STONE MOUNTAIN STATE PARK
Stream Restoration on the East Prong Roaring River

Prepared By:

NC Stream Restoration Institute
and
Stone Mountain Stream Restoration Steering Committee

For the

NC Wetland Restoration Program

April 17, 2000

nc stream restoration institute

NORTH CAROLINA STATE PARKS

N.C. Wetlands Restoration Program

Stone Mountain State Park
Stream Restoration Steering Committee

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Introduction

The Stone Mountain State Park stream restoration project is a collaborative effort between the NC Wetlands Restoration Program, NC Division of Parks and Recreation, and the NC Stream Restoration Institute. The project includes nearly 2 miles of stream restoration within the boundaries of the Stone Mountain State Park. The watershed area is approximately 22 square miles, and is shown in Figure 1. This document is designed to layout the existing condition of the project area, including the stream channel and adjacent floodplain area, present the natural channel design, and provide the necessary documentation associated with this design.

Goals and Objectives

The goals of the stream restoration project on the East Prong Roaring River at Stone Mountain State Park are as follows:

1. Improve water quality degraded by sedimentation by returning the East Prong Roaring River to a stable dimension, pattern, and profile.
2. Restore the aquatic and terrestrial habitat of the stream corridor.
3. Restore floodplain and wetland functionality.
4. Improve the natural aesthetics of the river corridor.

These goals will be met by implementing the following specific objectives for each stream reach. The stream reaches are discussed in detail under the existing condition survey and design sections, and are presented in Figures 2 and 3.

Reach 1

1. Re-introduce large woody debris and boulder clusters to improve aquatic habitat.

Reach 2

2. Re-establish a stable dimension, pattern, and profile by constructing a new bankfull channel.

Reach 3

3. Re-introduce large woody debris and boulder clusters to improve aquatic habitat.

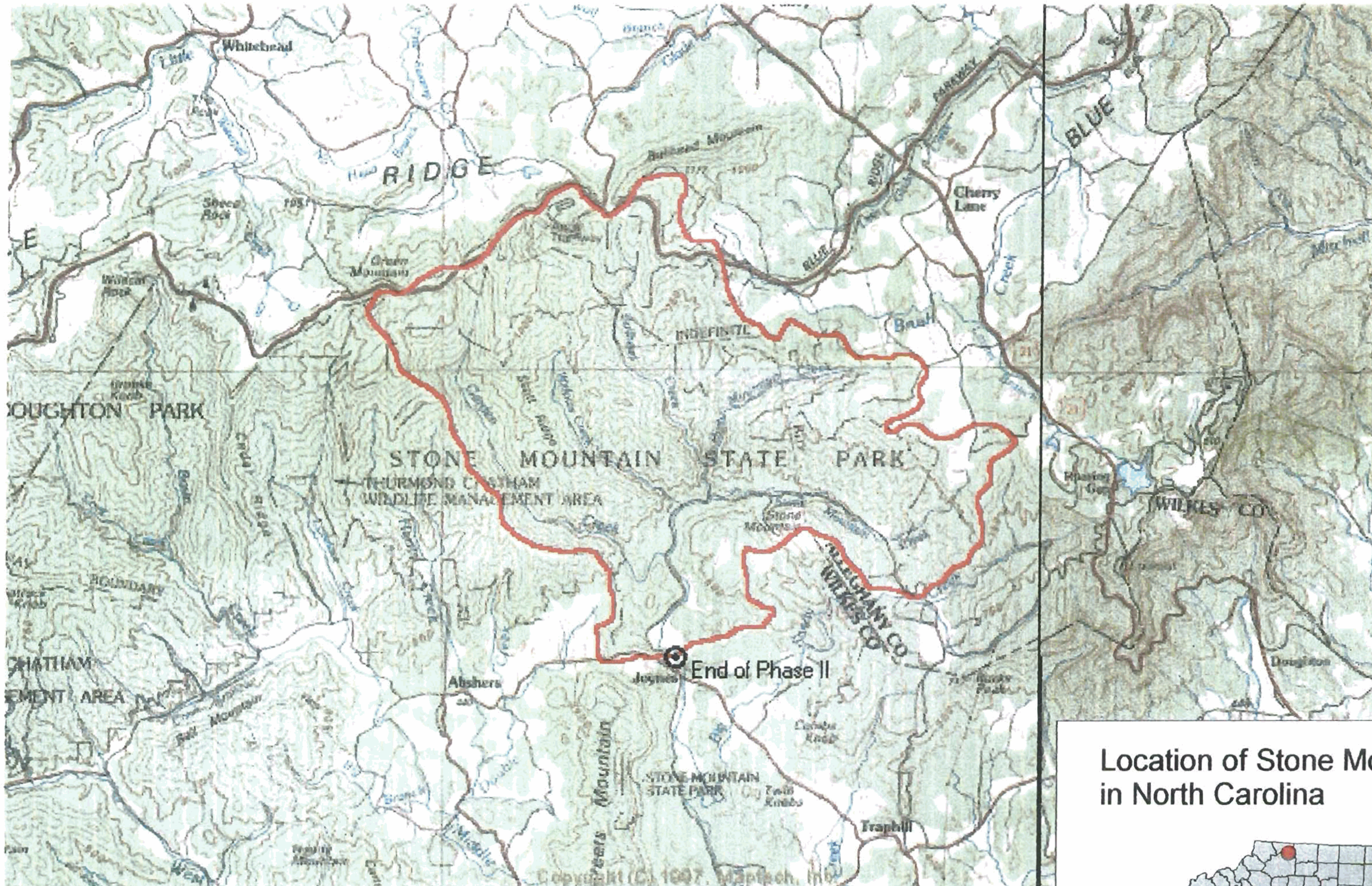
Reach 4

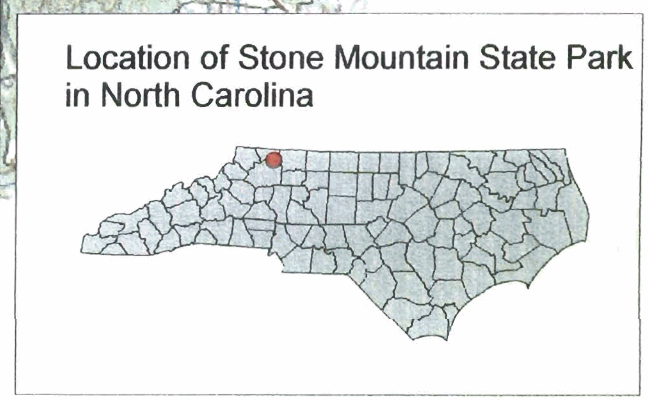
4. Re-establish a stable dimension, pattern, and profile by constructing a new bankfull channel.

Physical Setting

Stone Mountain State Park consists of two types of rocks, metamorphic and intrusive igneous. Stone Mountain itself is made up of quartz diorite to granodiorite rocks and are the youngest in the park aged at approximately 400 MY (Burt et.al. 1985). These rocks were formed from magma generated beneath the earth's surface and then slowly cooled. The rock surrounding the granite dome is much older (approximately 570-900 MY)

Figure 1. Stone Mountain State Park Stream Restoration - Watershed Area





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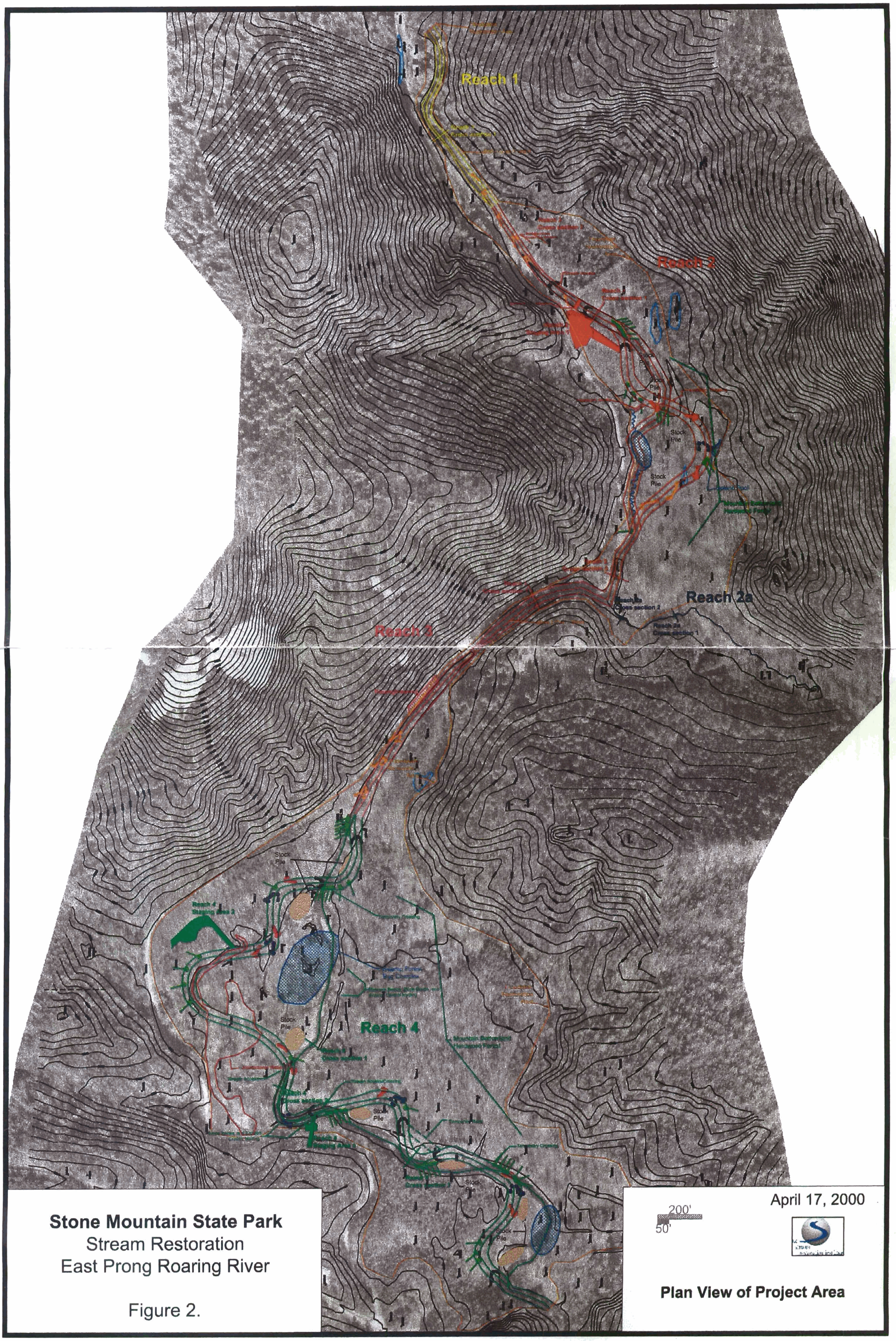

April 17, 2000

Plan View of Project Area

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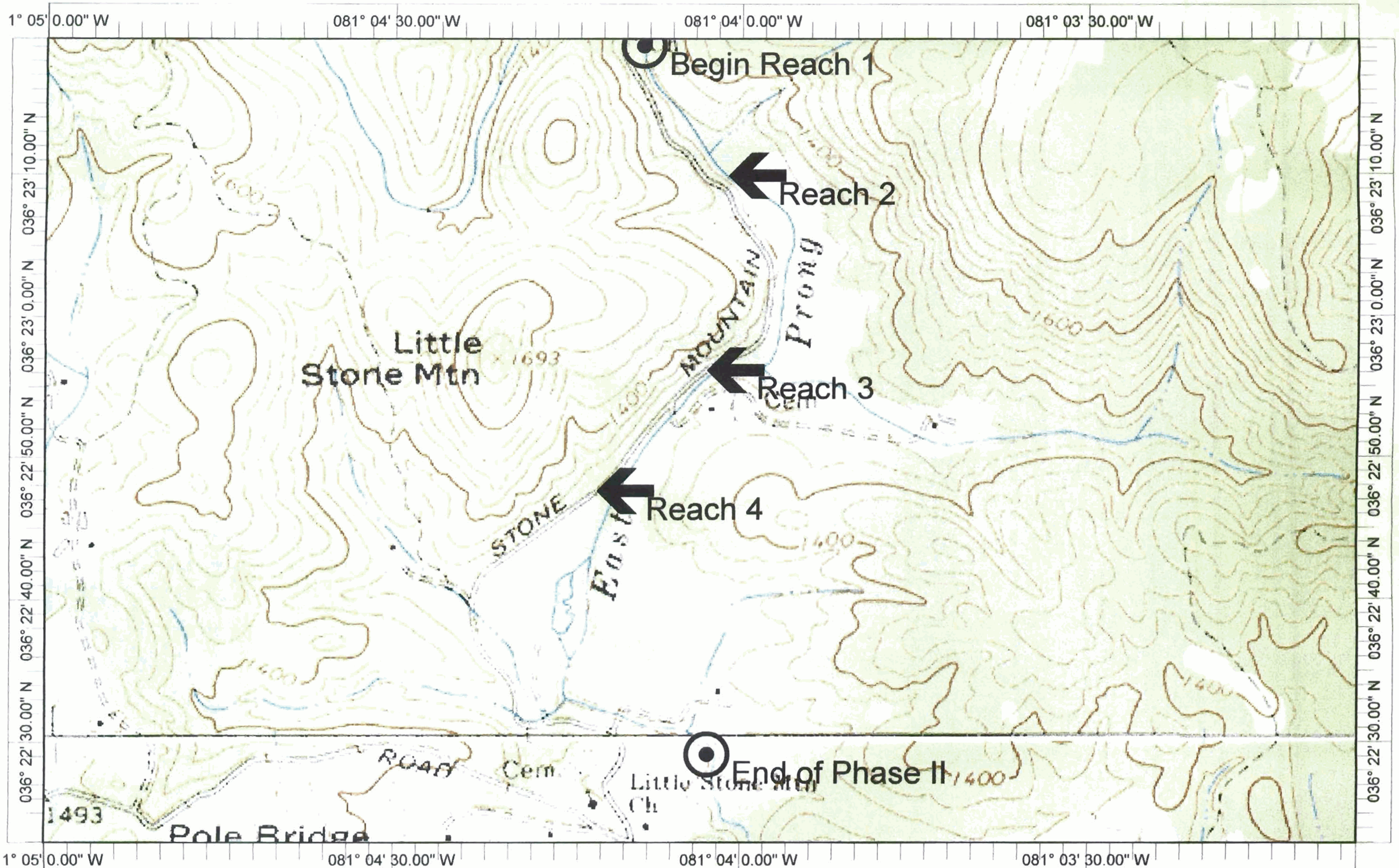
Figure 2.



Name: GLADE VALLEY
Date: 4/26/2000
Scale: 1 inch equals 1000 feet

Location: 036' 22' 51.3" N 081° 04' 03.4" W
Caption: Figure 3. Reachs in Project Area

gneiss formed by metamorphoses of igneous rocks. Both of these rock types are relatively competent and fairly resistant to erosion as suggested by their longevity in the landscape. Due to their strength, both rock types tend to support steep, dissected slopes in the headwater areas of the Roaring River and Big Sandy River. When granite and gneiss are eroded from the surface, they produce fine-grained sand that breaks down to silt and clay. Faulting and jointing of the rocks allow for production of gravel, cobble and boulders, which may also be exposed to weathering and further production of the finer fraction of sediments. Transport of these sediments from hillslopes in conjunction with stream flow, generally contributed to the formation of the alluvial valleys of the Roaring and Big Sandy Rivers.

Historical Land Use

Stone Mountain State Park was purchased by the state of North Carolina in the early 1960s. Prior to this purchase, all the streams in the alluvial valley portion of the park were modified to improve agricultural production. Field observations suggest that tributary streams in the alluvial valley were straightened. A large portion of Reach 4 was used for gravel mining. As part of this operation, the East Prong was channelized, impounded and moved several times, resulting in destabilization of the channel. Aerial photos (1999) and the 1968 USGS Glade Valley quadrangle indicates locations of the historic channel (Figures 4 and 5). The results of past land uses on each Reach are discussed below.

1717
10,728
12,445

Existing Condition Survey

The project is divided into four reaches as shown on Figure 2. The drainage area for the entire project is 22 mi^2. The pre and post restoration length of each stream reach is shown below in Table 1. Appendix 5 provides a summary of the existing condition survey.

Table 1: Pre and Post Restoration Stream Lengths

Reach ID	Pre-Restoration Length (Feet)	Post-Restoration Length (Feet)
Reach 1	936	936
Reach 2	2,238	~~2,996~~ 3496
Reach 3	1,640	1,640
Reach 4	3,522	~~4,300~~ 4550
Total	**8,336**	**10,622**

Reach 1 – East Prong Roaring River from Garden Creek to the Group Camp Bridge.

Reach 1 begins at the confluence of Garden Creek and the East Prong Roaring River and ends upstream of the footbridge to the group camping area. The stream type is a Rosgen B4c (Rosgen, 1996). Steep riffles and some deep pools dominate the upper part of this

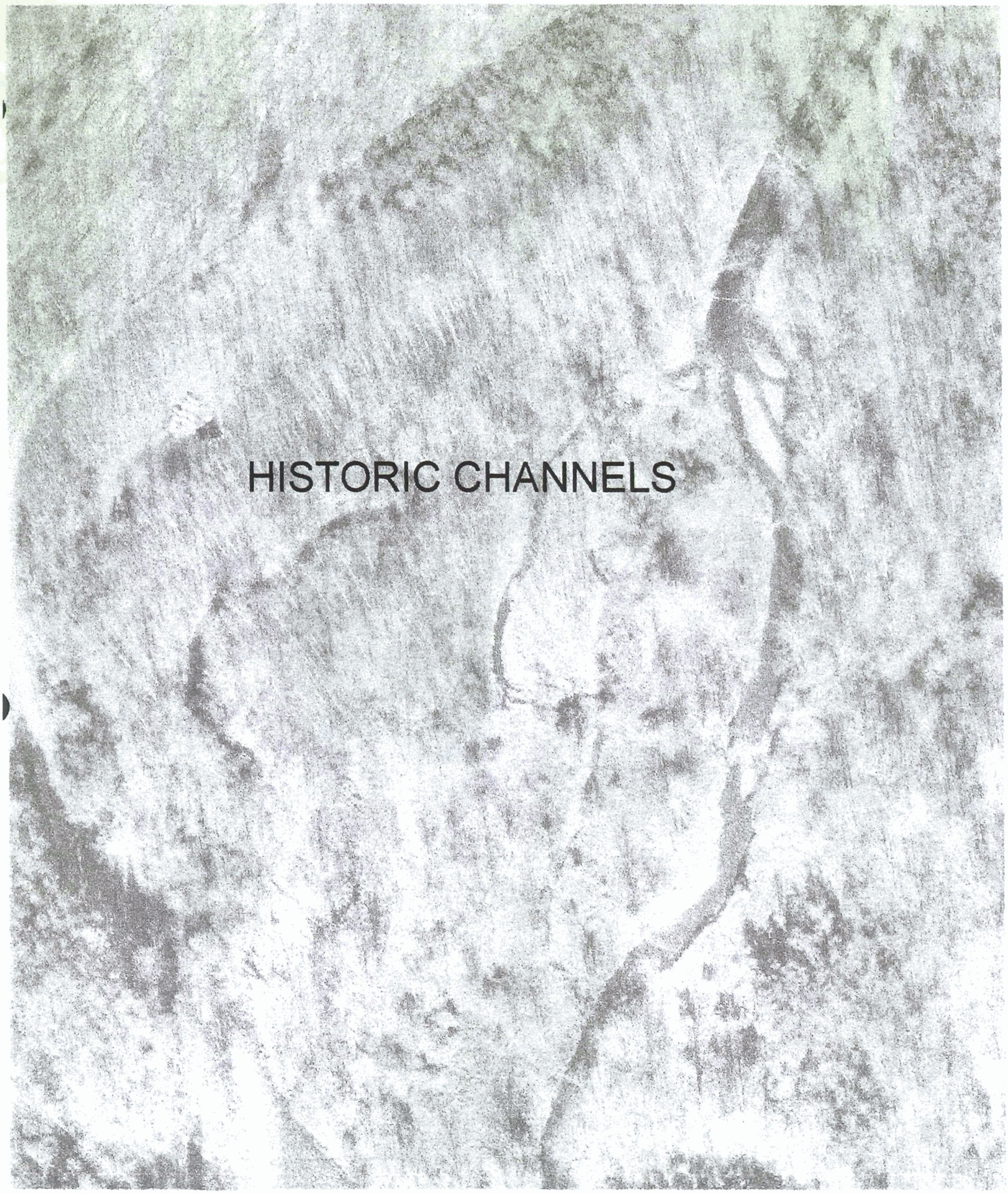


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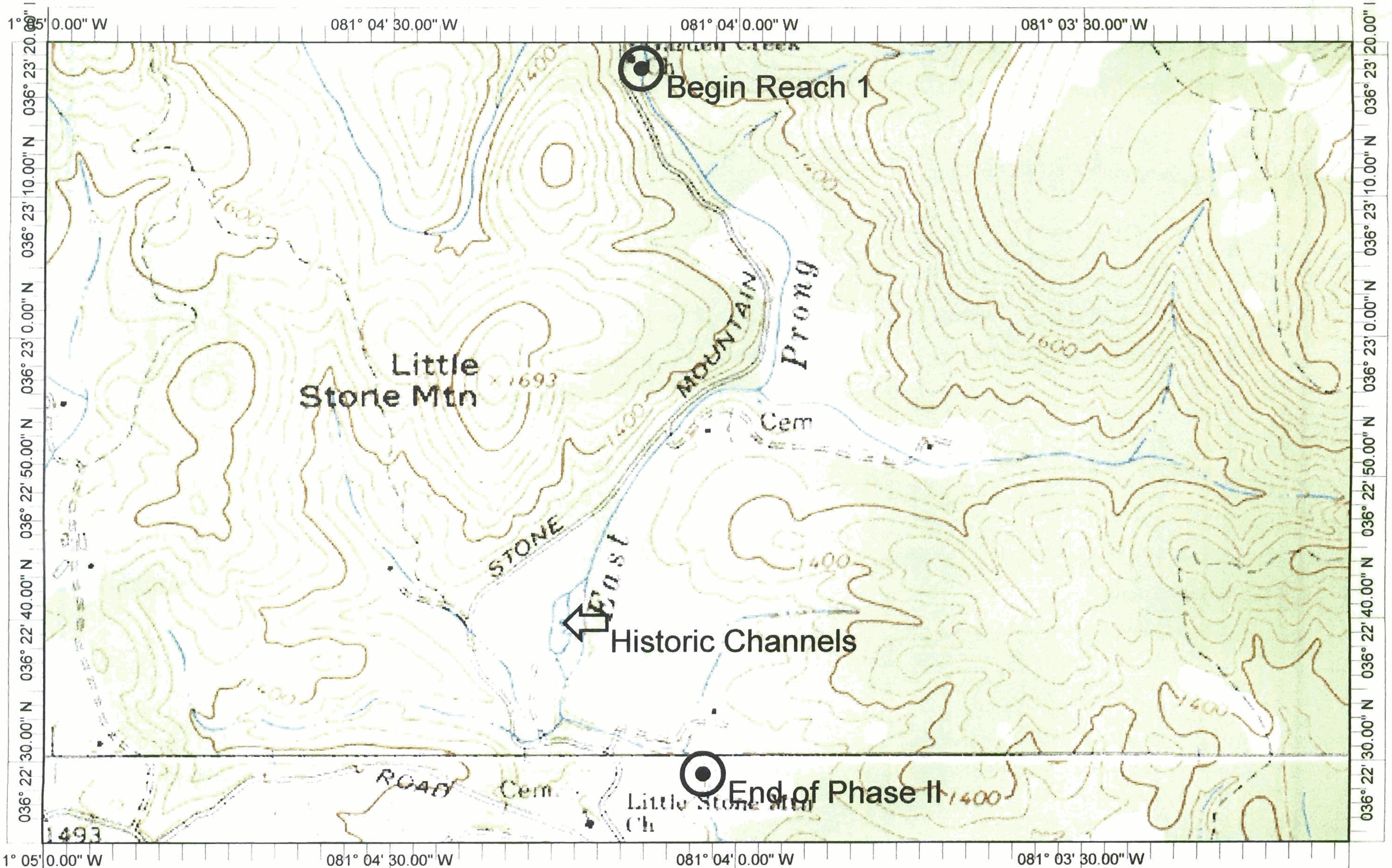
Figure 4

0 150
Feet

Aerial Photograph of Historic Channels



Name: GLADE VALLEY
Date: 4/26/2000
Scale: 1 inch equals 1000 feet

Location: 036° 22' 52.6" N 081° 04' 03.4" W
Caption: Figure 5. Historic Channel Locations

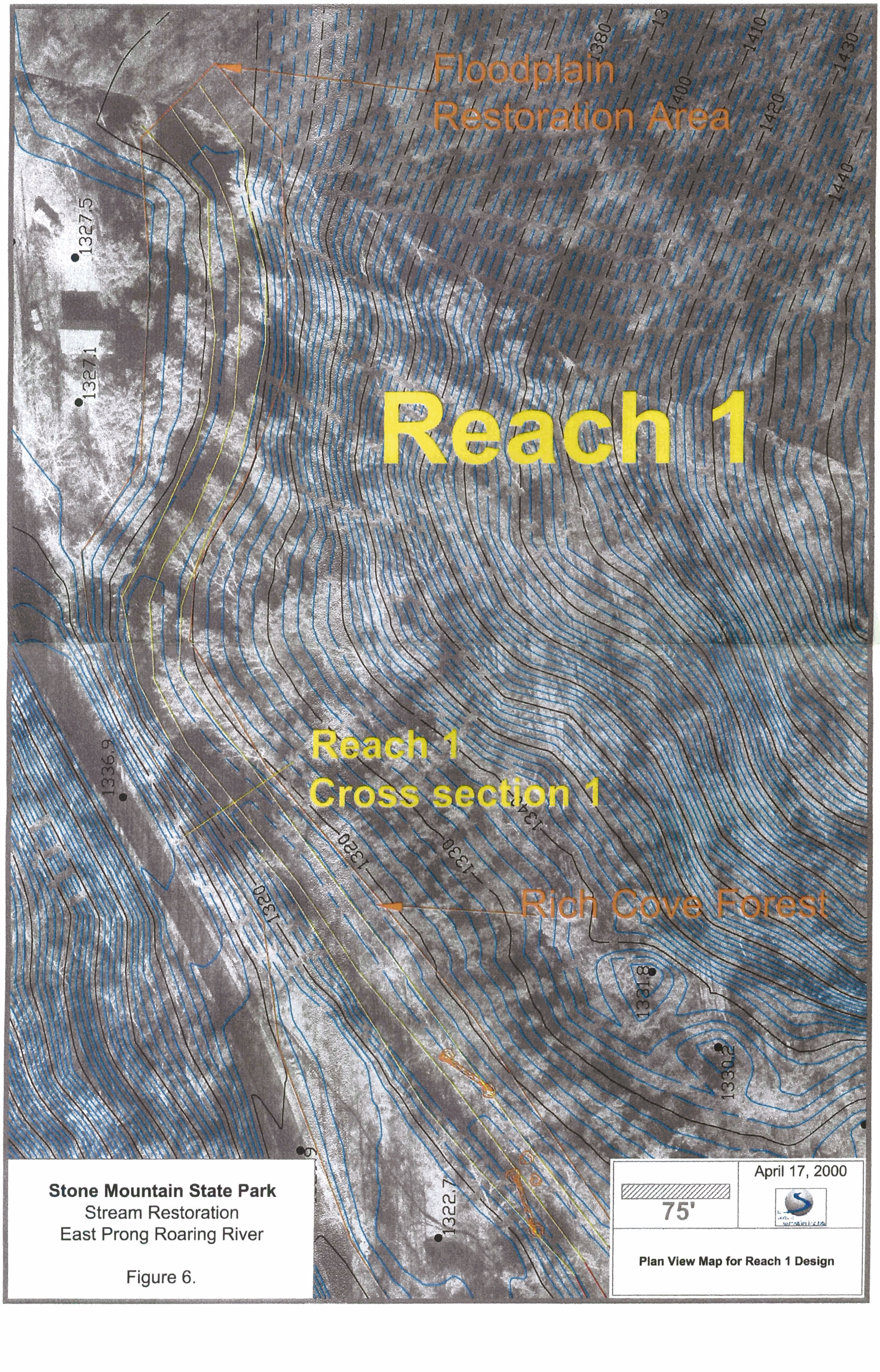


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Figure 6.

reach. The stream corridor is confined on both sides by steep hillslopes. Progressing downstream, the valley widens and becomes more alluvial.

Channel Dimension
The cross section representing Reach 1 (R1Xsec1) is shown as Figure 1.1 in Appendix 1. The bankfull cross sectional area, width, depth, and entrenchment ratio are typical for this Rosgen stream type and drainage area. However, the bank height ratio of 1.8 is high (stable range: 1.0-1.3) for this stream type when compared to reference reaches of the same stream type in the same type of valley. The channel carries nearly three times the bankfull discharge. The bankfull shear stress is 1.4 pounds per square foot (psf) as compared to the top of bank shear stress of 2.2 psf. The high banks decrease the functionality of the floodplain by not allowing flood flows to access the floodplains except during large storm events.

Channel Pattern
Channel pattern is appropriate for this stream type. The sinuosity is 1.1, typical of a B4c confined by valley walls. Stream power is primarily dissipated through the bedform features, e.g. riffles and pools. The longitudinal profile is controlled by bedrock knickpoints.

Channel Profile
The lower half of Reach 1 is characterized by long runs with minimal large wood or variability in flow patterns. The biological diversity was rated much lower than reference reaches of the same stream type. The substrate analyses consisted of the following Wolman type Pebble Counts: 1) 100 samples taken reach wide stratified by riffles and pools, and 2) 100 samples taken at the permanent cross section. The results are shown in Appendix 2. Figure 2.1 shows that the median grain size (D50) for this reach is approximately 30 mm, medium size gravel. The histogram on the same figure shows a well distributed range of grain sizes from silt to boulders, although there is an abundance of sand and bedrock. Figure 2.2 shows the substrate comparison of riffles and pools. The D50 is similar for both features; however, larger particles are present in the riffle, as expected. Although there is a high percentage of sand found in this reach, they are not filling the pools. The percentage of fines is approximately the same in the riffle and pool. This implies that the fines are effectively being transported through this reach, e.g. they are not accumulating in the pools. Figure 2.3 shows the pebble count results from R1Xsec1.

Floodplain Assessment
Reach 1 is characterized by steep valley walls that form a narrow floodplain valley, as shown in Figure 6. Valley widths for this reach range from approximately 75 feet to 200 feet. Soils on the floodplain are primarily of the Rosman-Reddies and Chestnut-Ashe complexes, indicating that both alluvial processes and the weathering of parent material have influenced the formation of the floodplain. As the stream has become more incised over time, alluvial sediment which was once deposited on the floodplain is now transported in-channel to the downstream reaches. No wetland systems were identified for this stream reach.

The terrestrial plant community type is Rich Cove Forest (Schafale and Weakley 1990). The upper canopy consists of tulip-poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), Virginia pine (*Pinus virginiana*), white pine (*Pinus strobus*), and Canada hemlock (*Tsuga canadensis*). The understory is mostly a dense thicket of Rhododendron (*Rhododendron maximum*) with scattered mountain laurel (*Kalmia latifolia*), dogwood (*Cornus florida*), and Canada hemlock seedlings.

The herb layer and seedling layer is sparse in this reach, as well as in the other reaches due to over-browsing by deer.

Reach 2 – East Prong Roaring River between the group camp to the Confluence with Reach 2a.

Reach 2 begins 500 feet upstream of the footbridge to the group camping area and ends at the confluence of the unnamed tributary, Reach 2a. The valley is much wider in Reach 2 than in Reach 1. The maximum valley width is almost 500 feet. The stream type in this reach is a C4 but is trending towards a D4. The reasons for this trend are described below.

Channel Dimension
The classification cross sections (R2Xsec1, R2Xsec2, and R2Xsec3) are shown as Figures 1.2, 1.3, and 1.5 in Appendix 1. The bankfull channel has a width/depth (w/d) ratio of 23, which is much higher than the stable C4 reference reach w/d ratio of 16. The results of a bank erosion assessment are shown in Appendix 3. Thirty percent of the total project length erosion is coming from Reach 2, producing approximately 134 tons per year of sediment. The rate of bank erosion is 75 lbs./ft/yr. This is the highest rate of bank erosion of all the evaluated reaches With a well-vegetated floodplain, it is unlikely that this reach will ever widen to a D4; however, the instability is causing adverse water quality impacts through increased sedimentation from eroding streambanks. The quality of the aquatic habitats is poor.

The channel is moderately incised with a bank height to bankfull height ratio of 1.8. Therefore, the channel is carrying well more than the bankfull flow, increasing shear stress and stream power. The top of bank shear stress and velocity is 2.2 psf and 9.6 ft/sec respectively. Additional hydrological information is provided in Appendix 8.

Channel Pattern
Among other factors, the increase in channel width has created a large chute cutoff across the inside of a meander bend. This is often a result of channel widening. As the channel width increases, the sinuosity decreases, and the average slope increases. This creates an imbalance in the sediment supply and size versus stream power and causes the channel to remain unstable.

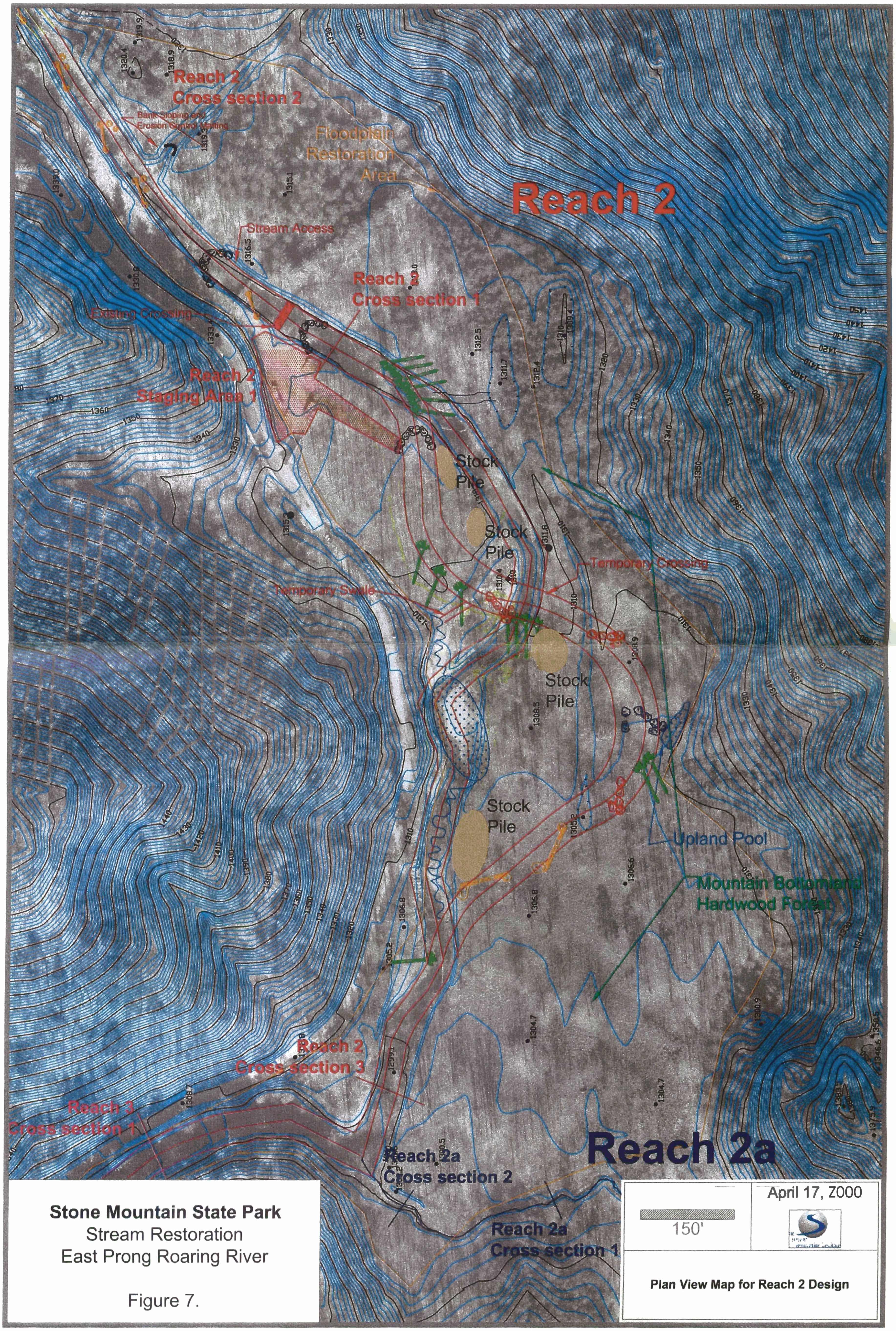

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Figure 7.

Channel Profile
The riffle / pool sequence is fairly good in Reach 2. The reach wide pebble count data are shown in Appendix 2. The grain sizes are well sorted; however, there is a large shift towards the fines in the pools as shown in Figure 2.5. This indicates that the pools are filling with fines produced by bank erosion. The increases in the w/d ratio and the subsequent decrease in sediment transport capacity compound the problem.

Tributary
An unnamed tributary enters the East Prong Roaring River at the Group Camping Area. The tributary is a G4c because the East Prong is moderately incised and a headcut is migrating up the tributary. The tributary is less incised above the headcut near the edge of the valley. The cross section (R2Xsec2) and longitudinal profile are shown as Figures 1.3 and 1.4 in Appendix 1.

Floodplain Assessment
Reach 2 begins where the floodplain for the East Prong of the Roaring River begins to widen into a more alluvial valley. Valley widths for Reach 2 range from approximately 100 to 500 feet. Soils in this valley are dominated by the Rosman-Reddies complex, indicating their alluvial origin. Throughout the floodplain valley there are scars which were most likely the result of agricultural practices and stream channel migration. In several areas there appear to be remnants of surface ditches which most likely provided drainage for the valley during agricultural production. One floodplain pool habitat approximately 700 ft^2 in size was identified during site assessment and is shown in Figure 7. It appears that this pool was formed in an abandoned drainage ditch where over time fine sediments settled out and formed a barrier to drainage. Several other wet, depressional areas were identified, but none appeared to support wetland functions. In addition to the tributary described above, a smaller tributary enters near the middle of the reach on the right side of the channel.

The floodplain community is classified as a Mountain Bottomland Forest (Schafale and Weakley 1990). The canopy is dominated by sycamore (*Platanus occidentalis*), black walnut (*Juglans nigra*), and tulip-poplar. Scattered persimmon (*Diospyros virginiana*) is located throughout the floodplain. The understory consists of spicebush (*Lindera benzoin*) and tag alder (*Alnus serrulata*). Muscadine (*Vitis rotundifolia*) is abundant throughout.

Reach 2a – Unnamed Tributary entering the East Prong at the end of Reach 2

Reach 2a is described below as part of the existing condition survey. However, a design for Reach 2a is not included in this report. A natural channel design will be prepared for Reach 2a in the fall of 2000, permitted in spring of 2001, and constructed in the summer of 2001. Reach 2a is included in these analyses because of its impact on Reach 3.

Reach 2a is an unnamed tributary entering the East Prong at the end of Reach 2. The tributary enters the East Prong in a tight bedrock controlled bend, called a "hammer head" pool. These pools are typically very deep because of the sharp radius of curvature and strong secondary currents. In this case; however, the pool is almost completed filled with sand from the eroding tributary.

Channel Dimension

The stream type is an unstable E5. Overall, the channel dimension for the unnamed tributary is stable. The w/d ratio of 3 and bankfull cross sectional area of 10 are appropriate for this stream type and drainage area.

Channel Pattern

The sinuosity for Reach 2a is 1.2, which is low for a stable E5 stream type. It is likely that this stream was straightened in the past because it is directly adjacent to the hillslope. The stream is trying to recreate a sinuous path by eroding the streambanks. It is estimated that 15.5 percent of the streambanks in this reach are eroding and that 82 tons per year of sediment are being exported from the watershed into the East Prong. More details on streambank erosion are provided in Appendix 3.

Channel Profile

Since the stream was straightened, the percentage of pools has been drastically decreased.

Floodplain Assessment

The floodplain valley for Reach 2a, where the stream is characterized as an E5, ranges from approximately 100 feet wide at the upstream end to 500 feet wide where the floodplain merges with the floodplain for Reach 2. Soils in the downstream portion of the reach are alluvial in nature (Rosman-Reddies complex), while soils in the upstream portion of the reach were formed by a combination of colluvial and alluvial processes (Tate-Cullowhee complex). An area of hydric soils was identified near the upstream portion of the reach. This area may have once been a functioning mountain bog, but it now appears that the site is too dry to support a diverse bog community. The restoration design for this reach will include plans to enhance the hydrological and ecological functions of this wetland area.

The plant community is Mountain/Bottomland Hardwood Forest (Schafale and Weakley 1990). See the Floodplain Assessment for Reach 2 for a complete description of this community. Deer browse is a problem along this reach as well.

Reach 3 – Confined Reach from Reach 2a to Below Low Water Bridge

Reach 3 begins at the confluence of Reach 2a with the East Prong Roaring River and ends downstream of the low water bridge to a Ranger's home. The reach is confined on the left by a steep hillslope and the right by the park road.

Channel Dimension

The stream type for this reach is a B4c. The bankfull cross sectional area for this reach is slightly lower than would be expected for the size drainage area because the entire right bank of the cross section is bedrock. The cross section (R3Xsec1) is shown in Appendix 1 as Figure 1.6. Overall, the dimension is stable in this reach. There is only one section, 50 feet long, of eroding bank that is producing an estimated 14 tons per year of sediment to the reach. Only 1.8 percent of the streambanks is eroding. The bank height ratios are high (1.8) in this reach because of the influence of the hillslope and park road. The bankfull shear stress and velocity are 2.63 psf and 8.9 ft/sec, respectively.

Channel Pattern
The sinuosity in reach 3 is 1.1, which is appropriate for a B4c.

Channel Profile
The bedform in this reach consists of bedrock-controlled riffles and deep pools. However, the heavy sediment load from tributary 2a, upstream bank erosion in the East Prong, and low channel slope have caused the entire grain size distribution to shift left as shown in Figure 2.8. In addition, the pools are filling in with sand and silt as shown in Figure 2.9. The reach wide pebble count data are shown in Figure 2.10. The R3Xsec1 pebble count data are shown in Figure 2.11.

Floodplain Assessment
Floodplain characteristics for Reach 3 are similar to those described for Reach 1. Valley widths range from approximately 70 feet on the upstream portions of the reach to 175 feet near the end of the reach.

The plant community is Rich Cove Forest (Schafale and Weakley 1990). See the Floodplain Assessment for Reach 1 for a complete description of this community.

Reach 4 East Prong Roaring River from Below Low Water Bridge to Project End

Reach 4 begins below the low water bridge, continues past the horse trailer parking lot and the old gravel mine to the end of the project. The end of the project is a large knickpoint at the park boundary.

Channel Dimension
The cross sections for Reach 4 are shown in Appendix 1 as Figures 1.7, 1.8 and 1.9. The stream type is a C4 moving towards a D4. The bankfull channel width varies from 55 feet (w/d = 18) to 107 feet (w/d = 50). The w/d ratio for stable C4 stream types varies from 12 to 18. The channel is moderately incised with bank height ratios ranging from 1.0 to 1.7. Streambank erosion is most severe in this reach with over 53.7% of the total erosion from all reaches (tons/year) coming from this reach. Bankfull shear stress ranges from 0.56 to 0.66 psf. These low shear stress values are in part due to the high width to depth ratios. The result is a loss in sediment transport capacity.

Channel Pattern
The pattern in Reach 4 has been heavily modified during the mining operation. The aerial photograph in Figure 3 shows evidence that the stream was moved several times, back and forth across the floodplain. Currently, the stream is cutting into a large terrace on the left bank. The existing radiuses of curvatures and meander wavelengths do not match reference reach conditions.

Channel Profile

The pebble count data are shown in Appendix 2. As with the other reaches, much of the fine sediment is being deposited in the pools, indicating an imbalance between the sediment supply and the sediment transport capacity.

Floodplain Assessment

Reach 4 is characterized by a broad alluvial valley with widths ranging from 150 to over 1000 feet. Rosman-Reddies complex soils are evident, however a large portion of the floodplain contains soils of the Ostin series. These cobble rich soils were where much of the mining operations were focused years ago. As a result, the floodplain landscape is very irregular, with many depressions and mounds left behind by the mining operations. Some of the depressions appear to be old stream channels where the stream was moved several times during mining. Three small tributaries enter the stream within Reach 4, two near the middle of the reach and the third near the end of the reach. Within the vicinity of the old mining operations exists a small wetland area. Delineation information for this wetland is included in Appendix 9.

