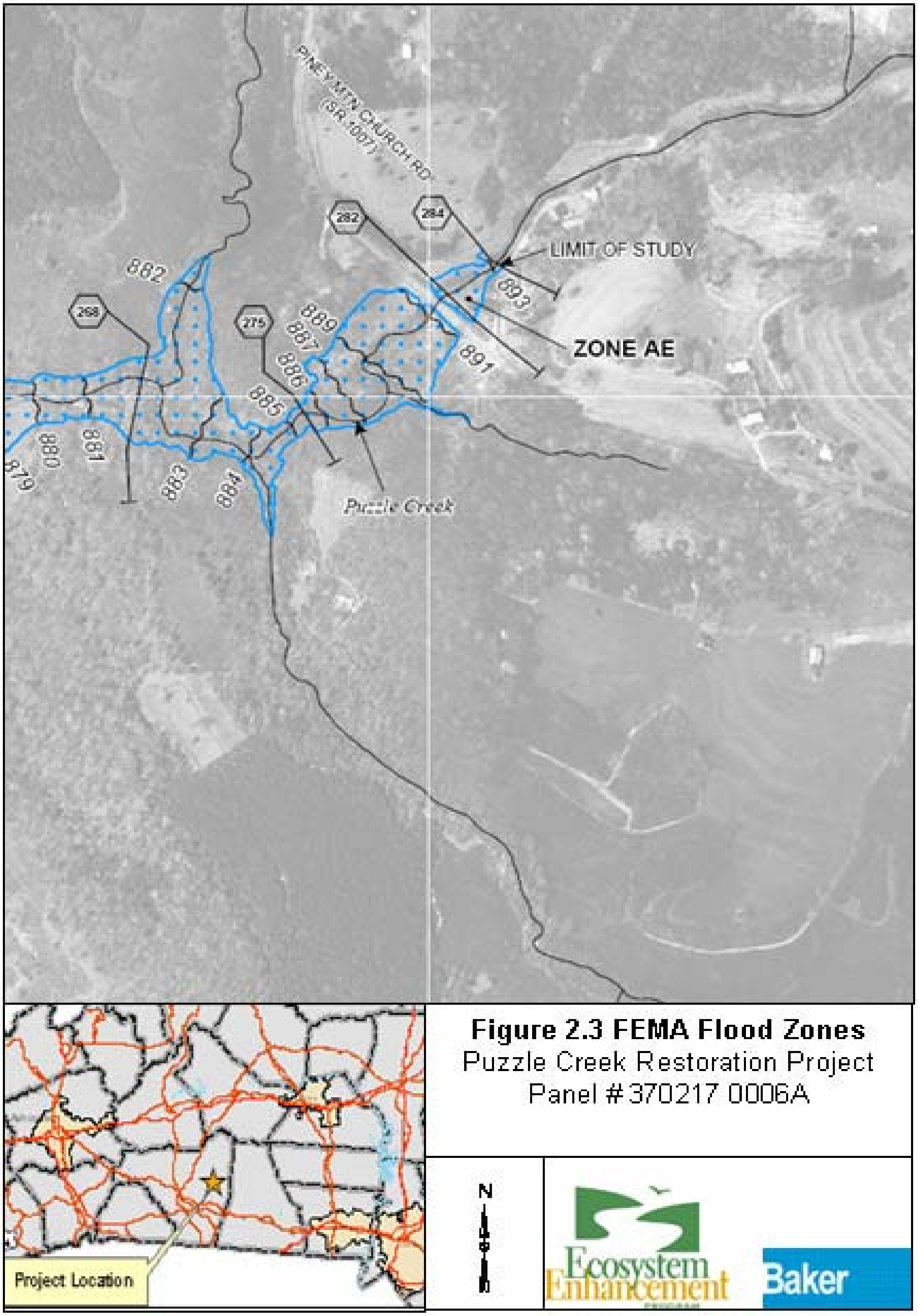
There are no utility services which traverse or follow adjacent to the creek in the project area.

2.7.1.4 Hydrologic Trespass and Floodplain Characterization

The FEMA Flood Insurance Rate Map (FIRM) for Rutherford County, (Map Number 370217 0006 A) indicates that the project is located within a regulatory floodplain, Figure 2.3 illustrates the FEMA mapping near the site.

As discussed in Section 6.6 several hundred feet of project reach lies within Zone A of the regulatory floodplain. Flood modeling is not required for impacts of less than 5 acres in a Zone A designated area. The impact from the restoration work located in the Zone A designated area is less than this threshold. Baker has also consulted with the Rutherford County Floodplain Administrator to discuss local floodplain management requirements. Because the design components will not increase flooding, Rutherford County does not require detailed flood modeling on the proposed channel work. However, a memorandum will be submitted to the County to document the project and certify that the work will not increase flooding.

Figure 2.3: FEMA Floodplain Map



3.0 PROJECT SITE STREAMS (EXISTING CONDITIONS)

3.1 Existing Channel Geomorphic Characterization and Classification

Baker performed a total station survey of the project reaches and floodplain to capture existing topography and measure geomorphic conditions. Along with providing a longitudinal profile, this survey included 5 specific cross-sections. Baker also collected substrate samples to characterize stream sediments. Figure 3.1 illustrates the locations of the cross-section surveys on the project reaches. While only 5 specific cross - sections were surveyed, channel shape was well-defined throughout the project during the existing conditions survey by capturing all relevant slope breaks both cross-sectionally and in the profile. An example of the surveyed cross-sectional data is provided in Appendix C (X5 on Puzzle Creek before the confluence with the unnamed tributary as shown on Figure 3.1). Cumulative frequency graphs based on sediment data are also included in Appendix C. The existing longitudinal profile is shown on the construction drawings.

The next sections of this report will qualitatively and quantitatively describe the designated project reaches: reach 1 of the unnamed tributary, unnamed tributary reach 2, Puzzle Creek reach 1, and Puzzle Creek reach 2. The existing length, drainage area, and regional curve data for these reaches are provided in Table 3.1.

Figure 3.1
Project Reaches and Surveyed Cross-section Locations

Puzzle Creek
Restoration Project

Legend

Cross-section
Existing Stream
Easement
Proposed Design

Rutherford County

0 250 500 Feet

N

Ecosystem Enhancement Program

Baker

Table 3.1 Puzzle Restoration Site Project Existing Reach Descriptions					
Reach	**Reach Length (LF)**	**Watershed Size (square miles)**	**Rural Piedmont Regional Curve (Wbkf) (ft)**	**Rural Piedmont Regional Curve (Dbkf) (ft)**	**Rural Piedmont Regional Curve (Abkf) (sq ft)**
Unnamed Tributary start of Reach 1	~2975 LF	1.6	14.6	1.74	29.5
Unnamed Tributary end of Reach 1		~1.60	14.6	1.74	29.5
Unnamed Tributary start of Reach 2	~250 LF	"	"	"	"
Unnamed Tributary end of Reach 2		"	"	"	"
Puzzle Creek start of Reach 1	~1023 LF	2.58	17.9	2.03	40.8
Puzzle Creek end of Reach 1		"	"	"	"
Puzzle Creek start of Reach 2	~845 LF	4.18	22	2.37	56.7
Puzzle Creek end of Reach 2		5.46	24.7	2.58	68
Total Existing Stream Length	~5093 LF				

3.1.1 Reach 1 of Unnamed Tributary

Reach 1 of the unnamed tributary flows west then northwest from the upstream end of the Schafer property boundary to a break in the easement just upstream of a significant grade control in the form of a rock outcropping waterfall. The reach is by far the longest on the restoration site at almost 3,000 linear feet. Four cross sections were surveyed on this reach: one pool and three riffles.

Table 3.2 summarizes the geomorphic parameters of reach 1 of the unnamed tributary. For these cross sections, "bankfull" indicators were not very obvious. The chosen indicators depict some disconnection from the floodplain as evident in the low entrenchment ratios. The HEC-RAS hydraulic model gives a more detailed picture of the reach than the individual cross-sections which also showed a disconnect between the floodplain and sections of Puzzle Creek. Portions of the reach have been channelized - a common, but significant geomorphic event that causes channel degradation. Width-to-depth ratios suggest that the stream may have experienced some widening or that it has tendencies of a C-channel. Due to the presence of bedrock, widening would occur after the stream degraded to bedrock. Widening is often limited by the cohesion of the bank material and by vegetation that establishes post-disturbance. These can be significant factors in lateral stability. Mature trees are limiting lateral migration in this reach, leaving a fairly stable but low sinuosity stream with variable floodplain disconnection depending on the depth of the bedrock. At the upper portion of the reach, mismatched bedform (riffles in meanders) and encroachment on the left valley wall produce stability issues to be addressed by restoration. In addition, the interval of flooding is some segments of the reach is somewhat less frequent than desired for maximum ecological function. However, the floodplain and its vegetation are mature and minimization of floodplain impacts is an important consideration. The width of the active floodplain is on the order of 100-200' in portions of reach 1 where flooding of the valley is likely to occur. In other areas, the width of the active floodplain is much smaller since the active flooded area consists of benches and developing features. In general, bedform diversity does exist in reach 1. In certain areas, stream banks are eroding and trees are at risk of falling into the channel.

The primary issues to be addressed are slight to moderate disconnection from the floodplain, localized erosion of streambanks and impingement on valley walls, sub-reaches with bed features that are inconsistent with the plan form of the stream, non-native vegetation, and severely leaning trees that need to be cut back or removed to avoid debris jams during the project recovery period. The restoration efforts will focus on these issues.

Table 3.2
Unnamed Tributary Reach 1 Cross-section Data

Parameter	Unnamed Tributary, Reach 1 XS #1	Unnamed Tributary, Reach 1 XS #2	Unnamed Tributary, Reach 1 XS #3	Unnamed Tributary, Reach 1 XS #4	Rural Piedmont Regional Curve	Unit of Measurement
Feature Type	Head of Riffle	Run/Pool	Head of Riffle	Riffle/Run		
Bankfull Width (W_{bkf})	17.6	18.2	19.8	19	14.6	Feet
Bankfull Mean Depth (d_{bkf})	1.45	1.86	1.7	1.81	1.74	Feet
Cross-sectional Area (A_{bkf})	25.4	33.7	33.7	34.4	29.5	Square feet
Width/Depth Ratio (W/D ratio)	12.2	N/A	11.7	10.5		
Bankfull Max Depth (d_{mbkf})	2.15	3.32	2.61	2.72		Feet
Floodprone Area Width (W_{fpa})	~30	>90	>180	~30		Feet
Entrenchment Ratio (ER)	1.7	N/A	>4.1	1.8		
d_{16}	1.5					mm
d_{50}	20					mm
d_{84}	64					mm
Water Surface Slope (S)	0.0086					Feet per foot

Channel Sinuosity (K)	1.18					
Rosgen Stream Type[2]	B4c	N/A (Pool)	C44	B4c		
Notes:						

3.1.2 Reach 2 of Unnamed Tributary

Reach 2 of the unnamed tributary starts below the base of the waterfall and flows primarily north, ending at the confluence of the unnamed tributary and Puzzle Creek, which enters from the east. Reach 2 is short, and fairly stable. The valley is confined near the waterfall and transitions from very steep to flat as the creek flows through the downstream alluvial valley.

The channel through this reach is relatively stable although some local areas of erosion are present. Diversity in bed features is found in the reach, along with bedrock. Most of the reach is stable because the banks are well-vegetated and the channel bed elevation is governed by bedrock. Local areas of erosion are present and non-native invasive vegetation is present.

The primary issues are to address are local bank erosion and non-native vegetation in the reach.

3.1.3 Puzzle Creek Reach 1

The upper portion of the reach flows southwest; starting from just below the bridge crossing on Piney Mountain Church Road (SR 1007). Steep riffles, eroding banks, and overly wide sections are present in this segment. Approximately 200 feet downstream, the stream encroaches upon the valley wall on the left side of the floodplain. At this point, the stream is forced to turn west whereupon it flows towards a pinch point in the valley. At the pinch point, it flows against the valley wall on the right side of the valley and is forced in a southwesterly direction to the confluence. It is straight and without bedform diversity below this bend, attempting to meander, but thus far only resulting in low flow lateral bars. The stream flows to the confluence with the unnamed tributary at a nearly right angle to the tributary flow.

Table 3.3 summarizes the geomorphic parameters from one cross-section taken on Puzzle Creek reach 1. A wide range of channel dimensions exist in the reach and are the primary evidence of instability. Incision is not severe in most portions of the reach, and a low floodplain on the inside bends provides frequent floodplain connectivity. However, the overall bedform diversity is fair, pool quality is low, and riffles range from steep to flat. Some of the bedforms are clogged with debris jams. Lateral and mid-channel bar development characterize much of the reach. The stream banks are protected by a single line of trees beyond which is a grassed field. In certain areas, the stream has cut into the banks resulting in fallen trees in the channel and unprotected banks. Despite vegetation, the encroachment on the left valley wall threatens immediate and long term stability due to the steepness and undercut nature of the left bank. A small tributary enters just upstream of this area.

The primary issues to be addressed are channelization, incision, erosion of stream banks and impingement on valley walls, poor bedform diversity, excessive channel debris causing lateral and vertical instability, non-native vegetation, and a sparse riparian buffer. Restoration will address these issues.

Table 3.3			
Representative Geomorphic Data for Puzzle Creek			
Parameter	**Puzzle Creek Reach 1 XS #5**	**Regional Curve**	**Unit of Measurement**
Feature Type	Riffle		
Bankfull Width (W_{bkf})	23.8	17.9	Feet
Bankfull Mean Depth (d_{bkf})	2.29	2.03	Feet
Cross-sectional Area (A_{bkf})	54.47	40.8	Square feet
Width/Depth Ratio (W/D ratio)	10.4		
Bankfull Max Depth (d_{mbkf})	3.38		Feet
Floodprone Area Width (W_{fpa})	~60		Feet
Entrenchment Ratio (ER)	2.6		
d_{16}	1.2		mm
d_{50}	11.8		mm
d_{84}	38.3		mm
Water Surface Slope (S)	0.008		Feet per foot
Channel Sinuosity (K)	1.17		
Rosgen Stream Type[2]	C4		

3.1.4 Puzzle Creek Reach 2

Downstream of its confluence with reach 2 of the unnamed tributary, Puzzle Creek is referred to as reach 2. The reach begins with a long straight run, and then enters a 90-degree bend to the right, a short, straight run, followed by a 180-degree meander that impinges on the right valley wall just after the apex of the bend; a tributary named Tom's Branch draining roughly 1.3 square miles enters in the bend. After this bend, a straight section carries flow to the end of the project. Debris jams are a significant factor in channel hydraulics at both low and high flow. A remnant horseshoe-shaped meander cutoff is present in the area of the 180-degree bend; considerable sand deposition has occurred in the cutoff, which appears to serve flood relief and sediment storage functions.

No cross-sections were surveyed in reach 2; however, surface model cross-sectional data from the existing conditions survey was analyzed extensively during the hydraulic modeling phase. The degree of floodplain connectivity is dependent on various debris jams, which significantly affect water depth. The floodplain is flat and wide, although the channel meanders into the right valley wall in parts of the reach. The bedform diversity is dominated by debris jams and sand deposition. The meander cutoff and current location of the channel are evidence of significant channel adjustments which have occurred as the stream attempts to balance channelization in this segment and in the downstream reach beyond the restoration property. The stream banks are well vegetated and the floodplain vegetation is a relatively mature bottomland forest.

The primary issues to be addressed are incision, erosion of stream banks and impingement on the right valley wall, excessive channel debris causing lateral and vertical instability, and non-native vegetation.

3.2 Channel Stability Assessment

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

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

Observed stream response to induced instability, as computed using Simon's (1989) Channel Evolution Model, describe extensive modifications to channel form resulting in profile, cross-sectional, and plan form changes which often take decades or longer to achieve resolution. Gross modifications or a combination of modifications to stream system variables often upsets the balance of Lane's relationship and induces instability. Channelization, dredging, changing land use, removal of streamside vegetation, upstream or downstream channel modifications, and/or change in other hydrologic variables result in adjustments in the channel dimension, profile, and pattern to compensate for the new condition(s). All of these disturbances can occur in both urban and rural environments.

The channels within the project area are perennial, have experienced prior channelization and watershed disturbance, and are currently wooded or partially wooded with adjacent grassed fields. Channel stability was assessed with the following methods: qualitative and quantitative site observations, watershed modeling, regional hydrologic comparison, comprehensive site-specific hydraulic modeling using detailed topographic data collected for the project, and site-specific hydraulic sediment modeling. Conclusions reached from these methods were used to define site stability and determine appropriate restoration approaches for each sub-reach. Specifics are further elaborated upon in subsequent sections of this report.

3.3 Assessment of Channel Forming Discharge

Baker engaged several methods to assess channel-forming discharge. In stable systems, the "bankfull" or main channel top-of-bank discharge represents the channel-forming discharge. It is widely accepted that the bankfull discharge has a recurrence interval in the range of 1 to 2 years (1.5 years is a commonly used average). Baker verified during assessment for this project that, "…slight differences in water surface elevation make large differences in discharge and thus in recurrence interval" (Leopold et al., 1964). It was also observed that channel roughness in the form of debris jams and bank vegetation is responsible for decreasing the return interval of floodplain flows due to their effect on water surface elevations. Flows in the 1-year to 5-year range of return intervals were focused on for their relative differences in resulting water surface elevations and their resulting contribution to floodplain processes.

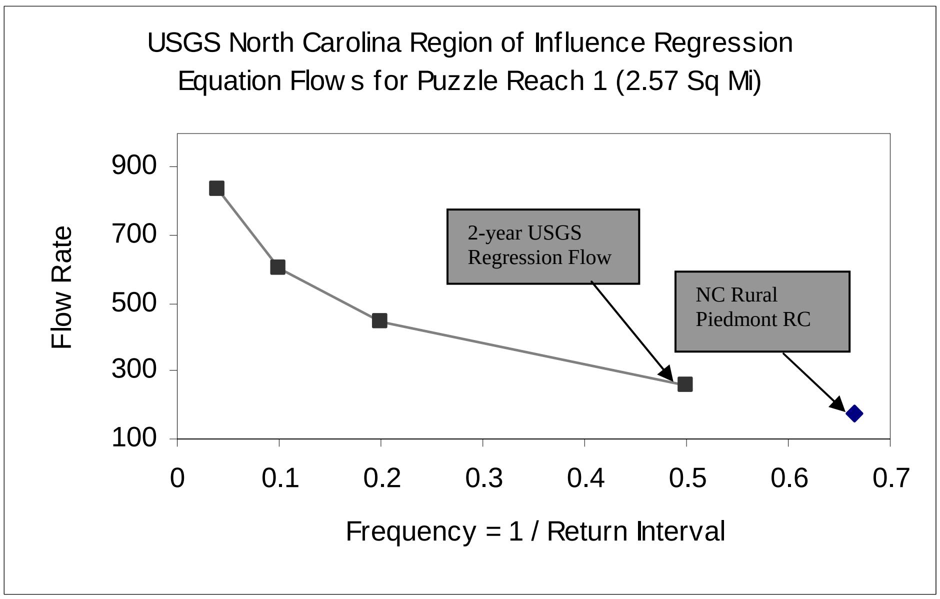
3.3.1 Regional Curve Equations

Publicly available and in-house bankfull regional curves are available for a range of stream types and physiographic provinces. The North Carolina Mountain (Harman et al., 2000) and Rural Piedmont Regional Curves (Harman et al., 1999) were used for comparison to other more site-specific means of estimating bankfull discharge. The Puzzle Creek restoration site is in a watershed which has foothill and Piedmont influences.

3.3.2 USGS Regression Equations

North Carolina USGS Regionalized Regression Equations (Pope et al. 2001) incorporate latitude, longitude, and drainage area information when used to calculate flood estimates based on data from USGS gages. These regression equations were used to calculate the estimates for the 2-, 5-, 10-, and 25-year floods. An example for Puzzle Creek reach 1 is plotted in Figure 3.2 below, with the NC regional curve flow for the rural Piedmont at the far right (assumed return interval of 1.5 or 0.66 frequency for plotting purposes). These regression equation flows were used as comparative estimates of different flow frequencies.

Figure 3.2. USGS Regional Regression Equation Flood Events



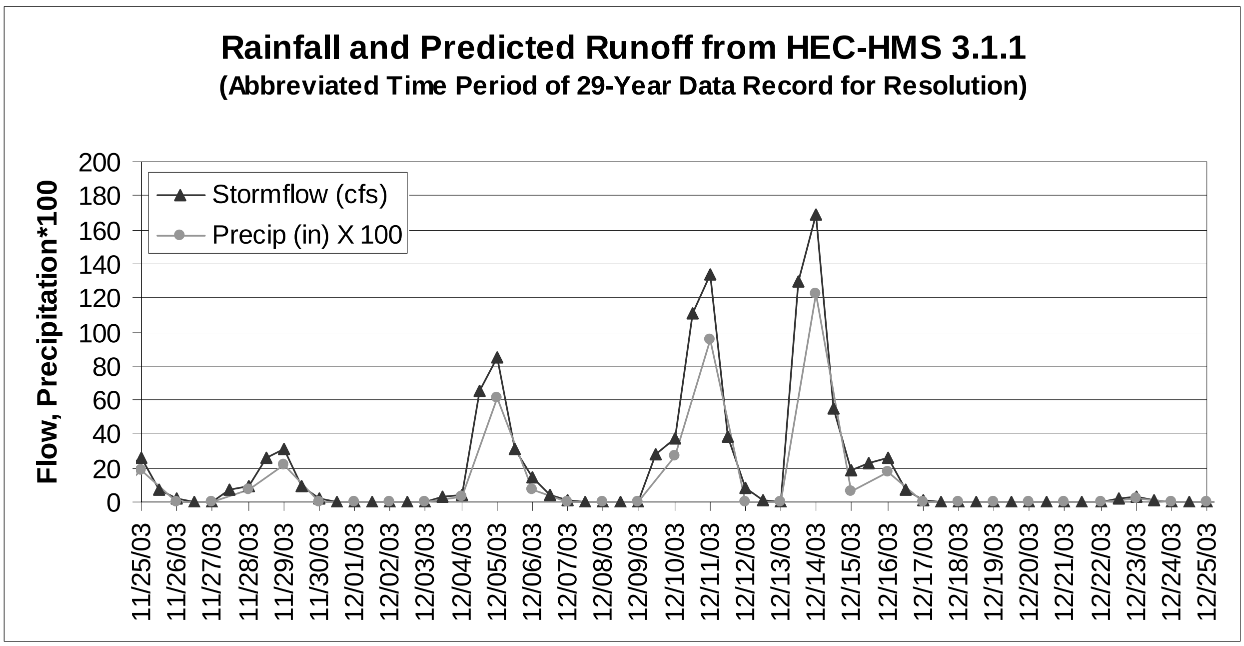
3.3.3 Watershed Modeling Using HEC-HMS 3.0.0

To further understand watershed hydrology, a watershed model was developed in HEC-HMS using topographic data (elevation files are LIDAR contours data obtained from the North Carolina Flood Mapping Program (www.ncfloodmaps.com), data release: March 2005), USGS National Landcover dataset (http://seamless.usgs.gov/) (2001), and NRCS Soil Data Mart (http://soildatamart.nrcs.usda.gov/) to estimate the curve number and lag time input data using the SCS Curve Number loss method. Two methods of flow modeling were investigated in an attempt to produce estimations of the channel-forming discharge.

The first method uses long-term rainfall data, processing it with HMS to create a long-term hydrograph from which a flow frequency or flow duration curve was extracted. The results of this method were used with discretion due to limitations of the HMS Model, feasibility and time constraints in developing input data, and limitations in modeling low flows. Baker obtained 29 years of daily total rainfall data from NOAA's National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html) for Forest City, NC, the closest location to the project site (~5 miles) with long term rainfall data. The HEC-HMS 3.0.0 "Specified Hyetograph" meteorological model can accept a long term hyetograph and run the model to produce the corresponding hydrograph. The SCS Curve Number Method is the "Loss Method" which determines the quantity of rainfall which is converted to runoff. Figure 3.3 depicts an abbreviated period of the rainfall and resulting output hydrograph- it depicts the runoff at the downstream end of the entire project for a 1-month period of the 29 year record. Note that the precipitation is multiplied by 100 for plotting comparison.

This study and future studies must consider the following shortcomings in producing a flow frequency curve in this manner: the rainfall data was not detailed enough (need 5 or 15-minute totals rather than daily), the SCS Curve Number Method is not suitable for the small events of interest in assessing channel-forming discharge, the Curve Number loss method does not consider antecedent moisture conditions and is not suitable for period of record data, and stream gage data is needed to obtain hydrograph data with which to calibrate the loss method, and other loss methods available in the HMS model may require exhaustive research to provide the appropriate input parameters.

Figure 3.3. HMS Input (Rainfall) and Output (Runoff) at Downstream Terminus of Project for Abbreviated Time Period



** Precipitation is multiplied by 100 for plotting comparison.*

The product of the flow frequency curve and the sediment discharge curve for a stream can be used to estimate the single discharge that moves the most sediment over time, or the most "effective" discharge. Sediment rating curves relating flow versus sediment discharge were developed in HEC-RAS (as discussed below and in Section 6.4 "Sediment Transport"). These calculations are based on the site-specific hydraulic model produced from cross-sectional and longitudinal data. The product of the sediment discharge and the flow frequency curve yielded a peak at the effective discharge. Secondary peaks often result and may coincide with the return interval of other hydraulically relevant flow, such as the flow corresponding with the "inner berm" depositional feature.

Figure 3.4 depicts the discharge rating curve overlapped on a cross-section in Puzzle Creek reach 2. As described in Section 3.3, slight differences in water surface elevation make large differences in discharge in the channel section. And as shown in Figure 3.2, small differences in the estimate of discharge correspond to relatively large differences in the recurrence interval of the flow. The product of the flow frequency curve and the sediment rating curve produce cumulative sediment discharge are depicted in Figure 3.5. For the Puzzle Creek outlet, where the watershed area is 5.46 square miles, the effective discharge curve reaches a maximum at a flow discharge of 500 cfs, a value slightly larger than the 2-year discharge predicted by the USGS Regression Equation (465 cfs). This difference could be related to un-calibrated roughness estimation, but the over-estimation of the effective discharge is not surprising given the issues present in developing a flow duration curve with the HMS model, which underestimates or omits lower flows due to initial abstraction calculations in the SCS Method Curve Number Method. In an attempt to rectify this limitation, another method was investigated to develop an adequate flow duration curve; this regional duration curve method is described in the next sub-section.

Figure 3.4 Stage-Discharge Relationship for Cross-section

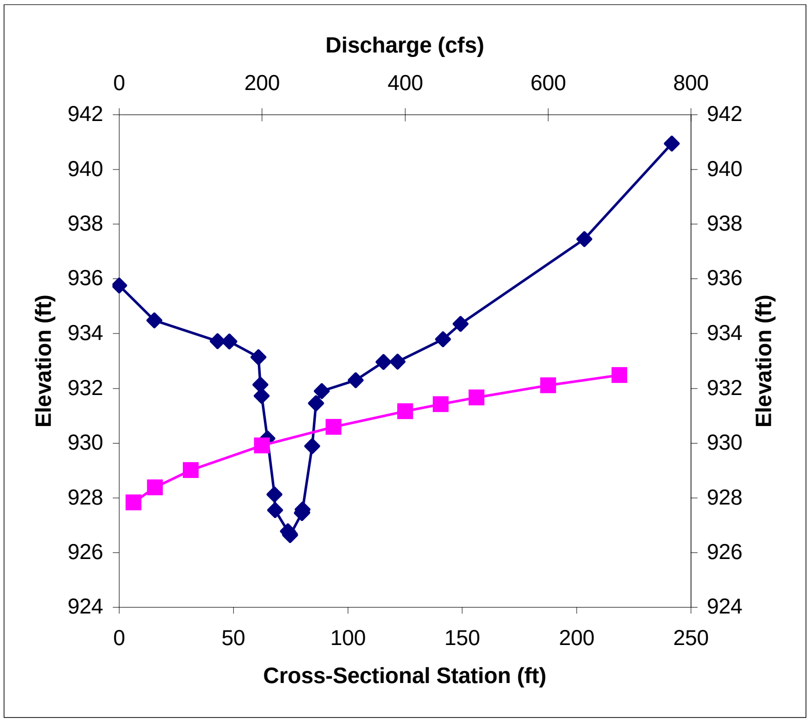
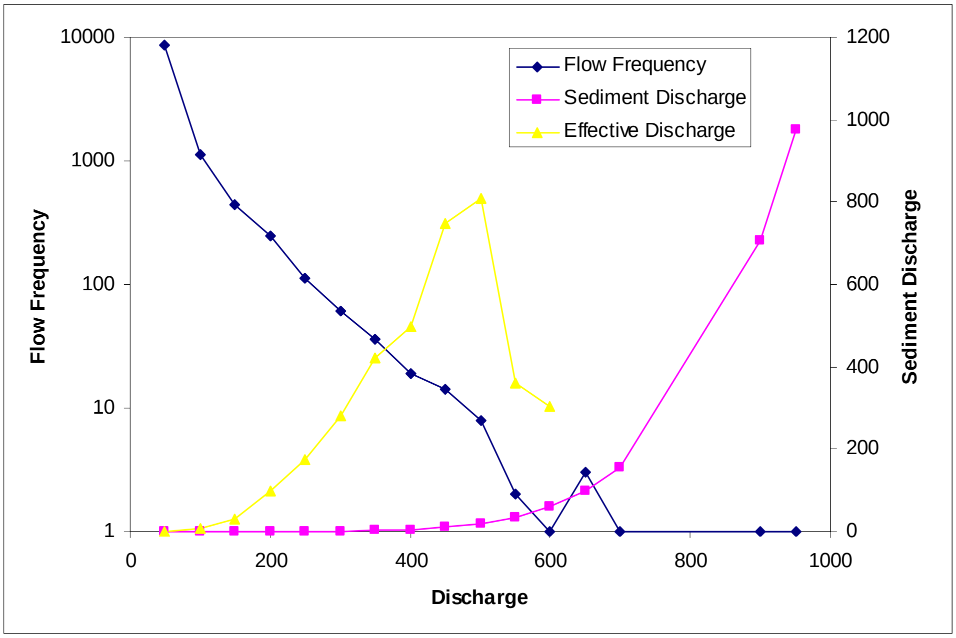


Figure 3.5 Effective Discharge Plot for Puzzle Creek Reach 2



The second method used to estimate channel-forming flow uses a table of rainfall frequency to extract a specific precipitation value as an input value for a specific design event.

