Greene Mitigation Site
Goose Creek, Mecklenburg County

Enhancement Plan

Prepared for the

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
STREAM MITIGATION PROGRAM

Transportation Improvement Project R-2420 B

Joseph H. Mickey, Jr.
Staci S. Hining

NORTH CAROLINA WILDLIFE RESOURCES COMMISSION

Division of Inland Fisheries

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Abstract.—This report details stream enhancement plans for 733 linear feet of Goose Creek known as the Greene site, Mecklenburg County, North Carolina. The enhancement plan is submitted as partial fulfillment of the off-site stream mitigation agreement between the North Carolina Department of Transportation (NCDOT) and North Carolina Wildlife Resources Commission (NCWRC) for the R-2420 B University Boulevard construction project, Mecklenburg County. The objectives of this project are to decrease streambank erosion by converting the unstable existing G4/F4 stream channel to a stable F4/C4 stream channel, to create a more stable floodplain at a lower elevation and to improve in-stream aquatic habitat. This is an Enhancement Level I mitigation category that generally includes improvements to the stream channel and riparian zone that restore dimension and profile. Other enhancement activities include placement of in-stream cover, reshaping and revegetation of selected streambanks.

The Goose Creek watershed in Mecklenburg and Union Counties represents one of two remaining North Carolina habitats of the federally endangered Carolina Heelsplitter mussel (*Lasmigona decorata*). As a result of concern for this species, the North Carolina Division of Water Quality (NCDWQ), North Carolina Wetlands Restoration Program (NCWRP), North Carolina Wildlife Resources Commission (NCWRC), United States Fish and Wildlife Service (USFWS), and Natural Resource Conservation Service (NRCS) have designated the entire Rocky River drainage, which includes Goose Creek, as a priority area for conservation and protection. Because of this concern, when the North Carolina Department of Transportation (NCDOT) proposed construction of University Boulevard and the I-485 corridor, United States Army Corps of Engineers (USCOE), NCDWQ and USFWS permit conditions required that NCDOT mitigate for project impacts by restoring degraded habitat in the Goose Creek watershed. The NCDOT then entered into a stream mitigation agreement in 1998 with the NCWRC to do the required stream mitigation. This plan is submitted as partial fulfillment of the off-site stream mitigation agreement between NCDOT and NCWRC for the R-2420 B project (I-485 outer loop). Under this agreement a total of 903 linear feet of stream mitigation is required by the USCOE (permit No.199830022) and NCDWQ (permit No. 3182). This plan documents existing conditions, objectives of the project and the proposed approach to stream enhancement (bank stabilization and habitat improvement) along 773 linear feet of Goose Creek known as the Greene site, Mecklenburg County (Figure 1).

Methods

Baseline conditions for Goose Creek at the Greene site were determined through field investigations and review of existing information. The geomorphology of the stream was classified using the Rosgen (1996) Level II classification system. Established stream mitigation restoration/enhancement guidelines were utilized for this project (USCOE et al. 2003; Doll et al. 2003; Rosgen 1996).

Morphology

Area topographical maps were used to determine stream drainage area and land use. Soil types for Mecklenburg County were obtained from United States Department of Agriculture, Natural Resource Conservation Service (1980) soil maps. Regional curve data was determined from Piedmont North Carolina stream data presented by Clinton et al. (1999), Harman et al.

(1999) and Doll et al. (2002). Cross-section geometry, longitudinal profile, and modified Wolman pebble count (Rosgen 1996) data was gathered during field surveys.

Representative riffle and pool cross-sections and longitudinal profile were measured using standard stream survey techniques (Harrelson et al. 1994). Cross-sections were positioned to illustrate stable and unstable characteristics of the channel. Measurements included all significant breaks in slope across the channel and important features including bankfull elevations, active floodplain, and stream terraces. The locations of each cross-section were plotted. Cross-section data was used to classify the stream type based on existing morphological features of the stream channel and valley type (Rosgen 1994, 1996).

The longitudinal profile was measured from established points along the thalweg of the stream channel located at the Greene site. The profile indicates the elevations of water surface, channel bed (thalweg), bankfull, and top of bank. Elevations and positions of stream defining characteristics (heads of riffles and pools, bedrock ledges, log jams, etc.) were located on this profile. Bankfull elevation was determined by regional curve data and by bankfull indicators including depositional features changes in bank angle, vegetation patterns, scour lines, and tops of point bars.

To determine quantitative composition of the bed material, modified Wolman pebble counts (Rosgen 1996) were taken at one or more riffle cross-sections. A representative reach pebble count (percentage of pools/riffles along the longitudinal profile) was also collected. Pebble count data was used to further classify a stream based on the median particle size of bed material (Rosgen 1994, 1996).

A search for reference reach streams used to assist in design formulations included only those streams within the Goose Creek watershed based on similarities in physiographic setting, channel slope, bedrock geology, and watershed size. Reference reaches were surveyed based on methods previously discussed.

Mussels

The federally endangered Carolina heelsplitter (*Lasmigona decorata*) is found in Goose Creek downstream of the project site. This species was historically known from several locations within the Pee Dee River system in North Carolina. However, the species' range has been seriously reduced by impoundments and the general deterioration of habitat and water quality due to siltation and other pollutants contributed by poor land use practices.

Conservation Easement

A conservation easement or a land purchase will be obtained along the stream corridor by NCDOT. The conservation easement/land purchase must have a minimum of 50 feet of riparian buffer along each bank measured from the bankfull elevation (USCOE et al. 2003).

Results

Goose Creek is a tributary to the Rocky River in the Yadkin River drainage in Mecklenburg and Union counties. The watershed area at the proposed project site is 3.15 mi^2. Land use consists of small farms containing pastures, forested areas, housing and commercial developments. The construction of the new I-485 corridor has resulted in this area being in transition from a rural to an urban landscape. Goose Creek upstream from this site has suffered from past and ongoing land disturbing activities including clearcutting, overgrazing of stream banks, channelization, and development. Streambank instability from poor riparian zone management and increased run-off is having a significant adverse effect on the stability of the stream's banks and channel. This bank instability is causing adverse water quality impacts through increased sedimentation from eroding streambanks.

Morphology

At the Greene site (Figure 1) the stream flows through a wide, gentle valley with a well developed floodplain (Valley Type VIII). Monacan (MO) soils are located along the stream corridor while Lignum gravelly silt loam (LgB) and Georgeville silty clay loam (GeD2) soils are found on the up slopes. The MO soils are somewhat poorly drained, nearly level soils on floodplains. The LgB soils are moderately well drained soils on low ridges (2 - 8% slope) and the GeD2 soils are well-drained soils on side slopes on the uplands (8 - 15% slope). All of these soils have low organic matter in the surface layer and moderate permeability. The GeD2 and LgB soils have a medium available water capacity, whereas MO soils have a high available water capacity with a slow surface runoff.

At this location, the riparian zone is intact along both banks with a mature bottomland forest consisting mainly of ironwood (*Carpinus caroliniana*), black walnut (*Juglans nigra*), sweetgum (*Liquidambar styraciflua*), sycamore (*Plantanus occidentalis*), and pine (*Pinus sp.*). One invasive exotic species, Chinese privet (*Ligustrum sinense*) dominates portions of the riparian zone and can impede colonization of beneficial native species.

The longitudinal profile survey determined that the site is 733 feet long and composed of 49% riffles and 50% pools (Figure 2). The stream has a sinuosity of 1.22. Bankfull was determined using field identified indicators, primarily a scour line and bar height, and using regional curve information (NCSU-Stream Restoration Institute). Bankfull was difficult to determine at many locations because of vertical, eroding stream banks (Appendix 1). Pebble count, pavement, and subpavement particle size data are summarized in Appendix 2. The bar material in riffles was considered medium gravel (D50 = 9.98 mm), whereas over the entire reach it was considered fine gravel (D50 = 5.70 mm). Cross-section dimension data is summarized in Figures 3.1 - 3.7. Based on data collected from riffle cross-sections 1+ 39 and 2+57 (Figures 3.1, 3.2), this reach of Goose Creek is classified as an unstable F4 and G4 stream type. These classifications indicate a stream that is entrenched and deeply incised in gentle terrain. Sediment supply in the F4 and G4 stream types is moderate to high, as indicated in the pebble count data with 19% sand in the riffle and 34% sand in the reach (Appendix 2). Stormwater channels enter Goose Creek from the left bank at stations 1+42, 3+23 and 6+72.

Channel incision has caused abandonment of the former floodplain as the channel continues to widen at its current elevation and develop new, lower point bars and floodplain surfaces inside the existing channel. The observed effects of vertical and lateral instability (Appendix 1) are primarily the combination of high streamflow energy and high available sediment supply. Severe bank erosion has resulted in many locations and where the channel is overly wide, deposition of fine sediments has occurred, creating some mid-channel bars and blanketing gravel bed materials. These types of activities are common in G and unstable F channels.

Riparian vegetation plays a marginal role in streambank stability due to the typically very high bank heights, which extend beyond the rooting depth of riparian vegetation. These stream types, especially G4, are very sensitive to watershed disturbance and tend to make significant adverse channel adjustments in response to changes in flow regimes and sediment supply.

It does not appear that this location was channelized in the past (sinuosity 1.22); however, there is evidence of past channelization up and downstream of this site. In all likelihood, this area was cleared 50-70 years ago and grazed by livestock. The degraded streambank and habitat conditions appear be the result of higher than normal flows created by upstream channelization, poor riparian zone management, and urbanization of the watershed.

Reference reach data (cross-sections, longitudinal profile, pebble counts) were collected from two locations. A total of 555 linear feet of Stevens Creek, located approximately 0.1 mile north of the I-485 crossing in Mecklenburg County (Appendix 3), were surveyed. Stevens Creek at this location has a drainage area 3.83 mi^2 and is classified as a G4c stream type (Rosgen 1996). A total of 657 linear feet of an unnamed tributary to Duck Creek, located west of the NC 218 crossing in Union County (Appendix 4), were surveyed. This unnamed tributary has a drainage area 2.64 mi^2 and is classified as an E4 stream type (Rosgen 1996). Dimensionless ratios of measurements taken from the reference reaches were compared with information taken from the project site. This information was also compared with the N.C. piedmont regional curve data (Doll et al. 2002). Information collected will be used in the design of this Priority 2 streambank stabilization and habitat enhancement project.

Mussels

The federally endangered Carolina heelsplitter mussel has not been found at this site. Mussel species found at the site include Carolina creekshell (*Villosa vaughaniana),* a federal species of concern and state endangered, *Elliptio* sp. and the introduced the Asian clam (*Corbiculla fluminea*) (M. Folkes, R. Heise, North Carolina Wildlife Resources Commission, personal communication).

Conservation Easement

For piedmont streams, a permit condition requires that the stream restoration or enhancement project have a 50 foot riparian corridor; both banks, placed in a conservation easement (CE). At this site, NCDOT purchased the entire left bank (looking downstream) stream corridor, approximately 773 feet and 3.47 acres, known as the Greene property. Along the right bank NCDOT purchased approximately 440 feet of stream frontage (1.58 acres) known as the

Gabbard property and obtained a 50 foot wide easement (0.47 acres) along approximately 330 feet of stream frontage along the Tyndall property. Right-of-way access to the easement by NCWRC personnel will be from Country Woods Drive (SR 4220), just before the culvert crossing Goose Creek. A copy of the property deeds for the Greene and Gabbard property and the Tyndall signed CE are found attached to this document titled "Easements and land purchases for the Greene mitigation site, Goose Creek, Mecklenburg County, N.C.".

Site Recommendations

The objectives of this project are to decrease streambank erosion by converting the unstable existing G4/F4 stream channel to a stable F4/C4 stream channel, to create a more stable floodplain at a lower elevation and to improve in-stream aquatic habitat. This is an Enhancement Level I mitigation category (USCOE et al. 2003) that generally includes improvements to the stream channel and riparian zone that restore dimension (cross-section) and profile (channel slopes). This category may also include other appropriate practices that provide improved channel stability, water quality, and stream ecology.

Stream enhancement

Figures 4.1 - 4.7 show the existing condition and the design and dimensions at established cross -sections. Design parameters are given in Table 2. Because of the existing sinuosity of 1.22 and to prevent damage to mature vegetation along the stream corridor, no change in pattern is planned. Design considerations based on the reference reach streams (Appendix 3, 4) were difficult since these streams were classified as E4/G4c. Design considerations were, therefore, based on professional judgement and the most stable characteristics of the reference reaches and stable sections of the existing F4/G4 channel.

Table 3 summarizes the location of proposed in-stream structures and bank stabilization improvements. Rock weirs, rock vanes, log vanes, and root wad structures (Appendix 5.1, 5.2, 5.3) will be used to reduce the near bank stress and direct flows towards the center of the stream. These structures will also improve in-stream aquatic habitat and provide long-term bank stability. Selected eroding streambanks will be graded on a 1.5:1 or 2:1 slope, whereas other areas will be graded to create a point bar to create a bankfull or floodplain bench (Appendix 5.4). The purpose of this activity is to reduce streambank erosion and create an area for bank re-vegetation. Stormwater channels at stations 1+42 (Figure 3.1), 3+23, and 6+72 are headcutting and will have to be stabilized with step-pool rock structures (Appendix 5.5). This work will have to be coordinated with the DOT stormwater proposal for these areas (Gilmore 2001, North Carolina Department of Transportation, letter communication).

Rock for vanes and weirs will be hauled from a local quarry. Rock vanes and weirs will constructed according to standard guidelines (Appendix 5.1, 5.2). Footer rocks will be placed approximately 2 feet below the normal stream bottom where bedrock is not encountered. Rock size will vary from approximately 500 pounds (4 ft^3) up to 1250 pounds (9 ft^3). Root wads and logs will be obtained from trees removed for construction access or streambank improvements. Root wads will be used to protect the outside of meanders and provide in-stream cover.

Structures will be built by a track-hoe with a thumb working from the top of the bank or from within the channel, if necessary.

In general, the degraded conditions associated with this mitigation site are the result of bank erosion where the channel is overly wide, resulting in some aggradation and unusual bar formation at some locations in the channel. In an attempt to stabilize itself, the channel has begun the process of point bar formation at some locations. We have evaluated the competency of the proposed channel to insure that sediment transport problems will not be created by this project (Table 4). The design maximum bankfull depth should allow sufficient shear stress to move the larger particles during bankfull events. The shear stress at the riffle was evaluated using Shields curve to insure that flows in the proposed channel could move the D_{84} pavement particle size of 145 mm (Appendix 2.1). The bankfull shear stress of 0.53 lb/ft^2 is able to move, on average, a particle of 175-180 mm. The shear stress in the proposed channel will move the D_{84} particles; therefore, the proposed bank stabilization activities are competent and the channel will be able to move its bed load.

Riparian Improvements

The current floodplain terrace contains a mature forest canopy with an understory of Chinese privet hedge. The mature forest canopy provides stream shading along this site that helps maintain cooler water temperatures during the summer months. At some locations, the rooting depth of existing vegetation is deep enough to provide long-term bank stability. However, at many locations vertical banks continue to undermine existing trees that contribute to streambank failure and increased sedimentation.

The riparian zone will be improved with a number of practices. Disturbed streambank sites will be shaped to approximately 1.5:1 or 2:1 slope. Bank sloping should reduce undercutting, improve the ability of vegetation growth to cover the slope and increase the stability of the bank. This will allow the water to rise along the sloped surface rather than eroding a vertical bank. After the streambank has been sloped it will be reseeded with brown top millet or winter wheat/rye (1 lb/1000 ft^2) and with a NCWRC native all-purpose grass/wildflower seed mix (10 lb/acre). Woody vegetation, including live stakes and rooted trees will be planted along all disturbed areas. Understory growing native woody species such as tag alder (*Alnus serrulata*), silky willow (*Salix sericea*), silky dogwood (*Cornus amomum*), and elderberry (*Sambucus canadensis*) will be planted along sloped streambanks. On the upper banks native trees that provide shade, bank stability, and cover and food for wildlife will be planted. Woody plantings will be at the rate of 320 stems per acre as per NCDWQ guidelines (USCOE et al. 2003). The exotic invasive species, Chinese privet, will be cut and stumps treated with a solution of glyphosate (North Carolina Botanical Garden 2001).