The plant community is Mountain Bottomland Hardwood Forest (Schafale and Weakley 1990). See the Floodplain Assessment for Reach 2 for a complete listing of plants for this community. The predominant vegetation in many areas of this floodplain are thickets of tag alder and spicebush.

Exotic species include Japanese honeysuckle, Japanese grass, and kudzu (*Pueraria lobata*). Fescue exists in open floodplain areas, as well.

Like the other areas, excessive deer browse limits growth of herbaceous species and mid-story development.

Bankfull Verification

The North Carolina Mountain regional curves were used to verify the bankfull stage identified in the field. The regional curves are provided in Appendix 4.

Reference Reach Analyses

Basin Creek, a C4 stream type, was used for the design ratios for Reach 2 and 4. Basin Creek was also used as a large woody debris reference for Reach 1 and 3. Basin Creek was cross-referenced with summary data from other C4 stream types in the mountains and foothills to determine the final ratios. The reference reach analyses is included in Appendix 5.

Natural Channel Design

Reach 1 – East Prong Roaring River from Garden Creek to the Group Camp Bridge.

Log vanes, root wads, and boulder clusters will be used to restore the bed features (profile) and improve aquatic habitat. Rock and log specifications are provided in Appendix 6. Figure 6 shows the plan view drawing for Reach 1. It is not feasible to decrease the bank height ratios in Reach 1. Therefore, it is imperative that a well-vegetated floodplain is maintained.

Floodplain Restoration

A combination of native seeding, planting, and staking will be performed on this reach of the project. Vegetation to be utilized includes, but is not limited to, orchard grass (*Dactylis glomerata*), deer-tongue grass (*Panicum* spp.), rye-grain, sycamore seedlings, silky dogwood stakes (*Cornus amomum*), and black willow stakes (*Betula nigra*). Newly planted trees will be protected against predators through a combination of repellant and tree guards. Vegetation will be obtained from local nurseries where applicable.

Reach 2 – East Prong Roaring River between the group camp to the Confluence with Reach 2a.

Two cross vanes will be installed in the upper part of Reach 2 to decrease the bankfull width from 64 feet to 52 feet. This will reduce the bankfull w/d ratio from 23 to 15 and improve sediment transport capacity. The existing versus design cross sections are shown in Figures 1.2, 1.3, and 1.5. In order to restore the remaining portion of Reach 2, a new channel with a stable dimension, pattern, and profile will be constructed as shown in Figure 7. Cross vanes will be used to raise the bed elevations in the riffles and decrease the bank height ratio to 1.0. This will allow all flows greater than a 1.5 year storm to access the 1470 foot wide floodplain. J-hook rock vanes, root wads, and logs will be used to stabilize streambanks and improve aquatic habitats.

Floodplain Restoration

The floodplain pool habitat identified during site assessment will be preserved and not impacted by this restoration design. Several additional floodplain pool type habitats will be established in the area to increase biological diversity and breeding habitat for amphibians. These pools will be created in wooded areas at the toe of the hillslope by excavating several shallow depressions with a compacted clay bottom. One riparian pool habitat will be enhanced by deepening an existing depression located near the stream channel. This pool will hold water year round and will be susceptible to stream flooding.

In order to provide fill for the old stream channel, one pond, approximately .25 acres in size, will be created by excavating the floodplain on the right side of the channel near the existing chute cutoff. No dams will be constructed for these ponds. These ponds will receive flow from the small tributary that currently drains directly to the stream. A small stable meandering channel will be constructed to carry flow from the upstream pond to the downstream pond, and then on to the new stream channel as shown on Figure 7.

A combination of native seeding, planting, staking, and transplant installation will be performed on this section of the project. Vegetation to be utilized includes, but is not limited to, orchard grass, deer-tongue grass, rye-grain, sycamore seedlings, black walnut seedlings, persimmon seedlings, silky dogwood stakes, and black willow stakes. Salvaged vegetation will primarily be placed along the new channel. The floodplain will be planted with hardwood species, especially mast producers such as walnut and persimmon.

Created pond perimeters as well as floodplain pools will be enhanced with native wetland and aquatic vegetation. Species will be selected depending on availability and habitat value.

Newly planted trees will be protected against predators through a combination of repellant and tree guards. Vegetation will be obtained from local nurseries where applicable. Exotic and invasive species, particularly tree-of-heaven, and fescue, will be controlled in these areas.

Reach 3 – Confined Reach from Reach 2a to Below Low Water Bridge

Log vanes, root wads, and boulder clusters will be used to restore the bed features (profile) and improve aquatic habitat. Rock and log specifications are provided in Appendix 6. Figure 8 shows the plan view drawing for Reach 3.

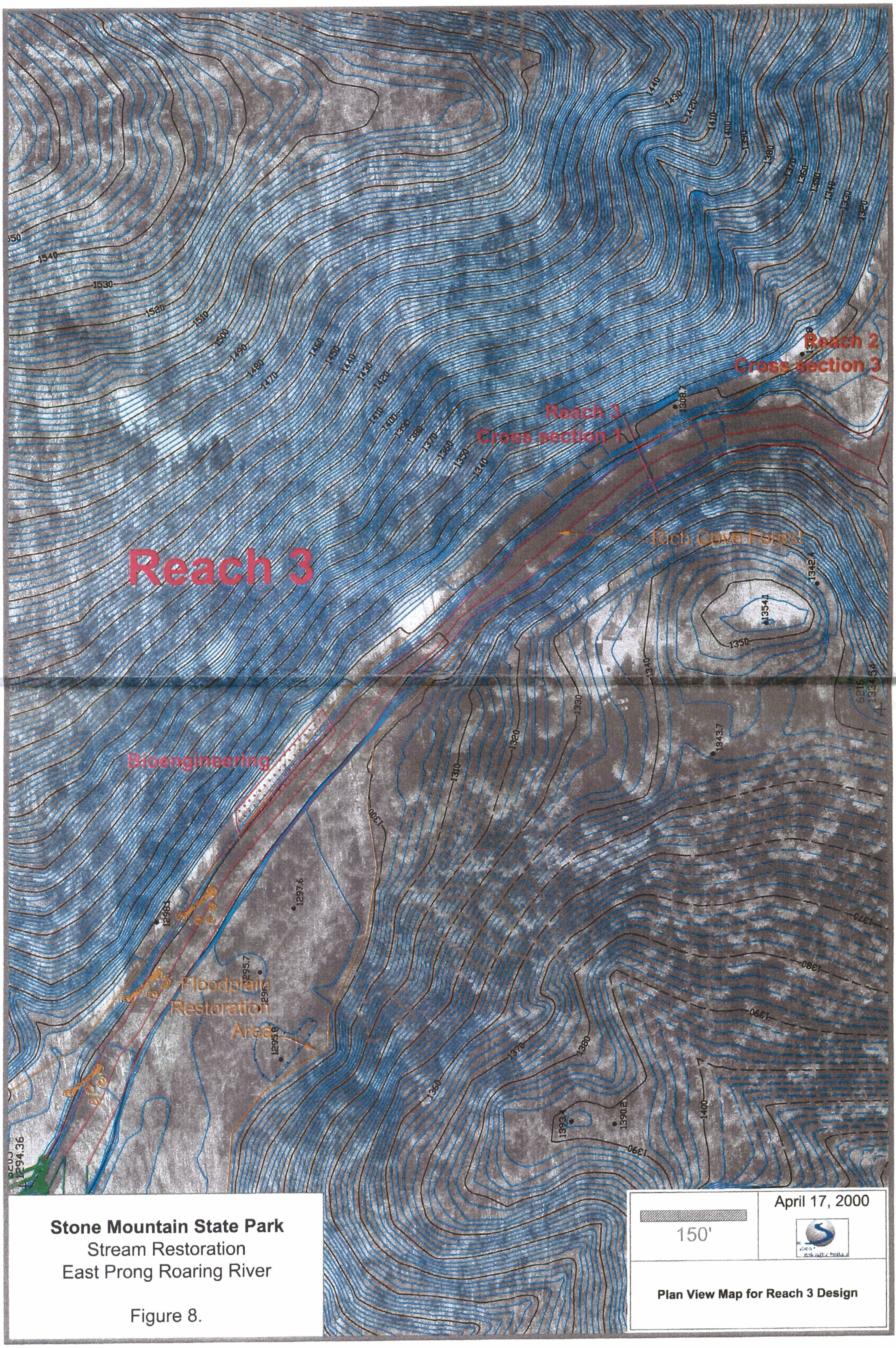

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Figure 8.

Floodplain Restoration

A combination of native seeding, planting, and staking will be performed on this reach of the project. Vegetation to be utilized includes, but is not limited to, orchard grass, deer-tongue grass, rye-grain, sycamore seedlings, silky dogwood stakes, and black willow stakes.

Newly planted trees will be protected against predators through a combination of repellant and tree guards. Vegetation will be obtained from local nurseries where applicable.

Reach 4 East Prong Roaring River from Below Low Water Bridge to Project End

In order to restore Reach 4, a new channel with a stable dimension, pattern, and profile will be constructed as shown in Figure 9. Typical riffle and pool cross sections are shown in Figures 1.1 and 1.9, respectively. Cross vanes will be used to raise the bed elevations in the riffles and decrease the bank height ratio to 1.0. This will allow all flows greater than a 1.5-year storm to access the 2014-foot wide floodplain. J-hook rock vanes, root wads, and logs will be used to stabilize streambanks and improve aquatic habitats.

Floodplain Restoration

Near the upper portion of Reach 4, a Swamp Forest-Bog complex (Schafale and Weakley 1990), approximately 1.43 acres in size, will be created on the floodplain. These systems have become quite rare due primarily to drainage alterations. The creation of this type of system will help to offset the approximately 0.89 acre impact to the existing wetland due to the new channel alignment. The addition of this community type will also help mitigate the historic loss of these habitats, as well as provide the park with increased biodiversity and environmental education opportunities. The swamp forest will be created by the excavation of floodplain sediments to lower surface topography to within several inches of the seasonal high water table. By varying excavation depths, depressions and hummocks will be formed which promote variable hydrologic conditions and biological diversity.

The two small tributaries located near the middle of this reach will be connected to the Roaring River by establishing stable meandering channels. A pond, approximately .5 acres in size, will be created near the end of Reach 4 to provide fill for the old channel. This pond will receive water from the small tributary near the end of the reach. A stable meandering channel will be created to carry flow from the pond to the Roaring River.

A combination of native seeding, planting, staking, and transplant installation will be performed on this reach of the project. Vegetation to be utilized includes, but is not limited to, orchard grass, deer-tongue grass, rye-grain, spicebush, alder, sycamore seedlings, black walnut seedlings, persimmon seedlings, silky dogwood stakes, and black willow stakes. Salvaged vegetation will primarily be placed along the new channel. The floodplain will be planted with hardwood species, especially mast producers such as walnut and persimmon. The swamp forest will be planted with a combination of

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Figure 9.

salvaged transplants, black willow, spicebush, alder, and native herbs, depending on availability.

Created pond perimeters will be enhanced with native wetland and aquatic vegetation. Species will be selected depending on availability and habitat value.

Newly planted trees will be protected against predators through a combination of repellant and tree guards. Vegetation will be obtained from local nurseries where applicable. Exotic and invasive species, particularly kudzu and fescue, will be controlled in these areas.

Sediment Transport

The critical shear stress for the proposed channel has to be sufficient to move the D_{84} of the bed material or the largest size on the point bar. The critical shear stress estimates were calculated for Reach 2 to represent sediment transport capacity for Reaches 2 and 4 since the grain size distributions and natural channel design are similar (refer to Figure 2.8). The critical dimensionless shear stress for R2Xsec1 is 0.11. The pavement and subpavement cumulative frequency curves are shown in Appendix 8. The critical depth is 3.7 feet. This matches well with the design riffle depths of 3.5 to 4.2 feet. A critical depth of 3.7 will move the largest particle size (120 mm) found on the well-developed point bar in Reach 2.

The top of bank shear stress will be reduced from 2.2 to1.4 psf. The top of bank velocity will be reduced from 9.6 to 6.9 ft/s. Shield's curve predicts that a boundary shear stress of 1.4 psf will move a particle size greater than 120 mm. Therefore, the decrease in shear stress will not decrease the sediment transport competency of the channel. Conversely, the R2Xsec1 pebble count data shown in Figure 2.6 shows a range of cobble that should not be moved by the design shear stress, implying that the stability of the riffle will remain intact. Appendix 8 shows the hydraulic and shear stress calculations for the existing and design channels.

Stone Mountain Monitoring and Evaluation Plan

Environmental components monitored in this program will be those that allow an evaluation of channel stability, floodplain functionality, and improvements to fish habitat. Specifically we will evaluate the success of channel modification, erosion control, shading, seeding, woody vegetation plantings and at some sites, the response of fish and invertebrates. This will be accomplished using photo reference sites, measurements of air and water temperature, measurements of stream shading, stream cross-sections, stream longitudinal profiles, groundwater table depths, survival plots of planted vegetation. The Division of Water Quality and Wildlife Resources Commission will collect samples of invertebrate and fish populations.

Photo Reference Sites
Photographs used to evaluate restored sites will be made with a 35-mm camera using slide film. Reference sites should be photographed before construction and continued for at least 5 years following construction. Reference photos should be taken twice a year, in winter and summer. After construction has taken place, reference sites should be permanently marked with stakes.

<u>Longitudinal reference photos</u>: The stream will be photographed longitudinally beginning at the downstream end of the mitigation site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations should be marked and described for future reference. Points should be close enough together to get an over all view of the reach. The angle of the shot will depend on what angle provides the best view and should be noted and continued in future shots. When modifications of stream position have to be made due to obstructions or other reasons the position should be noted along with any landmarks and the same position used in the future.

<u>Lateral reference photos</u>: 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 included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time. Photos of areas that have been treated differently should also be included; for example two different types of erosion control material used. This will allow for future comparisons.

<u>Success Criteria</u>: Photographs will be used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation and effectiveness of erosion control measures. Longitudinal photos should indicate the absences of developing bars within the channel or an excessive increase in channel depth. Lateral photos should not indicate excessive erosion or continuing degradation of the bank over time. A series of photos over time should indicate successional maturation of riparian vegetation. Vegetative succession should include initial herbaceous growth, followed by increasing densities of woody vegetation and then ultimately a mature overstory with herbaceous understory.

Shading and Temperature
One objective of the project is to increase the quantity of shade, through vegetative cover of the stream. This will be accomplished by planting shrub and tree species along the riparian zone. As this vegetation grows and matures the stream should become more and more shaded and the air temperature along the stream corridor should become more stable. We will evaluate this change by monitoring both temperature and shade.

<u>Shading</u>: The improvement in vegetative shading of the stream will be evaluated by monitoring the change in light penetration to the stream over time. Light penetration will

be evaluated at one riffle and pool cross section for each reach. A light meter will be used to measure the foot-candles of light at the ground surface, and at 3 feet above the ground and water surface along the transect. Measurements will be taken on both sides of the stream at the edge of the valley, in the middle of the valley, at the top of the stream bank, at the left edge of water, in the thalweg, and at the right edge of water.

Temperature: The ability of planted vegetation to thermally stabilize riparian zones will be evaluated by monitoring both water temperature and air temperature. Water temperature will be sampled using recording thermometers. These thermometers will be placed in a pool at the beginning of each reach and at the end of each reach. They will be set to record the water temperature every hour. They will be deployed by the 1st of June each year to record the water temperature through September. Streams in Western North Carolina usually are the warmest during these months and begin to cool by the end of September. Water temperature will be recorded each year for the length of the project.

Air temperature will be recorded at each location that light penetration is measured and each measurement will be taken 3 feet above the ground or water surface. Temperature stability will be measured using recorders to measure air temperature in the shade for same duration as water temperature measurements. This temperature stability measurement will be done within the valley and at the top of the stream bank, both along one of the established transect lines.

Success Criteria: Comparisons of air temperature and shading along a transect (from edge of valley to mid-stream) should indicate a lower temperature and increased shading. Water temperature should show a decreasing trend from the time of restoration until the riparian area is mature.

Cross Sections

Permanent cross sections should be established at a minimum of one riffle and one pool per reach for a minimum total of eight. These cross sections may be the same as ones taken to develop construction plans or they may be new. New cross-sections should be developed to monitor structures or other areas of the channel that are at an increased risk of failure. Each cross section should be marked on both banks with permanent pins to establish the exact transect used. A common benchmark should be used for cross-sections and consistently used to facilitate easy comparison of year to year data. The annual cross section survey should include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg. Riffle cross sections should be classified using the Rosgen stream classification system.

Success Criteria: There should be little or no 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 (down-cutting, erosion) or are minor changes that represent an increase in stability (settling, vegetative changes, deposition along the banks, decrease in width/depth ratio).

Longitudinal Profiles
A complete longitudinal profile should be completed once per year for Reaches 1 and 3. One meander wavelength should be measured in Reach 2 and 4. Measurements should include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these measurements should be taken at the head of each feature, e.g. riffle, run, pool, and glide, and the max pool depth. The survey should be tied to a permanent benchmark.

Success Criteria: The as-built longitudinal profiles should show that the bedform features are remaining stable, e.g. they are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steep and shallow.

Pebble Counts
Two types of pebble counts should be collected in each reach including 1) 100 counts reach wide stratified by the percentage of riffles and pools, and 2) 100 counts from each permanent cross section. The Wolman pebble count procedure will be used. Plots will be made showing the cumulative frequency curve and histogram for each cross section and reach wide. The pebble counts should be completed at the same time as the cross-sections and longitudinal surveys.

Success Criteria: The pebble count data should show a coarsening of the entire frequency distribution in Reach 3. In addition, the data should show a coarsening of the pools in reaches 2, 3 and 4.

Bank Erosion Estimates
Permanent bank erosion pins and bank profiles should be made at each permanent cross section. A bank toe pin should be installed close to the observed bank. The bank profile toe pin should be tied to a station in the longitudinal profile. Measurements should be made once per year at the same time the cross section is measured. A bank erodibility hazard index (BEHI) score should also be made. An estimate of near bank shear stress should be made by measuring the water surface slope along the observed bank length, as well as for the entire feature length, following the thalweg. Erosion rates for each cross section should be calculated.

Success Criteria: The BEHI score should be low by the second year of restoration. Bank erosion measurements should be less than 0.1 ft/year.

Scour Chains
Scour chains should be installed at each of the permanent cross sections. The chains should be installed every 2 feet from left edge of water to right edge of water and located by a cross section station. Chain length should equal 2 feet with 2 links exposed above the bed after installation. The chains should be excavated once per year and after a bankfull event. A bottomless bucket should be used to collect the substrate samples above the chain and separated by pavement and subpavement samples. The samples should be sieved in the lab.

Success Criteria: The data collected from the scour chain monitoring will be used to evaluate the accuracy of the sediment transport and shear stress estimations used in the design. The information collected will help improve future design estimations of shear stress and the depth of scour around instream structures.

Survival Plots

Survival of planted vegetation will be evaluated using survival plots or counts. Seeded areas will be subjectively evaluated using photographs of at least 6 staked survival plots. Plots will be 1 meter square and photos will be taken of these plots every quarter for 2 years. If survival and growth are acceptable then these plots will continue to be photographed at least twice a year, in winter and summer. If photos during the first 2 years do not show satisfactory survival and growth plans should be made to either sow more seed, fertilize the site or both. Survival of live stakes will be evaluated using enough plots or a size plot, that allows evaluating at least 100 live stakes. Evaluations of live stake survival will continue for at least 3 years before success or failure are determined. When stakes do not survive a determination should be made as to the need for replacement; in general if greater than 25% die replacement should be done. All rooted vegetation should be flagged and evaluated each spring for at least 3 years to determine survival. At least 5 stake survival plots will be evaluated each spring. Plots will be 100 meters square and all flagged stems will be counted in those plots. Success will be defined as 320 stems per acre after 3 years. When rooted vegetation does not survive, a determination should be made as to the need for replacement; in general, if greater than 25% die, replacement should be done.

Hydrology

A gage station will be installed near the end of Reach 4 to measure water level every 30 minutes. A stage/discharge relationship will be developed for the gage. The gage will be used to relate the stream stability and sediment transport data to various discharges, e.g. inner berm, bankfull, and peak.

Groundwater monitoring wells will be installed along several transects within reaches 2 and 4 to measure changes in local water table hydrology due to stream and wetland restoration efforts. Transects in Reach 4 will be used to assess the hydrologic impact to the existing wetland areas, and to evaluate the effectiveness of the swamp forest-bog complex restoration. Each transect will consist of several manually read wells and one recorder well, which will record water table depth every hour. Manual water table measurements will be taken at least once per month.

REFERENCES

Burt, et.al., 1985. Geologic Map of North Carolina, North Carolina Geologic Survey.

Clemmons, Micky. 1999. Draft Monitoring Guidelines for Stream Mitigation Sites. NC Wildlife Resources Commission. Waynesville, North Carolina.

Harman, et. al., 1999. Bankfull Regional Curves for North Carolina Mountain Streams.

Knighton, David. 1984. Fluvial Forms and Processes. Routledge, Chapman and Hall, Inc. New York, New York.

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

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

APPENDIX 1

EXISTING CONDITION

SURVEYS,

CROSS SECTIONS

Figure 1.1

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	B4	77	20.5	63.3	1317.88	42.8	3.1	13.7	134.1	4.1	1.8

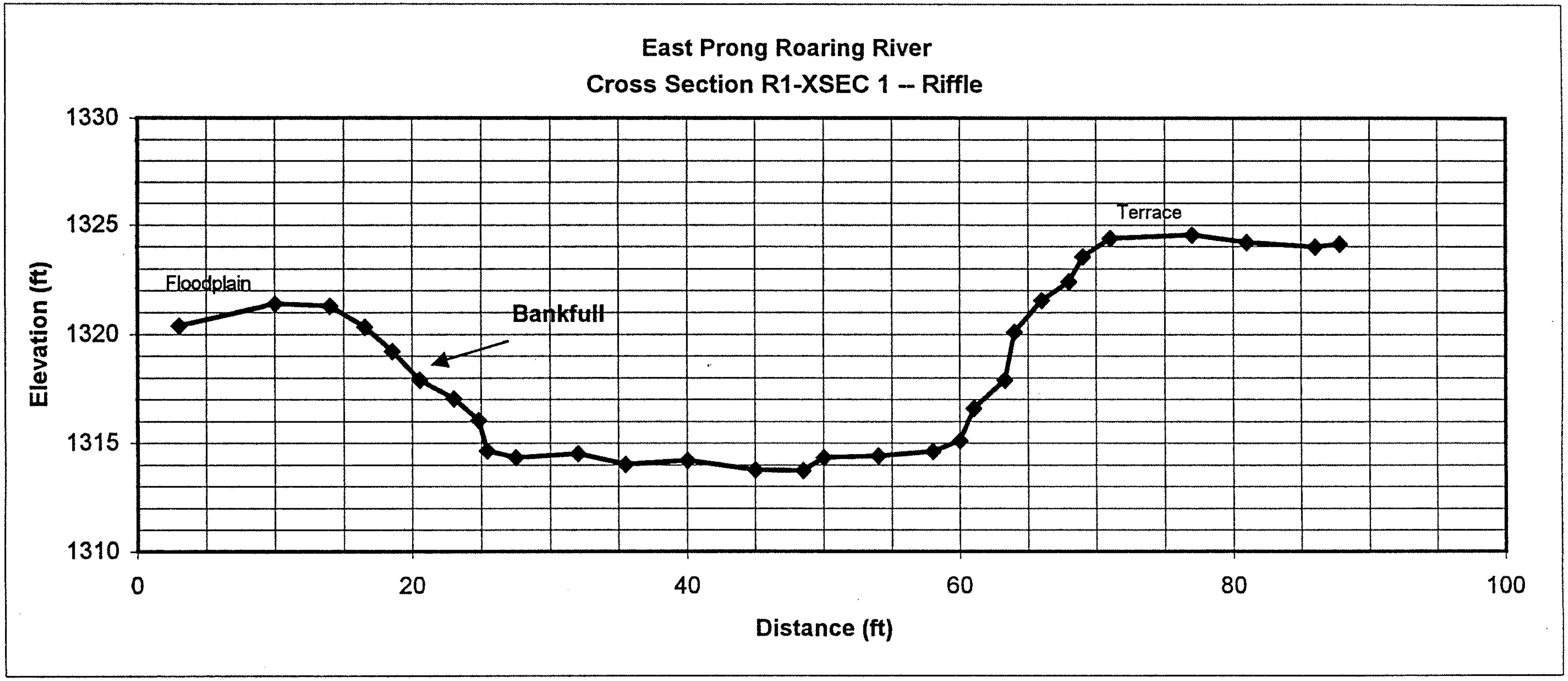


Figure 1.2

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	C4	459	39.0	102.8	1313.04	63.8	2.7	23.2	175.1	3.8	7.2
Design	Riffle	C4	459	45.1	95.8	1314.72	50.7	3.6	14.2	180.4	4.3	9.1

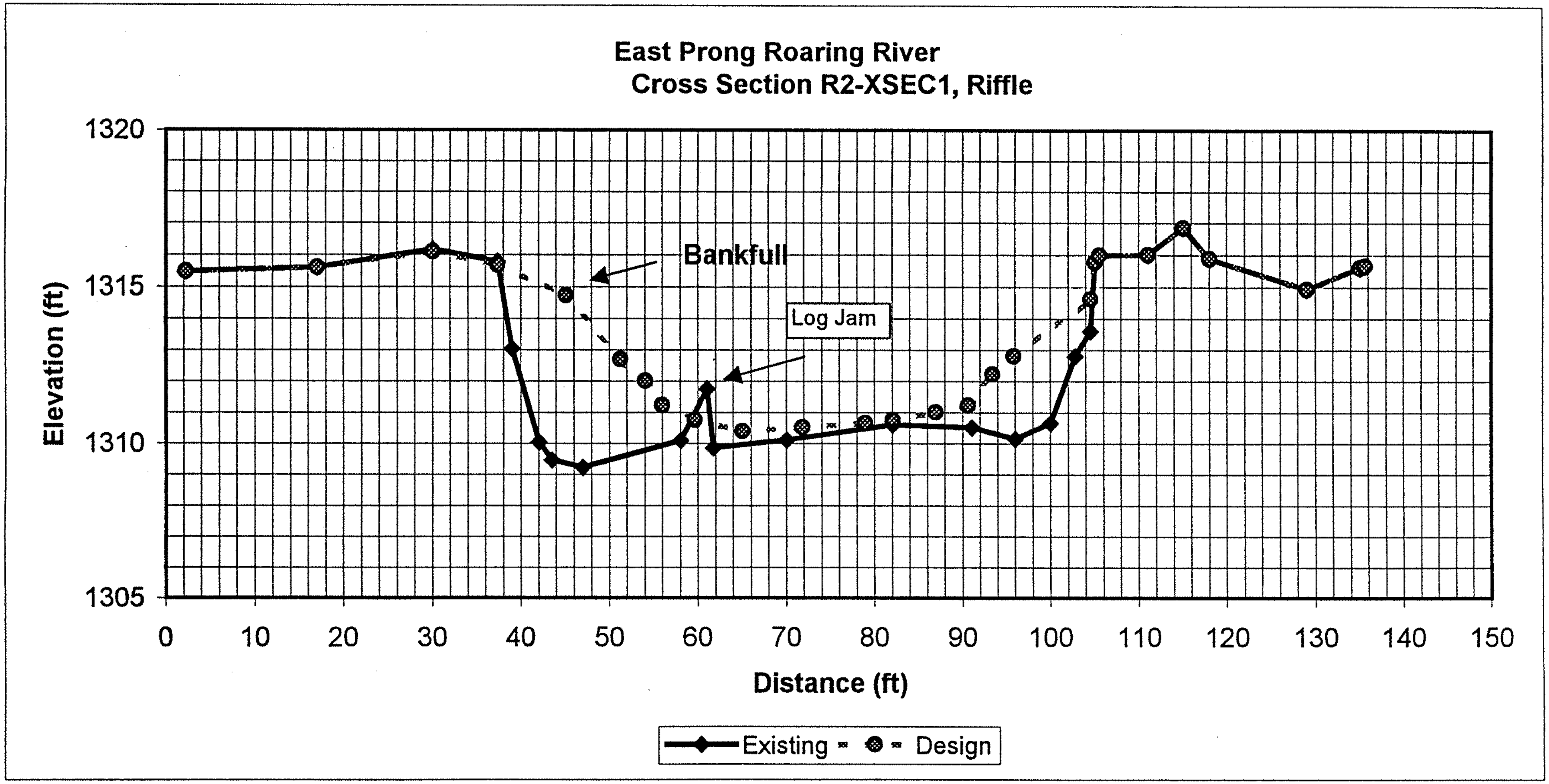


Figure 1.3

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	G5	8	24.0	30.6	97.14	6.6	1.0	6.7	6.5	1.3	1.2
Design	Riffle	E4	14	24.0	30.6	97.14	6.6	1.0	6.7	6.5	1.3	2.1

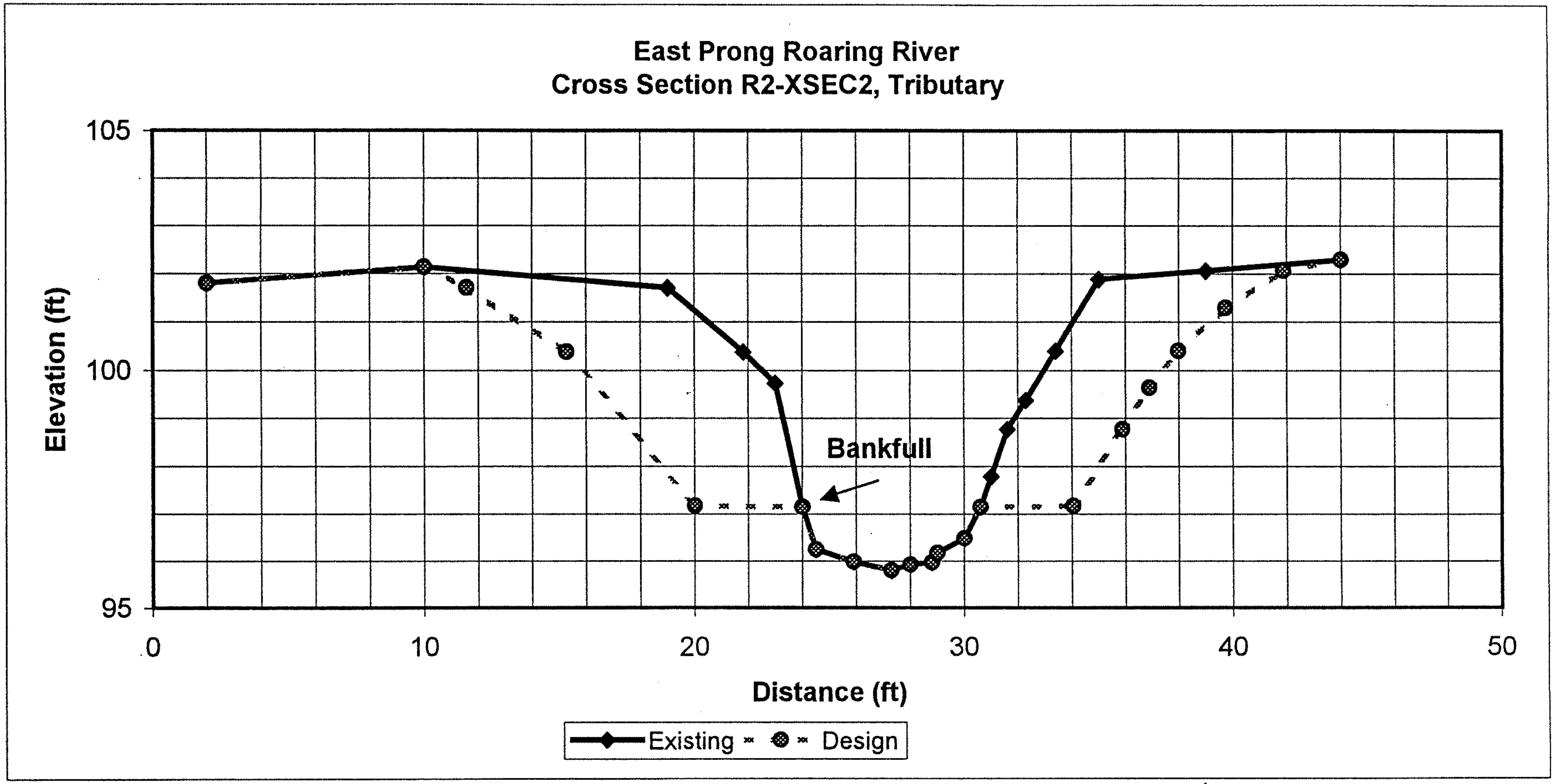


Figure 1.4

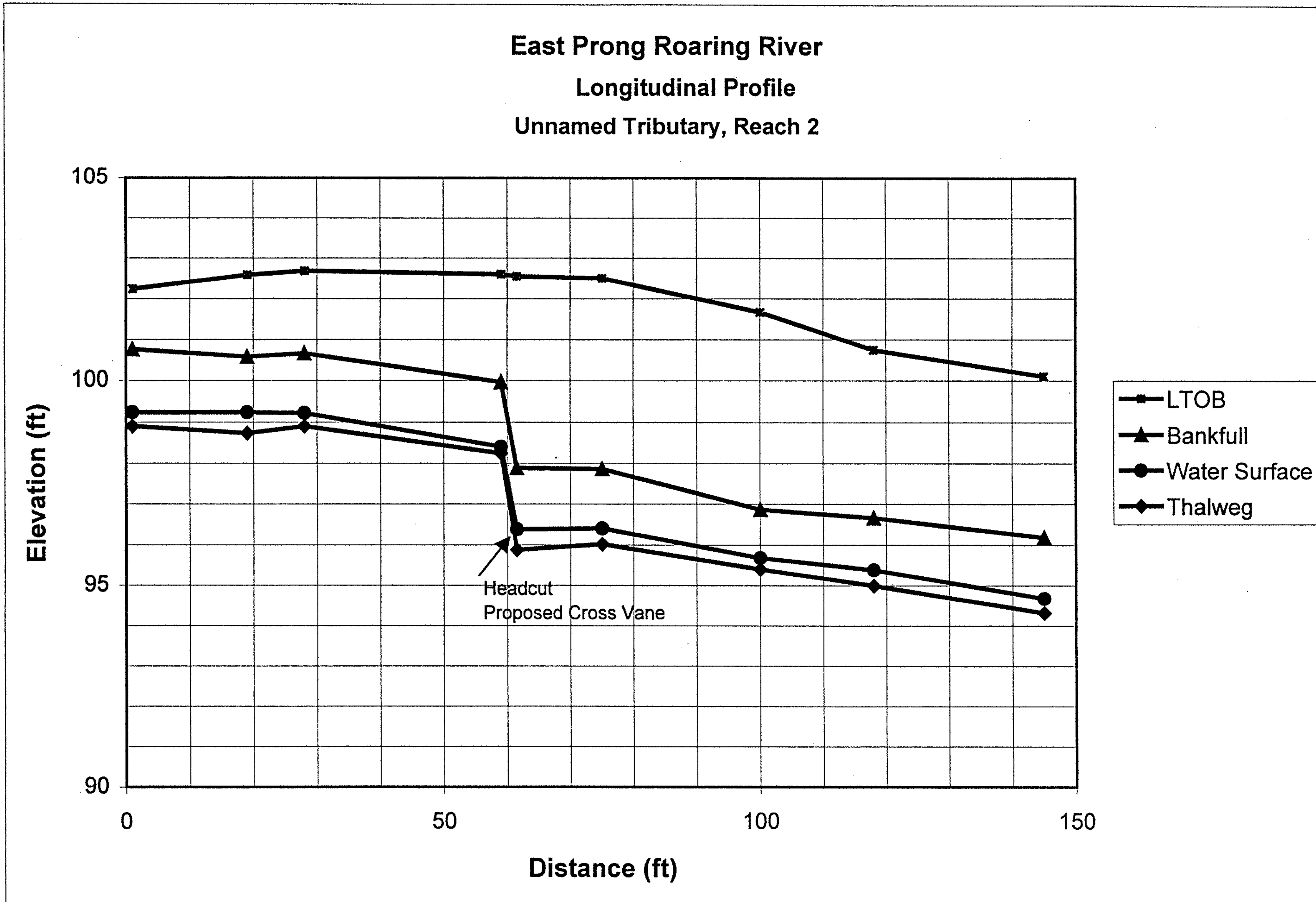

East Prong Roaring River
Longitudinal Profile
Unnamed Tributary, Reach 2
Elevation (ft)
105
100
95
90
0
50
100
150
Distance (ft)
Headcut
Proposed Cross Vane
LTOB
Bankfull
Water Surface
Thalweg

Figure 1.5

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	C	400	31.8	84.3	1303.14	52.5	3.7	14.2	193.8	3.8	7.6

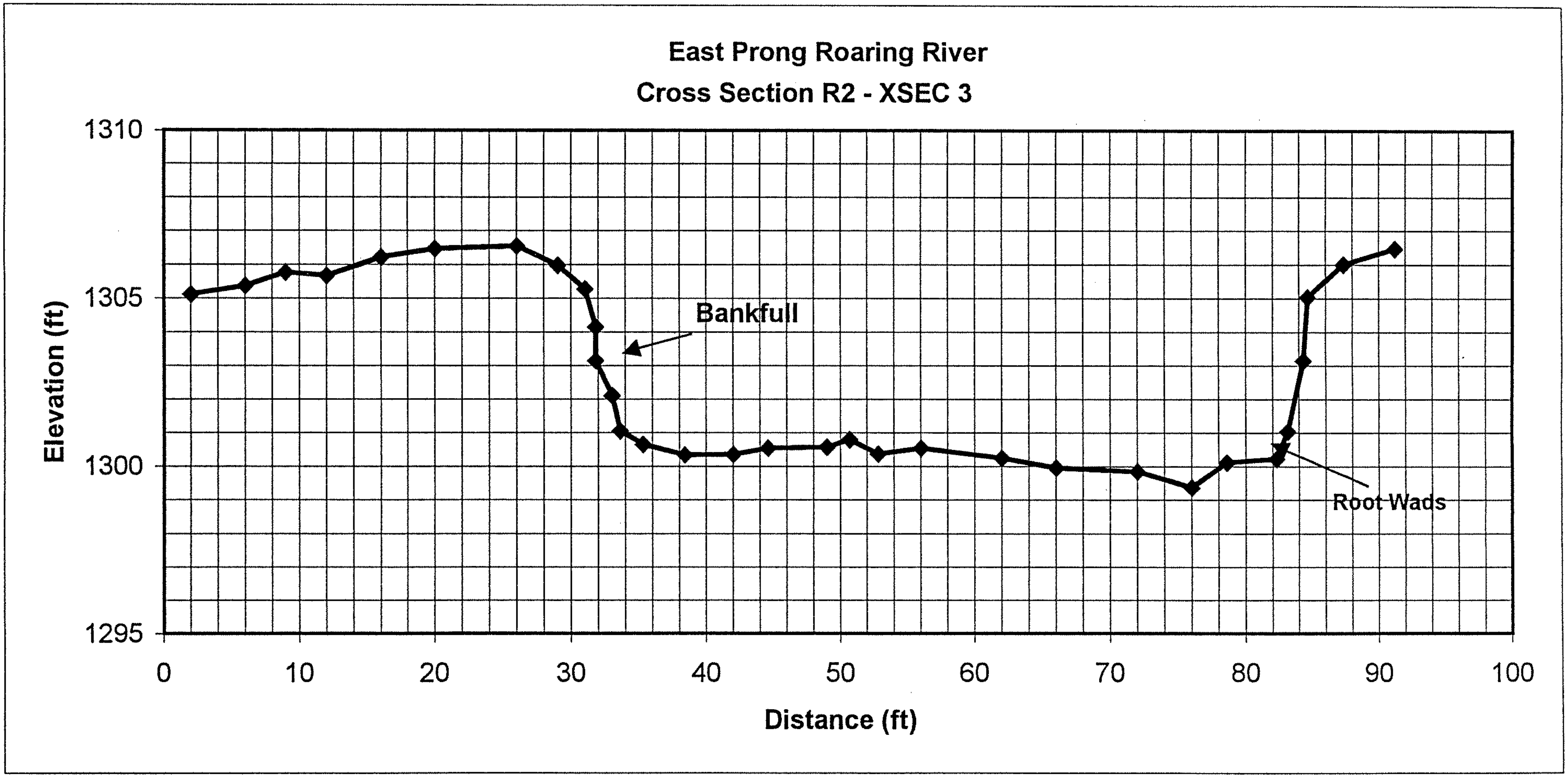


Figure 1.6

34+40	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	B4c	63	22.0	68.2	1299.66	46.2	3.4	13.7	155.4	5.1	1.4
Design	Riffle	B4c	63	22.0	68.2	1299.66	46.2	3.4	13.7	155.4	5.1	1.4

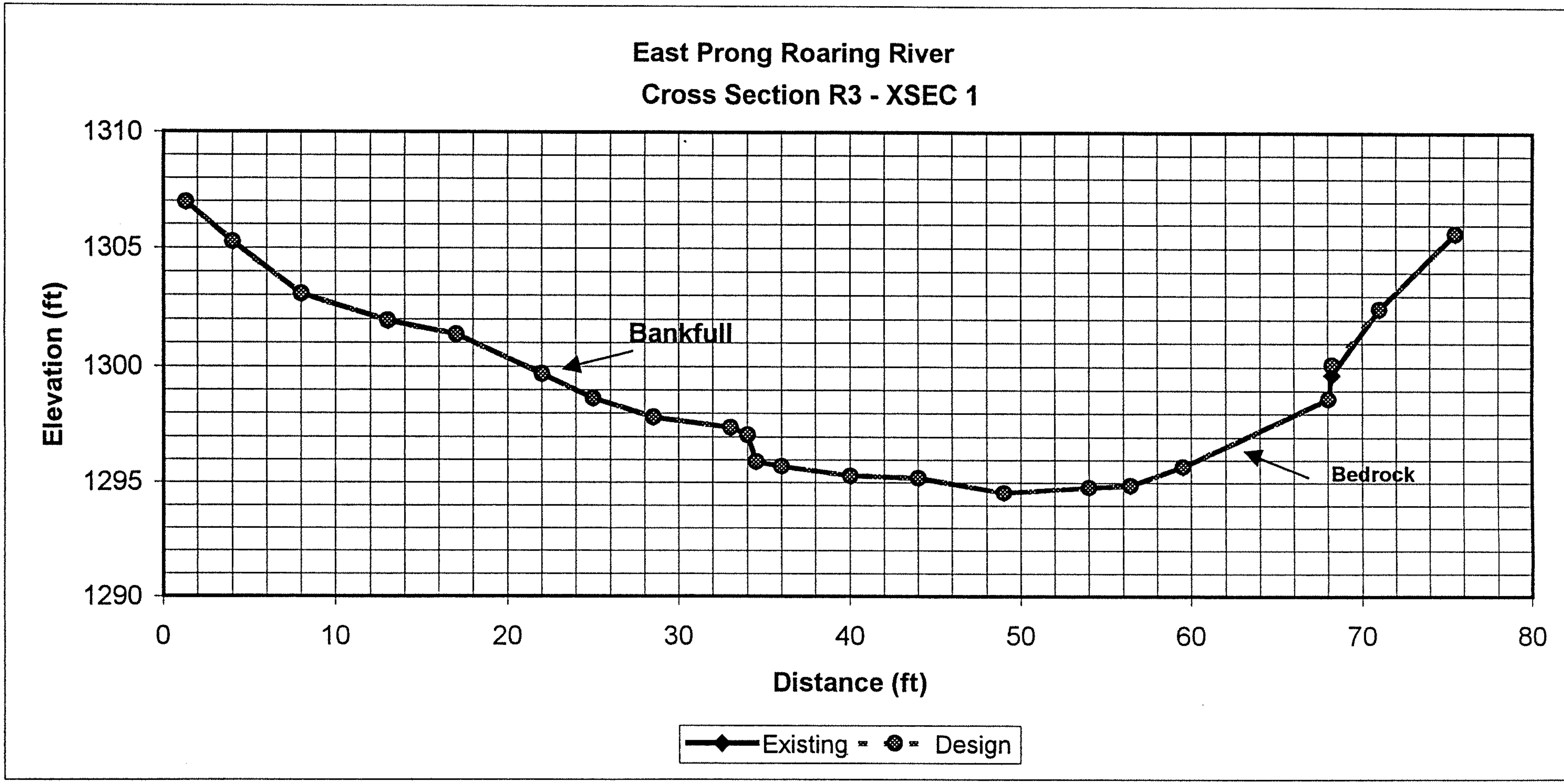


Figure 1.7

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	C4	400	98.0	162.0	98.52	84.0	2.4	35.3	199.8	4.2	4.8