Baker obtained location-specific rainfall frequency (and thus return interval) data from the NOAA Atlas 14 precipitation frequency data server (http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html). It contains data for the partial duration and annual maxima series. The prevailing assumption in using this data is that the X-year rainfall produces the X-year flow event (a commonly used assumption in the design of hydraulic structures). With this assumption, records from long-term rainfall gages in the area produce one value for the X-year rainfall event which is run through the model to determine the X-year flow. The lack of calibration data is still an issue using this method. NOAA Atlas 14 predicts 1-year and 2-year rainfall frequency data which were run through the HMS model to produce flows for comparison to flow estimates from other sources. The results were consistently high, suggesting the need to calibrate the watershed model in order to obtain more reliable data. With calibration, the method could produce an acceptable way to bracket the channel-forming flow.

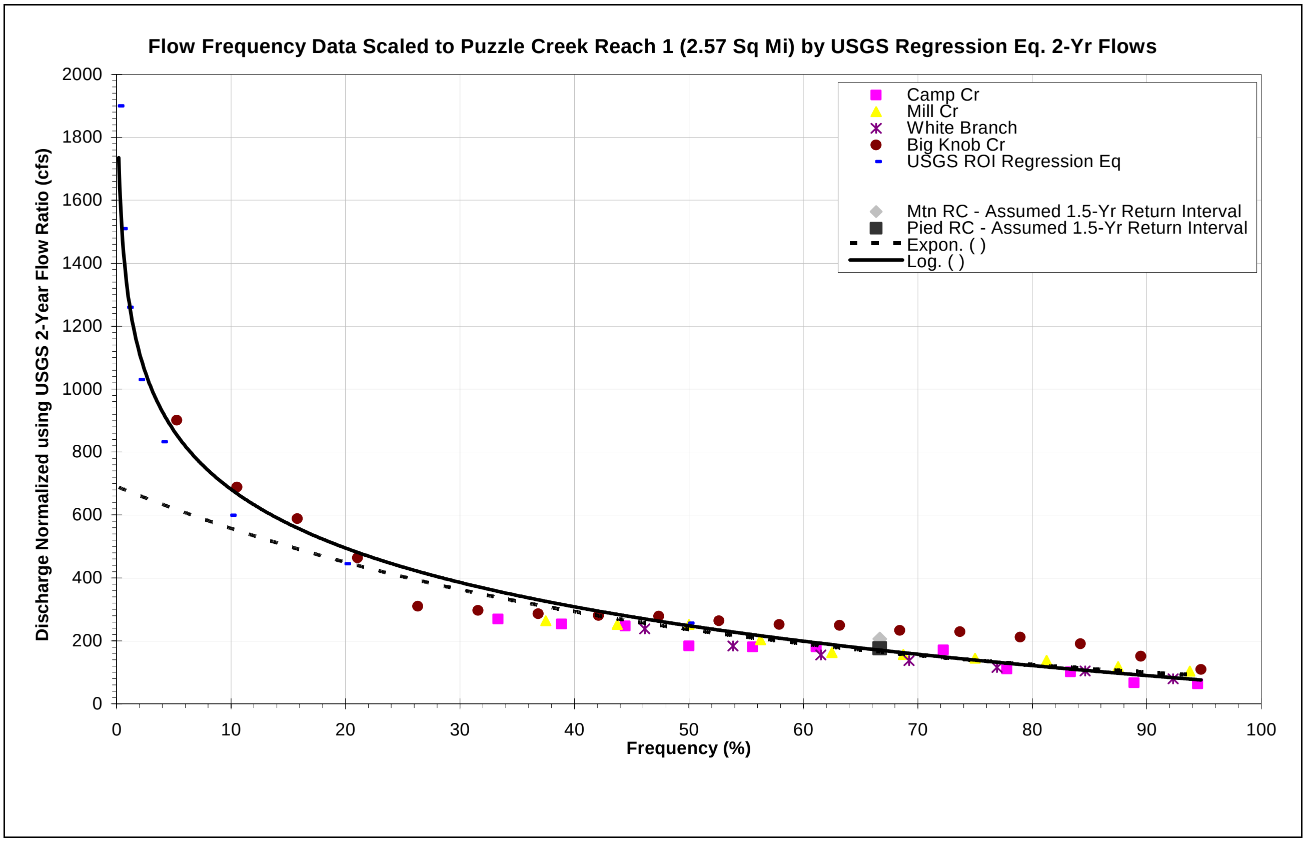
3.3.4 Regional Duration Curve Method

The regional duration curve method can be used (in conjunction with a flow rating curve) for effective flow calculations based on sediment transport, or as a stand-alone method to estimate channel-forming flow based on an assumed return interval.

Due to the lack of USGS gage data directly upstream or downstream of the vast majority of restoration sites, a regional-scaling method can be used to obtain a flow duration curve using gage data from nearby watersheds with similar characteristics (Biedenharn et al., 2000). Research has suggested that some ratio of flows can be used to normalize data from a gage upstream or downstream or in a watershed adjacent to the watershed of interest; the USGS multi-variate regression equations consider drainage area, channel slope, and slope length, making the relationship of Q/Q2 the best option, where Q2 is the 2-year USGS flow at the gage and Q is the flow from that gage's flow duration curve (Bledsoe, et al., 2002).

A number of gages were reviewed for the similarity of their watershed size and land use to the restoration watershed and for hydrologic consistency over their period of record; the best matches were scaled to produce a flow frequency curve for the restoration watershed. After being normalized by the Q2 flow for their watershed, they were multiplied by the Q2 flow for the restoration reach (in this case, Puzzle Creek reach 1). The resulting data points were fit with a best fit line estimating flow frequency as shown in Figure 3.6. Note that the large events (low frequency) do not coincide as well as the smaller events - most of the gages used here have a period of record much smaller than the return interval for the large events (15-20 years of gage data is often times inadequate at estimating the magnitude of a 100-year event). The regional curve and USGS regression flows are shown on the plot as reference flows. The basic procedure for this method is detailed in the reference above.

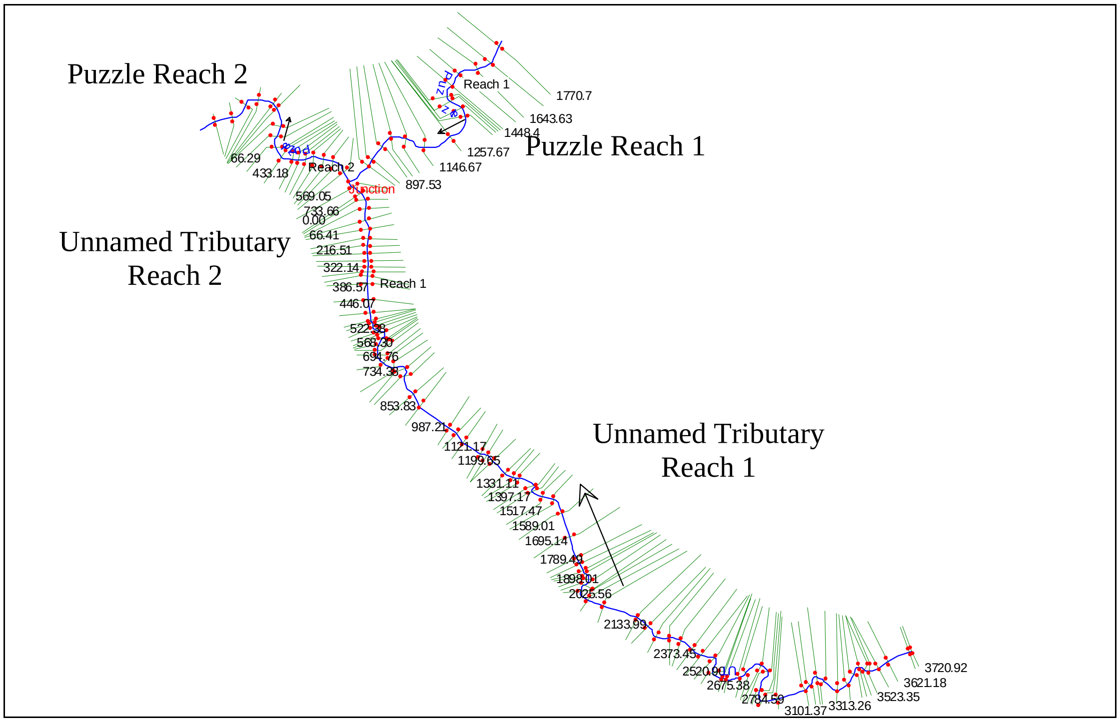
Figure 3.6 Regional Duration Curve for Puzzle Creek Reach 2



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

Extensive topographic data was collected during the existing conditions survey. This information was used to create a three-dimensional topographic surface, or Triangulated Irregular Network (TIN), in AutoCAD, from which it is possible to extract cross-sections at desired intervals and export them into HEC-RAS. By this method, a detailed hydraulic model was created in HEC-RAS (Figure 3.7 depicts the location of the cross-sections in green overlain on the reaches).

Figure 3.7 Puzzle Creek Restoration Reach HEC-RAS Hydraulic Model



The HEC-RAS 3.1.3 hydraulic model was refined in an attempt to model site conditions such as debris jams, vegetation, confluences, and other hydraulic conditions. The result was a detailed model that was used to determine the stage-discharge relationship throughout the restoration reach. In this manner, the model was used to assess the degree of connectivity to the floodplain that segments of stream exhibited at different modeled flow rates (mainly those flow rates thought to be reasonable estimates of the bankfull flow as determined from the previously described methods). Physical indicators such as the top of the bank and depositional benches and point bars were used to assess which flow rates of the estimates available were most consistent estimates of bankfull flow in each of the design reaches.

Using the USGS regression flows, the model was used to produce estimates of frequency of floodplain inundation in incised reaches. This brings to mind the earlier reference to Leopold which states that small stage differences can equate to large differences in discharge (and hence frequency of floodplain inundation) (Leopold, 1964). If modeling can show how often the floodplain is subject to inundation, that information can be used in design to determine the degree of necessity to modify a section which is incised by some distance. If the 5-year flow tops the floodplain and the 2-year does not, an interpolation can determine the interval of floodplain inundation and a judgment can be made on whether the frequency of inundation is acceptable given the relative stability of the channel.

To determine floodplain connectivity for the unnamed tributary, HEC-RAS data were plotted longitudinally using water surface and top-of-bank (reflected as “LOB” or “ROB” for left and right banks) elevations which are depicted in Figure 3.8 below. The water surface is for the chosen design discharge, 140 cfs. Cross-sectional data (see example in Figure 3.9) was also used to more carefully scrutinize water surface data and assess coincidence with top of bank, benches, slope breaks, and other depositional features throughout reaches of constant drainage area.

Figure 3.8 Existing Longitudinal Bed Profile for Unnamed Tributary Reaches 1 and 2 and HEC-RAS Water Surface Profile for Design Flow (140 cfs)

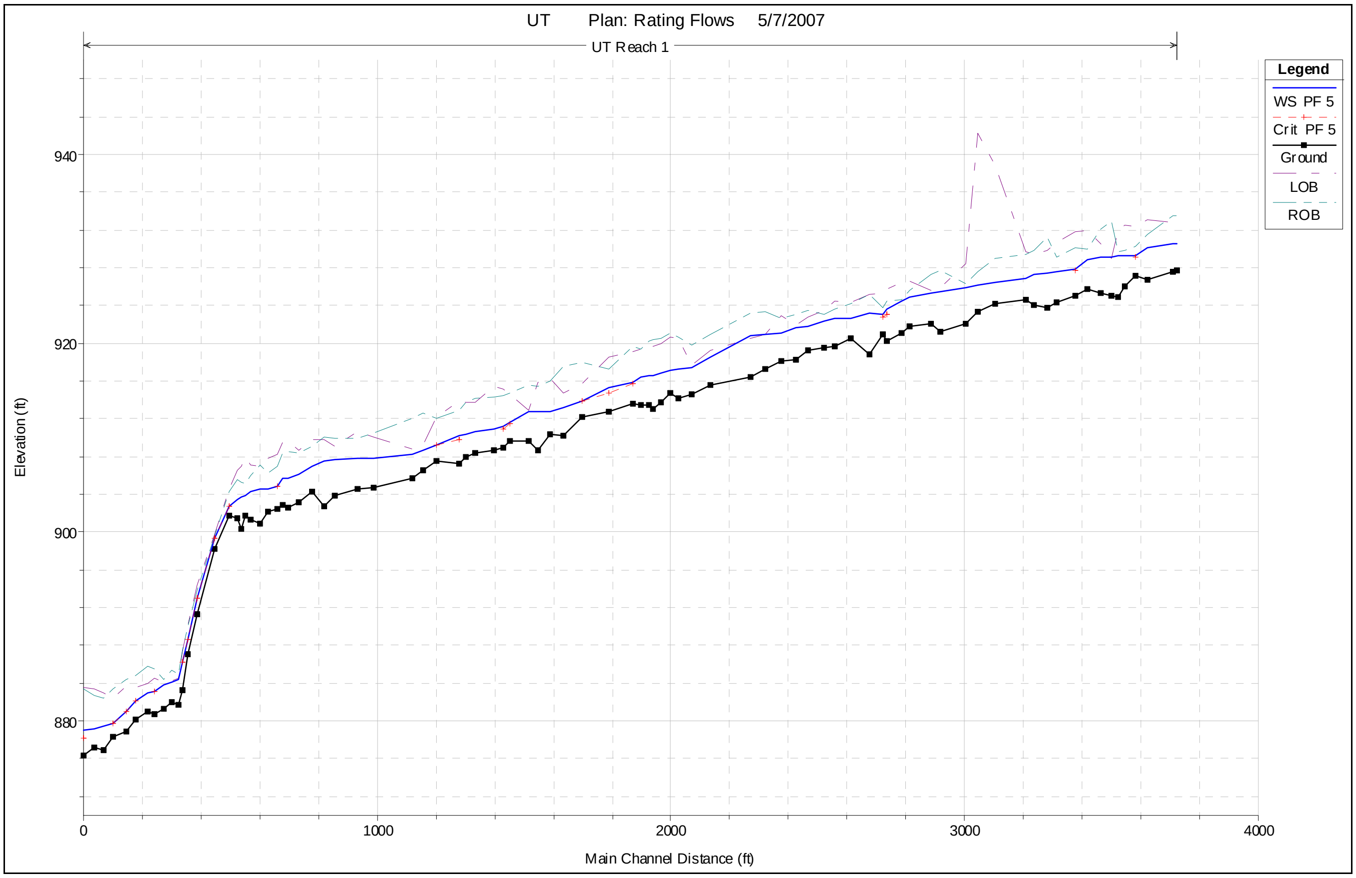
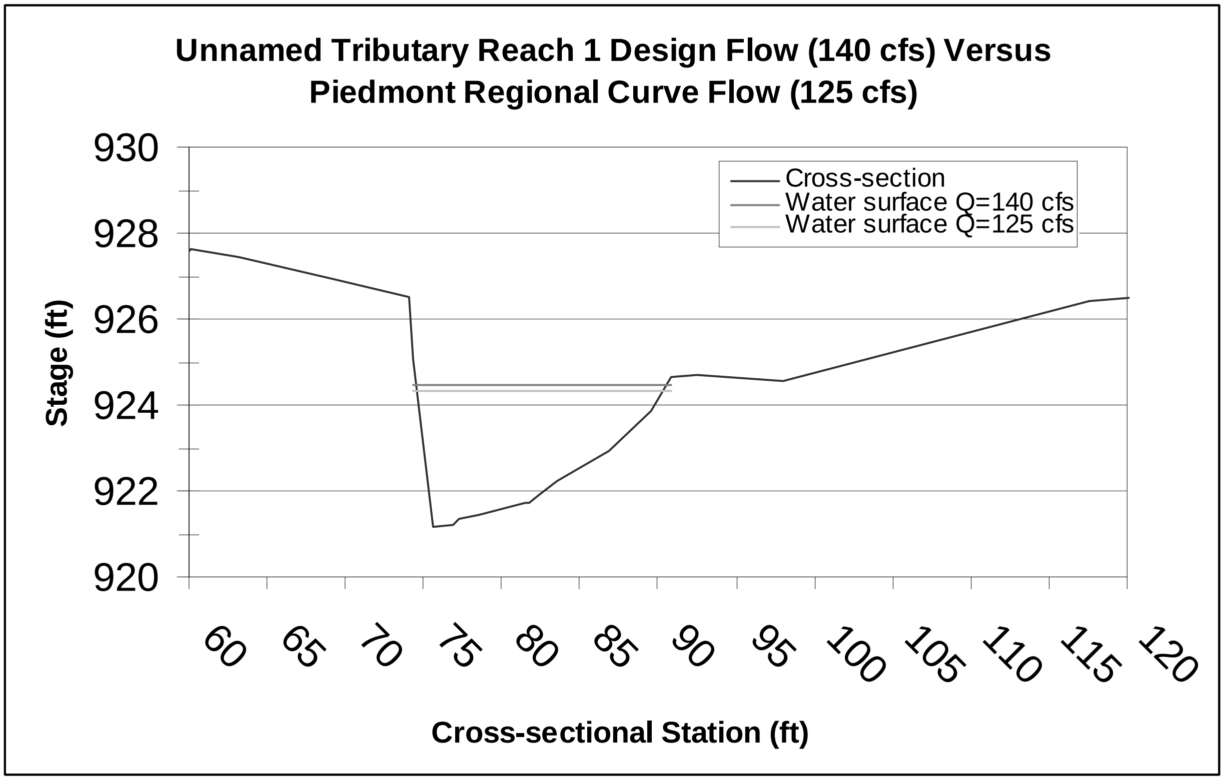


Figure 3.9 Cross-section and HEC-RAS Water Surface Elevations for Design Flow (140 cfs) and 1.6 Square Mile Rural Piedmont Regional Curve Flow (125 cfs) at Arbitrary Section of Unnamed Tributary Reach 1



3.4 Conclusions for Design Discharge

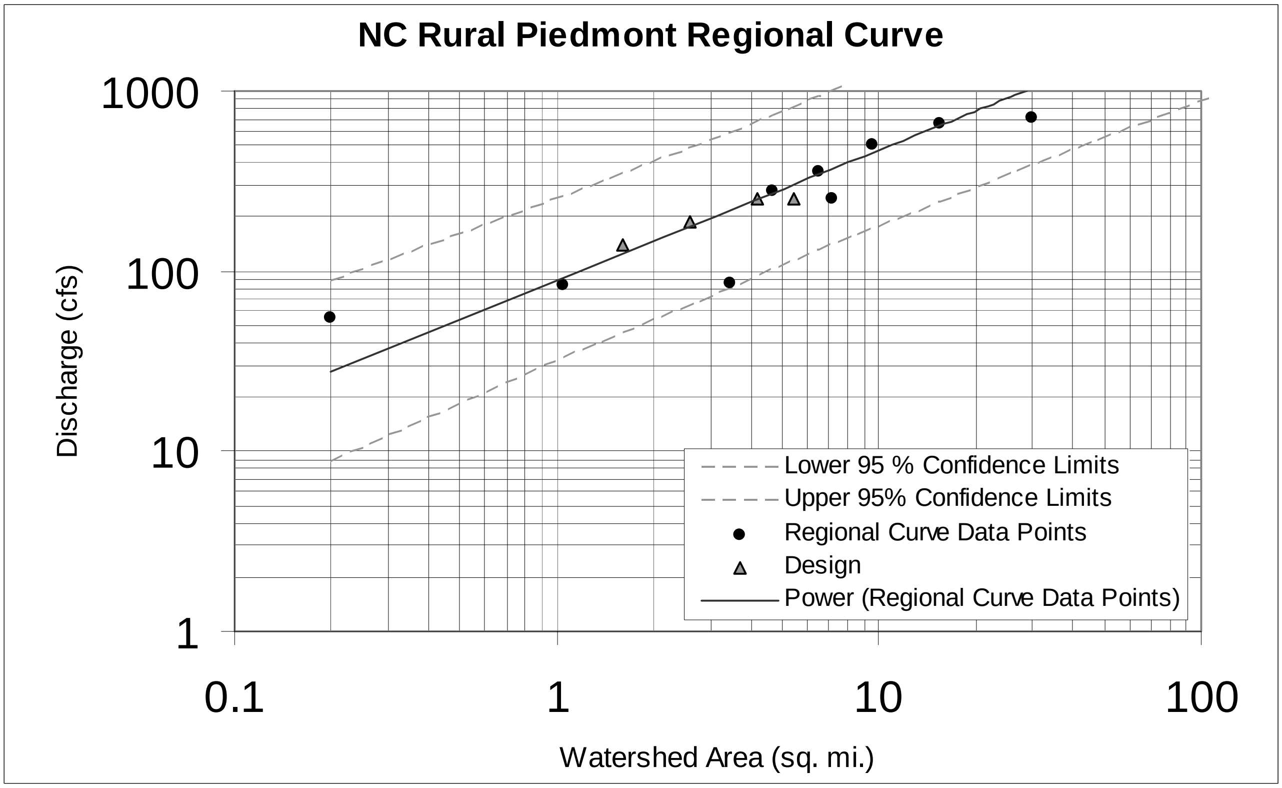
The methods discussed in Section 3.3 were used to build confidence in selecting design discharge. Due to the complexity of the site – varying condition of stream channel and floodplain, numerous significant changes in contributing drainage area at tributary confluences, physiographic overlap (Foothills designation with mountainous headwaters to Piedmont-like restoration reach), significant bedrock induced design constraints, and bed material heterogeneity, multiple approaches have enabled a more thorough analysis and hopefully a more ecologically and hydraulically sound design.

Table 3.4 below summarizes the design discharges chosen by reach and drainage area. For comparison, the design discharges have been overlain on the reference data making up the NC Rural Piedmont Regional Curve in Figure 3.10.

Table 3.4
Puzzle Creek and Tributary Design Discharge Summary

Project Feature	Downstream Drainage Area (mi^2)	Design Discharge (cfs)
Tributary Reaches 1 and 2	1.60	140
Puzzle Reach 1	2.58	190
Puzzle Reach 2	4.18	250

Figure 3.10 NC Rural Piedmont Regional Curve with Design Flows for all Streams on the Puzzle Restoration Site



3.5 Vegetation and Habitat Descriptions

The habitat within and adjacent to the proposed project area consists of fallow agricultural fields, Piedmont/Low Mountain Alluvial Forest, and Mesic Mixed Hardwood Forest (Piedmont Subtype) as described by Schafale and Weakley (1990). The riparian areas ranged from relatively disturbed to very disturbed. A general description of each community follows.

3.5.1 Agricultural Fields

This community covers approximately 15% of the project site. The fields have been used for a variety of agricultural purposes including crop rotation and hay production. Vegetation within these fallow fields primarily comprised of early successional species which include: yellow poplar, sweetgum, sycamore, black cherry, American holly, persimmon, and red cedar (*Juniperus virginiana*). Herbaceous and vines species consisted of poison ivy, Virginia creeper, trumpet creeper, morning glory (*Ipomoea* spp.), goldenrods, wingstem, horse nettle (*Solanum americanum*), blackberry (*Rubus* spp.), dog fennel (*Eupatorium capillifolium*), bushclover (*Lespedeza* spp.), pokeweed (*Phytolacca americana*), soft rush (*Juncus effusus*), and sedges (*Carex* spp.). This community type is heavily infested with exotic invasive species that include tree-of-heaven (*Ailanthus altissima*), multiflora rose (*Rosa multiflora*), Nepal grass, Japanese honeysuckle and kudzu.

3.5.2 Piedmont/Mountain Bottomland Forest

This ecological community covers approximately 75% of the project area and is located on large floodplains in the project area. The riparian buffer varied from narrow corridors of 10 to 15 feet in width to broad corridors exceeding 50 feet in width. The dominant canopy species of the Piedmont/Mountain alluvial forest included yellow poplar (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), river birch (*Betula nigra*), swamp chestnut oak (*Quercus michauxii*), shag-bark hickory (*Carya ovata*), red maple (*Acer rubrum*), and black walnut (*Juglans nigra*). Understory species included flowering dogwood (*Cornus florida*), ironwood (*Carpinus caroliniana*), spicebush (*Lindera benzoin*), paw paw (*Asimina triloba*), American holly (*Ilex opaca*), black cherry (*Prunus serotina*), and persimmon (*Diospyros virginiana*). Woody vine and herbaceous species consisted of poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), trumpet creeper (*Campsis radicans*), grape (*Vitis* spp.), Christmas fern (*Polystichum acrostichoides*), Virginia dayflower (*Commelina virginica*), violets (*Viola* spp.), asters (*Asters* spp.), Indian strawberry (*Duchesnea indica*), Queen Anne's lace (*Daucus carota*), wingstem (*Verbesina alternifolia*), goldenrods (*Solidago* spp.), slender spike grass (*Chasmanthium laxum*) and long-leaf spike grass (*Chasmanthium sessiliflorum*). Herbaceous hydrophytic species are present stream side on mid-channel and lateral bars throughout the reach. These species included false nettle (*Boehmeria cylindrica*), jewelweed (*Impatiens* spp.), green-headed coneflower (*Rudbeckia laciniata*), lady's thumb (*Polygonum persicaria*), tearthumb (*Polygonum sagittatum*), beggars tick (*Bidens* spp.), giant cane (*Arundinaria gigantea*), and deer tongue witchgrass (*Dichanthelium clandestinum*). Many places are heavily invaded with exotic invasive species that include Japanese honeysuckle (*Lonicera japonica*), Nepal grass (*Microstegium vimineum*), Chinese privet (*Ligustrum sinense*), and kudzu (*Pueraria montana var. lobata*), which are having an adverse affect on native vegetation.

3.5.3 Mesic Mixed Hardwood Forest (Piedmont Subtype)

This ecological community covers approximately 10% of the project area and is an upslope transition of the Piedmont/Mountain alluvial forest located on a steep north-facing slope on the furthest upstream section of UT1. The canopy is dominated by mesophytic trees that include American beech (*Fagus grandifolia*), white oak (*Quercus alba*), northern red oak (*Quercus rubra*), and (*Acer rubrum*) red maple. Understory trees and shrub species include flowering dogwood, red maple, black cherry, American holly, ironwood, and mountain laurel (*Kalmia latifolia*). Woody vine and herbaceous species consisted of poison ivy, Christmas fern, violets (*Viola* spp.), chickweed (*Stellaria* spp.), and rattlesnake root (*Prenanthes alba*).

4.0 REFERENCE STREAMS

Hydraulic and sediment modeling using HEC-RAS was instrumental in ascertaining information about stream processes and stability that could then be used as design information, and the reach directly upstream of the unnamed tributary was surveyed to estimate upstream supply. The NCDOT reference reach and in-house project databases were also sources of reference information for determining design ratios. In addition, two reference reaches were surveyed in the Broad River Basin within ten miles of the Puzzle Creek site (Table 4.0). Both sites were selected based on the confidence with which channel-forming features were identified, the apparent cross-sectional stability, and the natural state of the stream. Although the reference reaches drain relatively small watersheds, their planform, dimensions, and response to land use provided additional data to figure meaningful dimensionless ratios for guidance in design. The design rationale is further described in detail in Section 6.2.

Table 4.0 Geomorphic Characteristics of the Surveyed Reference Reaches

	Unnamed Tributary		Wheat Creek	
	Min	Max	Min	Max
1. Stream Type	E5		E5	
2. Drainage Area – square miles	0.2		2.3	
3. Bankfull Width (w_{bkf}) – feet	7.8	10.5	14.8	
4. Bankfull Mean Depth (d_{bkf}) – feet	0.8	1.4	2.1	
5. Width/Depth Ratio (w/d ratio)	5.4	11.1	7.1	
6. Cross-Sectional Area (A_{bkf}) – SF	7.5	12.5	31.0	
7. Bankfull Mean Velocity (v_{bkf}) - fps	3.1	3.3		
8. Bankfull Discharge (Q_{bkf}) – cfs	23.1	28.5		
9. Bankfull Max Depth (d_{mbkf}) - feet	1.3	1.8	2.6	
10. d_{mbkf} / d_{bkf} ratio	1.2	1.6	1.2	
11. Low Bank Height to d_{mbkf} Ratio	1.0	1.7	2.1	
12. Floodprone Area Width (w_{fpa}) – feet	16.7	61.5	48.8	
13. Entrenchment Ratio (ER)	1.8	7.9	3.3	
14. Meander length (L_m) – feet	63.6			
15. Ratio of Meander Length to Bankfull Width (L_m/w_{bkf})	6.1	8.2		
16. Radius of Curvature (R_c) – feet	12.7			
17. Ratio of Radius of Curvature to Bankfull Width (R_c / w_{bkf})	1.2	1.6		
18. Belt Width (w_{blt}) – feet	62.4			
19. Meander Width Ratio (w_{blt}/W_{bkf})	6.0	8.0		
20. Sinuosity (K) Stream Length/ Valley Distance	1.9			
21. Valley Slope – feet per foot	0.0168			
22. Channel Slope ($s_{channel}$) – feet per foot	.0090			
23. Pool Slope (s_{pool}) – feet per foot	0.0000	.0124		
24. Ratio of Pool Slope to Average Slope (s_{pool} / $s_{channel}$)	0.0	1.4		
25. Maximum Pool Depth (d_{pool}) – feet	2.2	2.5		
26. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	1.9	2.1		
27. Pool Width (w_{pool}) – feet	8.1	11.8		

Table 4.0 Geomorphic Characteristics of the Surveyed Reference Reaches				
	Unnamed Tributary		**Wheat Creek**	
	Min	**Max**	**Min**	**Max**
28. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	0.9	1.3		
29. Pool Area (A_{pool}) – square feet	9.1	13.1		
30. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	1.0	1.2		
31. Pool-to-Pool Spacing – feet	23.7	42.3		
32. Ratio of Pool-to-Pool Spacing to Bankfull Width (p-p/w_{bkf})	3.1	4.0		
33. Riffle Slope (s_{riffle}) – feet per foot	.0006	.0576		
34. Ratio of Riffle Slope to Average Slope (s_{riffle}/ s_{bkf})	.067	6.400		

Particle Size Distribution of Channel Material

	Unnamed Tributary	**Wheat Creek**
Material (d_{50})	Fine gravel	Coarse sand
d_{16} – mm	NA	0.5
d_{35} – mm	0.35	0.07
d_{50} – mm	0.92	0.9
d_{84} – mm	30.04	4.8
d_{95} – mm	56.91	12.5

5.0 PROJECT SITE WETLANDS

5.1 Jurisdictional Wetlands

Following an in-office review of the National Wetland Inventory (NWI) map a pedestrian survey was performed to investigate all wetlands and surface waters within the project area. The project area was examined utilizing the jurisdictional definition detailed in the United States Army Corps of Engineers (USACE) Wetland Delineation Manual (USACE, 1987). Supplementary information to further support wetland determinations was found in the National List of Plant Species that Occur in Wetlands: Southeast (Region 2) (Reed, 1988).