Mussels

Before any construction takes place, the site will be surveyed for mussels by qualified personnel (NCWRC, USFWS, private consultant). All mussels will be identified and relocated out of the project site into similar habitat. If mussels are found during construction, work will be

halted and the area searched for additional specimens. An attempt will be made to identify the mussels and they will be relocated out of the project site.

Livestock Exclusion

An important part of any stream mitigation plan is the exclusion of livestock from the riparian buffer of the stream within the conservation easement boundaries. At this site a livestock exclusion plan is not required since the site is owned by NCDOT, except for the Tyndall property which has a 50 foot conservation easement buffer and the area is not used for livestock grazing.

Erosion Control

Equipment access will be along the left bank (facing downstream) from Country Woods Drive (SR 4220). A stable construction entrance consisting of surge stone will be constructed. A section of the existing guardrail will be removed by NCDOT for this access. One stream crossing (ford) for moving equipment over the channel will be constructed just above cross-section 1+39. Movement of equipment along streambanks will be on designated passageways located inside the easements. During construction, equipment will only access the stream when absolutely necessary. For this project, it is anticipated that all track hoe work can be accomplished from the top of the bank. However, equipment may be in the stream during the construction when no other construction alternative exists.

All construction materials including rock, root wads, logs, and erosion control materials will be stockpiled at a central location at the site. To limit disturbance of soils, all equipment will travel along identified travel corridors. Less than 0.5 acres of streambank construction will be done at one time. Disturbance of soils will be limited to only what work can be accomplished and stabilized on a daily basis. As a structure is completed, the site will be graded and seeded. Once the streambanks are sloped, they will be fertilized, limed and hand seeded. All bare disturbed soils will be seeded with a temporary ground cover of millet, barley, rye, or winter wheat. Streambanks will be permanently seeded with a native riparian seed mix. After seeding, the surface of the sloped bank will be covered with excelsior erosion control matting and anchored in place with wooden survey stakes and landscape staples. Disturbed areas on level ground will be seeded and mulched with straw. Stockpiled soils within 50 feet of flowing water will be surrounded on the down-slope side by a silt fence. High ground areas where soil is disposed of will be graded, seeded, and mulched as soon as soil moving is completed.

Spill Containment

All equipment supplied by the contractor must be in good working order and should not be leaking any fluids that could contaminate the stream or property. In case of an accidental spill of hazardous materials (hydraulic fluids, gas, oil) two Attack Pac emergency spill kits will be on site during construction. Any spills of hazardous materials will be cleaned up immediately with contaminated soils disposed of according to state regulations.

Monitoring

Once the project is complete an as-built survey will be completed. Future monitoring surveys can then be compared to the as-built survey to note if the channel is stable or moving towards an unstable condition. Environmental components monitored at this site will be those that allow an evaluation of channel stability and riparian improvements. Monitoring will be conducted for five years after construction and will follow the "Stream Mitigation Guidelines" for monitoring developed by the USCOE, NCDWQ, NCWRC and U.S. Environmental Protection Agency (2003) for Enhancement Level I projects. It is expected that biological monitoring will not be required at this site.

Conclusion

Past disturbances have impacted aquatic and riparian habitat along Goose Creek. Through this Enhancement Level I project the stream can be improved to resemble a more natural stream environment. Water quality will be improved through reduced sedimentation and aquatic and wildlife habitat will be improved with the return of a functioning riparian corridor.

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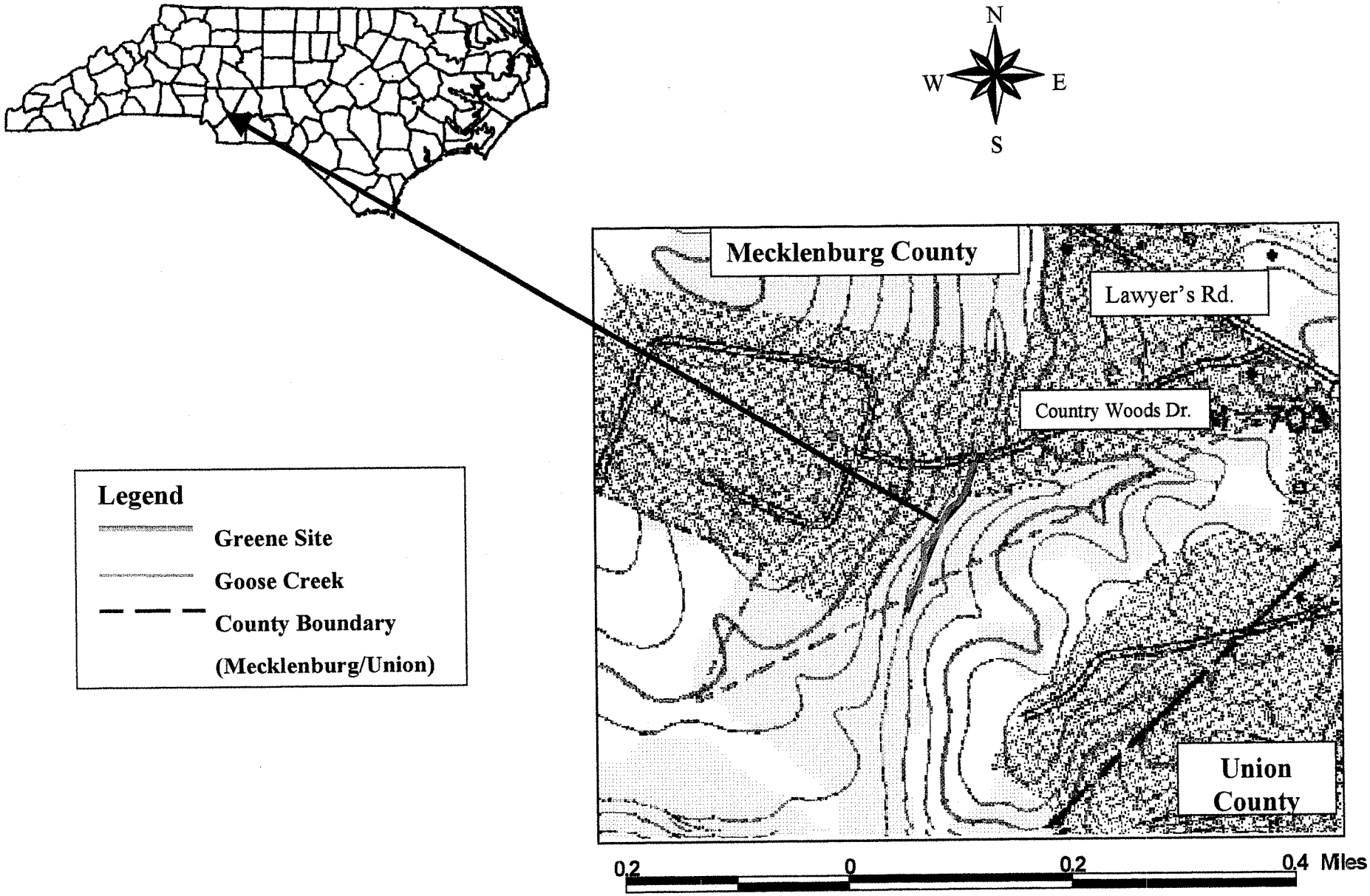


FIGURE 1. Greene site map. Goose Creek. Mint Hill, Mecklenburg County. 2003.

FIGURE 2. Longitudinal profile, Greene mitigation site, Goose Creek, Yadkin drainage, Mecklenburg County, January 2003.

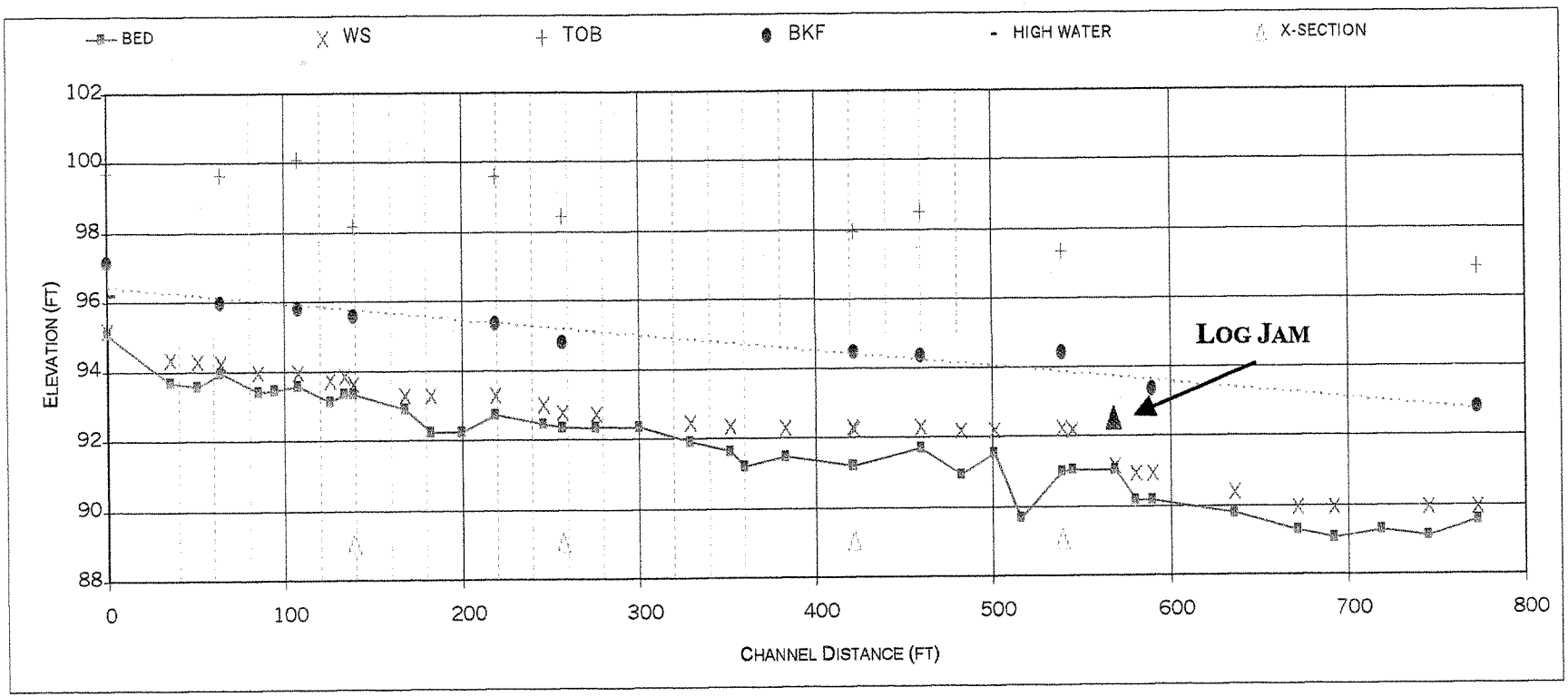


FIGURE 3. Four pre-construction cross-sections for the Greene mitigation site, Goose Creek, Yadkin drainage, Mecklenburg County, January 2003.

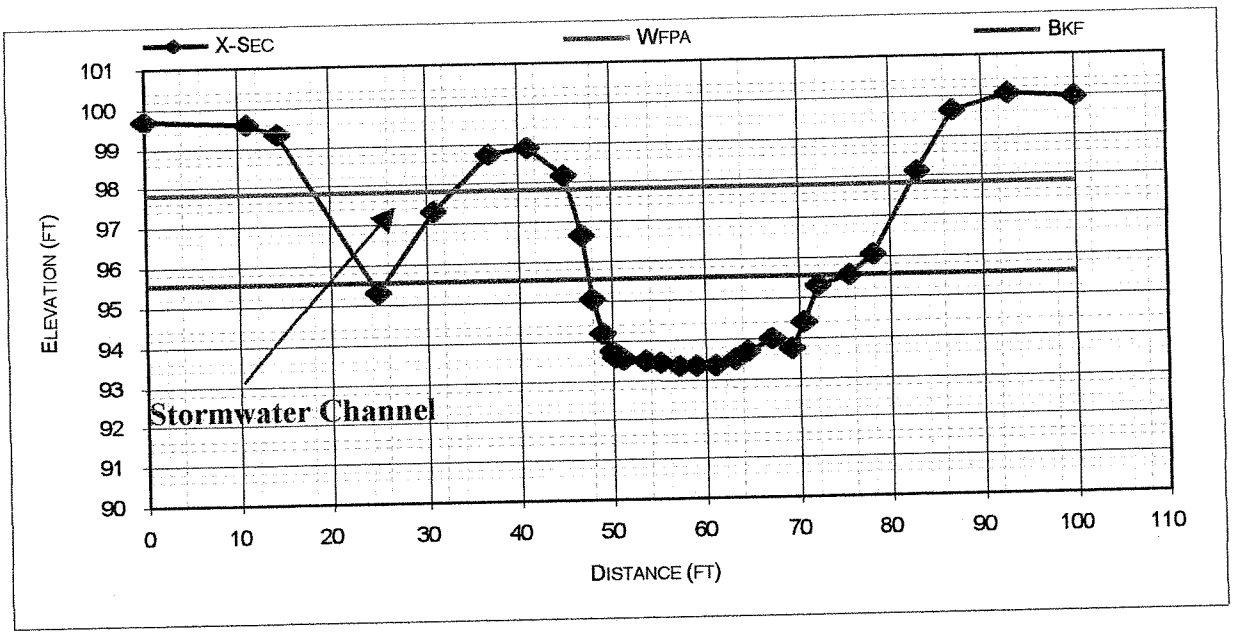


FIGURE 3.1. Cross-section station 1+39, riffle.

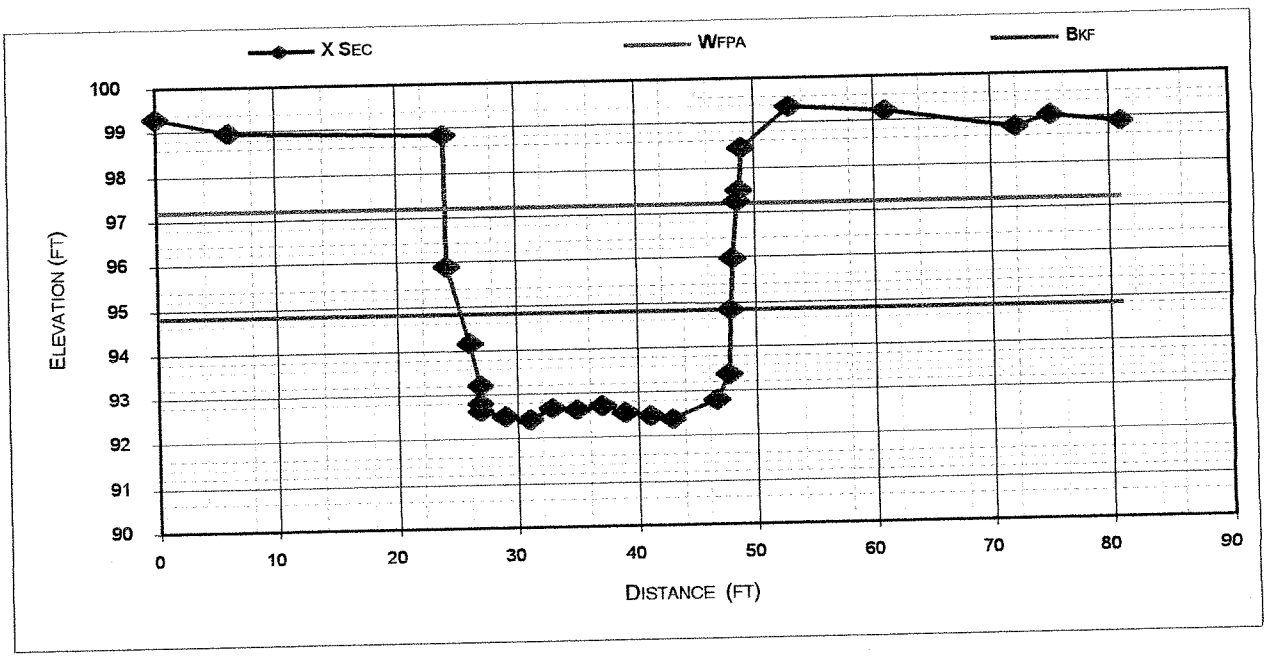


FIGURE 3.2. Cross-section station 2+57, riffle.