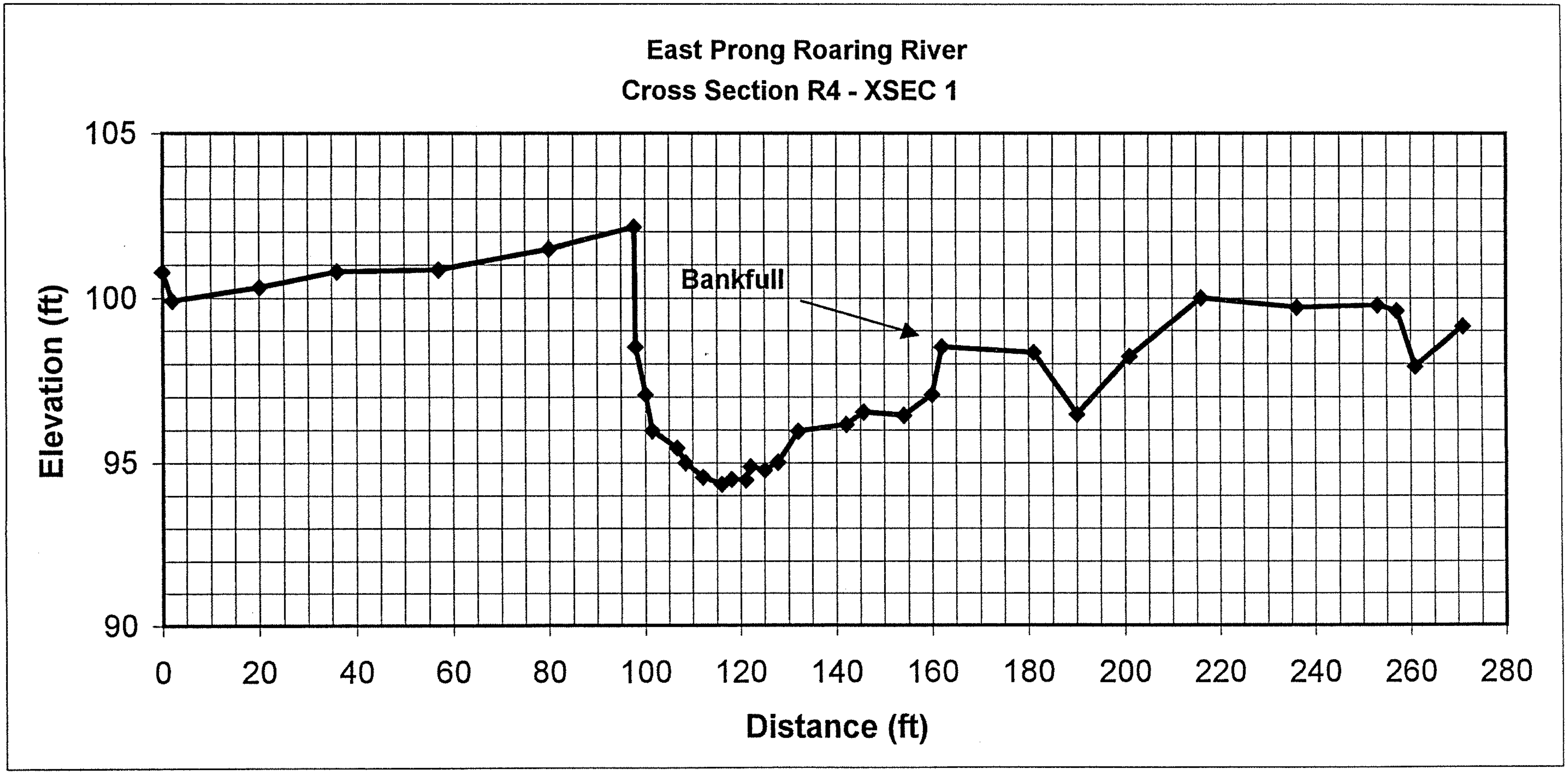


Figure 1.8

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	C	600	42.0	97.3	96.49	55.3	3.0	18.2	167.9	4.7	10.8
Design	Riffle	C	600	42.0	97.3	96.49	55.3	3.0	18.2	167.9	4.7	10.8

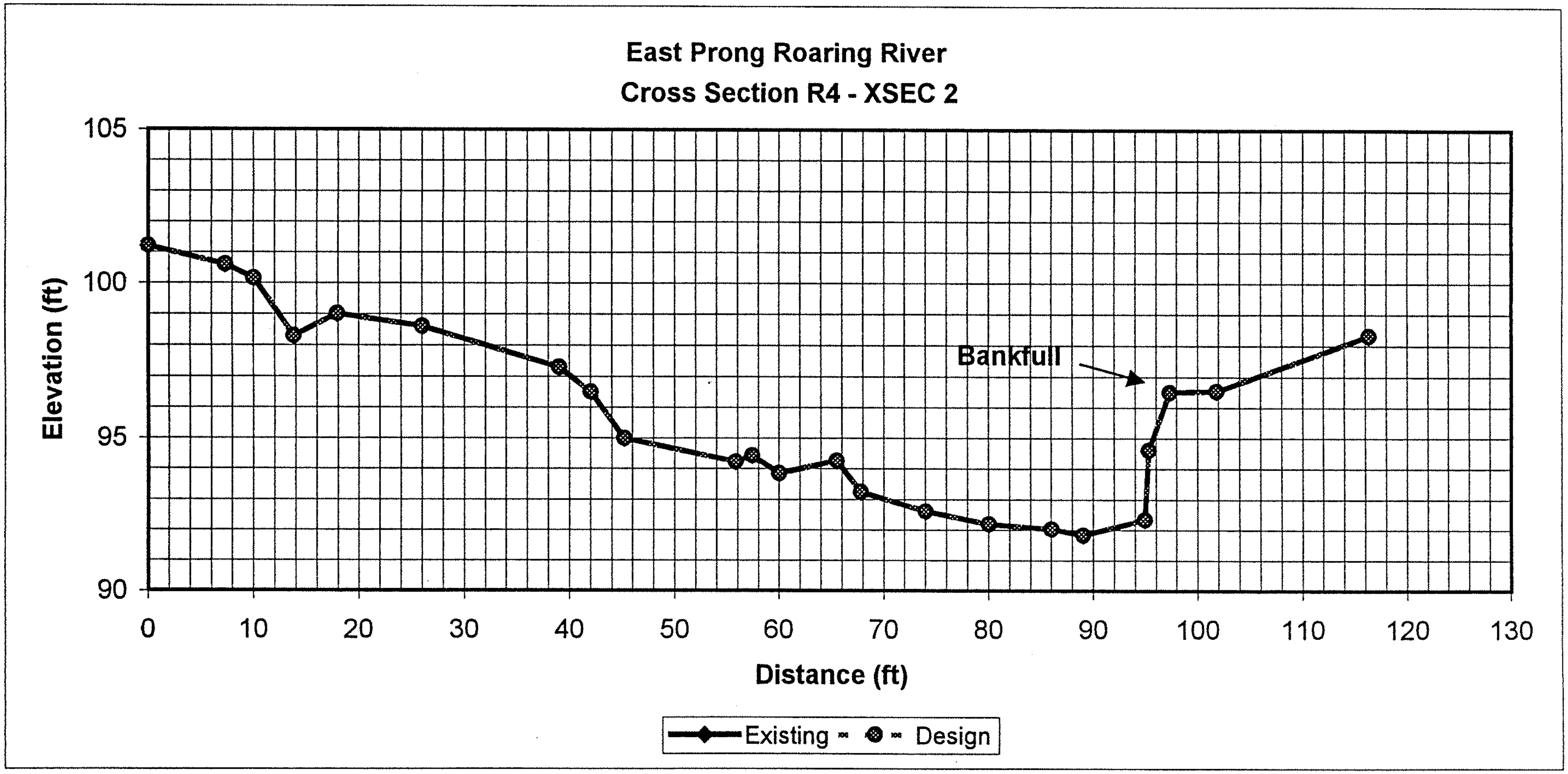
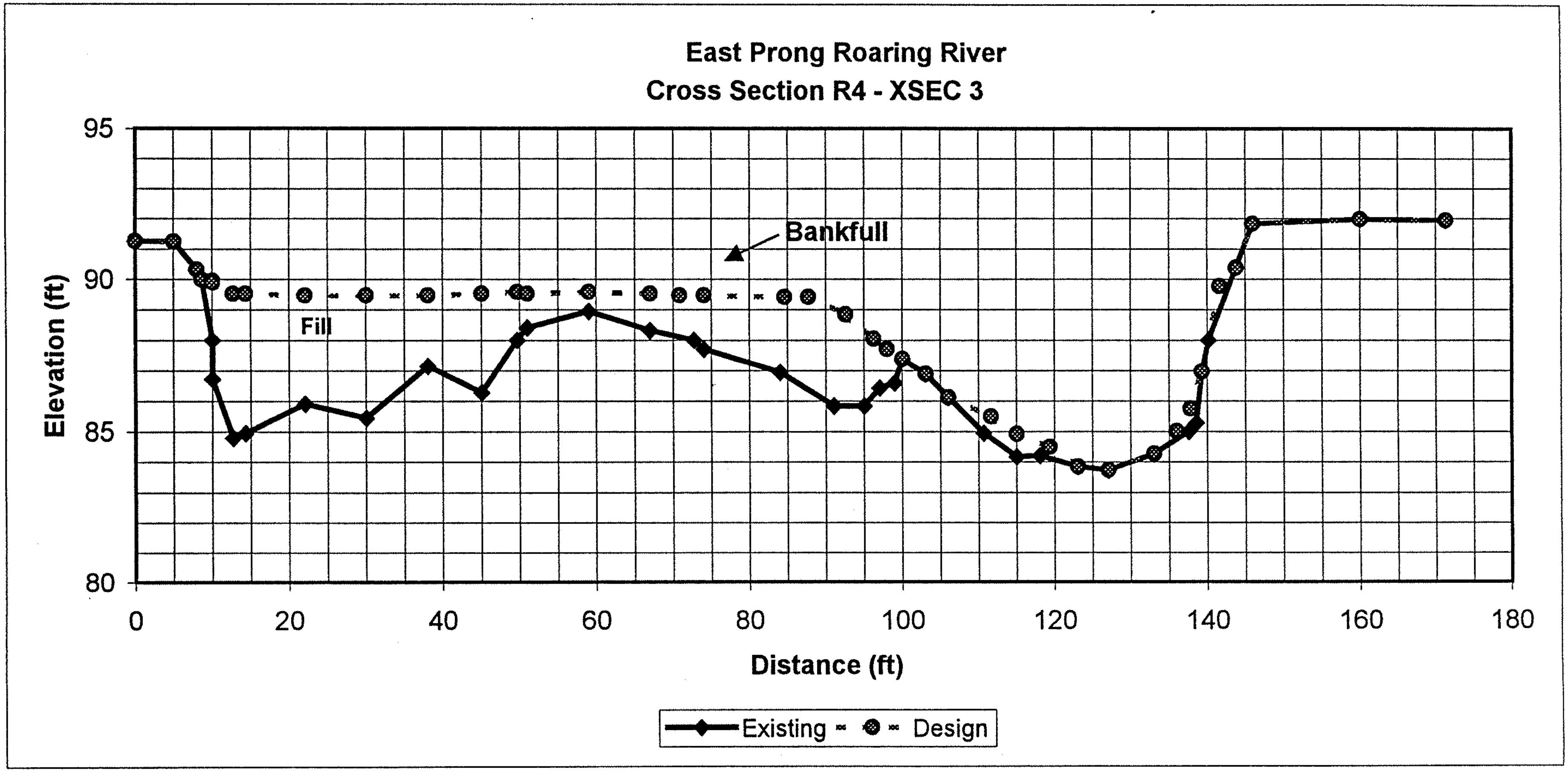


Figure 1.9

	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Pool	C4	600	10.0	140.2	87.99	130.2	1.8	73.3	231.3	4.3	4.6



APPENDIX 2

EXISTING CONDITION

SURVEYS,

PEBBLE COUNTS

Figure 2.1

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 1

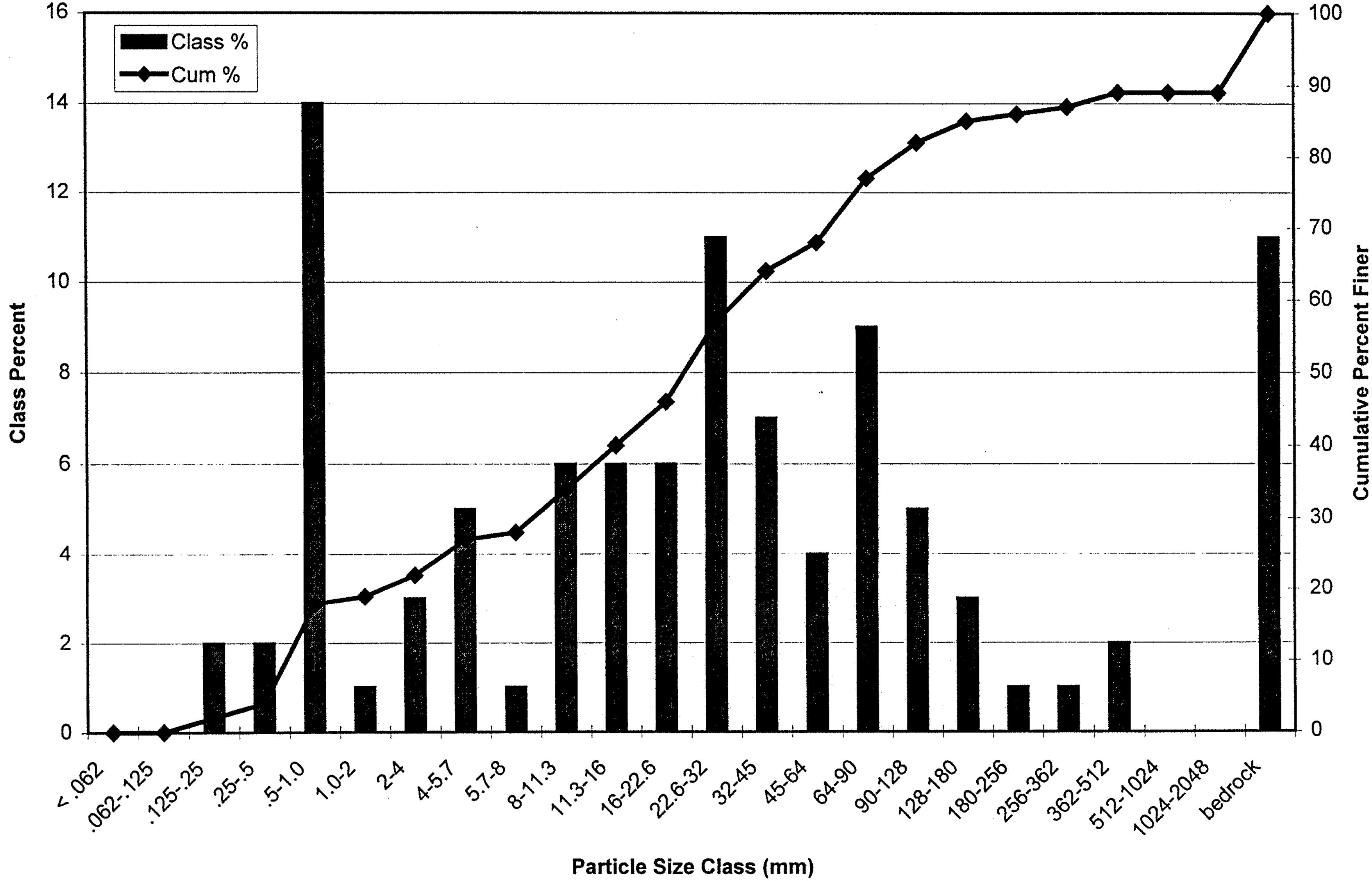
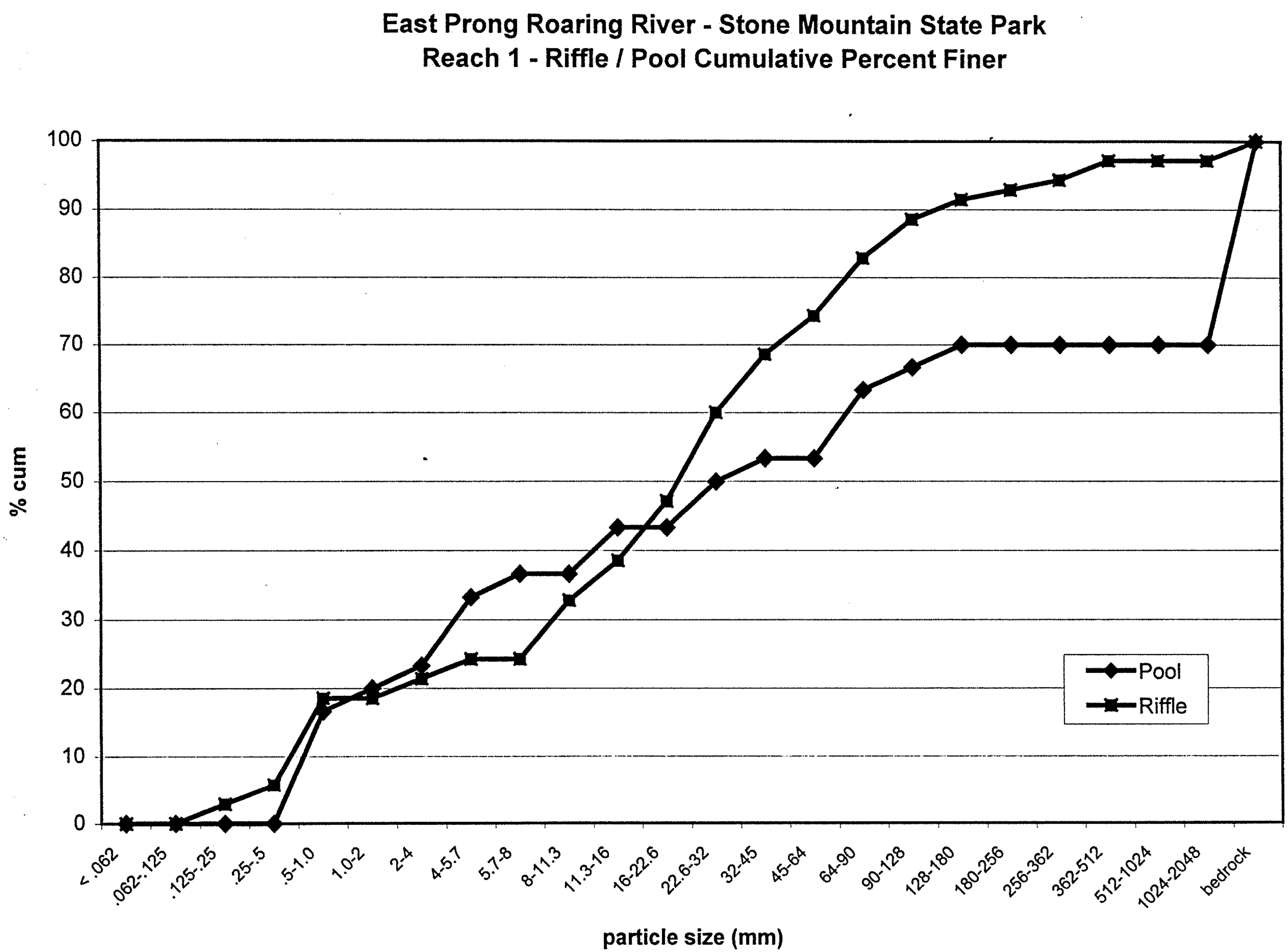
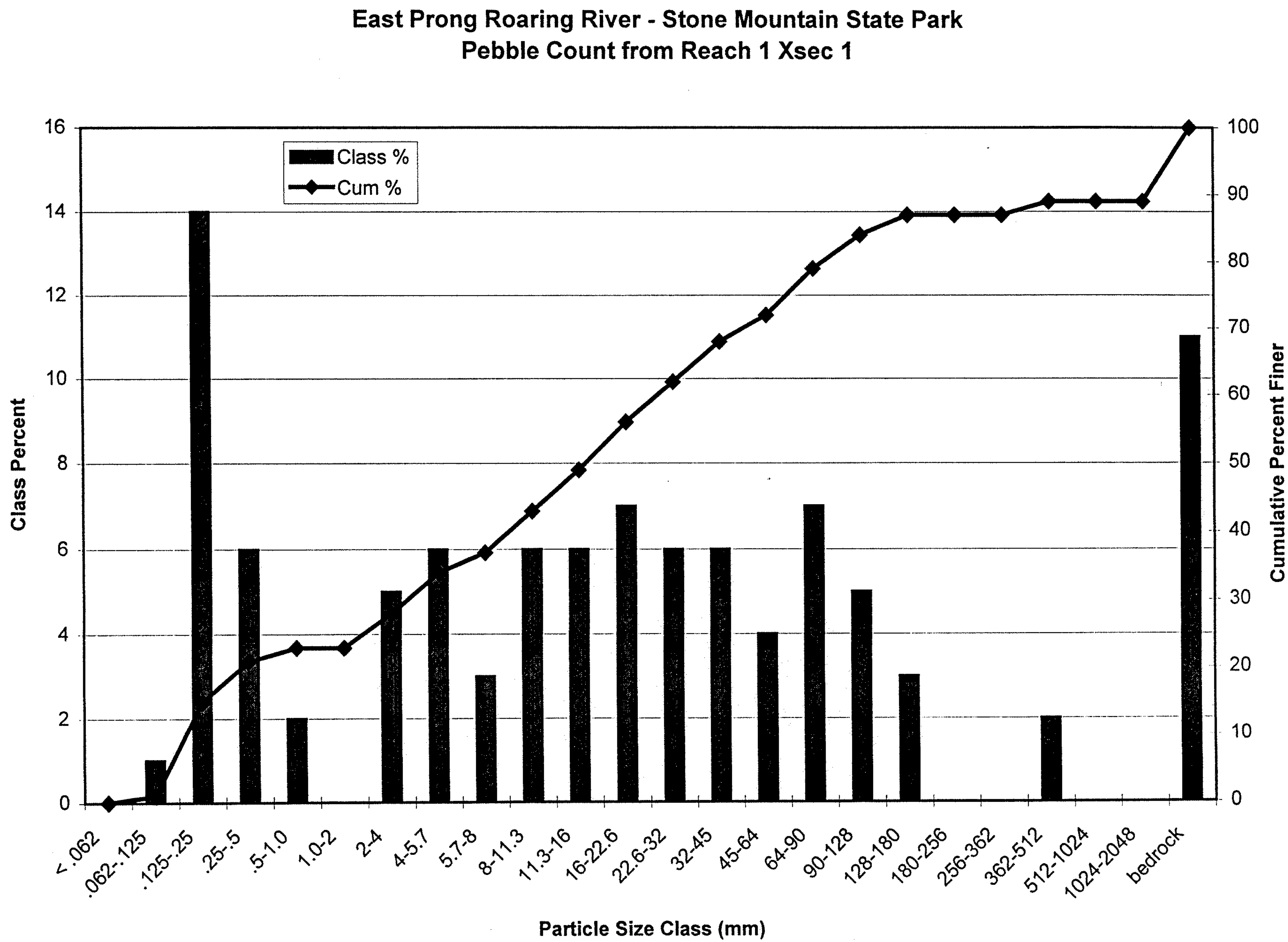


Figure 2.2



East Prong Roaring River - Stone Mountain State Park
Reach 1 - Riffle / Pool Cumulative Percent Finer
% cum
100
90
80
70
60
50
40
30
20
10
0
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
particle size (mm)
Pool
Riffle

Figure 2.3



East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 1 Xsec 1
Class %
Cum %
Class Percent
Cumulative Percent Finer
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80
90
100
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
Particle Size Class (mm)

Figure 2.4

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 2

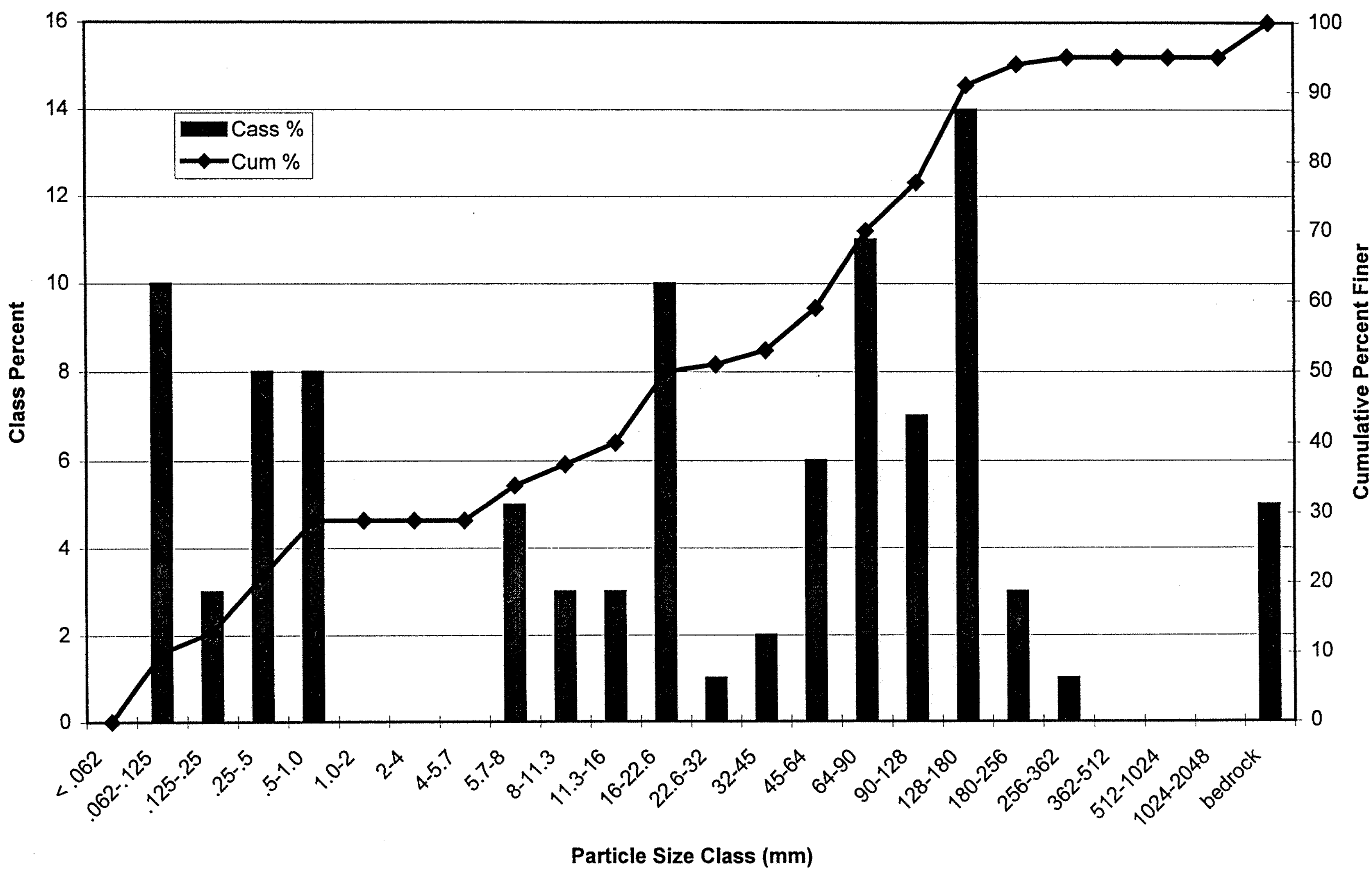


Figure 2.5

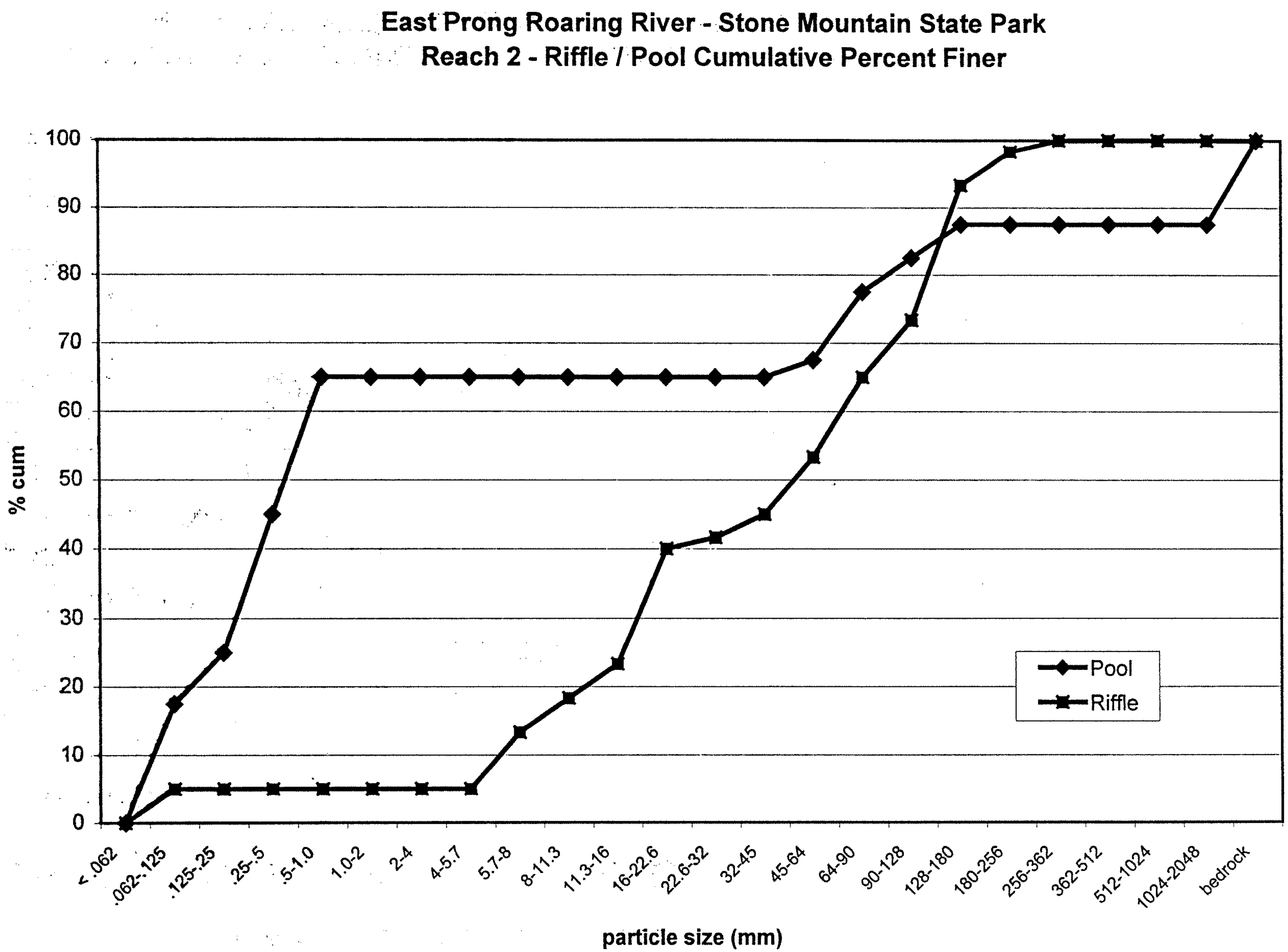
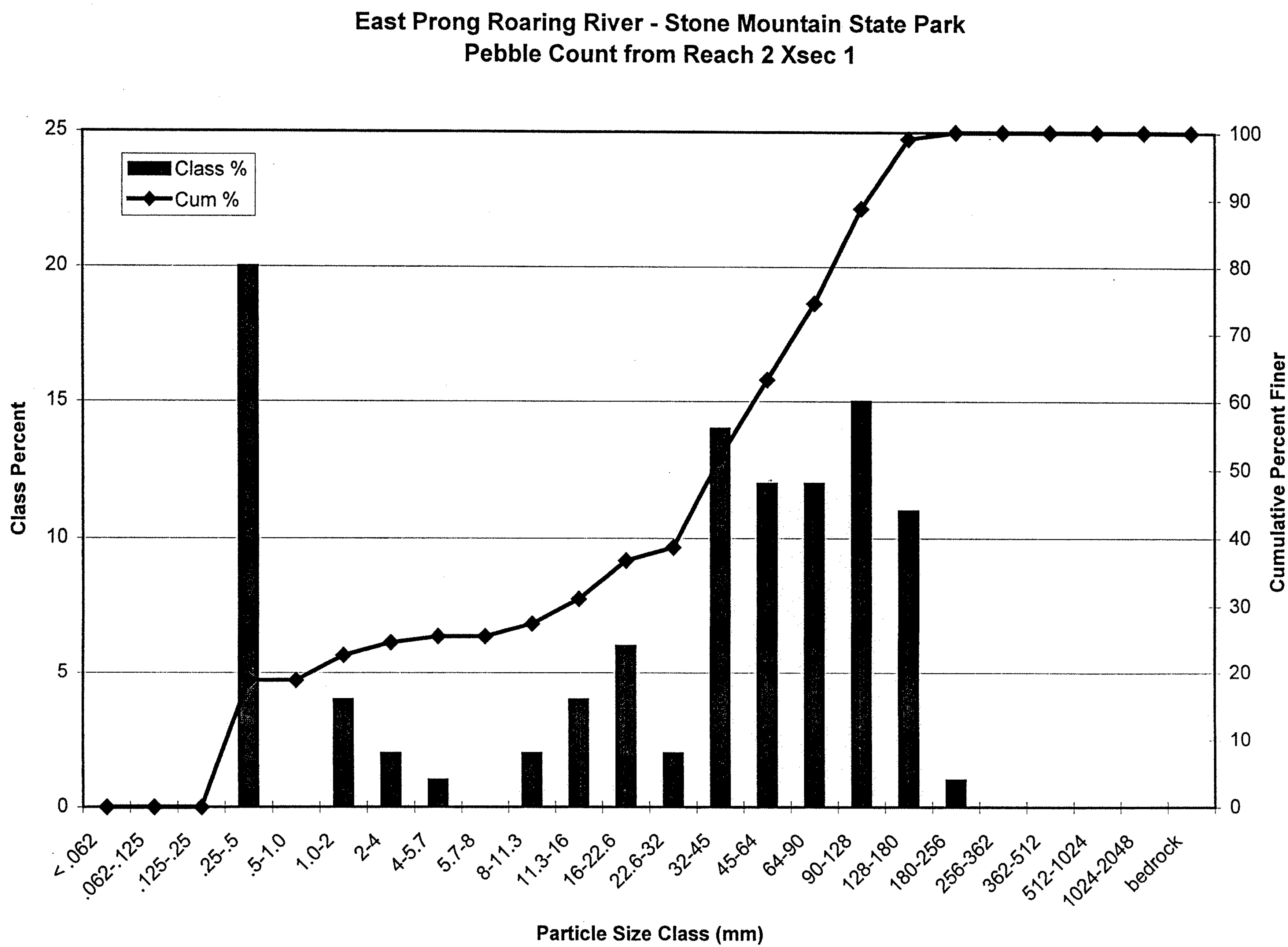

East Prong Roaring River - Stone Mountain State Park
Reach 2 - Riffle / Pool Cumulative Percent Finer
% cum
100
90
80
70
60
50
40
30
20
10
0
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
particle size (mm)
Pool
Riffle

Figure 2.6



East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 2 Xsec 1
Class %
Cum %
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock

Figure 2.7

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 2 Xsec 3

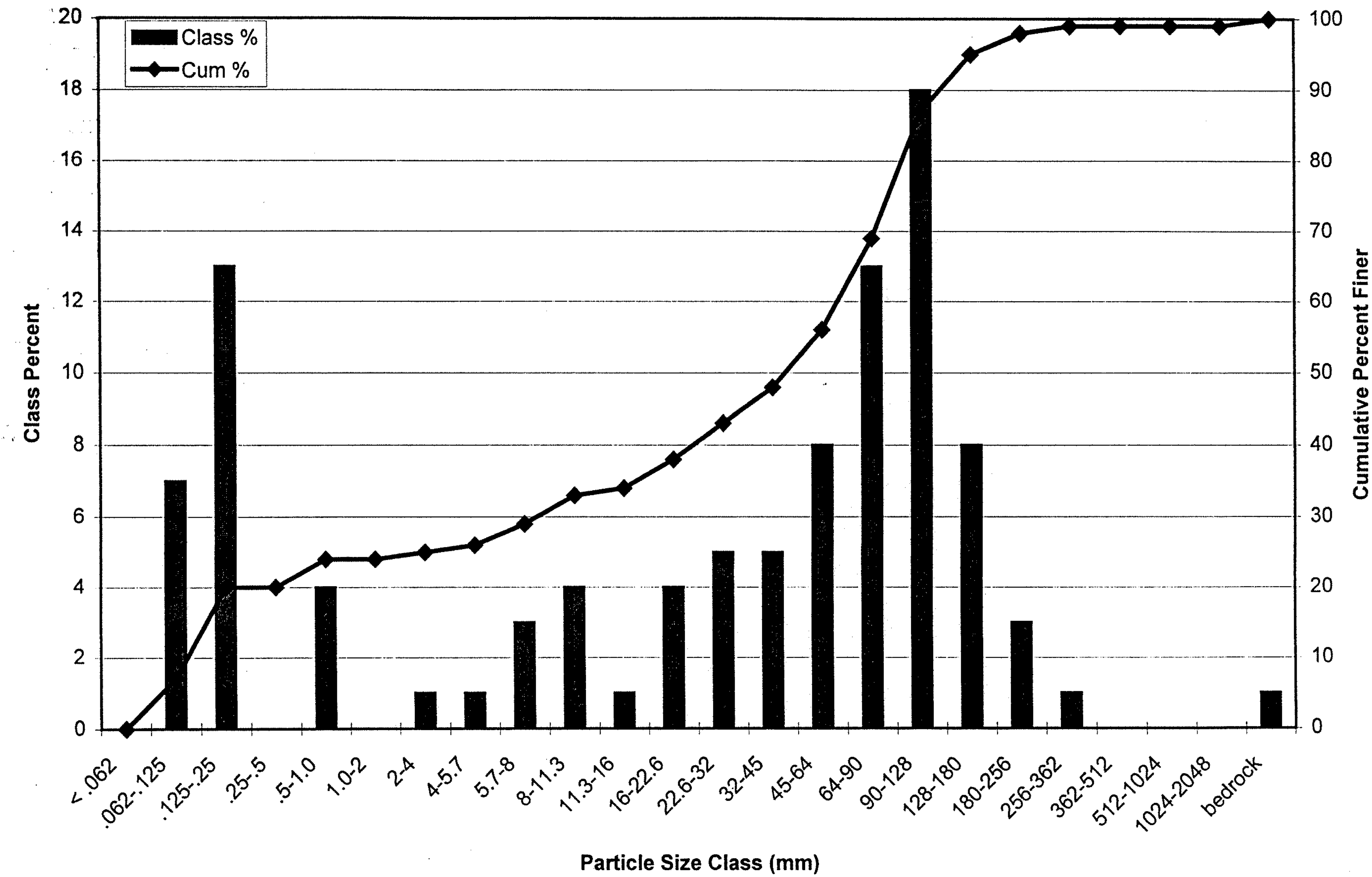


Figure 2.8

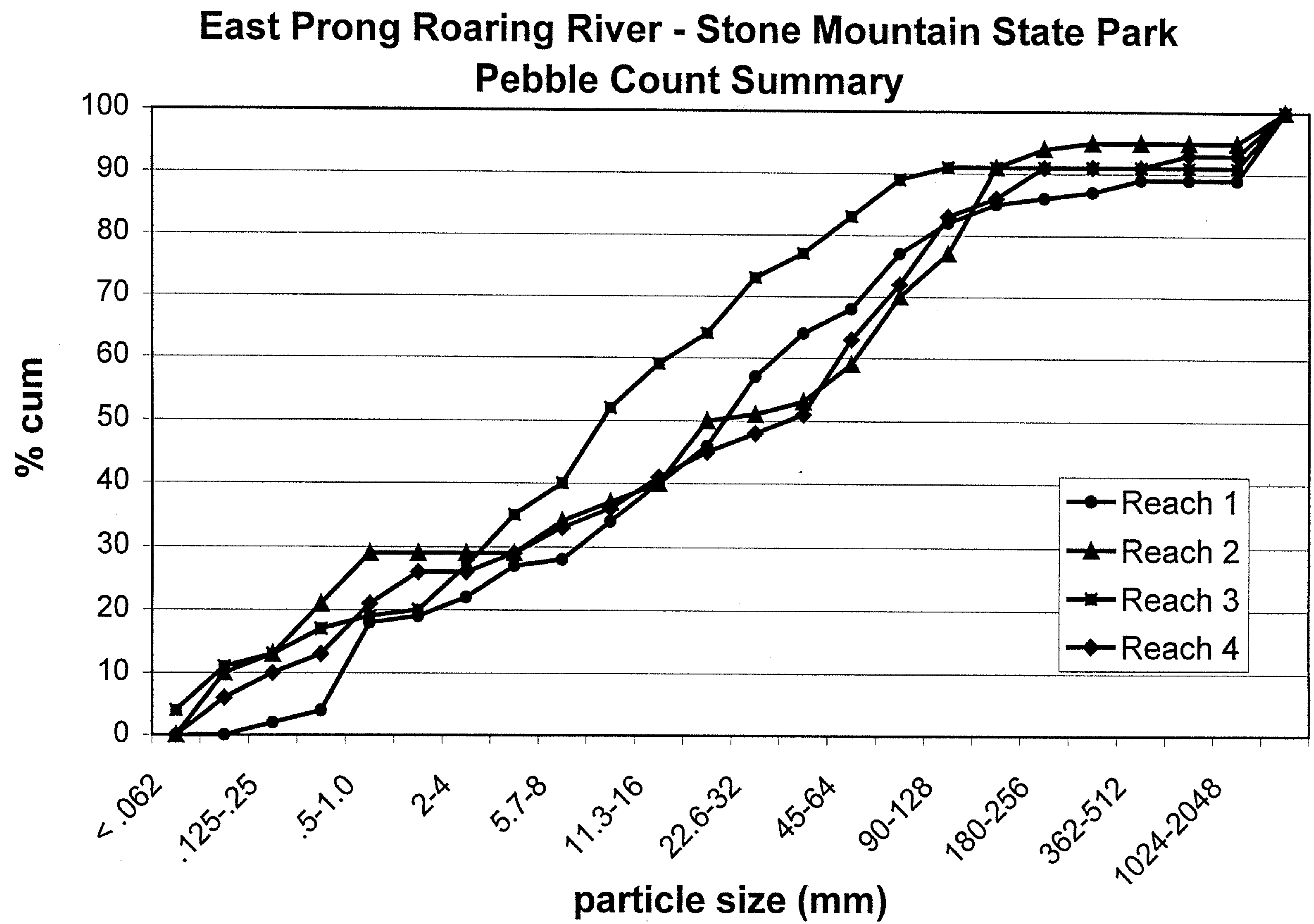

East Prong Roaring River - Stone Mountain State Park
Pebble Count Summary
% cum
100
90
80
70
60
50
40
30
20
10
0
< .062
.125-.25
.5-1.0
2-4
5.7-8
11.3-16
22.6-32
45-64
90-128
180-256
362-512
1024-2048
particle size (mm)
Reach 1
Reach 2
Reach 3
Reach 4