An on-site survey of the project areas was conducted on August 1, 2006, to identify potential USACE jurisdictional wetland locations in the project area. There were no areas in the project site that displayed true wetland characteristics.

6.0 PROJECT SITE RESTORATION PLAN

This section discusses the design objectives selected for stream restoration on the Puzzle Creek project site.

6.1 Restoration Project Goals and Objectives

The design objectives for Puzzle Creek and the unnamed tributary were based on the general goals listed in the introduction:

- ✓ Improve hydrologic connections between creeks and floodplains.
- ✓ Improve the water quality in the Puzzle Creek watershed.
- ✓ Improve aquatic and terrestrial habitat along the project corridor.
- ✓ Create geomorphically stable conditions on the project reaches.

Design objectives are a set of guidelines used to accomplish these goals effectively and efficiently. The following objectives were incorporated into the design of the streams on this site:

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

The accompanying plans show the proposed restoration measures. These measures are described in detail for the various reaches in the following sections.

The upper reach (reach 1) of the mainstem of Puzzle Creek is severely laterally unstable resulting in the presence of self-perpetuating debris jams. Bank erosion, falling trees, incision, and impingement on the valley wall are significant and irreversible trends present in the reach. Further lateral and vertical instability in the reach is inevitable. The existing conditions and design constraints make the creation of a new channel through the floodplain on the right side of the existing channel the best option. This will provide an accessible floodplain on both sides of the channel, a stable pattern and profile, and be the most technically feasible option, taking advantage of the existing open field. The new channel and adjacent floodplain will be reforested to provide stability and create an adequate riparian buffer with native species that will complement the channel restoration. The upstream terminus of the project must tie in to the existing bridge at Piney Mountain Church Road. Embankments on the right and left banks of the creek will not be disturbed and the restoration of the floodplain will begin just downstream of these structures. A combination of Priority I and Priority II restoration approaches will be implemented along reach 1; the floodplain will be excavated in some areas and the channel will be elevated in other sections.

The reach of Puzzle Creek downstream of the confluence with the unnamed tributary (reach 2) suffers from large debris jams. This reach is severely impacted by a cycle of debris jams, lateral instability, bank erosion, channel avulsion, and falling trees. This irreversible trend has diminished the habitat quality of the reach.

Tom's Branch enters from the east (right bank) mid-way through the project reach. The channel is incised through this reach, but some flood relief is achieved from the presence of the remnant channel in the left floodplain.

A combination approach of Priority I and Priority II restoration will be applied in reach 2 to create a meandering pattern with stable riffles and pools. The first two bends will incorporate parts of the existing flow area in order to preserve existing bank vegetation and for the sake of constructability (access and soil removal being significant issues in this reach). Subsequent meander bends will be built offline in the vicinity of the meander cutoff. This approach will bring the channel away from the right valley wall and improve the profile, cross-section, and stability of the pattern.

Reach 1 of the unnamed tributary flows west then northwest from the upstream end of the Schafer property boundary to a break in the easement above the waterfall. The primary issues to be addressed are slight to moderate disconnection from the floodplain, localized erosion of streambanks and impingement on valley walls, sub-reaches with bed features that are inconsistent with the plan form of the stream, non-native vegetation, and severely leaning trees that need to be cut back or removed to avoid debris jams during the project recovery period. The restoration efforts will focus on these issues. There is a requisite stream crossing in the upstream portion of the reach. Relative stability of banks and acceptable floodplain connectivity are taken advantage of by staying online and making minor adjustments to the dimension, pattern, and profile through the segment below the crossing. A long straight section will be addressed by going offline to create a diverse and stable channel. The channel is brought back online into an existing intact meander bend and is then brought back offline again due to further impacts from channelization. A significant amount of bedrock is present throughout the reach. The channel is brought back online where bedrock is present. In most cases, connectivity and stability is acceptable in these reaches since the bedrock has prevented downcutting.

Throughout the unnamed tributary a combination of Priority I, II, and III restoration will be implemented. At the uppermost end of the reach, floodplain connectivity will be addressed by changing the bed profile in order to raise the water surface. By creating backwater in meander bends, naturally-sustainable pools will be created. This technique will raise the water surface as much as a foot higher for approximately the first 150 feet of the tributary. Modification of the water surface below this point is not possible due to the slope requirements to match natural ground further downstream. Beginning at station 3+20, a new channel will be constructed to bring the stream away from the valley wall and to create a riffle and pool sequence.

Below this offline section, bank grading will be implemented to improve stream stability while following the existing channel course. A riprap stream crossing will be installed in this section for land-owner access to both sides of the creek. Below the crossing, the restoration plan will take advantage of the intact banks and bed diversity making only minor changes to the channel cross-section and profile as necessary to improve bank stability and sediment transport continuity.

Just below station 8+70, new channel will be constructed offline for one meander wavelength to add pattern and adjust the channel dimensions and profile. At the end of that wavelength, the channel will rejoin to the existing channel while the bed will be modified to create a pool. At station 10+30, the channel will be constructed offline again to add pattern and diversity to the bed profile. The proposed pattern returns to the existing channel at station 13+00 in order to avoid disturbance to a significant grove of trees on the left bank and also avoid possible construction problems with bedrock near the channel bottom in this reach. Below station 15+50, the channel is overly wide due to prior channelization. Modifications to the cross-section will occur starting upstream of this station and the channel will be brought offline below this station with a new design pattern and profile until its return to the existing stream at station 21+00.

Below this point, between stations 21+00 and 25+00, modifications to the profile and cross-section will be made but the channel will be kept on its existing alignment to take advantage of prevailing diversity in bedform and bank stability. For these reasons, along with valley constraints in the reach, Enhancement level I is proposed. Beginning with station 25+00, Priority II restoration will be implemented as new channel will be constructed offline to improve planform diversity through the reach; in the 50 feet before the channel resumes its existing path, a pool will be constructed. The reentrance to the existing channel occurs with an improvement in the riffle angle going into the next pool. Below this pool, the left bank will be graded, but bedrock and the downstream waterfall serve as barriers to any significant changes. Existing channel stability in this reach is acceptable and banks are well vegetated.

Reach 2 of the unnamed tributary starts after the easement break, downstream of the sloping rock waterfall which drops at an even rate totaling approximately 15 feet over a distance of 150 feet. This lower reach is approximately 300 feet long and transitions from a steep valley type without a floodplain, which is present at the waterfall, back to a flatter alluvial valley. The banks will be graded in this section and native vegetation will be established, providing stability to the confluence of the tributary with Puzzle Creek. Enhancement level II is proposed for Reach 2 from its upstream end to station 34+00. Valley constraints and bedrock in this reach prevent channel pattern and profile from being altered; however, bank stability will be improved through the use of vegetated geolifts. Downstream of station 34+00, priority II restoration will be implemented.

6.2 Design Criteria Selection for Stream Restoration

A number of analyses and data were incorporated in the development of site-specific natural channel design criteria in the form of design targets and limits. Among these are estimates of hydrology, hydraulic and sediment transport analyses, data from existing stable areas on site, incorporation of reference reach databases, regime equations, and evaluation of results from past projects.

Design criteria are dependent on the general restoration approach that was determined to be a best fit for the Puzzle Creek site. The general approach to restoration and enhancement was based on the streams' need and potential for restoration, as determined during initial site assessment. This general approach was tailored to specific reaches and segments of the stream during the design process. The plan layout, section dimensions, and profile have been designed to meet the design targets and limits and are consistent with the analyses and data available.

During the application of the design criteria, spot-specific solutions are tailored to incorporate the existing valley morphology, to avoid encroachment on easement boundaries and the valley wall, to minimize unnecessary disturbance of the existing riparian forest, and to promote natural channel adjustment following construction. The construction documents have been laid out to produce a cost- and resource-efficient design that is constructible. The underlying philosophy of the design and subsequent construction is that the streams will adapt to the inherent uniformity of the restoration project and be allowed to reform nuances and a greater physical diversity over long periods of time under the processes of flooding, re-colonization of vegetation, and geologic influences.

The project design is intended to maximize the chance of project success in accommodating the existing and future hydrologic and sediment contributions. The proposed stream types for the project are summarized in Table 6.1.

Table 6.1
Project Design Stream Types

Reach	Proposed Stream Type	Rationale
Unnamed Tributary Reach 1	C4	Priority I and II restoration will be used to change profile and cross-section characteristics. Use of the existing channel will limit grading and disturbance. In some areas, a floodplain bench will be excavated adjacent to the channel to mimic similar upstream and downstream character and improve floodplain access. Also, the channel will be rerouted in areas using Priority 1 restoration in order to improve pattern and provide connection with the floodplain. Enhancement I will be applied

Table 6.1 Project Design Stream Types		
Reach	**Proposed Stream Type**	**Rationale**
		to a 400-ft reach (station 21+00 to 25+00) that is constrained by a narrow valley, which precludes pattern adjustment.
Unnamed Tributary Reach 2	C4	Enhancement II will be used to change profile and cross-section characteristics from the beginning of the reach to station 34+00; Priority II restoration will be used from station 34+00 to the end of the reach. Use of the existing channel will limit grading and disturbance.
Puzzle Creek Reach 1	C4	Priority I & II restoration will reroute the channel through the middle of the valley to avoid encroachment on the valley wall and to improve pattern, profile, and dimension characteristics.
Puzzle Creek Reach 2	C4	Priority I & II restoration will improve channel dimension and bedform while creating a stable pattern

6.3 Design Parameters

The primary objective of the restoration design is to construct geomorphically stable stream reaches so that natural process will create the hydrologic and ecologic functions necessary to sustain a vigorous ecosystem. The philosophy applied by Baker throughout the Puzzle Creek project area is to rely upon process-based guidance supplemented by form-based information to create a stable channel. The resulting design is a primarily C-type with relatively low width-depth ratios but relatively flat bank slopes. As an alluvial system, the channels will be free to naturally adjust according to the prevailing geomorphologic trends in the system. The proposed design for each of the reaches is detailed in Table 6.2.

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

Dimension

Many sections of the design reaches involve modifications to the cross-section and/or profile to improve sediment transport continuity through the reach and reduce bank erosion. Certain sub-reaches involve creation of a new channel with floodplain connectivity, sediment transport continuity, and bank stability. The selected design parameters reduce erosive boundary stresses, provide the appropriate degree of sediment transport, and restore sufficient access to the floodplain. The lower end of a C-type channel width to depth ratio was chosen; the channel may narrow to an E-type morphology over time. E-type channels are difficult to construct due to high instability immediately after construction. A low bank height ratio (BHR) of 1.0 was designed so the channel has access to the floodplain during events having flows in excess of the design discharge. Typical sections are shown on the plan sheets.

Pattern

The proposed channel alignments are intended to create sinuous riffle-pool streams with stable slopes. The overall length of restored and enhanced channel will increase from 4,747 to 4,840 LF. Higher meander width ratios on the restored channels are proposed to allow for lateral dissipation of energy and provide a floodplain sufficient for future natural channel development. Some isolated lengths of the channel were constrained by a narrow valley. In these locations, the proposed belt width is limited but profile diversity will be restored. Plan views of the main channels are shown on the attached plan sheets.

Aside from reaches that are confined, radii of curvature fall into the range of approximately two to three times the channel's proposed bankfull width. A balance of tighter curves which are likely to produce deeper pools and gentler curves which enhance stability immediately following completion of construction were incorporated into the design.

Profile/Bedform

Except in areas where the existing bedform is sufficiently stable and diverse, the design intent is to establish a pool-riffle sequence which is both hydraulically diverse and stable. Certain areas with severe debris jams will be improved to prevent lateral instability and poor or planar bedform. Where possible, profile restoration will include efforts to raise the water surface in order to restore flooding processes without compromising the existing trees and stable banks. Riffles throughout the design reaches are between 1.5 and 2 times the average slope of the channel. The maximum pool depth is proposed to be constructed from the meander curve apex to a point one-half of the distance along the profile from the apex to the head of the next downstream riffle.

Table 6.2 presents the proposed stream restoration design criteria applied throughout the project area.

Table 6.2
Design Parameters and Proposed Geomorphic Characteristics

	Unnamed Tributary Reaches 1 and 2		**Puzzle Creek Reach 1**		**Puzzle Creek Reach 2**	
	Min	Max	Min	Max	Min	Max
1. Stream Type	C4-5		C4-5		C4-5	
2. Drainage Area – square miles	1.6		2.58		4.18	
3. Bankfull Width (w_{bkf}) – feet	14-18		22.0		25	
4. Bankfull Mean Depth (d_{bkf}) – feet	1.5-1.7		1.9		2.1	
5. Width/Depth Ratio (w/d ratio)	8.2-12		11.6		11.9	
6. Cross-sectional Area (A_{bkf}) – SF	24-28		42.5		52.6	
7. Bankfull Mean Velocity (v_{bkf}) - fps	5-5.8		4.5		4.75	
8. Bankfull Discharge (Q_{bkf}) – cfs	140		190		250	
9. Bankfull Max Depth (d_{mbkf}) - feet	2		2.5		2.7	
10. d_{mbkf} / d_{bkf} ratio	1.2-1.3		1.3		1.3	
11. Low Bank Height to d_{mbkf} Ratio	1.0-1.2		1.0-1.2		1.0-1.2	
12. Floodprone Area Width (w_{fpa}) – feet	50+		100+		100+	
13. Entrenchment Ratio (ER)	>2.8		>4.5		>4.0	
14. Meander length (L_m) – feet	130	213	136	160	174	248
15. Ratio of meander length to bankfull width (L_m/w_{bkf})	**7.2**	**15.2**	**6.2**	**7.3**	**7.0**	**10.0**
16. Radius of curvature (R_c) – feet	28	52	35	68	45	62
17. Ratio of radius of curvature to bankfull width (R_c / w_{bkf})	**1.6**	**3.7**	**1.6**	**3.1**	**1.8**	**2.5**
18. Belt width (w_{blt}) – feet	50	93	68	156	87	198
19. Meander Width Ratio (w_{blt}/W_{bkf})	**2.8**	**6.6**	**3.1**	**7.1**	**3.5**	**8.0**
20. Sinuosity (K) Stream Length/ Valley Distance	**1.21**	**1.21**	**1.3**		**1.2**	
21. Valley Slope – feet per foot	0.0106		0.0106		0.0097	
22. Channel Slope ($s_{channel}$) – feet per foot	**0.0085**		**0.0080**		**0.0079**	
23. Pool Slope (s_{pool}) – feet per foot	0	0.000025	0		0	
24. Maximum Pool Depth (d_{pool}) – feet	4.0	7.0	4.2	5.8	5.0	8.0
25. Ratio of Pool Depth to Average Bankfull Depth (d_{pool}/d_{bkf})	**2.0**	**3.5**	**2.2**	**3+**	**2.0**	**3.2**
26. Pool Width (w_{pool}) – feet	14-18		22		25	
27. Ratio of Pool Width to Bankfull Width (w_{pool} / w_{bkf})	**1.0**		**1.0**		**1.0**	
28. Pool Area (A_{pool}) – square feet	38.5		62.5		88	
29. Ratio of Pool Area to Bankfull Area	1.4-1.6		1.5		1.7	

Table 6.2 Design Parameters and Proposed Geomorphic Characteristics						
	Unnamed Tributary Reaches 1 and 2		**Puzzle Creek Reach 1**		**Puzzle Creek Reach 2**	
	Min	Max	Min	Max	Min	Max
(A_{pool}/A_{bkf})						
30. Pool-to-Pool Spacing – feet	50	90	58	136	74	174
31. Ratio of Pool-to-Pool Spacing to Bankfull Width (p-p/w_{bkf})	**2.7**	**6.4**	**2.6**	**6.2**	**7**	**10**
32. Riffle Slope (s_{riffle}) – feet per foot	**0.0120**	**0.0200**	**0.0142**	**0.0142**	**0.0158**	**0.0158**
33. Ratio of Riffle Slope to Average Slope (s_{riffle}/s_{bkf})	**1.3**	**2.3**	**1.8**	**1.8**	**2.0**	**2.0**

6.4 Sediment Transport

As discussed in Section 3.2 Channel Stability Assessment, Lane (1955) describes a generalized relationship of stream stability wherein the product of sediment load and sediment size is proportional to the product of stream slope and discharge. But whereas sediment size, stream slope, and stream discharge can be assessed in a straight-forward manner, sediment load is difficult to quantify because of the numerous processes controlling sediment delivery and movement within the stream system.

Sediment transport competency is a measure of a stream's ability to move a particle of a certain size and is an important part of understanding geomorphic process at work in the system; for the project reaches, the coarsest sediment sampled moves readily through the system and thus competency is not a design concern. From a mass-balance standpoint, sediment transport capacity is a much more important analysis. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross-section per unit of time, expressed in pounds/second or tons/year. Sediment transport capacity can be assessed directly by developing a sediment transport rating curve using measured sediment transport data from the site taken during flow events. But since measured rating curve development is extremely difficult, other empirical relationships are often used to assess sediment transport capacity. In this case, sediment transport capacity was calculated based on the empirically-developed Meyer-Peter & Müller Equation, which is one of the options available in HEC-RAS for transport calculation (Bruner, 2002). It is important to note that sediment transport capacity estimates do not reveal sediment supply to the stream, such that a stream may be carrying much less sediment than it has the potential to carry, if the sediment transport is limited by sediment supply. However, by estimating sediment transport capacity in the stream reach immediately upstream of the project reach and creating similar capacity to carry sediment in the design reach, sediment transport continuity can be achieved by balancing potential sediment supply with transport capacity using a mass-balance approach between reaches.

The sediment transport modeling capabilities of HEC-RAS were used to determine stable channel designs (cross-sectional shape and energy slope) given sediment supply and design discharge for existing cross-sections within or just upstream of the project which were chosen for design based on their present stability. Design based on a capacity limited approach assumes that the sediment supply into the reach will be sufficient. If the sediment load entering the project reach is not severely limited, the reach is not at risk of down-cutting and is not at risk of aggrading if the channel is designed according to the stable channel design calculations, provided that proper assumptions are made.

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

6.4.1 Methodology

Numerous data, as described earlier, were used to create a detailed HEC-RAS model. In each reach, an existing stable cross-section was chosen to use for design reference. Based on the findings of bulk and sub-pavement sampling from point bar and mid-channel bar locations, appropriate sediment distributions and sediment transport predictor equations were determined for sediment transport modeling. The HEC-RAS sediment transport module incorporates sediment distribution data from field samples to estimate the concentration of sediment moving during design flow conditions based on the results of the water surface profile and velocities and shear stresses produced by the physical characteristics of the channel and floodplain. The result is a volumetric sediment discharge (or capacity) for the chosen design flow rate.

Appendix C contains cumulative frequency graphs for sediment samples used in the sediment transport analyses. Project reaches have median particle sizes in the range of small to large gravel. The analyses were also checked for sensitivity to design sediment size; transport capacity had an acceptably small sensitivity to the variations in distribution exhibited in the sediment samples.

Volumetric sediment discharge was analyzed at existing stable cross-sections in the project reach. These reference cross-sections are used to determine what the design sediment discharge should be. Chapter 12 of the HEC-RAS Hydraulic Reference Manual (Bruner, 2002) discusses the Copeland Method for stable channel design. This method allows the modeler to incorporate design sediment discharge and design flow rate data in order to produce dimensions and energy slopes that will capably transport the sediment and water. Various combinations of channel cross-section and profile were assessed for their capability to move the design sediment discharge. These stable dimensions and slopes were incorporated into the typical riffle cross-section and design slope of the project.

6.5 In-Stream Structures

A variety of in-stream structures are proposed for the Puzzle Creek site. Structures such as root wads, log drops, and log vanes will be used to create flow acceleration and deep pool development; bioengineering such as vegetated geolifts and brush mattresses will be used to stabilize the new channel. Wood structures will primarily be used on this site because that is the material observed in the existing system and will be generated during the channel construction process. Table 6.3 summarizes the use of in-stream structures at the site.

Table 6.3
Proposed In-Stream Structure Types and Locations

Structure Type	Location
Root Wad	Outside bank of smaller radius meander bends.
Brush Mattress	Outside bank of shorter arcs and larger radius meander bends in sections of cut.
Vegetated Geolift	To create new banks in areas where cutting a new channel is not an option.
Log Drop	For grade control and hydraulic diversity in reaches requiring grade drop.
Log Vane	For hydraulic diversity and flow diversion.
Cover Log	In pools to provide habitat features.

Root Wad

Root wads are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also serve as a food source for aquatic insects. Root wads will be placed throughout the Puzzle Creek project.

Brush Mattress

Brush mattresses are placed on bank slopes on the outside of meander bends for stream bank protection. Layers of live, woody cuttings are tied together and staked into the bank. Brush mattresses help to establish dense vegetation on the bank to secure the soil. Once the vegetation is established, the cover also provides habitat for wildlife

Vegetated Geolift

Geolifts are used to create a geotechnically stable bank in areas where building a bank or making a significant change in slope or vegetation to a bank is necessary and shear stresses are expected to be moderate or high. They may also be used to create a steeper bank than can be constructed with only fill soil. Geolifts are often used for bank sloping on the outside of meander bends for stream bank protection. A stone toe is usually built at the base of the structure to prevent undermining. Lifts of soil are placed in 1-2 foot thick layers and are supported above and below by a coir fabric which covers the outward facing side of the lift in order to guard against erosion of the face. Live, woody cuttings are layered on top of the lifts with the tops facing outward and subsequent lifts are placed. Geolifts establish an immediately stable slope which is enhanced by the growth of the vegetation sandwiched between the soils lifts.

Log Drop

The log drop was developed for this project to provide grade control and gentle grade drops where an otherwise overly steep or constructed riffle would have been used. The Log Drop consists of two logs which overlap at a pour-over point and both pivot about the same base log which is perpendicular to the flow just upstream of the pour-over. Log structures are more natural in streams such as Puzzle Creek and can be constructed with material from on-site.

Log Vane

A log vane is used to turn the thalweg away from the bank. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes can be located either upstream or downstream along a meander bend where they function to initiate or complete the redirecting the flow thereby reducing shear stresses on the outside bank or fixing the alignment. Vanes are located just downstream of the point where the stream flow intercepts the bank at acute angles.

Cover Log

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

6.6 HEC-RAS Analysis

6.6.1 Preliminary Modeling

A HEC-RAS model was built from the existing conditions survey to evaluate design discharge and sediment transport as explained in Sections 3.3 and 6.4. However, proposed conditions have not been modeled at this point in project planning to determine how the project might affect flooding. It is unknown whether further study will be required by the local floodplain manager, but Baker will consult with that office to determine local municipal code requirements.

According to the FEMA Flood Insurance Rate Map (FIRM) for Rutherford County, NC, (Panel Number 370217 0006 A) the last few hundred feet of the project reach below the confluence with Tom's Branch is within a regulatory floodplain, Zone A (Figure 2.3). Flood modeling is not required for impacts of less than 5 acres in a Zone A designated area. The impact from the restoration work located in the Zone A designated area is expected to be less than this threshold. Nevertheless, Baker will use the proposed alignment and typical sections for modeling in HEC-RAS to determine what impact the proposed design may have on flooding as deemed necessary by the floodplain manager. No insurable structures are in the area of the stream project and any change in the 100-year water surface is expected be minimal.

6.7 Natural Plant Community Restoration

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

6.7.1 Stream Buffer Vegetation

Bare-root trees, live stakes, and permanent seeding will be planted within designated areas of the conservation easement. A preferred 50-foot buffer measured from the top of banks (sometimes slightly less and quite often, substantially more) will be established along the restored stream reaches. In many areas, the combined buffer width for left and right banks will be in excess of 100 feet. Bare-root vegetation will be planted at a target density of 680 stems per acre, or an 8-foot by 8-foot grid. The proposed species to be planted are listed in Table 6.5. Planting of bare-root trees and live stakes will be conducted during the first dormant season following construction. If construction activities are completed in summer/fall of a given year, all vegetation will be installed prior to the start of the growing season of the following calendar year.

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

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

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

Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 6.6 lists the species, mixtures, and application rates that will be used. A mixture is provided for floodplain wetland and floodplain non-wetland areas. Mixtures will also include temporary seeding (rye grain or browntop millet). The permanent seed mixture specified for floodplain areas will be applied to all disturbed areas outside the banks of the restored stream channel and is intended to provide rapid growth of herbaceous ground cover and biological habitat value. The species provided are deep-rooted and have been shown to proliferate along restored stream channels, providing long-term stability.

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

Table 6.4 Proposed Bare-Root and Live Stake Species		
Common Name	**Scientific Name**	**Percent Planted by Species**
Riparian Buffer Plantings		
Trees		
Sycamore	*Platanus occidentalis*	20%
Willow Oak	*Quercus phellos*	7%
River birch	*Betula nigra*	15%
Persimmon	*Diospyros virginiana*	10%
Alternate Species		
Tulip Poplar	*Liriodendron tulipifera*	20%
Green Ash	*Fraxinus pennsylvanica*	15%
Swamp Chestnut Oak	*Quercus michauxii*	8%
Black Cherry	*Prunus serrulata*	5%
Shrubs/small trees		
Pawpaw	*Asimina triloba*	15%
Witch-hazel	*Hamamelis virginiana*	15%
Spicebush	*Lindera benzoin*	20%
Alternate Species		
Sweet Shrub	*Calycanthus floridus*	15%
Pinxterbloom Azalea	*Rhododendron nudiflorum*	10%
American Hazelnut	*Corylus americana*	15%
Arrowwood Viburnum	*Viburnum dentatum*	10%
Woody Vegetation for Live Stakes		
Silky willow	*Salix sericea*	
Ninebark	*Physocarpus opulifolia*	
Elderberry	*Sambucus canadensis*	
Silky Dogwood	*Cephalanthus occidentalis*	
Note: Species selection may change due to availability at the time of planting.		

Table 6.5
Proposed Permanent Seed Mixture

Common Name	Scientific Name	Percent of Mixture	Seeding Density (lbs/acre)	Wetness Tolerance
Fringed sedge	*Carex crinata*	25	2	OBL
Soft rush	*Juncus effusus*	25	3	OBL
Woolgrass	*Scirpus cyperinus*	25	3	FACW
Joe pye weed	*Eupatorium fistulosum*			FAC
River oats	*Uniola latifolia*			OBL
Cardinal flower	*Lobelia cardinalis*			FACW+

Note: Species selection may change due to availability at the time of planting.

6.7.2 On-Site Invasive Species Management

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

7.0 PERFORMANCE CRITERIA

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

7.1 Stream Monitoring

Channel stability and vegetation survival will be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success.

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

7.1.1 Bankfull Events

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

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

7.1.2 Cross Sections

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

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

7.1.3 Longitudinal Profile

A longitudinal profile survey will be completed each year of the monitoring period. A representative 3,000 LF segment of the restored stream will be surveyed. Annual measurements will include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these measurements will be taken at the head of each feature (e.g., riffle, pool) and at the maximum pool depth. The survey will be tied to a permanent benchmark.

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

7.1.4 Bed Material Analyses

Bulk samples will be conducted for the permanent cross-sections on the project reaches. Sediment collection will be conducted one year after construction and at two-year intervals thereafter, at the time the longitudinal field surveys are performed. Sediment data will be plotted on a semi-log graph and compared with data from previous years.

7.1.5 Photo Reference Sites

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

Lateral reference photos. Reference photo transects will be taken at each permanent cross-section.

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

Structure photos. Photographs will be taken at each grade control structure along the restored stream. Photographers should make every effort to consistently maintain the same area in each photo over time.

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

7.2 Vegetation Monitoring

Successful restoration of the vegetation on a site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, vegetation monitoring quadrants will be installed across the restoration site. The number of quadrants required will be based on the species/area curve method, with a minimum of three quadrants. The size of individual quadrants will vary from 100 square meters for tree species to 1 square meter for herbaceous vegetation. Vegetation monitoring will occur in spring, after leaf-out has occurred. Individual quadrant data will be provided and will include diameter, height, density, and coverage quantities. Relative values will be calculated, and importance values will be determined. Individual seedlings will be marked to ensure that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living, planted seedlings and the current year's living, planted seedlings.