FIGURE 3. Continued.

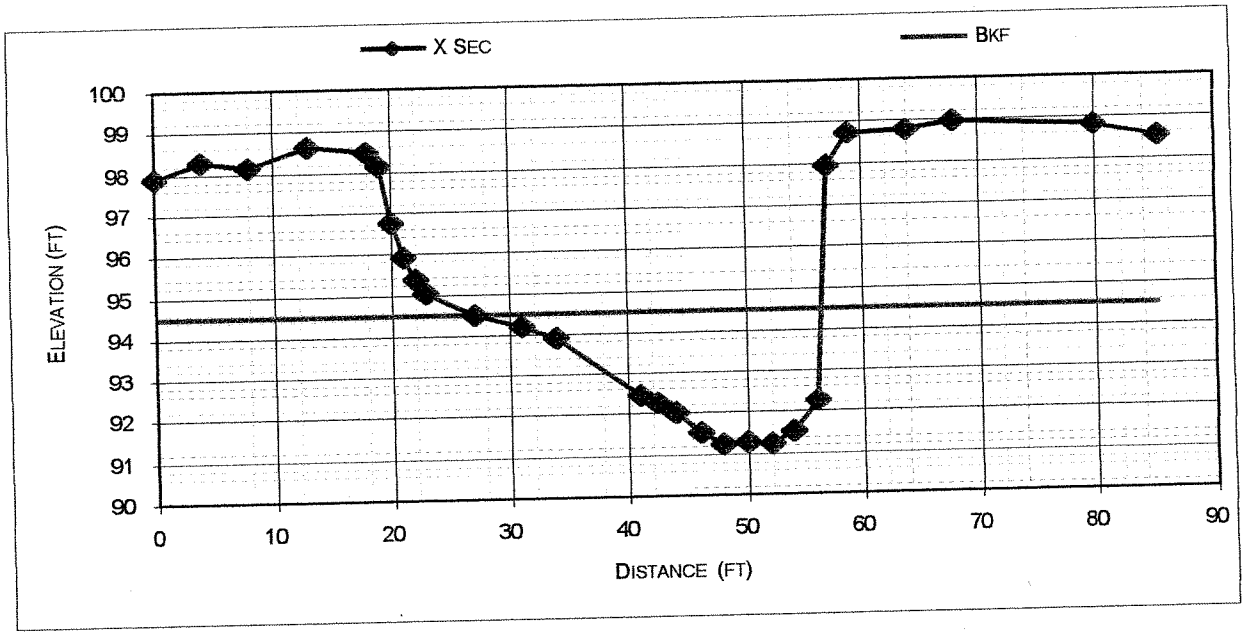


FIGURE 3.3. Cross-section station 4+22, pool.

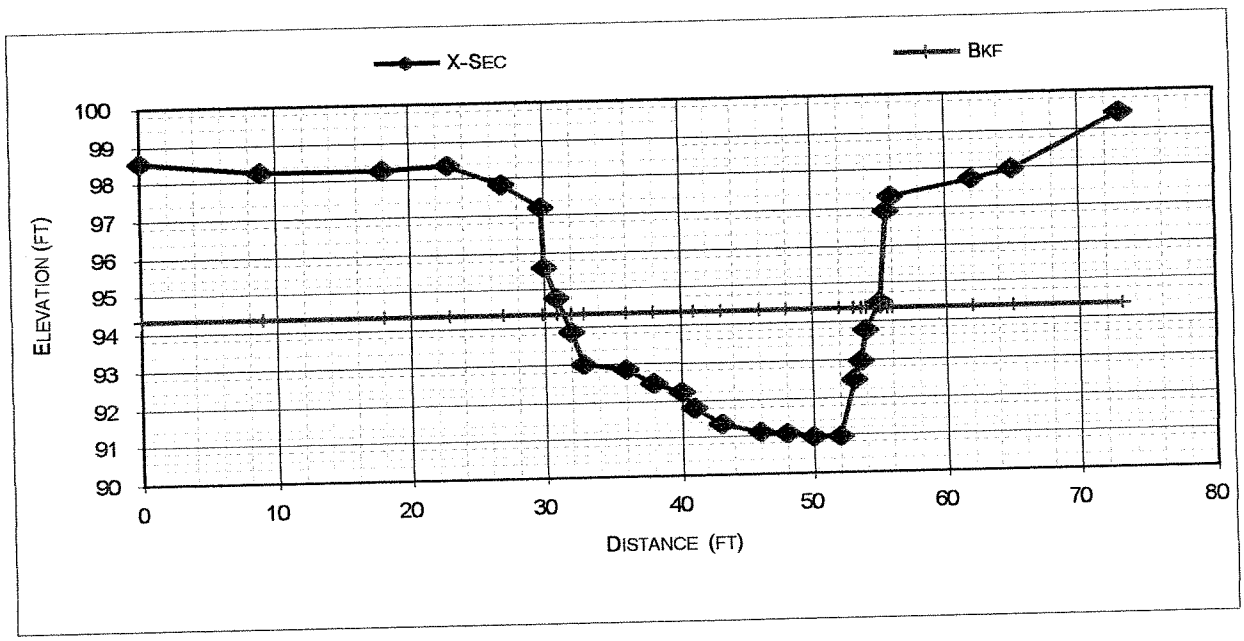


FIGURE 3.4. Cross-section station 5+39, pool.

FIGURE 4. Design cross-sections. Greene Site, Goose Creek, Yadkin drainage, Mecklenburg County, January 2003.

2+57	Feature	Type	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Riffle	G	24	25.5	48.1	94.80	22.6	2.1	10.8	47.1	2.4	1.1
Design	Riffle	F	24	25.5	48.1	94.80	22.6	1.8	12.4	41.2	2.4	1.1

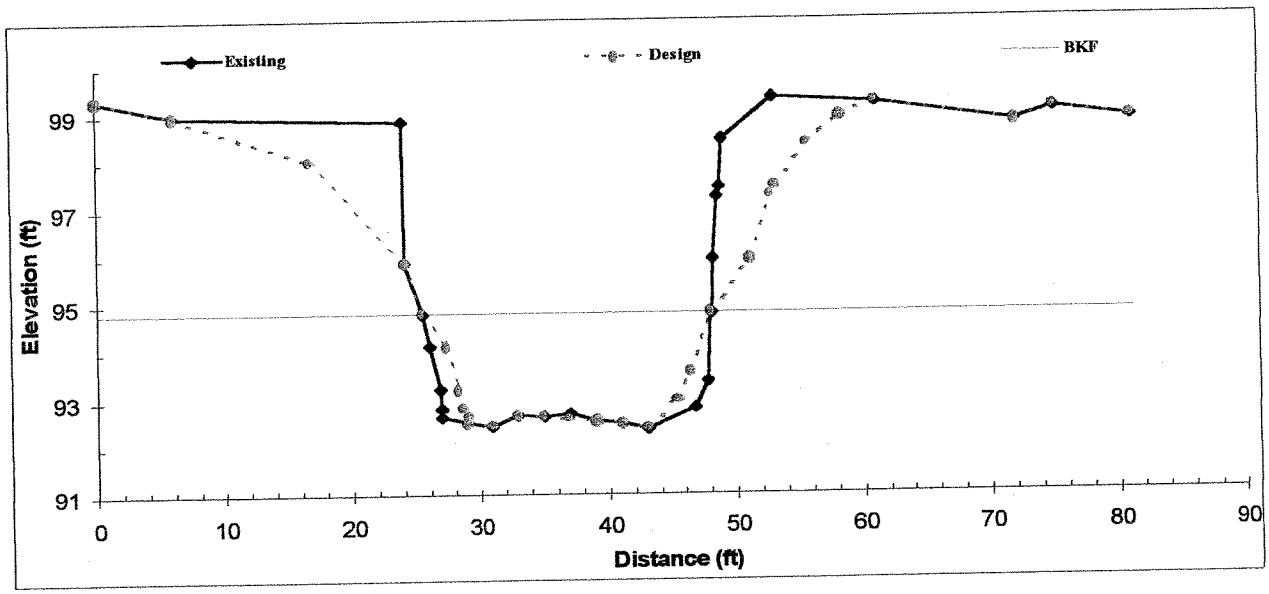


FIGURE 4.1 Cross-section station 2+57, riffle.

4+22	Feature	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Pool	37	27.0	56.5	94.47	29.5	1.8	16.4	53.2	3.3	1.3
Design	Pool	37	27.0	56.5	94.47	29.5	1.8	16.4	53.2	3.3	1.3

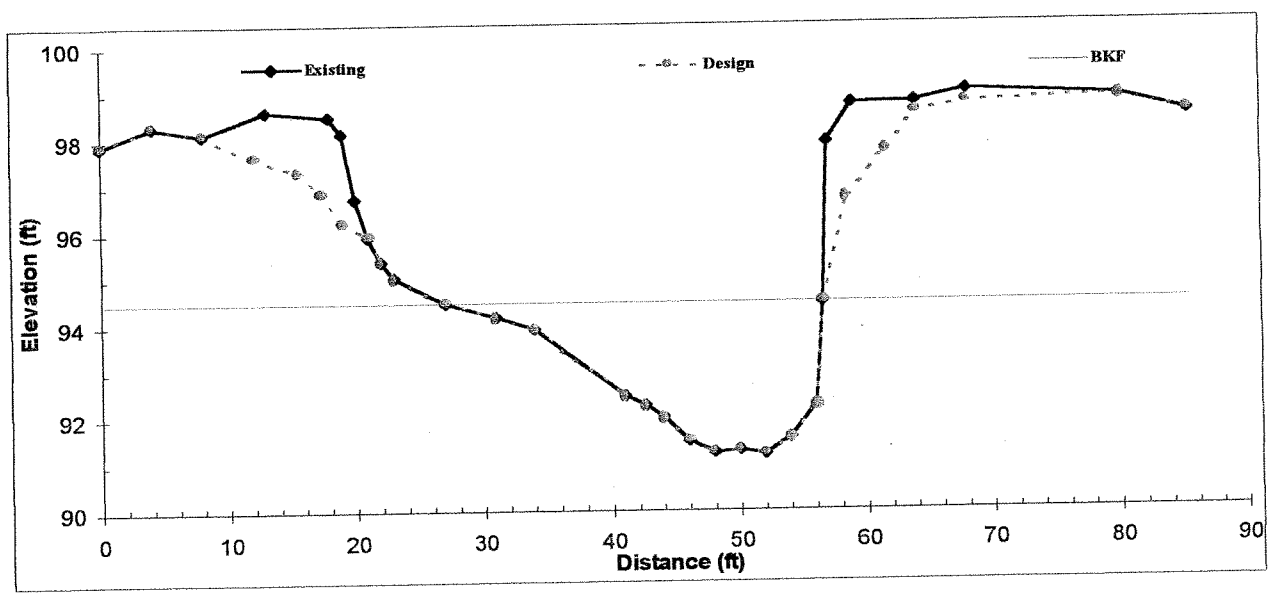


FIGURE 4.2 Cross-section station 4+22, pool.

FIGURE 4. Continued.

5+39	Feature	Wfpa	LBKF	RBKF	ELEVbkf	Wbkf	Dbkf	W/D	Abkf	Dmax	ER
Existing	Pool	37	31.3	54.9	94.37	23.6	2.3	10.3	54.2	3.4	1.6
Design	Pool	37	31.3	54.9	94.37	23.6	2.2	10.6	52.3	3.4	1.6

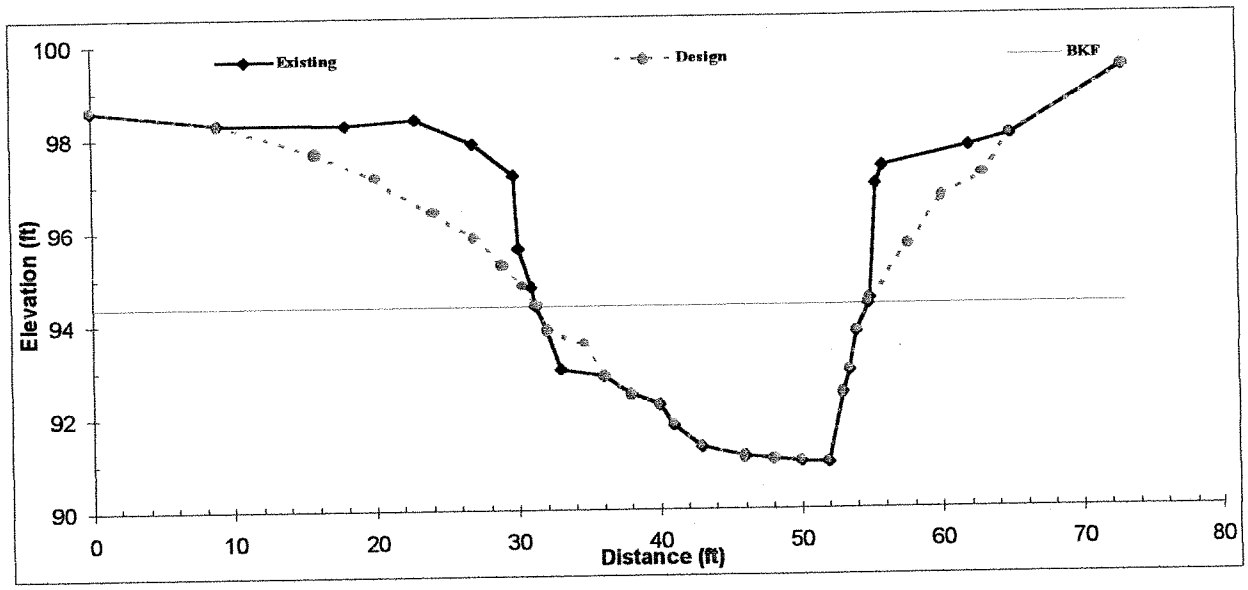


TABLE 1. Feature lengths and slopes. Greene Site, Goose Creek, Yadkin drainage, Mecklenburg County, January 2003.

Feature	Elevation	elev diff	Station	Distance	Riffle Lengths	Pool Lengths	R elev diff	P elev diff	R slope	P slope	P-P spacing
HOR	94.78	-0.51	0	31	31		-0.51		0.0165		
HOP	94.27	-0.02	31	14		14		-0.02		0.0014	
HOR	94.25	-0.06	45	8	8		-0.06		0.0075		22
HOP	94.19	-0.01	53	16		16		-0.01		0.0006	
HOR	94.18	-0.38	69	48	48		-0.38		0.0079		64
HOP	93.8	0.03	117	7		7		0.03		0.0043	
HOR	93.83	-0.09	124	8	8		-0.09		0.0112		15
HOP	93.74	0	132	6		6		0		0.0000	
HOR	93.74	-0.2	138	42	42		-0.2		0.0048		48
HOP	93.54	0	180	68		68		0		0.0000	
HOR	93.54	-0.07	248	35	35		-0.07		0.0020		103
HOP	93.47	-0.01	283	185		185		-0.01		0.0001	
HOR	93.46	0.07	468	28	28		0.07		0.0025		213
HOP	93.53	-0.1	496	59		59		-0.1		0.0017	
HOR	93.43		555								
Minimum					8.00	6.00			0.0020	0.0000	15.00
Average					28.57	50.71			0.0075	0.0012	77.50
Maximum					48.00	185.00			0.0165	0.0043	213.00

TABLE 2. Stream reach data for Goose Creek, Stevens Creek, Duck Creek, design data and regional curve data, Mecklenburg and Union counties, 2003.