Figure 2.9

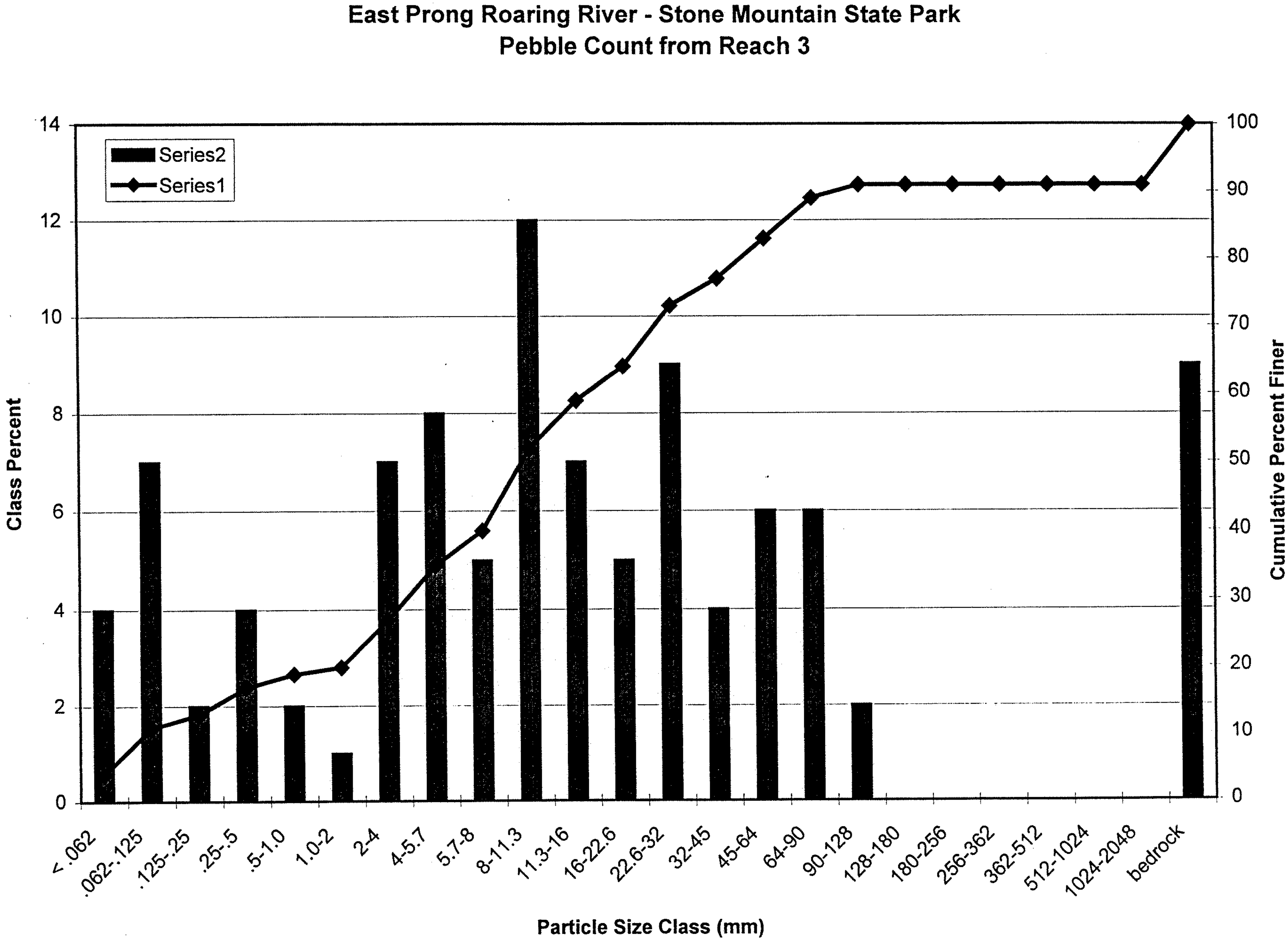
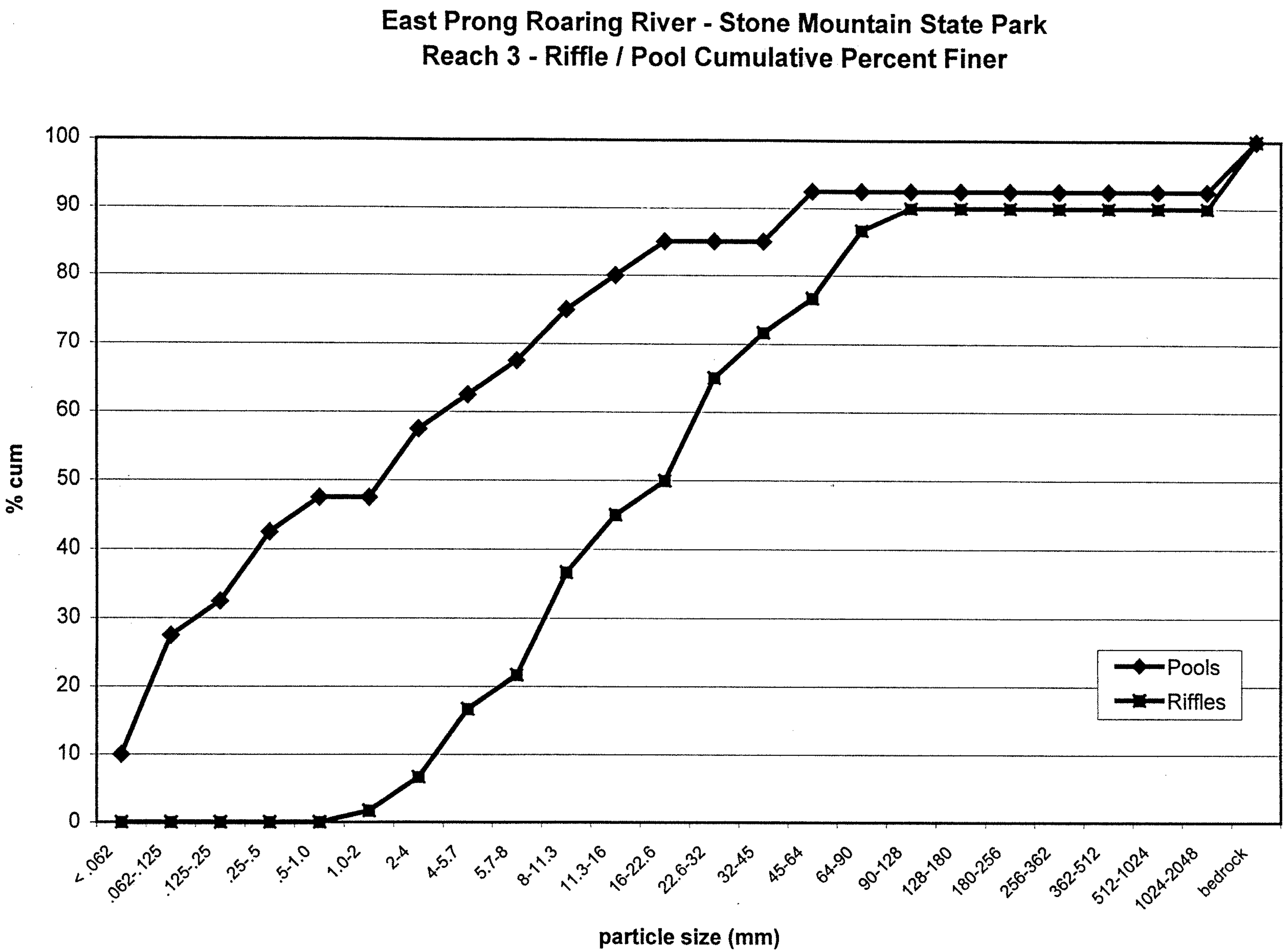

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 3
Series2
Series1
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
80
90
100
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock

Figure 2.10



East Prong Roaring River - Stone Mountain State Park
Reach 3 - Riffle / Pool Cumulative Percent Finer
100
90
80
70
60
50
40
30
20
10
0
% cum
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
particle size (mm)
Pools
Riffles

Figure 2.11

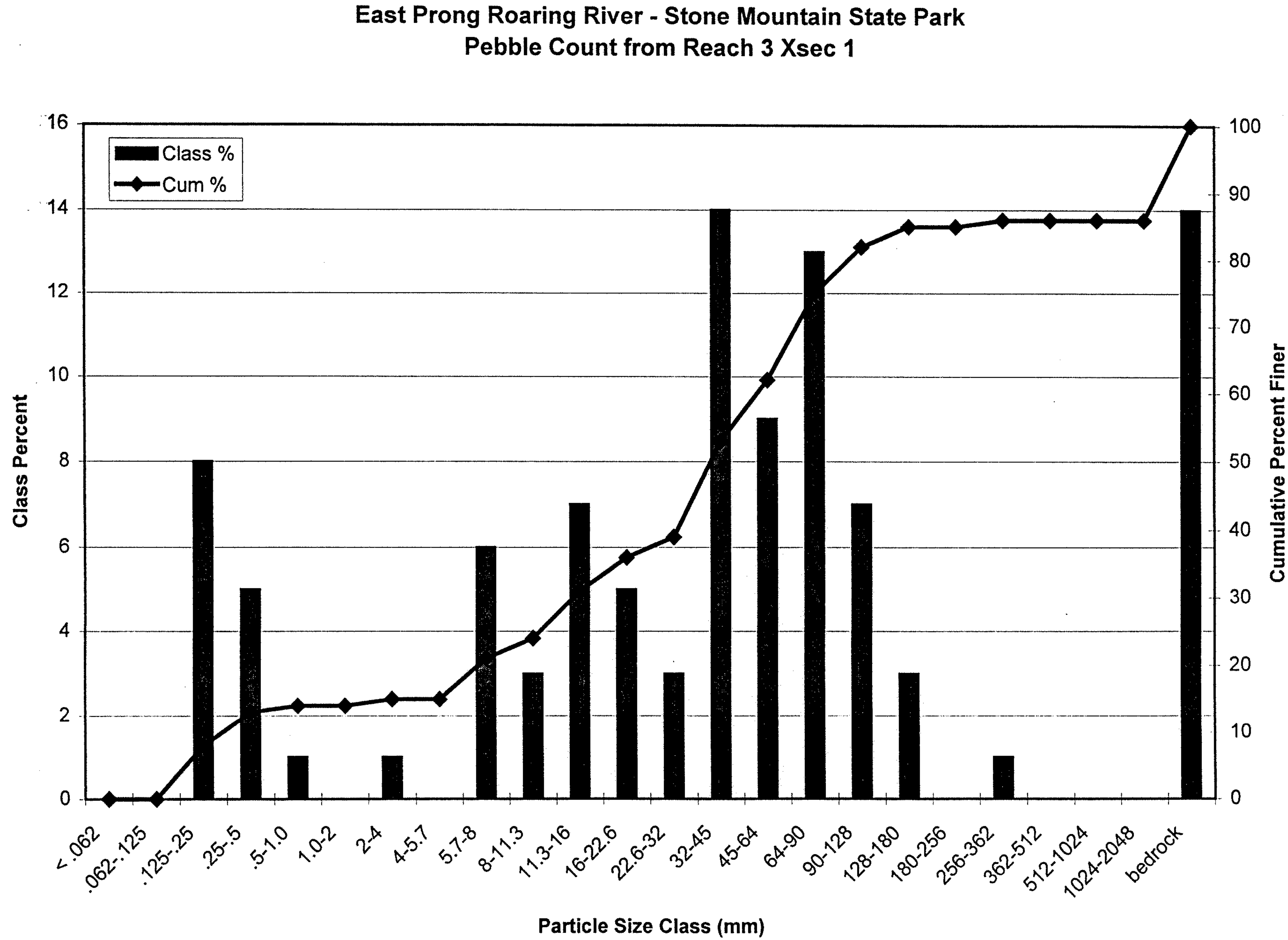

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 3 Xsec 1
Class %
Cum %
Class Percent
Cumulative Percent Finer
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
Particle Size Class (mm)

Figure 2.12

East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 4

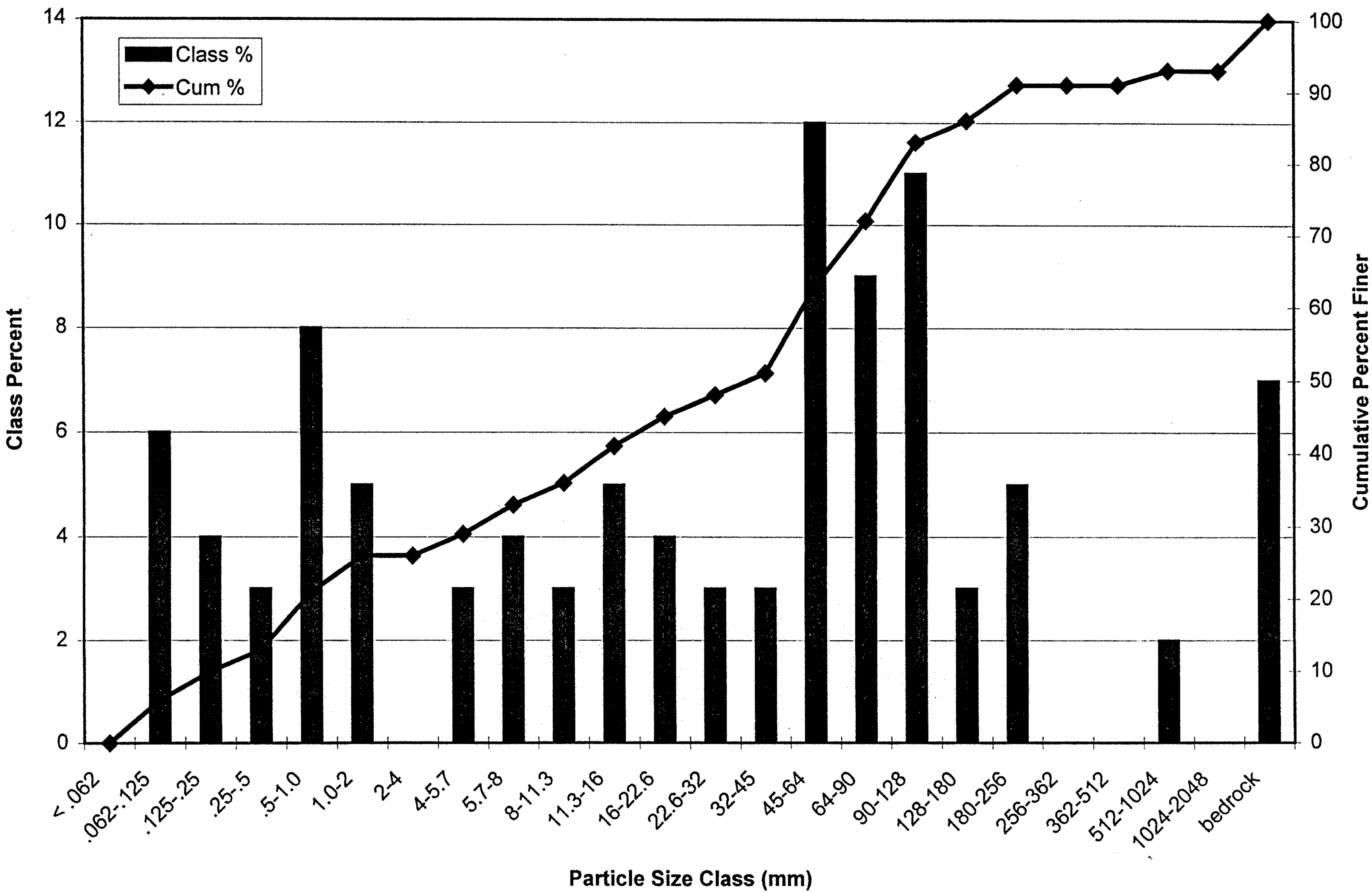


Figure 2.13

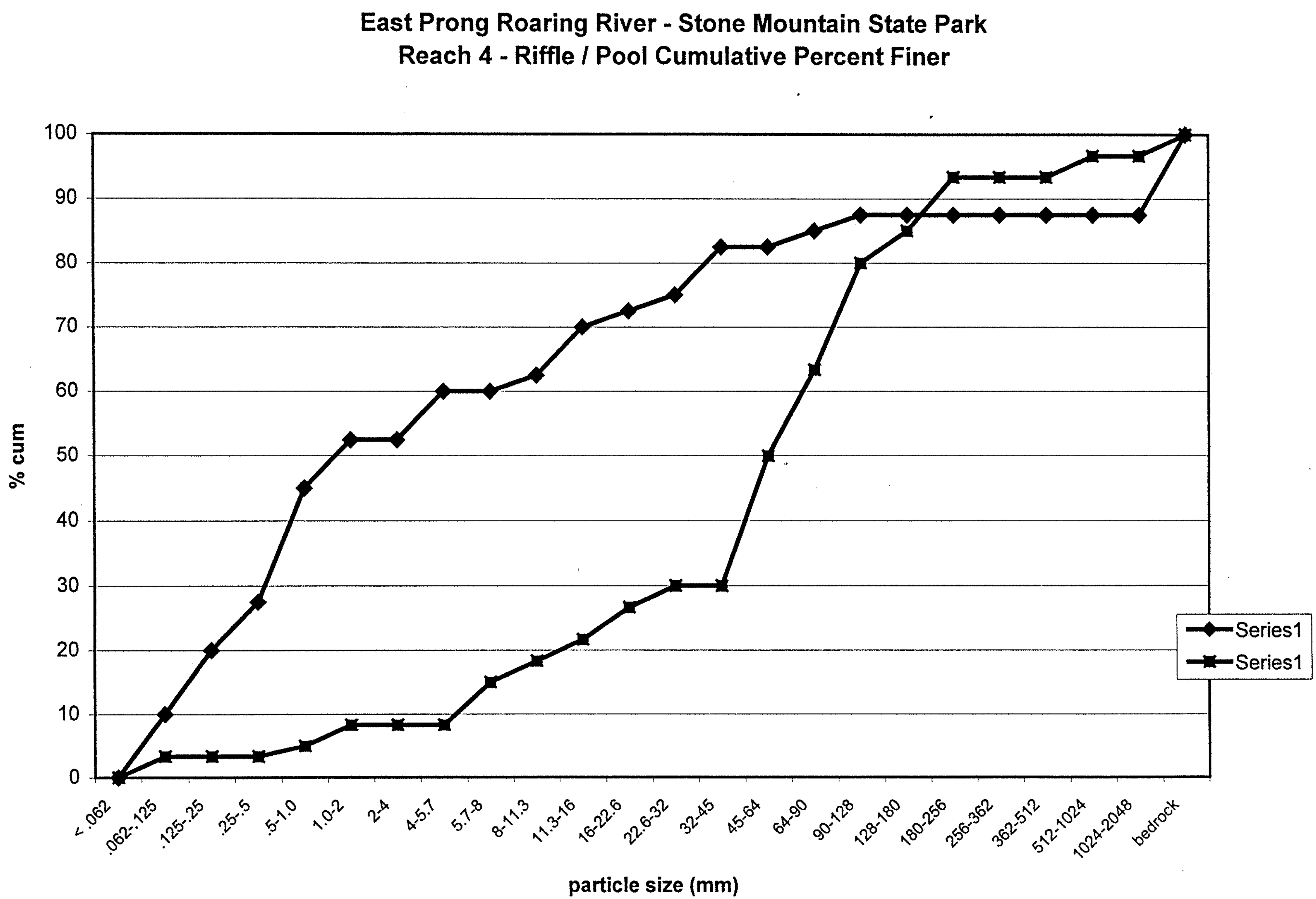
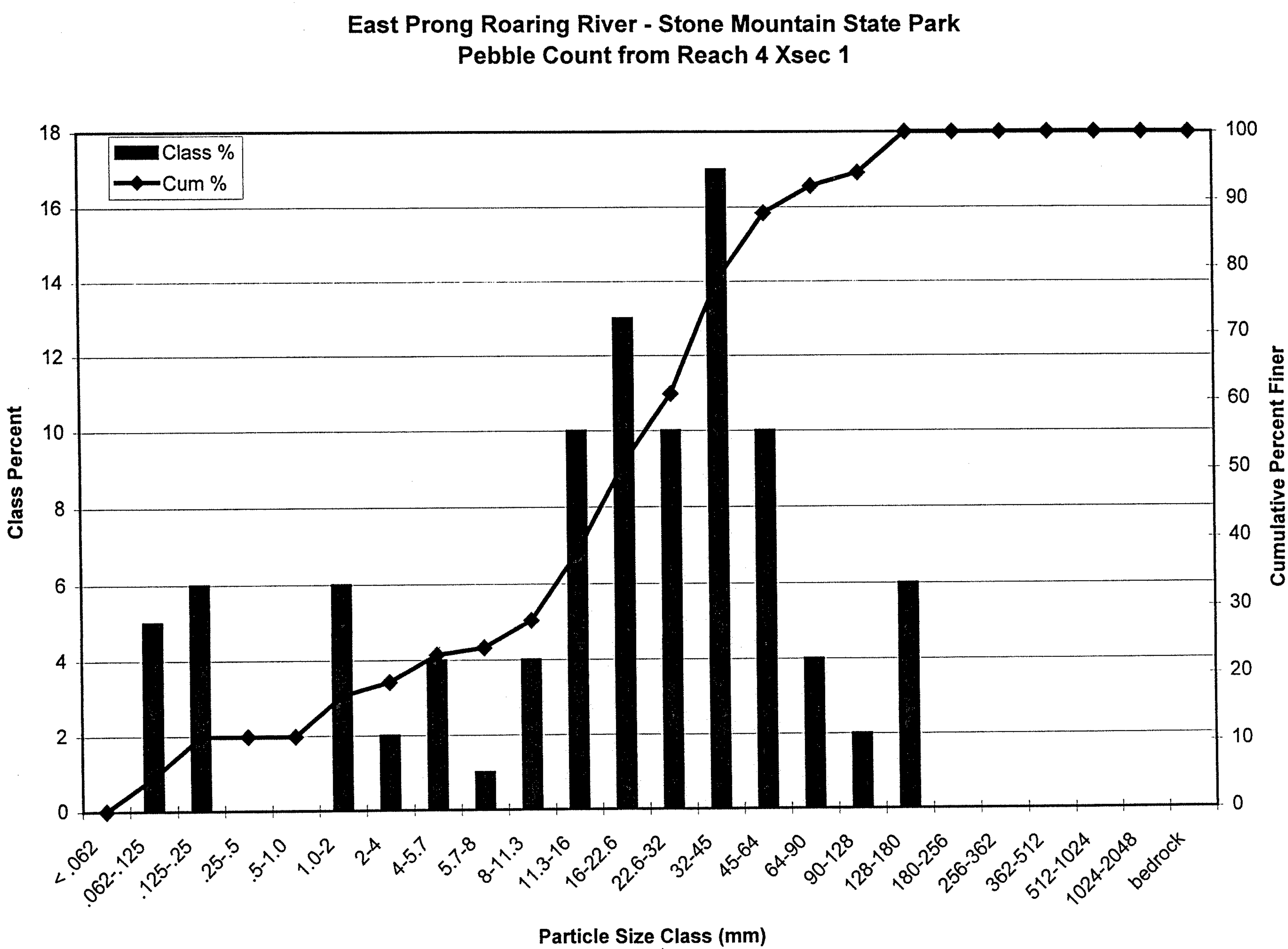

East Prong Roaring River - Stone Mountain State Park
Reach 4 - Riffle / Pool Cumulative Percent Finer
% cum
100
90
80
70
60
50
40
30
20
10
0
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
particle size (mm)
Series1
Series1

Figure 2.14



East Prong Roaring River - Stone Mountain State Park
Pebble Count from Reach 4 Xsec 1
Class %
Cum %
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock

APPENDIX 3

STREAMBANK EROSION ASSESSMENT

Streambank Erosion Assessment

Basin: Yadkin
Watershed: East Prong Roaring River
Project Name: Stone Mountain State Park
Date collected: 03/09/2000
Field Crew: Harman, Wise, Russell

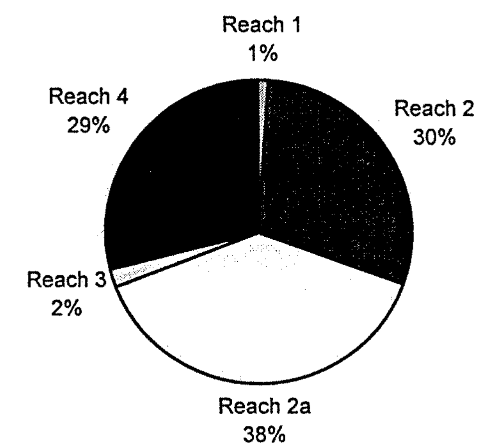
Reach ID	Total Streambank Length	Eroding Streambank Length	Percent of Reach Length Eroding	Percent of Total Length Eroding	Total Erosion in Tons/Year	Total Erosion in Pounds/Ft/Yr	Percent of Total Erosion
Reach 1	2544	20	0.8	0.8	0.9	1	0.2
Reach 2	3544	790	22.3	30.0	133.5	75	27.0
Reach 2a	6450	1000	15.5	38.0	81.5	25	16.5
Reach 3	2724	50	1.8	1.9	13.5	10	2.7
Reach 4	7790	770	9.9	29.3	265.8	68	53.7
Total	23052	2630	11.4	100.0	495.0	43	100.0

Streambank Erosion Assessment

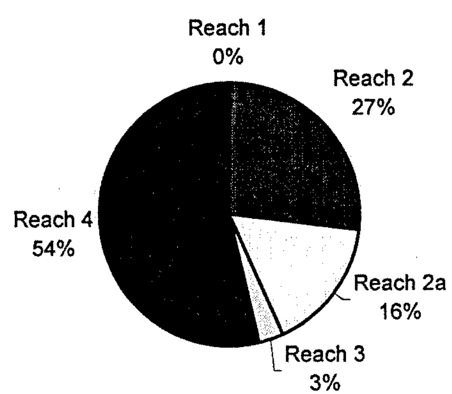
East Prong Roaring River - Stone Mountain State Park

Field Data Collected on 3/7/00

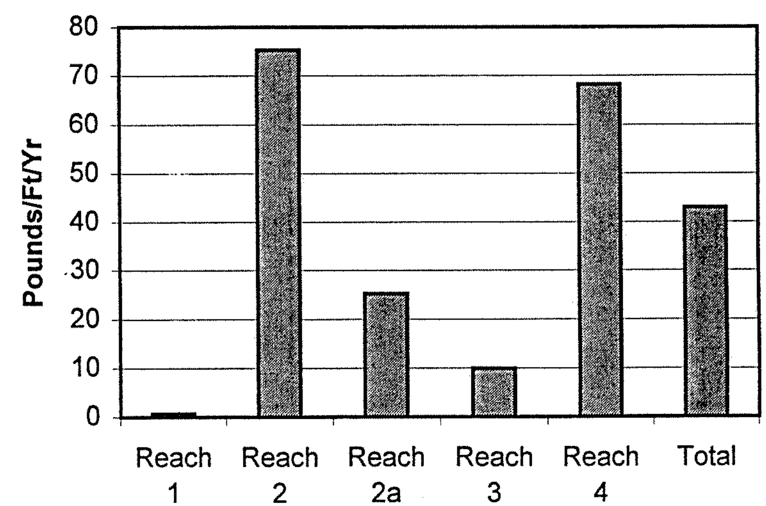
Percent of all Streambanks (ft) that are Eroding by Reach



Percent of Total Bank Erosion Loading (Tons/Yr) by Reach



Bank Erosion Rate per Reach



Streambank Erosion Assessment

Basin: Yadkin
Watershed: East Prong Roaring River
Project Name: Stone Mountain State Park
Date collected: 03/09/2000
Field Crew: Harman, Wise, Russell

Reach ID	Total Streambank Length	Eroding Streambank Length	Percent of Reach Length Eroding	Percent of Total Length Eroding	Total Erosion in Tons/Year	Total Erosion in Pounds/Ft/Yr	Percent of Total Erosion
Reach 1	2544	20	0.8	0.8	0.9	1	0.2
Reach 2	3544	790	22.3	30.0	133.5	75	27.0
Reach 2a	6450	1000	15.5	38.0	81.5	25	16.5
Reach 3	2724	50	1.8	1.9	13.5	10	2.7
Reach 4	7790	770	9.9	29.3	265.8	68	53.7
Total	23052	2630	11.4	100.0	495.0	43	100.0

APPENDIX 4

MOUNTAIN REGIONAL

CURVE

BANKFULL REGIONAL CURVES FOR NORTH CAROLINA MOUNTAIN STREAMS

W.A. Harman[1], D.E. Wise[1], M.A. Walker[2], R. Morris[3], M. A. Cantrell[4],
M. Clemmons[5], G.D. Jennings[1], D. Clinton[1], and J. Patterson[1]

ABSTRACT: Bankfull hydraulic geometry relationships, also called regional curves, relate bankfull stream channel dimensions and discharge to watershed drainage area. This paper describes preliminary results of bankfull regional curve relationships developed for North Carolina Mountain streams. Gage stations were selected with a minimum of 10 years of continuous or peak discharge measurements, no major impoundments, no significant change in land use over the past 10 years, and impervious cover ranges of <20%. To supplement data collected in gaged watersheds, stable reference reaches in un-gaged watersheds were also included in the study. Cross-sectional and longitudinal surveys were measured at each study reach to determine channel dimension, pattern, and profile information. Log-Pearson Type III distributions were used to analyze annual peak discharge data for USGS gage station sites. Power function relationships were developed using regression analyses for bankfull discharge, channel cross-sectional area, mean depth, and width as functions of watershed drainage area. The bankfull return interval for the rural mountain gaged watersheds ranged from 1.1 to 1.7 years, with a mean of 1.3 years. The mean bankfull return interval for rural North Carolina Piedmont gage stations was 1.4 years. Continuing work will expand this database for the North Carolina Mountain Physiographic Region.
KEY TERMS: Hydraulic Geometry, Regional Curve, Bankfull, Flood Frequency Analyses, Mountains

INTRODUCTION

Stream channel hydraulic geometry theory developed by Leopold and Maddock (1953) describes the interrelations between dependent variables such as width, depth and area as functions of independent variables such as discharge. Hydraulic geometry relationships are empirically derived and can be developed for streams in the same physiographic region with similar rainfall/runoff relationships (FISRWG, 1998). Bankfull hydraulic geometry relationships, also called regional curves, relate bankfull channel dimensions to drainage area (Dunne and Leopold, 1978). Gage station analyses throughout the United States have shown that the bankfull discharge has an average return interval of 1.5 years or 67% annual exceedence probability (Dunne and Leopold, 1978; Leopold, 1994). A primary purpose for developing regional curves is to aid in identifying bankfull stage and dimension in un-gaged watersheds and to help estimate the bankfull dimension and discharge for natural channel designs (Rosgen, 1994). This paper describes the process used in North Carolina to develop hydraulic geometry relationships at the bankfull stage. Preliminary results for rural watersheds in the Blue Ridge Mountain physiographic region are presented.

NORTH CAROLINA MOUNTAIN STUDY AREAS

North Carolina contains three major physiographic provinces: the Mountains, Piedmont, and Coastal Plain. The highest (100 inches) and the lowest (40 inches) mean annual precipitation in the Eastern U.S. is recorded in the North Carolina Mountains, both within the project study area and within 50 miles of each other. The steep mountain topography is also a factor in stream morphology, with the highest peak east of the Rocky Mountains at Mt. Mitchell (6,684 feet). In general, watersheds are more than 50% forested. Land cover dominated by human influences is locally high, but is less than 40% overall. Because rainfall/runoff relationships vary by province and land cover, separate bankfull hydraulic geometry relationships are being developed for rural and urban areas for each physiographic province. It may be necessary to further

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[4] Biologist, U.S. Fish and Wildlife Service
[5] Biologist, NC Wildlife Resources Commission

stratify the data for unique areas such as high rainfall areas in the Mountains and the Sandhills bordering the Piedmont and Coastal Plain.

USGS gage stations were identified with at least 10 years of continuous or peak discharge measurements, no major impoundments, no significant change in land use over the past 10 years, and impervious cover ranges of <20%. A geographic information system was used to analyze Thematic Mapper (TM) 1996 data to select watersheds with less than 20% impervious cover. To supplement data collected in gaged watersheds and provide points in smaller drainage areas, stable reference reaches in un-gaged watersheds were also selected using the same criteria. Project study sites are shown in Figure 1.

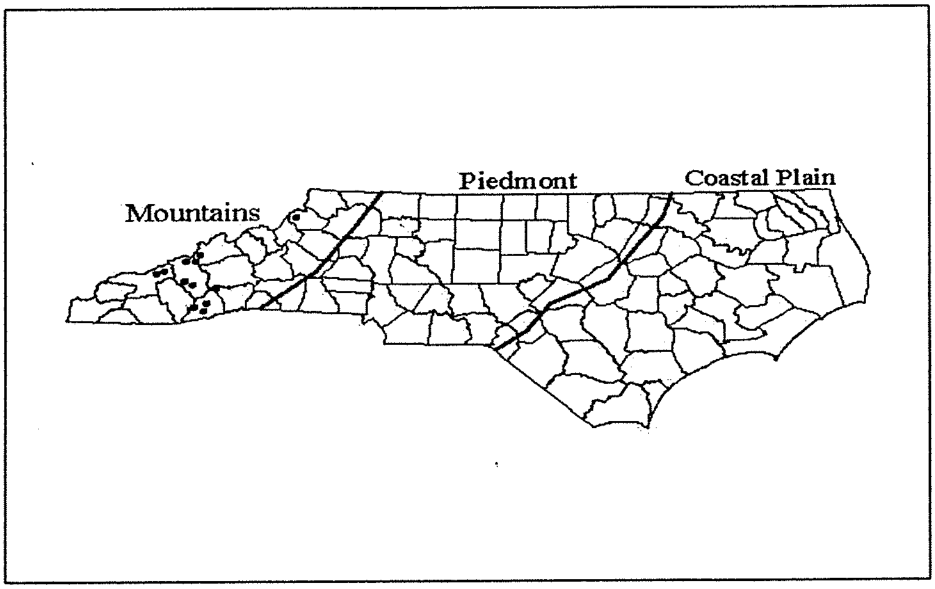

Figure 1: North Carolina map showing physiographic provinces with Mountain study sites shown has dots.

Field Identification of Bankfull

Accurate identification of the bankfull stage in the field can be difficult and subjective (Williams, 1978; Knighton, 1984; and Johnson and Heil, 1996). Numerous definitions exist of bankfull stage and methods for its identification in the field (Wolman and Leopold, 1957; Nixon, 1959; Schumm, 1960; Kilpatrick and Barnes, 1964; and Williams 1978). The identification of bankfull stage in the humid Southeast is especially difficult because of dense understory vegetation and long history of channel modification and subsequent adjustment in channel morphology. It is generally accepted that bankfull stage corresponds with the discharge that fills a channel to the elevation of the active floodplain. The bankfull discharge is considered to be the channel-forming agent that maintains channel dimension and transports the bulk of sediment over time. Field indicators include the back of point bars, other significant breaks in slope, changes in vegetation type, the highest scour line, or the top of the bank (Leopold, 1994). The most consistent bankfull indicators for streams in North Carolina are the highest scour line and the back of the point bar. It is rarely the top of the bank or the lowest scour or bench.

DATA COLLECTION AND ANALYSES

The following gage station records were obtained from the United States Geological Survey: 9-207 forms, stage/discharge rating tables, annual peak discharges, and established reference marks. Bankfull stage was flagged upstream and downstream of the gage station using the field indicators listed above. Once a consistent indicator was found, a cross-sectional survey was completed at a riffle or run near the gage plate. Temporary pins were installed in the left and right banks, looking downstream. The elevations from the survey were related to the elevation of a gage station reference mark. Each cross section survey started at or beyond the top of the left bank. Moving left to right, morphological features were surveyed including top of bank, bankfull stage, lower bench or scour, edge of water, thalweg, and channel bottom (Harrelson et al., 1994). From the survey data, bankfull hydraulic geometry was calculated.

For each reach, a longitudinal survey was completed over a stream length approximately equal to 20 bankfull widths (Leopold, 1994). Longitudinal stations were established at each bed feature (heads of riffles and pools, maximum pool depth, scour holes, etc.). The following channel features were surveyed at each station: thalweg, water surface, low bench or scour, bankfull stage, and top of the low bank. The longitudinal survey was carried through the gage plate to obtain the bankfull stage. Using the current rating table and bankfull stage, the bankfull discharge was determined. Log-Pearson Type III distributions were used to analyze annual peak discharge data for the USGS gage station sites (Harman et al., 1999). Procedures outlined in USGS Bulletin #17B Guidelines for Determining Flood Flow Frequency were followed (U.S. Geological Survey, 1982). The bankfull discharge recurrence interval was then calculated from the flood frequency analyses. The stream was classified using the Rosgen (1994) method.

Ungaged, stable streams were also surveyed to provide points in watersheds with relatively small drainage areas. A stability analyses was completed before the stream was surveyed which included a bank erosion assessment, channel incision measurements, floodplain assessments, and review of historical maps and aerial photographs. To obtain a bankfull discharge (Q) estimate, at the stable ungaged watersheds, Manning's equation was used as:

$$Q = 1.4865\ AR^{2/3}\ S^{1/2} / n \qquad (1)$$

Where, R = hydraulic radius (ft), A = cross sectional area(ft^2), S = average channel slope or energy slope (ft/ft), and n = roughness coefficient estimated using the bankfull mean depth and channel bed materials. Flood frequency analyses was not completed on ungaged streams.

RESULTS AND DISCUSSION

The regional curves for the rural Mountains of North Carolina are shown in Figures 2a, b, c, and d. These relationships represent 9 USGS gage stations and 3 un-gaged reaches ranging in watershed area from 2.0 to 126 mi^2. The power function regression equations and corresponding coefficients of determination for bankfull discharge, cross sectional area, width, and mean depth are shown in Table 1.

Table 1: Power function regression equations for bankfull discharge and dimensions, where Q_{bkf} = bankfull discharge (cfs), A_w = watershed drainage area (mi^{2}), A_{bkf} = bankfull cross sectional area (ft^2), W_{bkf} = bankfull width(ft), and D_{bkf} = bankfull mean depth (ft).

Parameter	Power Function Equation	Coefficient of Determination R^2
Bankfull Discharge	$Q_{bkf} = 115.7A_w^{0.73}$	0.88
Bankfull Area	$A_{bkf} = 22.1A_w^{0.67}$	0.88
Bankfull Width	$W_{bkf} = 19.9A_w^{0.36}$	0.81
Bankfull Depth	$D_{bkf} = 1.1A_w^{0.31}$	0.79

Table 2 summarizes field measurements and hydraulic geometry. Table 3 summarizes bankfull discharge, flood frequency, and mean annual rainfall analyses. The moderately high coefficients of determination indicate good agreement between the measured data and the best-fit relationships. The vast range in mean annual precipitation (42 inches to 98 inches) explains the large degree of variability. Other sources of variability include the age of the forest, topography, land cover, soil type, runoff patterns, stream type and the natural variability of stream hydrology (Leopold, 1994). The bankfull return interval ranged from 1.1 to 1.9 years, with an average of 1.5 years. The mean bankfull return interval for rural North Carolina Piedmont gage stations was 1.4 years (Harman et al., 1999). Dunne and Leoplod (1978) reported a bankfull return interval of 1.5 years from a national study.

CONCLUSION

Bankfull hydraulic geometry relationships are valuable to engineers, hydrologists, geomorphologists, and biologists involved in stream restoration and protection. They can be used to assist in field identification of bankfull stage and dimension in un-gaged watersheds. They can also be used to help evaluate the relative stability of a stream channel. Results of this study indicate good fit for regression equations of hydraulic geometry relationships in the rural Mountains of North Carolina. Further work is necessary to develop additional data points to further explain the variability.

ACKNOWLEDGEMENTS

The NC Stream Restoration Institute is developing bankfull hydraulic geometry relationships for all three physiographic regions in North Carolina. Special thanks go to Angela Jessup, Richard Everhart, Ben Pope, Ray Riley, Sherman Biggerstaff, Kevin Tweedy, Jean Spooner, Carolyn Buckner, Barbara Doll, Rachel Smith, Louise Slate, and Brent Burgess. The authors acknowledge the AWRA reviewers for their thorough review of this manuscript.

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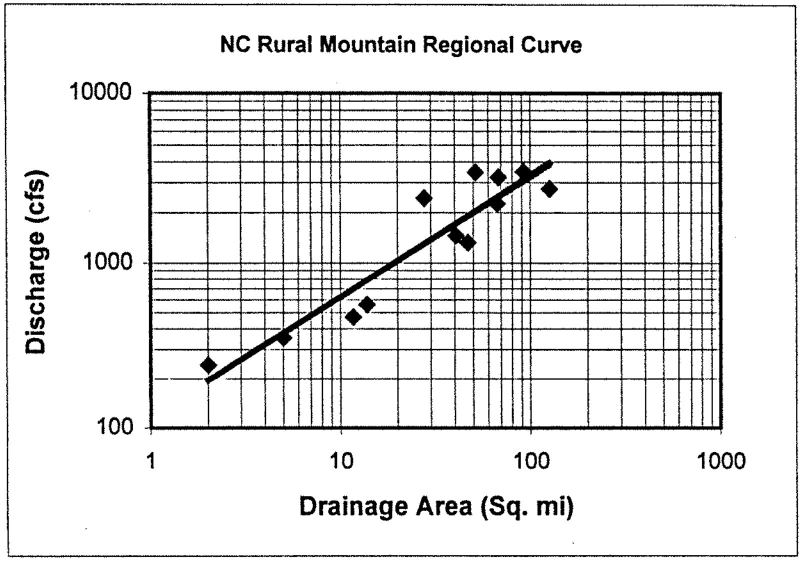


Figure 2a - Bankfull Discharge vs Drainage Area

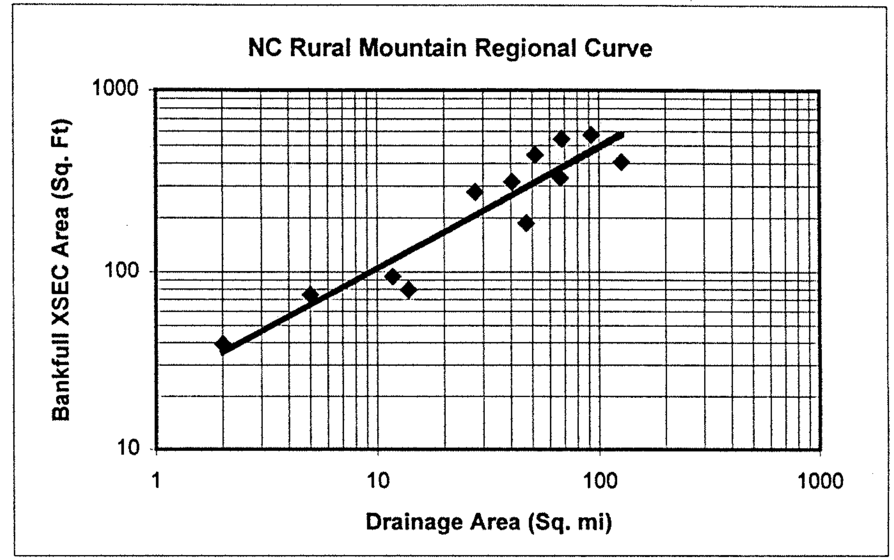


Figure 2b - Bankfull Cross Sectional Area vs Drainage Area

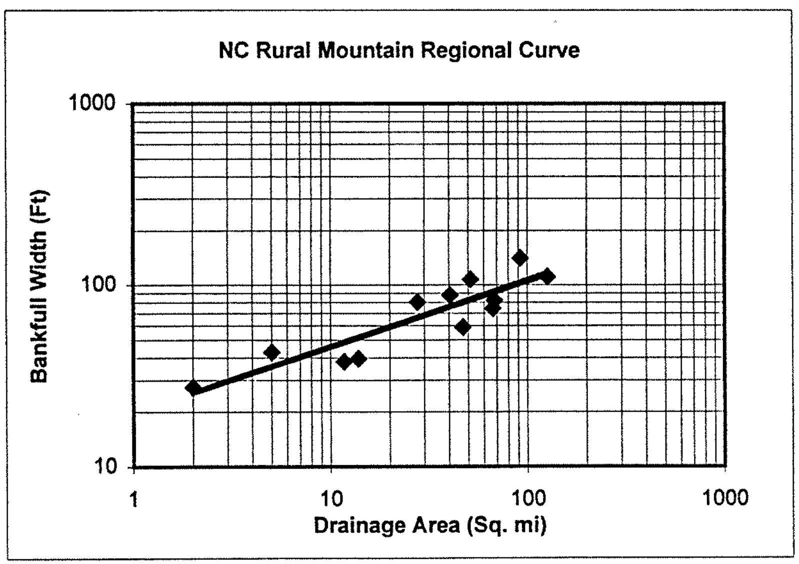


Figure 2c - Bankfull Width vs Drainage Area

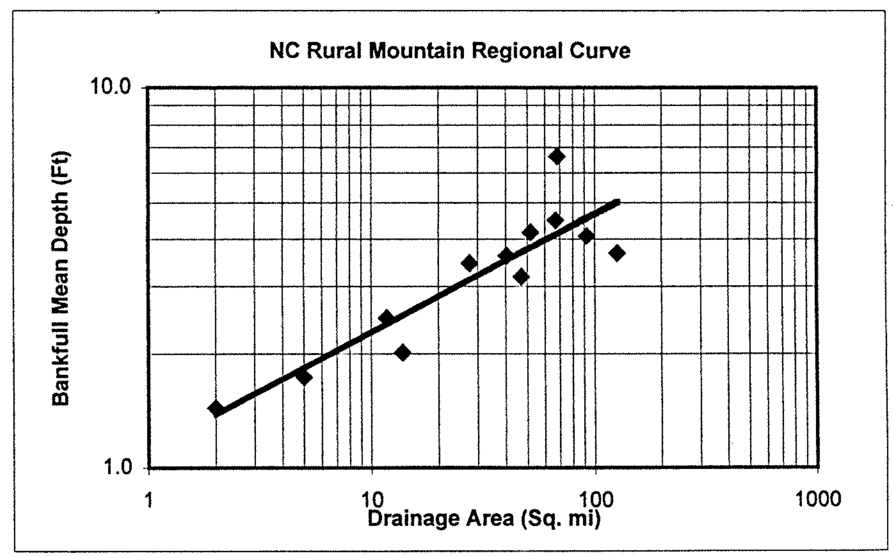


Figure 2d - Bankfull Depth vs Drainage Area

Table 2: Summary of field measurements and hydraulic geometry.