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

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

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

7.3 Maintenance Issues

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

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

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. The conditions listed above and any other factors that may have necessitated maintenance will be discussed.

7.4 Schedule/ Reporting

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

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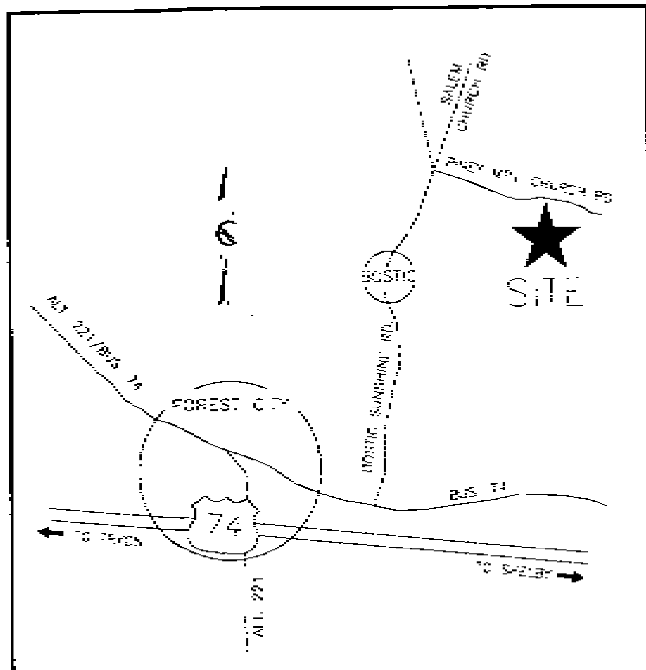
REVISED 60% RESTORATION PLAN SET MAILED 11-21-07



VICINITY MAP
NOT TO SCALE

NC Ecosystem Enhancement Program

Puzzle Creek Restoration Project

Bostic, North Carolina

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION

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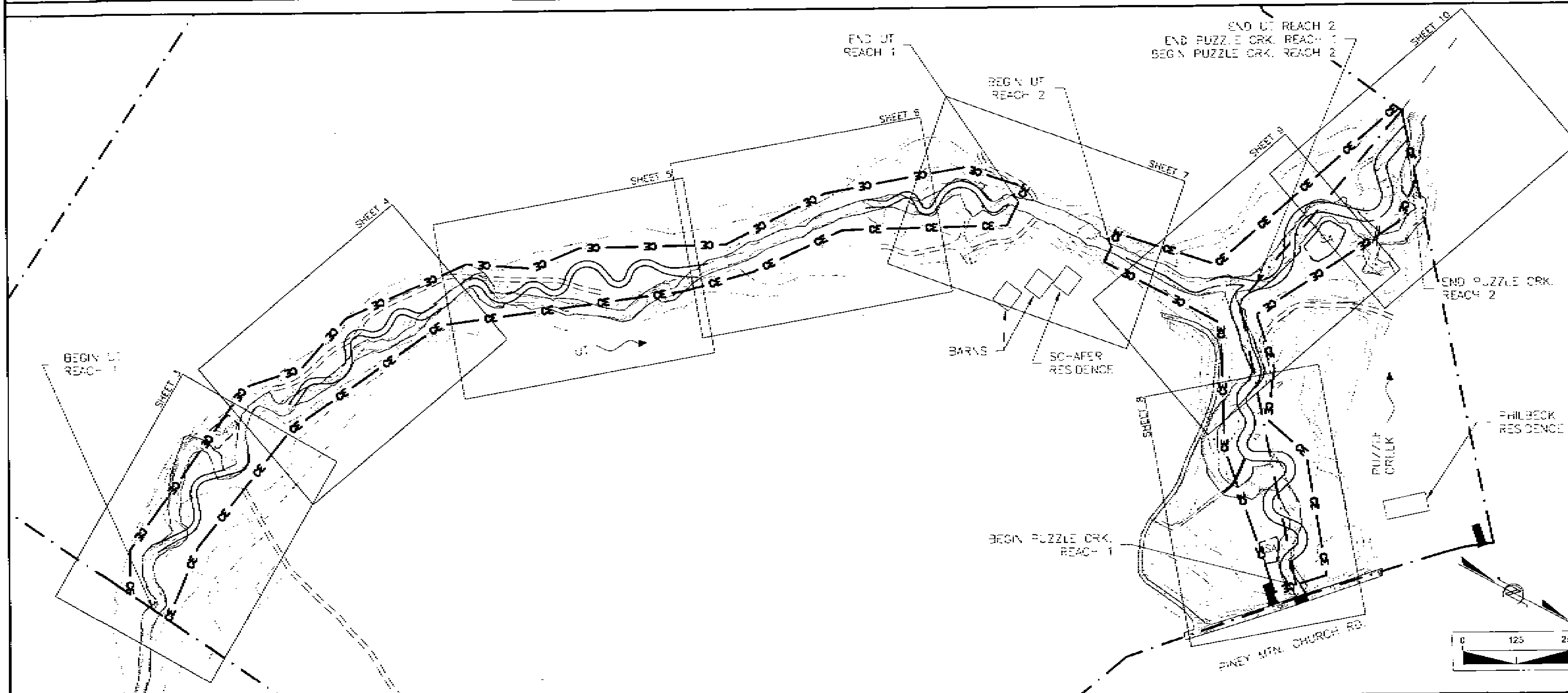
28-29	Details

Datum Description:

Horizontal Datum is on NCGS NAD 83. Temporary contol points are present on site and will be used to establish grade and position by a Baker representative at the time of construction



DESIGNED: JLB
DRAWN: JLB
APPROVED: ADB

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

TITLE PAGE

Prepared for:
Ecosystem Enhancement Program
2728 Capitol Blvd. Suite 1H 103
Raleigh, NC 27604
Phone: 919 715-0476
Fax: 919-715-2219

Baker Project Number: AH-109277
Date: 11/20/2007
Drawing Sheet No.
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LEGEND OF SYMBOLS

- BRUSH MATTRESS
- VEGETATED GEOLIFT
- ROOTWAD CLUSTER
- LOG VANE
- LOG DROP
- CHANNEL PLUG
- EXISTING TREE
- EXISTING TREE TO BE REMOVED
- BAKER CONTROL POINT
- CHECK DAM
- CONSTRUCTION ENTRANCE
- STONE FORD CROSSING
- EXISTING ROAD – UNPAVED
- EXISTING ROAD – PAVED
- JOIN TO EXISTING CONTOUR
- PROPOSED ROAD – UNPAVED
- TEMPORARY STREAM CROSSING
- SOIL STOCKPILE AREA
- PROPOSED THALWEG / CONTROL LINE
- PROPOSED TOP OF BANK
- CE — CE — CONSERVATION EASEMENT BOUNDARY
- SF — SF — SILT FENCE
- PROPERTY BOUNDARY
- EXISTING CONTOUR – INDEX
- EXISTING CONTOUR – INTERMEDIATE
- PROPOSED PERMANENT FENCE
- PROPOSED GRADING LIMIT
- PROPOSED TEMPORARY SAFETY FENCE
- PROPOSED GATE
- PROPOSED STAGING AREA
- FLOODPLAIN PLANTING ZONE
- UPLAND PLANTING ZONE

SUMMARY OF QUANTITIES

ITEM	DESCRIPTION	QUANTITY	UNIT
A	MOBILIZATION AND DEMOBILIZATION		
B	CLEARING AND GRUBBING		
C	INVASIVE SPECIES REMOVAL		
D	SAFETY FENCE		
E	SILT FENCE		
F	COIR MATTING		
G	BRUSH MATTRESS		
H	GRADING – CUT		
	GRADING – FILL		
J	CLASS A STONE		
K	CLASS B STONE		
L	CLASS 1 STONE		
M	BOULDERS		
N	FILTER FABRIC		
O	ROOT WADS		
P	LOG VANES		
Q	LIVE STAKES		
R	WOODY VEGETATION		
S	PERMANENT SEEDING		
T	TEMPORARY SEEDING		
U	MULCH		

GENERAL CONSTRUCTION SEQUENCE

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

SYMBOLOGY AND NOTES

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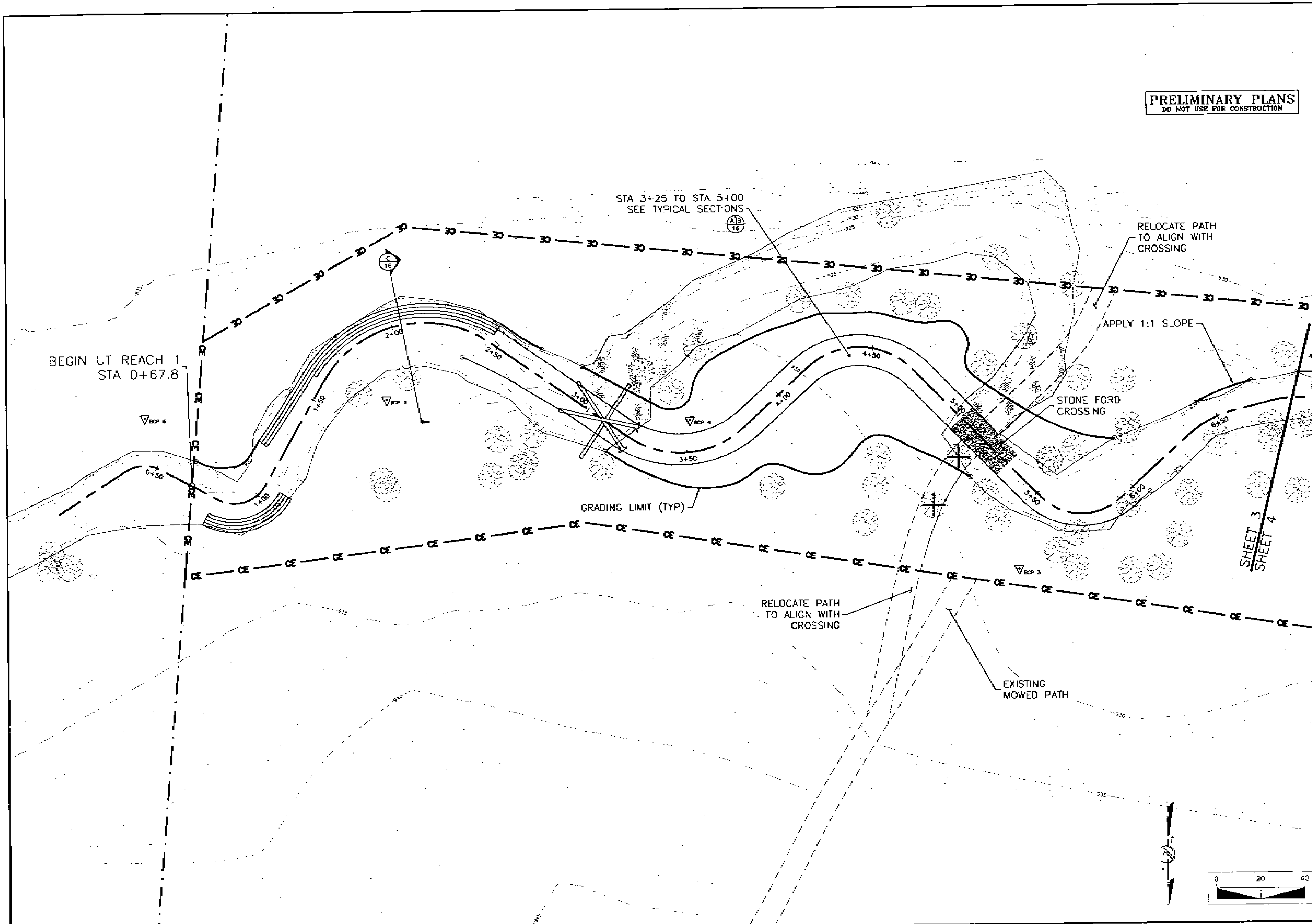

DESIGNED: [illegible]
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GRADING PLAN

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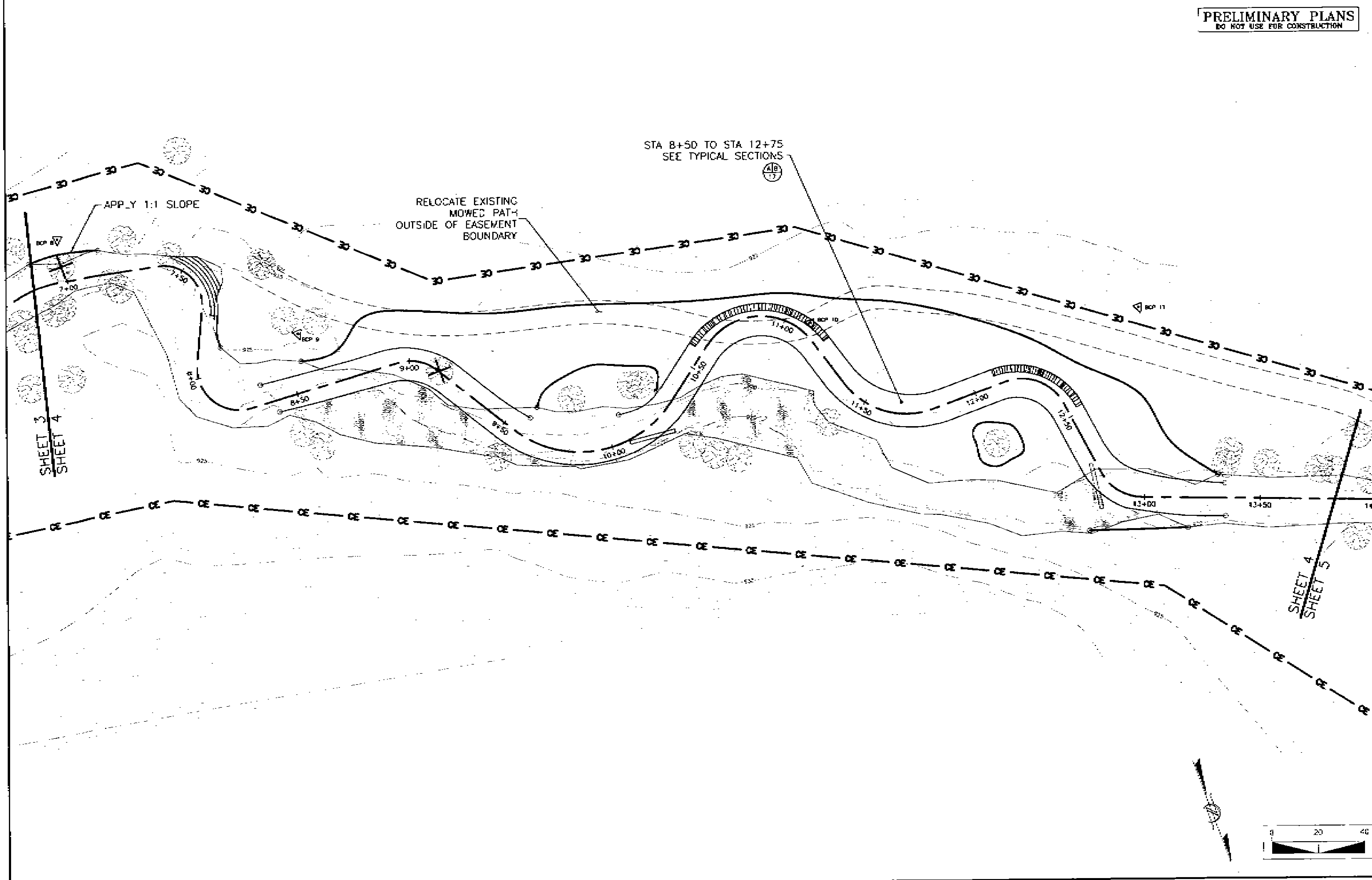

DESIGNED: JLB
DRAWN: JLB
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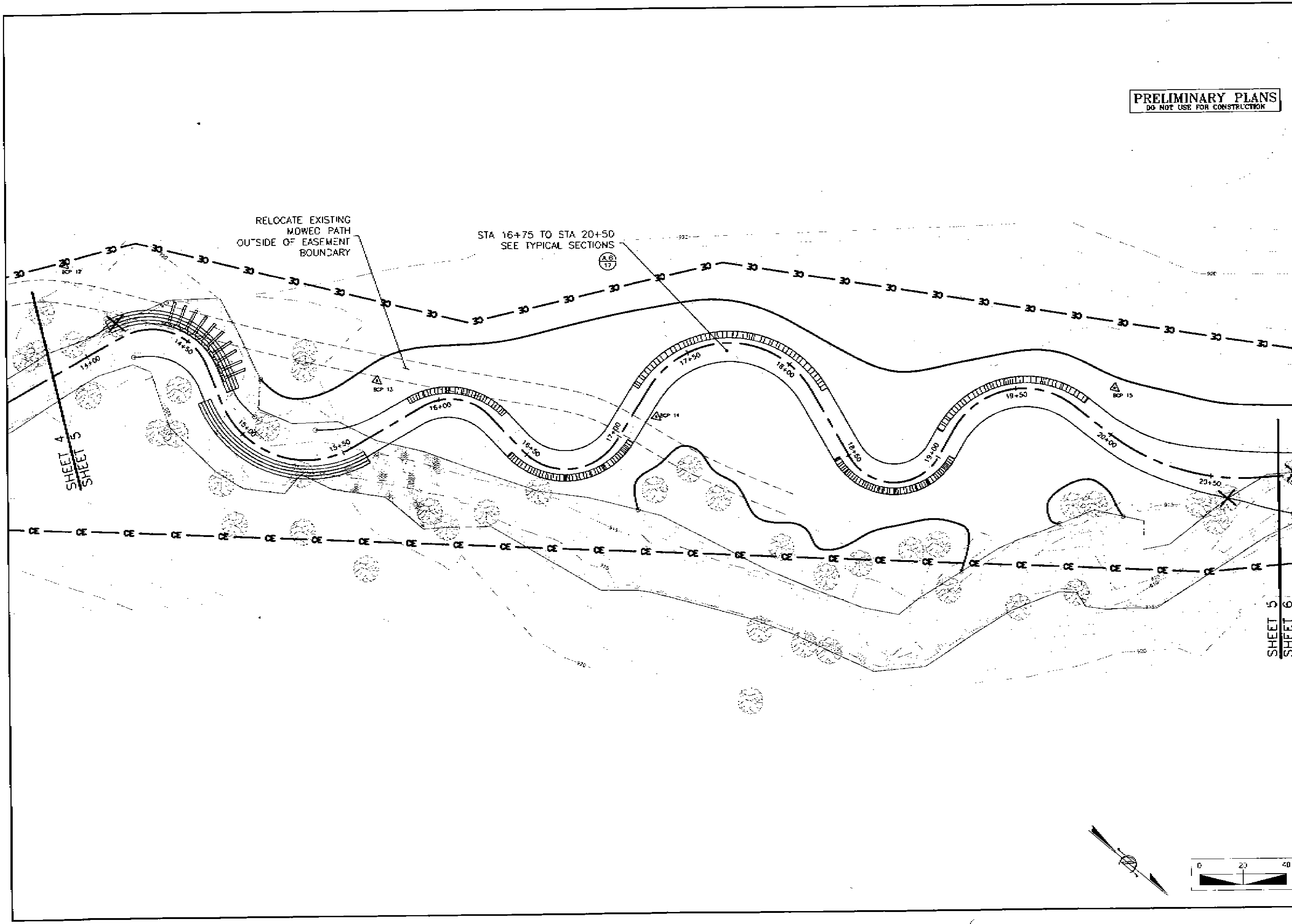

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Baker Project Number: AH-09277

Date: 11/2?/2007

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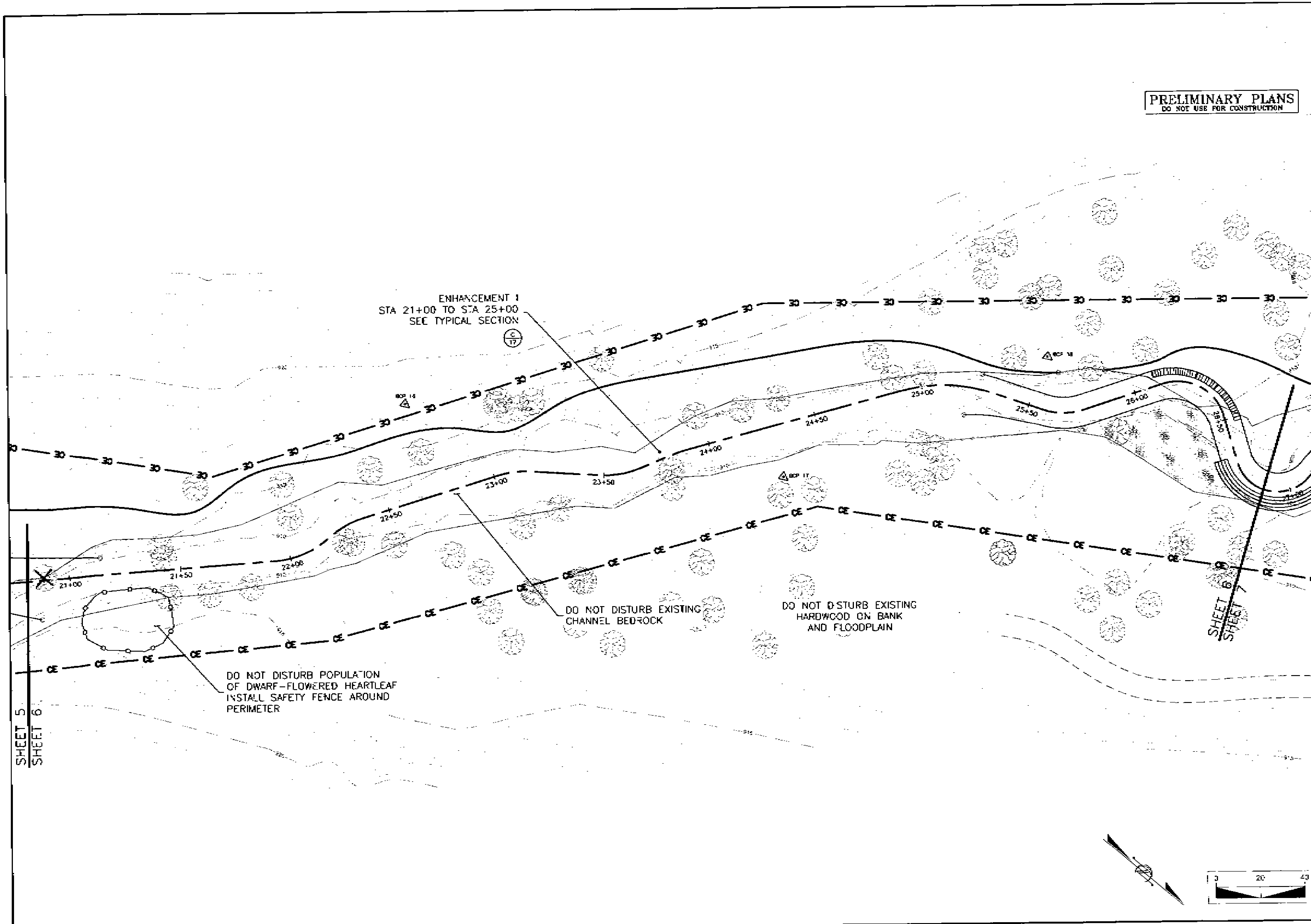

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Baker Project Number

Date

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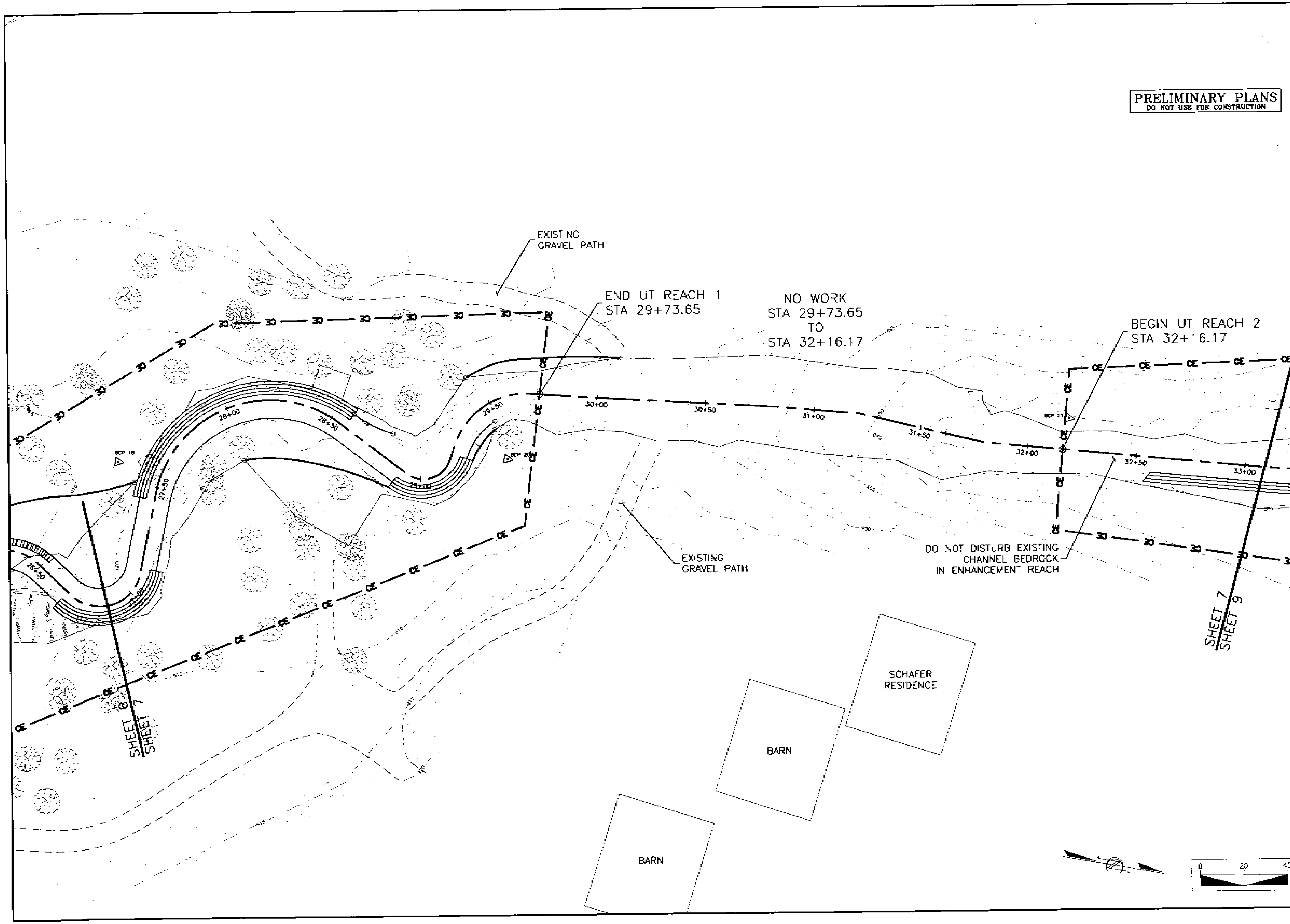

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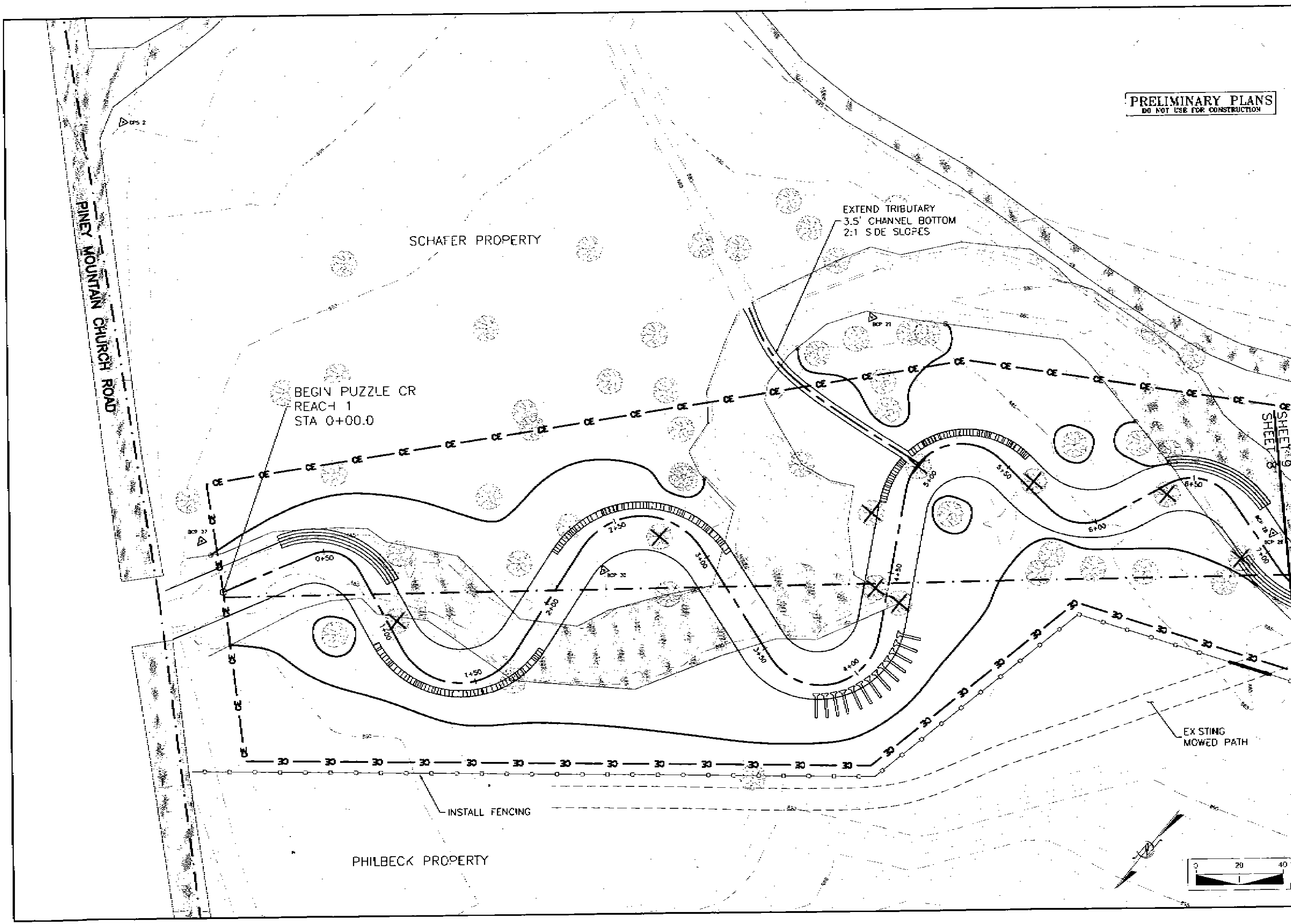