Stream Name: Goose Creek Date: 1/13/03
Basin Name: Yadkin Drainage: 2016 Ac. 3.15 Mi^2
Location: Greene stream mitigation site, south of the SR 4220 (Country Woods Drive) Culvert crossing over Goose Creek. Mint Hill
Observers: J. H. Mickey, S. S. Hining, NCWRC-Stream Mitigation

			Reference Reaches			
Measurement	X-Section 1+38	X-Section 2+57	Stevens Creek	Duck Creek	Design	Regiona curve data
Bankfull width (ft):	28	22.6	25	20	20-23	21
Mean depth (ft):	1.6	2.1	2.1	2	2	2.2
Bankfull X-sectional area (ft^2):	45.3	47.1	53.5	40.3	46-50	46-48
Width / Depth ratio:	17.2	10.8	11.6	10	>12	
Maximum depth(ft):	2.2	2.4	3.1	2.8	2.3	
Width of Flood-Prone Area (ft):	38	24	38	100	50	
Entrenchment ratio:	1.4	1.1	1.50	5	>2.2	
Channel Materials D50 (mm):	8.3	8.3	10.4	11.9	10	
Water surface slope:	0.0068	0.0068	0.0024	0.003	0.0068	
Channel sinuosity:	1.22	1.22	1.43	1.4	1.22	
Stream type:	F4	G4	G4c	E4	C4[a]	

[a]Some channel improvements will represent a C channel whereas other areas will remain a F channel type.

TABLE 3. Location of in-stream structures and bank stabilization improvements, Greene site, Goose Creek, Mecklenburg County, January 2003

Location (Stn. #)[a]	Existing in-stream feature	Proposed Improvements	Remarks
1+40	tributary entering from the left bank that is headcutting into terrace	head cut needs to be stabilized with step pools	tributary headcut is eroding back towards abandoned terrace, needs to be stabilized.
1+40	riffle	rock weir	needed to help protect stream banks and UT confluence that enters from left.
1+80	pool at bend	rock vane/bank sloping revegetation	install rock vane to help protect left bank which is eroding, slope bank and stabilize.
2+18 - 2+71	riffle/run/ complex	2 rock weirs and slope banks revegetation	use rock weirs and bank sloping to stabilize eroding right bank, see photo A1.2.
2+46 - 2+94	riffle/run complex	bank sloping/revegetation	stabilize eroding left bank
2+66	riffle/run complex	rock weir	use rock weir to maintain bank stabilization and create habitat
3+00	riffle	rock vane	install rock vane to help protect bank
3+23 - 3+75	riffle	2 rock vanes and slope banks rework point bar and remove downed tree	use rock weirs and bank sloping to stabilize eroding bank, reconstruct point bar, see photo A1.3.
4+01 - 4+54	pool	2 rock vanes and slope banks	eroding right bank needs sloping and revegetation. Rock vanes to help protect banks and create in-stream habitat.

TABLE 3. Continued.

Location (Stn. #)	Existing in-stream feature	Proposed Improvements	Remarks
4+82 - 5+05	pool	slope right bank and install rock vane at station 5+01	eroding right bank needs sloping and revegetation.
5+01	pool	rock vane	Rock vane used to protect bank and create instream habitat.
5+05 - 5+68	pool	slope right bank and add rock vane, slope left bank and make a point bar.	eroding banks need sloping and stabilization with rock vane and created point bar. See photo A.1.6 & A1.7.
5+05	pool	root wads	use root wads to help stabilize eroding banks.
5+68	pool	root wads	use root wads to help stabilize eroding banks.
5+68 - 6+76	pool/riffle	2-3 rock vanes and slope right bank	use rock vanes and bank sloping to eliminate vertical, eroding banks. See photo A1.7.
6+92 - 7+45	pool/riffle	slope left bank	slope and stabilize left bank.

[a]Note that all structures are at approximate locations since stream conditions may have changed by time of construction. Structure type could change due to adjustments made to stream conditions at time of construction.

TABLE 4. Sediment transport calculations: Greene site, Goose Creek, Mecklenburg County, January 2003.

Bankfull mean depth (ft)	1.81
Bankfull mean width (ft)	25.5
Bankfull cross-sectional area (ft)	46.2
Hydraulic radius	1.8
D50 pavement (mm)	136.2
D50 subpavement (mm)	11.7
Largest particle from pavement (mm)	150
Largest particle from subpavement (mm)	62
Water surface slope (ft/ft)	0.00479
Critical dimensionless shear stress	0.00981
Bankfull shear stress movable particle size (mm)	175
Depth to move the largest particle from subpavement (ft)	0.67
Slope required to move the largest particle from subpavement (ft/ft)	0.0018
Bankfull shear stress (lb/ft^2)	0.53
Shields curve to find bankfull shear stress movable particle size (mm):	180

Appendix 1. Greene site pictures, Goose Creek, Mecklenburg County, January 2003.

A1.1. Cross-section 1+39, looking downstream, 01-13-03.

A.1.2. Cross-section 2+57, looking downstream, 01-13-03.

A.1.3. Cross-section 3+60, looking upstream, 01-13-03.

A.1.4. Cross-section 4+22, looking upstream, 01-13-03.

Appendix 1. Continued.

A.1.5. Cross-section 4+22, looking downstream, 01-13-03.

A.1.6. Cross-section 5+39, looking upstream, 01-13-03.

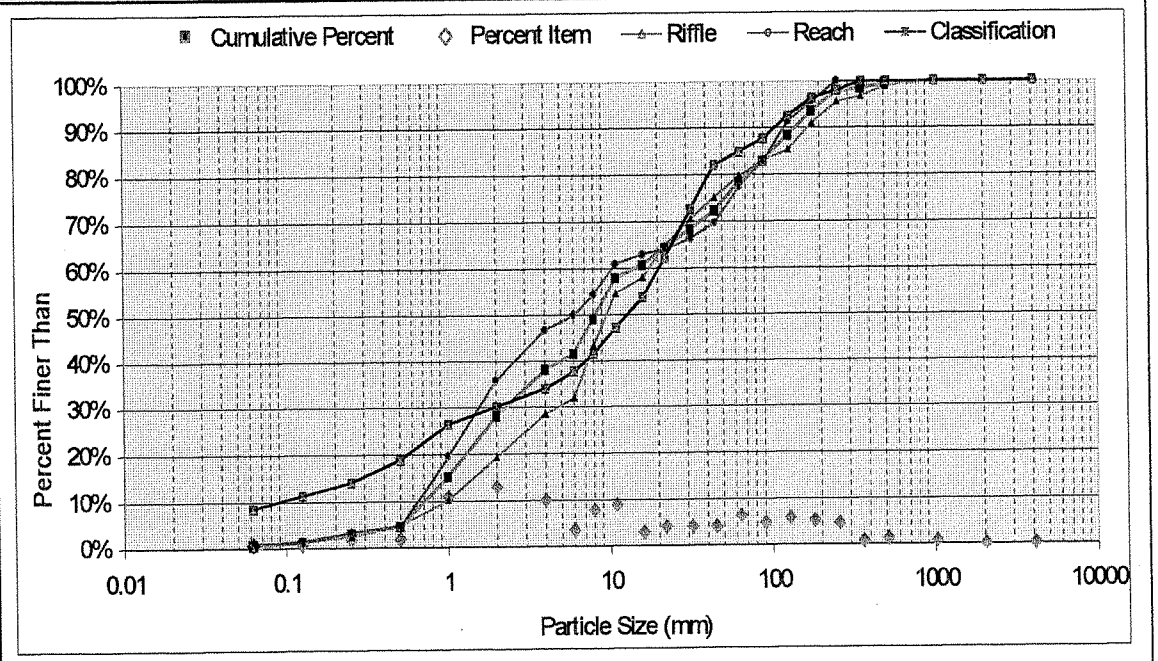
A.1.7. Cross-section 5+68, looking downstream, 01-13-03.

Appendix 2. Sediment transport data. Greene Site, Goose Creek, Yadkin drainage, Mecklenburg County, January 2003.

Percent Riffle:	49	Percent Run:	
Percent Pool:	51	Percent Glide:	

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	0.5	# #
very fine sand	0.062	0.13	0.5	# #
fine sand	0.13	0.25	1.5	# #
medium sand	0.25	0.5	1.5	# #
coarse sand	0.5	1	9.7	# #
very coarse sand	1	2	11.6	# #
very fine gravel	2	4	9.1	# #
fine gravel	4	6	3.0	# #
fine gravel	6	8	7.0	# #
medium gravel	8	11	8.0	# #
medium gravel	11	16	2.5	# #
coarse gravel	16	22	3.5	# #
coarse gravel	22	32	3.5	# #
very coarse gravel	32	45	3.5	# #
very coarse gravel	45	64	5.6	# #
small cobble	64	90	4.0	# #
medium cobble	90	128	5.1	# #
large cobble	128	180	4.5	# #
very large cobble	180	256	4.0	# #
small boulder	256	362	0.5	# #
small boulder	362	512	1.0	# #
medium boulder	512	1024	0.5	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			9.5	#
		Weighted Count:	100	
		True Total Particle Count:	306	

	Goose Creek
	Yadkin/Pee Dee
	Mint Hill
Note:	



Size percent less than (mm)				
D16	D35	D50	D84	D95
1.049	3.25	8.3	97	204

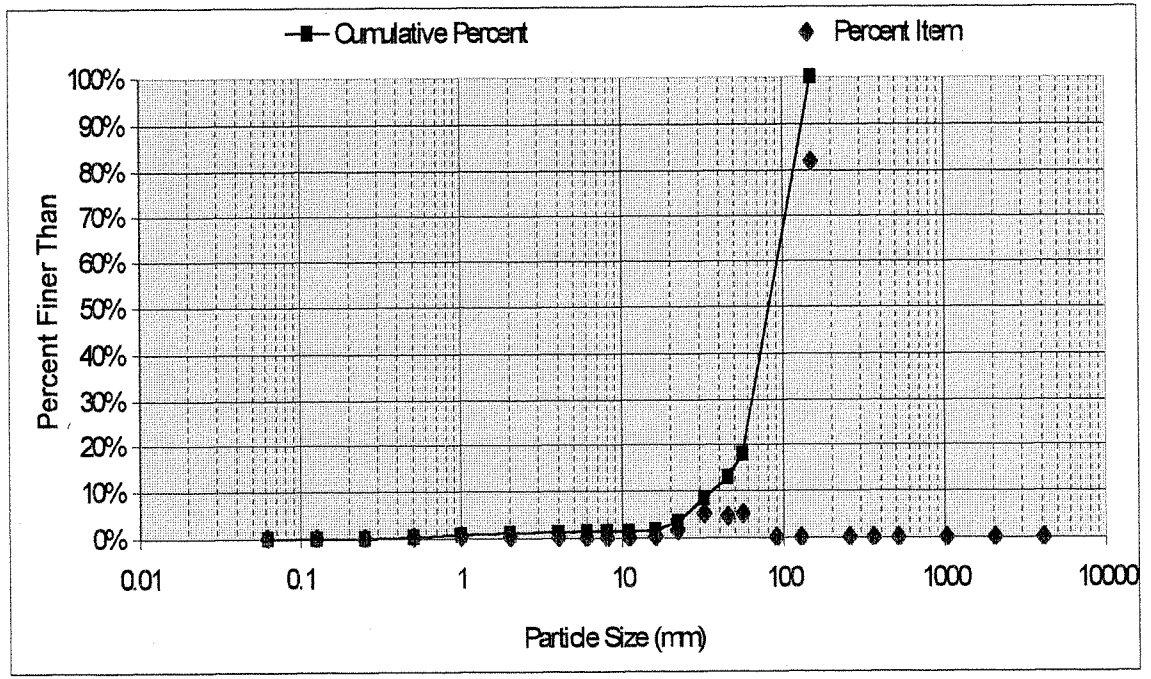
Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
1%	25%	46%	18%	2%	9%

A.2.1 Weighted pebble count data.

Appendix 2. Continued.

Material	Size Range (mm)		Count	
silt/clay	0	0.062	0.001	#
very fine sand	0.062	0.13	0.01	#
fine sand	0.13	0.25	4	#
medium sand	0.25	0.5	16	#
coarse sand	0.5	1	30	#
very coarse sand	1	2	24	#
very fine gravel	2	4	10	#
fine gravel	4	6	1	#
fine gravel	6	8	1	#
medium gravel	8	11	3	#
medium gravel	11	16	23	#
coarse gravel	16	22	113	#
coarse gravel	22	32	362	#
very coarse gravel	32	45	310	#
very coarse gravel	45	56	346	#
small cobble	64	90		#
medium cobble	90	128		#
large cobble	128	150	5594	#
very large cobble	180	256		#
small boulder	256	362		#
small boulder	362	512		#
medium boulder	512	1024		#
large boulder	1024	2048		#
very large boulder	2048	4096		#
bedrock				#
		Total Particle Count:	6827.011	

	Goose Creek
	Yadkin/Pee Dee
	Mint Hill
Note:	Largest Particle: 150mm,5594g; 2nd largest: 56mm,139g



Size percent less than (mm)				
D16	D35	D50	D84	D95
51.235	132.27	136.2	145	149

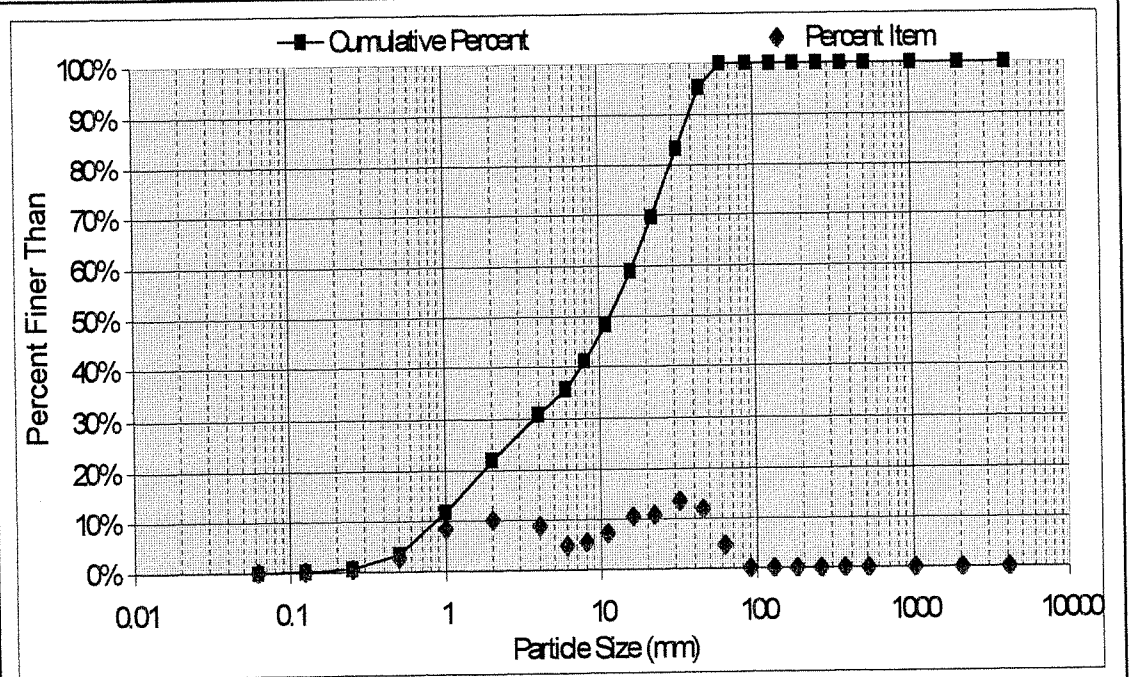
Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
0%	1%	17%	82%	0%	0%

A.2.2 . Pavement sample.