Stream Name	Gage Station ID	Stream Type (Rosgen)	Drainage Area (mi^2)	Bankfull Xsec Area (ft^2)	Bankfull Width (ft)	Bankfull Mean Depth (ft)	Water Surface Slope (ft/ft)
French Broad at Rosman	3439000	E4	67.9	545	82.4	6.6	0.0009
Mills River	3446000	C4	66.7	333	74.3	4.5	0.0035
Davidson River	3441000	B4c	40.4	316	87.6	3.6	0.004
Catheys Creek near Brevard	344000	B4c	11.7	93.1	38.0	2.5	0.013
West Fork of the Pigeon	3456100	B3	27.6	278	80.6	3.4	0.0077
East Fork Pigeon River	3456500	B	51.5	446	107	4.2	Incomplete
Watauga River	3479000	B4c	92.1	572	140	4.1	0.0033
Big Laurel	3454000	B	126	362	111	3.3	0.0045
East Fork Hickey Fork Creek	n/a	B3a	2.0	39.3	27.4	1.4	0.045
Cold Spring Creek	n/a	B4	5.0	74.4	42.9	1.7	0.025
Caldwell Fork	n/a	B	13.8	88.6	38.8	2.3	0.02
Cataloochee	3460000	B3c	46.9	187	58.7	3.2	0.01

Table 3: Summary of bankfull discharge, flood frequency, and rainfall.

Stream Name	Gage Station ID	Bankfull Discharge (cfs)	Return Interval (Years)	Mean Annual Rainfall (Inches)
French Broad at Rosman	3439000	3226	1.30	98
Mills River	3446000	2263	1.90	90
Davidson River	3441000	1457	1.10	94
Catheys Creek near Brevard	344000	470	1.67	94
West Fork of the Pigeon	3456100	2430	1.10	70
East Fork Pigeon River	3456500	3450	1.59	70
Watauga River	3479000	3492	1.25	56
Big Laurel	3454000	2763	1.59	42
East Fork Hickey Fork Creek	n/a	242	n/a	48
Cold Spring Creek	n/a	352	n/a	50
Caldwell Fork	n/a	412	n/a	74
Cataloochee	3460000	1320	1.60	74

APPENDIX 5

REFERENCE REACH SURVEY and NATURAL CHANNEL DESIGN

Design Parameters

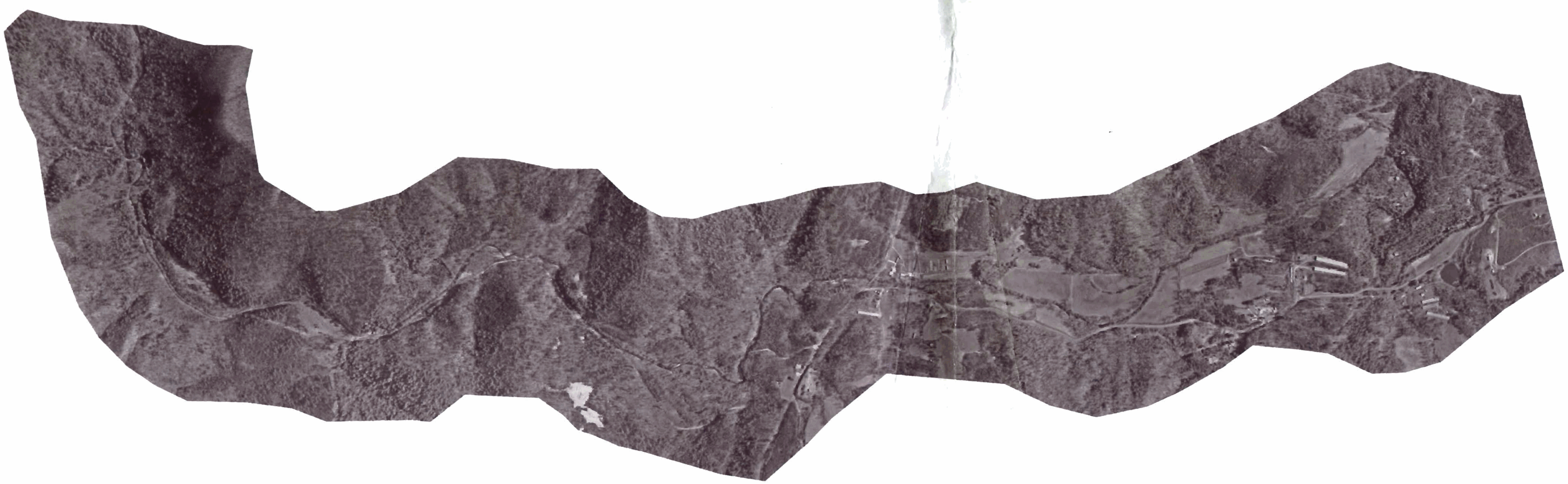
East Prong Roaring River
Yadkin River Basin, Alleghany, NC
SRI

Parameter	Design	Existing	Gage Station	Reference
Reach Name or Info Source	**Reach 2&4**	**Reach 2&4**	Regional Curv	Basin Creek
Stream Type	**C4**	C4	Mountain	C4
Drainage Area (sq mi)	**22**	22	22	6.8
Bkf Cross Sec Area, Abkf (sq ft)	**180**	175 - 231	183	57.4
Bankfull Width, Wbkf (ft)	**52**	53 - 130	60	30.7
Bankfull Mean Depth, Dbkf (ft)	**3.5**	1.8 - 3.7	3.1	1.9
Width/Depth Ratio, Wbkf/Dbkf	**15.0**	14 - 73	19.7	16.4
Bankfull Max Depth, Dmax (ft)	**4.2**	3.8 - 4.7		3.1
Width Flood Prone Area, Wfpa (ft)	**500**	400		70
Entrenchment Ratio, Wfpa/Wbkf	**9.6**	4.2 - 10.8		2.3
Bankfull Discharge, Qbkf (cfs)	**1203**	1203	1105	
Bankfull Mean Velocity, vbkf (ft/s)	**6.7**		6.0	
Min Meander Length, Lm (ft)	**520**	980		
Max Meander Length, Lm (ft)	**624**	1300		
Min Meander Len Ratio, Lm/Wbkf	**10.0**	18.5		11.4
Max Meander Len Ratio, Lm/Wbkf	**12.0**	24.5		11.4
Min Radius of Curvature, Rc (ft)	**68**	55		
Max Radius of Curvature, Rc (ft)	**229**	150		
Min Rc Ratio, Rc/Wbkf	**1.3**	1.0		2.5
Max Rc Ratio, Rc/Wbkf	**4.4**	5.0		4.4

Design Parameters

East Prong Roaring River
Yadkin River Basin, Alleghany, NC
SRI

Parameter	Design	Existing	Gage Station	Reference
Min Belt Width, Wblt (ft)	**156**	200		
Max Belt Width, Wblt (ft)	**260**	420		
Min MW Ratio, Wblt/Wbkf (ft)	**3.0**	3.8		3.0
Max MW Ratio, Wblt/Wbkf (ft)	**5.0**	7.9		3.4
Sinuosity, K	**1.4**	1.11		
Valley Slope, Sval (ft/ft)	**0.0060**	0.0060		
Channel Slope, Schan=Sval/K (ft/ft)	**0.0043**	0.0050		
Pool Slope, Spool (ft/ft)	**0.0001**	0.0003		
Pool Slope Ratio, Spool/Schan	**0.03**	0.06		0.03
Min Pool Depth, Dpool (ft)	**5.2**	4.0		
Max Pool Depth, Dpool (ft)	**9.0**	9.0		
Min Pool Depth Ratio, Dpool/Dbkf	**1.5**	1.1		1.5
Max Pool Depth Ratio, Dpool/Dbkf	**2.6**	2.5		3.1
Min Pool Width, Wpool (ft)	**57.2**	53		
Max Pool Width, Wpool (ft)	**72.7**	130		
Min Pool Wid Ratio, Wpool/Wbkf	**1.1**	1.0		1.1
Max Pool Wid Ratio, Wpool/Wbkf	**1.4**	2.5		1.4
Min Length Pool Spacing, Lps (ft)	**260**	300		
Max Length Pool Spacing, Lps (ft)	**364**	500		
Min Pool Spacing Ratio, Lps/Wbkf	**5.0**	5.7		2.0
Max Pool Spacing Ratio, Lps/Wbkf	**7.0**	9.4		4.0



Dimensionless Ratios for C Type Streams
Summary Sheet

	C STREAM TYPES			
Channel Dimension	**Mean**	**Median**	**Min**	**Max**
Riffle Width / Mean Bkf Depth (Rw/Dr)	17.2	17.2	14.0	20.8
Max Pool Depth / Max Riffle Depth (Dp/Dr)	1.5	1.5	1.2	1.7
Pool Width / Riffle Width (Wp/Wr)	0.9	0.8	0.7	1.3
Pool Area / Riffle Area (Ap/Ar)	1.1	1.1	0.6	1.3
Max Pool Depth / Mean Bkf Depth (Dp_{max}/Dr)	2.1	2.2	1.7	2.7
Max Riffle Depth / Mean Bkf Depth (Dr_{max}/Dr)	1.4	1.4	1.2	1.7
Lowest Bank Ht. / Max Bkf Depth (Bh_{low}/Dr_{max})	1.0			
Channel Pattern				
Meander Width Ratio (MWR = Wblt/Wr)	3.7	2.7	1.5	8.0
Radius of Curvature / Bkf Width (Rc/Wr)	2.8	2.2	0.8	5.7
Meander Length / Bkf Width (Lm/Wr)	7.1	8.7	0.9	11.4
Sinuosity (K)	1.2			
Channel Profile				
Riffle Slope / Avg. Water Surface Slope	3.8	3.0	0.8	11.0
Pool Slope / Avg. Water Surface Slope	0.1	0.0	0.0	0.5
Run Slope / Avg. Water Surface Slope	0.7	0.7	0.0	3.7
Glide Slope / Avg. Water Surface Slope	0.2	0.0	0.0	0.6
Run Depth /Mean Bkf Depth (Dr)	1.3	1.3	1.0	1.7
Glide Depth / Mean Bkf Depth (Dr)	1.3	1.3	0.9	1.7
Pool Length / Bkf Width (Pl / Wr)	2.1	2.2	0.2	4.4
Pool to Pool Spacing / Bkf Width (PPS / Wr)	5.9	6.3	1.9	9.7

REFERENCE REACH Summary Data

Stream Name: BASIN CREEK
Location: DOUGHTON PARK, WILKES COUNTY, NC
Date: ########
Crew: Dan Clinton, Jan Patterson, Louise O'Hara, Jon Williams
Stream Type: C4
Watershed Area: 6.8 sq. miles

Channel Dimensions

Max. Riffle Depth(drmax)(ft.):	2.5
Riffle Width(Wr)(ft.):	30.7
Riffle X-Sect. Area(Ar)(ft^2):	57.4
Riffle Mean Bankfull Depth(dmbkf):	1.9

Max. Pool Depth(dpmax)(ft.):	3.1
Pool Width(Wp)(ft.):	40.6
Pool X-Sect. Area(Ap)(ft.):	64.4

Ratio: Max. Pool Depth/Max. Riffle Depth(dpmax/drmax):	1.24	
Ratio: Pool Width/Riffle Width(Wp/Wr):	1.32	
Ratio: Pool Area/Riffle Area(Ap/Ar):	1.12	
Ratio: Max. Pool Depth/Mean Bankfull Depth(dpmax/dbkf):	1.66	
Ratio: Lowest Bank Height/Max. Bankfull Depth(Bhlow/dmbkf):	1	
Streamflow: Estimated Mean Velocity(u) @ Bankfull Stage:		ft./sec.
Streamflow: Estimated Discharge(Q) @ Bankfull Stage:		CFS

Channel Pattern

	Mean	Median	Min	Max	
Meander Wavelength(Lm):	350.0				ft.
Radius of Curvature(Rc):	105.2	105.2	76.7	133.8	ft.
Beltwidth(Wblt):	105				ft.

Meander Width Ratio(MWR=Wblt/Wbkf):	3.42

RATIO: Radius of Curvature/Bankfull Width(Rc/Wbkf):	3.43	3.43	2.50	4.36	
RATIO: Meander Wavelength/Bankfull Width(Lm/Wbkf):	11.40				

Channel Profile

Valley Slope:	0.0139	ft./ft			
Water Surface Slope:	0.0141	ft./ft			
Riffle Slope:	0.0509	0.0349	0.0177	0.1000	ft./ft
Pool Slope:	0.0055	0.0055	0.0049	0.0061	ft./ft
Run Slope:	0.0113	0.0113	0.0105	0.0120	ft./ft
Glide Slope:	0.0000	0.0000	0.0000	0.0000	ft./ft
Riffle Length:	73.0	67.0	5.0	147.0	ft.
Pool Length:	70.0	70.0	41.0	99.0	ft.
Run Length:	34.5	34.5	19.0	50.0	ft.
Glide Length:	14.0	14.0	13.0	15.0	ft.
Riffle to Riffle Spacing:	143.3	143.3	48.5	238.0	ft.
Pool to Pool Spacing:	224.0				ft.
Riffle to Pool Spacing:	91.8	91.8	60.5	123.0	ft.

RATIO: Riffle Slope/ Water Surface Slope:	3.61	2.48	1.25	7.09
RATIO: Pool Slope/Water Surface Slope:	0.388	0.388	0.346	0.430
RATIO: Run Slope/Water Surface Slope:	0.799	0.799	0.747	0.851
RATIO: Glide Slope/ Water Surface Slope:	0.000	0.000	0.000	0.000
RATIO: Max. Riffle Depth/Mean Bankfull Depth:	1.34			
RATIO: Max.Pool Depth/Mean Bankfull Depth:	1.66			
RATIO: Max. Run Depth/Mean Bankfull Depth:	n/a			
RATIO: Max. Glide Depth/Mean Bankfull Depth:	n/a			
RATIO: Riffle Length/Bankfull Width:	2.38	2.18	0.16	4.79
RATIO: Pool Length/Bankfull Width:	2.28	2.28	1.34	3.22
RATIO: Run Length/Bankfull Width:	1.12	1.12	0.62	1.63
RATIO: Glide Length/Bankfull Width:	0.46	0.46	0.42	0.49
RATIO: Riffle to Riffle Spacing/Bankfull Width:	4.67	4.67	1.58	7.75
RATIO: Pool to Pool Spacing/Bankfull Width:	7.30			
RATIO: Riffle to Pool Spacing/Bankfull Width:	2.99	2.99	1.97	4.01

D84:	130	mm
dmbkf:	570	mm
dmbkf/D84:	4.38	
u/u* :	6.5	Reference: Rosgen Reference Reach Field Book
Mannings 'n':	0.035	"

APPENDIX 6

IN-STREAM STRUCTURE DESIGN, CUT-FILL ESTIMATES, and SPECIFICATIONS

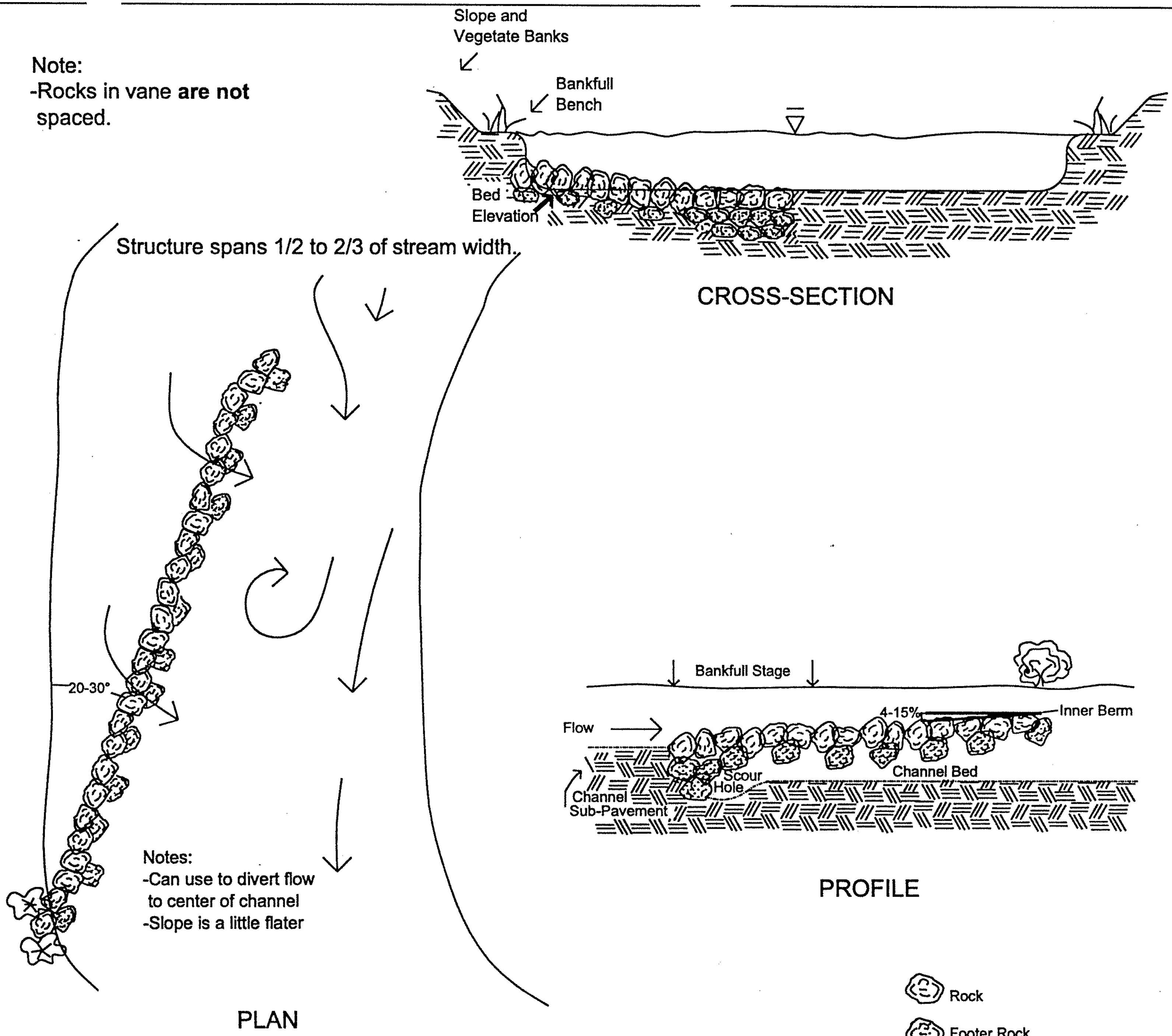
Yadkin River Basin, Alleghany, NC

SRI

Structure Specifications								
Reach	**Structure**	**# of Structures**	**# of Rocks Per Structure**	**# of Logs Per Structure**	**Total # of Rocks**	**Total # of Logs**	**Total Rock Vol. (CY)**	**Total Rock Wt (ton)**
1	Log Vane	2	6	3	12	6	32.4	49
2	Cross Vane	3	30	0	90	0	243	365
2	Vanes	4	15	0	60	0	162	243
2	Log Vane	6	6	3	36	18	97.2	146
2	Root Wads	20	1	0.5	20	10	54	81
3	Log Vane	3	6	3	18	9	48.6	73
4	Cross Vane	6	30	0	180	0	486	729
4	Vanes	13	15	0	195	0	526.5	790
4	Root Wads	40	1	0.5	40	20	108	162
	Total	**97**					**1758**	**2637**

Notes: Rock size = 6' X 4' X 3'

Cut/Fill Ratios			
Location	**New Channel Cut (CY)**	**Existing Channel Fill (CY)**	**Cut/Fill**
Reach 2	9,348	9,061	**1.0**
Reach 4	30,348	33,203	**0.9**
Total	**39,696**	**42,264**	**0.9**



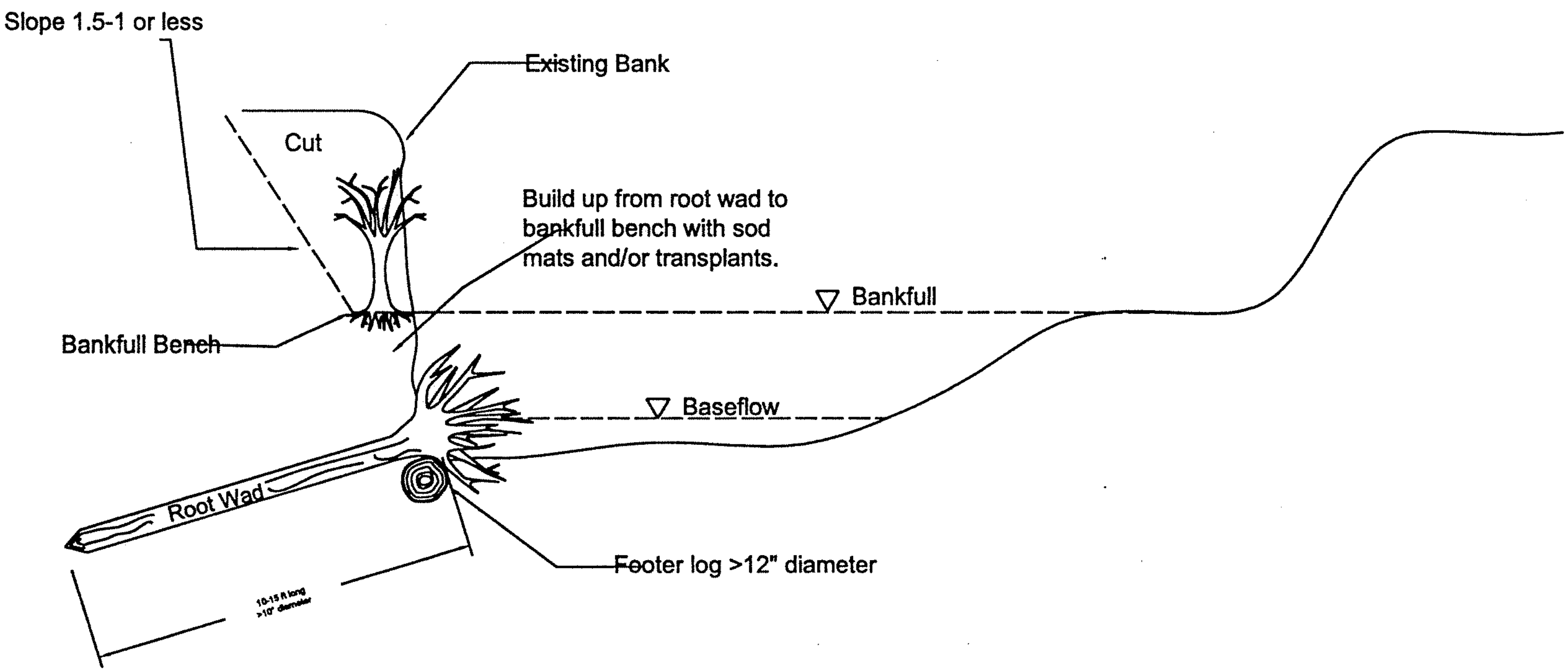
Typical Vane Design

(Adapted from Rosgen, 1998)

Design By:
Will Harman

Drawn By:
Rachel Smith

03/29/00

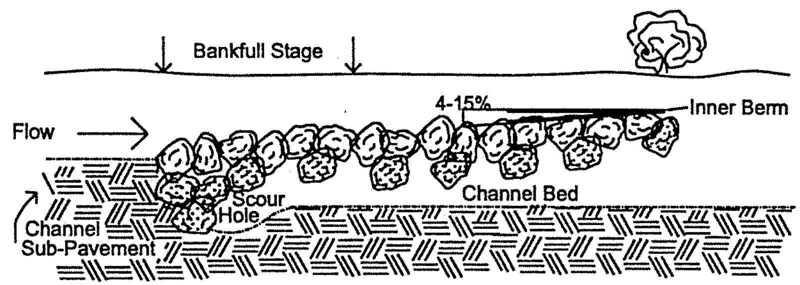


Typical Root Wad Cross Section

Design By:
Will Harman

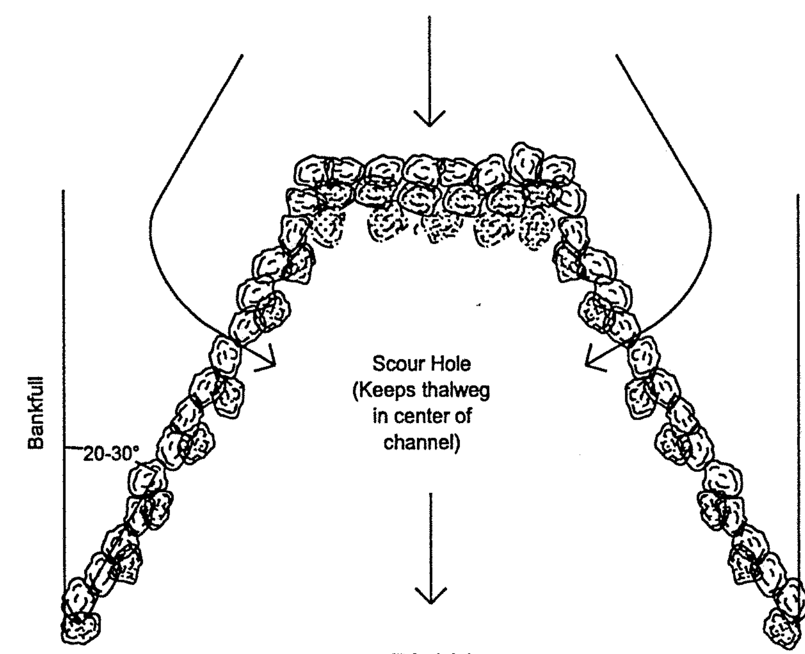
Drawn By:
Rachel Smith

03/29/00

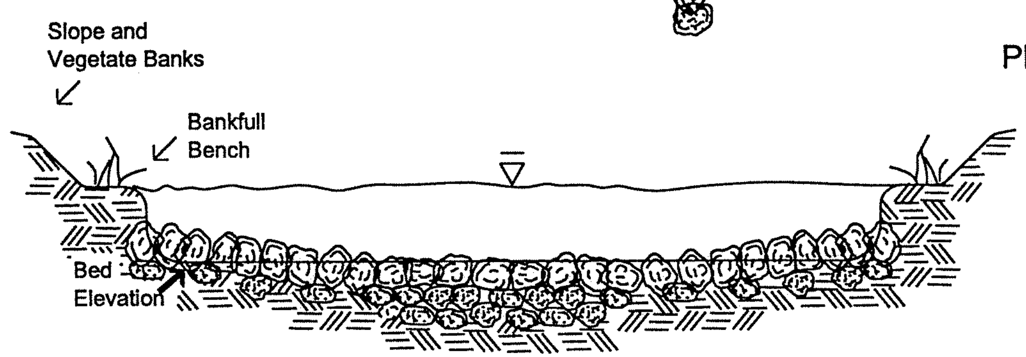


PROFILE

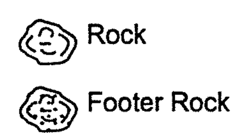
Note:
-There should be no gaps between the rocks in the cross vane.



PLAN



CROSS-SECTION



Typical Cross Vane Design

(Adapted from Rosgen, 1998)

Design By:
Will Harman

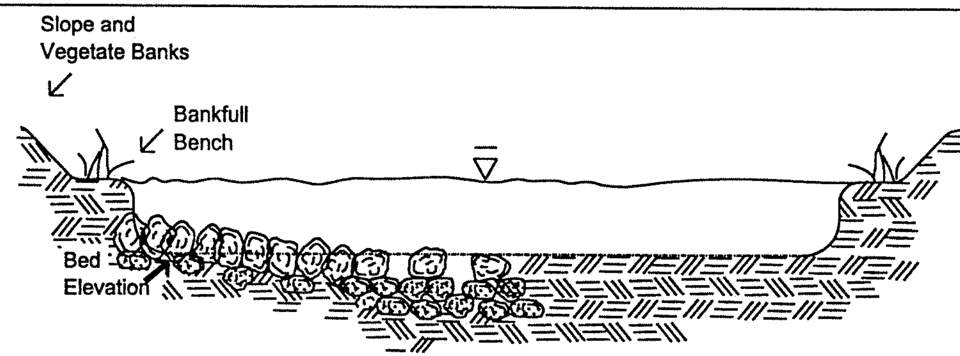
Drawn By:
Rachel Smith

03/29/00

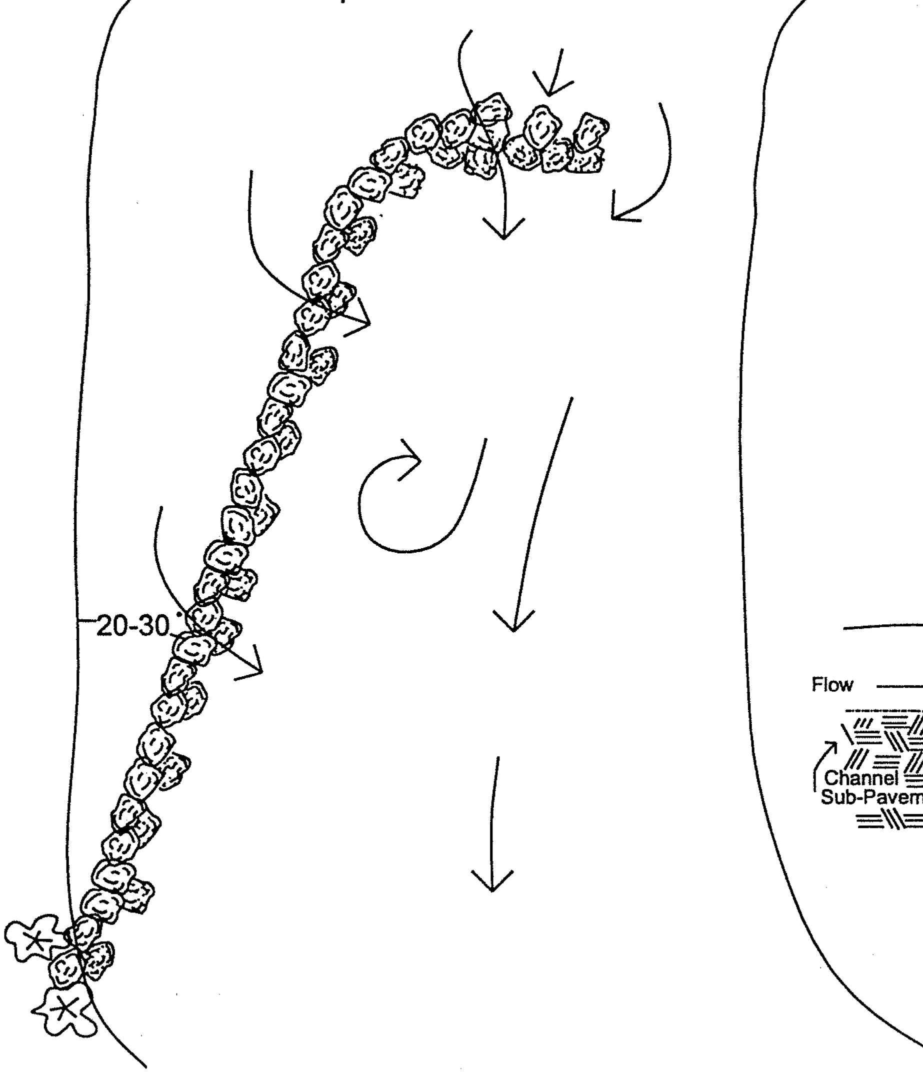
Typical "J" Hook Vane Design

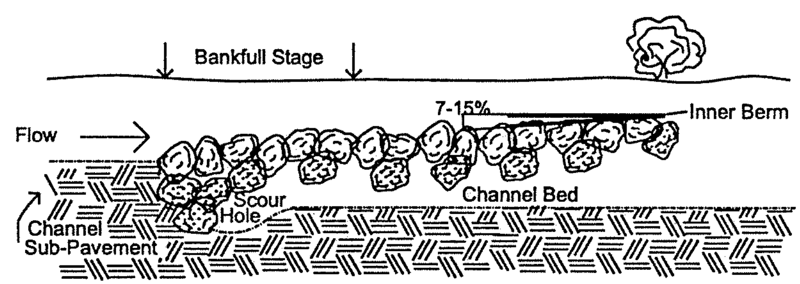
(Adapted from Rosgen, 1998)

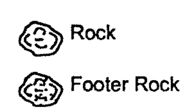
Notes:
- Rocks in vane **are not** spaced.
- Rocks in "J" section **are** spaced 1/2 rock width.



Structure spans 1/2 to 2/3 of stream width.







Design By: Will Harman

Drawn By: Rachel Smith

03/29/00

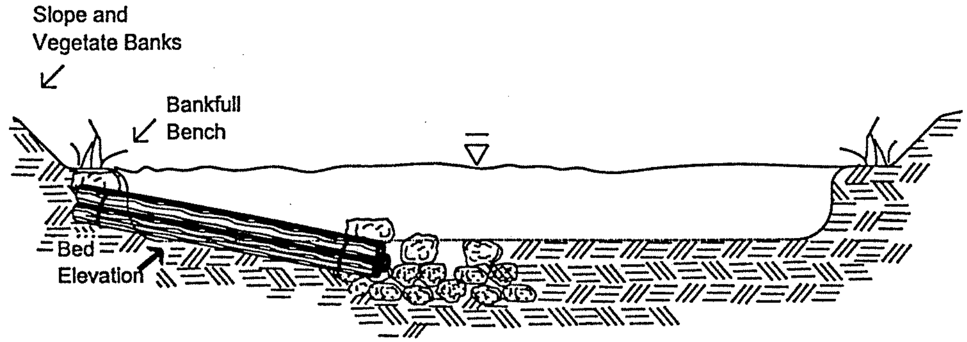
Typical Log "J" Hook Vane Design

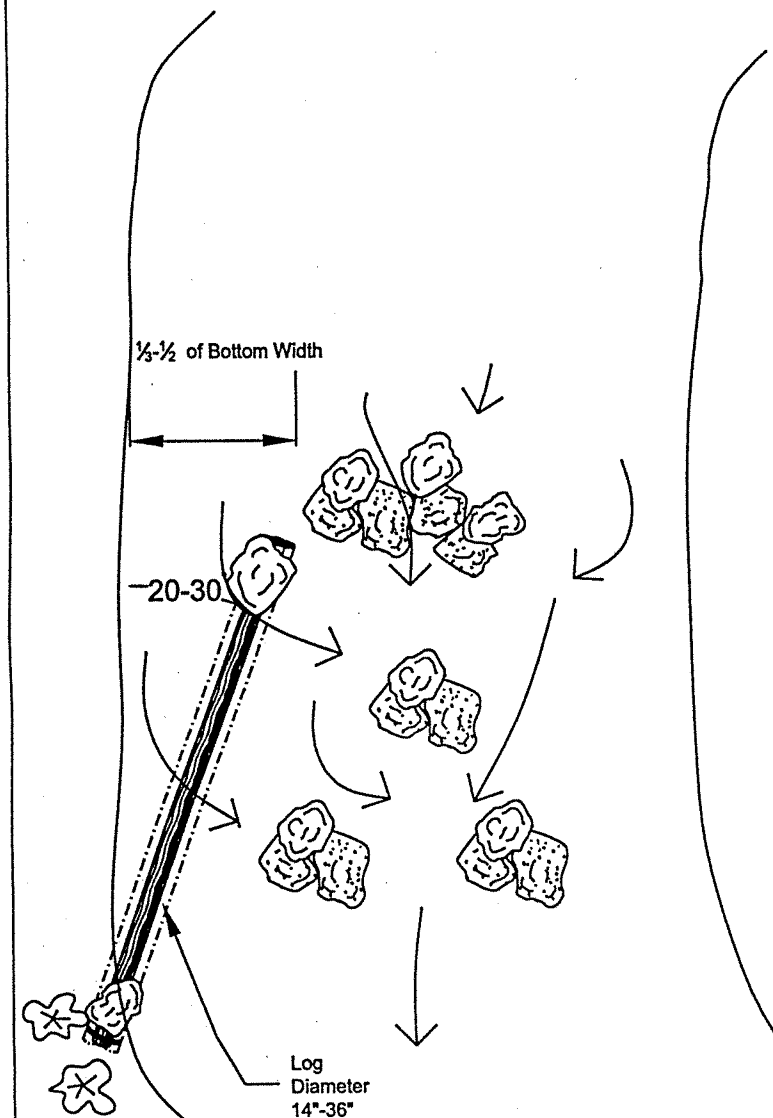
Design By:
Will Harman

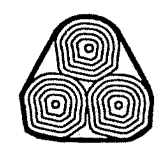
Drawn By:
Rachel Smith

04/26/00

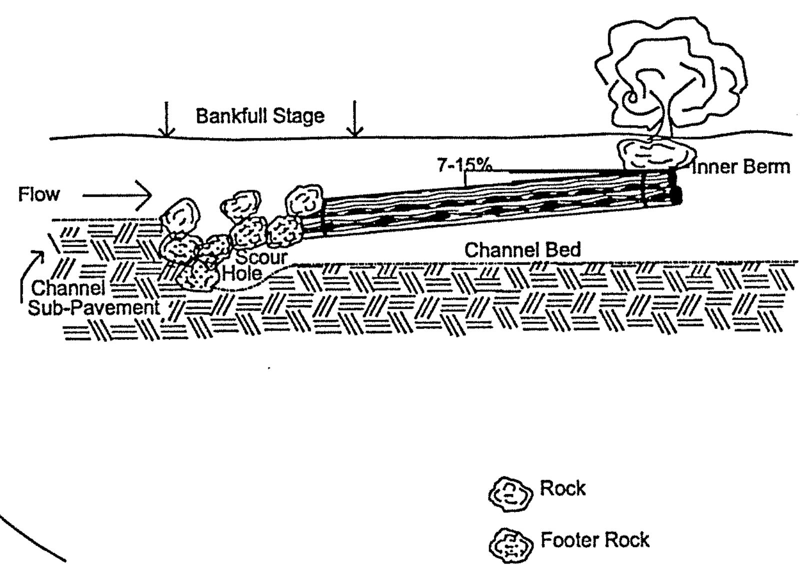
Notes:
-Rocks in "J" section are spaced ½ rock width.







For logs <24" diameter, cable 3 logs (10"-12") on ends using ½" cable. Bottom two logs should be below the stream bed.



APPENDIX 7

CONSTRUCTION SEQUENCE and SEDIMENT and EROSION CONTROL PLAN

Stone Mountain State Park
East Prong Roaring River, Stream Restoration Project
Wilkes County, North Carolina

Construction Sequence

The construction sequence for the stream restoration project on the East Prong Roaring River in Stone Mountain State Park will take place in two phases. The first phase includes Reaches 1 and 2 and the second phase includes Reaches 3 and 4 (Figure 2). Construction activities include the following sequence. North Carolina State University, Water Quality Group (NCSU) staff will provide onsite construction management and layout.

Phase 1 -- Reaches 1 and 2

1. Use the group camping parking lot for all staging activities related to Phase 1. The General Contractor (GC) is required to properly and safely identify and secure the parking lot and stream as a construction site. Park staff will close the parking lot from the public. Prior to construction activities, the GC shall identify and mark boundaries of the staging area as directed by NCSU staff. Acceptable materials for identifying the staging area include highly visible tape, silt fence, or orange boundary fencing.
2. Stockpile all construction materials, including rock boulders, root wads, riprap, gravel, erosion control devices, etc. in the group camp staging area. Any soil materials that are stockpiled shall have a silt fence properly installed to ensure materials are contained. Silt fence installation specifications are provided in Appendix 7.
3. Park all construction equipment, including trucks, trailers, and heavy equipment in the group camp staging area.
4. To limit the disturbance of soils on site, the GC shall restrict the movement of all construction equipment within the sensitive areas. Prior to construction activities, the GC shall identify the boundaries of all sensitive areas by using a highly visible tape, silt fencing, or orange boundary fencing, and will stake the limits of where construction equipment is permitted to travel, as directed by NCSU staff.
5. Access Reach 1 using the existing stream crossing, located on Figure 6. Equipment will only access the stream when absolutely necessary and when other options are more destructive.
6. For Reach 1, equipment will cross the stream and then re-enter the stream upstream of the footbridge. Install a new stream crossing on the left bank only (looking downstream) per the specifications outlined in Appendix 7. The location of the access is shown in Figure 6.
7. For the portion of Reach 2 below the footbridge, a short access road will be constructed as shown in Figure 7. The road will be extended slightly passed the

new channel and used as a stock piling area for material excavated from the new channel.

8. The GC will work in Reach 1 and 2 simultaneously.
9. Working in the stream, install log vanes, boulder clusters, and the cross vane (see #10) in Reach 1 and Reach 2 (above footbridge) as shown on Figures 6 and 7 and Appendix 6. Equipment is not allowed to remove streamside vegetation while installing the structures.
10. Install rock cross vane and grade the streambanks in the tributary, as shown in Figure 6 and Appendix 6, before installing cross vane in main channel above bridge.
11. Once Reach 1 is completed, re-grade the access road upstream of the footbridge and existing crossing to match the adjacent streambank. Seed and straw all disturbed areas as specified in Appendix 7.
12. Begin clearing trees in the new channel for Reach 2. The new channel will be accessed from the parking lot as shown in Figure 7. Trees will be pushed down, rather than cut, in order to keep the root mass intact with the trunk. The trunk will be cut at 15 ft from the ball (or length specified by NCSU), sharpened to a point and stockpiled on the edge of the bank. The trees will be used later as root wads and vanes.
13. Brush created from downed trees will be spread by hand on the adjacent floodplain or buried in the abandoned channel away from stream crossings, e.g. away from plugs. NCSU and Park staff will provide direction during construction.
14. Sod mats, shrubs, and trees less than 3" in diameter will be saved for transplanting (using a loader) and stockpiled at the top of the bank. Plants that are to be transplanted will be marked with highly visible tape.
15. The entire new channel will be cleared. The new channel will be used as the construction road for heavy equipment and materials.
16. Build a stream crossing where the new channel crosses the existing channel following the specifications in Appendix 7. Do not dam the existing channel. All moving water should remain in the existing channel until the new channel is completely finished. This includes structures, transplants and seeding.
17. Excavate the new channel, starting at the downstream end and working upstream, per the specifications in Figures 7 and Appendix 7. Stockpile bed material (everything below sod mat to the thalweg depth) in the stockpile areas shown on Figure 7. The stockpiles must be placed above the top of bank, on the valley floor. DO NOT excavate laterally beyond the top of the streambank.
18. Install instream structures as shown in Figure 7 and Appendix 6, starting downstream and working upstream. Use boulders stockpiled in staging area and along the edge of the existing channel. Use existing boulders (those along existing streambank) for downstream portion and those in staging area for the upstream portion.
19. As a structure is completed, finish grading the streambed and replace sod mats and transplants as directed by NCSU.
20. Once one-half of a meander wavelength has been completed, seed and straw all disturbed downstream areas as specified in Appendix 7. Continue until the new channel has been completed.

21. Once the new channel has been completely constructed and stabilized, install the upstream root wad diversion as shown in Appendix 6. Use the soil/sediment from the upstream most stockpile to fill behind the root wads.
22. Repeat step 20 at the next two crossings.
23. Once the water is diverted from the old channel to the new channel, several crews with backpack electrofishing units and buckets will walk the old channel collecting as many fish as possible and transferring them to the new channel. In order to do this rather quickly, several backpack electrofishing crews should be present. Each crew needs at least 5 people, 1 to run the electrofishing unit, two dip netters, and two carrying buckets. It would be best to have at least 4-5 electrofishing units, which will be supplied by the Wildlife Resources Commission. DWQ should have some also. Staff support will come from State Parks, NCSU, WRC and volunteers. With 5 shockers there should be 25 folks present to do the work. If fish have to be hauled a considerable distance (too far for people to run from point A to point B with a bucket of water and fish in 5 minutes or less), WRC will provide a small, portable stocking tank carried on the back of a pick-up truck.
24. Fill the existing channel with material from stockpiles and ponds. Compact with track hoe, track loader, or bulldozer.

Reach 2 Ponds and Tributary Construction

25. After the stream in Reach 2 has been turned into the newly constructed channel, construction of two floodplain ponds downstream of the Phase I staging area will begin.
26. Create a temporary grass swale, reinforced with BN 125 erosion control matting for tributary flow. The swale will direct flow from the tributary into the new channel and around the area to be disturbed during construction of the ponds. Cut material will be stockpiled along the downstream side of the swale and used to fill the swale once construction of the ponds and new tributary channel are completed.
27. Construct the downstream pond. Cut material from the pond excavation will be used to fill in the old channel between the pond and the new channel.
28. After the downstream pond is completed, a small tributary channel will be constructed to carry flow from the pond to the Roaring River. Natural channel design concepts will be used to design this stream channel, and grade control structures will be used to prevent downcutting of the stream.
29. Construct the upstream pond. Cut material from the pond excavation will be used to fill the remaining areas of old channel.
30. A small channel will be constructed to carry flow from the upstream pond to the downstream pond.
31. The tributary upstream of the ponds will be restored to a natural meandering pattern and connected with the upstream pond.
32. Flow from the tributary will be turned into the new tributary channel and the temporary swale will be backfilled, seeded, and covered with straw.

