Clear Creek
Stream Restoration
2004-2005 Monitoring Reports
October 2005

2004/2005 Clear Creek Monitoring Report

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Executive Summary

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Executive Summary

Clear Creek was restored through the North Carolina Wetlands Restoration Program (NCWRP). The goals and objectives of this project are as follows:

1. Improve water quality by reducing the sediment load generated by eroding banks;
2. Reestablish stable channel dimension, pattern, and profile to Clear Creek;
3. Restore a functioning floodplain;
4. Establish a riparian buffer of woody plant species, preferably native;
5. Enhance aquatic and terrestrial habitats in the stream corridor; and
6. Stabilize banks to safeguard a sanitary sewer line that runs parallel to Clear Creek along the left (south) side of the channel.

2004 was the 1st year of the 5-year monitoring plan for Clear Creek.

Table 1 Background Information

Project Name	Clear Creek
Designer's Name	EcoLogic Associates, P.C. 4321-A South Elm-Eugene Street Greensboro, NC 27406 336-335-1108
Contractor's Name	Shamrock Environmental, Inc.
Project County	Henderson County
Directions to Project Site	From the intersection of Interstate 26, take US 64 west to Hendersonville. At about 0.7 mile, bear right at the fork. At the first light, (about 800 feet), turn right onto Dana Road. Follow Dana Road to the dead end. Turn left and proceed to the intersection (about 100 feet) at Clear Creek Road. Turn right on Clear Creek Road and travel about 0.9 mile. Just before the bridge over Clear Creek there is a driveway and an unpaved road on the right. This road leads to the sewer line right-of-way bordering the restoration reach.
Drainage Area	44 sq. mi.
USGS Hydro Unit	06010105
NCDWQ Subbasin	04-03-02
Project Length	1,250 linear feet
Restoration Approach	1,250 linear feet of dimension, pattern, and profile adjustment
	9 acres of existing floodplain were included in the conservation easement
Date of Completion	2003
Monitoring Dates	Physical monitoring June 2004, Vegetation monitoring. April 2005

Table 2 Summary of Channel Conditions						
DIMENSION	Clear Creek					
	Riffle		Pool			
	As-built	2004	As-built	2004		
Bankfull Cross-sectional Area (sf)	337.0	336.0	317.0	321.0		
Bankfull Width (ft)	71.7	69.0	72.6	74.2		
Bankfull Mean Depth (ft)	4.7	4.9	4.4	4.3		
Bankfull Max Depth (ft)	7.8	7.8	8.7	8.5		
PATTERN	Clear Creek					
	As-built	2004				
Meander Wave Length (ft)	720	720				
Radius of Curvature (ft)	272	272				
Belt Width (ft)	230	230				
PROFILE		Clear Creek			Clear Creek	
	As-built			2004		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Riffle Length (ft)	19.0	23.0	21.0	33.0	48.0	38.0
Riffle Slope (ft/ft)	0.0045	0.0066	0.0050	0.0030	.0173	0.0079
Pool Length (ft)	52.0	93.0	71.0	18.0	73.0	44.0
Pool to Pool Spacing (ft)	197.0	354.0	271.0	160.0	404.0	254.0
SUBSTRATE	Clear Creek					
	Riffle		Pool			
	As-built	2004	As-built	2004		
d50 (mm)	4.4	11.5	0.8	1.7		
d85 (mm)	11	27	3	7		
VEGETATION						
The woody trees and shrubs were planted only 2 +/- months before the first year physical monitoring. Estimated planting in 2004: 1,742 trees and shrubs per acre (5’ spacing) and 4,840 lives stakes per acre (3’ spacing). Eight 100-sq. meter blocks monitored April 2005: 1,806 total stems per acre of which 1,022 were trees and shrubs. Survival rate for trees and shrubs is estimated to be 59%.						

Results and Discussion

Overall, the Clear Creek restoration has accomplished 5 of its 6 goals and objectives and is functioning fairly well. The objective to improve the in-stream aquatic habitat and bed features is only partially accomplished due to the heavy sand loading of the creek and adverse impact of storm flows on the bed stability. The banks are currently stable and well vegetated throughout most of the reach. Several sections of bank have receded (steepened) from the as-built geometry, but appear to have stabilized at the steeper angle.

One problem with the restoration is the cross vanes and j-hooks do not appear to be controlling the thalweg at low to medium flows. The result is that the base flow channel is wide with the thalweg very close to the bank in several locations. The central portions of cross vanes 3 and 4 appear to have shifted and may be sinking into the sandy substrate. In at least one case, a large sunken log appears to have rammed a cross vane rock off its footers. Cross vanes 1 and 2 are performing adequately but should be monitored closely. The rocks at the end of most of the j-hooks have likewise sunken into the bed or have become buried by the high bedload of sand in this low slope, alluvial channel.

The low slope of the reach, controlled by the sewer line crossing at the lower end, promotes the deposition of sand and woody debris throughout the restoration area. The woody debris promotes local scour and deposition, so the bed morphology is dominated by many small holes connected by an irregular and dynamic thalweg. Many of these pieces of wood are colonized by aquatic plants, some of which form rather large colonies.

The bank vegetation appears robust, but quantitative survey was difficult since the woody plants were planted without the involvement of the designer. For April 2005 monitoring purposes, the planting contractor provided an estimate of the approximate planting density and a general species list. All floodplain buffer plants were installed as containerized material in 1-gallon and 3-gallon sizes. The survival rate appears good in spite of the hurricane-induced floods that impacted the valley only 6 months after planting. The live stakes on the banks are also growing well, even in areas of recent sand deposition on the bankfull benches. There is also a significant amount of volunteer herbaceous vegetation within the channel banks and good growth of the seed mix on the floodplain terrace.

Photos

The following are photographs of typical areas and areas of concern throughout the project.

Photo 1 Reference riffle cross-section at Station 2+25. The low flow channel is of uniform depth and width throughout the reach with only a few small patches of gravel. The bed morphology is dominated by a heavy load of large woody debris and sand.