Appendix 2. Continued.

Material	Size Range (mm)		Count	
silt/clay	0	0.062	9	#
very fine sand	0.062	0.13	25	#
fine sand	0.13	0.25	85	#
medium sand	0.25	0.5	476	#
coarse sand	0.5	1	1446	#
very coarse sand	1	2	1730	#
very fine gravel	2	4	1511	#
fine gravel	4	6	834	#
fine gravel	6	8	935	#
medium gravel	8	11	1250	#
medium gravel	11	16	1819	#
coarse gravel	16	22	1854	#
coarse gravel	22	32	2335	#
very coarse gravel	32	45	2058	#
very coarse gravel	45	62	812	#
small cobble	64	90		#
medium cobble	90	128		#
large cobble	128	180		#
very large cobble	180	256		#
small boulder	256	362		#
small boulder	362	512		#
medium boulder	512	1024		#
large boulder	1024	2048		#
very large boulder	2048	4096		#
		Total Particle Count:	17179	

	Goose Creek
	Yadkin/Pee Dee
	Mint Hill
Note:	Largest particle: 62mm|190g; 2nd 55mm|173g

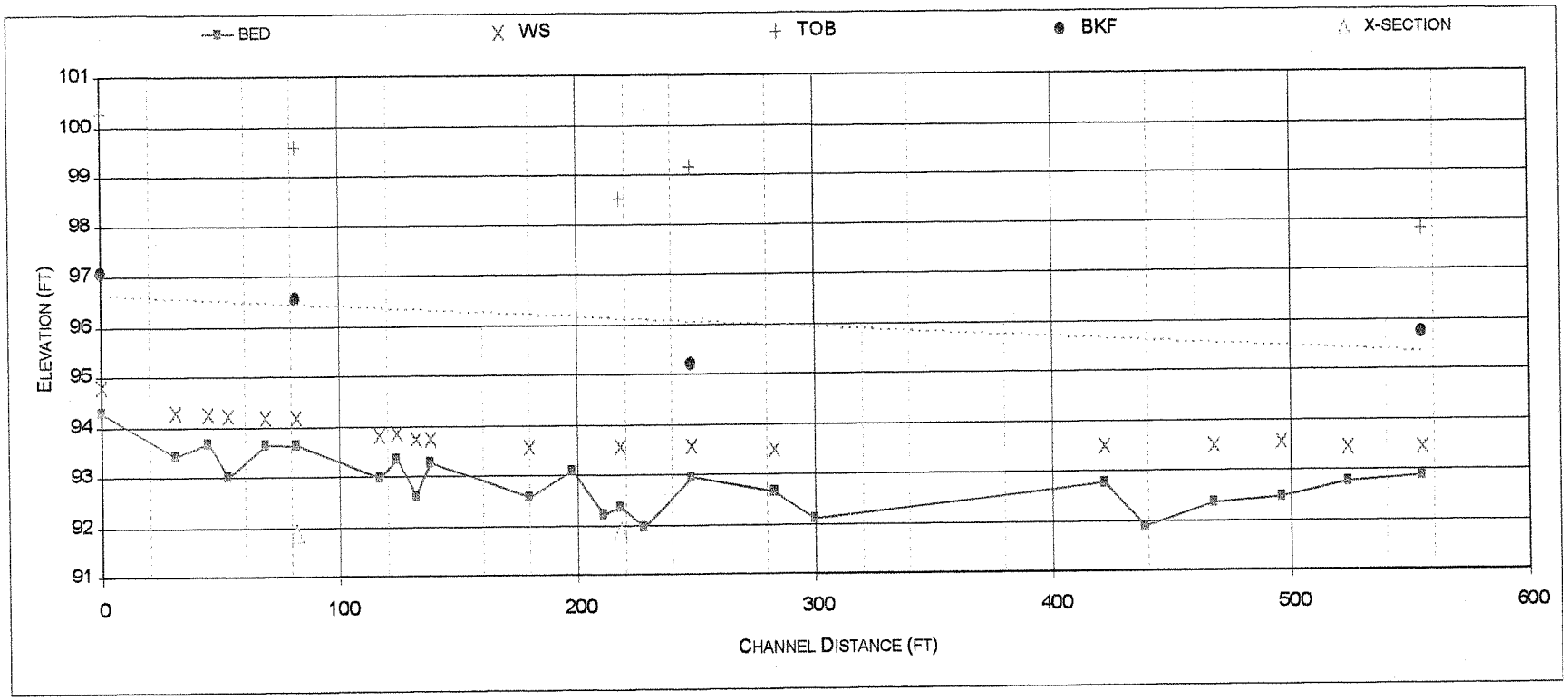


Size percent less than (mm)				
D16	D35	D50	D84	D95
1.328	5.71	11.7	33	45

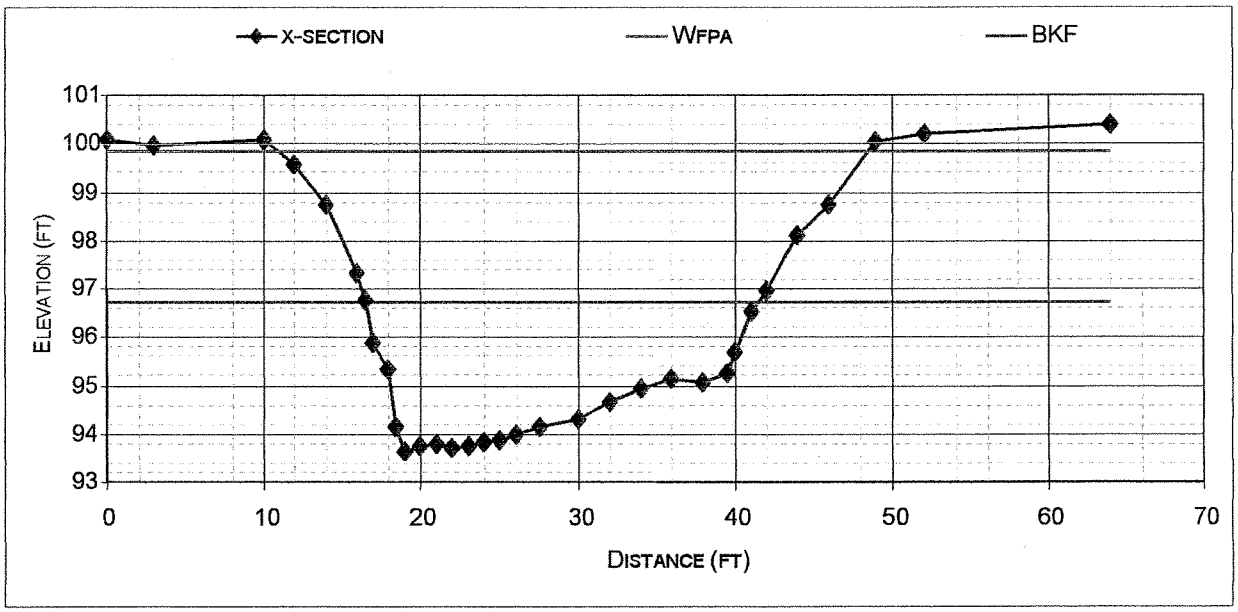
Percent by substrate type				
silt/clay	sand	gravel	cobble	boulder
0.1%	22%	78%	0%	0%

A.2.3. Subpavement sample.

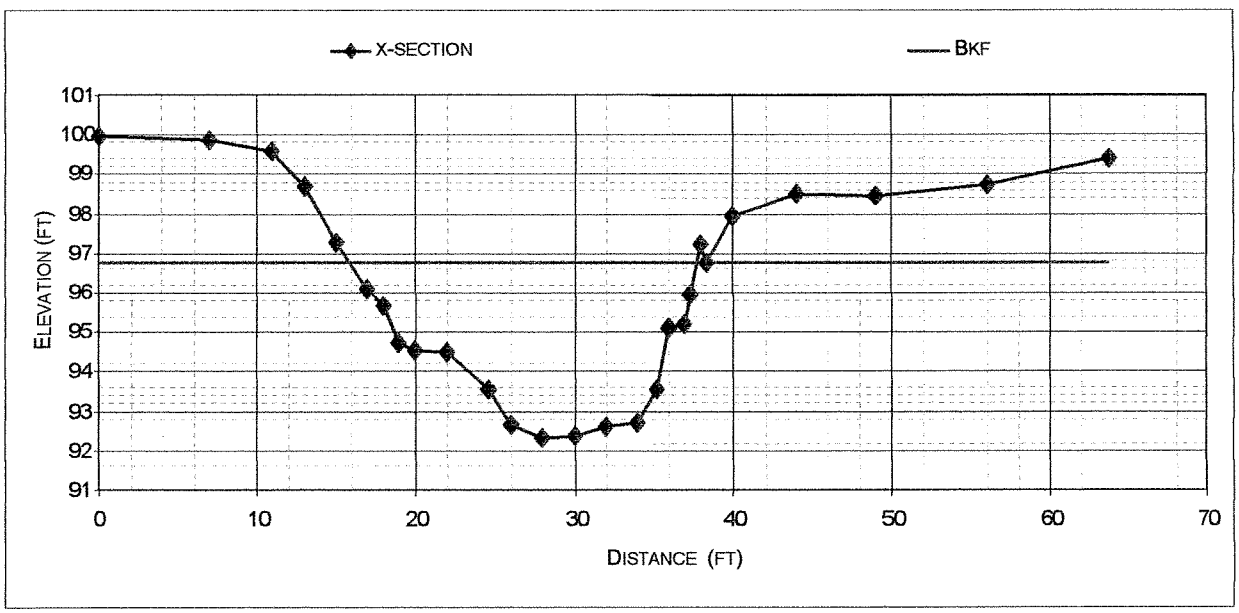
Appendix 3. Steven's Creek reference reach. Yadkin drainage, Mecklenburg County, January 2003.



A.3.1. Longitudinal profile.



A.3.2. Cross-section station 0+82, riffle.



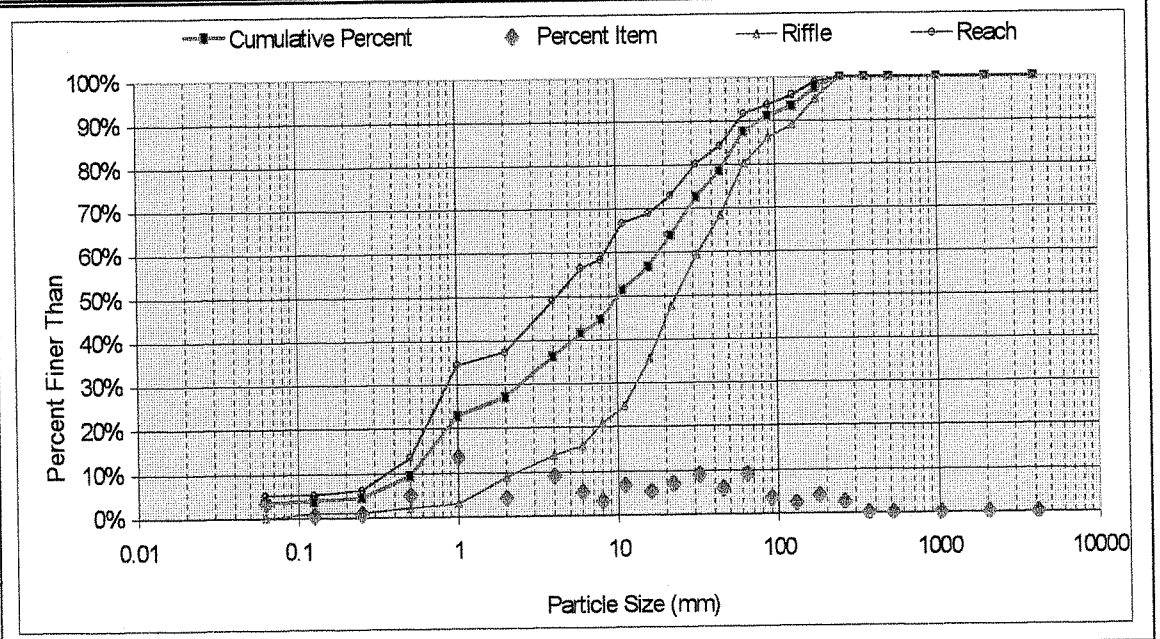
A.3.3. Cross-section station 2+18, pool.

Appendix 3. Continued.

Percent Riffle:	36	Percent Run:	
Percent Pool:	64	Percent Glide:	

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	3.2	# #
very fine sand	0.062	0.13	0.4	# #
fine sand	0.13	0.25	0.6	# #
medium sand	0.25	0.5	4.8	# #
coarse sand	0.5	1	13.2	# #
very coarse sand	1	2	4.0	# #
very fine gravel	2	4	8.8	# #
fine gravel	4	6	5.2	# #
fine gravel	6	8	3.0	# #
medium gravel	8	11	6.5	# #
medium gravel	11	16	5.2	# #
coarse gravel	16	22	6.8	# #
coarse gravel	22	32	8.7	# #
very coarse gravel	32	45	5.7	# #
very coarse gravel	45	64	8.7	# #
small cobble	64	90	3.4	# #
medium cobble	90	128	2.3	# #
large cobble	128	180	4.0	# #
very large cobble	180	256	2.4	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			2.9	#
		Weighted Count:	100	
		True Total Particle Count:	202	

	Steven's Creek
	Yadkin/PeeDee
	Mint Hill
Note:	



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.705	3.69	10.4	56	146

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
3%	23%	59%	12%	0%	3%

A.3.4. Weighted pebble count.

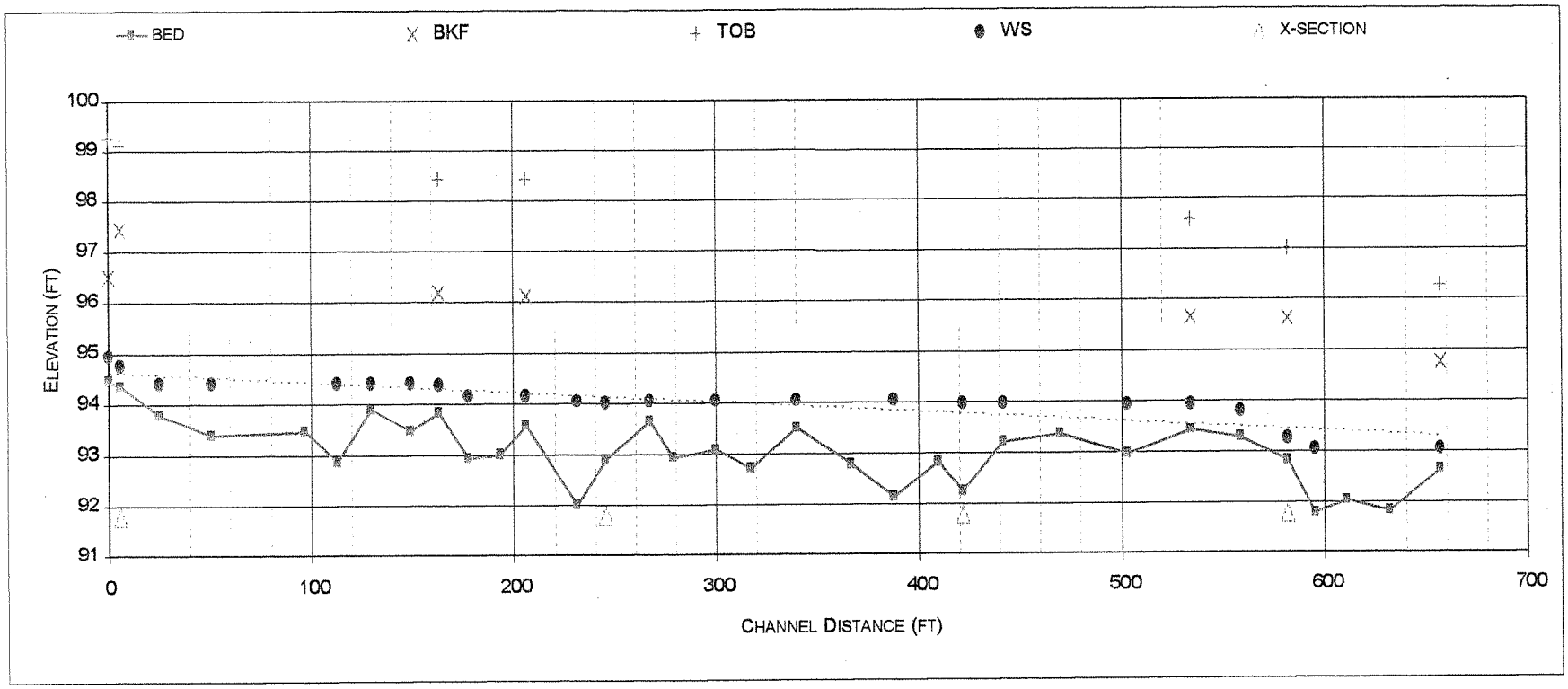
Appendix 3. Continued.