33. Sod mats and transplants will be used to stabilize tributary streambanks. All disturbed areas will receive seed and straw as specified in Appendix 7.
34. Once construction is completed in Reaches 1 and 2, all construction equipment and materials should be moved to the horse trailer parking lot. Any damages made to the group camping parking lot will be repaired. The parking lot should be in the same condition as when the project started.

Phase 2 – Reaches 3 and 4

35. The Horse Trailer parking lot (shown in Figure 8) will be used for all staging activities related to Phase 2. The General Contractor (GC) is required to properly identify and secure the parking lot as a construction site. Materials such as highly visible tape, orange boundary fencing and/or silt fencing will be used to mark off the staging area.
36. Another staging area will be established at the road pulloff as shown in Figure 9. This staging area will be used to unload rock boulders delivered by dump trucks. These boulders will be used for the instream structures downstream of this staging area. The purpose of this staging area is to minimize the impact of the new channel and upstream wetland area by decreasing equipment traffic. This staging area will not be used to store equipment or other materials.
37. Prior to construction activities, the GC shall identify and mark the boundaries of the staging areas, as directed by NCSU staff. All construction materials, including rock boulders, root wads, riprap, gravel, erosion control devices, etc. should be stock piled in the horse parking lot staging area. Any soil materials that are stockpiled shall have a silt fence properly installed to ensure the materials are contained.
38. All construction equipment, including trucks, trailers, and heavy equipment will be parked in the staging area.
39. Begin clearing trees in the new channel for Reach 4. Trees will be pushed down, rather than cut, in order to keep the root mass intact with the trunk. The trunk will be cut at 15 ft from the ball (or length specified by NCSU), sharpened to a point and stockpiled on the edge of the bank. The trees will be used later as root wads and vanes.
40. Brush created from downed trees will be spread by hand on the adjacent floodplain or buried in the abandoned channel away from stream crossings, e.g. away from plugs. NCSU and Park staff will provide direction during construction.
41. Sod mats, shrubs, and trees less than 3" in diameter will be saved for transplanting (using a loader) and stockpiled at the top of the bank.
42. The entire new channel will be cleared. The new channel will be used as the construction road for heavy equipment and materials.
43. Build a stream crossing where the new channel crosses the existing channel following the specifications in Appendix 7. Do not dam the existing channel. All moving water should remain in the existing channel until the new channel is completely finished. This includes structures, transplants and seeding.
44. At this point, construction can begin simultaneously in Reaches 3 and 4.

45. For Reach 3, install the log vanes and boulder clusters as shown in Appendix 6.
46. Note: The GC is not responsible for the bioengineering in Reach 3. Project staff will complete this section in Winter of 2000 using the bioengineering techniques shown in Appendix
47. For Reach 4, excavate the new channel, starting at the downstream end and working upstream, per the specifications in Figures 9. Stockpile bed material (everything below sod mat to the thalweg depth) in the stockpile areas shown on Figure 9. DO NOT excavate laterally beyond the top of the streambank.
48. Install instream structures as shown in Figures 9, starting downstream and working upstream. Use boulders stockpiled in staging area.
49. As a structure is completed, finish grading the streambed and replace sod mats and transplants as directed by NCSU.
50. Once one meander length has been completed, seed and straw all disturbed downstream areas as specified in Appendix 7. Continue until the new channel has been completed.
51. Once the new channel has been completely constructed and stabilized, install the upstream root wad diversion as shown in Figure 9. Use the soil/sediment from the upstream most stockpiles to fill behind the root wads.
52. Once the water is diverted from the old channel to the new channel, several crews with backpack electrofishing units and buckets will walk the old channel collecting as many fish as possible and transferring them to the new channel. In order to do this rather quickly, several backpack electrofishing crews should be present. Each crew needs at least 5 people, 1 to run the electrofishing unit, two dip netters, and two carrying buckets. It would be best to have at least 4-5 electrofishing units, which will be supplied by the Wildlife Resources Commission. DWQ should have some also. Staff support will come from State Parks, NCSU, WRC and volunteers. With 5 shockers there should be 25 folks present to do the work. If fish have to be hauled a considerable distance (too far for people to run from point A to point B with a bucket of water and fish in 5 minutes or less), WRC will provide a small, portable stocking tank carried on the back of a pick-up truck.
53. Repeat step 51 and 52 at the remaining crossings and new channel lengths.
54. Begin filling existing channel as shown in Figure 9.

Reach 4 Wetland and Pond Construction, Tributary Restoration

55. Prior to construction and excavation of the large wetland area in Reach 4, NCSU personnel will identify specimen trees, and tree protection fences will be installed. These trees will not be disturbed during construction.
56. Grade stakes will be placed by NCSU personnel and used to mark the locations and depths for excavation of material on the floodplain.
57. Any shrubs or woody vegetation located in areas for excavation and suitable for transplanting will be removed and stockpiled, to be replanted later. Remove larger trees by pushing them down, rather than cutting, in order to keep the root mass

intact with the trunk. These trees will be stockpiled and used for instream structures (root wads, log vanes, etc.).

58. Begin excavation of material from the floodplain in both the wetland and pond areas. Material excavated from the wetland area will be used to fill the abandoned stream channel in the upper part of Reach 4. Material excavated from the pond will be used to fill the abandoned stream channel in the lower part of Reach 4.
59. Once excavation of the pond has been completed, begin cutting new stream channel to carry flow from the pond to the Roaring River. Install grade control structures, then sod mats and transplants to stabilize banks.
60. Cut new stream channel to connect existing tributary stream with the pond. Install grade control structures, then sod mats and transplants to stabilize banks before turning water into the new tributary channel.
61. Turn water into new tributary/pond system by installing earthen plug and root wads. Backfill the abandoned tributary channel.
62. Plant transplants and nursery stock in the wetland area, and around the newly created pond fringe.
63. Begin restoration of two tributary streams near the middle of Reach 4 by clearing paths for new stream channels.
64. Cut new stream channels for tributaries, beginning at the Roaring River and working upstream.
65. Install instream structures, sod mats, and transplants before turning water into the new channels.
66. Turn water into the new channels using earthen plugs and root wads. Fill the abandoned stream channels.
67. Begin excavation of pond at the end of Reach 4. Material excavated from the pond area will be used to fill the abandoned stream channel in the lower part of Reach 4.
68. Once excavation of the pond has been completed, begin cutting new stream channel to carry flow from the pond to the Roaring River. Install grade control structures, then sod mats and transplants to stabilize banks.
69. Seed and straw will be spread on all disturbed areas as specified in Appendix 7.
70. Once construction is completed in Reaches 3 and 4, all construction equipment and materials should be moved to the horse trailer parking lot. Any damages made to the group camping parking lot will be repaired. The parking lot should be in the same condition as when the project started.

Temporary Seeding Specifications

Temporary seeding will be used on all areas disturbed by construction activities, including, but not limited to stream banks, access areas, and stockpile areas. Seeding will take place immediately after construction activities are completed onsite. The work shall consist of preparing the area, furnishing and placing seed, mulch, fertilizer, soil amendments, and anchoring mulch in the designated areas as specified.

Seedbed Preparation

On sites where equipment can be operated safely, the seedbed shall be adequately loosened. Disking may be needed in areas where soil is compacted. Steep banks my require roughening, either by hand scarifying or by equipment, depending on site conditions. NCSU personnel will determine condition needs onsite. If seeding is done immediately following construction, seedbed preparation may not be required except on compacted, polished or freshly cut areas.

Fertilizing/Liming

Fertilizer and lime shall be evenly distributed over the area to be seeded. Fertilizer and lime shall be uniformly mixed into the top 3 inches of soil. If site conditions are gravelly or cobbled, not incorporation is required. Fertilizer and lime shall be applied at the following rates:

10-10-10 Fertilizer	10 lbs per 1,000 sq ft
Lime	50 lbs per 1,000 sq ft

Seeding

Temporary seeding shall be used where needed for erosion control, when permanent vegetation cannot be established due to planting season, and where temporary ground cover is needed to allow native or woody vegetation to become established. Apply the following vegetation at the listed rates.

Rye grain	1 lb per 1,000 sq ft
Browntop Millet	1 lb per 1,000 sq ft

Mulching

Mulching should be performed within 48 hours of seeding. Grain straw mulch should be applied on seeded areas at a rate of 3 bales per 1,000 sq ft. Apply mulch uniformly. Anchor with appropriate biodegradable netting.

Woody Vegetation Planting Specifications

Woody vegetation, including live stakes, transplants, and bare root vegetation shall be used in all areas designated as "Floodplain Restoration Area". The work covered in this section consists of furnishing, installing, maintaining, and replacing vegetation as shown in the plans or in locations as directed by NCSU personnel.

Live Staking

Live stake materials should be dormant and gathered locally or purchased from a reputable commercial supplier. Stakes should by ½ to 2 inches in diameter and living based on the presence of young buds and green bark. Stakes shall be angle on the bottom and cut flush on the top with buds oriented upwards. All side branches shall be cleanly trimmed so the cutting is one single stem. Stakes should be kept cool and moist to improve survival and to maintain dormancy.

Live staking plant material shall consist of a random assortment of materials selected from the following:

Silky Dogwood	(*Cornus amomum*)
Black willow	(*Salix nigra*)
Elderberry	(*Sambucus canadensis*)

Other species may be substituted upon approval of NCSU personnel.

Planting shall take place in late fall. Stakes should be installed randomly 2 to 3 feet apart using triangular spacing or at a density of 160 to 360 stakes per 1,000 sq ft along the stream banks above bankfull elevation. Site variations may require slightly different spacing. Stakes shall be driven into the ground using a rubber hammer or by creating a hole and slipping the stake into it. The stakes should be tamped in at a right angle to the slope with 4/5 of the stake installed below the ground surface. At least two buds (lateral and/or terminal) shall remain above the ground surface. The soils shall be firmly packed around the hole after installations. Split stakes shall not be installed. Stakes that split during installations shall be replaced.

Bare Root Vegetation

Bare root vegetation to be planted along both sides of the new channel stream banks above bankfull elevation and in the floodplain restoration area shall consist of a random assortment of tree species including, but not limited to the following:

Common Name	Scientific Name
Sycamore	*Platanus occidentalis*
Black walnut	*Juglans nigra*
Black cherry	*Prunus serotina*
Silverbell	*Halesia carolina*

Persimmon	*Diospyros virginiana*
Blackgum	*Nyssa sylvatica*
Witch-hazel	*Hamamelis virginiana*
Spicebush	*Lindera benzoin*
Tag alder	*Alnus serrulata*

Planting shall take place in late fall. Immediately following delivery to the project site, all plants with bare roots, if not promptly planted, shall be heeled-in in constantly moist soil or sawdust in an acceptable manner corresponding to generally accepted horticultural practices.

While plants with bare roots are being transported to and from heeling-in beds, or are being distributed in planting beds, or are awaiting planting after distribution, the contractor shall protect the plants from drying out by means of wet canvas, burlap, or straw, or by other means acceptable to NCSU personnel and appropriate to weather conditions and the length of time the roots will remain out of the ground.

(800)

Soil in the area of shrub and tree plantings shall be loosened to a depth of at least 5 inches. This is necessary only on compacted soil. Bare root vegetation may be planted in hole made by a mattock, dibble, planting bar, or other means approved by NCSU personnel. Rootstock shall be planted in a vertical position with the root collar approximately ½ inch below the soil surface. The planting trench or hole shall be deep and wide enough to permit the roots to spread out and down without J-rooting. The plant stem shall remain upright. Soil shall be replaced around the transplanted vegetation and tamped around the shrub or tree firmly to eliminate air pockets.

$\frac{20}{1,000} = \frac{x}{43,560}$

The following spacing guidelines of rooted shrubs and trees are provided in the following table.

Type	Spacing	# Per 1,000 sq ft
Shrubs (<10 ft tall)	3 to 6 ft	25 to 110
Shrubs and trees (10-25 ft)	6 to 8 ft	15 to 25
Trees (>25 ft tall)	8 to 15 ft	4 to 15

Shrub and Tree Transplants

Shrub and trees less than 3 inches in diameter shall be salvaged onsite in areas designated for construction, access areas, and other sites that will necessarily be disturbed. Vegetation to be transplanted will be identified by NCSU personnel. Transplanted vegetation shall carefully be excavated with rootballs and surrounding soil remaining intact. Care shall be given not to rip limbs or bark from the shrub and tree transplants. Vegetation should be transplanted immediately, if possible. Otherwise, transplanted vegetation shall be stored in designated stockpile areas until replanted. The rootballs of transplanted stock shall adequately be protected by a soil or sawdust covering that is kept moist constantly in an acceptable manner appropriate to weather or seasonal conditions. The solidity of the plants shall be carefully preserved.

Installation of shrub and tree transplants shall be located in designated areas along the stream bank above bankfull elevation or in floodplain restoration areas as directed by NCSU personnel. Soil in the area of vegetation transplants shall be loosened to a depth of at least 1 foot. This is only necessary on compacted soil. Transplants shall be replanted to the same depth as they were originally growing. The planting trench or hole shall be deep and wide enough to permit the roots to spread out and down without J-rooting. The plant stem shall remain upright. Soil shall be replaced around the transplanted vegetation and tamped around the shrub or tree firmly to eliminate air pockets.

Spacing of vegetation transplants will be determined onsite by NCSU personnel.

Permanent Seeding Specifications

Permanent seeding will be used in combination with woody plantings on the up-slope side of the riparian areas and down to the bankfull elevation in Reaches 2 and 4. Permanent seeding will occur in conjunction with temporary seeding where applicable. This mixture will also be used in any terrestrial (areas not inundated) riparian area that has been disturbed by construction, is designated as wetland and/or riparian enhancement, or as directed by NCSU personnel. This mixture shall be planted **in late fall** in combination with the temporary seeding operation and woody plant installations. Seeding should be done evenly over the area using a mechanical or hand seeder. A drag should be used to cover the seed with no more than ½ inch of soils. Where a drag cannot safely be utilized, the seed should be covered by hand raking.

Seedbed Preparation

On sites where equipment can be operated safely, the seedbed shall be adequately loosened. Disking may be needed in areas where soil is compacted. Steep banks may require roughening, either by hand scarifying or by equipment, depending on site conditions. NCSU personnel will determine condition needs onsite. If seeding is done immediately following construction, seedbed preparation may not be required except on compacted, polished or freshly cut areas. If permanent seeding is performed in conjunction with temporary seeding, seedbed preparation only needs to be executed once.

Fertilizing/Liming

Areas fertilized for temporary seeding shall be sufficiently fertilized for permanent seeding; additional fertilizer is not required for permanent seeding.

Seeding

A riparian seed mix at the rate of ¼ lb per 1,000 sq ft or 10 lbs per acre shall be used for seeding. The following table lists herbaceous, permanent seed mixture labeled "riparian seed mix"

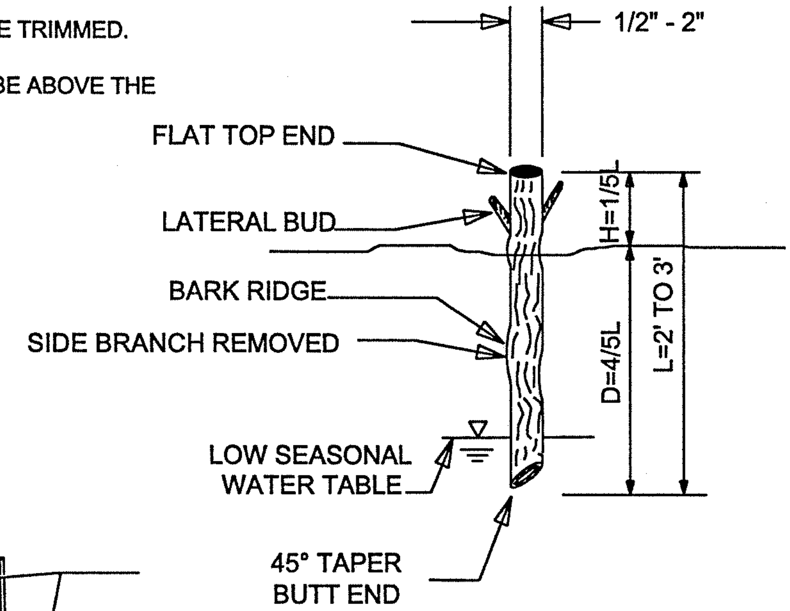
Common Name	Scientific Name	%
Rice Cut Grass	*Leersia oryzoides*	10
Soft Rush	*Juncus effusus*	10
Deertongue	*Panicum clandestinum*	10
Switchgrass	*Panicum virgatum*	5
Jack-in-the-Pulpit	*Arisaema triphyllum*	5
Ironweed	*Vernonia noveboracensis*	5
Three-square Bulrush	*Scirpus americanus*	5
Woolgrass	*Scirpus cyperinus*	5
Virginia Wildrye	*Elymus virginicus*	5
Sensitive Fern	*Onoclea sensibilis*	5

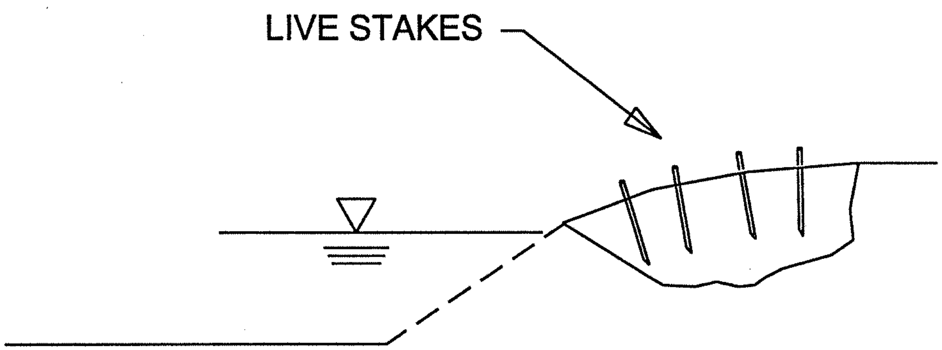
Hop Sedge	*Carex lupilina*	5
Fox Sedge	*Carex vulpinoidea*	5
Swamp Sunflower	*Helianthus angustifolius*	5
Joe Pye Weed	*Eupatorium fistulosum*	5
Cinnamon Fern	*Osmunda cinnamomea*	5
Cardinal Flower	*Lobelia cardinalis*	5
Witch-hazel	*Hamamelis virginiana*	5

NOTES:

1. ALL LATERAL BRANCHES SHALL BE TRIMMED.

2. A MINIMUM OF TWO BUDS SHALL BE ABOVE THE PLANTING DEPTH.





INSTALLING LIVE STAKES:

A.) PRIOR TO INSTALLATION OF LIVE STAKES, THE STREAM BANK SHOULD BE FERTILIZED, LIMED AND SEEDED.

B.) LIVE STAKING PLANT MATERIAL SHALL CONSIST OF A RANDOM ASSORTMENT OF MATERIALS SELECTED FROM THE FOLLOWING: SILKY DOGWOOD (CORNUS AMOMUM), BLACK WILLOW (SALIX NIGRA) AND AMERICAN ELDERBERRY (SAMBUCUS CANADENSIS). OTHER SPECIES MAY BE SUBSTITUTED UPON APPROVAL OF NCSU PERSONNEL.

C.) INSTALLATION SHOULD OCCUR DURING THE DORMANT SEASON i.e. LATE FALL.

D.) LIVE STAKES SHOULD BE $\frac{1}{2}$ TO 2 INCHES DIAMETER, 2 TO 3 FEET IN LENGTH, ANGLED ON THE BOTTOM AND CUT FLUSH ON THE TOP, WITH BUDS ORIENTED UPWARDS.

E.) STAKES SHOULD BE INSTALLED RANDOMLY 2 TO 3 FEET APART USING TRIANGULAR SPACING OR AT A DENSITY OF 2 TO 4 STAKES PER SQUARE YARD ALONG THE STREAM BANKS. SITE VARIATIONS MAY REQUIRE SLIGHTLY DIFFERENT SPACING. STAKES SHALL BE DRIVEN INTO THE GROUND USING A RUBBER HAMMER OR BY CREATING A HOLE AND SLIPPING THE STAKE INTO IT. THE STAKES SHALL BE TAMPED IN AT A RIGHT ANGLE TO THE SLOPE WITH 4/5 OF THE STAKE INSTALLED BELOW THE GROUND SURFACE. THE SOIL SHALL BE FIRMLY PACKED AROUND THE HOLE AFTER INSTALLATION. SPLIT STAKES SHALL NOT BE INSTALLED. STAKES THAT SPLIT DURING INSTALLATION SHALL BE REPLACED.

LIVE STAKE DETAIL

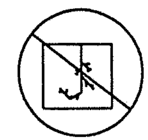
Adapted from "Guidelines for Streambank Restoration," Georgia Soil and Water Conservation Commission, 1994.

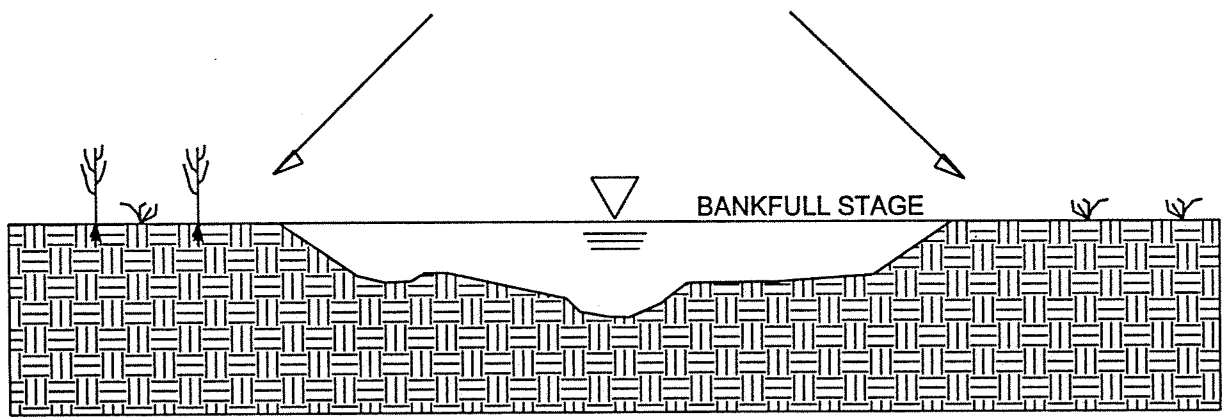
04/25/00

NOTES:

1. HOLE MUST BE LARGE ENOUGH SO THAT J-ROOTING DOES NOT OCCUR.

2. TREE BARE ROOT STOCK WILL BE PLANTED ALONG EACH SIDE OF THE STREAM ON 8 FT. CENTERS.





INSTALLATION OF BARE ROOT TREES AND SHRUBS

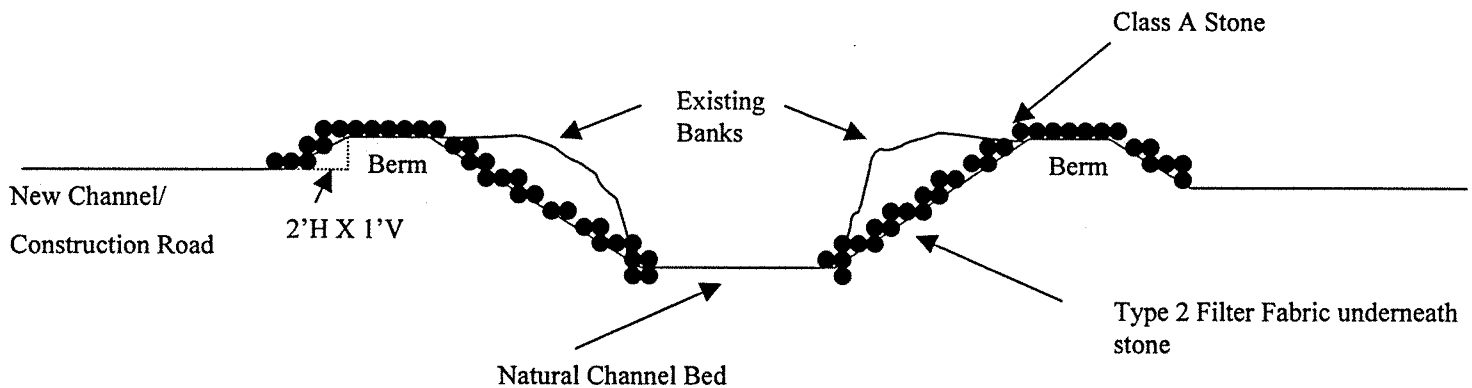
BARE ROOT SHRUBS AND TREES SHALL BE PLANTED ABOVE BANKFULL ELEVATION. SOIL IN THE AREA OF SHRUB AND TREE PLANTINGS SHALL BE LOOSENED TO A DEPTH OF AT LEAST 5 INCHES. THIS IS NECESSARY ONLY ON COMPACTED SOIL. BARE ROOT VEGETATION MAY BE PLANTED IN HOLES MADE BY A MATTOCK, DIBBLE, PLANTING BAR, OR OTHER MEANS APPROVED BY NCSU PERSONNEL. ROOTSTOCK SHALL BE PLANTED IN A VERTICAL POSITION WITH THE ROOT COLLAR APPROXIMATELY 0.5 INCHES BELOW THE SOIL SURFACE. THE PLANTING TRENCH OR HOLE SHALL BE DEEP AND WIDE ENOUGH TO PERMIT THE ROOTS TO SPREAD OUT AND DOWN WITHOUT J-ROOTING. THE PLANT STEM SHALL REMAIN UPRIGHT. SOIL SHALL BE REPLACED AROUND THE TRANSPLANTED VEGETATION AND TAMPED AROUND THE SHRUB OR TREE FIRMLY TO ELIMINATE AIR POCKETS.

BARE ROOT PLANTING DETAIL

DESIGN BY:
Karen R. Hall

04/25/00

Temporary Stream Crossing



Notes

1. Construct stream crossing when flow is low.

2. Have all necessary materials and equipment onsite before work begins

3. Minimize clearing and excavation of streambanks. Do not excavate channel bottom. Complete one side before starting another side.

4. Install stream crossing at right angle to flow.

5. Grade side slopes to a 2:1 slope. Transplant sod from original streambank onto side slopes.

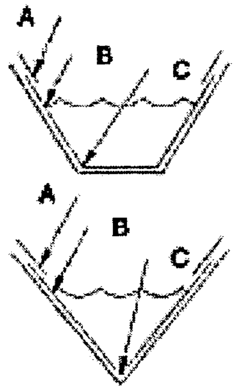
6. Maintain crossing so that runoff in the construction road does not enter existing channel.

7. A stabilized pad of Class "A" stone, 6 inches thick, lined with type 2 filter fabric shall be used over the berm and access slopes. Do not use in channel.

8. Width of the crossing shall be sufficient to accommodate the largest vehicle crossing the existing channel.

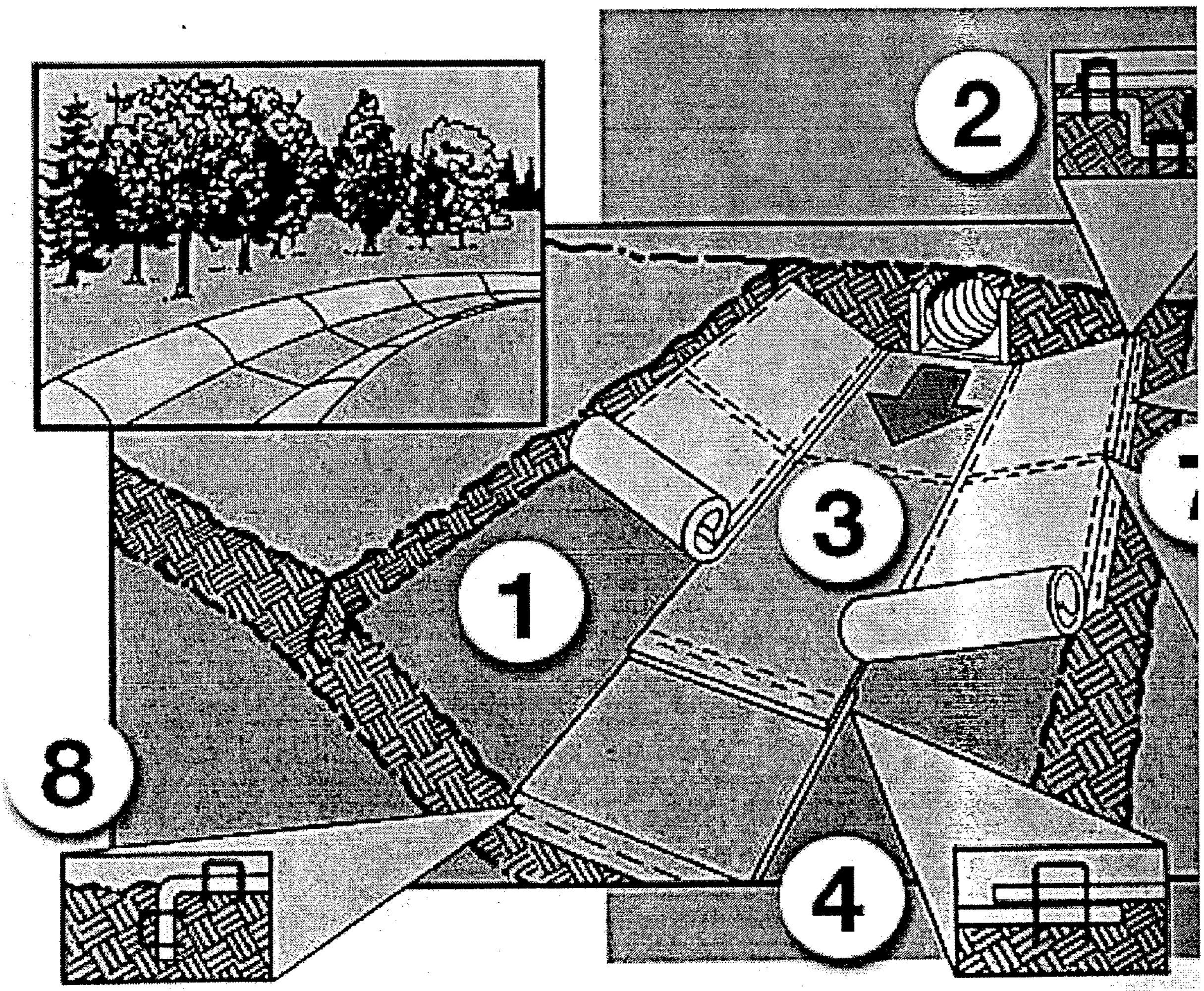
9. Contractor shall determine an appropriate ramp angle according to the equipment utilized.

EROSION CONTROL INSTALLATION (BN 125)



CRITICAL POINTS

A. OVERLAPS AND SEAMS
B. PROJECTED WATER LINE
C. CHANNEL BOTTOM/SIDE
SLOPE VERTICES



1. Prepare soil before installing blankets, including any necessary application on lime, fertilizer, and seed.

2. Begin at the toe of the streambank by anchoring the blanket in a 6" (15 cm) deep X 6" (15 cm) wide trench with approximately 12" (30 cm) of blanket extended beyond the up-slope portion of the trench. Anchor the blanket with a row of staples/stakes approximately 12" (30 cm) apart in the bottom of the trench. Backfill and compact the trench after stapling. Apply seed to compacted soil and fold remaining 12" (30 cm) portion of blanket back over seed and compacted soil. Secure blanket over compacted soil with a row of staples/stakes spaced approximately 12" (30 cm) apart across the width of the blanket.

3. Roll blanket in direction of water flow. Blankets will unroll with appropriate side against the soil surface. All blankets must be securely fastened to soil surface by placing staples/stakes in appropriate locations as shown in the staple pattern guide.

4. Place consecutive blankets end over end (shingle style) with a 4" - 6" (10 cm - 15 cm) overlap. Use a double row of staples staggered 4" (10 cm) apart and 4" (10 cm) on center to secure blankets.

5. Full length edge of blankets at top of side slopes must be anchored with a row of staples/stakes approximately 12" (30 cm) apart in a 6" (15 cm) deep X 6" (15 cm) wide trench. Backfill and compact the trench after stapling.

6. Adjacent blankets must be overlapped approximately 2" - 5" (5 cm - 12.5 cm) and stapled. To ensure proper seam alignment, place the edge of the overlapping blanket (blanket being installed on top) on the blanket being overlapped.

7. A staple check slot is required at 30 to 40 foot (9m - 12m) intervals. Use a double row of staples staggered 4" (10 cm) apart and 4" (10 cm) on center over entire width of the bank.

8. The terminal end of the blankets must be anchored with a row of staples/stakes approximately 12" (30 cm) apart in a 6" (15 cm) deep X 6" (15 cm) wide trench. Backfill and compact the trench after stapling.

notes : horizontal staple spacing should be altered if necessary to allow staples to secure the critical points along the channel surface.

in loose soil conditions, the use of staple or stake lengths greater than 6" (15 cm) may be necessary to properly anchor the blankets.

SEDIMENT FENCE (Silt Fence)

Purpose

To retain sediment from small, sloping disturbed areas by reducing the velocity of sheet flow (Figure 6.62a).

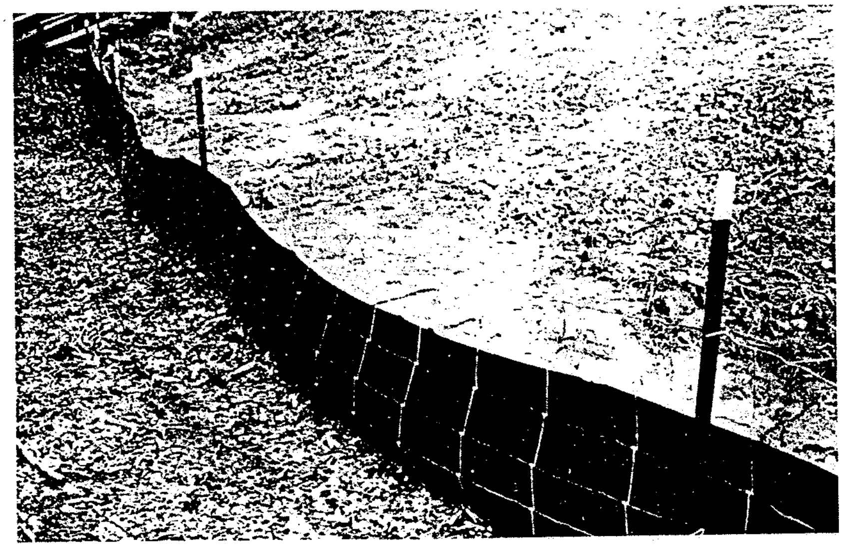


Figure 6.62a
Sediment trapped behind well supported sediment fence.

Minimum Requirements

- **Drainage area:** limited to 1/4 acre per 100 ft of fence. Area is further restricted by slope steepness as shown in Table 6.62a.

Table 6.62a
Maximum Land Slope and Distance for Which Sediment Fence Is Applicable

Land Slope (%)	Maximum Slope Distance Above Fence (ft)[1]
< 2	100
2 to 5	75
5 to 10	50
10 to 20	25
> 20	15

[1]Slope distance may be increased if design is supported by appropriate runoff calculations.

- **Location:** Fence should be nearly level and at least 10 ft from the toe of slopes to provide a broad, shallow sediment pool (Figure 6.62b).
- **Spacing of support posts:** 8 ft maximum if fence is supported by wire, 6 ft maximum for extra-strength fabric without support-wire backing.
- **Trench:** bottom 1 ft of fence must be buried 8 inches deep minimum.
- **Fence height:** depth of impounded water should not exceed 1.5 ft at any point along the fence.
- **Support posts:** 4-inch diameter pine or 1.33 lb/linear ft steel, buried or driven to depth of 18 inches. Steel posts should have projections for fastening fabric.
- **Support wire:** wire fence (14 ga with 6-inch mesh) is required to support standard-strength fabric.
- **Reinforced, stabilized outlets** (Figure 6.62c): located to limit water depth to 1.5 ft measured at lowest point along fenceline. Outlet allows safe storm flow bypass.

    Crest height—1 ft maximum
    Width of splash pad—5 ft minimum
    Length of splash pad—5 ft minimum

- **Fence fabric:** synthetic filter fabric conforming to specifications in Table 6.62b, and containing UV inhibitors and stabilizers to provide a life of 6 months minimum at temperatures from 0° to 120° F. (Burlap may be used for short periods, not exceeding 60 days.)

Table 6.62b Specifications for Sediment Fence Fabric

Physical Properties	Minimum Requirements
Filtering efficiency	85%
Tensile strength at 20% (max) elongation:	
Standard strength	30 lb/linear inch
Extra strength	50 lb/linear inch
Slurry flow rate	0.3 gpm/ft²

Installation

NOTE: Sediment fence captures sediment by backing up water to allow deposition. It is relatively ineffective for filtration because it clogs too rapidly. The sedimentation pool behind the fence is very effective and may reduce the need for expensive sediment basins and traps.

To use sediment fence effectively, provide access to the locations where sediment accumulates and provide reinforced, stabilized outlets for emergency overflow (Figure 6.62c).

Sediment fence is most effective when used in conjunction with other practices such as perimeter dikes or diversions.

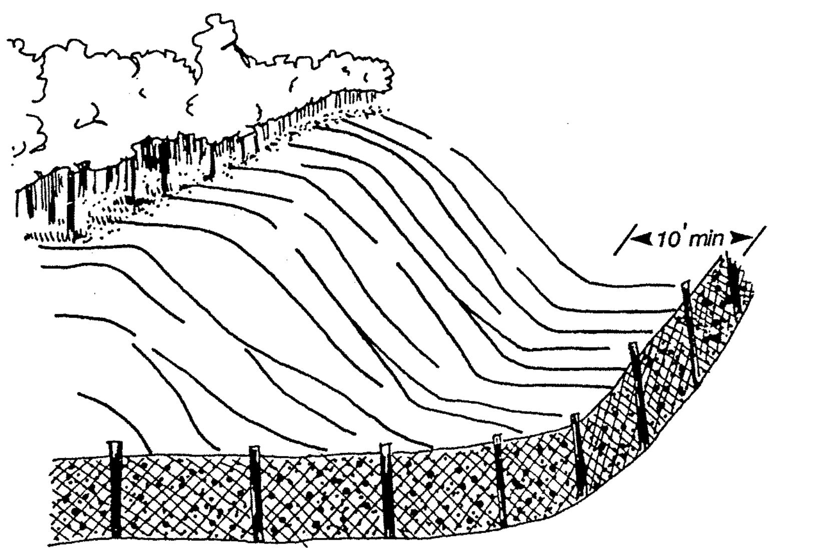
Location

Locate the fence at least 10 ft from the toe of steep slopes to provide sediment storage and access for cleanout (Figure 6.62b).

The fence line should be nearly level through most of its length to impound a broad, temporary pool. Stabilized outlets are required for bypass flow, unless fence is designed to retain all runoff from the 10-yr storm (Figure 6.62b).

The fence line may run slightly off level (grade less than 1%) if it terminates in a level section with a stabilized outlet, diversion, basin, or sediment trap. There must be no gullying along the fence or at the ends. Sediment fence should not be used as a diversion.

Figure 6.62b Level fence line with room for temporary pool.



Reinforced, Stabilized Outlets

Any outlet where storm flow bypass occurs must be stabilized against erosion.

Set outlet elevation so that water depth cannot exceed 1.5 ft at the lowest point along the fenceline (Figure 6.62c).

Set fabric height at 1 ft maximum between support posts spaced no more than 4 ft apart. Install a horizontal brace between the support posts to serve as an overflow weir and to support top of fabric. Provide a riprap splash pad as shown in Figure 6.62c.

Excavate foundation for the splash pad a minimum 5 ft wide, 1 ft deep, and 5 ft long on level grade. The finished surface of the riprap should blend with surrounding area, allowing no overfall. The area around the pad must be stable.

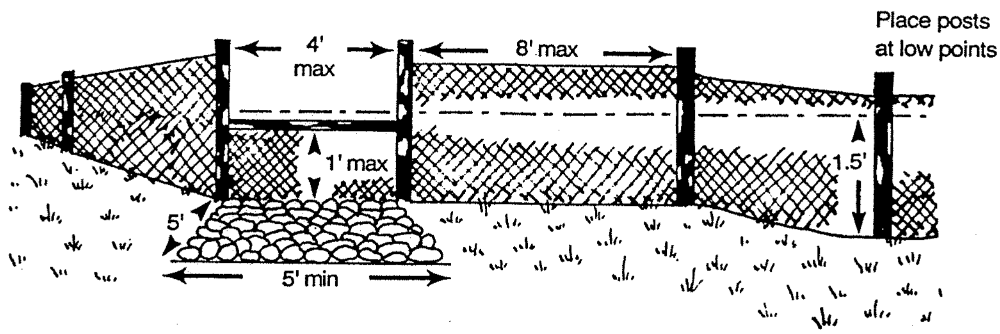


Figure 6.62c Perspective of reinforced, stabilized outlet for sediment fence.

Construction

Dig a trench approximately 8 inches deep and 4 inches wide, or a V-trench, in the line of the fence as shown in Figure 6.62d.

Drive posts securely, at least 18 inches into the ground, on the downslope side of the trench. Space posts a maximum of 8 ft if fence is supported by wire, 6 ft if extra-strength fabric is used without support wire. Adjust spacing to place posts at low points along the fenceline.

Fasten support wire fence to upslope side of posts, extending 6 inches into the trench as shown in Figure 6.62d.

Attach continuous length of fabric to upslope side of fence posts. Avoid joints, particularly at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

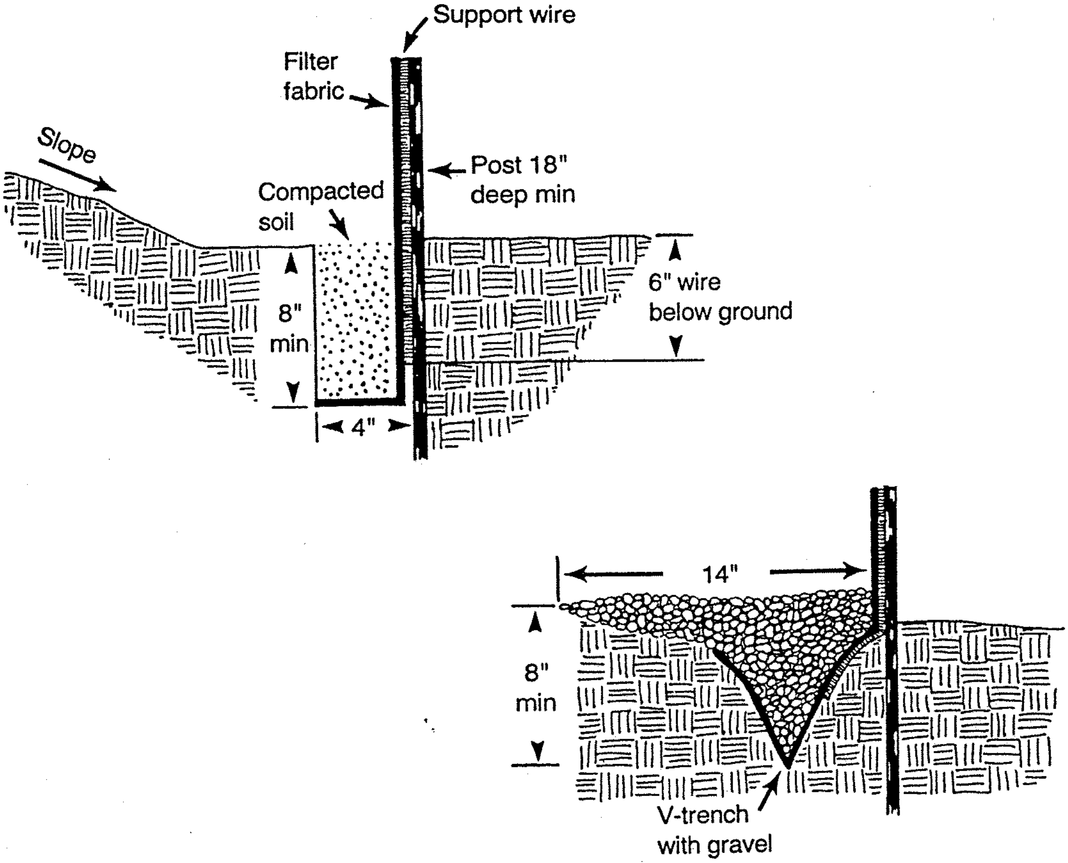


Figure 6.62d Detail of sediment fence installation.

Place the bottom 1 ft of fabric in 8-inch deep trench lapping toward the upslope side. Backfill with compacted earth or gravel as shown in Figure 6.62d.

To reduce maintenance, excavate a shallow sediment storage area on upslope side of fence where sedimentation is expected. Provide good access to deposition areas for cleanout and maintenance.

Allow for safe bypass of storm flow to prevent overtopping failure of fence.

DO NOT install sediment fence across intermittent or permanent streams, channels, or any location where concentrated flow is anticipated.

Common Trouble Points

Fence sags or collapses—common causes are:

- drainage area too large,
- too much sediment accumulation allowed before cleanout,
- approach too steep, or
- fence not adequately supported.