Photo 2 Pool cross-section at Station 10+50. The outside of this bend is where the most stable pool occurs other than the plunge pools below each cross vane. The low flow depth is over 5 feet just off the root wads in the bank.

Photo 3 Cross vane at Station 1+90. Note center section shifted and piping at several locations. At high flows, the arms of the cross vane accumulate sediment and protect the banks.

Photo 4 Bank instability at Station 1+00. Insufficient toe protection and too few root wads allowed steepening of the bank at this point.

1.0 Background Information

1.1 Goals and Objectives

The goals and objectives of this project are as follows:

1. Improve water quality by reducing the sediment load generated by eroding banks;
2. Reestablish stable channel dimension, pattern, and profile to Clear Creek;
3. Restore a functioning floodplain;
4. Establish a riparian buffer of woody plant species, preferably native;
5. Enhance aquatic and terrestrial habitats in the stream corridor; and
6. Stabilize banks to safeguard a sanitary sewer line that runs parallel to Clear Creek along the left (south) side of the channel.

1.2 Project Location

From the intersection of Interstate 26, take US 64 west to Hendersonville. At about 0.7 mile, bear right at the fork. At the first light, (about 800 feet), turn right onto Dana Road. Follow Dana Road to the dead end. Turn left and proceed to the intersection (about 100 feet) at Clear Creek Road. Turn right on Clear Creek Road and travel about 0.9 mile. Just before the bridge over Clear Creek there is a driveway and an unpaved road on the right. This road leads to the sewer line right-of-way bordering the restoration reach. The sewer line is maintained by the City of Hendersonville, and the access points are not gated or posted.

The restoration reach is located between the Interstate 26 bridge at the upstream end and the Clear Creek Road bridge at the lower end. The lower end of the reach is about 2,700 feet upstream of the confluence with Mud Creek, which is the location of the Hendersonville sewage treatment plant. This location is also 4.7 river miles upstream from the confluence with the French Broad River.

The project is located in a floodplain of approximately 4 acres, the majority of which is now in a conservation easement. The reach has a sanitary sewer main adjacent to the channel's south bank and running along the south margin of the floodplain. The project ends just before the Clear Creek Bridge at a point where a lateral sewer line crosses the creek about 1.5 feet above the bed elevation. In order to protect the sewer line, a large amount of rock has been dumped, creating an artificial riffle under the bridge.

The head of the restoration reach likewise starts at the bottom of a man-made riffle that apparently was constructed to protect the I-26 bridge from head cutting.

1.3 Project Description

An impaired, previously straightened, stream flowing through a cow pasture, Clear Creek was restored using channel dimension, pattern, and profile modifications and the replanting of riparian zone woody plants adjacent to the creek. The restored channel profile is maintained through the use of rock cross vanes. Channel pattern is maintained through the use of root wads, single wing vanes, J-hooks and ultimately vegetation on the channel banks. Easement boundaries include the floodplain to the toe of the surrounding forested slopes. Cattle have been permanently removed, so fencing was not required.

Prior to restoration, the existing condition included very few locations with woody vegetation on the banks. The lack of vegetation was a result of past agricultural activity and the results of beaver activity. Cattle grazing on the banks and beaver activity within the channel resulted in bare, failing banks and temporary impoundments that accumulated sediment. As a result, the creek had some very wide sections with vegetated central bars, which resulted from beaver damming of the main channel. Vertical, unvegetated banks over 8 feet tall were common throughout the reach. Several sharp curves had developed in the reach, with one section resulting in flow perpendicular to the valley and focused directly on the bank containing the sewer line.

The restoration approach included constructing a new channel with a wider belt width to dissipate erosive energy, and moving the channel away from the sewer line. The new channel includes wide bankfull benches and bank slopes that permit vegetation establishment. The sandy, cohesionless nature of the soils in the valley required the use of rock vanes, j-hooks and coir fiber matting to help deflect energy from the newly constructed banks. Cross vanes were also installed to try and enforce some bed morphology and possibly create better aquatic habitat than had been noted in the relatively flat and featureless existing condition. This goal of the restoration appears to have been largely unsuccessful to date.

The project was constructed during the spring of 2003 during which time the Hendersonville area received a record amount of rain. During construction there were four major storms causing discharges greater than bankfull, which caused the creek to flood and overtop of the banks. Three of these storms deposited 3 to 6 inches of sediment on the project, covering the coir fiber matting and burying the newly seeded areas. These wet conditions and high water levels increased the difficulty of construction and compromised the result.

The planting of woody vegetation was not part of the main construction contract and was coordinated directly by NCWRP without the involvement of the designer. The planting occurred in March 2004. As a result of the late planting date, vegetation monitoring occurred in April 2005.

2.0 Year 1 (2004) Results and Discussion

2.1 Vegetation (April 2005)

The floodplain and bank vegetation was not surveyed at the time of physical monitoring since the woody plants were only installed 2 months prior. The ultimate survival could only be determined after a season of exposure to site and meteorological conditions, so an additional vegetation monitoring visit was made in April 2005.

The bank vegetation appears robust, but quantitative survey was difficult since the woody plants were planted without the involvement of the designer. For April 2005 monitoring purposes, the planting contractor provided an estimate of the approximate planting density and a general species list. All floodplain buffer plants were installed as containerized material in 1-gallon and 3-gallon sizes. The survival rate appears good in spite of the hurricane-induced floods that impacted the valley only 6 months after planting.

The live stakes on the bank are growing well, even in areas of recent sand deposition on the bankfull benches. There is also a significant amount of volunteer herbaceous vegetation within the channel banks and good growth of the seed mix on the floodplain terrace.

There were several locations that were seeded at least twice with temporary seed and once or twice with the permanent seed mix. In addition, the entire site was overseeded at the end of construction. At the end of the summer of 2003 the site had a patchy thick cover of brown millet, which was thick enough to exclude other species. In some locations, the brown millet was apparently the only species able to grow through several inches of sediment; it was also thick enough to out-compete other vegetation.