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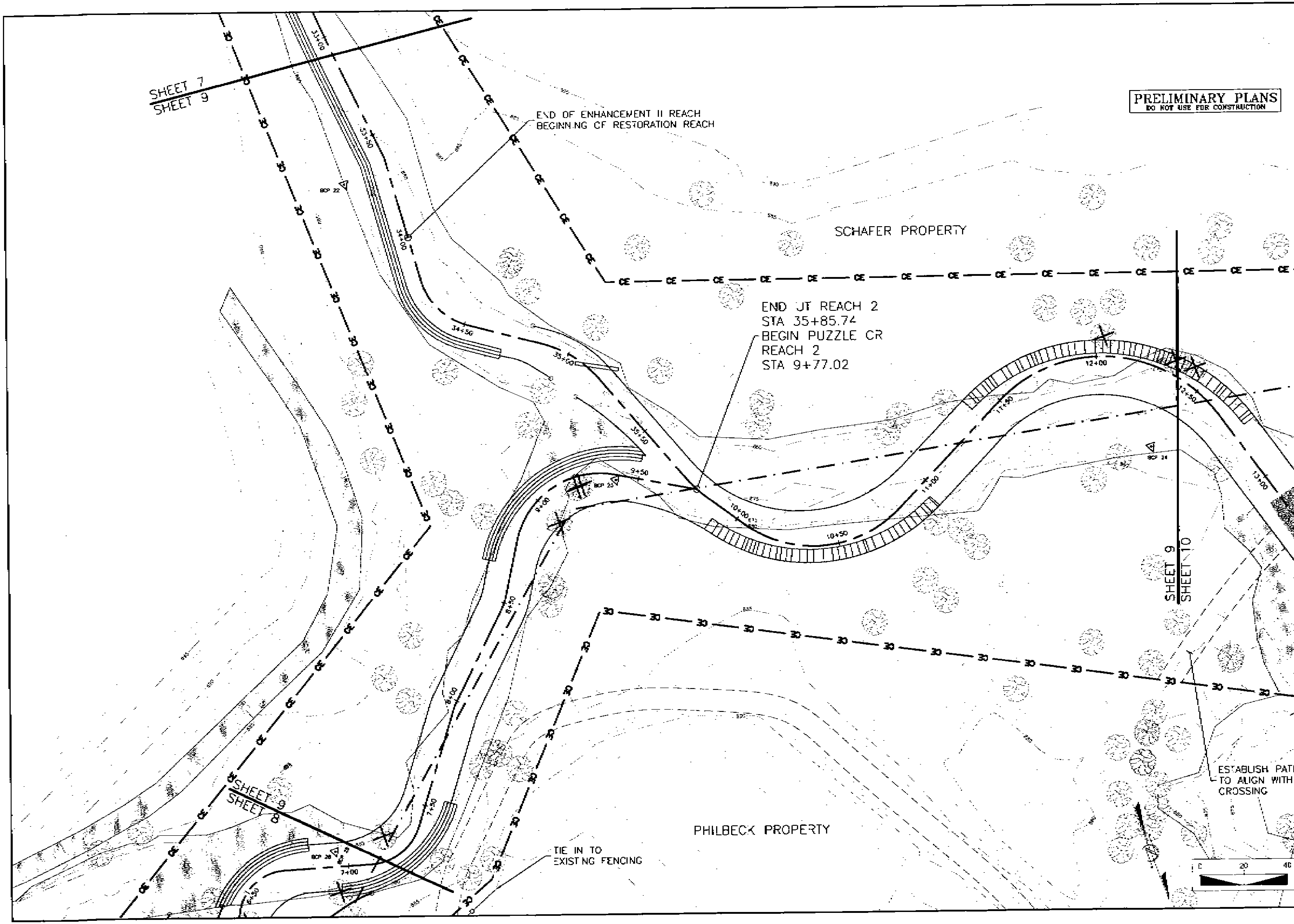

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PUZZLE CREEK RESTORATION PROJECT
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Date: 1/23/2007
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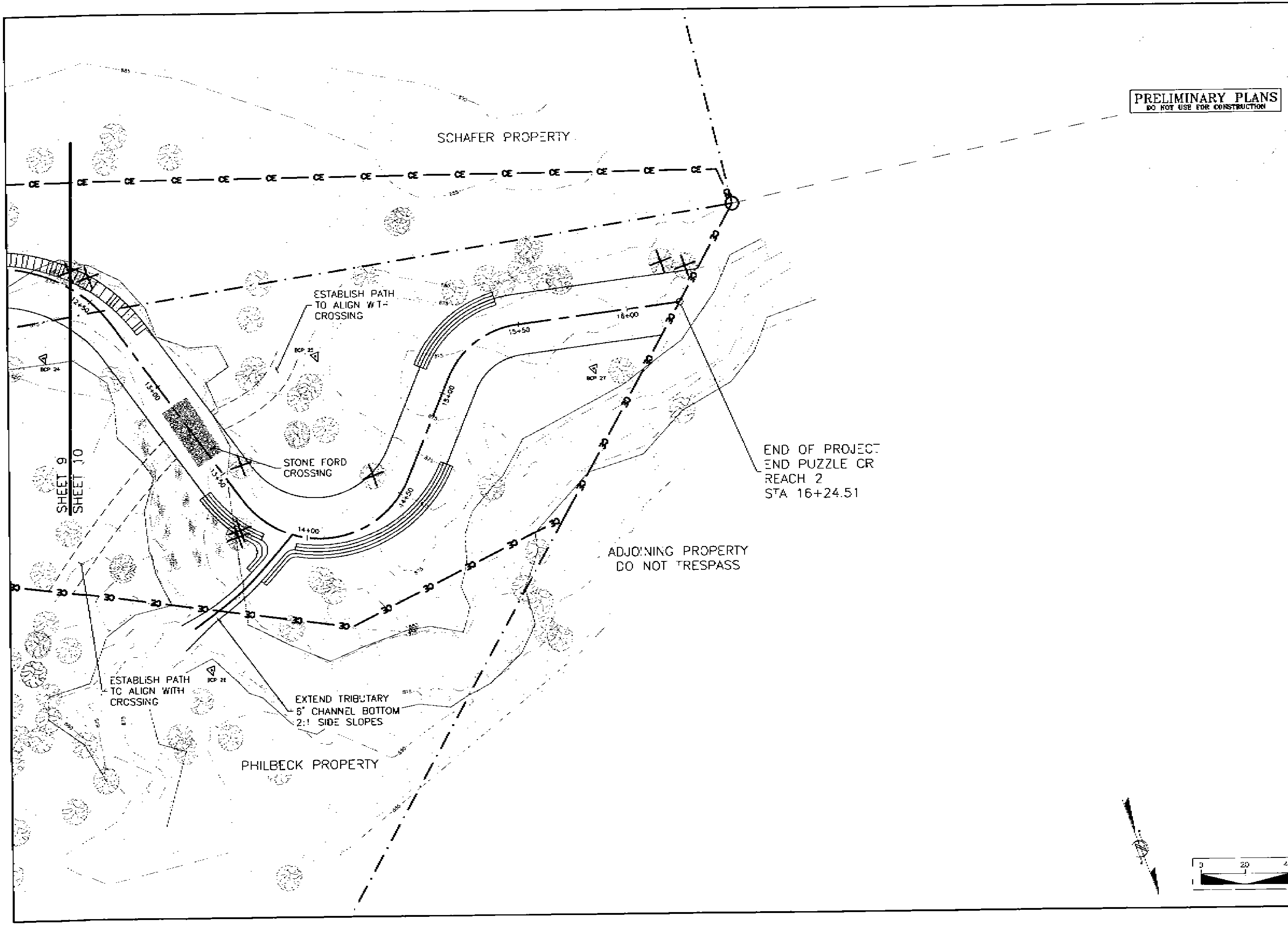

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Date: 11/20/2007
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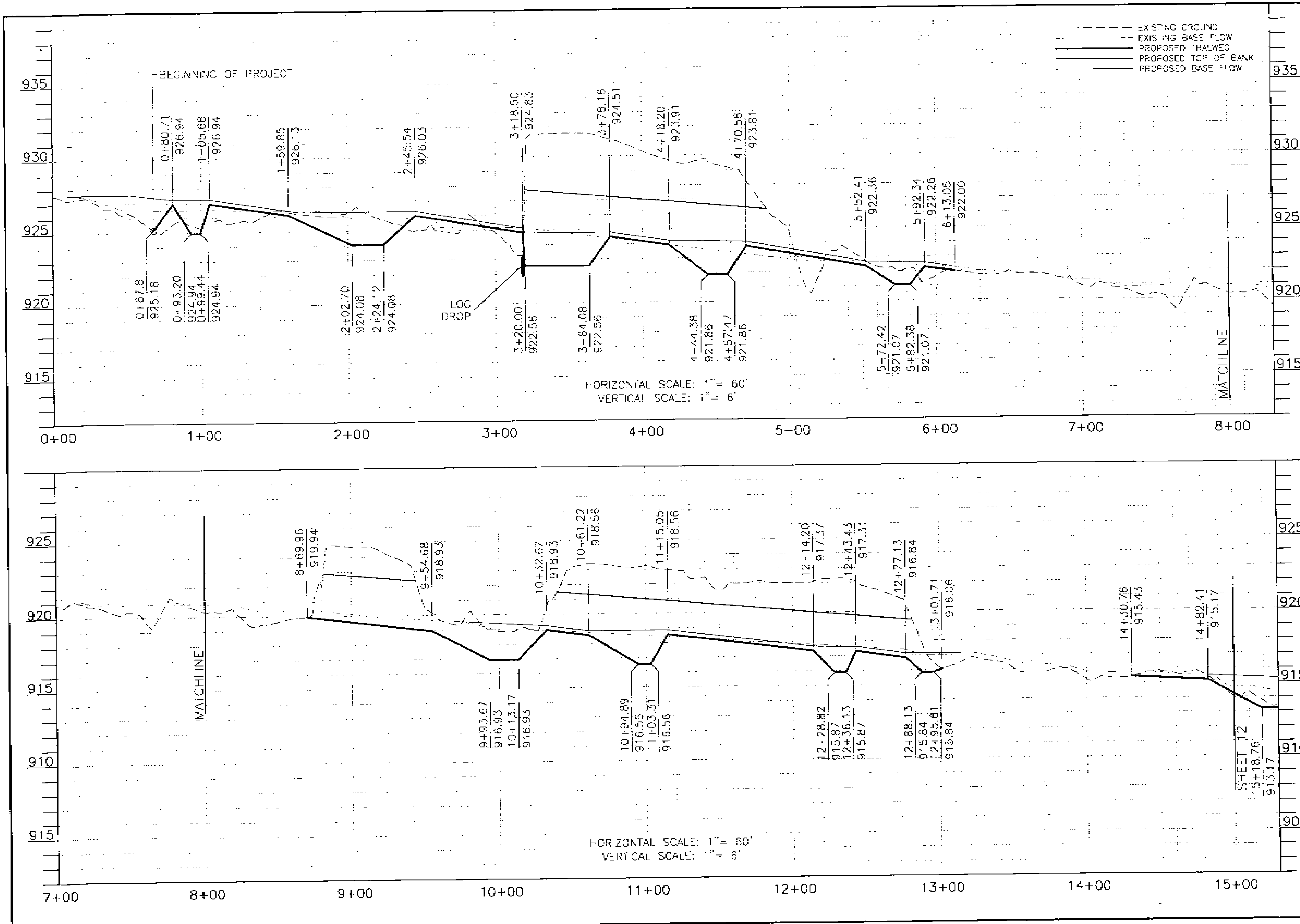

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

PROFILE: UT

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Date: 11/20/2007
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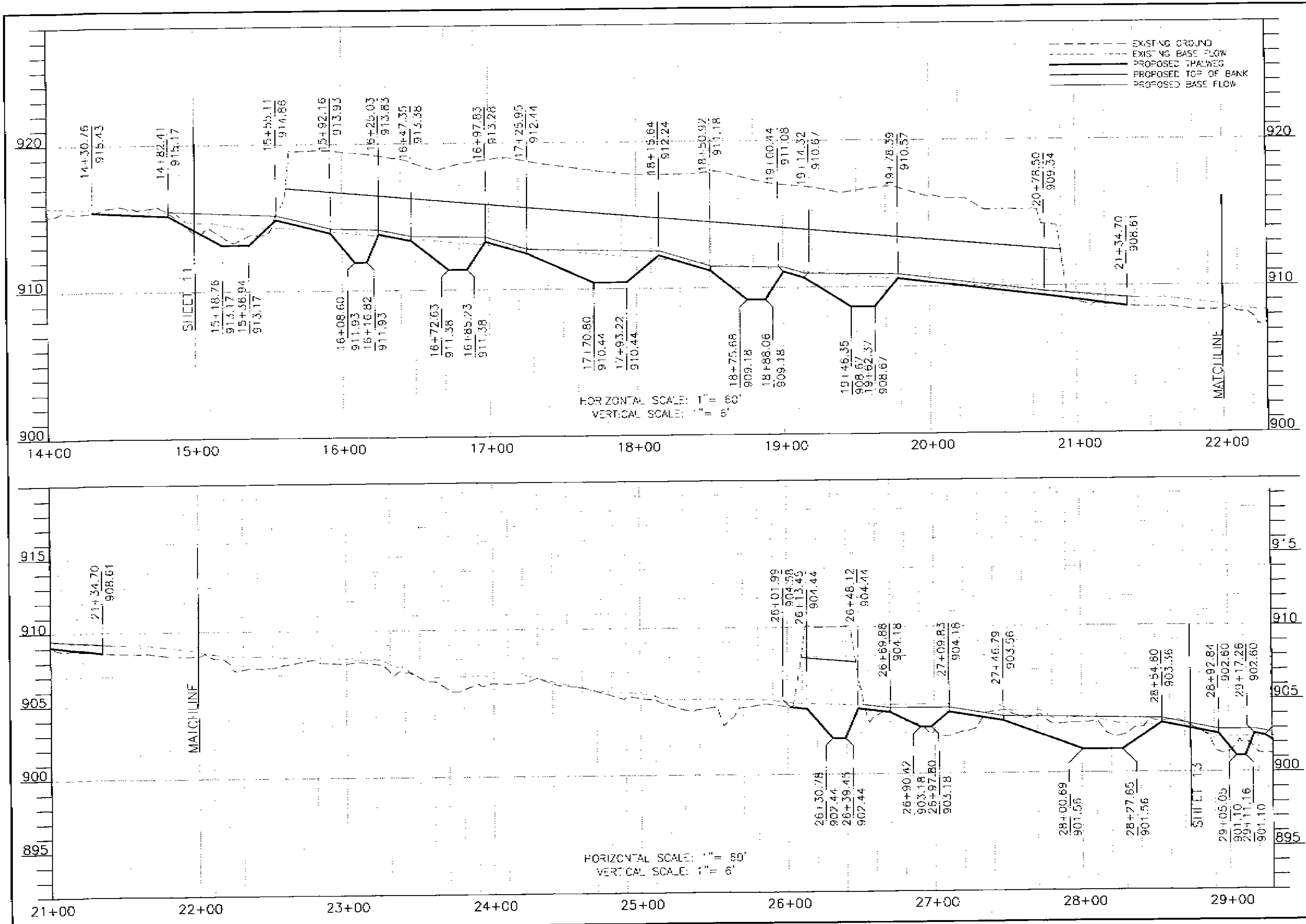

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PUZZLE CREEK RESTORATION PROJECT
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PROFILE: UT

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Baker Project Number
A-109277
Date: 11/20/2007
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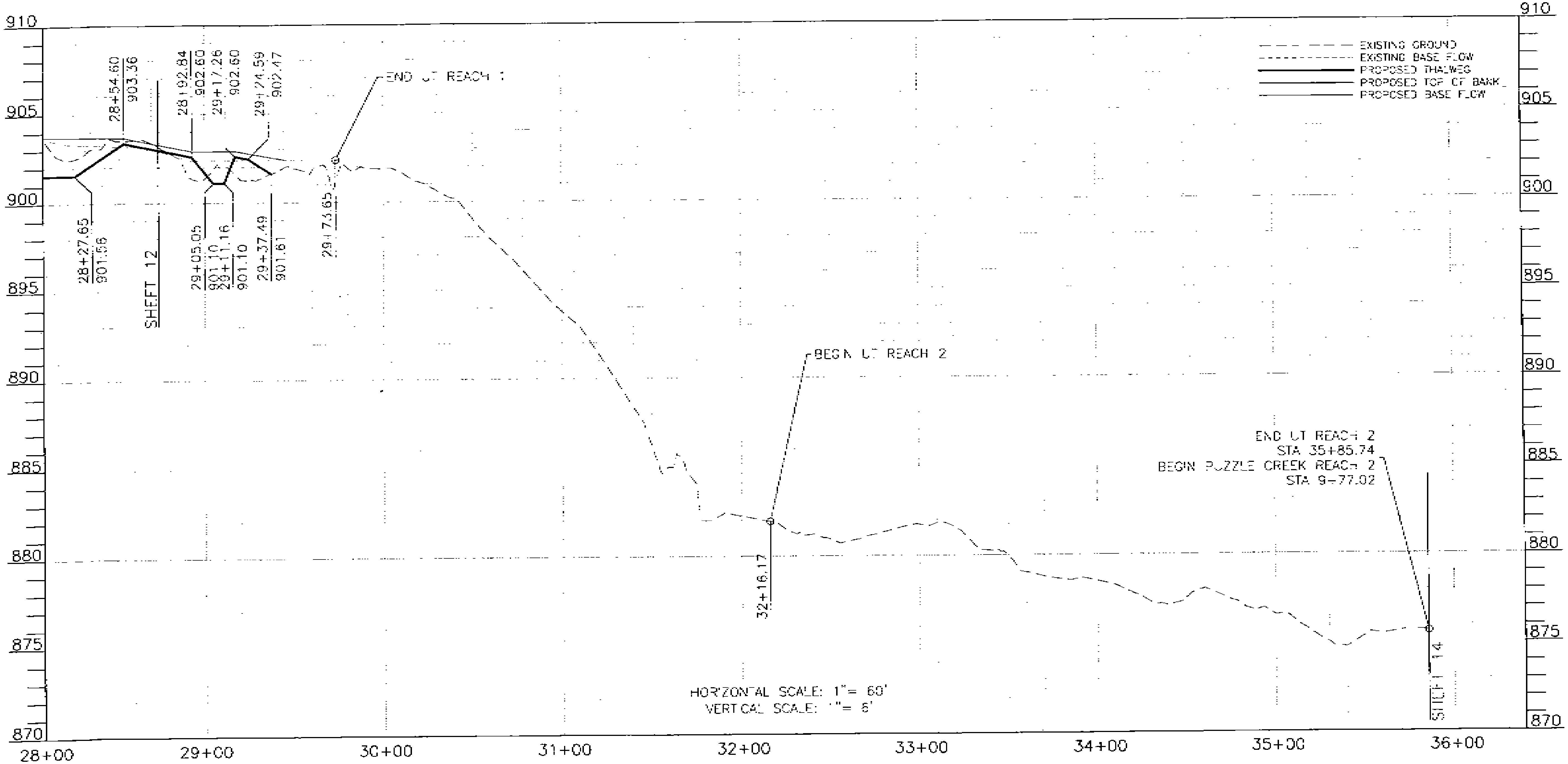

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

PROFILE: UT

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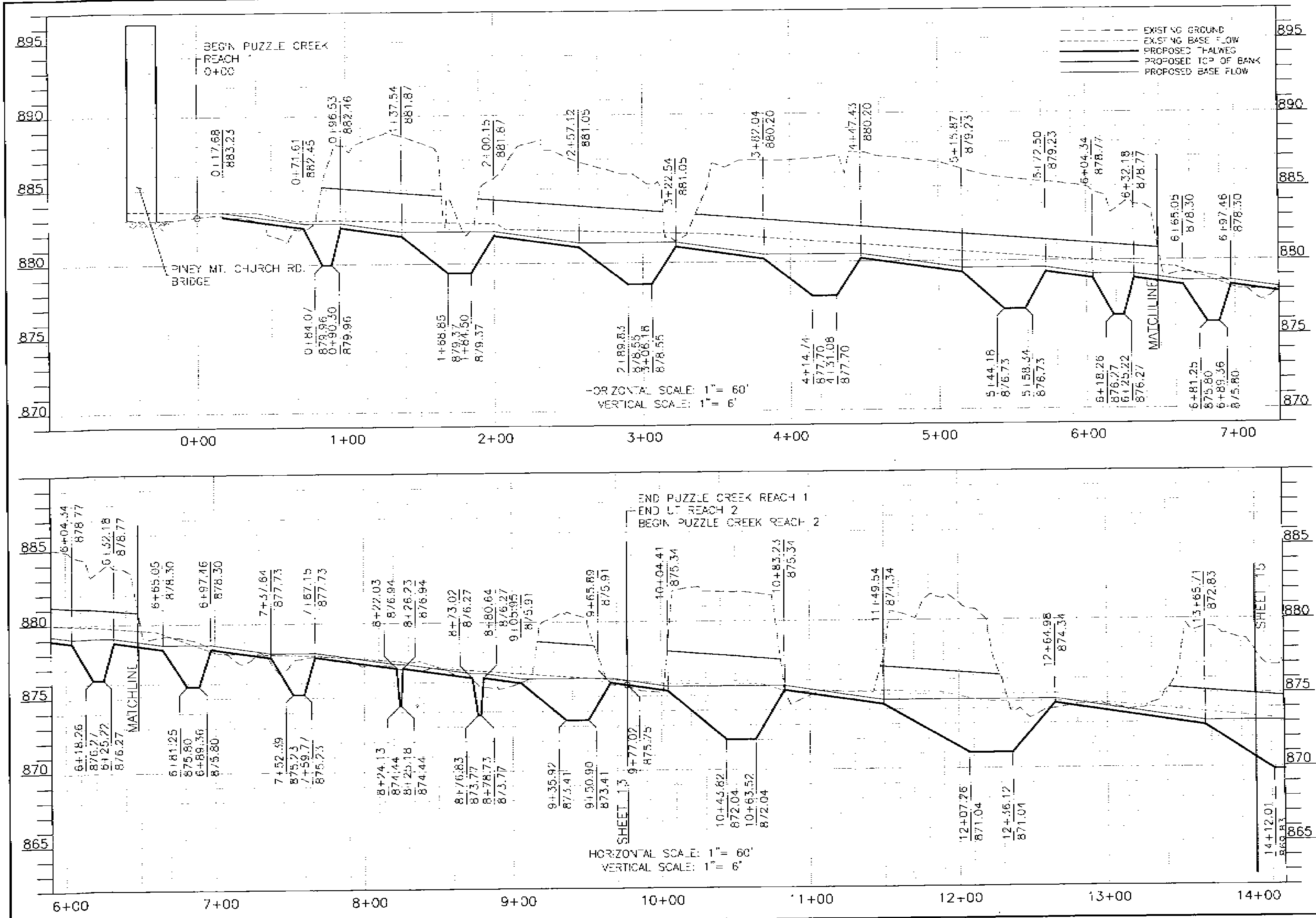

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

PROFILE: PUZZLE CREEK

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Baker Project Number
AR-108277

Date: 11/20/2007

Drawing Sheet No.
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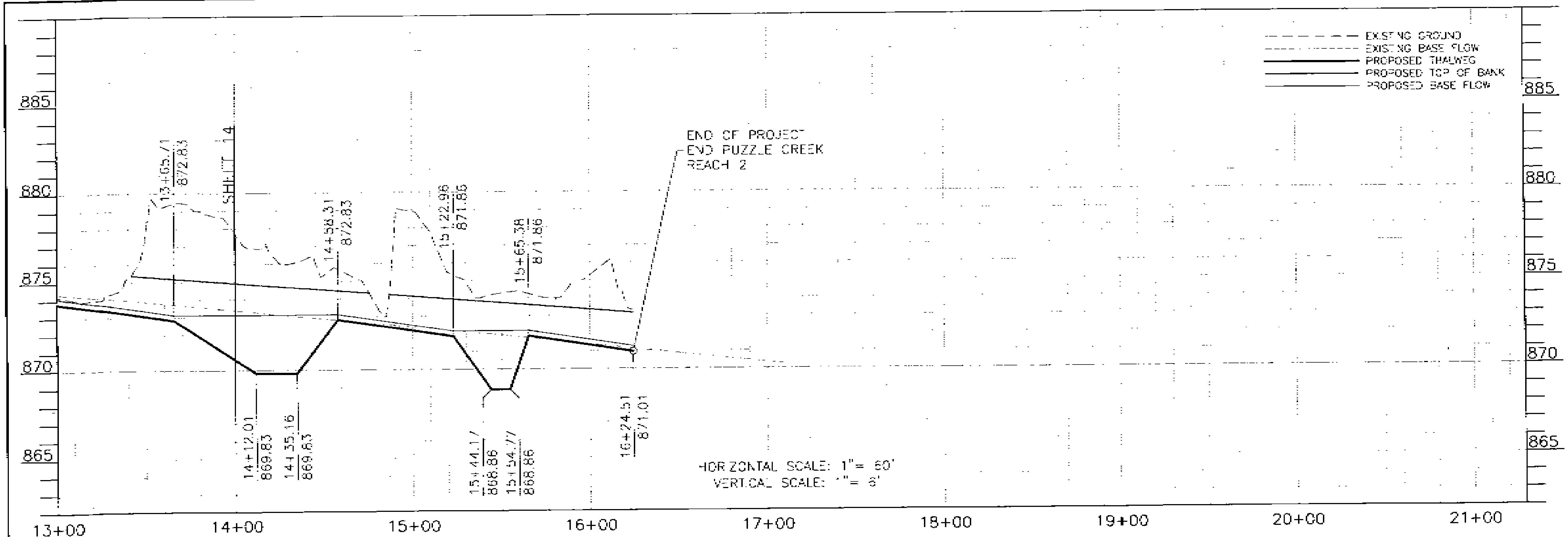

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

PROFILE: PUZZLE CREEK

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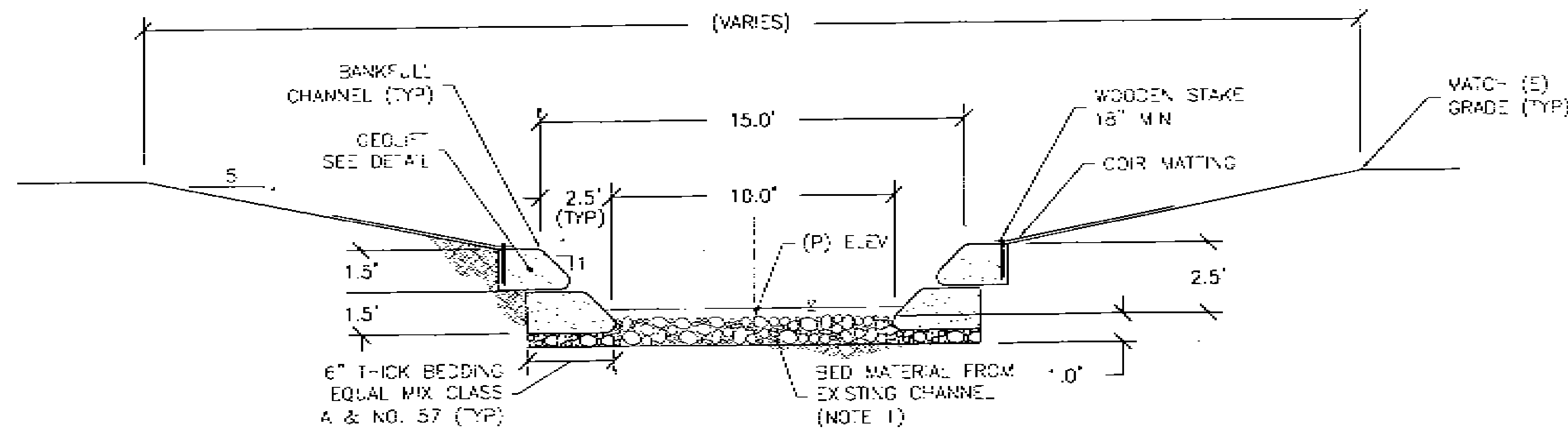
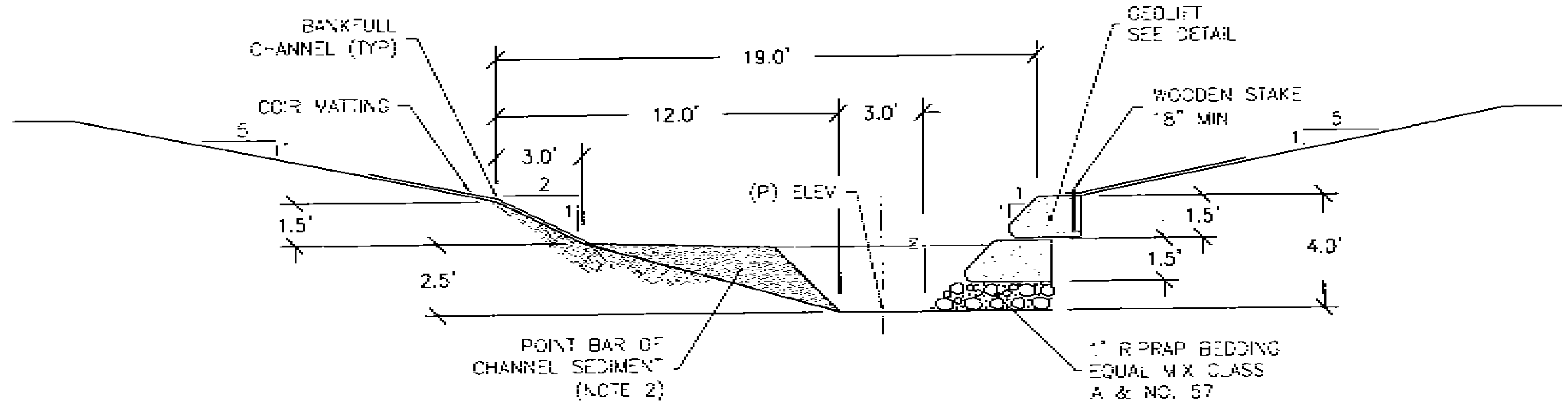
Baker Project Number
AH-106277