Fence fails from undercutting—common causes are:

- bottom of fence not buried at least 8 inches at all points,
- trench not backfilled with compacted earth or gravel,
- fence installed on excessive slope, or
- fence located across drainageway.

Fence is overtopped—common causes are:

- storage capacity inadequate, or
- no provision made for safe bypass of storm flow.
- **Do not locate fence across drainage way.**

Erosion occurs around end of fence—common causes are:

- fence terminates at elevation below the top of the temporary pool,
- fence terminates at unstabilized area, or
- fence located on excessive slope.

Maintenance

Sediment fence requires a great deal of maintenance. Inspect sediment fences periodically and after each rainfall event.

Should fabric tear, decompose, or in any way become ineffective, replace it immediately. Replace burlap at least every 60 days.

Remove sediment deposits promptly to provide adequate storage volume for the next rain and to reduce pressure on fence. Take care to avoid undermining fence during clean out.

Remove all fencing materials and unstable sediment deposits after the contributing drainage area has been properly stabilized, inspected, and approved. Bring the disturbed area to grade and stabilize as shown in the vegetation plan.

APPENDIX 8

HYDROLOGY and SEDIMENT TRANSPORT ASSESSMENT

Sediment Transport

A stable stream has the capacity to move its sediment load without aggrading or degrading. The total load of sediment can be divided into bed load and suspended load. Suspended load is normally composed of fine sands, silts and clay and transported in suspension. Bed load is transported by rolling, sliding, or hopping (saltating) along the bed. At higher discharges, some portion of the bed load can be suspended, especially if there is a sand component in the bed load.

The movement of particles depends on their physical properties, notably size, shape and density. Grain size has a direct influence on the mobility of a given particle. Critical dimensionless shear stress ($\tau *_{ci}$) is a measure of the force required to move a given size particle resting on the channel bed. It can be calculated using a surface and subsurface particle sample from a representative riffle in the reach.

$$\tau *_{ci} = 0.0834\left(\frac{d_i}{\hat{d}_{50}}\right)^{-0.872}$$

Where, $\tau*_{ci}$ = critical dimensionless shear stress
$d_i = d_{50}$ of riffle bed surface (mm)
$\hat{d}_{50}$ = subsurface d_{50} (mm)

Note: Equation applies only to gravel bed streams

Critical dimensionless shear stress can then be used in the following equation to predict the water depth required to move the largest particle found in the bar sample. The water depth is calculated by:

$$d = \frac{\tau *_{ci}\left((\rho_{sand} - \rho_{water}) / \rho_{water}\right) D_i}{S}$$

Where, d = water depth (ft)
$\tau*_{ci}$ = critical dimensionless shear stress
ρ_{sand} = denisty of sand (2.65 g/c^3)
ρ_{water} = density of water (1.0 g/c^3)
D_i = largest particle found in the point bar sample (ft)
S = average riffle slope

Note: Equation applies only to gravel bed streams

If the design mean riffle depth is significantly larger or smaller than the depth needed to move the largest particle, then the width to depth ratio may need to be adjusted up or down, respectively, to correct the depth.

Shear stress at the riffle should also be checked using Shield's Curve. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma R s$$

Where, τ = shear stress (lb/ft^2)
γ = specific gravity of water (62.4 lb/ft^3)
R = hydraulic radius (ft)
S = average riffle slope (ft/ft)

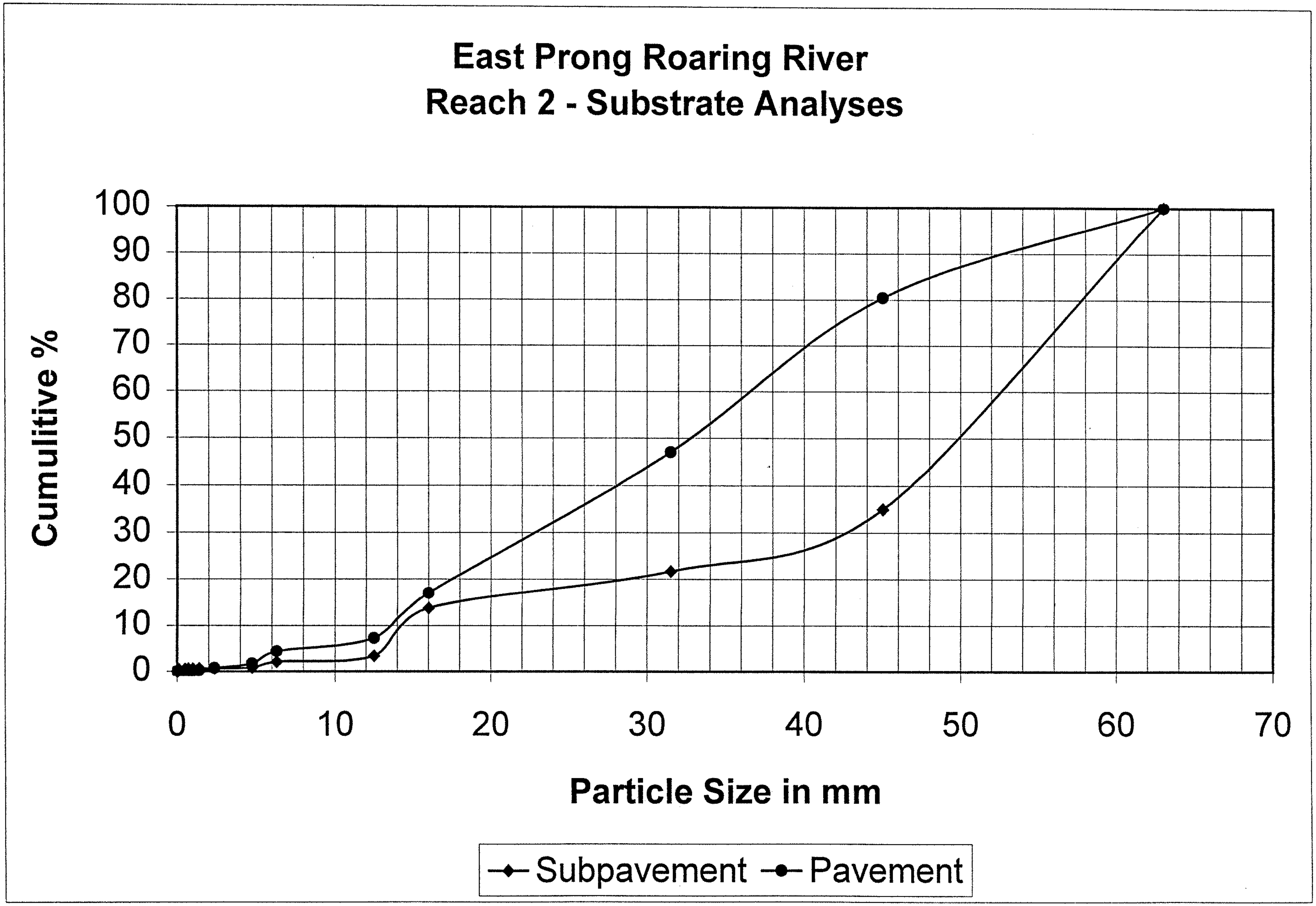
If the shear stress is determined from the Shield's diagram to move a particle size that is significantly larger or smaller than the D_{84} of the Bar or Pavement sample, then the sinuosity may need to be increased or decreased respectively, in order to decrease the average channel slope, thus reducing the shear stress.

Field Measurement Procedures:

Pavement Sample: To sample the pavement of the stream, first locate a representative riffle. Using a bottomless bucket, isolate a section of the riffle that is more depositional than the rest for sampling. Carefully remove the top veneer of the deposition within the sample area by picking the particles off the top, removing the smaller particles first. Continue removing the small and then the large particles working from one side of the sample area to the other. Measure the intermediate axis of the largest particle. Sieve the sample and then, plot the results on a cumulative frequency curve. The D_{50} and D_{84} particle for the pavement sample can then be determined from the curve.

Sub-Pavement Sample: The Sub-Pavement Sample should be collected beneath the Pavement sample. The material below the Pavement sample should be excavated and removed to a depth equal to the intermediate axis of the largest particle that was collected from the Pavement Sample. The bottomless bucket should continue to define the boundaries of the sampling area. The sample should be sieved and the cumulative frequency curve plotted from the results. The D_{50} and D_{84} particle for the Sub-Pavement sample can then be determined from the curve.

Bar Sample: A Bar Sample should be collected from the lower (downstream) third of a well-developed point bar in the stream. By scanning the lower third of the point bar, collect the largest particle from the surface of the bar and measure the intermediate axis of this particle. This length will determine the depth of excavation for the bar sample. A bottomless bucket should be placed on the lower third of the bar half way between the thalweg and the bankfull elevation. If significant bank erosion or watershed disturbance has caused sedimentation of the lower third of the bar, then the middle of the bar should be used for the sample. The depositional material within the sample area should be excavated to a depth equal to the intermediate axis of the largest particle found on the lower third of the bar. This material should be removed and sieved. The sieve results should be plotted on a cumulative frequency curve. The D_{50} and D_{84} particle for the Bar sample can then be determined from the curve.


East Prong Roaring River
Reach 2 - Substrate Analyses
Cumulitive %
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
Particle Size in mm
Subpavement
Pavement

G: L\ST .PHA \XS 32XS OUT
Input File: G:\WILL\STONE\PHASEII\XSPRO\R2XSEC1.DAT
Run Date: 04/18/00
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 04/09/00
R2XSEC 1 -- Existing Condition

Subsections/Dividing stations
C / 37.30/ A / 105.50/ B / 135.60/ @

Resistance Method: Thorne and Zevenbergen
D84: 120.000 mm

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)	
1.50	T	33.77	57.79	56.52	0.58	0.60	0.015	0.053	2.39	80.76	0.55	
1.60	T	39.44	58.41	56.97	0.68	0.69	0.015	0.051	2.72	107.41	0.63	
1.70	T	45.16	59.03	57.42	0.77	0.79	0.015	0.050	3.04	137.16	0.70	
1.80	T	50.92	59.65	57.86	0.85	0.88	0.015	0.048	3.34	169.84	0.77	
1.90	T	56.73	60.26	58.31	0.94	0.97	0.014	0.047	3.62	205.30	0.84	
2.00	T	62.58	60.88	58.76	1.03	1.07	0.014	0.047	3.89	243.40	0.91	
2.10	T	68.48	61.50	59.21	1.11	1.16	0.014	0.046	4.15	284.02	0.98	
2.20	T	74.42	62.12	59.66	1.20	1.25	0.014	0.045	4.39	327.04	1.04	
2.30	T	80.41	62.74	60.10	1.28	1.34	0.014	0.045	4.63	372.35	1.10	
2.40	T	86.44	63.36	60.55	1.36	1.43	0.014	0.044	4.86	419.84	1.16	
2.50	T	92.52	63.98	61.00	1.45	1.52	0.013	0.044	5.07	469.43	1.21	
2.60	T	98.63	64.38	61.30	1.53	1.61	0.013	0.043	5.30	522.31	1.27	
2.70	T	104.77	64.68	61.53	1.62	1.70	0.013	0.043	5.51	577.76	1.33	
2.80	T	110.93	64.99	61.76	1.71	1.80	0.013	0.042	5.73	635.16	1.38	
2.90	T	117.12	65.30	61.99	1.79	1.89	0.013	0.042	5.93	694.40	1.44	
3.00	T	123.33	65.60	62.22	1.88	1.98	0.013	0.042	6.13	755.41	1.49	
3.10	T	129.56	65.91	62.45	1.97	2.07	0.013	0.041	6.31	818.09	1.54	
3.20	T	135.82	66.21	62.68	2.05	2.17	0.012	0.041	6.50	882.35	1.59	
3.30	T	142.09	66.52	62.91	2.14	2.26	0.012	0.041	6.67	948.12	1.63	
3.40	T	148.39	66.82	63.14	2.22	2.35	0.012	0.041	6.84	1015.30	1.67	
3.50	T	154.72	67.13	63.37	2.30	2.44	0.012	0.041	7.01	1083.82	1.71	
3.60	T	161.07	67.45	63.62	2.39	2.53	0.012	0.040	7.16	1153.43	1.75	
3.70	T	167.44	67.83	63.93	2.47	2.62	0.012	0.040	7.31	1223.50	1.79	
3.80	T	173.85	68.21	64.25	2.55	2.71	0.011	0.040	7.45	1294.70	1.82	BKF
3.90	T	180.29	68.57	64.53	2.63	2.79	0.011	0.040	7.58	1367.19	1.86	
4.00	T	186.75	68.92	64.81	2.71	2.88	0.011	0.040	7.71	1440.71	1.89	
4.10	T	193.25	69.28	65.09	2.79	2.97	0.011	0.040	7.84	1515.12	1.91	
4.20	T	199.77	69.63	65.37	2.87	3.06	0.011	0.039	7.96	1590.34	1.94	
4.30	T	206.32	69.99	65.64	2.95	3.14	0.011	0.039	8.08	1666.29	1.97	
4.40	T	212.89	70.30	65.87	3.03	3.23	0.011	0.039	8.19	1743.59	1.99	
4.50	T	219.48	70.52	65.95	3.11	3.33	0.010	0.039	8.31	1823.07	2.02	
4.60	T	226.08	70.74	66.04	3.20	3.42	0.010	0.039	8.42	1902.96	2.04	
4.70	T	232.69	70.96	66.12	3.28	3.52	0.010	0.039	8.52	1983.20	2.06	
4.80	T	239.30	71.19	66.21	3.36	3.61	0.010	0.039	8.62	2063.69	2.08	
4.90	T	245.92	71.41	66.29	3.44	3.71	0.010	0.039	8.72	2144.35	2.10	
5.00	T	252.56	71.63	66.38	3.53	3.80	0.010	0.038	8.81	2225.11	2.12	
5.10	T	259.20	71.85	66.46	3.61	3.90	0.009	0.038	8.90	2305.87	2.13	
5.20	T	265.85	72.07	66.55	3.69	3.99	0.009	0.038	8.98	2386.56	2.14	
5.30	T	272.50	72.29	66.63	3.77	4.09	0.009	0.038	9.05	2467.09	2.15	
5.40	T	279.17	72.51	66.72	3.85	4.18	0.00[illegible]	0.038	9.12	2547.38	2.16	
5.50	T	[illegible]5.84	72.73	66.80	3.93	4.28	0.0[illegible]	0.038	9.19	2627.34	2.17	
5.60	T	292.53	72.95	66.89	4.01	4.37	0.009	0.038	9.25	2706.89	2.18	

[illegible]	T	299.22	73.17	66.98	4.09	4.47	0.009	0.038	9.31	2785.95		2.18
[illegible]	A	305.[illegible]	[illegible].39	67.[illegible]	[illegible]7	.56	0.0	0	[illegible]6	2864[illegible]		2.1[illegible]
5.80	B	0.10	2.04	2.03	0.05	0.05	0.008	0.216	0.08	0.01		0.03
5.80	T	306.02	75.43	69.09	4.06	4.43	0.008	0.037	9.36	2864.43		2.12
5.90	A	312.63	73.61	67.15	4.25	4.66	0.008	0.038	9.41	2942.23		2.18
5.90	B	0.41	4.10	4.08	0.10	0.10	0.008	0.142	0.20	0.08		0.05
5.90	T	313.03	77.71	71.23	4.03	4.39	0.008	0.036	9.40	2942.31		2.07
6.00	A	319.34	73.83	67.23	4.33	4.75	0.008	0.038	9.45	3019.28		2.18
6.00	B	0.92	6.16	6.13	0.15	0.15	0.008	0.111	0.34	0.31		0.07
6.00	T	320.26	79.99	73.37	4.00	4.37	0.008	0.036	9.43	3019.59		2.02
6.10	A	326.07	74.05	67.32	4.40	4.84	0.008	0.038	9.49	3095.48		2.18
6.10	B	1.63	8.23	8.19	0.20	0.20	0.008	0.093	0.48	0.79		0.10
6.10	T	327.70	82.28	75.50	3.98	4.34	0.008	0.035	9.45	3096.27		1.97
6.20	A	332.80	74.27	67.40	4.48	4.94	0.008	0.037	9.53	3170.74		2.17
6.20	B	2.55	10.29	10.24	0.25	0.25	0.008	0.081	0.64	1.63		0.12
6.20	T	335.36	84.56	77.64	3.97	4.32	0.008	0.035	9.46	3172.37		1.92
6.30	A	339.55	74.49	67.49	4.56	5.03	0.008	0.037	9.56	3244.98		2.17 ← TOB
6.30	B	3.68	12.35	12.29	0.30	0.30	0.008	0.073	0.80	2.93		0.14
6.30	C	0.18	6.28	6.22	0.03	0.03	0.008	0.078	0.16	0.03	*	0.01
6.30	T	343.41	93.12	86.00	3.69	3.99	0.008	0.033	9.46	3247.93	*	1.75
6.40	A	346.30	74.71	67.57	4.64	5.12	0.007	0.037	9.58	3318.09		2.16
6.40	B	5.01	14.53	14.46	0.34	0.35	0.007	0.067	0.94	4.73		0.16
6.40	C	1.32	15.40	15.24	0.09	0.09	0.007	0.092	0.27	0.36	*	0.04
6.40	T	352.63	104.63	97.27	3.37	3.63	0.007	0.031	9.42	3323.18	*	1.57
6.50	A	353.06	74.93	67.66	4.71	5.22	0.007	0.037	9.60	3389.97		2.15
6.50	B	6.54	16.10	15.95	0.41	0.41	0.007	0.066	1.06	6.91	*	0.19
6.50	C	2.96	17.82	17.56	0.17	0.17	0.007	0.097	0.40	1.18	*	0.08
6.50	T	362.56	108.85	101.16	3.33	3.58	0.007	0.030	9.37	3398.06	*	1.52
6.60	A	359.83	75.20	67.85	4.79	5.30	0.007	0.037	9.61	3459.26		2.14
6.60	B	8.20	17.37	17.12	0.47	0.48	0.007	0.062	1.24	10.14	*	0.21
6.60	C	4.85	21.15	20.79	0.23	0.23	0.007	0.089	0.53	2.56	*	0.10
6.60	T	372.88	113.72	105.76	3.28	3.53	0.007	0.030	9.31	3471.96	*	1.46
6.70	A	366.63	75.44	68.08	4.86	5.39	0.007	0.037	9.62	3527.79		2.12
6.70	B	9.95	18.15	17.78	0.55	0.56	0.007	0.058	1.44	14.29	*	0.24
6.70	C	7.14	25.45	24.98	0.28	0.29	0.007	0.084	0.63	4.52	*	0.12
6.70	T	383.72	119.04	110.84	3.22	3.46	0.007	0.029	9.24	3546.60	*	1.41

*******************************WINXSPRO***********************************
G:\WILL\STONE\PHASEII\XSPRO\R2XSEC1R.OUT
Input File: G:\WILL\STONE\PHASEII\XSPRO\R2XSEC1R.DAT
Run Date: 04/18/00
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 04/17/00
R2XSEC1 - Design

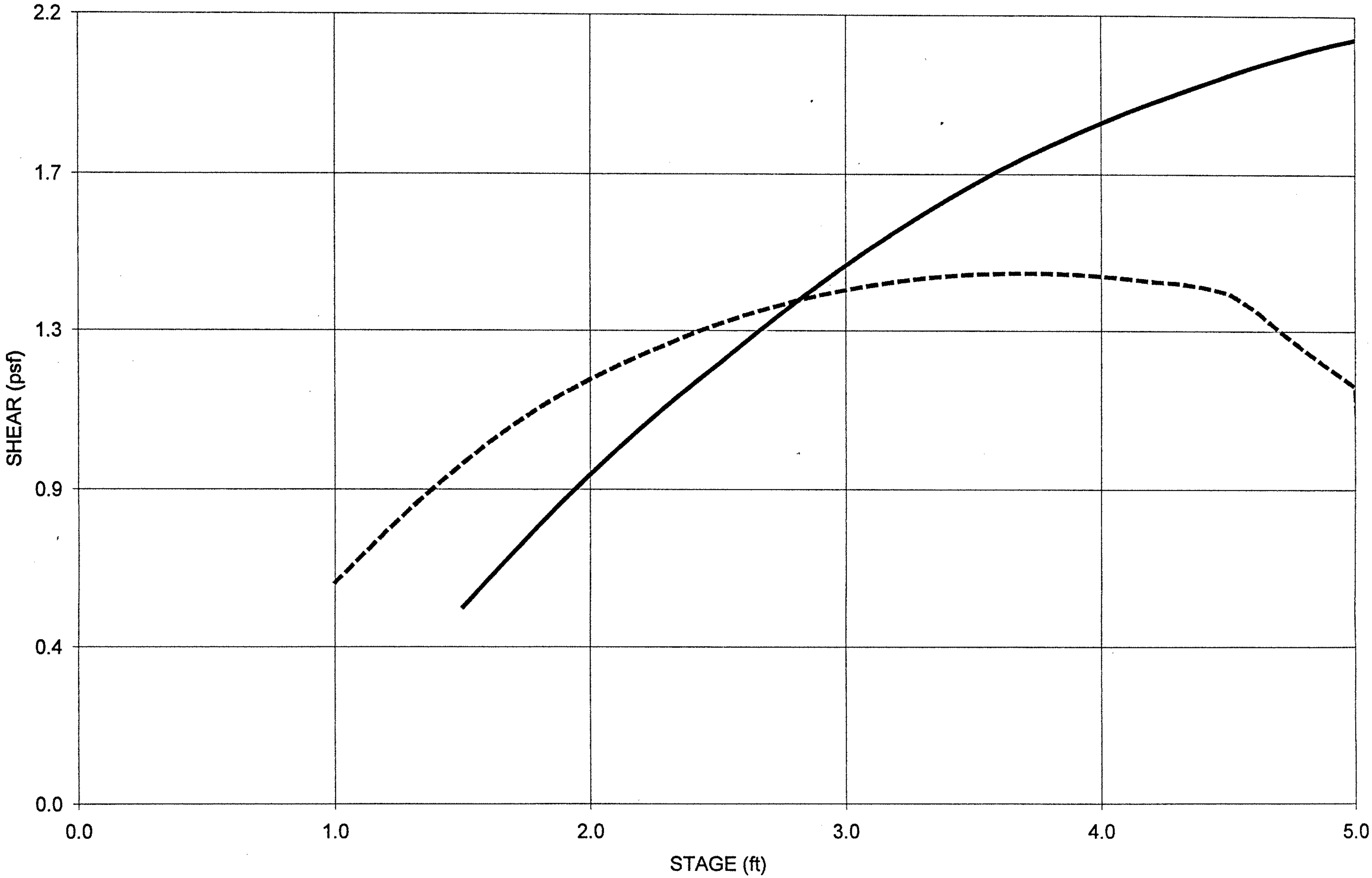
Subsections/Dividing stations
C / 30.00/ A / 105.50/ B / 135.60/ @

Resistance Method: Thorne and Zevenbergen
D84: 120.000 mm

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)	
1.00	T	23.38	35.61	35.49	0.66	0.66	0.015	0.056	2.47	57.76	0.61	
1.10	T	26.96	36.18	36.02	0.75	0.75	0.015	0.054	2.78	74.99	0.69	
1.20	T	30.59	36.74	36.55	0.83	0.84	0.015	0.052	3.08	94.08	0.76	
1.30	T	34.27	37.31	37.08	0.92	0.92	0.014	0.050	3.35	114.93	0.82	
1.40	T	38.00	37.87	37.61	1.00	1.01	0.014	0.049	3.62	137.45	0.88	
1.50	T	41.79	38.44	38.14	1.09	1.10	0.014	0.048	3.87	161.56	0.94	
1.60	T	45.63	39.01	38.67	1.17	1.18	0.014	0.047	4.10	187.19	1.00	
1.70	T	49.52	39.69	39.33	1.25	1.26	0.013	0.046	4.32	213.80	1.05	
1.80	T	53.49	40.41	40.02	1.32	1.34	0.013	0.046	4.52	241.66	1.10	
1.90	T	57.53	41.20	40.78	1.40	1.41	0.013	0.045	4.70	270.49	1.14	
2.00	T	61.65	42.05	41.60	1.47	1.48	0.013	0.045	4.87	300.34	1.17	
2.10	T	65.85	42.89	42.42	1.54	1.55	0.013	0.044	5.03	331.44	1.21	
2.20	T	70.13	43.73	43.24	1.60	1.62	0.012	0.044	5.19	363.72	1.24	
2.30	T	74.49	44.58	44.06	1.67	1.69	0.012	0.043	5.33	397.15	1.27	
2.40	T	78.93	45.33	44.78	1.74	1.76	0.012	0.043	5.48	432.29	1.30	
2.50	T	83.45	46.12	45.55	1.81	1.83	0.012	0.043	5.61	468.18	1.33	
2.60	T	88.04	46.93	46.33	1.88	1.90	0.012	0.042	5.74	504.98	1.35	
2.70	T	92.71	47.73	47.11	1.94	1.97	0.011	0.042	5.85	542.72	1.37	
2.80	T	97.46	48.54	47.88	2.01	2.04	0.011	0.042	5.97	581.36	1.39	
2.90	T	102.29	49.34	48.66	2.07	2.10	0.011	0.042	6.07	620.84	1.41	
3.00	T	107.19	50.15	49.44	2.14	2.17	0.011	0.041	6.17	661.11	1.42	
3.10	T	112.17	50.95	50.22	2.20	2.23	0.010	0.041	6.26	702.10	1.43	
3.20	T	117.23	51.76	51.00	2.27	2.30	0.010	0.041	6.34	743.77	1.44	
3.30	T	122.37	52.56	51.78	2.33	2.36	0.010	0.041	6.42	786.05	1.45	
3.40	T	127.58	53.37	52.55	2.39	2.43	0.010	0.041	6.50	828.87	1.46	
3.50	T	132.88	54.17	53.33	2.45	2.49	0.010	0.040	6.56	872.18	1.46	
3.60	T	138.25	54.98	54.11	2.51	2.55	0.009	0.040	6.63	915.89	1.47	
3.70	T	143.70	55.78	54.89	2.58	2.62	0.009	0.040	6.68	959.95	1.47	
3.80	T	149.22	56.59	55.67	2.64	2.68	0.009	0.040	6.73	1004.27	1.47	
3.90	T	154.83	57.39	56.45	2.70	2.74	0.009	0.040	6.77	1048.78	1.46	
4.00	T	160.51	58.20	57.22	2.76	2.80	0.008	0.040	6.81	1093.39	1.46	
4.10	T	166.27	59.00	58.00	2.82	2.87	0.008	0.039	6.84	1138.02	1.45	
4.20	T	172.11	59.80	58.78	2.88	2.93	0.008	0.039	6.87	1182.58	1.44	
4.30	T	178.02	60.39	59.30	2.95	3.00	0.008	0.039	6.91	1230.12	1.44	BKF
4.40	T	183.97	61.12	59.96	3.01	3.07	0.008	0.039	6.93	1274.92	1.43	
4.50	T	190.01	62.06	60.83	3.06	3.12	0.007	0.039	6.93	1316.27	1.41	
4.60	A	196.13	63.01	61.71	3.11	3.18	0.007	0.039	6.92	1357.18	1.39	
4.60	B	0.04	1.22	1.21	0.03	0.03	0.007	0.295	0.04	0.00	0.01	
4.60	T	196.17	64.23	62.92	3.05	3.12	0.007	0.038	6.92	1357.18	1.37	
4.70	A	202.35	63.95	62.58	3.16	3.23	0.007	0.039	6.91	1397.54	1.37	
4.70	B	0.26	3.28	3.26	0.08	0.08	0.00	0.162	0.14	0.04	0.03	
4.70	T	202.61	67.23	65.85	3.01	3.08	0.007	0.038	6.90	1397.58	1.31	

4.80	A	208.65	64.90	63.45	3.22	3.29	0.007	0.039	6.89	1437.24		1.35
[illegible]	B	0[illegible]	34	5	3	.13	0.0	0.	6	C		[illegible].05
4.80	T	209.34	70.24	68.77	2.98	3.04	0.007	0.037	6.87	1437.42		1.25
4.90	A	215.03	65.84	64.33	3.27	3.34	0.007	0.039	6.86	.1476.14		1.33
4.90	B	1.32	7.40	7.37	0.18	0.18	0.007	0.099	0.38	0.51		0.07
4.90	T	216.36	73.25	71.70	2.95	3.02	0.007	0.036	6.83	1476.65		1.20
5.00	A	221.51	66.79	65.20	3.32	3.40	0.006	0.038	6.84	1514.12		1.31
5.00	B	2.16	9.47	9.42	0.23	0.23	0.006	0.086	0.52	1.12		0.09
5.00	T	223.67	76.25	74.62	2.93	3.00	0.006	0.036	6.77	1515.24		1.15
5.10	A	228.07	67.73	66.08	3.37	3.45	0.006	0.038	6.80	1551.04		1.28
5.10	B	3.21	11.53	11.47	0.28	0.28	0.006	0.076	0.65	2.09		0.11
5.10	C	0.02	2.03	2.01	0.01	0.01	0.006	0.071	0.07	0.00	*	0.00
5.10	T	231.30	81.29	79.56	2.85	2.91	0.006	0.035	6.71	1553.13	*	1.08
5.20	A	234.72	68.68	66.95	3.42	3.51	0.006	0.038	6.76	1586.73		1.25
5.20	B	4.46	13.59	13.53	0.33	0.33	0.006	0.069	0.79	3.51		0.12
5.20	C	0.75	12.70	12.58	0.06	0.06	0.006	0.083	0.21	0.16	*	0.02
5.20	T	239.93	94.97	93.06	2.53	2.58	0.006	0.032	6.63	1590.40	*	0.93
5.30	A	241.46	69.79	68.00	3.46	3.55	0.006	0.038	6.70	1618.28		1.22
5.30	B	5.92	15.59	15.48	0.38	0.38	0.006	0.063	0.94	5.54	*	0.13
5.30	C	2.29	17.16	16.94	0.13	0.14	0.006	0.098	0.30	0.68	*	0.05
5.30	T	249.67	102.55	100.42	2.43	2.49	0.006	0.031	6.51	1624.50	*	0.86
5.40	A	248.35	71.68	69.83	3.46	3.56	0.005	0.038	6.59	1636.51		1.18
5.40	B	7.53	16.87	16.65	0.45	0.45	0.005	0.063	1.01	7.62	*	0.15
5.40	C	4.12	19.97	19.65	0.21	0.21	0.005	0.092	0.42	1.71	*	0.07
5.40	T	259.99	108.52	106.13	2.40	2.45	0.005	0.031	6.33	1645.84	*	0.81
5.50	A	255.43	73.67	71.80	3.47	3.56	0.005	0.038	6.47	1652.77		1.13
5.50	B	9.25	17.98	17.66	0.51	0.52	0.005	0.060	1.16	10.72	*	0.17
5.50	C	6.22	22.78	22.35	0.27	0.28	0.005	0.084	0.54	3.35	*	0.09
5.50	T	270.89	114.43	111.81	2.37	2.42	0.005	0.031	6.15	1666.84	*	0.77
5.60	A	262.70	75.64	73.74	3.47	3.56	0.005	0.038	6.35	1668.81		1.08
5.60	B	11.04	20.85	20.41	0.53	0.54	0.005	0.058	1.19	13.12	*	0.17
5.60	C	8.59	25.59	25.06	0.34	0.34	0.005	0.077	0.66	5.67	*	0.10
5.60	T	282.33	122.08	119.21	2.31	2.37	0.005	0.031	5.98	1687.60	*	0.72

East Prong Roaring River R2XSEC1 Existing and Design Shear Stress



Dashed Line = Design   Solid Line = Existing

G:\WILL\STONE\PHASEII\XSPRO\R3XSEC1.OUT
Input File: G:\WILL\STONE\PHASEII\XSPRO\R3XSEC1.DAT
Run Date: 04/17/00
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 04/17/00
R3XSEC1 - Existing and Design

Subsections/Dividing stations
A / 75.49/ @

Resistance Method: Thorne and Zevenbergen
D84: 155.000 mm

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)	
1.00	T	12.03	21.70	21.55	0.55	0.56	0.022	0.068	2.18	26.24	0.76	
1.10	T	14.26	23.09	22.91	0.62	0.62	0.022	0.065	2.46	35.01	0.84	
1.20	T	16.61	24.26	24.07	0.68	0.69	0.022	0.062	2.74	45.48	0.92	
1.30	T	19.07	25.29	25.08	0.75	0.76	0.021	0.060	3.02	57.57	1.00	
1.40	T	21.61	26.01	25.74	0.83	0.84	0.021	0.058	3.32	71.75	1.10	
1.50	T	24.20	26.43	26.08	0.92	0.93	0.021	0.056	3.64	88.04	1.20	
1.60	T	26.83	26.85	26.41	1.00	1.02	0.021	0.054	3.94	105.70	1.29	
1.70	T	29.49	27.26	26.74	1.08	1.10	0.021	0.053	4.23	124.69	1.38	
1.80	T	32.18	27.68	27.08	1.16	1.19	0.020	0.052	4.51	144.95	1.47	
1.90	T	34.90	28.09	27.41	1.24	1.27	0.020	0.051	4.77	166.44	1.56	
2.00	T	37.66	28.51	27.74	1.32	1.36	0.020	0.050	5.02	189.12	1.64	
2.10	T	40.45	28.92	28.07	1.40	1.44	0.020	0.050	5.26	212.94	1.72	
2.20	T	43.27	29.34	28.41	1.47	1.52	0.019	0.049	5.50	237.86	1.79	
2.30	T	46.13	29.75	28.74	1.55	1.61	0.019	0.048	5.72	263.85	1.86	
2.40	T	49.02	30.17	29.07	1.62	1.69	0.019	0.048	5.93	290.88	1.93	
2.50	T	51.94	30.58	29.40	1.70	1.77	0.019	0.047	6.14	318.90	1.99	
2.60	T	54.90	31.18	29.96	1.76	1.83	0.019	0.047	6.31	346.42	2.04	
2.70	T	57.93	31.83	30.57	1.82	1.89	0.018	0.047	6.47	374.58	2.09	
2.80	T	61.02	32.47	31.18	1.88	1.96	0.018	0.046	6.62	403.76	2.13	
2.90	T	64.18	33.61	32.30	1.91	1.99	0.018	0.046	6.69	429.24	2.14	
3.00	T	67.48	34.97	33.64	1.93	2.01	0.018	0.046	6.73	454.05	2.14	
3.10	T	70.91	36.33	34.97	1.95	2.03	0.018	0.045	6.77	480.30	2.14	
3.20	T	74.47	37.68	36.31	1.98	2.05	0.017	0.045	6.82	507.99	2.14	
3.30	T	78.16	38.80	37.40	2.01	2.09	0.017	0.045	6.90	539.60	2.15	
3.40	T	81.94	39.55	38.12	2.07	2.15	0.017	0.045	7.03	576.19	2.19	
3.50	T	85.79	40.29	38.83	2.13	2.21	0.017	0.045	7.16	613.86	2.22	
3.60	T	89.70	41.04	39.55	2.19	2.27	0.016	0.044	7.28	652.60	2.25	
3.70	T	93.69	41.78	40.27	2.24	2.33	0.016	0.044	7.39	692.39	2.28	
3.80	T	97.76	42.53	40.98	2.30	2.39	0.016	0.044	7.50	733.20	2.30	
3.90	T	101.89	43.27	41.70	2.35	2.44	0.016	0.044	7.61	775.02	2.33	
4.00	T	106.09	44.02	42.42	2.41	2.50	0.016	0.043	7.71	817.84	2.35	
4.10	T	110.37	44.70	43.06	2.47	2.56	0.015	0.043	7.81	862.52	2.38	
4.20	T	114.69	45.11	43.37	2.54	2.64	0.015	0.043	7.95	911.84	2.41	
4.30	T	119.04	45.51	43.68	2.62	2.73	0.015	0.043	8.08	961.86	2.45	
4.40	T	123.42	45.92	43.99	2.69	2.81	0.015	0.043	8.20	1012.54	2.48	
4.50	T	127.84	46.33	44.30	2.76	2.89	0.015	0.043	8.32	1063.82	2.51	
4.60	T	132.28	46.74	44.61	2.83	2.97	0.014	0.042	8.43	1115.67	2.53	
4.70	T	136.76	47.15	44.92	2.90	3.04	0.014	0.042	8.54	1168.03	2.56	
4.80	T	141.26	47.56	45.23	2.97	3.12	0.014	0.042	8.64	1220.85	2.58	
4.90	T	145.80	47.97	45.54	3.04	3.20	0.01[illegible]	0.042	8.74	1274.09	2.60	
5.00	T	[illegible]0.37	48.38	45.85	3.11	3.28	0.01[illegible]	0.042	8.83	1327.68	2.62	
5.10	T	154.97	48.79	46.16	3.18	3.36	0.013	0.042	8.92	1381.60	2.63	← BKF

[illegible]	T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.99	1435.01	2.64	
[illegible]	T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.65	
5.40	T	168.99	50.15	47.34	3.37	3.57	0.013	0.041	9.13	1542.47	2.66	
5.50	T	173.74	50.60	47.74	3.43	3.64	0.012	0.041	9.19	1596.53	2.67	
5.60	T	178.53	51.06	48.13	3.50	3.71	0.012	0.041	9.25	1650.74	2.67	
5.70	T	183.36	51.51	48.53	3.56	3.78	0.012	0.041	9.30	1705.04	2.67	
5.80	T	188.24	51.96	48.92	3.62	3.85	0.012	0.041	9.35	1759.39	2.67	
5.90	T	193.15	52.42	49.32	3.68	3.92	0.012	0.041	9.39	1813.73	2.66	
6.00	T	198.10	52.87	49.71	3.75	3.98	0.011	0.041	9.43	1868.01	2.66	
6.10	T	203.09	53.32	50.11	3.81	4.05	0.011	0.041	9.46	1922.16	2.65	
6.20	T	208.12	53.78	50.51	3.87	4.12	0.011	0.040	9.50	1976.13	2.64	
6.30	T	213.18	54.23	50.90	3.93	4.19	0.011	0.040	9.52	2029.86	2.63	
6.40	T	218.29	54.68	51.30	3.99	4.26	0.011	0.040	9.54	2083.29	2.62	
6.50	T	223.44	55.14	51.69	4.05	4.32	0.010	0.040	9.56	2136.35	2.61	
6.60	T	228.63	55.59	52.09	4.11	4.39	0.010	0.040	9.57	2188.97	2.59	
6.70	T	233.86	56.05	52.48	4.17	4.46	0.010	0.040	9.58	2241.09	2.58	
6.80	T	239.12	56.50	52.88	4.23	4.52	0.010	0.040	9.59	2292.63	2.56	
6.90	T	244.45	57.34	53.68	4.26	4.55	0.009	0.040	9.54	2332.65	2.52	
7.00	T	249.86	58.19	54.48	4.29	4.59	0.009	0.040	9.49	2372.29	2.48	
7.10	T	255.34	59.04	55.28	4.32	4.62	0.009	0.040	9.44	2411.63	2.44	
7.20	T	260.91	59.89	56.08	4.36	4.65	0.009	0.040	9.39	2450.60	2.40	
7.30	T	266.56	60.74	56.88	4.39	4.69	0.009	0.040	9.34	2489.11	2.36	
7.40	T	272.28	61.52	57.61	4.43	4.73	0.008	0.040	9.29	2529.17	2.32	← TOB
7.50	T	278.07	62.11	58.15	4.48	4.78	0.008	0.040	9.26	2573.62	2.29	
7.60	T	283.91	62.70	58.68	4.53	4.84	0.008	0.040	9.22	2616.99	2.25	
7.70	T	289.80	63.29	59.22	4.58	4.89	0.008	0.039	9.18	2659.17	2.22	
7.80	T	295.75	63.88	59.76	4.63	4.95	0.008	0.039	9.13	2700.04	2.18	
7.90	T	301.75	64.47	60.30	4.68	5.00	0.007	0.039	9.08	2739.51	2.14	
8.00	T	307.81	65.09	60.88	4.73	5.06	0.007	0.039	9.02	2776.63	2.10	
8.10	T	313.92	65.72	61.46	4.78	5.11	0.007	0.039	8.96	2812.04	2.06	
8.20	T	320.10	66.34	62.03	4.83	5.16	0.007	0.039	8.89	2845.72	2.02	
8.30	T	326.33	66.96	62.61	4.87	5.21	0.006	0.039	8.82	2877.52	1.97	
8.40	T	332.62	67.59	63.19	4.92	5.26	0.006	0.039	8.74	2907.30	1.93	
8.50	T	338.96	68.21	63.77	4.97	5.32	0.006	0.039	8.66	2934.88	1.88	
8.60	T	345.36	68.62	64.13	5.03	5.39	0.006	0.039	8.59	2966.27	1.84	
8.70	T	351.79	69.00	64.45	5.10	5.46	0.006	0.039	8.52	2995.62	1.79	
8.80	T	358.25	69.38	64.78	5.16	5.53	0.005	0.039	8.44	3021.87	1.75	
8.90	T	364.74	69.77	65.10	5.23	5.60	0.005	0.039	8.35	3044.79	1.70	
9.00	T	371.26	70.15	65.43	5.29	5.67	0.005	0.039	8.25	3064.14	1.65	

5.20	T	159.60	49.24	46.55	3.24	3.43	0.013	0.041	8.99	1435.01	2.64	
[illegible]	T	164.[illegible]	[illegible].69	46.[illegible]	[illegible]1	[illegible].50	0.0[illegible]	0.[illegible]	[illegible]6	1488.[illegible]	2.65	
5.40	T	168.99	50.15	47.34	3.37	3.57	0.013	0.041	9.13	1542.47	2.66	
5.50	T	173.74	50.60	47.74	3.43	3.64	0.012	0.041	9.19	1596.53	2.67	
5.60	T	178.53	51.06	48.13	3.50	3.71	0.012	0.041	9.25	1650.74	2.67	
5.70	T	183.36	51.51	48.53	3.56	3.78	0.012	0.041	9.30	1705.04	2.67	
5.80	T	188.24	51.96	48.92	3.62	3.85	0.012	0.041	9.35	1759.39	2.67	
5.90	T	193.15	52.42	49.32	3.68	3.92	0.012	0.041	9.39	1813.73	2.66	
6.00	T	198.10	52.87	49.71	3.75	3.98	0.011	0.041	9.43	1868.01	2.66	
6.10	T	203.09	53.32	50.11	3.81	4.05	0.011	0.041	9.46	1922.16	2.65	
6.20	T	208.12	53.78	50.51	3.87	4.12	0.011	0.040	9.50	1976.13	2.64	
6.30	T	213.18	54.23	50.90	3.93	4.19	0.011	0.040	9.52	2029.86	2.63	
6.40	T	218.29	54.68	51.30	3.99	4.26	0.011	0.040	9.54	2083.29	2.62	
6.50	T	223.44	55.14	51.69	4.05	4.32	0.010	0.040	9.56	2136.35	2.61	
6.60	T	228.63	55.59	52.09	4.11	4.39	0.010	0.040	9.57	2188.97	2.59	
6.70	T	233.86	56.05	52.48	4.17	4.46	0.010	0.040	9.58	2241.09	2.58	
6.80	T	239.12	56.50	52.88	4.23	4.52	0.010	0.040	9.59	2292.63	2.56	
6.90	T	244.45	57.34	53.68	4.26	4.55	0.009	0.040	9.54	2332.65	2.52	
7.00	T	249.86	58.19	54.48	4.29	4.59	0.009	0.040	9.49	2372.29	2.48	
7.10	T	255.34	59.04	55.28	4.32	4.62	0.009	0.040	9.44	2411.63	2.44	
7.20	T	260.91	59.89	56.08	4.36	4.65	0.009	0.040	9.39	2450.60	2.40	
7.30	T	266.56	60.74	56.88	4.39	4.69	0.009	0.040	9.34	2489.11	2.36	
7.40	T	272.28	61.52	57.61	4.43	4.73	0.008	0.040	9.29	2529.17	2.32	← TOB
7.50	T	278.07	62.11	58.15	4.48	4.78	0.008	0.040	9.26	2573.62	2.29	
7.60	T	283.91	62.70	58.68	4.53	4.84	0.008	0.040	9.22	2616.99	2.25	
7.70	T	289.80	63.29	59.22	4.58	4.89	0.008	0.039	9.18	2659.17	2.22	
7.80	T	295.75	63.88	59.76	4.63	4.95	0.008	0.039	9.13	2700.04	2.18	
7.90	T	301.75	64.47	60.30	4.68	5.00	0.007	0.039	9.08	2739.51	2.14	
8.00	T	307.81	65.09	60.88	4.73	5.06	0.007	0.039	9.02	2776.63	2.10	
8.10	T	313.92	65.72	61.46	4.78	5.11	0.007	0.039	8.96	2812.04	2.06	
8.20	T	320.10	66.34	62.03	4.83	5.16	0.007	0.039	8.89	2845.72	2.02	
8.30	T	326.33	66.96	62.61	4.87	5.21	0.006	0.039	8.82	2877.52	1.97	
8.40	T	332.62	67.59	63.19	4.92	5.26	0.006	0.039	8.74	2907.30	1.93	
8.50	T	338.96	68.21	63.77	4.97	5.32	0.006	0.039	8.66	2934.88	1.88	
8.60	T	345.36	68.62	64.13	5.03	5.39	0.006	0.039	8.59	2966.27	1.84	
8.70	T	351.79	69.00	64.45	5.10	5.46	0.006	0.039	8.52	2995.62	1.79	
8.80	T	358.25	69.38	64.78	5.16	5.53	0.005	0.039	8.44	3021.87	1.75	
8.90	T	364.74	69.77	65.10	5.23	5.60	0.005	0.039	8.35	3044.79	1.70	
9.00	T	371.26	70.15	65.43	5.29	5.67	0.005	0.039	8.25	3064.14	1.65	