A.3.5. Photos of Stevens Creek reference reach upstream of the I-485 crossing, Mecklenburg County, January 13, 2003

Looking up-stream to riffle cross-section 0+82

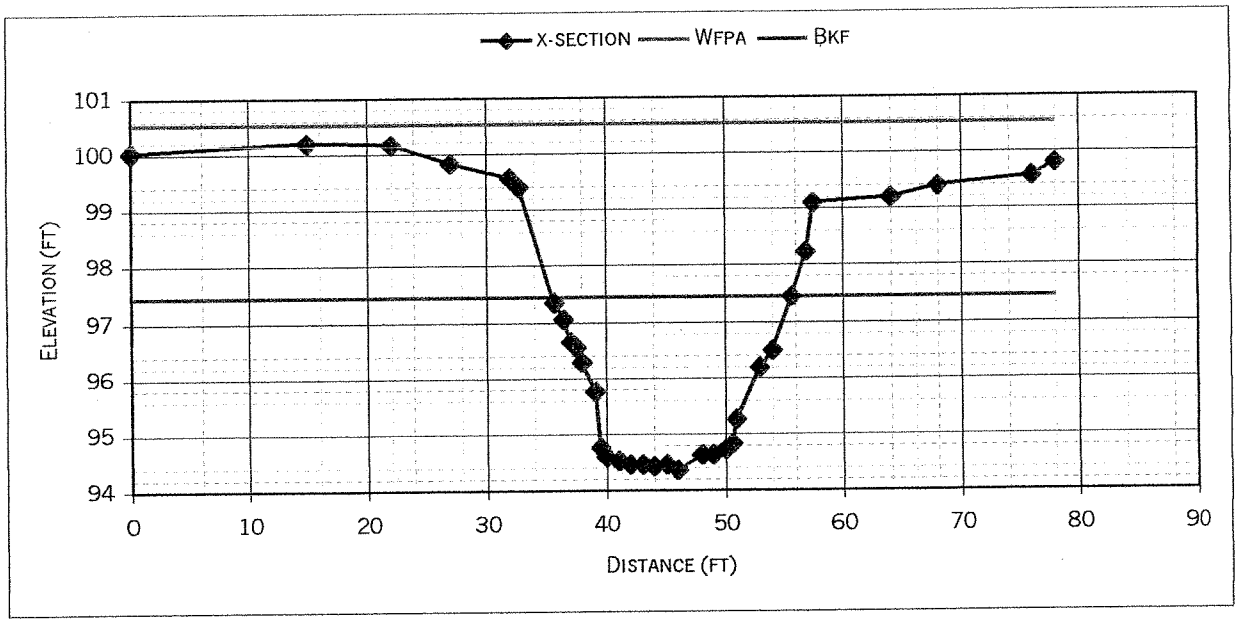
Looking upstream to pool cross-section XS 2+18

Appendix 4. Unnamed tributary to Duck Creek reference reach. Yadkin drainage. Union County. January 2003.

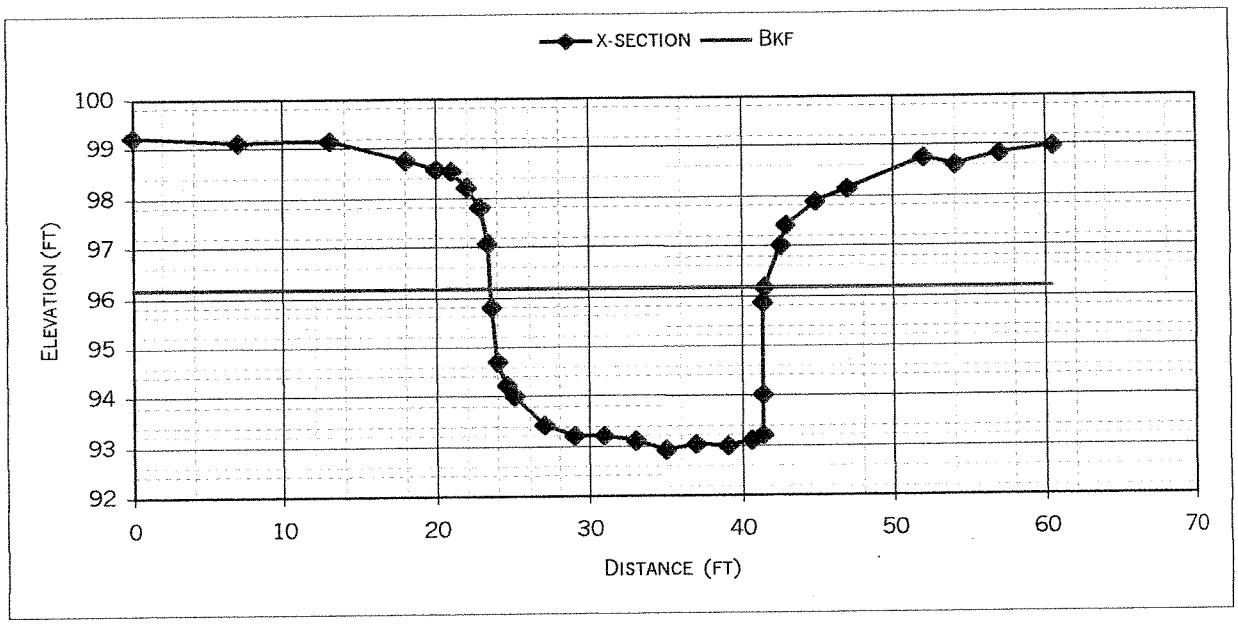


A.4.1. Longitudinal profile.

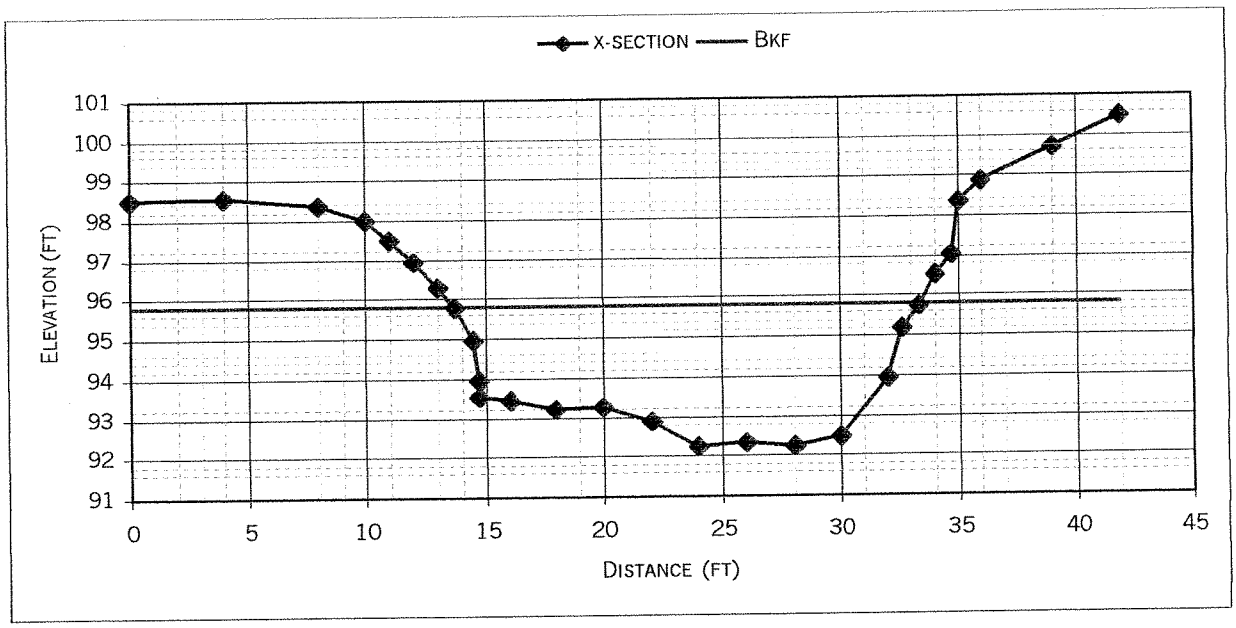
Appendix 4. Continued.



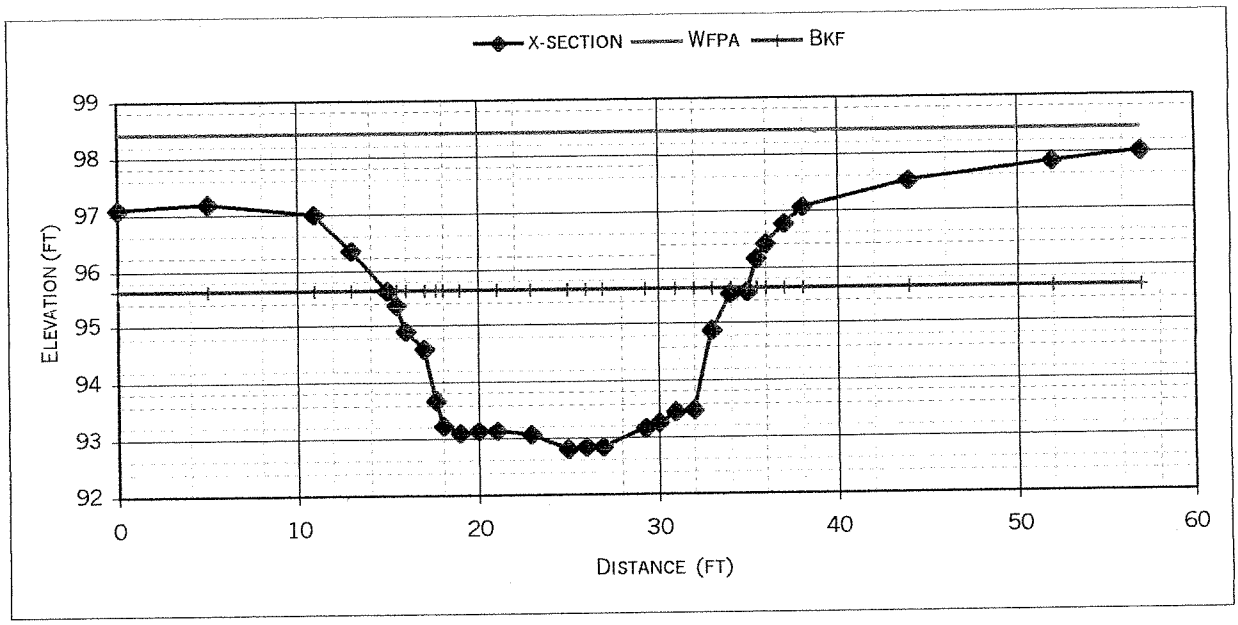
A.4.2. Cross-section station 0+06, riffle.



A.4.3. Cross-section station 2+45, pool.



A.4.4. Cross-section station 4+22, pool.



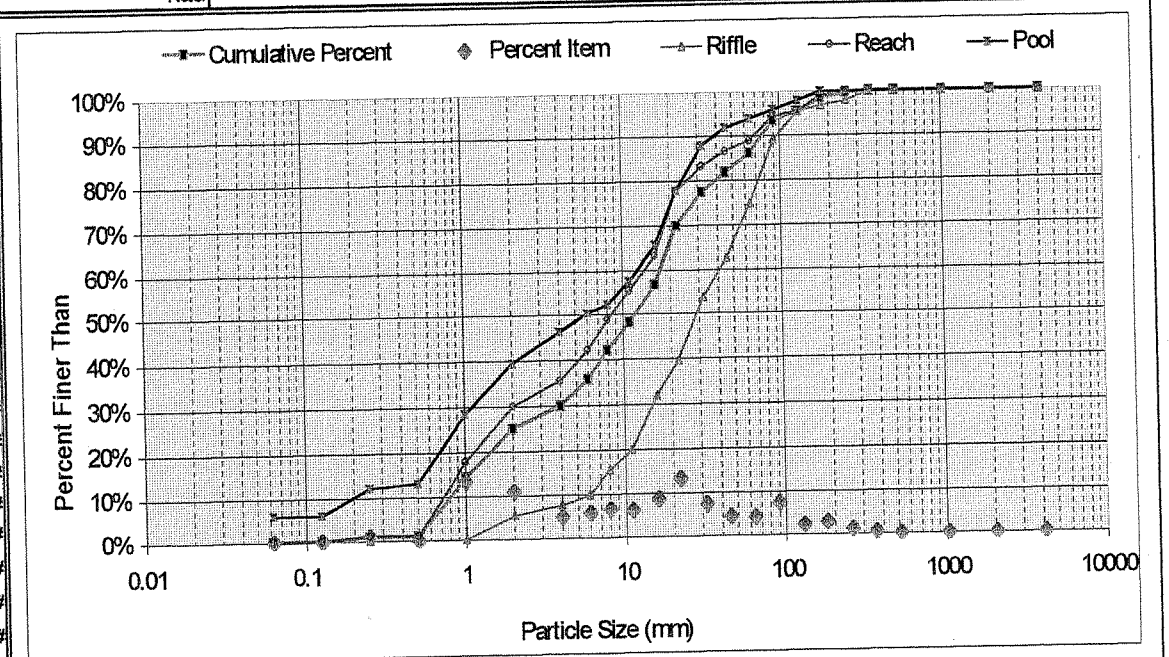
A.4.5. Cross-section station 5+82, riffle.

Appendix 4. Continued.