Since construction was completed in May, the woody plantings were delayed until the following winter when dormant stock was available. The planting was organized and coordinated directly by NCWRP staff with no involvement of the designer. It appears that the live stakes were planted in January 2004 and the containerized trees and shrubs were installed in late March.

A complete inventory of planted woody species by vegetation plot is shown in Table 4 appended to this document. Since the initial plant composition of each of the vegetation plots is unknown, and they suffered damage from the hurricane-induced floods of fall 2004, information from discussions with the planting contractor was used to arrive at a probable initial planting density. Based on the contractor's recollection of a planting density of trees and shrubs on 5-foot centers and live stakes on 3-foot centers, an initial density of 1,742 trees and shrubs per acre and 4,840 live stakes per acre is assumed. We counted a total of 357 woody plants (not counting volunteers) in 800 square meters, which equals 1,806 plants per acre. Subtracting the 784 live stakes from the total gives 1,022 trees and shrubs per acre, or a 59% survival rate. The survival rate for live stakes is not calculable.

2.2 Morphology

The channel morphology indices of dimension and pattern appear to be stable and appropriate to the design target values. The notable exception appears to be the decreased maximum depth of the pools, which is evidently a result of the low slope of the channel and the high load of sediment partially filling the pools. The pattern measures of beltwidth, radius of curvature and meander wavelength all appear unchanged and match the design target value range. The channel thalweg appears to have moved dramatically between observations. This can be explained by the dynamics of the channel substrate, the large woody debris, and the low level of channel control provided by the structures at low flows. The structures appear to be functioning at high flows and less effective or ineffective at low flows.

Most of the channel bottom is made up of a thin layer of course sand/small gravel pavement over very fine sand subpavement, which is uniform throughout the restoration reach. The only significant bed morphology is adjacent to the structures and other large woody debris in the channel. Since this woody material moves during high flow events, the bed morphology is more dynamic than designed or anticipated. Some of the submerged logs are large enough to have dislodged rocks from the cross vanes upon high flow impacts. Some of these woody pieces form significant scour holes and are substrate for several species of aquatic plant life.

The profile of the channel is very flat with very few well-defined riffles and pools. The majority of the reach appears to be morphologically a run. As a result, the morphological features that can be identified as riffles are short and have not accumulated enough course sediments to be stable at this point. These riffles are also relatively flat. Over the course of the monitoring period (1 year), the riffles seem to have lengthened and flattened. The substrate has also coarsened slightly. When walking down the channel, one can feel a thin pavement collapsing underfoot. Under the pavement is a deep layer of very soft sand and silty deposits.

The pools are closely associated with the functioning cross vanes and the outside of the bends that have clustered rootwads. The pools seem to have become shorter, less deep and more numerous, with large woody debris determining the number, size and distribution of many of the pools not associated with structures.

The pebble counts of the restoration reach show the overall coarsening of the sediments with the reach d50 going from 1.4 to 4.8mm. The reach d84 went from 8 to 19mm.

2.3 Aquatic Habitat and Benthic Macroinvertebrates

A benthic macroinvertebrate sample was collected from the reach prior to construction. The sample was a composite of the habitats within the reach including the man-made riffles at the upper and lower ends. The data from this benthos sample in included in Table 3.

Our field survey also noted the presence of several types of fish (unidentified species) including some large fish in the deeper pools and in the scour holes around the root wads. In addition, our long profile survey noted several fish nests throughout the restoration reach. No nests were noted during the pre-construction surveys.

There is also a significant amount of woody debris in the bottom of the channel. The largest of these create significant scour holes and in many cases have become colonized by several species of aquatic plants.

Figure 1 Aquatic plants growing on submerged wood

2.4 Areas of Concern

Overall, the Clear Creek restoration has accomplished 5 of its 6 goals and objectives and is functioning fairly well. The 5th goal of improving in-stream aquatic habitat was only partially successful due to the heavy sediment loads and sandy nature of the bed material which makes development of bed structures more dynamic than expected.

The banks are currently stable and well vegetated throughout most of the reach. Several sections of bank have receded (steepened) from the as-built geometry, but appear to have stabilized at the steeper angle.

One problem with the restoration is the cross vanes and j-hooks do not appear to be controlling the thalweg at low to medium flows. The result is that the base flow channel is wide with the thalweg very close to the bank in several locations. The central portions of cross vanes 3 and 4 appear to have shifted and may be sinking into the sandy substrate. In at least one case, a large sunken log appears to have rammed a cross vane rock off its footers. Cross vanes 1 and 2 are performing adequately but should be monitored closely. The rocks at the end of most of the j-hooks have likewise sunken into the bed or have become buried by the high bedload of sand in this low slope, alluvial channel.

The low slope of the reach, controlled by the sewer line crossing at the lower end, promotes the deposition of sand and woody debris throughout the restoration area. The woody debris promotes local scour and deposition, so the bed morphology is dominated by many small holes connected by an irregular and dynamic thalweg.