Date 11/20/2007

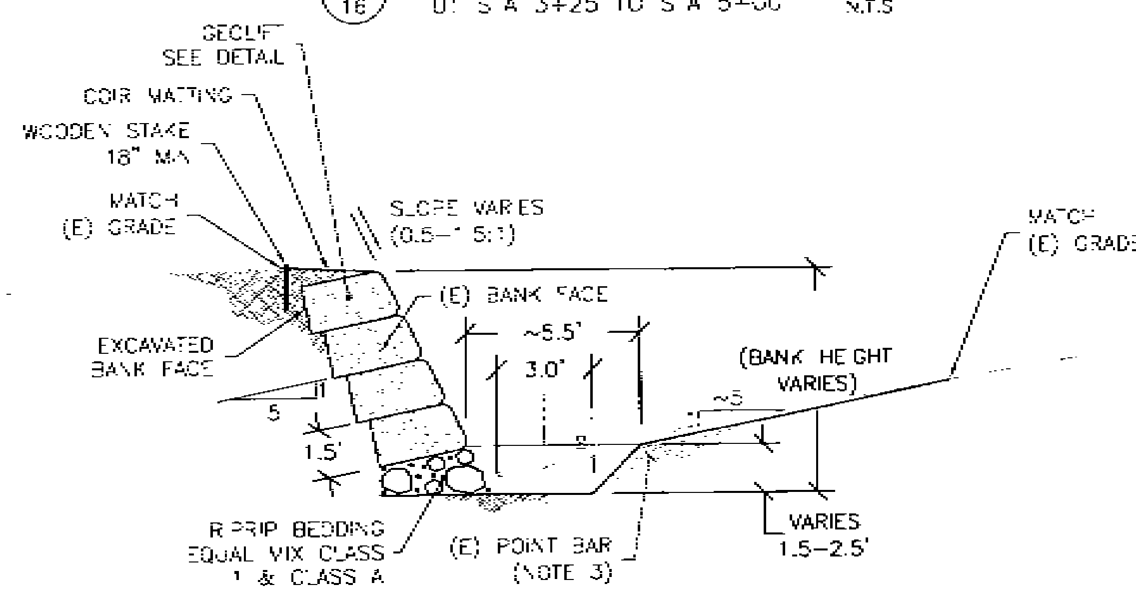
Drawing Sheet No.
Sheet 15 of 29



A TYPICAL SECTION: RIFFLE
15 UT STA 3+25 TO STA 5+00 N.T.S



B TYPICAL SECTION: MAX POOL
16 UT STA 3+25 TO STA 5+00 N.T.S



C TYPICAL SECTION: MAX POOL
16 UT BENDWAY STABILIZATION N.T.S

NOTES:

1) IN EXISTING SECTIONS OF STREAM CHANNEL TO BE ABANDONED, CHANNEL BED MATERIAL SHALL BE EXCAVATED AND STOCKPILED TO BE TRANSFERRED TO SECTIONS OF PROPOSED STREAM CHANNEL. BED MATERIAL SHALL BE STOCKPILED SEPARATELY FROM SOIL AND SHALL BE KEPT FREE OF FINE SEDIMENT OR BRUSH MATERIAL.

2) POINT BARS SHALL BE CONSTRUCTED OF CHANNEL SEDIMENT ACCORDING TO THE DIMENSIONS SHOWN IN THE TYPICAL SECTIONS. CHANNEL SEDIMENT IS DEFINED AS COBBLE, GRAVEL, AND SAND PARTICLES FOUND IN THE EXISTING CHANNEL BED, SEDIMENT SHOALS AND BARS, AND SECTIONS OF ABANDONED CHANNEL. SUCH CHANNEL SEDIMENT MUST BE FREE OF SILT, CLAY, AND ORGANIC DEBRIS.

3) POINT BARS SHALL NOT BE SEEDED OR PLANTED AND SHALL NOT BE COVERED WITH COIR MATTING

LEGEND:

(E)/(P) EXISTING/PROPOSED
APPROXIMATE LEVEL OF BASEFLOW WATER SURFACE
RIPRAP STONE: EQUAL MIX OF CLASS A & NO. 57
RIPRAP STONE: EQUAL MIX OF CLASS 1 & CLASS A
CHANNEL BED MATERIAL
CHANNEL SEDIMENT
UNDISTURBED IN-SITU SOIL
CHANNEL THALWEG / CONTROL LINE

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

TYPICAL SECTIONS

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Baker Project Number NY-109277
Date: 11/20/2007
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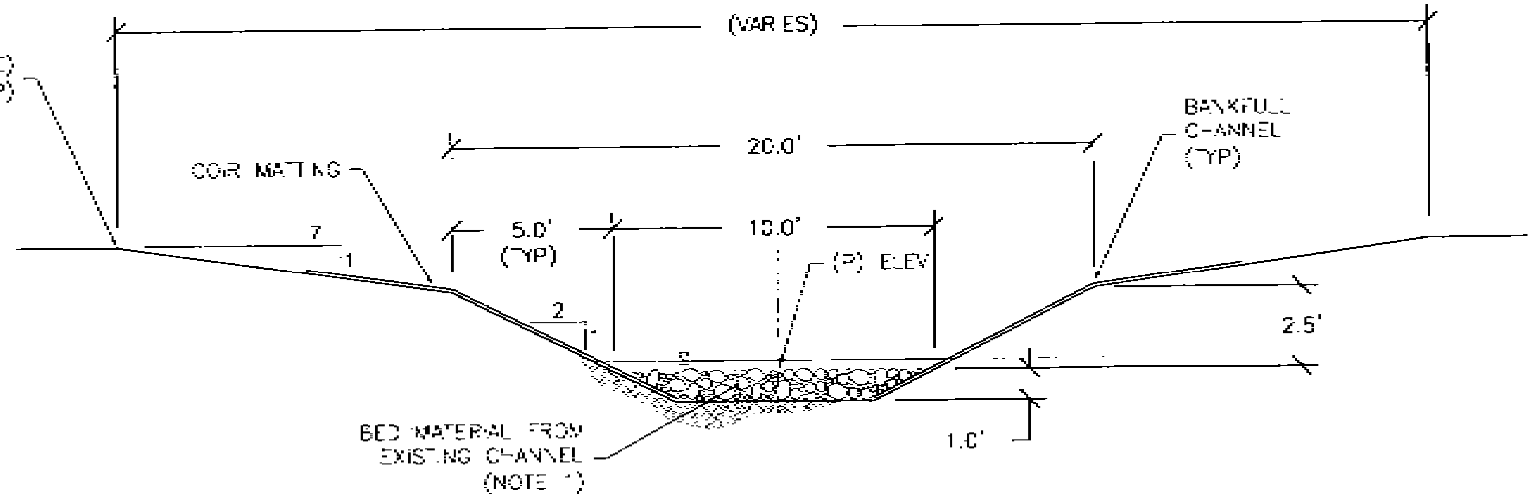
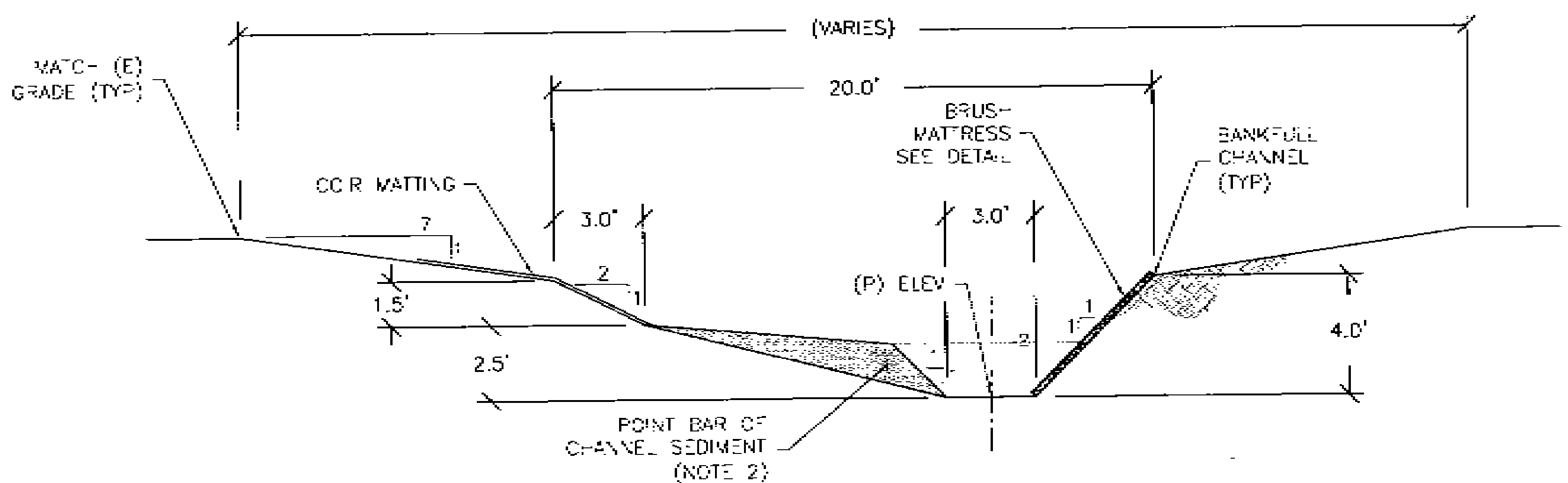
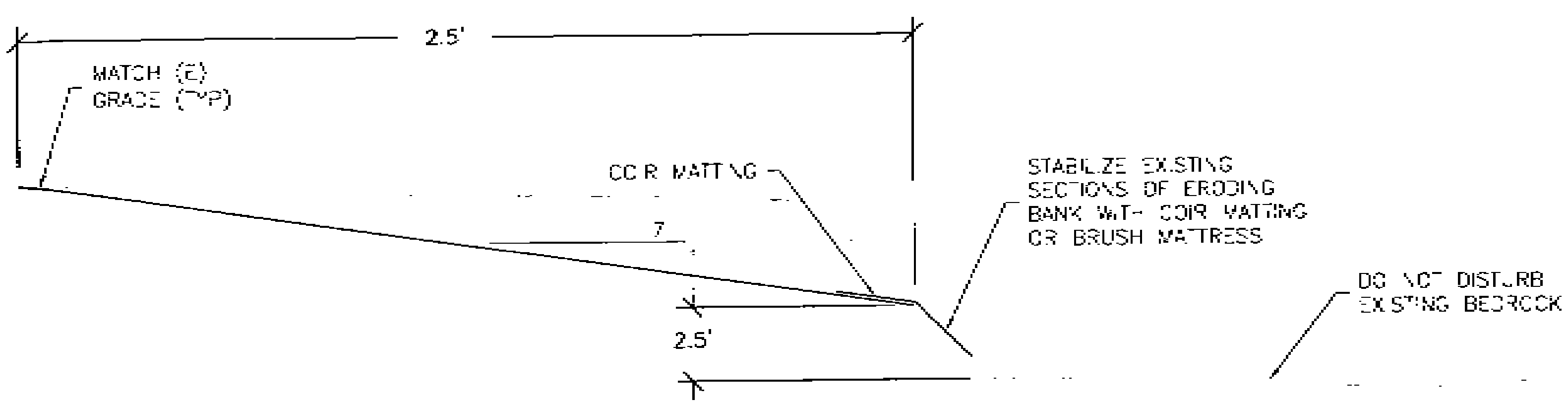


A/17 TYPICAL SECTION: RIFFLE
UT STA 8+50 TO STA 12+75 N.T.S
UT STA 16+75 TO STA 20+50



B/17 TYPICAL SECTION: MAX POOL
UT STA 8+50 TO STA 12+75 N.T.S
UT STA 16+75 TO STA 20+50



PRESERVE EXISTING HARDWOODS ON RIGHT BANK AND FLOODPLAIN

C/17 TYPICAL SECTION
UT STA 21+00 TO STA 25+00 N.T.S

NOTES:

1) IN EXISTING SECTIONS OF STREAM CHANNEL TO BE ABANDONED, CHANNEL BED MATERIAL SHALL BE EXCAVATED AND STOCKPILED TO BE TRANSFERRED TO SECTIONS OF PROPOSED STREAM CHANNEL. BED MATERIAL SHALL BE STOCKPILED SEPARATELY FROM SOIL AND SHALL BE KEPT FREE OF FINE SEDIMENT OR BRUSH MATERIAL.

2) POINT BARS SHALL BE CONSTRUCTED OF CHANNEL SEDIMENT ACCORDING TO THE DIMENSIONS SHOWN IN THE TYPICAL SECTIONS. CHANNEL SEDIMENT IS DEFINED AS COBBLE, GRAVEL, AND SAND PARTICLES FOUND IN THE EXISTING CHANNEL BED, SEDIMENT SHOALS AND BARS, AND SECTIONS OF ABANDONED CHANNEL. SUCH CHANNEL SEDIMENT MUST BE FREE OF SILT, CLAY, AND ORGANIC DEBRIS.

3) POINT BARS SHALL NOT BE SEEDED OR PLANTED AND SHALL NOT BE COVERED WITH COIR MATTING.

LEGEND:

(E)/(P)	EXISTING/PROPOSED
	APPROXIMATE LEVEL OF BASEFLOW WATER SURFACE
	CHANNEL BED MATERIAL
	CHANNEL SEDIMENT
	UNDISTURBED IN-SITU SOIL
	CHANNEL THALWEG / CONTROL LINE

DESIGNED: / DRAWN: / APPROVED:

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

TYPICAL SECTIONS

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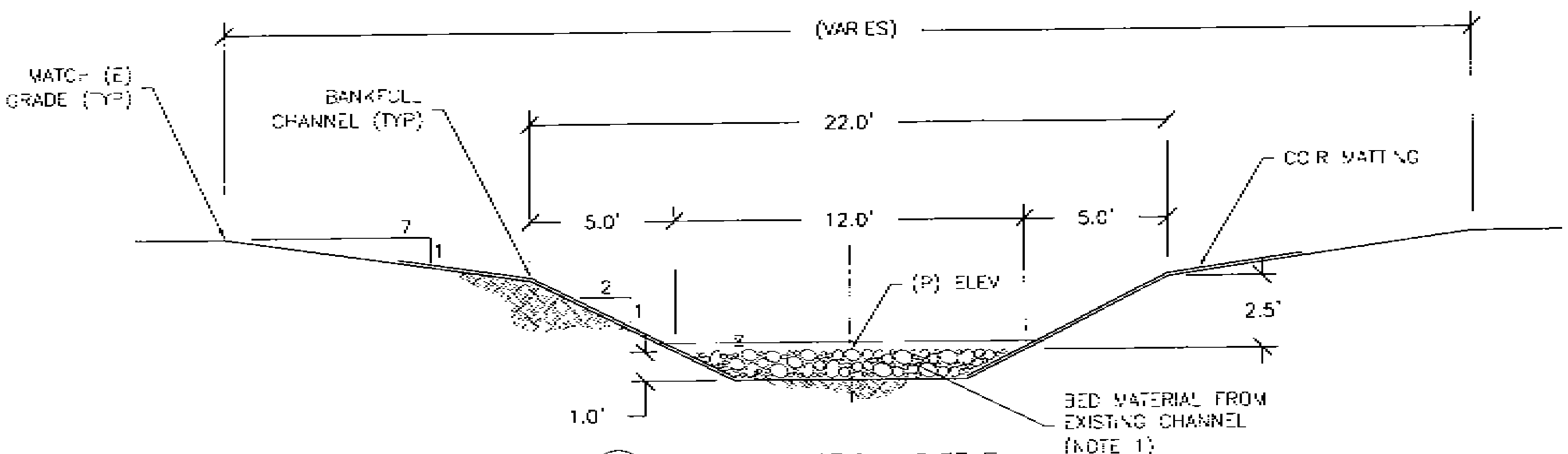
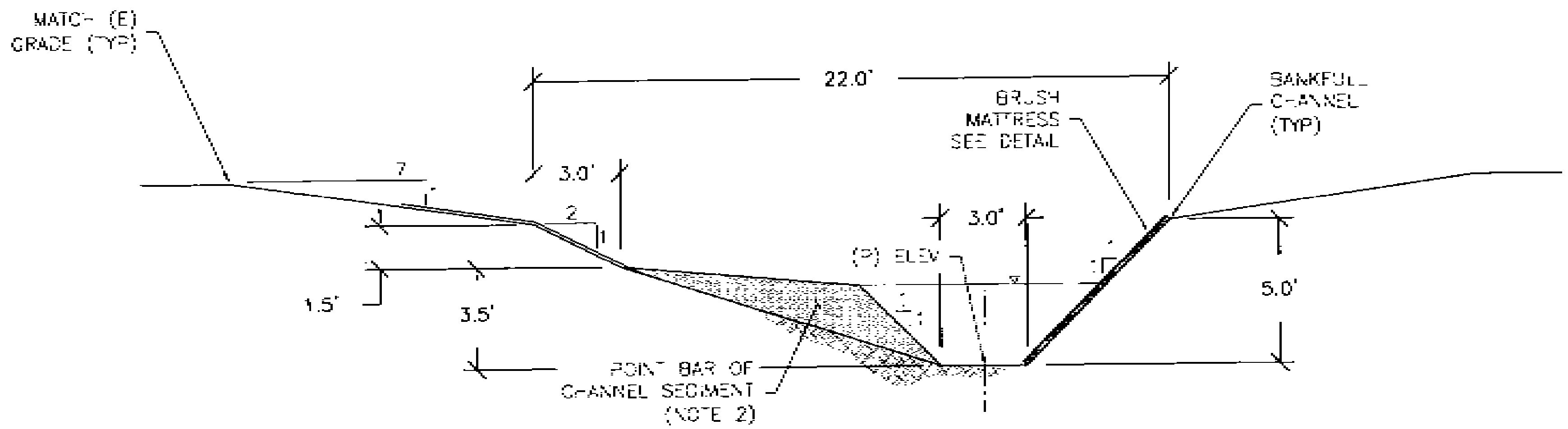
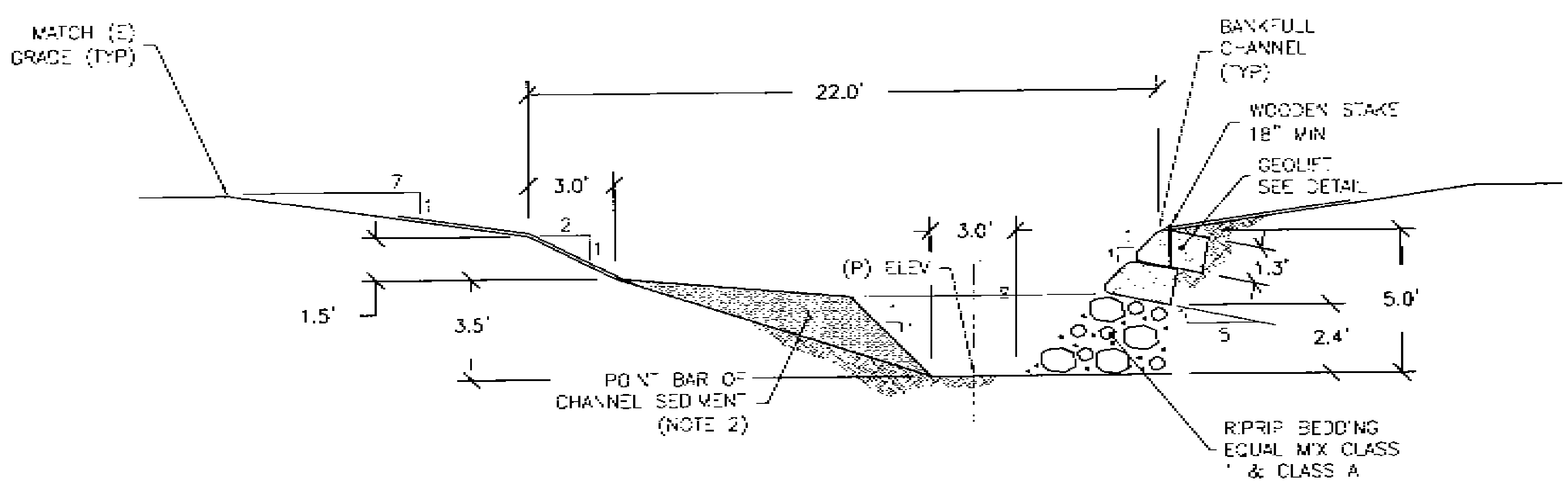


A/18 TYPICAL SECTION: RIFFLE
PUZZLE CREEK REACH 1 N.T.S
STA 0+00 TO 9+77.02



B/18 TYPICAL SECTION: MAX POOL W/ BRUSH MATTRESS
PUZZLE CREEK REACH 1 N.T.S
STA 0+00 TO 9+77.02



C/18 TYPICAL SECTION: MAX POOL W/ GEOLIFTS
PUZZLE CREEK REACH 1 N.T.S
STA 0+00 TO 9-77.02

NOTES:

1) IN EXISTING SECTIONS OF STREAM CHANNEL TO BE ABANDONED, CHANNEL BED MATERIAL SHALL BE EXCAVATED AND STOCKPILED TO BE TRANSFERRED TO SECTIONS OF PROPOSED STREAM CHANNEL. BED MATERIAL SHALL BE STOCKPILED SEPARATELY FROM SOIL AND SHALL BE KEPT FREE OF FINE SEDIMENT OR BRUSH MATERIAL.

2) POINT BARS SHALL BE CONSTRUCTED OF CHANNEL SEDIMENT ACCORDING TO THE DIMENSIONS SHOWN IN THE TYPICAL SECTIONS. CHANNEL SEDIMENT IS DEFINED AS COBBLE, GRAVEL, AND SAND PARTICLES FOUND IN THE EXISTING CHANNEL BED, SEDIMENT SHOALS AND BARS, AND SECTIONS OF ABANDONED CHANNEL. SUCH CHANNEL SEDIMENT MUST BE FREE OF SILT, CLAY, AND ORGANIC DEBRIS.

3) POINT BARS SHALL NOT BE SEEDED OR PLANTED AND SHALL NOT BE COVERED WITH COIR MATTING.

LEGEND:

(E)/(P)	EXISTING/PROPOSED
	APPROXIMATE LEVEL OF BASEFLOW WATER SURFACE
	RIPRAP STONE: EQUAL MIX OF CLASS 1 & CLASS A
	CHANNEL BED MATERIAL
	CHANNEL SEDIMENT
	UNDISTURBED IN-SITU SOIL
	CHANNEL THALWEG / CONTROL LINE

DESIGNED: DRAWN: APPROVED:

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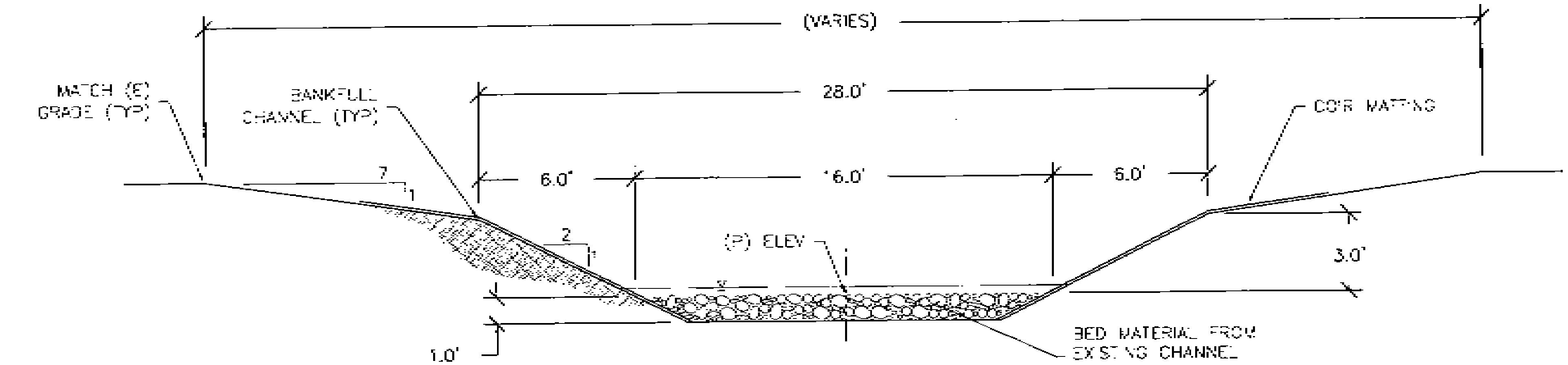
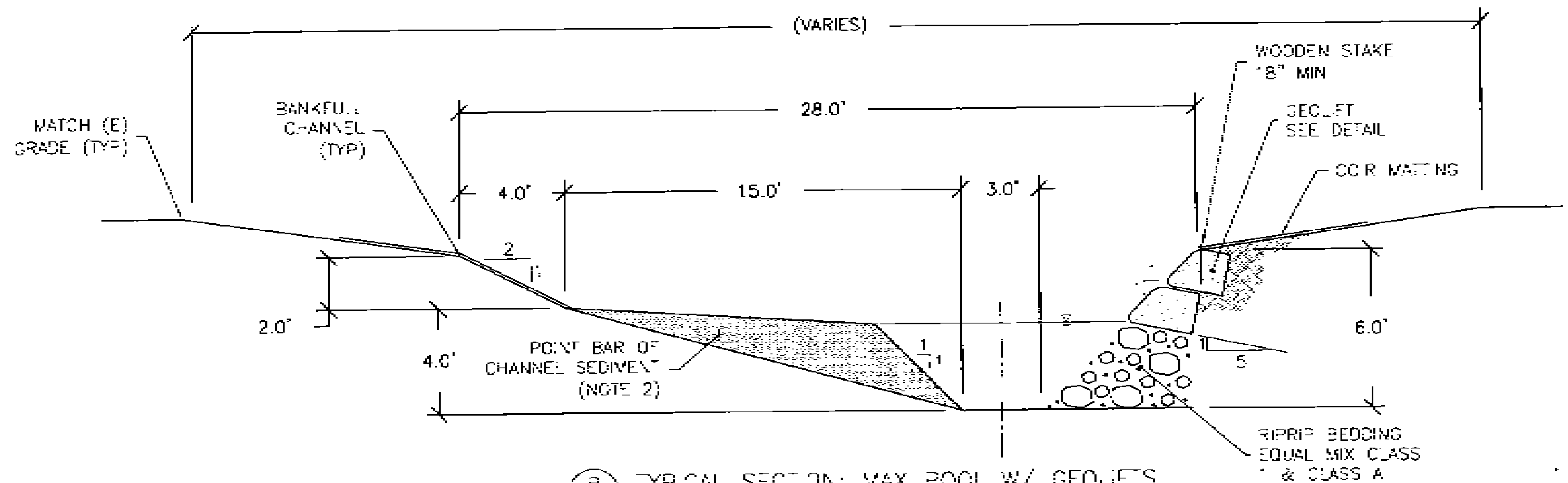
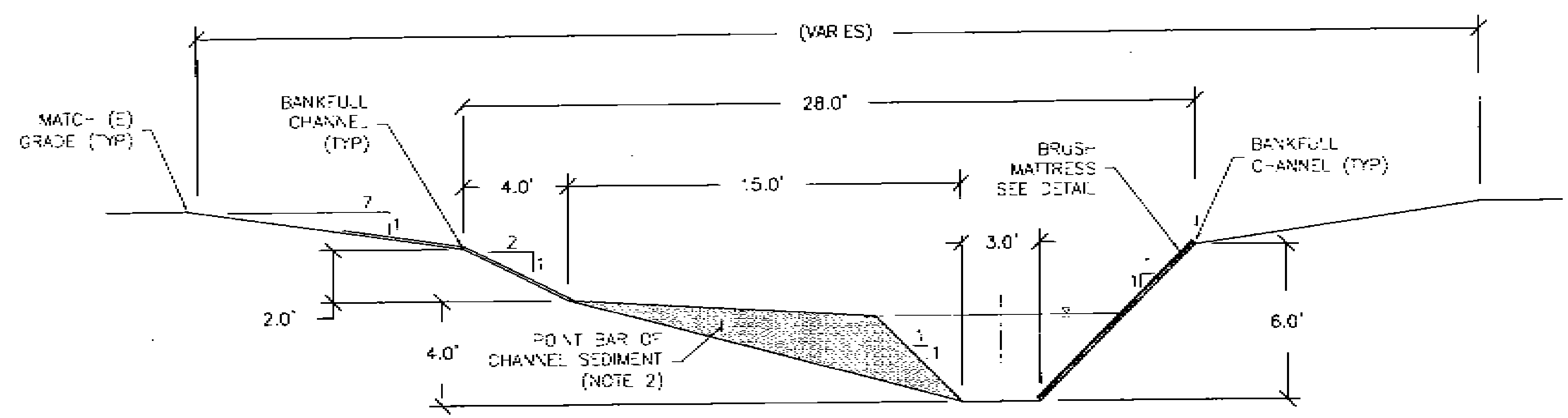


A TYPICAL SECTION: RIFFLE
19 PUZZLE CREEK REACH 2 N.T.S
STA 9+77.02 TO END



B TYPICAL SECTION: MAX POOL W/ GEOLIFTS
19 PUZZLE CREEK REACH 2 N.T.S
STA 9+77.02 TO END



C TYPICAL SECTION: MAX POOL W/ GEOLIFTS
19 PUZZLE CREEK REACH 2 N.T.S
STA 9+77.02 TO END

NOTES:

1) IN EXISTING SECTIONS OF STREAM CHANNEL TO BE ABANDONED, CHANNEL BED MATERIAL SHALL BE EXCAVATED AND STOCKPILED TO BE TRANSFERRED TO SECTIONS OF PROPOSED STREAM CHANNEL. BED MATERIAL SHALL BE STOCKPILED SEPARATELY FROM SOIL AND SHALL BE KEPT FREE OF FINE SEDIMENT OR BRUSH MATERIAL.

2) POINT BARS SHALL BE CONSTRUCTED OF CHANNEL SEDIMENT ACCORDING TO THE DIMENSIONS SHOWN IN THE TYPICAL SECTIONS. CHANNEL SEDIMENT IS DEFINED AS COBBLE, GRAVEL, AND SAND PARTICLES FOUND IN THE EXISTING CHANNEL BED, SEDIMENT SHOALS AND BARS, AND SECTIONS OF ABANDONED CHANNEL. SUCH CHANNEL SEDIMENT MUST BE FREE OF SILT, CLAY, AND ORGANIC DEBRIS.

3) POINT BARS SHALL NOT BE SEEDED OR PLANTED AND SHALL NOT BE COVERED WITH COIR MATTING

LEGEND:

(E)/(P) EXISTING/PROPOSED

APPROXIMATE LEVEL OF BASEFLOW WATER SURFACE

RIPRAP STONE: EQUAL MIX OF CLASS 1 & CLASS A

CHANNEL BED MATERIAL

CHANNEL SEDIMENT

UNDISTURBED IN-SITU SOIL

CHANNEL THALWEG / CONTROL LINE

DESIGNED
DRAWN
APPROVED

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

TYPICAL SECTIONS

Prepared for:
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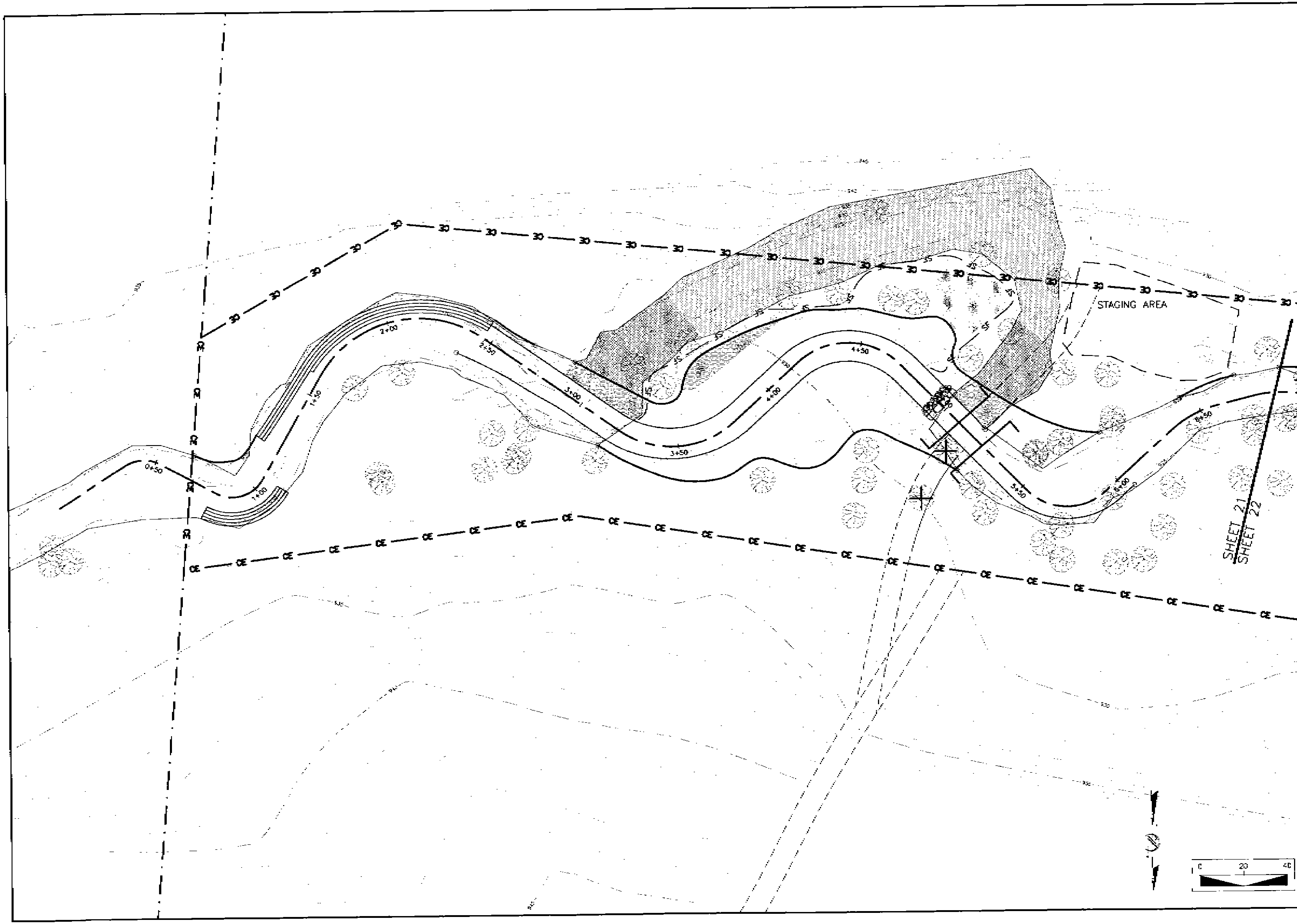
Baker Project Number
AH-09277
Date: 11/25/2007
Drawing Sheet No.
Sheet 19 of 29



DESIGNED
DRAWN
APPROVED

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

EROSION CONTROL & PLANTING PLAN

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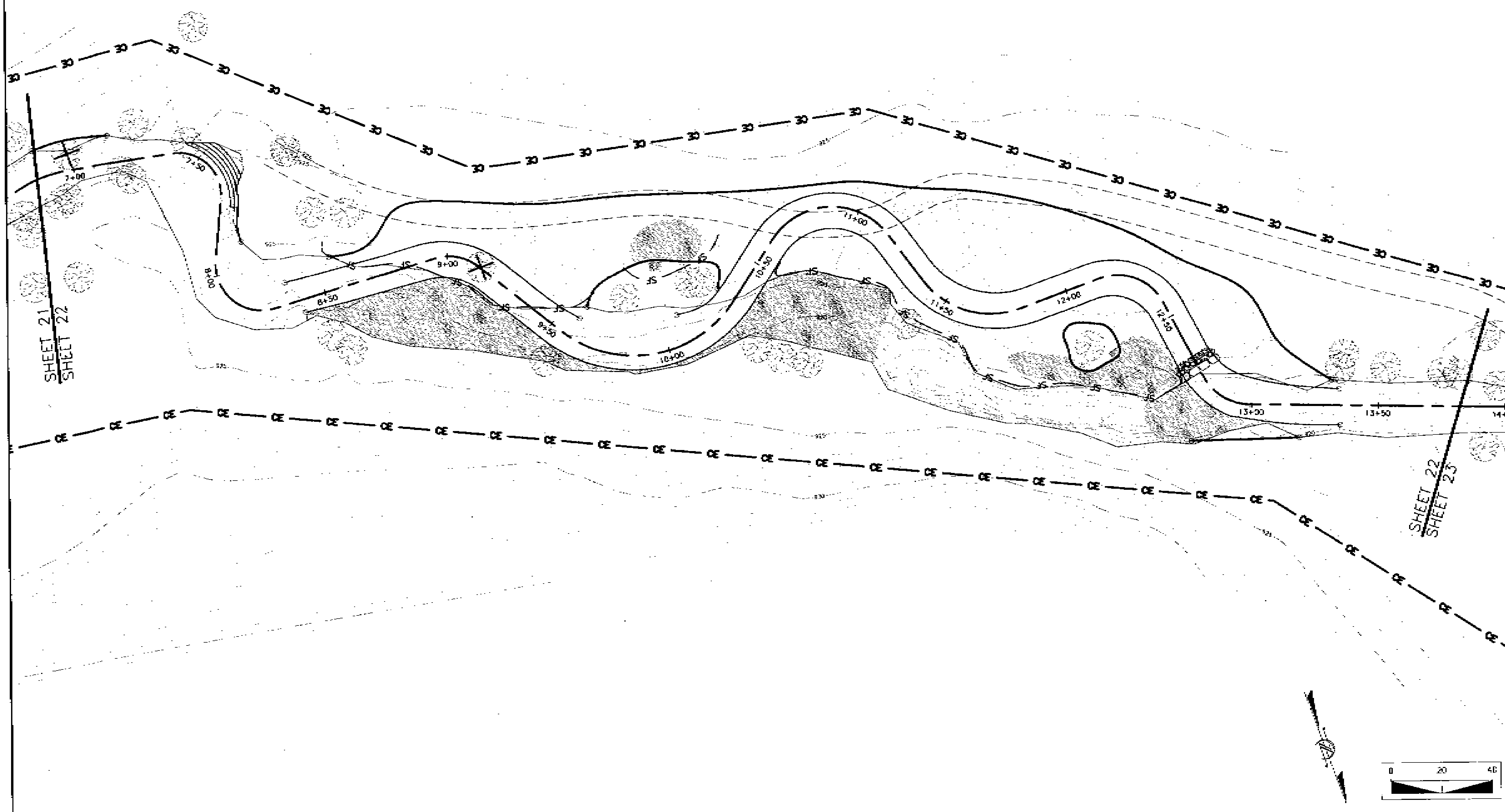
Baker Project Number
AH-103277

Date 11/20/2007

Drawing Sheet No.
Sheet 20 of 23



DESIGNED: JLB
DRAWN: JLB
APPROVED: ADB

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PUZZLE CREEK RESTORATION PROJECT
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AF-139277
Date: 11/20/2007
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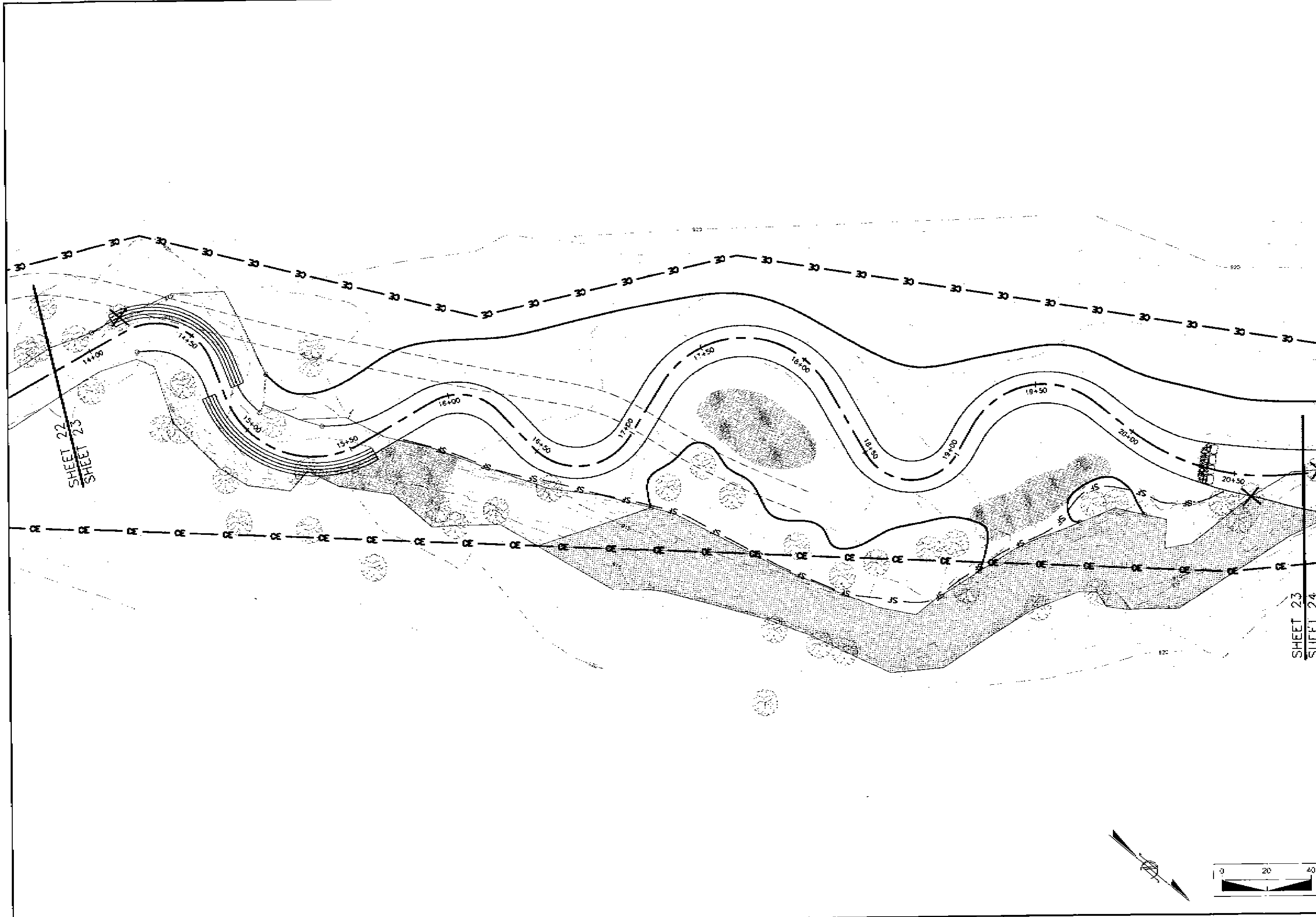
Sheet 21 of 29



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PUZZLE CREEK RESTORATION PROJECT
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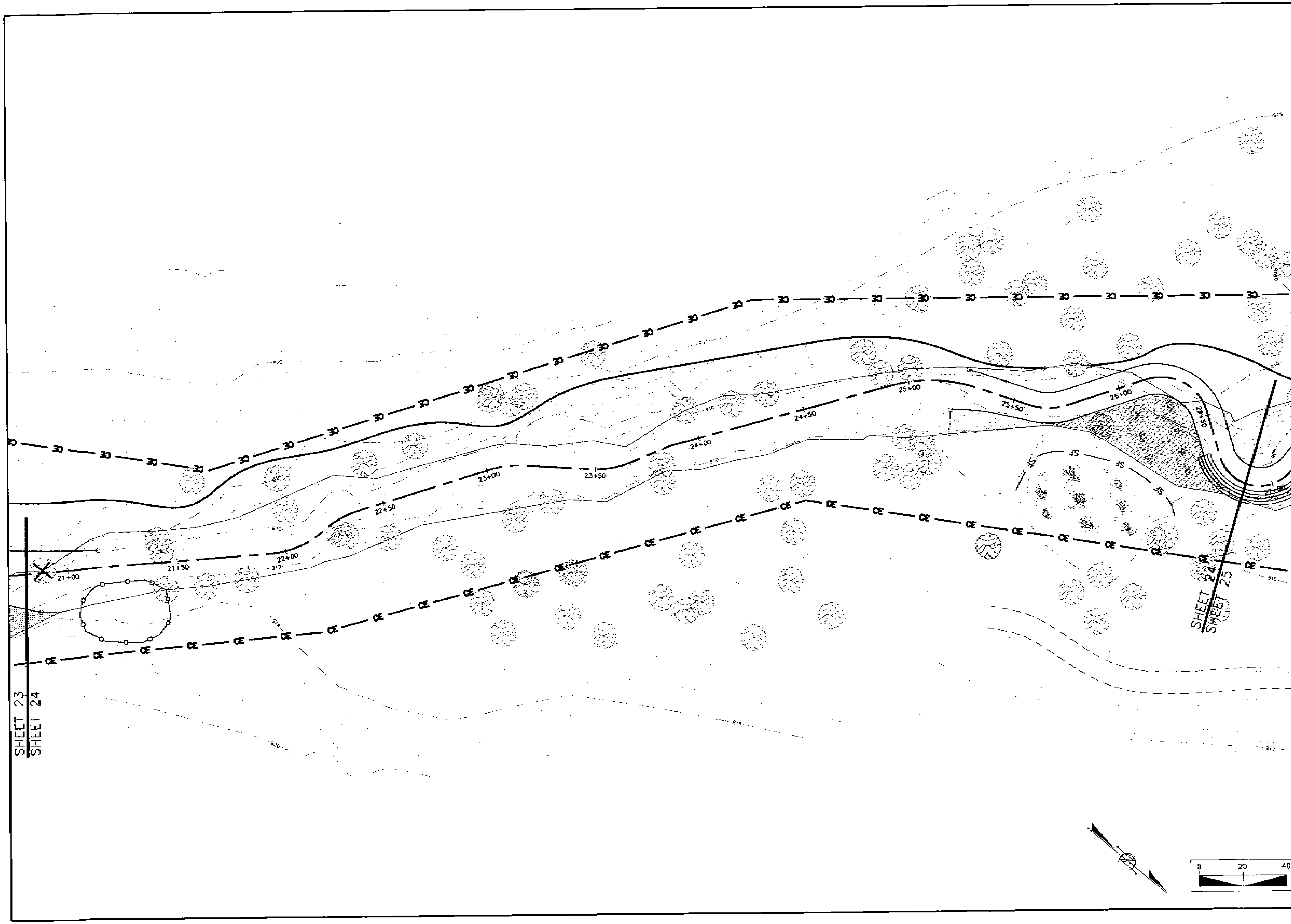

DESIGNED:
DRAWN:
APPROVED:

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PUZZLE CREEK RESTORATION PROJECT
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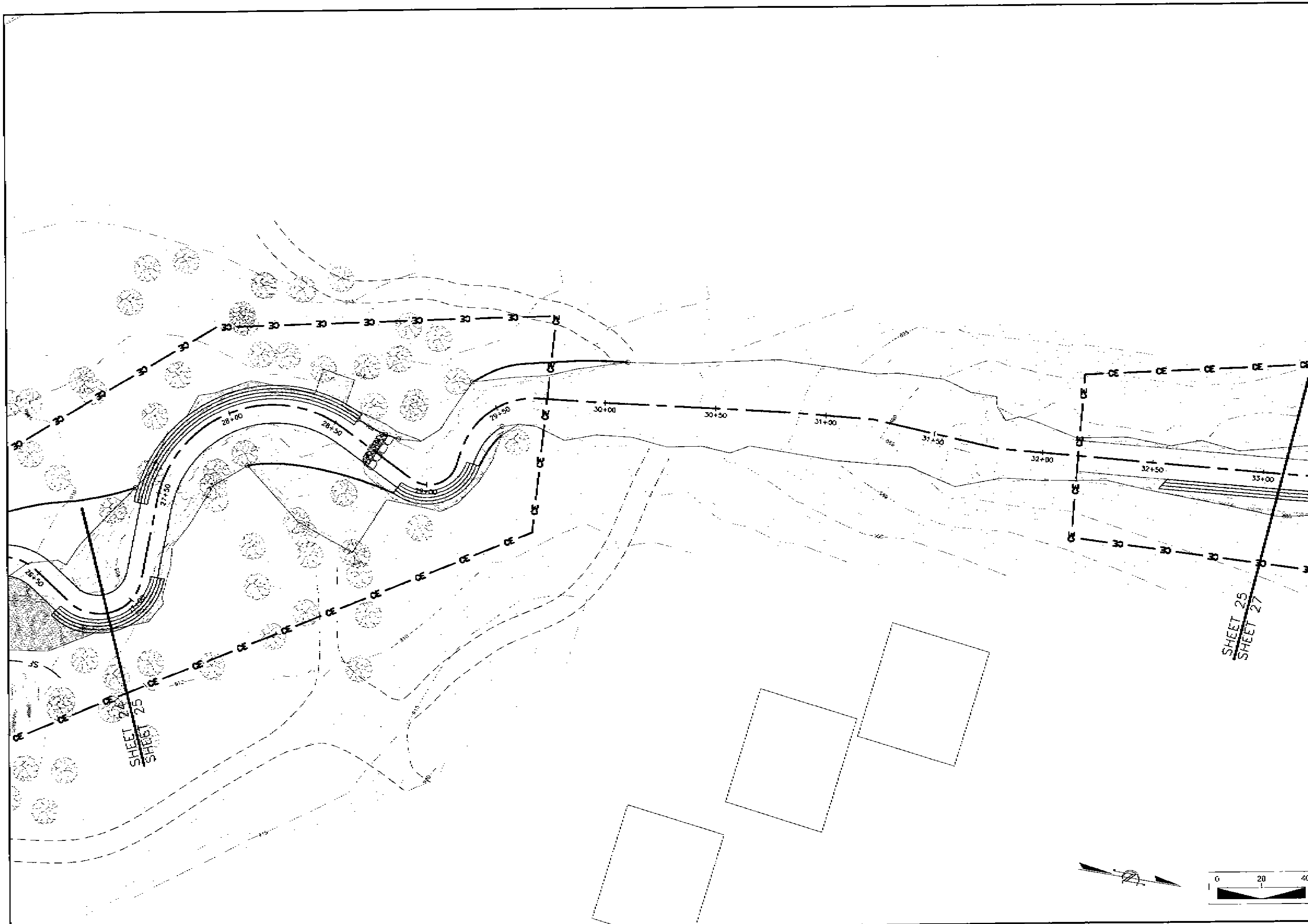
Sheet: 24 of 29



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Drawing Sheet No.
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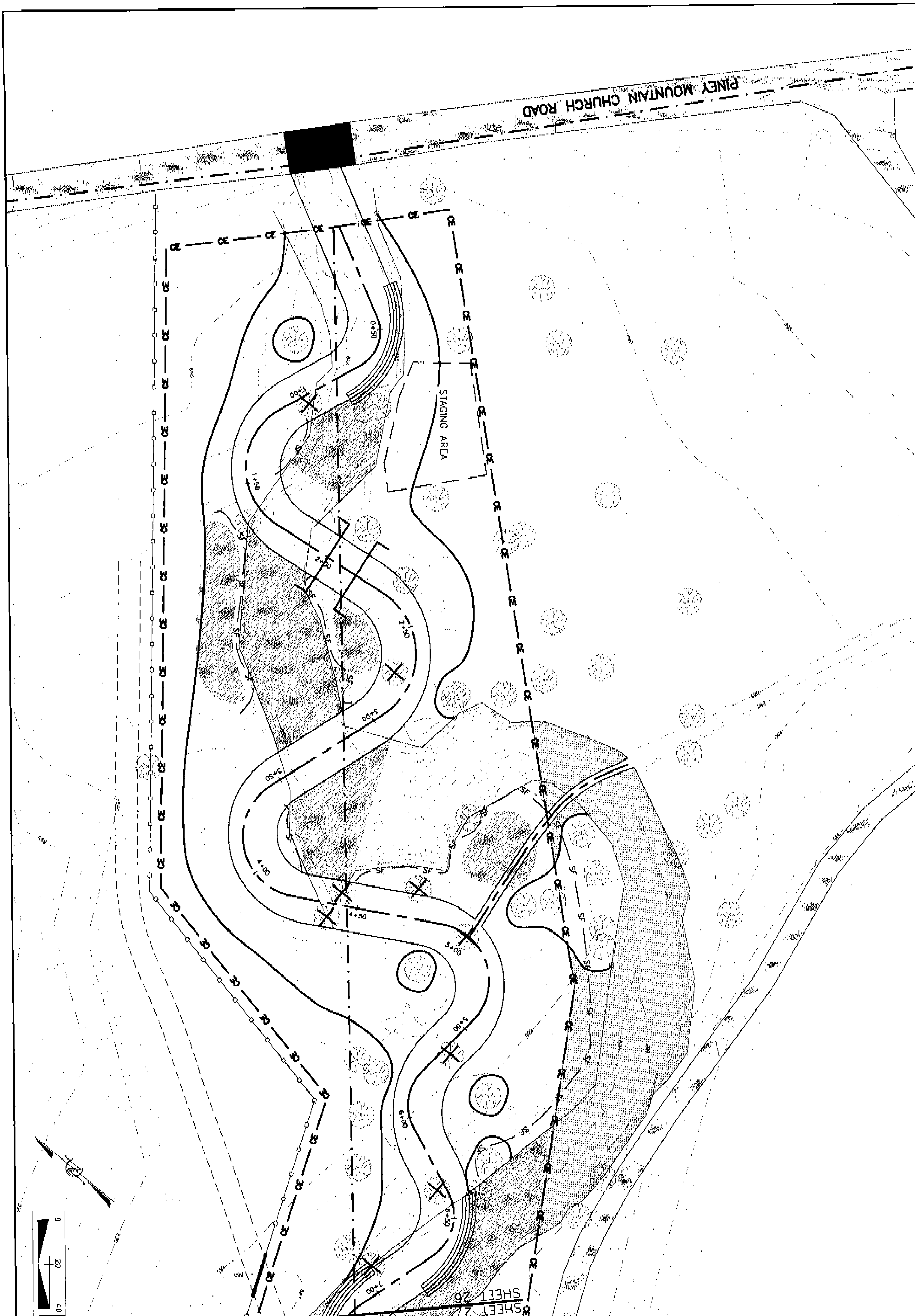
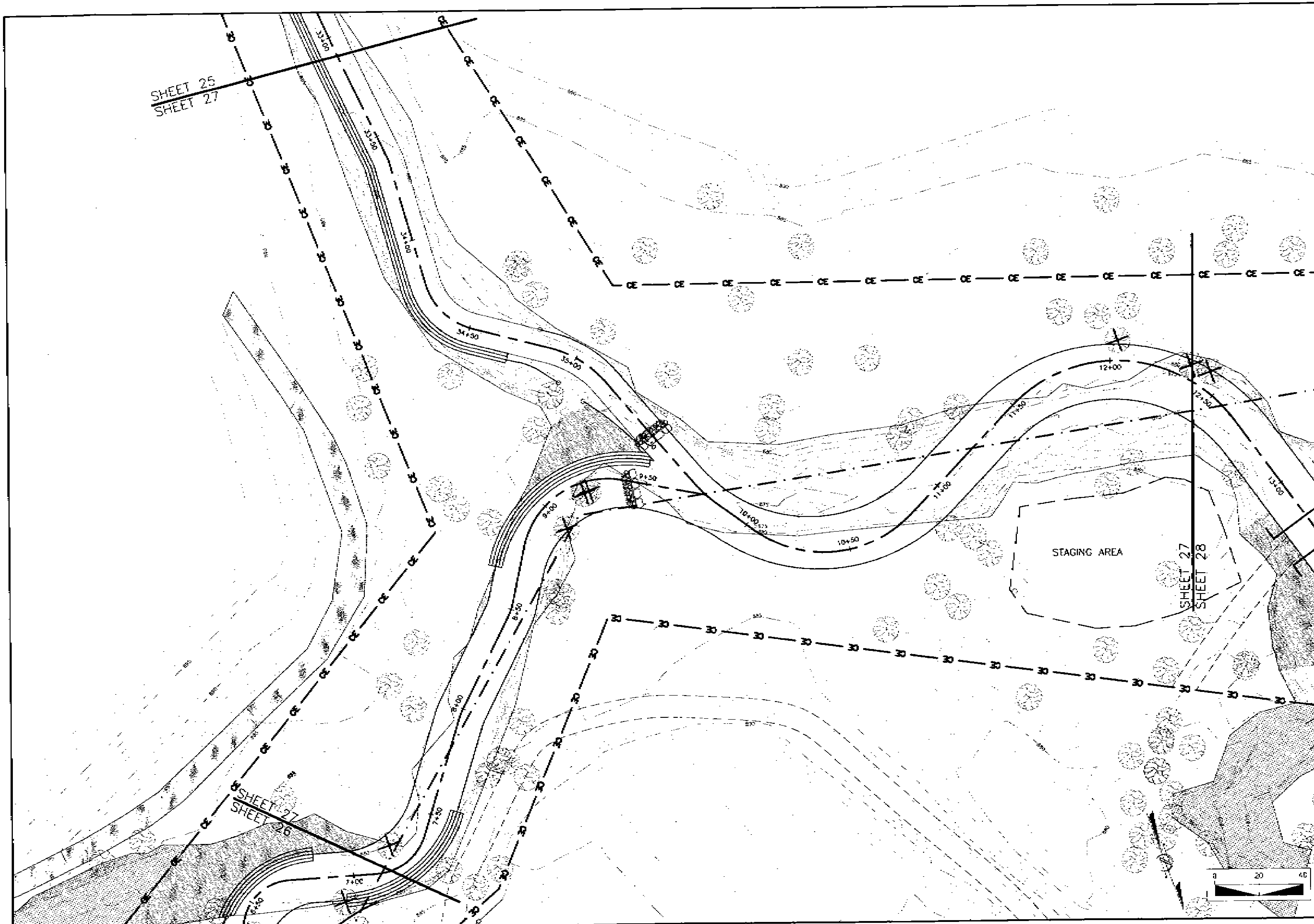


Baker Project Number AH-139277 Date: 11/23/2007 Drawing Sheet No. Sheet 25 of 29	Prepared for: Ecosystem Enhancement Program 2728 Capitol Blvd, Suite 1H 103 Raleigh, NC 27604 Phone 919-715-0476 Fax: 919-715-2219	PUZZLE CREEK RESTORATION PROJECT BOSTIC, NC EROSION CONTROL & PLANTING PLAN	Baker Engineering NY, Inc. 797 Haywood Road Suite 201 Asheville, North Carolina 28806 Phone: 828.350.1408 Fax: 828.350.1409

DESIGNED: DRAWN: APPROVED:



DESIGNED: [illegible]
DRAWN: [illegible]
APPROVED: ABB

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Baker Project Number
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Date: 11/20/2007
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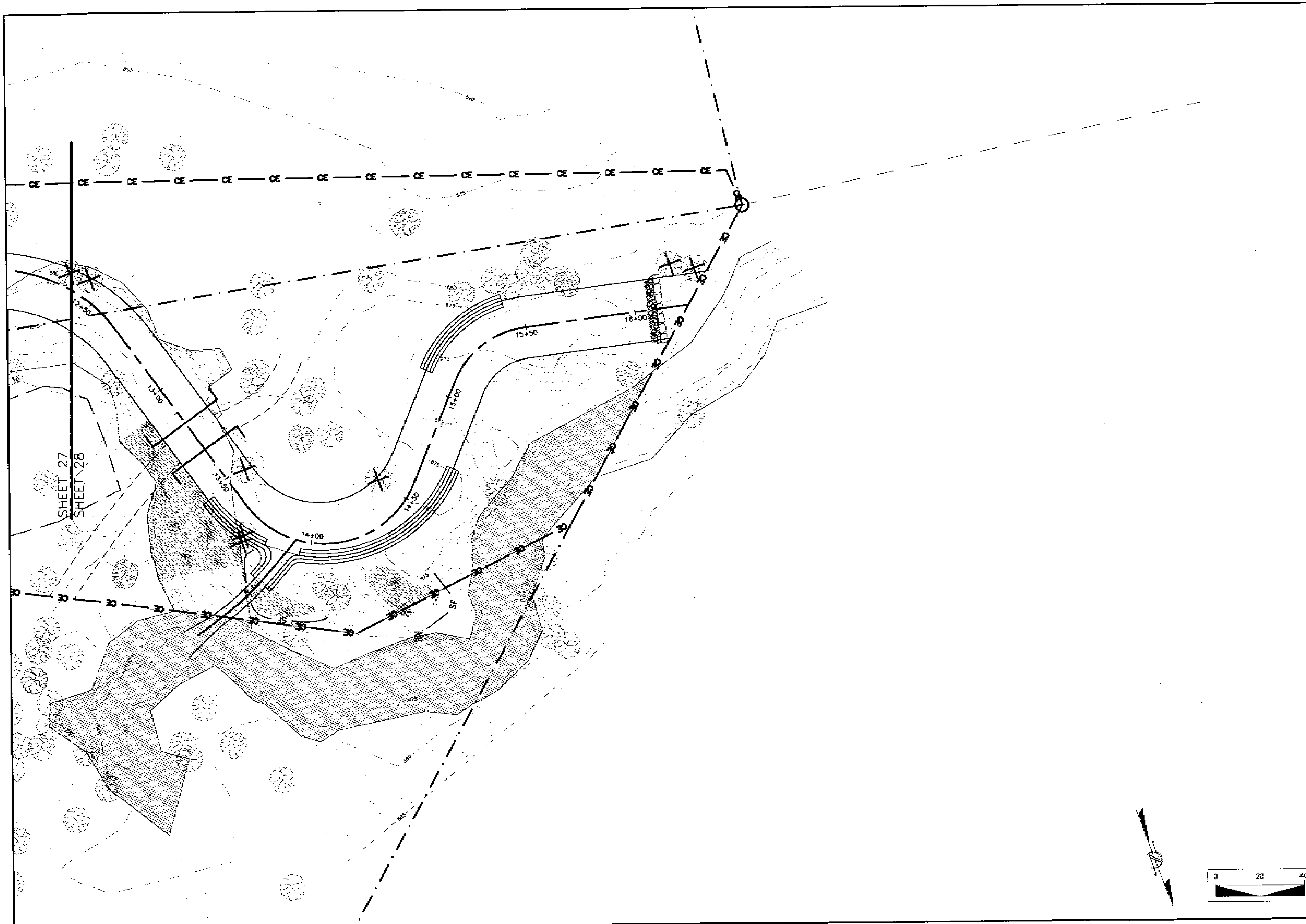

DESIGNED:
DRAWN:
APPROVED:

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PUZZLE CREEK RESTORATION PROJECT
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[illegible]09277
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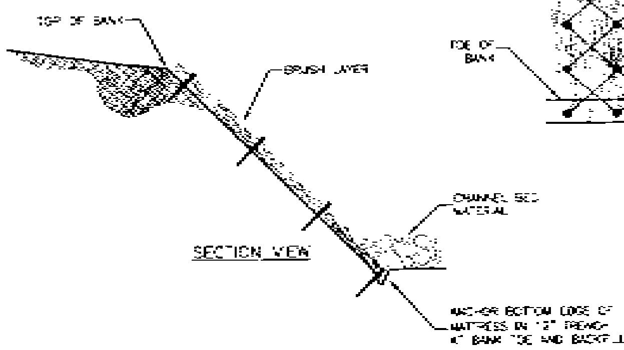
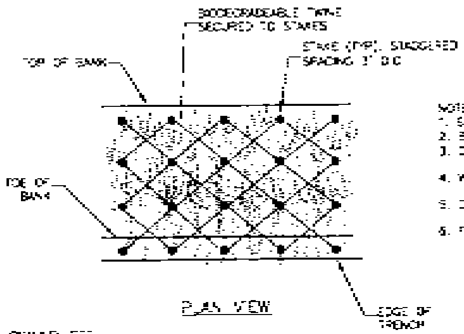
Sheet 27 of 29

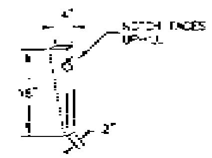


SECTION VIEW



PLAN VIEW

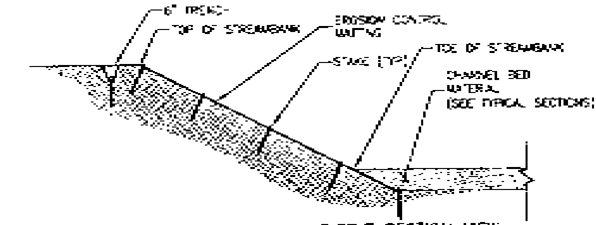
NOTES:
1. 50 BRANCHES MINIMUM PER 5 SF
2. BRANCH MAXIMUM DIAMETER 1"
3. DRIVE STAKES HALFWAY INTO BANK 3' ON CENTER BETWEEN BRANCHES.
4. WRAP TWINE AROUND STAKES AND OVER BRANCHES TIGHTLY.
5. DRIVE STAKES FURTHER TO TIGHTEN TWINE AND SECURE BRANCHES TO SLOPE.
6. FILL VOIDS BETWEEN THE BRANCHES WITH SOIL FROM ON-SITE; ADD SOIL TO A DEPTH OF 3" ABOVE BRANCHES.



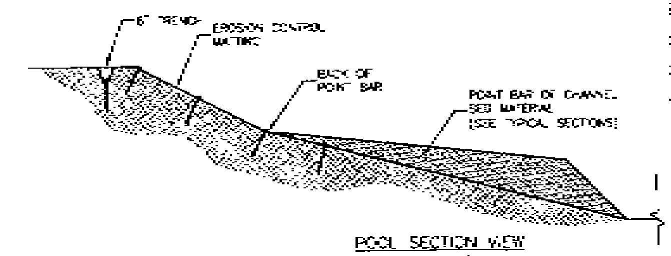
TYPICAL STAKE

BRUSH MATTRESS

NTS



RIFFLE SECTION VIEW



POOL SECTION VIEW

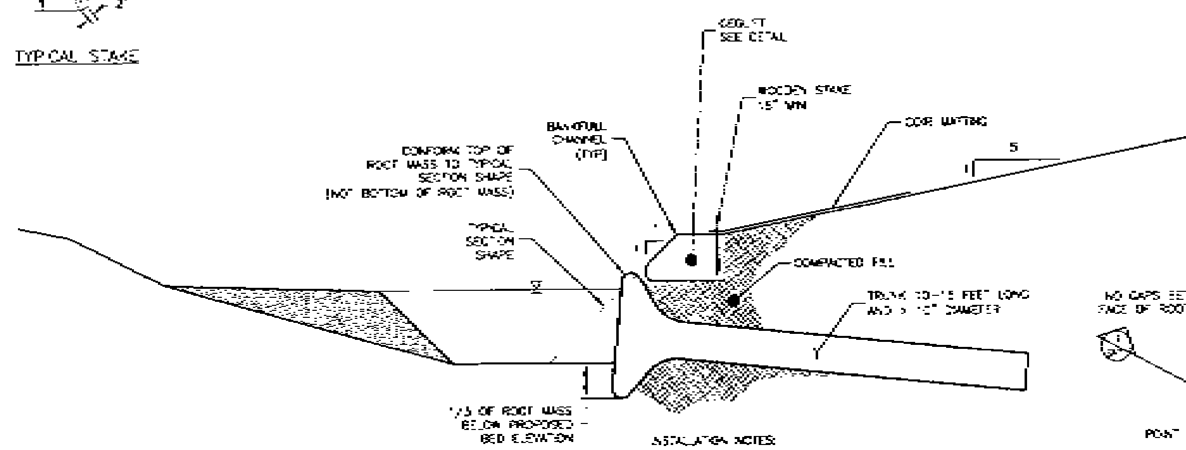
THE WOOD STAKE SHALL BE THE NORTH AMERICAN GREEN ECO-STAKE OR APPROVED EQUIVALENT WITH THE FOLLOWING DIMENSIONS:

LEG LENGTH	11.00 IN (27.94 CM)
HEAD WIDTH	1.25 IN (3.18 CM)
HEAD THICKNESS	0.40 IN (1.02 CM)
LEG WIDTH	0.60 IN (1.52 CM) (TAPERED TO POINT)
LEG THICKNESS	0.50 IN (1.27 CM)
TOTAL LENGTH	12.00 IN (30.48 CM)

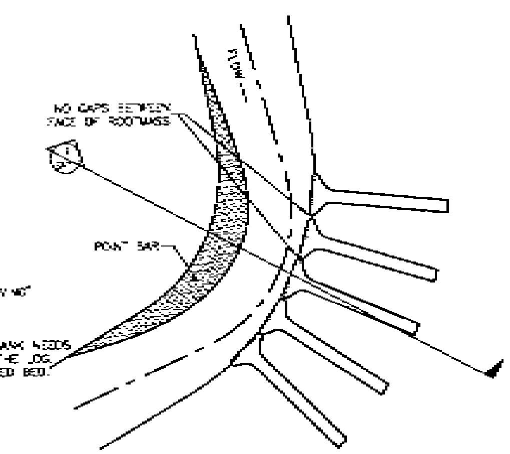
NOTES:
1) BANKS SHALL BE SEEDED AND MULCHED PRIOR TO INSTALLATION OF MATTING
2) MATTING SHALL BE PLACED ACCORDING TO MANUFACTURER'S SPECIFICATIONS
3) MATTING SHALL BE STAKED IN DIAMOND PATTERN
4) AT TOP OF BANK, MATTING SHALL BE PLACED IN 6" DEEP TRENCH, STAKED, BACKFILLED, AND COMPACTED

COIR MATTING

NTS



MAX POOL SECTION VIEW



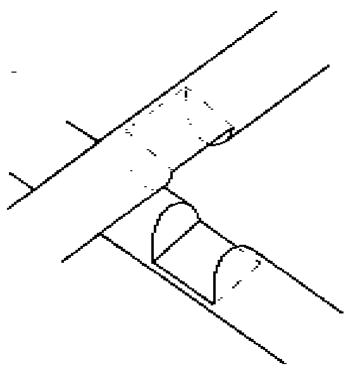
INSTALLATION NOTES:

DRIVE-POINT METHOD
SHARPEN THE END OF THE LOG WITH A CHAINSAW BEFORE "DRIVING" IT INTO THE BANK.

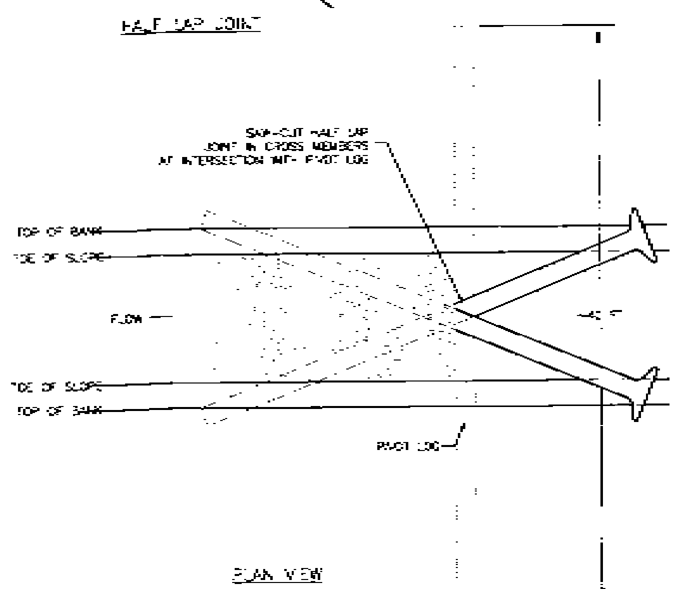
TRENCHING METHOD
IF THE ROOTWAD CANNOT BE DRIVEN INTO THE BANK OR THE BANK NEEDS TO BE RECONSTRUCTED, A TRENCH SHALL BE EXCAVATED FOR THE LOG. ONE-THIRD OF THE ROOTWAD SHALL REMAIN BELOW THE FINISHED BED.

ROOTWAD CLUSTER

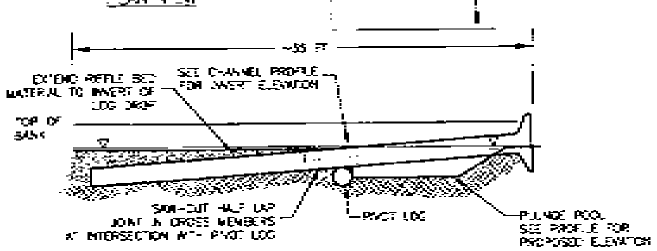
NTS



HALF LAP JOINT



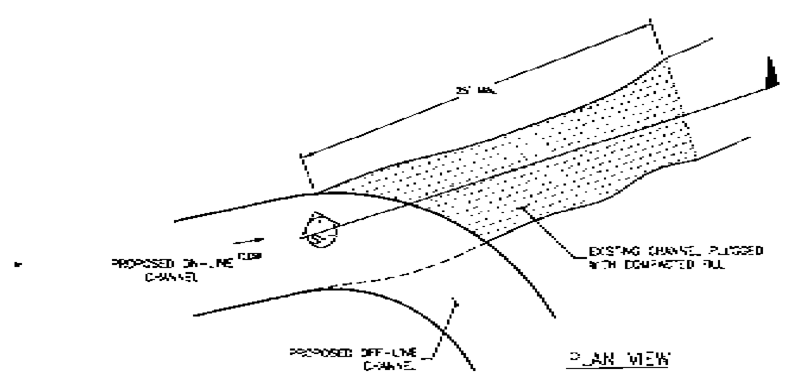
PLAN VIEW



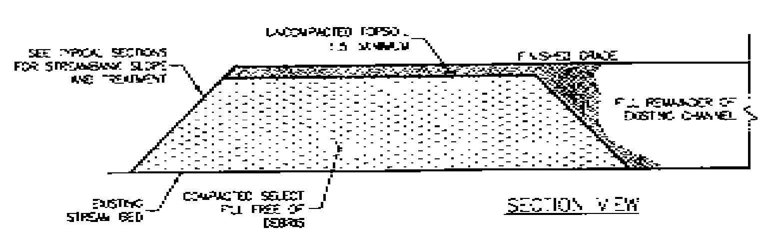
PROFILE VIEW

LOG DROP

CONSTRUCTION NOTES:
1. LOGS SHALL BE HARDWOOD SPECIES APPROXIMATELY 18" IN DIAMETER; THE TWO CROSS MEMBER LOGS SHOULD BE STRAIGHT AND NEARLY IDENTICAL IN SIZE.
2. A WATER SURFACE ELEVATION DROP ACROSS THE STRUCTURE SHALL BE ~ 0.20 FT.



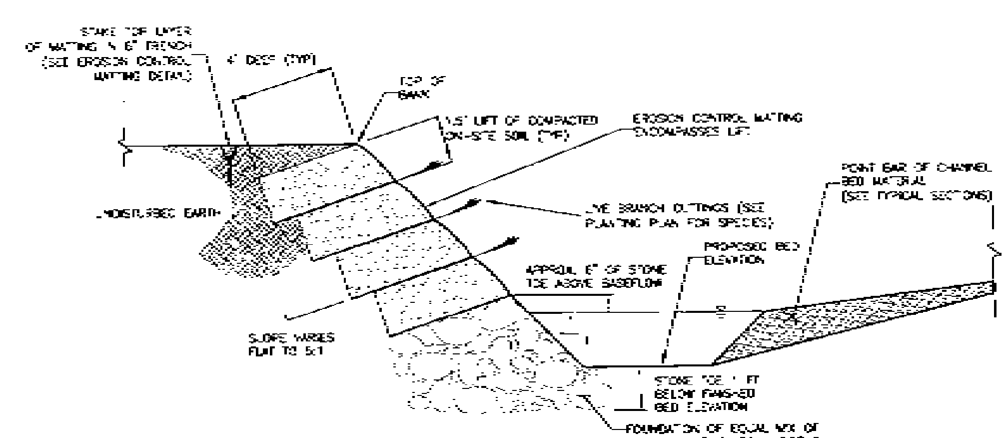
PLAN VIEW



SECTION VIEW

CHANNEL PLUG

NTS



VEGETATED GEOLIFT

NTS

DESIGNED: JJR
DRAWN: JJR
APPROVED: ADB

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PUZZLE CREEK RESTORATION PROJECT
BOSTIC, NC

DETAILS - GRADING

Prepared for:
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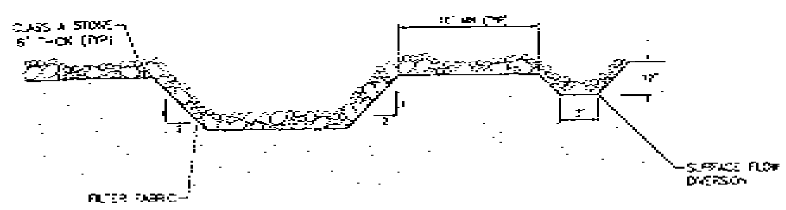
Baker Project Number
AH-109277

Date: 11/26/2007

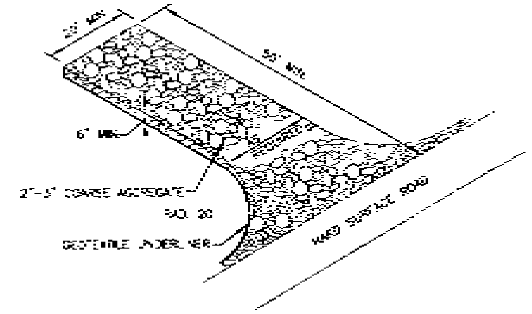
Drawing Sheet No.

Sheet 26 of 29

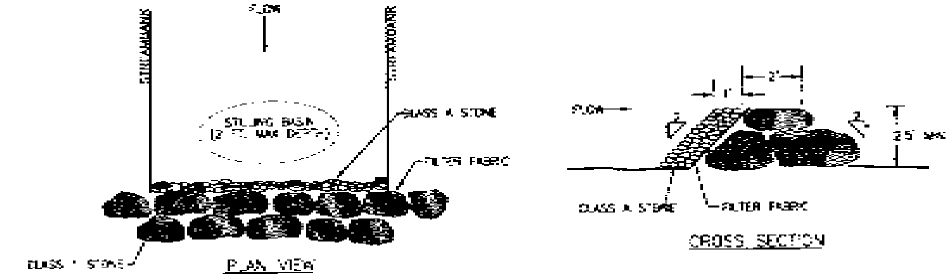
NOTES:
1) CONSTRUCT CROSSING DURING LOW FLOW
2) HAVE NECESSARY MATERIALS AND EQUIPMENT ON-SITE BEFORE BEGINNING WORK
3) MINIMIZE CLEARING AND EXCAVATION OF STREAM BANKS. DO NOT EXCAVATE CHANNEL BOTTOM. COMPLETE ONE SIDE AT A TIME
4) INSTALL CROSSING PERPENDICULAR TO FLOW
5) MAINTAIN CROSSING SO THAT RUNOFF IN THE CONSTRUCTION ROAD DOES NOT ENTER THE STREAM
6) WIDTH OF THE CROSSING SHALL BE SUFFICIENT TO ACCOMMODATE THE LARGEST VEHICLE CROSSING THE STREAM



TEMPORARY STREAM CROSSING
NTS



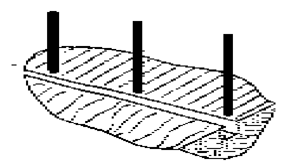
CONSTRUCTION ENTRANCE
NTS



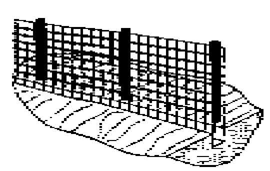
NOTES:
CLEAN OUT STILLING BASIN OF TRAPPED SEDIMENT PRIOR TO REMOVAL.

CHECK DAM
NTS

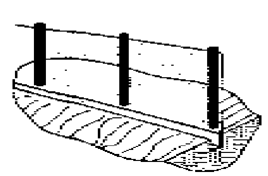
1. SET 2'0" (MIN) STEEL POSTS AT 5' MAX SPACING AND EXCAVATE A 4"X4" TRENCH UPSLOPE ALONG THE LINE OF POSTS.



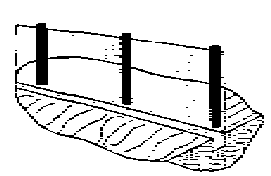
2. STAPLE 6"X6" 14 GAUGE WIRE FENCING TO THE STEEL POSTS.



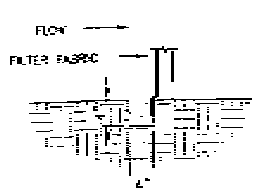
3. ATTACH THE FILTER FABRIC TO THE WIRE FENCE AND EXTEND IT INTO THE TRENCH.



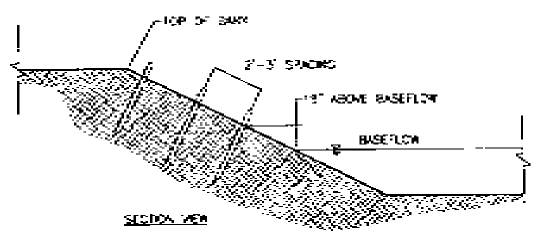
4. BACKFILL AND COMPACT THE EXCAVATED SOIL.

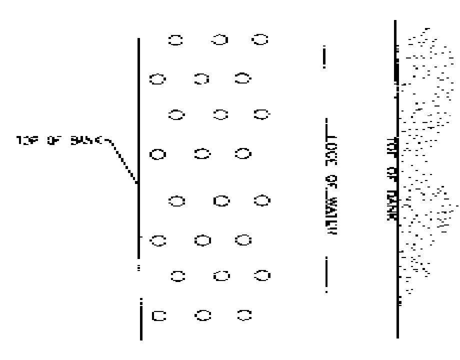


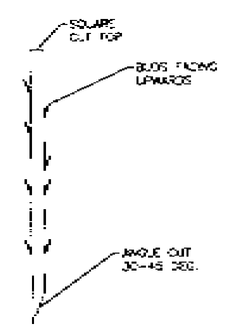
5. EXTEND FABRIC AND WIRE INTO THE TRENCH.



CONSTRUCTION OF A SILT FENCE
NTS



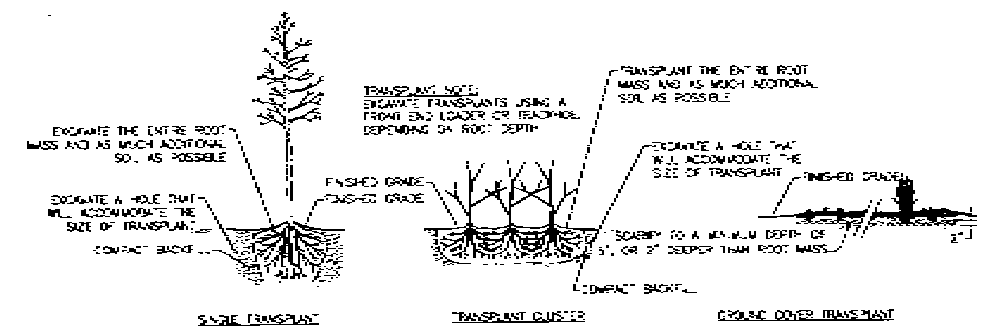


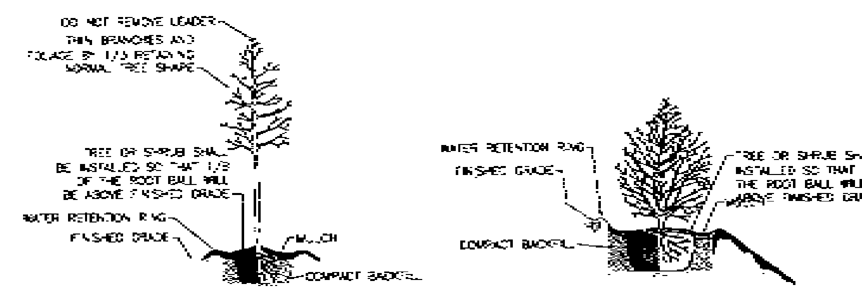


NOTES:
1. STAKES SHALL BE CUT AND INSTALLED ON THE SAME DAY
2. STAKES THAT HAVE BEEN SPLIT SHALL BE REJECTED AND NOT USED FOR CONSTRUCTION
3. STAKES SHALL BE INSTALLED WITH BUDS POINTING UPWARD
4. STAKES SHALL BE INSTALLED PERPENDICULAR TO BANK
5. STAKES SHALL BE 1/2 TO 2 INCHES IN DIAMETER AND 2 TO 3 FT LONG
6. STAKES SHALL BE INSTALLED WITH 1/3 TO 1/5 OF STAKE REMAINING ABOVE GROUND

LIVE STAKING
NTS

TRANSPLANT NOTE:
EXCAVATE TRANSPLANTS USING A FRONT END LOADER OR TRACKHOE, DEPENDING ON ROOT DEPTH

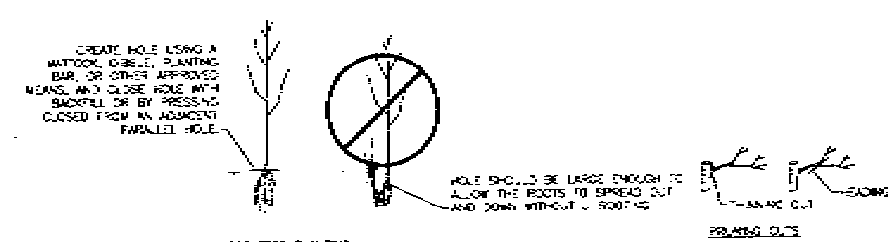




CONTAINERIZED PLANTING
GROUND LEVEL

CONTAINERIZED PLANTING
SLOPING GROUND

CONTAINERIZED PLANTING NOTES:
1. WHEN PREPARING THE HOLE FOR A CONTAINERIZED PLANT, EXCAVATE THE HOLE 6-12 INCHES LARGER THAN THE DIAMETER OF THE POT AND THE SAME DEPTH AS THE POT.
2. REMOVE THE PLANT FROM THE POT. LAY THE PLANT ON ITS SIDE IF NECESSARY TO REMOVE THE POT.
3. IF THE PLANT IS ROOTBOUND (ROOTS GROWING IN A SPIRAL AROUND THE ROOT BALL) MAKE VERTICAL CUTS WITH A KNIFE OR SPADE JUST DEEP ENOUGH TO CUT THE NET OF ROOTS. ALSO MAKE A CRISS-CROSS CUT ACROSS THE BOTTOM OF THE BALL.
4. PLACE THE PLANT IN THE HOLE.
5. FILL HALF OF THE HOLE WITH SOIL (SAME SOIL REMOVED FOR BACKFILL).
6. WATER THE SOIL TO REMOVE AIR POCKETS AND FILL THE REST OF THE HOLE WITH THE REMAINING SOIL.



BARE ROOT TREE PLANTING

PRUNING CUTS

GENERAL NOTES:
1. KEEP ROOTS MOIST WHILE DISTRIBUTING OR WAITING TO PLANT BY MEANS OF WET CANVAS, BURLAP, OR STRAW.
2. HEEL-IN PLANTS IN MOIST SOIL OR SAWDUST IF NOT PROMPTLY PLANTED UPON ARRIVAL TO PROJECT SITE.
3. PRUNE ANY BROKEN LIMBS AND TREAT TORN BARK WITH TREE WOUND DRESSING.
4. EVERY EFFORT SHOULD BE MADE TO KEEP SOIL EXCAVATED FOR PLANTING FROM ENTERING STREAM. ACCIDENTAL FILL SHOULD BE REMOVED IMMEDIATELY.

TREE AND SHRUB PLANTING
NTS

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APPROVED: ADE

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DETAILS - EROSION CONTROL AND PLANTING

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