Percent Riffle:	20	Percent Run:	
Percent Pool:	80	Percent Glide:	

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	0.0	# #
very fine sand	0.062	0.13	0.0	# #
fine sand	0.13	0.25	0.8	# #
medium sand	0.25	0.5	0.0	# #
coarse sand	0.5	1	12.0	# #
very coarse sand	1	2	9.8	# #
very fine gravel	2	4	4.4	# #
fine gravel	4	6	5.2	# #
fine gravel	6	8	5.8	# #
medium gravel	8	11	5.6	# #
medium gravel	11	16	7.8	# #
coarse gravel	16	22	11.8	# #
coarse gravel	22	32	6.7	# #
very coarse gravel	32	45	4.0	# #
very coarse gravel	45	64	3.8	# #
small cobble	64	90	6.7	# #
medium cobble	90	128	2.0	# #
large cobble	128	180	2.6	# #
very large cobble	180	256	1.0	# #
small boulder	256	362	0.4	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			9.4	#
		Weighted Count:	100	
		True Total Particle Count:	298	

	UT Duck Creek
	Yadkin
	Union County
Note:	



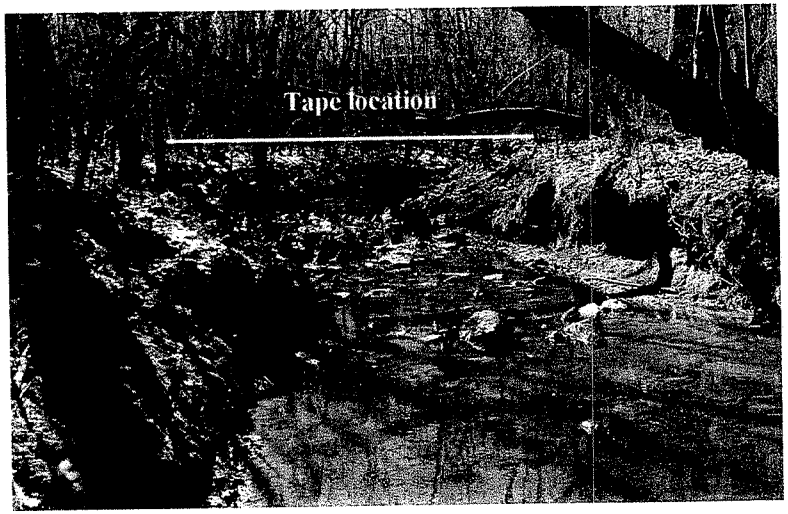
Size percent less than (mm)				
D16	D35	D50	D84	D95
1.127	5.75	11.9	54	117

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
0%	23%	55%	12%	0%	9%

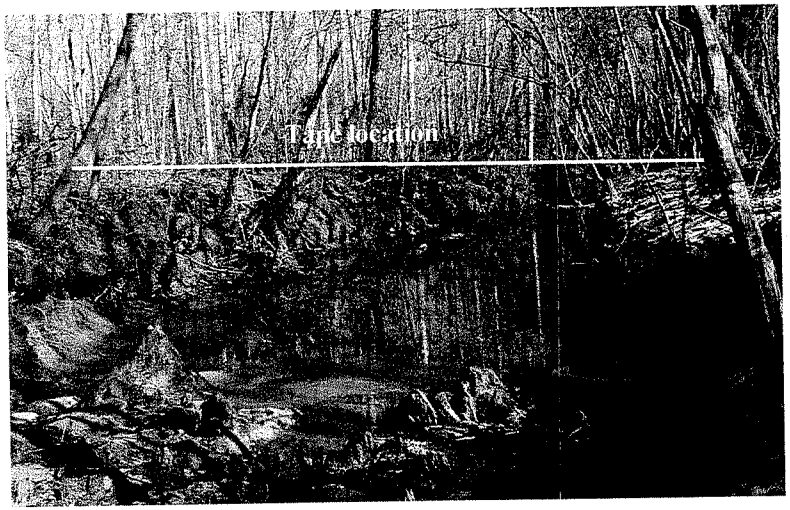
A.4.6. Weighted pebble count.

Appendix 4. Continued.

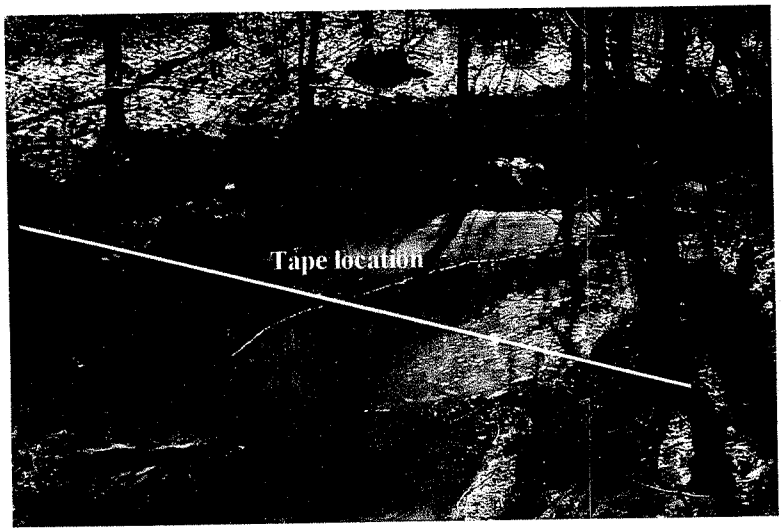
A.4.7. Photos of the unnamed tributary to Duck Creek above NC 218 bridge, Union County, March 27, 2003



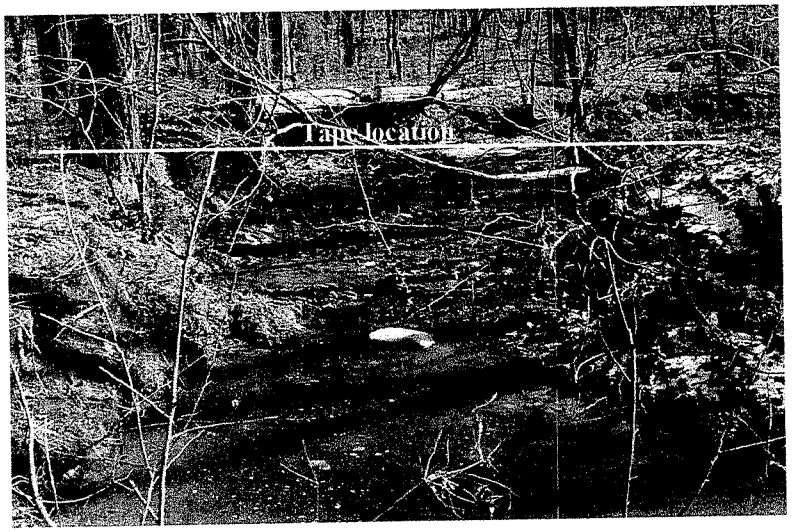
Looking upstream at start of reference reach to riffle cross-section 0+06.



Looking downstream to pool cross-section 2+45.



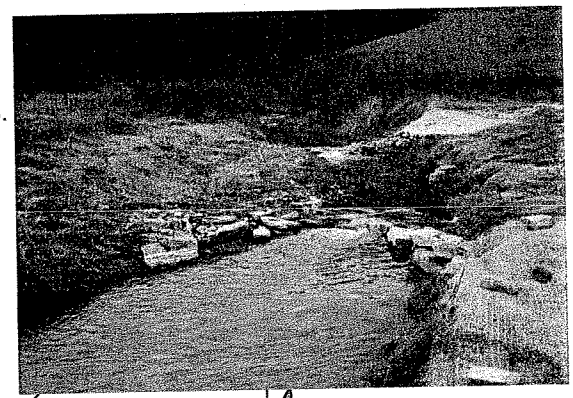
Looking upstream to pool cross-section 4+22.

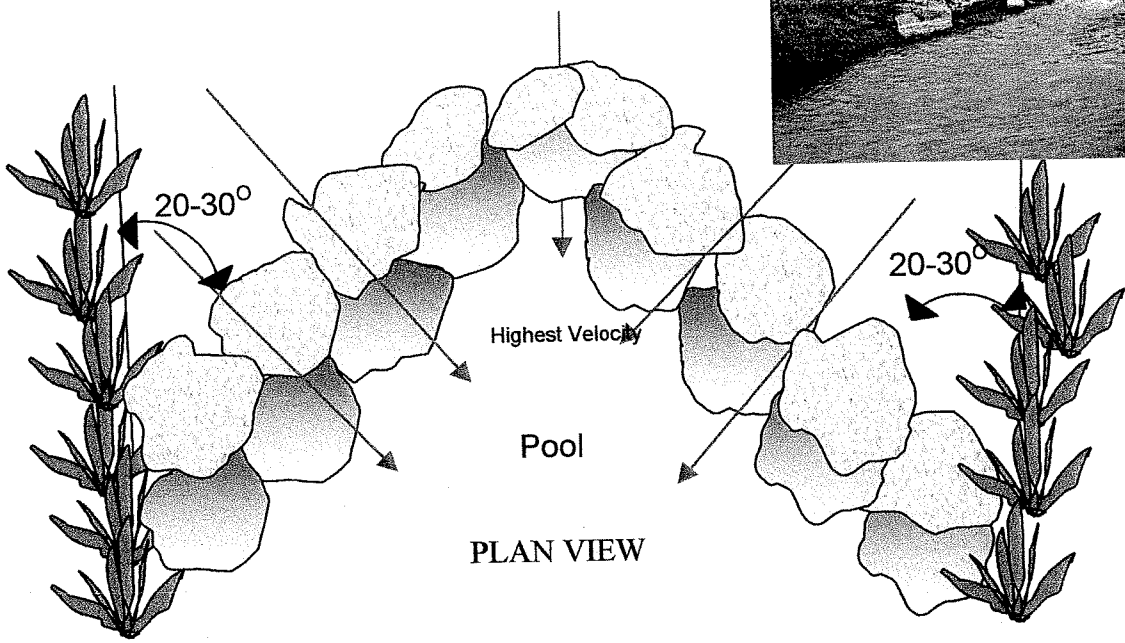


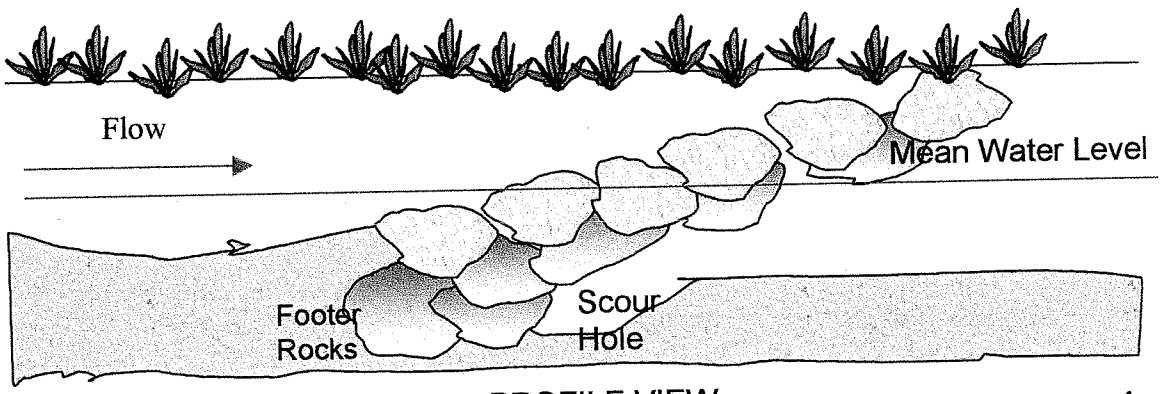
Looking upstream to riffle cross-section 5+82

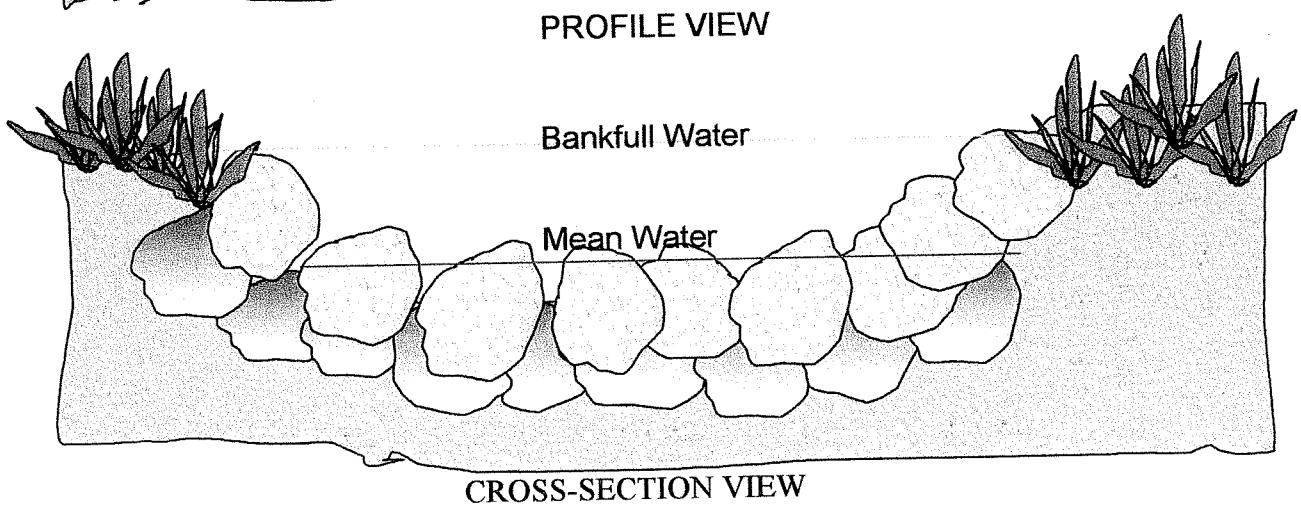
Appendix 5. In-stream structures.

A.5.1. Rock Weir showing plan, profile, and cross section views.



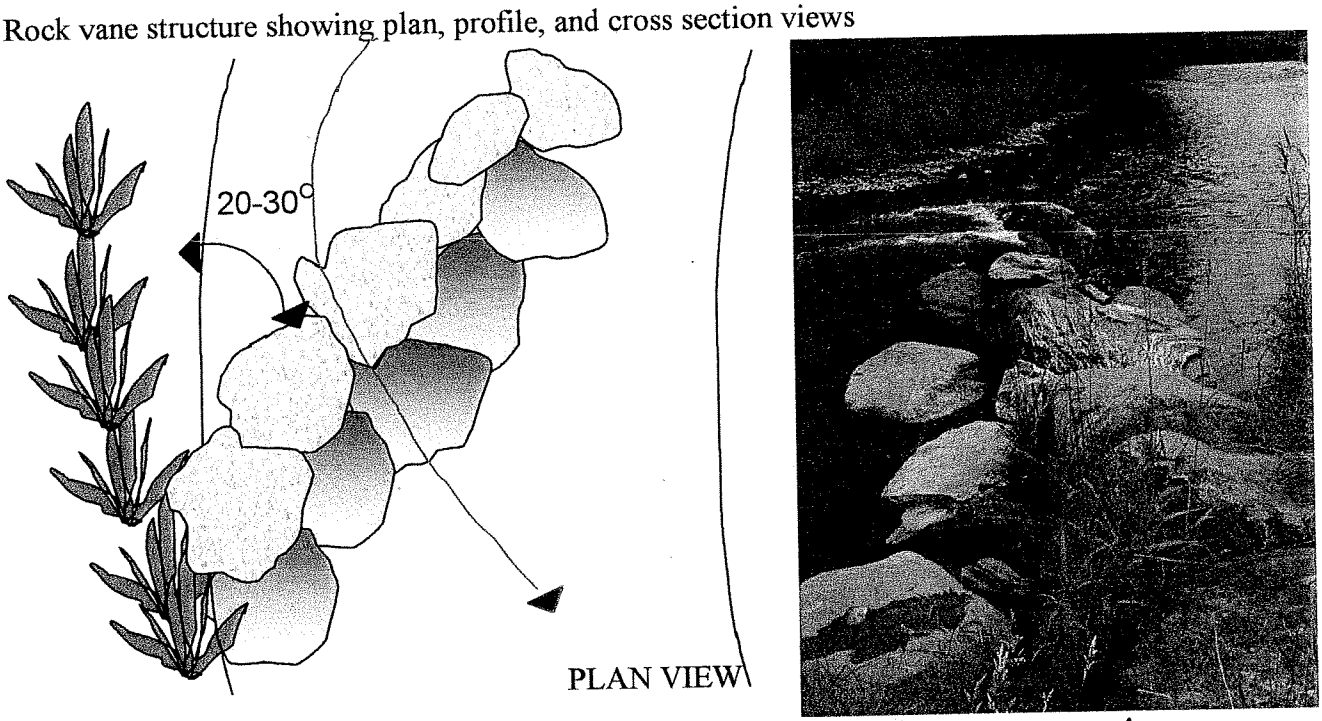


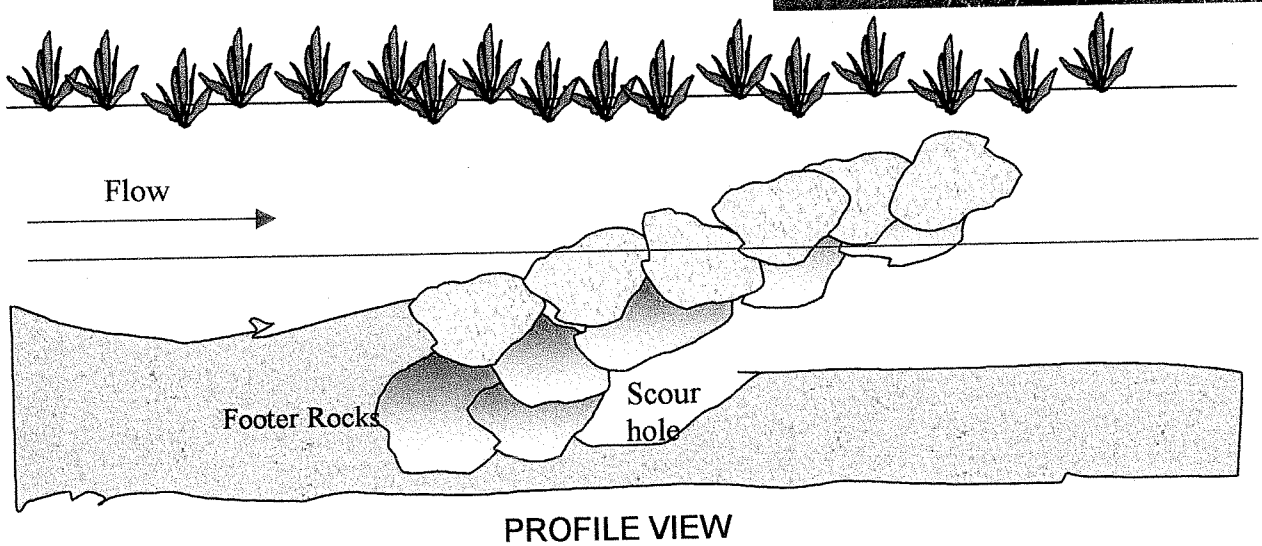


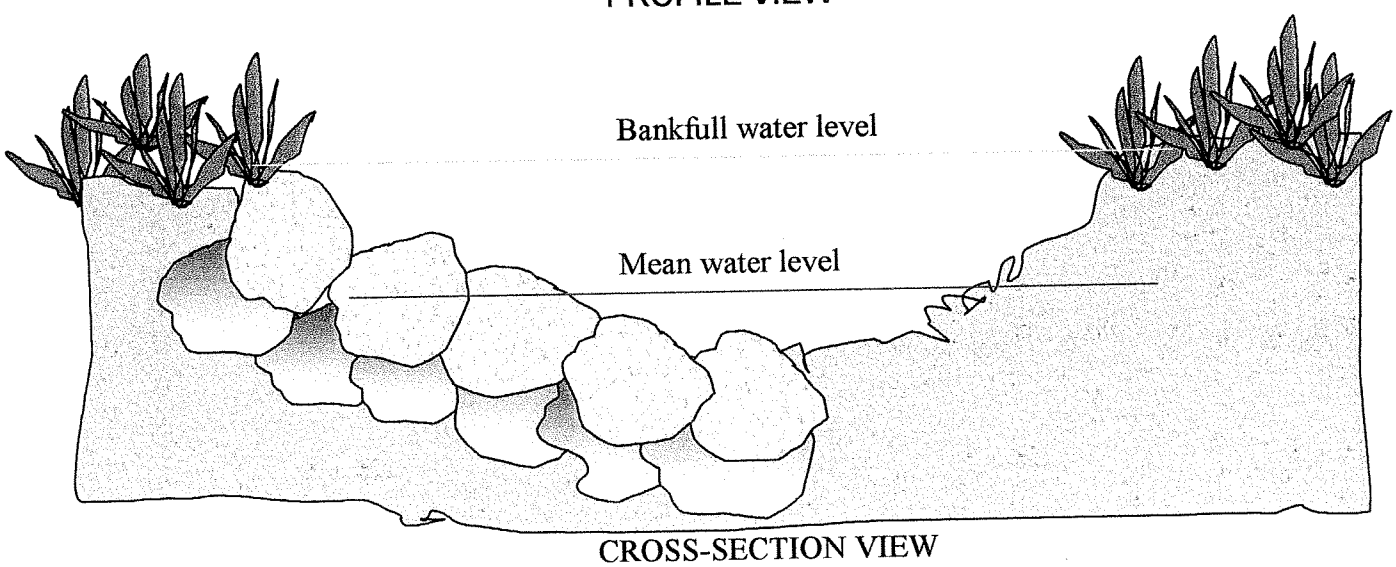


Appendix 5. Continued

A.5.2. Rock vane structure showing plan, profile, and cross section views

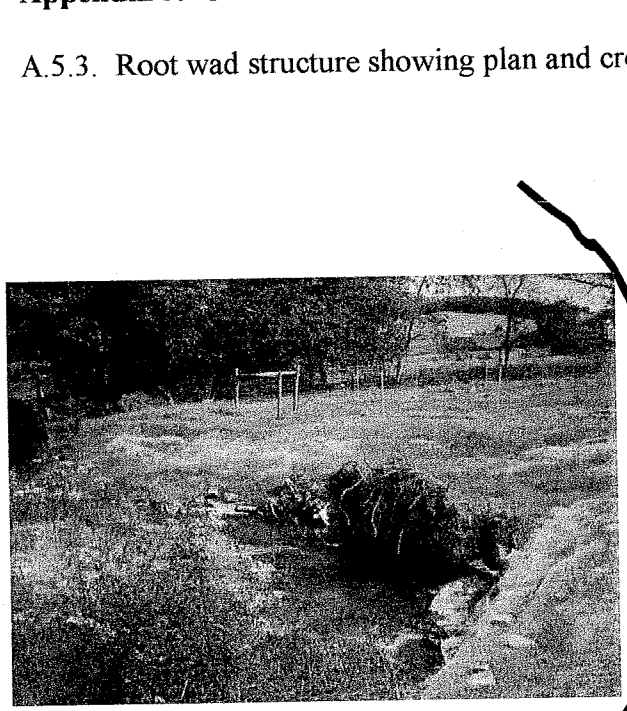


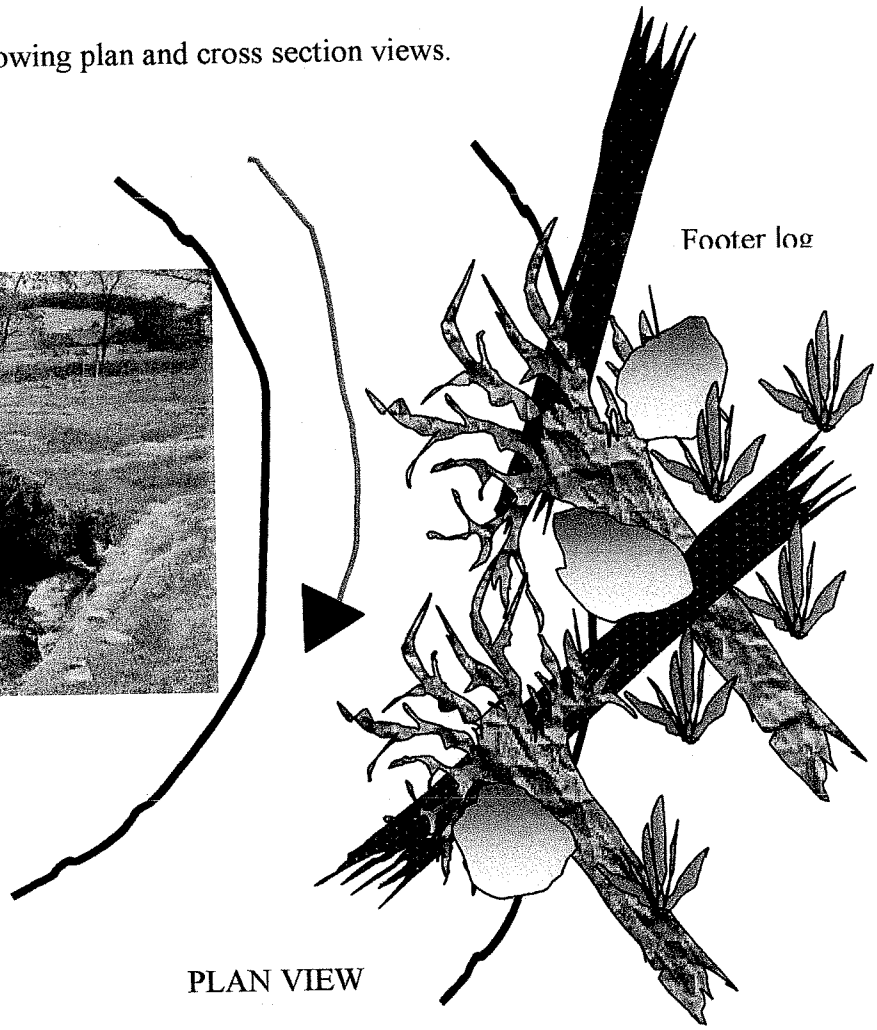


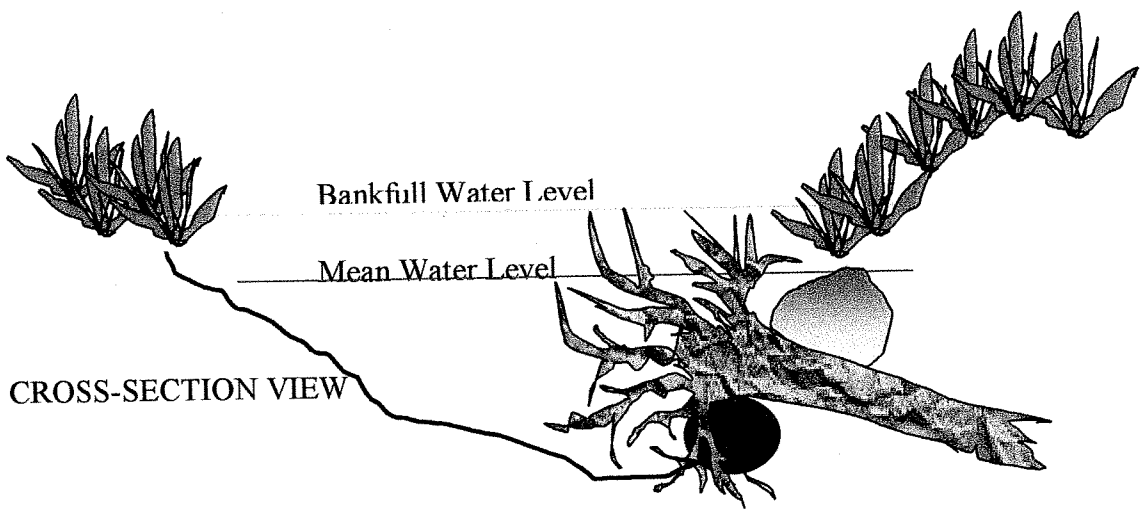


Appendix 5. Continued.

A.5.3. Root wad structure showing plan and cross section views.

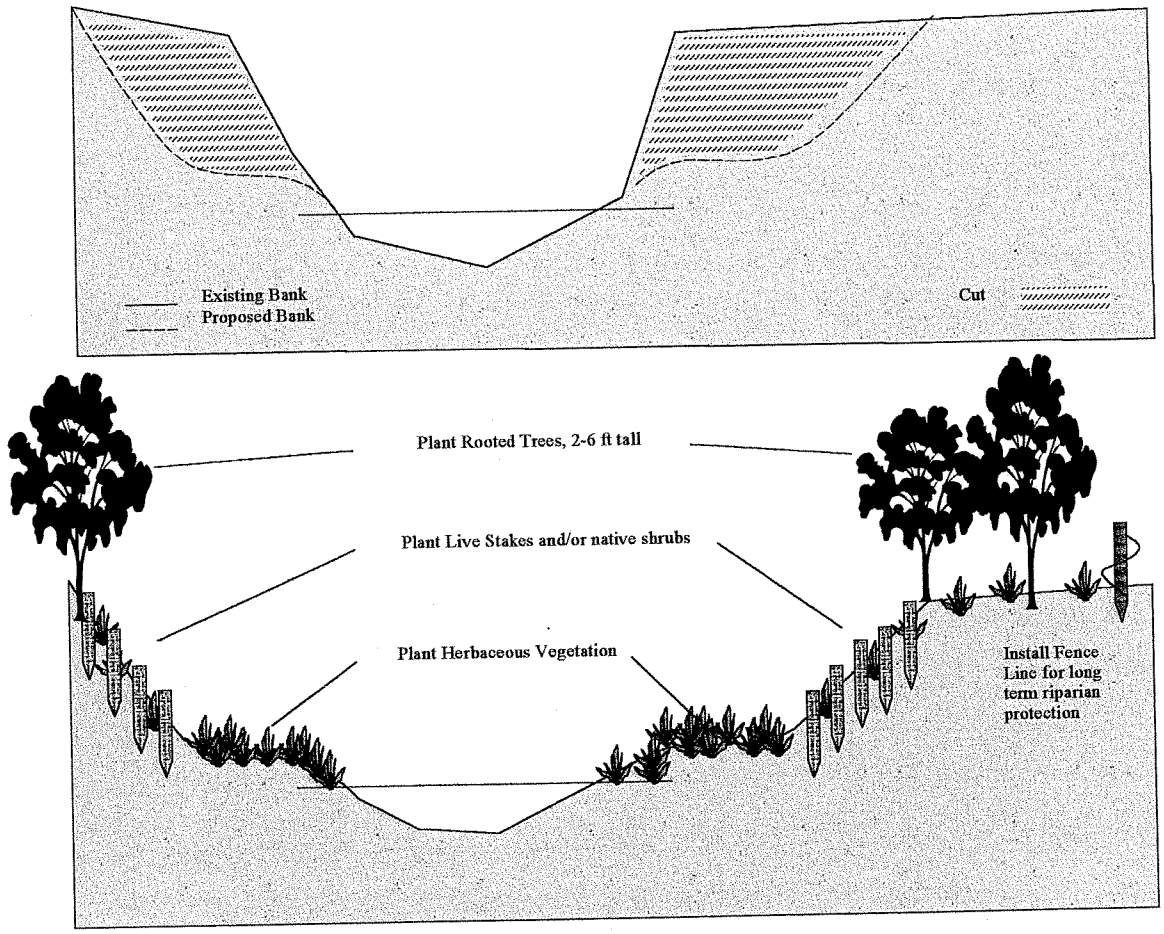


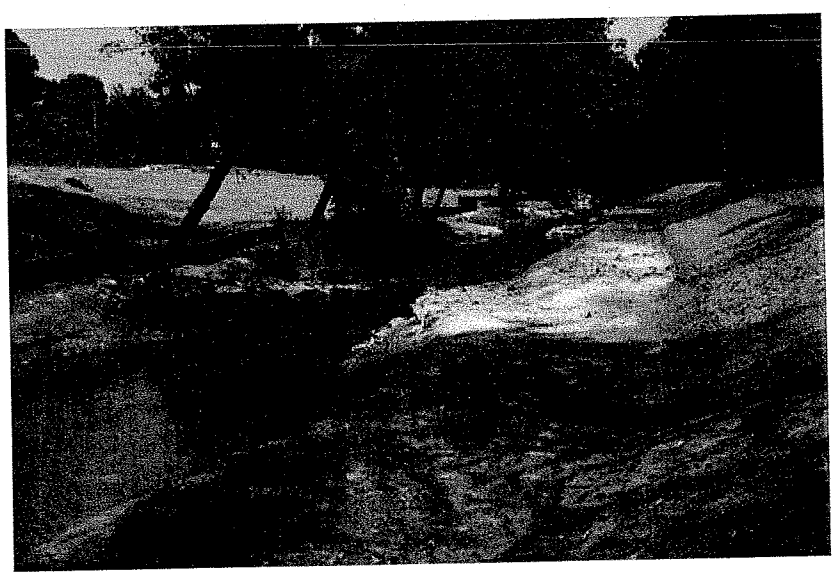




Appendix 5. Continued.

A.5.4. Typical bank grading and revegetation.





Appendix 5. Continued.

A.5.5. Stair-step pool structure showing cross-section view.