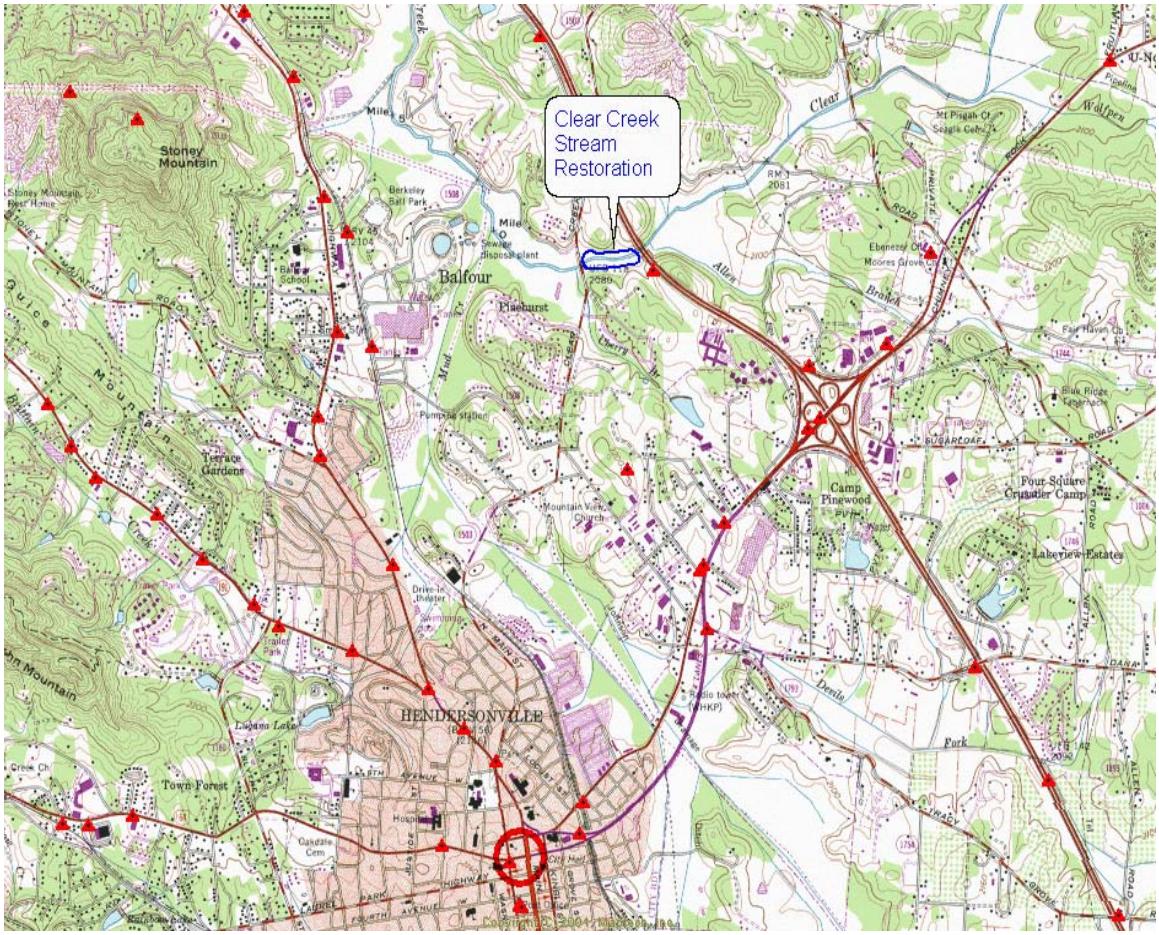


Figure 2 Map of Project Location

Clear Creek stream restoration is located 2 miles north of the center of Hendersonville, North Carolina. The site is situated between I-26 to the east and Clear Creek Road to the west.

Figure 3 Ortho-photo of the Clear Creek Restoration Reach

This is a 1996 photo of the site, 7 years before restoration.

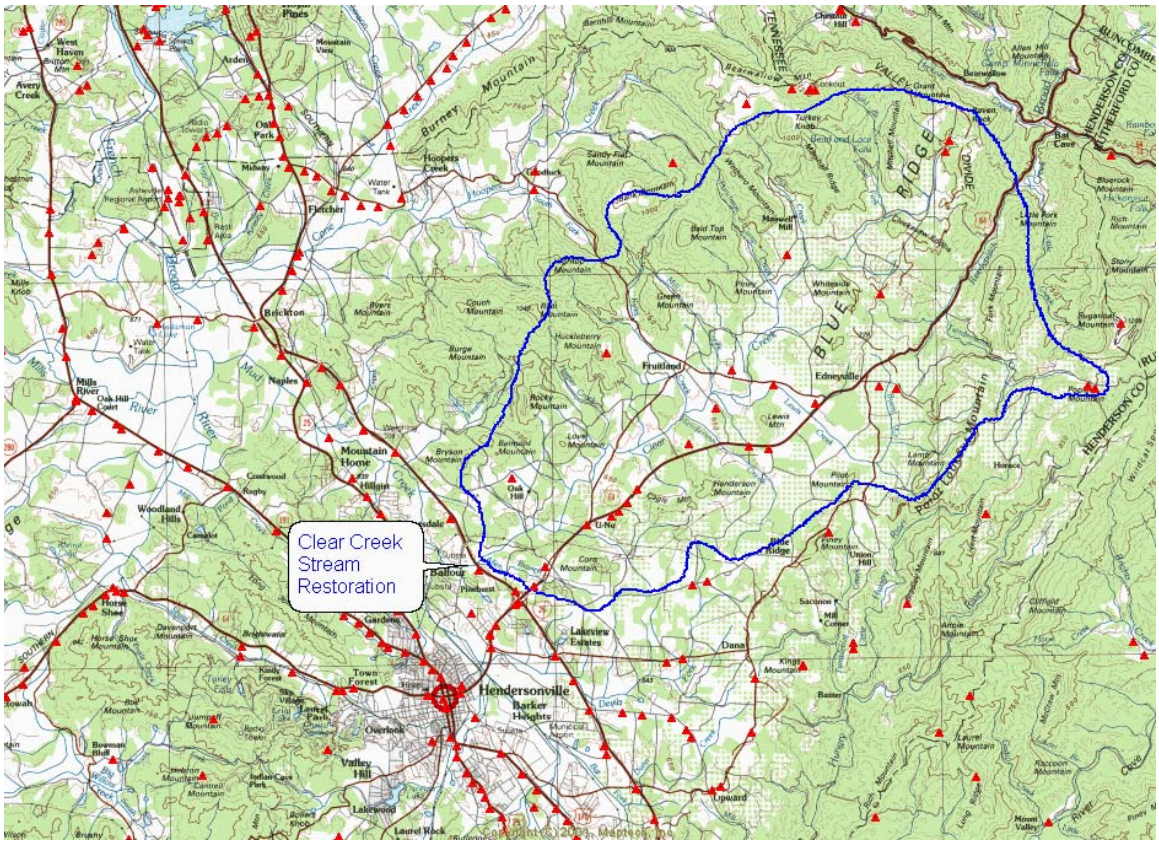


Figure 4 Approximate Watershed Boundary

The Clear Creek watershed is approximately 45 square miles, with about 16 miles of stream channel upstream of the project.

Table 3 Benthic Macroinvertibrate Pre-restoration Sample

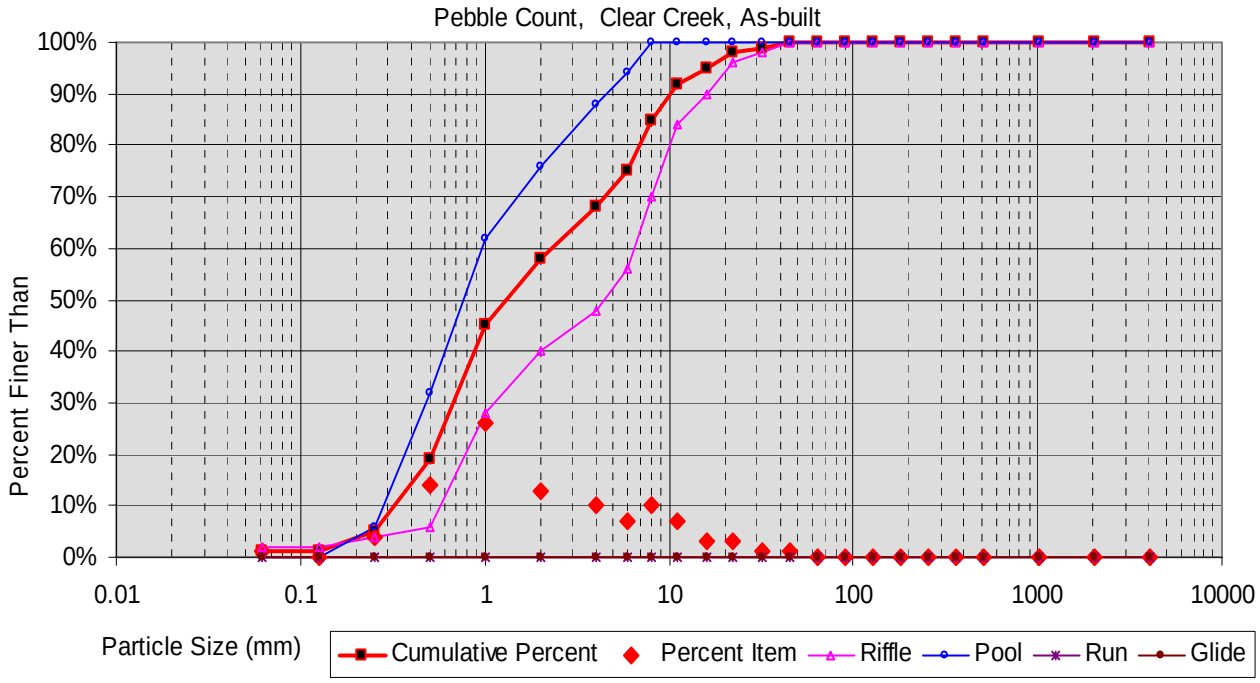
SPECIES	T.V.**	F.F.G.***	NO.	
MOLLUSCA				
Bivalvia				
Veneroida				
Corbiculidae				
Corbicula fluminea	**6.12**	**FC**	1	
Gastropoda				
Mesogastropoda				
Pleuroceridae				
Elimia clavaeformis	***5**	**SC**	1	
Basommatophora				
Physidae				
Physella sp.	**8.84**	**CG**	1	
Planorbidae	***6**	**SC**		
Helisoma anceps	**6.23**	**SC**	1	
ANNELIDA				
Oligochaeta	***10**	**CG**		
Haplotaxida				
Lumbricidae		**CG**	5	
ARTHROPODA				
Crustacea				
Decapoda				
Cambaridae				
Cambarus sp.	**7.62**	**CG**	1	
Insecta				
Ephemeroptera				
Ephemerellidae				
Ephemerella sp.	***1**	**SC**	1	
Heptageniidae	***4**	**SC**		
Stenonema modestum	**5.5**	**SC**	7	
Odonata				
Aeshnidae	***3**	**P**		
Boyeria vinosa	**5.89**	**P**	1	
Coenagrionidae	***9**	**P**		
Enallagma sp.	**8.91**	**P**	2	
Gomphidae	***1**	**P**		
Gomphus sp.	**5.8**	**P**	1	
Erpetogomphus sp.	***1**	**P**	2	
Plecoptera				
Taeniopterygidae	***2**	**SH**		
Taeniopteryx sp.	**5.37**	**SH**	1	
Hemiptera				

Corixidae	**9**	**PI**	1	
Megaloptera				
Corydalidae	***0**	**P**		
Corydalus cornutus	**5.16**	**P**	1	
Nigronia serricornis	**4.95**	**P**	2	
Trichoptera				
Hydropsychidae	***4**	**FC**		
Cheumatopsyche sp.	**6.22**	**FC**	23	
Hydropsyche betteni gp.	**7.78**	**FC**	14	
Diptera				
Chironomidae				
Cardiocladius obscurus	***5**	**P**	1	
Cricotopus sp.	***7**	**CG**	1	
Parametriocnemus lundbecki	**3.65**	**CG**	1	
Rheotanytarsus sp.	**5.89**	**FC**	2	
Simuliidae	***6**	**FC**		
Simulium sp.	**4**	**FC**	1	
Tipulidae	***3**	**SH**		
Antocha sp.	**4.25**	**CG**	1	
Tipula sp.	**7.33**	**SH**	4	
TOTAL NO. OF ORGANISMS			**77**	
TOTAL NO. OF TAXA			**25**	
EPT INDEX			**5**	
BIOTIC INDEX			**6.27**	

*Hilsenhoff Tolerance Values used when North Carolina Tolerance Values are not available.
**T.V. - North Carolina Tolerance Values: Range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant of organic wastes.
***F.F.G. - Functional Feeding Group: CG=Collector/Gatherer, FC=Filtering/Collectors, SC=Scrapers, SH=Shredders, P=Predators and PI=Piercer

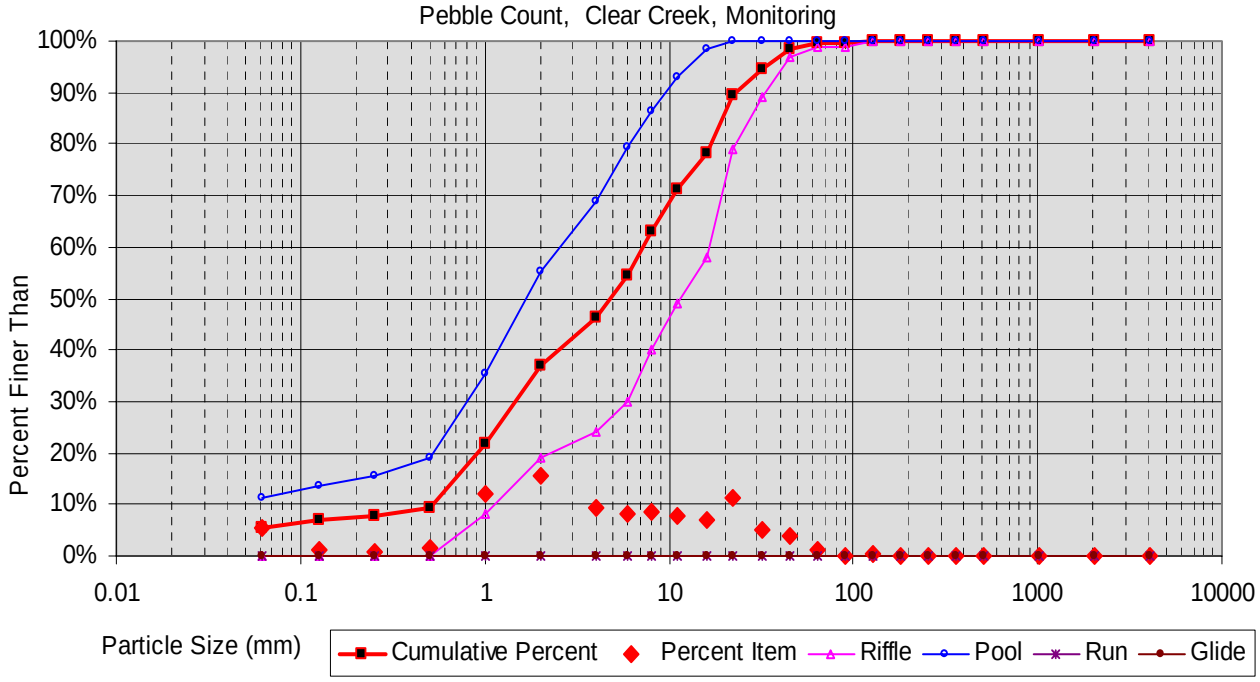
Figure 5 Clear Creek Particle Analysis

As-Built (2003)



As-Built d50= 1.3mm d84=8mm

Monitoring Year One (2004)



MY1 d50=4.8mm d84=19mm

Figure 6 Cross Sections from As-Built Survey (2003)

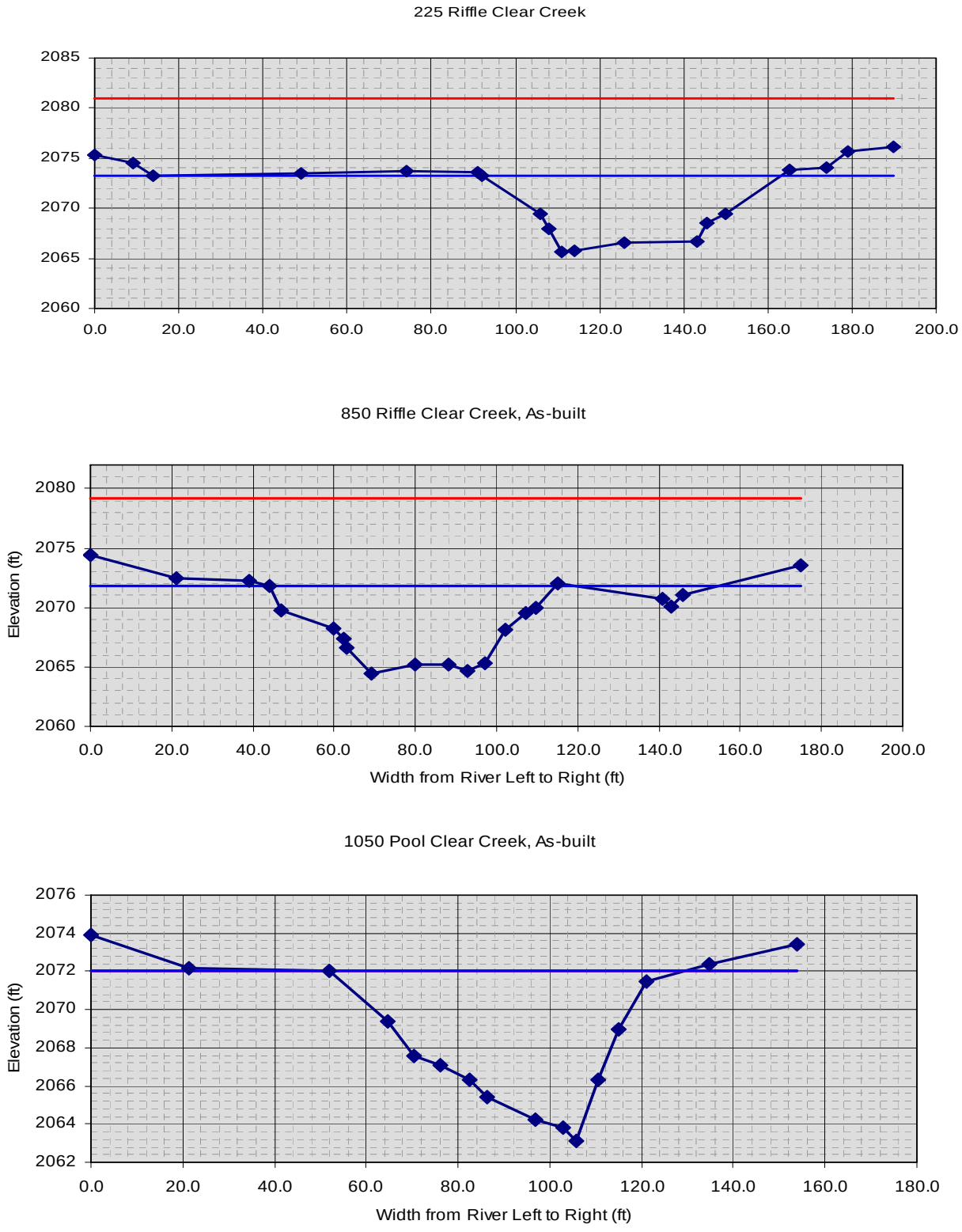


Figure 7 Cross Sections from Monitoring Year One (2004)

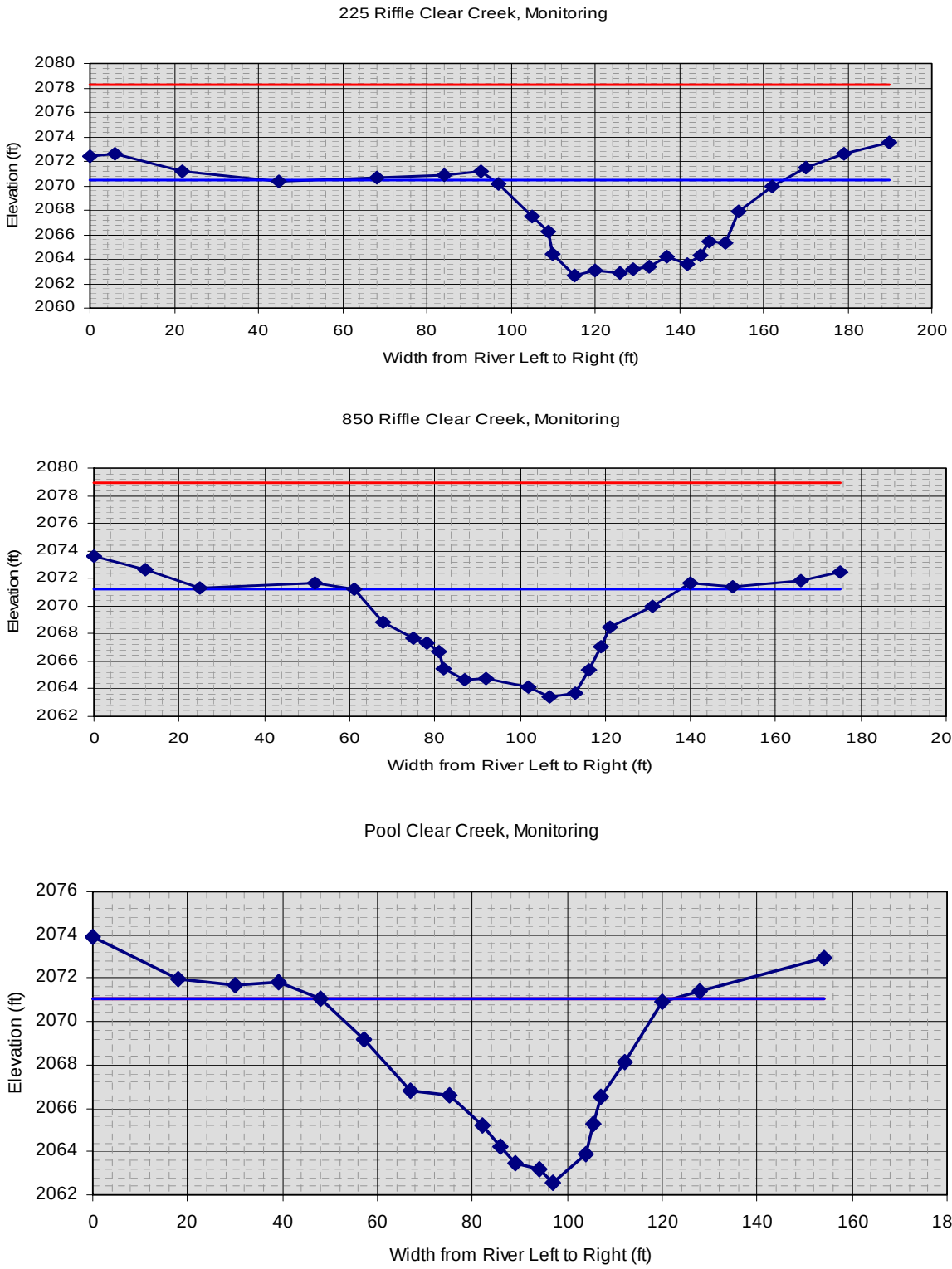
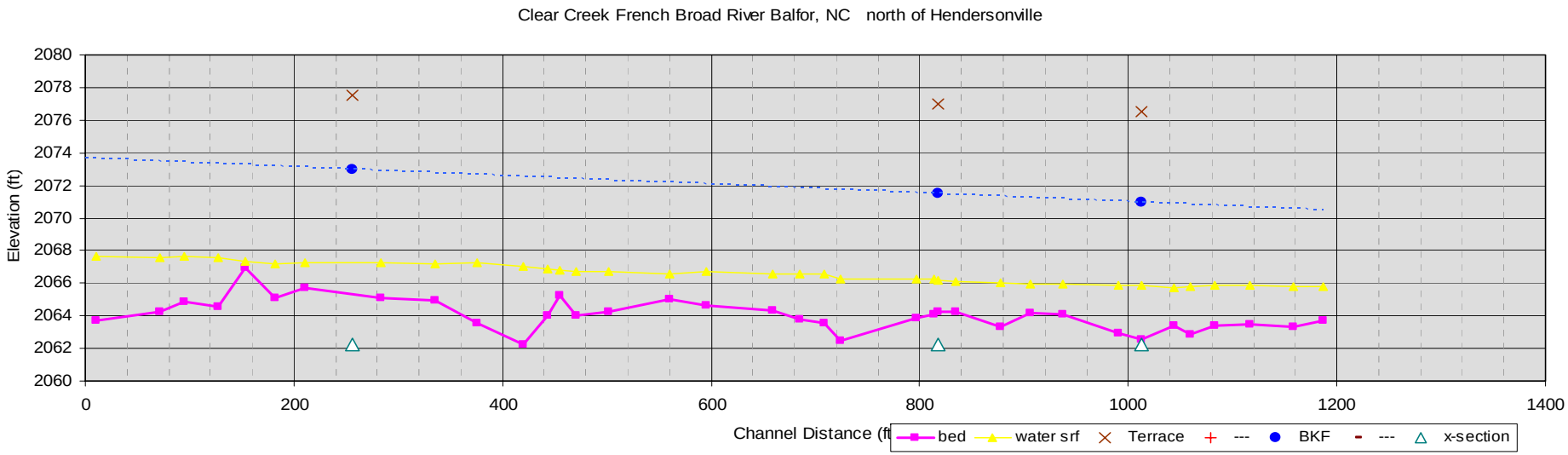


Figure 8 Clear Creek Longitudinal Profiles

As-Built (2003)



Monitoring Year One (2004)

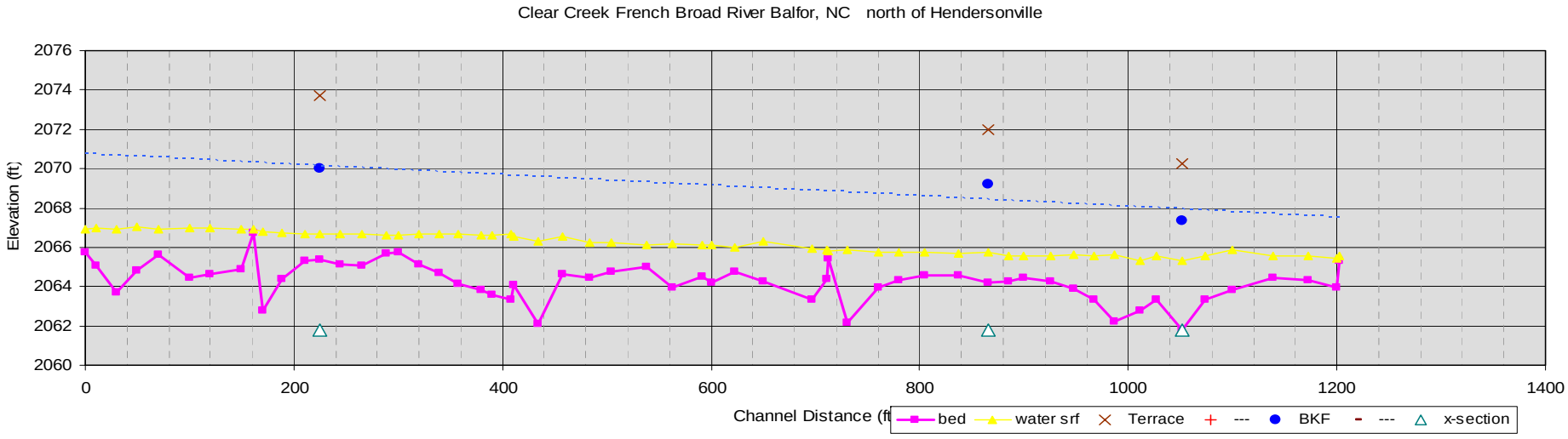


Table 4 Stem Counts by Species and Plot

Species	Plots								Initial Totals	Year 1 Totals	% Survival
	1	2	3	4	5	6	7	8			
Shrubs											
Elderberry LS				3					NA	3	UNKNOWN
Silky Dogwood LS		18	11	56				4	NA	89	UNKNOWN
Red twig Dogwood	3	4	8	14	6		4	4	NA	43	UNKNOWN
Clethra	2	1	1		9		2	2	NA	17	UNKNOWN
Blueberry	4	5	1						NA	10	UNKNOWN
Witch hazel			2						NA	2	UNKNOWN
Ninebark			4		5		3	2	NA	14	UNKNOWN
Yellowroot		1	1						NA	2	UNKNOWN
Trees											
Black willow LS		45	3	3	1		3	8	NA	63	UNKNOWN
Sycamore			1		1		1		NA	3	UNKNOWN
River birch	4	2	3		3			7	NA	19	UNKNOWN
Persimmon					5	1			NA	6	UNKNOWN
Black gum	2	7	3	1	6	1	4	3	NA	27	UNKNOWN
Flowering Dogwood			2		1		1		NA	4	UNKNOWN
Hemlock						1	1		NA	2	UNKNOWN
Green Ash	1	2			1				NA	4	UNKNOWN
Hophornbeam			1	1	2				NA	4	UNKNOWN
Serviceberry	2		1				1		NA	4	UNKNOWN
Hawthorn	2	2	1						NA	5	UNKNOWN
Sourwood					3				NA	3	UNKNOWN
White Pine					1	6			NA	7	UNKNOWN
Sugarberry			1						NA	1	UNKNOWN
Red Oak			1		1	9			NA	11	UNKNOWN
Water Oak	1		1		5			1	NA	8	UNKNOWN
Cherrybark Oak					2			1	NA	3	UNKNOWN
Redbud	1		1				1		NA	3	UNKNOWN
Totals	22	87	47	78	52	18	21	32	NA	357	

NA= Not Available