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*******************************WinXSPRO*******************************
r4:    l.ou
Input File:              G:\WILL\STONE\PHASEII\XSPRO\R4XSEC1.DAT
Run Date:                04/17/00
Analysis Procedure:      Hydraulics
Cross Section Number:    1
Survey Date:             04/17/00
R4XSEC1 - Existing

Subsections/Dividing stations
A / 271.00/ @

Resistance Method:       Thorne and Zevenbergen
            D84:         55.000 mm
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STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)		SHEAR (psf)	
1.00	T	13.79	22.37	22.17	0.62	0.62	0.005	0.039	1.95	26.87		0.19	
1.10	T	16.05	23.25	23.02	0.69	0.70	0.005	0.038	2.15	34.50		0.22	
1.20	T	18.43	24.70	24.46	0.75	0.75	0.005	0.038	2.30	42.41		0.23	
1.30	T	20.94	26.16	25.90	0.80	0.81	0.005	0.037	2.45	51.30		0.25	
1.40	T	23.61	27.61	27.34	0.85	0.86	0.005	0.037	2.59	61.20		0.27	
1.50	T	26.41	29.07	28.78	0.91	0.92	0.005	0.036	2.73	72.16		0.28	
1.60	T	29.36	30.52	30.21	0.96	0.97	0.005	0.036	2.87	84.21		0.30	
1.70	T	32.58	35.02	34.69	0.93	0.94	0.005	0.036	2.82	91.76		0.29	
1.80	T	36.30	40.19	39.82	0.90	0.91	0.005	0.036	2.77	100.70		0.28	
1.90	T	40.41	42.11	41.70	0.96	0.97	0.005	0.035	2.91	117.79		0.30	
2.00	T	44.64	43.23	42.78	1.03	1.04	0.005	0.035	3.09	137.91		0.32	
2.10	T	48.97	44.34	43.86	1.10	1.12	0.005	0.035	3.26	159.55		0.34	
2.20	T	53.90	55.60	55.06	0.97	0.98	0.005	0.035	2.98	160.67		0.30	
2.30	T	59.52	57.85	57.24	1.03	1.04	0.005	0.034	3.13	186.00		0.32	
2.40	T	65.35	60.09	59.43	1.09	1.10	0.005	0.034	3.27	213.40		0.34	
2.50	T	71.40	62.34	61.62	1.15	1.16	0.005	0.034	3.40	242.92		0.36	
2.60	T	77.67	64.58	63.80	1.20	1.22	0.005	0.034	3.54	274.60		0.38	
2.70	T	84.16	66.82	65.99	1.26	1.28	0.005	0.034	3.67	308.49		0.39	
2.80	T	90.84	68.45	67.54	1.33	1.35	0.005	0.033	3.82	346.68		0.41	
2.90	T	97.67	69.92	68.92	1.40	1.42	0.005	0.033	3.97	387.59		0.44	
3.00	T	104.63	71.39	70.31	1.47	1.49	0.005	0.033	4.12	430.72		0.46	
3.10	T	111.73	72.86	71.70	1.53	1.56	0.005	0.033	4.26	476.08		0.48	
3.20	T	118.97	74.33	73.08	1.60	1.63	0.005	0.033	4.40	523.69		0.50	
3.30	T	126.35	75.80	74.47	1.67	1.70	0.005	0.033	4.54	573.56		0.52	
3.40	T	133.86	77.26	75.86	1.73	1.76	0.005	0.033	4.67	625.70		0.54	
3.50	T	141.52	78.73	77.25	1.80	1.83	0.005	0.032	4.81	680.14		0.56	
3.60	T	149.31	80.42	78.84	1.86	1.89	0.005	0.032	4.93	735.53		0.58	
3.70	T	157.32	82.97	81.29	1.90	1.94	0.005	0.032	5.01	788.02		0.59	
3.80	T	165.57	85.53	83.73	1.94	1.98	0.005	0.032	5.09	843.13		0.60	
3.90	T	174.07	88.10	86.20	1.98	2.02	0.005	0.032	5.17	900.77		0.62	
4.00	T	182.82	90.87	88.87	2.01	2.06	0.005	0.032	5.25	959.81		0.63	
4.10	T	192.34	103.71	101.60	1.85	1.89	0.005	0.032	4.98	957.26		0.58	
4.20	T	203.12	114.39	112.19	1.78	1.81	0.005	0.032	4.84	983.22		0.55	BKF
4.30	T	214.43	116.43	114.10	1.84	1.88	0.005	0.032	4.97	1066.38		0.57	
4.40	T	225.94	118.47	116.01	1.91	1.95	0.005	0.032	5.10	1152.90		0.60	
4.50	T	237.63	120.50	117.93	1.97	2.02	0.005	0.032	5.23	1242.81		0.62	
4.60	T	249.52	122.54	119.84	2.04	2.08	0.005	0.032	5.35	1336.13		0.64	
4.70	T	261.60	124.58	121.75	2.10	2.15	0.005	0.032	5.48	1432.88		0.66	
4.80	T	273.87	126.62	123.67	2.16	2.21	0.005	0.031	5.60	1533.09		0.67	
4.90	T	286.29	127.93	124.76	2.24	2.29	0.005	0.031	5.74	1642.64	*	0.70	
5.00	T	8.82	129.24	125.85	2.31	2.37	0.00	0.031	5.87	1755.52	*	0.72	
5.10	T	[illegible]11.46	130.55	126.95	2.39	2.45	0.005	0.031	6.01	1871.71	*	0.74	

5.20	T	324.21	131.86	128.04	2.46	2.53	0.005	0.031	6.14	1991.21	*	0.77
[illegible]	T	337[illegible]	[illegible].01	129[illegible]	[illegible]2	.59	0.0	0.[illegible]	[illegible]5	2105[illegible]	*	0.7[illegible]
5.40	T	350.41	147.97	143.73	2.37	2.44	0.005	0.031	6.01	2104.73	*	0.74
5.50	T	365.95	165.15	160.71	2.22	2.28	0.005	0.031	5.75	2105.06	*	0.69

G: L\ST .PHA \XS! R4XS OUT

Input File: G:\WILL\STONE\PHASEII\XSPRO\R4XSEC2.DAT
Run Date: 04/17/00
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 04/17/00
R4XSEC2 - Existing and Design

Subsections/Dividing stations
A / 116.30/ @

Resistance Method: Thorne and Zevenbergen
D84: 155.000 mm

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)	
1.00	T	14.08	23.49	23.02	0.60	0.61	0.005	0.067	1.12	15.79	0.19	
1.10	T	16.43	24.56	24.01	0.67	0.68	0.005	0.064	1.27	20.84	0.21	
1.20	T	18.88	25.64	24.99	0.74	0.76	0.005	0.061	1.41	26.61	0.23	
1.30	T	21.43	26.71	25.98	0.80	0.82	0.005	0.059	1.54	33.10	0.25	
1.40	T	24.08	27.79	26.96	0.87	0.89	0.005	0.057	1.67	40.31	0.27	
1.50	T	26.80	28.36	27.43	0.95	0.98	0.005	0.056	1.83	48.96	0.29	
1.60	T	29.56	28.70	27.67	1.03	1.07	0.005	0.054	1.98	58.67	0.32	
1.70	T	32.34	29.05	27.92	1.11	1.16	0.005	0.053	2.14	69.15	0.35	
1.80	T	35.14	29.40	28.16	1.20	1.25	0.005	0.052	2.29	80.39	0.37	
1.90	T	37.97	29.75	28.40	1.28	1.34	0.005	0.051	2.43	92.36	0.40	
2.00	T	40.82	30.10	28.65	1.36	1.43	0.005	0.050	2.57	105.05	0.42	
2.10	T	43.75	31.83	30.26	1.37	1.45	0.005	0.050	2.62	114.57	0.43	
2.20	T	46.88	33.91	32.23	1.38	1.45	0.005	0.049	2.65	124.09	0.43	
2.30	T	50.20	36.00	34.19	1.39	1.47	0.005	0.049	2.68	134.63	0.44	
2.40	T	53.72	38.08	36.15	1.41	1.49	0.005	0.049	2.72	146.22	0.44	
2.50	T	57.52	41.55	39.50	1.38	1.46	0.005	0.049	2.70	155.10	0.43	
2.60	T	61.60	44.25	42.10	1.39	1.46	0.005	0.048	2.72	167.71	0.43	
2.70	T	65.89	45.85	43.61	1.44	1.51	0.005	0.048	2.81	184.86	0.45	
2.80	T	70.32	47.34	45.01	1.49	1.56	0.005	0.047	2.89	203.46	0.46	
2.90	T	74.89	48.86	46.50	1.53	1.61	0.005	0.047	2.98	223.07	0.48	
3.00	T	79.62	50.39	47.98	1.58	1.66	0.005	0.047	3.06	243.86	0.49	
3.10	T	84.49	51.92	49.46	1.63	1.71	0.005	0.046	3.15	265.86	0.51	
3.20	T	89.51	53.10	50.60	1.69	1.77	0.005	0.046	3.25	290.51	0.53	
3.30	T	94.58	53.48	50.91	1.77	1.86	0.005	0.046	3.38	319.69	0.55	
3.40	T	99.69	53.86	51.23	1.85	1.95	0.005	0.045	3.51	350.09	0.58	
3.50	T	104.83	54.24	51.55	1.93	2.03	0.005	0.045	3.64	381.72	0.60	
3.60	T	110.00	54.62	51.87	2.01	2.12	0.005	0.045	3.77	414.54	0.63	
3.70	T	115.20	55.00	52.18	2.09	2.21	0.005	0.044	3.89	448.56	0.65	
3.80	T	120.43	55.38	52.50	2.17	2.29	0.005	0.044	4.02	483.76	0.68	
3.90	T	125.70	55.76	52.82	2.25	2.38	0.005	0.044	4.14	520.14	0.70	
4.00	T	131.00	56.14	53.14	2.33	2.47	0.005	0.044	4.26	557.68	0.73	
4.10	T	136.33	56.52	53.45	2.41	2.55	0.005	0.043	4.37	596.38	0.75	
4.20	T	141.69	56.90	53.77	2.49	2.63	0.005	0.043	4.49	636.24	0.78	
4.30	T	147.08	57.28	54.09	2.57	2.72	0.005	0.043	4.60	677.23	0.80	
4.40	T	152.51	57.66	54.41	2.65	2.80	0.005	0.043	4.72	719.37	0.83	
4.50	T	157.96	58.04	54.73	2.72	2.89	0.005	0.043	4.83	762.64	0.85	
4.60	T	163.45	58.42	55.04	2.80	2.97	0.005	0.042	4.94	807.03	0.87	← BKF

G:\WILL\STONE\PHASEII\XSPRO\R4XSEC3.OUT
Input File: G:\WILL\STONE\PHASEII\XSPRO\R4XSEC3.DAT
Run Date: 04/17/00
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 04/17/00
R4XSEC3 - Existing

Subsections/Dividing stations
B / 59.00/ C / 100.00/ A / 171.30/ @

Resistance Method: Thorne and Zevenbergen
D84: 155.000 mm

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	T	14.76	24.14	24.02	0.61	0.61	0.005	0.066	1.14	16.87	0.19
1.10	A	17.22	25.35	25.20	0.68	0.68	0.005	0.063	1.29	22.17	0.21
1.10	B	0.00	0.26	0.26	0.01	0.01	0.005	1.343	0.00	0.00	0.00
1.10	T	17.23	25.61	25.46	0.67	0.68	0.005	0.063	1.29	22.17	0.21
1.20	A	19.80	26.55	26.39	0.75	0.75	0.005	0.061	1.43	28.24	0.23
1.20	B	0.09	1.58	1.54	0.06	0.06	0.005	0.319	0.05	0.00	0.02
1.20	T	19.90	28.13	27.93	0.71	0.71	0.005	0.059	1.42	28.24	0.22
1.30	A	22.49	27.57	27.39	0.82	0.82	0.005	0.059	1.57	35.27	0.25
1.30	B	0.30	2.63	2.55	0.11	0.12	0.005	0.198	0.13	0.04	0.04
1.30	T	22.79	30.20	29.94	0.75	0.76	0.005	0.056	1.55	35.31	0.24
1.40	A	25.27	28.34	28.14	0.89	0.90	0.005	0.057	1.72	43.39	0.28
1.40	B	0.60	3.61	3.49	0.17	0.17	0.005	0.144	0.22	0.13	0.05
1.40	T	25.87	31.96	31.63	0.81	0.82	0.005	0.054	1.68	43.52	0.25
1.50	A	28.12	29.12	28.89	0.97	0.97	0.005	0.055	1.86	52.32	0.30
1.50	B	1.00	4.59	4.44	0.22	0.23	0.005	0.113	0.34	0.34	0.07
1.50	T	29.12	33.71	33.32	0.86	0.87	0.005	0.053	1.81	52.65	0.27
1.60	A	31.05	29.79	29.51	1.04	1.05	0.005	0.054	2.00	62.24	0.33
1.60	B	1.49	5.57	5.38	0.27	0.28	0.005	0.094	0.47	0.69	0.08
1.60	T	32.53	35.37	34.89	0.92	0.93	0.005	0.052	1.93	62.94	0.29
1.70	A	34.02	30.30	29.94	1.12	1.14	0.005	0.053	2.15	73.26	0.35
1.70	B	2.07	6.56	6.32	0.32	0.33	0.005	0.080	0.61	1.26	0.10
1.70	T	36.09	36.86	36.27	0.98	1.00	0.005	0.050	2.06	74.52	0.31
1.80	A	37.03	30.82	30.38	1.20	1.22	0.005	0.052	2.30	85.08	0.37
1.80	B	2.82	9.32	9.03	0.30	0.31	0.005	0.086	0.55	1.56	0.09
1.80	T	39.86	40.14	39.41	0.99	1.01	0.005	0.048	2.17	86.65	0.31
1.90	A	40.09	31.33	30.81	1.28	1.30	0.005	0.051	2.44	97.72	0.40
1.90	B	3.89	12.52	12.19	0.31	0.32	0.005	0.086	0.56	2.18	0.10
1.90	T	43.98	43.86	43.00	1.00	1.02	0.005	0.046	2.27	99.90	0.31
2.00	A	43.20	31.85	31.25	1.36	1.38	0.005	0.050	2.57	111.16	0.42
2.00	B	5.26	15.73	15.34	0.33	0.34	0.005	0.084	0.61	3.19	0.10
2.00	T	48.46	47.58	46.59	1.02	1.04	0.005	0.045	2.36	114.35	0.32
2.10	A	46.34	32.36	31.68	1.43	1.46	0.005	0.049	2.71	125.39	0.45
2.10	B	6.95	18.94	18.50	0.37	0.38	0.005	0.080	0.67	4.67	0.11
2.10	T	53.30	51.30	50.18	1.04	1.06	0.005	0.044	2.44	130.06	0.32
2.20	A	49.53	32.87	32.12	1.51	1.54	0.005	0.049	2.83	140.42	0.47
2.20	B	8.96	21.63	21.15	0.41	0.42	0.005	0.076	0.77	6.92	0.13
2.20	C	0.40	4.90	4.88	0.08	0.08	0.005	0.162	0.12	0.05	0.03
2.20	T	58.89	59.41	58.14	0.99	1.01	0.005	0.042	2.50	147.39	0.31
2.30	A	52.77	33.39	32.55	1.58	1.62	0.005	0.048	2.96	156.23	0.49
2.30	B	11.10	22.29	21.76	0.50	0.51	0.005	0.066	1.01	11.16	0.16
2.30	C	0.94	5.90	5.85	0.16	0.16	0.00	0.133	0.23	0.22	0.05
2.30	T	64.81	61.57	60.17	1.05	1.08	0.005	0.042	2.59	167.61	0.33

[illegible]	[illegible]	[illegible]	[illegible]	32.99	1.65	1.70	0.005	0.048	3.08	172.83	0.52
[illegible]	B	13.[illegible]	[illegible].95	22.[illegible]	[illegible]8	[illegible].59	0.0[illegible]	0[illegible]	[illegible]5	15[illegible]	0.1[illegible]
2.40	C	1.57	6.89	6.83	0.23	0.23	0.005	0.106	0.37	0.58	0.07
2.40	T	70.92	63.74	62.19	1.11	1.14	0.005	0.043	2.66	188.72	0.35
2.50	A	59.37	34.41	33.42	1.73	1.78	0.005	0.047	3.20	190.22	0.54
2.50	B	15.58	23.60	22.99	0.66	0.68	0.005	0.061	1.32	20.51	0.21
2.50	C	2.30	7.89	7.80	0.29	0.29	0.005	0.088	0.53	1.21	0.09
2.50	T	77.24	65.91	64.21	1.17	1.20	0.005	0.043	2.74	211.93	0.37
2.60	A	62.73	34.92	33.85	1.80	1.85	0.005	0.047	3.32	208.39	0.56
2.60	B	17.92	24.71	24.04	0.73	0.75	0.005	0.059	1.45	26.00	0.23
2.60	C	3.13	8.89	8.78	0.35	0.36	0.005	0.075	0.70	2.19	0.11
2.60	T	83.77	68.52	66.67	1.22	1.26	0.005	0.043	2.82	236.58	0.38
2.70	A	66.14	35.43	34.28	1.87	1.93	0.005	0.046	3.44	227.33	0.58
2.70	B	20.41	26.49	25.76	0.77	0.79	0.005	0.057	1.55	31.61	0.24
2.70	C	4.06	9.96	9.83	0.41	0.41	0.005	0.066	0.87	3.55	0.13
2.70	T	90.60	71.88	69.87	1.26	1.30	0.005	0.042	2.90	262.49	0.39
2.80	A	69.58	35.94	34.71	1.94	2.00	0.005	0.046	3.55	247.06	0.60
2.80	B	23.07	28.27	27.47	0.82	0.84	0.005	0.056	1.65	37.96	0.25
2.80	C	5.13	11.71	11.57	0.44	0.44	0.005	0.064	0.95	4.89	0.14
2.80	T	97.78	75.93	73.76	1.29	1.33	0.005	0.042	2.96	289.91	0.40
2.90	A	73.08	36.46	35.14	2.00	2.08	0.005	0.046	3.66	267.56	0.63
2.90	B	25.90	30.05	29.18	0.86	0.89	0.005	0.055	1.74	45.11	0.27
2.90	C	6.37	13.18	13.02	0.48	0.49	0.005	0.059	1.10	6.98	0.15
2.90	T	105.34	79.69	77.35	1.32	1.36	0.005	0.042	3.03	319.65	0.41
3.00	A	76.61	36.97	35.58	2.07	2.15	0.005	0.045	3.77	288.85	0.65
3.00	B	28.90	31.83	30.90	0.91	0.94	0.005	0.054	1.84	53.09	0.28
3.00	C	7.71	13.99	13.78	0.55	0.56	0.005	0.070	1.01	7.76	0.17
3.00	T	113.23	82.78	80.26	1.37	1.41	0.005	0.042	3.09	349.70	0.43
3.10	A	80.19	37.48	36.01	2.14	2.23	0.005	0.045	3.88	310.91	0.67
3.10	B	32.07	33.54	32.47	0.96	0.99	0.005	0.053	1.93	62.04	0.30
3.10	C	9.12	14.79	14.54	0.62	0.63	0.005	0.066	1.15	10.50	0.19
3.10	T	121.39	85.80	83.02	1.41	1.46	0.005	0.042	3.16	383.44	0.44
3.20	A	83.82	38.08	36.53	2.20	2.29	0.005	0.045	3.97	333.15	0.69
3.20	B	35.40	35.24	34.04	1.00	1.04	0.005	0.052	2.03	71.86	0.31
3.20	C	10.62	15.59	15.30	0.68	0.69	0.005	0.063	1.29	13.67	0.21
3.20	T	129.83	88.91	85.88	1.46	1.51	0.005	0.042	3.22	418.68	0.46
3.30	A	87.50	38.84	37.23	2.25	2.35	0.005	0.045	4.06	355.20	0.70
3.30	B	38.88	36.95	35.62	1.05	1.09	0.005	0.051	2.12	82.60	0.33
3.30	C	12.21	16.95	16.62	0.72	0.73	0.005	0.061	1.38	16.83	0.22
3.30	T	138.59	92.74	89.47	1.49	1.55	0.005	0.042	3.28	454.64	0.47
3.40	A	91.26	39.60	37.94	2.30	2.41	0.005	0.044	4.14	378.02	0.72
3.40	B	42.52	38.66	37.19	1.10	1.14	0.005	0.051	2.22	94.29	0.34
3.40	C	13.94	18.45	18.09	0.76	0.77	0.005	0.060	1.46	20.38	0.24
3.40	T	147.73	96.71	93.22	1.53	1.58	0.005	0.042	3.34	492.69	0.48
3.50	A	95.09	40.37	38.65	2.36	2.46	0.005	0.044	4.22	401.68	0.73
3.50	B	46.27	39.18	37.60	1.18	1.23	0.005	0.050	2.36	109.35	0.37
3.50	C	15.82	19.95	19.55	0.79	0.81	0.005	0.058	1.55	24.48	0.25
3.50	T	157.18	99.50	95.80	1.58	1.64	0.005	0.042	3.41	535.51	0.49
3.60	A	98.99	41.13	39.37	2.41	2.51	0.005	0.044	4.31	426.19	0.75
3.60	B	50.04	39.58	37.87	1.26	1.32	0.005	0.049	2.51	125.67	0.39
3.60	C	17.85	21.45	21.01	0.83	0.85	0.005	0.057	1.63	29.17	0.26
3.60	T	166.89	102.17	98.26	1.63	1.70	0.005	0.042	3.48	581.02	0.51
3.70	A	102.95	41.52	39.71	2.48	2.59	0.005	0.044	4.41	454.53	0.77
3.70	B	53.84	39.97	38.15	1.35	1.41	0.005	0.048	2.66	142.96	0.42
3.70	C	20.02	22.86	22.40	0.88	0.89	0.005	0.056	1.73	34.59	0.27
3.70	T	176.82	104.35	100.26	1.69	1.76	0.005	0.042	3.57	632.08	0.53
3.80	A	106.93	41.65	39.79	2.57	2.69	0.005	0.043	4.54	485.73	0.80
3.80	B	57.67	40.36	38.43	1.43	1.50	0.005	0.048	2.80	161.23	0.45
3.80	C	22.33	24.19	23.73	0.92	0.94	0.005	0.055	1.82	40.75	0.29
3.80	T	6.93	106.21	101.95	1.76	1.83	0.0[illegible]	0.042	3.68	687.70	0.55
3.90	A	10.91	41.79	39.88	2.65	2.78	0.005	0.043	4.67	517.80	0.83

[illegible]	C	24	53	25	7	.99	0.0	0	2	47	0.30	
3.90	T	197.21	108.08	103.65	1.82	1.90	0.005	0.042	3.78	745.82	0.57	
4.00	A	114.91	41.92	39.97	2.74	2.87	0.005	0.043	4.79	550.73	0.86	
4.00	B	65.41	41.15	38.98	1.59	1.68	0.005	0.047	3.07	200.58	0.50	
4.00	C	27.34	26.61	26.13	1.03	1.05	0.005	0.053	2.03	55.59	0.32	
4.00	T	207.66	109.68	105.08	1.89	1.98	0.005	0.041	3.89	806.90	0.59	
4.10	A	118.91	42.05	40.06	2.83	2.97	0.005	0.043	4.92	584.51	0.88	
4.10	B	69.32	41.55	39.26	1.67	1.77	0.005	0.046	3.20	221.65	0.52	
4.10	C	29.98	27.06	26.58	1.11	1.13	0.005	0.052	2.18	65.36	0.35	
4.10	T	218.21	110.67	105.90	1.97	2.06	0.005	0.041	3.99	871.52	0.62	
4.20	A	122.92	42.19	40.15	2.91	3.06	0.005	0.043	5.04	619.14	0.91	
4.20	B	73.26	41.94	39.53	1.75	1.85	0.005	0.046	3.33	243.62	0.55	
4.20	C	32.66	27.52	27.03	1.19	1.21	0.005	0.051	2.32	75.88	0.37	
4.20	T	228.84	111.65	106.71	2.05	2.14	0.005	0.041	4.10	938.64	0.64	
4.30	A	126.94	42.34	40.26	3.00	3.15	0.005	0.042	5.16	654.39	0.94	
4.30	B	77.23	42.36	39.85	1.82	1.94	0.005	0.046	3.45	266.39	0.57	
4.30	C	35.39	28.51	28.01	1.24	1.26	0.005	0.050	2.43	85.88	0.39	
4.30	T	239.56	113.21	108.13	2.12	2.22	0.005	0.041	4.20	1006.65	0.66	← BKF
4.40	A	130.97	42.52	40.41	3.08	3.24	0.005	0.042	5.27	690.15	0.96	
4.40	B	81.23	42.81	40.24	1.90	2.02	0.005	0.045	3.57	289.89	0.59	
4.40	C	38.28	30.30	29.79	1.26	1.28	0.005	0.050	2.48	94.83	0.39	
4.40	T	250.49	115.63	110.45	2.17	2.27	0.005	0.041	4.29	1074.86	0.68	
4.50	A	135.02	42.70	40.56	3.16	3.33	0.005	0.042	5.38	726.73	0.99	
4.50	B	85.28	43.27	40.63	1.97	2.10	0.005	0.045	3.69	314.31	0.61	
4.50	C	41.35	32.08	31.57	1.29	1.31	0.005	0.049	2.53	104.69	0.40	
4.50	T	261.65	118.05	112.77	2.22	2.32	0.005	0.041	4.38	1145.73	0.69	
4.60	A	139.08	42.89	40.72	3.24	3.42	0.005	0.042	5.49	764.14	1.01	
4.60	B	89.36	43.72	41.02	2.04	2.18	0.005	0.045	3.80	339.63	0.64	
4.60	C	44.60	33.76	33.25	1.32	1.34	0.005	0.049	2.60	115.79	0.41	
4.60	T	273.04	120.37	114.99	2.27	2.37	0.005	0.041	4.47	1219.56	0.71	
4.70	A	143.16	43.07	40.87	3.32	3.50	0.005	0.042	5.60	802.37	1.04	
4.70	B	93.49	44.52	41.75	2.10	2.24	0.005	0.044	3.89	363.77	0.66	
4.70	C	47.99	35.04	34.52	1.37	1.39	0.005	0.048	2.69	128.91	0.43	
4.70	T	284.63	122.63	117.14	2.32	2.43	0.005	0.041	4.55	1295.04	0.72	
4.80	A	147.26	43.25	41.02	3.40	3.59	0.005	0.042	5.71	841.41	1.06	
4.80	B	97.74	46.13	43.31	2.12	2.26	0.005	0.044	3.93	384.09	0.66	
4.80	C	51.50	36.31	35.79	1.42	1.44	0.005	0.048	2.78	142.95	0.44	
4.80	T	296.50	125.69	120.12	2.36	2.47	0.005	0.040	4.62	1368.44	0.74	
4.90	A	151.37	43.43	41.17	3.49	3.68	0.005	0.042	5.82	881.25	1.09	
4.90	B	102.15	47.74	44.86	2.14	2.28	0.005	0.044	3.97	405.61	0.67	
4.90	C	55.14	37.58	37.06	1.47	1.49	0.005	0.047	2.86	157.94	0.46	
4.90	T	308.66	128.75	123.09	2.40	2.51	0.005	0.040	4.68	1444.80	0.75	
5.00	A	155.49	43.61	41.32	3.57	3.76	0.005	0.041	5.93	921.90	1.11	
5.00	B	106.71	49.35	46.41	2.16	2.30	0.005	0.044	4.01	428.34	0.67	
5.00	C	58.91	38.86	38.33	1.52	1.54	0.005	0.047	2.95	173.91	0.47	
5.00	T	321.11	131.82	126.07	2.44	2.55	0.005	0.040	4.75	1524.15	0.76	
5.10	A	159.63	43.80	41.48	3.64	3.85	0.005	0.041	6.03	963.35	1.14	
5.10	B	111.43	50.95	47.96	2.19	2.32	0.005	0.044	4.06	452.31	0.68	
5.10	C	62.81	40.13	39.60	1.57	1.59	0.005	0.047	3.04	190.88	0.49	
5.10	T	333.87	134.88	129.04	2.48	2.59	0.005	0.040	4.81	1606.55	0.77	
5.20	A	163.78	43.98	41.63	3.72	3.93	0.005	0.041	6.14	1005.60	1.16	
5.20	B	116.30	52.56	49.51	2.21	2.35	0.005	0.044	4.11	477.55	0.69	
5.20	C	66.83	41.40	40.87	1.61	1.64	0.005	0.046	3.13	208.89	0.50	
5.20	T	346.92	137.94	132.01	2.51	2.63	0.005	0.040	4.88	1692.03	0.78	
5.30	A	167.96	44.16	41.78	3.80	4.02	0.005	0.041	6.24	1048.64	1.19	
5.30	B	121.27	52.83	49.73	2.30	2.44	0.005	0.043	4.23	513.05	0.72	
5.30	C	70.93	41.53	41.00	1.71	1.73	0.005	0.046	3.28	232.46	0.53	
5.30	T	360.16	138.52	132.51	2.60	2.72	0.005	0.040	4.98	1794.15	0.81	
5.40	A	2.14	44.34	41.93	3.88	4.11	0.00	0.041	6.35	1092.46	1.21	
5.40	B	126.25	52.95	49.81	2.38	2.53	0.005	0.043	4.36	550.69	0.74	

[illegible]	T	373.[illegible]	[illegible].83	132.[illegible]	[illegible]9	[illegible].81	0.0[illegible]	0[illegible]	[illegible]9	190[illegible]	0.8[illegible]
5.50	A	176.34	44.52	42.08	3.96	4.19	0.005	0.041	6.45	1137.07	1.24
5.50	B	131.23	53.08	49.88	2.47	2.63	0.005	0.043	4.49	589.44	0.77
5.50	C	79.13	41.53	41.00	1.91	1.93	0.005	0.045	3.59	283.98	0.59
5.50	T	386.71	139.13	132.96	2.78	2.91	0.005	0.040	5.20	2010.49	0.87
5.60	A	180.56	44.70	42.23	4.04	4.28	0.005	0.041	6.55	1182.47	1.26
5.60	B	136.22	53.20	49.95	2.56	2.73	0.005	0.043	4.62	629.29	0.80
5.60	C	83.23	41.53	41.00	2.00	2.03	0.005	0.045	3.74	311.38	0.63
5.60	T	400.01	139.44	133.18	2.87	3.00	0.005	0.040	5.31	2123.14	0.90
5.70	A	184.79	44.89	42.39	4.12	4.36	0.005	0.041	6.65	1228.64	1.28
5.70	B	141.22	53.32	50.02	2.65	2.82	0.005	0.043	4.75	670.23	0.83
5.70	C	87.33	41.53	41.00	2.10	2.13	0.005	0.044	3.89	339.86	0.66
5.70	T	413.34	139.74	133.40	2.96	3.10	0.005	0.040	5.42	2238.73	0.92
5.80	A	189.03	45.07	42.54	4.19	4.44	0.005	0.041	6.75	1275.59	1.31
5.80	B	146.23	53.44	50.09	2.74	2.92	0.005	0.042	4.87	712.24	0.85
5.80	C	91.43	41.53	41.00	2.20	2.23	0.005	0.044	4.04	369.40	0.69
5.80	T	426.69	140.05	133.63	3.05	3.19	0.005	0.040	5.52	2357.22	0.95
5.90	A	193.30	45.25	42.69	4.27	4.53	0.005	0.041	6.85	1323.31	1.33
5.90	B	151.24	53.57	50.16	2.82	3.02	0.005	0.042	4.99	755.31	0.88
5.90	C	95.53	41.53	41.00	2.30	2.33	0.005	0.044	4.19	399.98	0.72
5.90	T	440.07	140.35	133.85	3.14	3.29	0.005	0.040	5.63	2478.60	0.98
6.00	A	197.57	45.43	42.84	4.35	4.61	0.005	0.040	6.94	1371.80	1.36
6.00	B	156.26	53.69	50.23	2.91	3.11	0.005	0.042	5.12	799.44	0.91
6.00	C	99.63	41.53	41.00	2.40	2.43	0.005	0.044	4.33	431.59	0.75
6.00	T	453.46	140.65	134.07	3.22	3.38	0.005	0.040	5.74	2602.83	1.01
6.10	A	201.86	45.61	42.99	4.43	4.70	0.005	0.040	7.04	1421.06	1.38
6.10	B	161.29	53.81	50.30	3.00	3.21	0.005	0.042	5.24	844.60	0.94
6.10	C	103.73	41.53	41.00	2.50	2.53	0.005	0.043	4.48	464.22	0.78
6.10	T	466.88	140.96	134.29	3.31	3.48	0.005	0.040	5.85	2729.88	1.03
6.20	A	206.17	45.80	43.15	4.50	4.78	0.005	0.040	7.14	1471.09	1.40
6.20	B	166.32	53.93	50.37	3.08	3.30	0.005	0.042	5.36	890.79	0.96
6.20	C	107.83	41.53	41.00	2.60	2.63	0.005	0.043	4.62	497.86	0.81
6.20	T	480.32	141.26	134.52	3.40	3.57	0.005	0.040	5.95	2859.73	1.06
6.30	A	210.49	45.98	43.30	4.58	4.86	0.005	0.040	7.23	1521.87	1.43
6.30	B	171.36	54.10	50.50	3.17	3.39	0.005	0.042	5.47	937.42	0.99
6.30	C	111.93	41.53	41.00	2.69	2.73	0.005	0.043	4.76	532.49	0.84
6.30	T	493.79	141.62	134.80	3.49	3.66	0.005	0.040	6.06	2991.78	1.09
6.40	A	214.83	46.16	43.45	4.65	4.94	0.005	0.040	7.32	1573.42	1.45
6.40	B	176.42	54.31	50.68	3.25	3.48	0.005	0.041	5.58	984.68	1.01
6.40	C	116.03	41.53	41.00	2.79	2.83	0.005	0.043	4.90	568.10	0.87
6.40	T	507.28	142.00	135.13	3.57	3.75	0.005	0.040	6.16	3126.20	1.11
6.50	A	219.18	46.34	43.60	4.73	5.03	0.005	0.040	7.42	1625.73	1.48
6.50	B	181.50	54.51	50.86	3.33	3.57	0.005	0.041	5.69	1032.95	1.04
6.50	C	120.13	41.53	41.00	2.89	2.93	0.005	0.042	5.03	604.69	0.90
6.50	T	520.81	142.39	135.46	3.66	3.84	0.005	0.040	6.27	3263.36	1.14
6.60	A	223.55	46.52	43.75	4.81	5.11	0.005	0.040	7.51	1678.79	1.50
6.60	B	186.59	54.74	51.06	3.41	3.65	0.005	0.041	5.80	1081.84	1.06
6.60	C	124.23	41.53	41.00	2.99	3.03	0.005	0.042	5.17	642.23	0.93
6.60	T	534.37	142.80	135.82	3.74	3.93	0.005	0.040	6.37	3402.87	1.17
6.70	A	227.93	46.70	43.90	4.88	5.19	0.005	0.040	7.60	1732.63	1.52
6.70	B	191.72	55.08	51.39	3.48	3.73	0.005	0.041	5.90	1130.19	1.09
6.70	C	128.33	41.53	41.00	3.09	3.13	0.005	0.042	5.30	680.73	0.96
6.70	T	547.98	143.32	136.29	3.82	4.02	0.005	0.040	6.47	3543.55	1.19
6.80	A	232.33	46.89	44.06	4.96	5.27	0.005	0.040	7.69	1787.22	1.55
6.80	B	196.87	55.42	51.72	3.55	3.81	0.005	0.041	5.99	1179.54	1.11
6.80	C	132.43	41.53	41.00	3.19	3.23	0.005	0.042	5.44	720.17	0.99
6.80	T	561.63	143.84	136.77	3.90	4.11	0.005	0.040	6.56	3686.94	1.22
6.90	A	[illegible]36.74	47.07	44.21	5.03	5.36	0.005	0.040	7.78	1842.57	1.57
6.90	B	[illegible]2.06	55.76	52.04	3.62	3.88	0.00[illegible]	0.041	6.09	1229.90	1.13
6.90	C	[illegible]36.53	41.53	41.00	3.29	3.33	0.005	0.042	5.57	760.55	1.03

	A	241	.25	44	.0	.44	0.C	0	37	189[illegible]	1.5[illegible]
7.00	B	207.28	56.11	52.37	3.69	3.96	0.005	0.041	6.18	1281.26	1.15
7.00	C	140.63	41.53	41.00	3.39	3.43	0.005	0.042	5.70	801.85	1.06
7.00	T	589.08	144.89	137.72	4.07	4.28	0.005	0.040	6.76	3981.77	1.27
7.10	A	245.62	47.43	44.51	5.18	5.52	0.005	0.040	7.96	1955.50	1.62
7.10	B	212.53	56.45	52.69	3.77	4.03	0.005	0.041	6.27	1333.62	1.17
7.10	C	144.73	41.53	41.00	3.48	3.53	0.005	0.042	5.83	844.06	1.09
7.10	T	602.88	145.41	138.20	4.15	4.36	0.005	0.040	6.86	4133.19	1.29
7.20	A	250.07	47.61	44.66	5.25	5.60	0.005	0.040	8.05	2013.09	1.64
7.20	B	217.82	56.79	53.02	3.84	4.11	0.005	0.041	6.37	1386.99	1.20
7.20	C	148.83	41.53	41.00	3.58	3.63	0.005	0.041	5.96	887.18	1.12
7.20	T	616.72	145.93	138.68	4.23	4.45	0.005	0.040	6.95	4287.26	1.32
7.30	A	254.55	47.79	44.81	5.33	5.68	0.005	0.039	8.14	2071.42	1.66
7.30	B	223.14	57.13	53.35	3.91	4.18	0.005	0.040	6.46	1441.37	1.22
7.30	C	152.93	41.53	41.00	3.68	3.73	0.005	0.041	6.09	931.20	1.15
7.30	T	630.61	146.45	139.15	4.31	4.53	0.005	0.040	7.05	4443.99	1.34
7.40	A	259.04	47.97	44.96	5.40	5.76	0.005	0.039	8.22	2130.49	1.68
7.40	B	228.49	57.47	53.67	3.98	4.26	0.005	0.040	6.55	1496.75	1.24
7.40	C	157.03	41.53	41.00	3.78	3.83	0.005	0.041	6.22	976.11	1.18
7.40	T	644.55	146.97	139.63	4.39	4.62	0.005	0.040	7.14	4603.35	1.37
7.50	A	263.54	48.15	45.11	5.47	5.84	0.005	0.039	8.31	2190.30	1.71
7.50	B	233.87	57.81	54.00	4.05	4.33	0.005	0.040	6.64	1553.13	1.26
7.50	C	161.13	41.53	41.00	3.88	3.93	0.005	0.041	6.34	1021.91	1.21
7.50	T	658.54	147.49	140.11	4.46	4.70	0.005	0.039	7.24	4765.34	1.39

APPENDIX 9

WETLAND DELINEATION

SHEETS

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site:	*Stone Mountain*	Date:	*04/20/2000*
Applicant/Owner:		County:	*Wilkes*
Investigation:	*Karen Hall*	State:	*NC*

			Community ID: *Wetland*
Do Normal Circumstances exist on the site?	Yes x	No	Transect ID:
Is the site significantly disturbed (Atypical Situation)?	Yes	No x	Plot ID:
Is the area a potential Problem Area? (If needed, explain in remarks.)	Yes	No x	

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
Salix nigra	*Canopy*	*OBL*			
Alnus serrulata	*Shrub*	*FACW+*			
Carex sp.	*Herb*	*FACW*			
Juncus effusus	*Herb*	*FACW+*			
Microstegium vimineum	*Herb*	*FAC*			
Panicum sp.	*Herb*	*FAC*			
Festuca arundinacea	*Herb*	*FAC-*			

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-) 86

Remarks:

HYDROLOGY

Recorded Data (Describe in Remarks:)

- ___ Stream, Lake or Tide Gauge
- ___ Aerial Photographs
- ___ Other
- x No Recorded Data Available

Field Observations:

Depth of Surface Water: *0* (in.)

Depth to Free Water in Pit: *0* (in.)

Depth to Saturated Soil: *0* (in.)

Wetland Hydrology Indicators:

Primary Indicators:

- x Inundated
- x Saturated in Upper 12 inches
- x Water Marks
- ___ Drift Lines
- ___ Sediment Deposits
- x Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):

- x Oxidized Root Channels in Upper 12 in.
- x Water-Stained Leaves
- ___ Local Soil Survey Data
- ___ FAC-Neutral Test
- ___ Other (Explain in Remarks)

Remarks:

Community ID: *Wetland*
Transect ID:
Plot ID:

SOILS

Map Unit Name
(Series and Phase): *Ostin*

Taxonomy Subgroup:

Drainage Class:
Confirm Mapped Type?
___ Yes
x No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-4	*A*	*10 YR 3/2*			*silt loam*
4-16	*B*	*10 YR 4/2*			*sandy loam*

Hydric Soil Indicators:

___ Histosol
___ Histic Epipedon
___ Sulfidic Odor
___ Aquic Moisture Regime
x Reducing Conditions
x Gleyed or Low-Chroma Colors

___ Concretions
___ High Organic Content in Surface Layer in Sandy Soils
___ Organic Streaking in Sandy Soils
___ Listed on Local Hydric Soils List
___ Listed on National Hydric Soils List
___ Other (Explain in Remarks)

Remarks: *Oxydized Rhizospheres*

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	x Yes	___ No
Wetland Hydrology Present?	x Yes	___ No
Hydric Soils Present?	x Yes	___ No
Is this Sampling Point Within a Wetland?	x Yes	___ No

Remarks:

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site:	*Stone Mountain*	Date:	*04/20/2000*
Applicant/Owner:		County:	*Wilkes*
Investigation:	*Karen Hall*	State:	*NC*

	Yes	No
Do Normal Circumstances exist on the site?	x	
Is the site significantly disturbed (Atypical Situation)?		x
Is the area a potential Problem Area? (If needed, explain in remarks.)		x

Community ID: *Upland*
Transect ID:
Plot ID:

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
Juglans nigra	*Canopy*	*FACU*			
Prunus serotina	*Canopy*	*FACU*			
Liriodendron tulipifera	*Canopy*	*FAC*			
Cornus florida	*Subcan.*	*FACU*			
Microstegium vimineum	*Herb*	*FAC*			
Lonicera japonica	*Vine*	*FAC-*			
Vitis rotundifolia	*Vine*	*FAC*			

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-) 43

Remarks:

HYDROLOGY

Recorded Data (Describe in Remarks:)
- ____ Stream, Lake or Tide Gauge
- ____ Aerial Photographs
- ____ Other
- x No Recorded Data Available

Field Observations:

Depth of Surface Water: *>12* (in.)

Depth to Free Water in Pit: *>12* (in.)

Depth to Saturated Soil: *>12* (in.)

Wetland Hydrology Indicators:

Primary Indicators:
- ____ Inundated
- ____ Saturated in Upper 12 inches
- ____ Water Marks
- ____ Drift Lines
- ____ Sediment Deposits
- ____ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- ____ Oxidized Root Channels in Upper 12 in.
- ____ Water-Stained Leaves
- ____ Local Soil Survey Data
- ____ FAC-Neutral Test
- ____ Other (Explain in Remarks)

Remarks:

Community ID: *Upland*
Transect ID:
Plot ID:

SOILS

Map Unit Name (Series and Phase): *Rosman-Reddies Complex*

Drainage Class: ______
Confirm Mapped Type?
x Yes
___ No

Taxonomy Subgroup: ______

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
1-16	*A-B*	*7.5 YR 4/3*			*fine sandy silt loam*

Hydric Soil Indicators:

___ Histosol
___ Histic Epipedon
___ Sulfidic Odor
___ Aquic Moisture Regime
___ Reducing Conditions
___ Gleyed or Low-Chroma Colors

___ Concretions
___ High Organic Content in Surface Layer in Sandy Soils
___ Organic Streaking in Sandy Soils
___ Listed on Local Hydric Soils List
___ Listed on National Hydric Soils List
___ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present? ___ Yes x No
Wetland Hydrology Present? ___ Yes x No
Hydric Soils Present? ___ Yes x No
Is this Sampling Point Within a Wetland? ___ Yes x No

Remarks: