ECOLOGICAL FUNCTIONS OF RESTORED STREAM SYSTEMS:
Benthic Macroinvertebrates

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EXECUTIVE SUMMARY

This report summarizes benthic macroinvertebrate information from fifty (50) stream restoration projects in North Carolina. However, to date only 14 of the 50 projects summarized in this report have post-construction information and only 7 of these projects have more than one year of post-construction data. Many of these projects were constructed as compensatory mitigation and did not fully comply with the protocols outlined in this report. As a result of the work done by the grant protocols have been established for the collection and analyses of these macrobenthos data. These protocols suggest that pre-construction data should be collected, then allow stream conditions approximately one year to equilibrate followed by three annual and consecutive surveys (a total of 5 year monitoring period). All surveys should limit the effects of seasonal variability and use collection protocols established by the NC Division of Water Quality. The protocols also recommend that a minimum of two stations per project be established: an upstream monitoring location above the restoration reach and one site within the section of stream receiving restoration. Other stations such as an ecoregional reference location, or recovery location below the restoration reach are optional. Very low flow, drought conditions have been recorded from streams in North Carolina. These unusual, low flow conditions may have affected the results of many of these investigations. However, in most instances, biological data will continue to be collected during normal flow regimes.

Preliminary results and observations of these data suggest that some limited reestablishment of ecological stream functions occur relatively soon after restoration. In most instances, these results have been noted from rural catchments that have stable reference reaches connected to the restored stream reach. However these data also indicate that there are suites of benthic insect taxa that are habitat-specific and movement of these taxa into restored stream reaches will take much longer due to habitat requirements. These specific microhabitats include macrophytes such as Podostemum, fine rootlets in the current along the stream banks, large woody materials and logs. Also, in many instances, stream restoration projects in small, rural catchments are attempting to replant riparian vegetation. Successful reestablishment of reference, wooded conditions would therefore shift feeding types of benthic macroinvertebrate communities from those dominated by grazers (lack of wooded buffers) to shredders (wooded buffers).

Preliminary data from many of the restoration projects that are within urban catchments indicate that stormwater or urban nonpoint runoff has an overriding impact on the biological integrity of restored reaches. These data suggest that stream restoration in urban streams should include active stormwater management if successful reestablishment of ecological functions are expected. Many of the more recent urban stream restoration projects do have stormwater management plans and part of future analyses of these data will examine whether stormwater management of restored urban streams is beneficial to the biology of these systems. These data also indicate the importance of having stable, upstream reference reaches for comparison to restored reaches.

Based on preliminary data and observations, draft biological success criteria have been established. These criteria are based on the selection and use of appropriate reference data. These draft success criteria will be examined and refined based on further collection and analyses of additional benthic macroinvertebrate data over the next few years. These criteria will be further tested and improved as data storage and manipulation capabilities are refined within the Unit.

GRANT DELIVERABLES AND PRODUCTS

1) Benthic Macroinvertebrate Monitoring Protocols for Compensatory Stream Restoration Projects: This internal technical guidance document was written to assist consultants with the proper collection and analyses of benthic macroinvertebrate samples and was used as reference material for the training classes. This document can be downloaded from the DWQ Wetlands Unit website (http://h2o.enr.state.nc.us/ncwetlands/).
2) Training Classes: A series of two-day training sessions were conducted in the Raleigh area to instruct individuals in standard operating procedures recommended by the Division of Water Quality for the collection of benthic macroinvertebrates (curriculum for class is Attached as Appendix 3. To date, personnel from 36 private consulting firms and approximately 120 students have successfully completed this training.
3) Ecological Functions of Restored Streams (this document): This document summarizes the biological data from 50 stream restoration projects in North Carolina. To date, 14 of these 50 projects have pre- and post-construction data summarized.
4) Data Files: For each of the stream restoration projects in NC tracking forms have been completed (example of a tracking form is attached as Appendix 4) and hard copies of all data have been maintained.

SUCCESS/VALUE OF GRANT

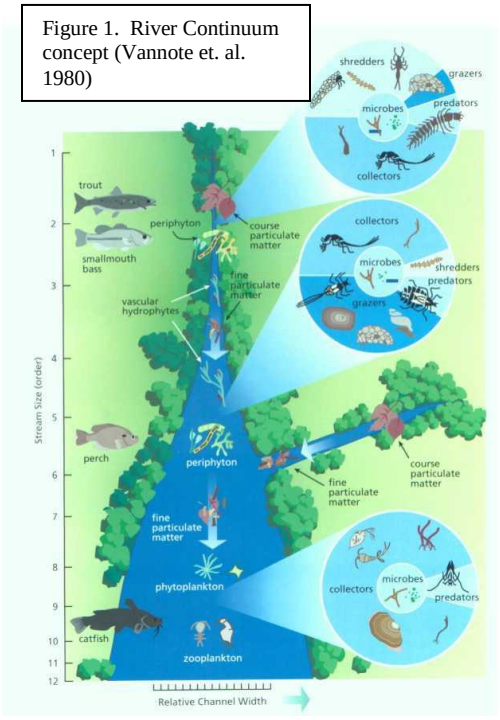
Stream restoration has become an important national initiative (Charbonneau and Resh 1992, Roni et al. 2002, and Kondolf and Micheli 1995) with participation and oversite from many state and federal regulatory agencies as well as private entities. Despite this commitment of resources, post-construction evaluation of the biological success of restoration projects has been limited. The data summarized in this document is an initial attempt by a regulatory agency to monitor the biological integrity of restored channels and attempts to define preliminary success criteria.

INTRODUCTION AND REVIEW OF LITERATURE

Stream management and restoration require knowledge of the complex interactions between the catchment and stream processes. Stream systems are dynamic environments where channel stability location and habitat characteristics frequently change in response to erosion, deposition or sediment processing efficiency. Stream restoration projects attempt to stabilize channels in such a way that physical long-term equilibrium is ensured. Stream restoration projects summarized in this document are projects in which the pattern, dimension and profile of altered stream systems are modified to mimic reference conditions. Biological communities in streams must adapt to these changing environments. However, very little is known about the response of ecosystem structure and function to stream restoration. It is generally assumed that as habitat heterogeneity following restoration increases, that diversity and taxa richness of keystone species will increase as well (MacArthur, 1965). But this hypothesis has not been tested and the success or failure of stream restoration projects based on these data is poorly understood. The restoration of degraded streams has become a major initiative nationally (Charbonneau and Resh 1992, Roni et al. 2002). However, the restoration of stream channels, including the construction of instream habitats, and associated responses within aquatic insect populations is a relatively new area of interest.

The river continuum concept (Vannote et. al., 1980) is one of the most popular tools for predicting how biological communities change from headwater reaches to the mouth of a stream (Figure 1, reprinted with permission EPA 1999). The river continuum concept hypothesizes that small first to third order streams are heterotrophic systems. These streams are dependent upon the energy produced in the surrounding watershed and have functional feeding assemblages of aquatic insects associated with this energy source (Minshall et. al. 1983, Cummins and Klug 1979). The benthic insect communities in these small streams, as illustrated in Figure 1, are dominated by shredder organisms. Taxa such as the stonefly Tallaperla, which are common in mountain streams, are important shredders that feed on bacteria and breakdown leaf material. As streams become larger, energy sources become more autotrophic as primary production increases in response to increase light levels. Functional feeding assemblages of aquatic insects then shift to a community dominated by grazers or collector organisms (see Figure 1). The dynamic equilibrium of many small stream systems in North Carolina have been altered due to deforestation for pasture or agriculture and in many instances these streams have been selected for restoration. In very short reaches, these small stream systems have been modified from heterotrophic to autotrophic systems. Therefore one potential goal of stream restoration managers should include restoration of heterotrophic energy sources to streams.

Figure 1. River Continuum concept (Vannote et. al. 1980)



The dynamic equilibrium of stream systems can be disrupted by a variety of factors. In very general terms, as stream systems become unstable, the width/depth ratios become larger and essentially streams become wider and shallower. Streams then loose their ability to process sediment, deposition of sediments increases and habitat loss is observed. Benthic communities become dominated by those taxa that have the ability to tolerate unstable conditions. The design

of many stream restoration projects includes establishment of a stream's ability to process sediment and to increase the amount of stable habitat. Therefore after restoration, stream habitats should once again become more heterogeneous and stable and the aquatic insect populations will recover or recolonize previously unstable reaches. Habitat forming mechanisms are driven by geomorphic and hydraulic processes and are central to the success of stream restoration projects (Dorava et. al. 2001, Palmer 1997, Statzner et. al. 1988). Statzner et. al. (1988) introduces the concept of "hydraulic stream ecology" and notes that stream hydraulics will affect the sequence of aquatic insect species assemblages along the stream continuum and that hydraulic characteristics such as shear stress, shear velocity or boundary Reynolds numbers will influence behavioral characteristics of these insects.

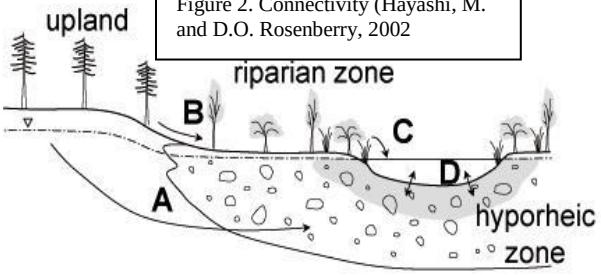


Figure 2. Connectivity (Hayashi, M. and D.O. Rosenberry, 2002

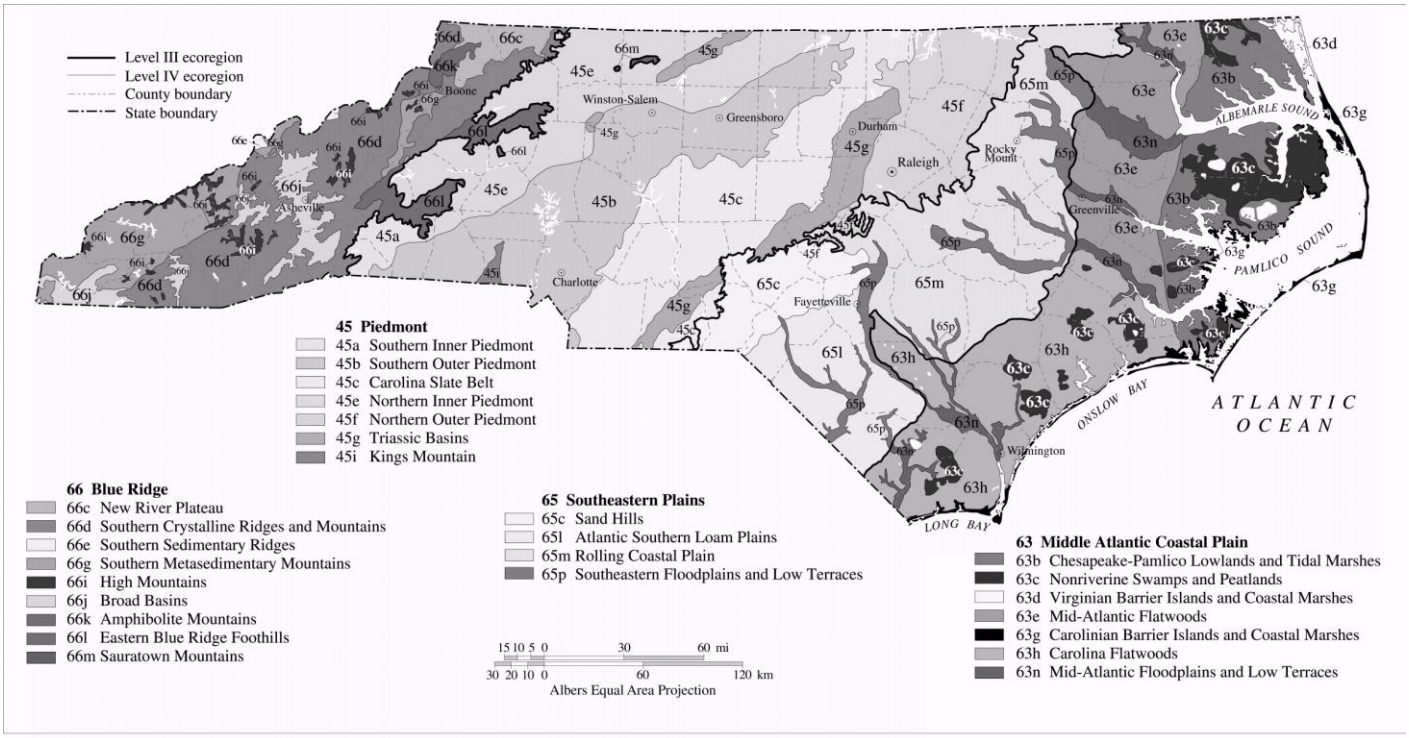
The river continuum concept also addresses connectivity between the stream and its watershed. The degree of connectivity between a restored stream reach and its refugium will, to some degree, determine the success of a restoration project. Potential sources of recolonization of insect species includes stable upstream reaches, but also migration from interstitial and hyporheic zones beneath the stream substrate. The concept of connectivity is poorly reviewed in the literature, but may be an important concept for the determination of ecological function in restored stream systems. The National Research Council (1992) defined restoration as "*The return of an ecosystem to a close approximation of its condition before disturbance. In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are recreated. Merely recreating the form without the functions, or the functions in an artificial configuration bearing little resemblance to a natural resource, does not constitute restoration. The goal is to emulate a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs."* The Division of Water Quality further defines stream restoration as *"the process of converting an unstable, altered or degraded stream corridor, including adjacent riparian zone and flood prone areas to its natural or referenced, stable conditions considering recent and future watershed conditions. This biological and chemical integrity, including transport of water and sediment is produced by the stream's watershed in order to achieve dynamic equilibrium"* (N.C. DWQ 2001). The primary objective of this grant is to look at the benthic macroinvertebrate community in restored streams with the goals of 1) determining whether stream restoration results in biological improvement and 2) producing a possible monitoring strategy for the determination of project success or failure.

METHODS: SITE SELECTION CRITERIA AND COLLECTION PROTOCOLS

Early in the planning process for this grant, several conferences were held with cooperating agencies (including the US Army Corps of Engineers, NC Wildlife Resources Commission and the NC Wetlands Restoration Program). Monitoring of stream restoration projects in North Carolina was discussed. Participants in these meetings suggested that biological monitoring (specifically the benthic macroinvertebrate community) should be included as a monitoring tool for selected projects and that these data would be analyzed prior to making any policy decisions regarding the use of benthic macroinvertebrate data as success criteria.

In response to these meetings, DWQ developed the following monitoring protocol. Projects to be monitored were selected from each of the eight major ecoregion types in North Carolina (Figure 3) and represent both rural and urban streams as well as projects from both small and large stream systems. A preliminary goal of 5 projects from each category (rural/urban and small/large catchments) was also established resulting in a total of up to 80 stream restoration projects. Finally projects to be monitored must have include those with at least a minimum of 1000 linear feet of restoration.

Figure 3. Ecoregions of North Carolina (printed with permission from Glen Griffith US EPA)



Benthic macroinvertebrate samples were collected by the NC Division of Water Quality at many of the restoration projects. Most of these were cooperative monitoring projects with the NC Wetlands Restoration Program; however, some high priority projects were also conducted cooperatively with the Wildlife Resources Commission or with the NC Department of Transportation. Monitoring at other projects were conducted by private consulting firms; the Division of Water Quality then reviewed the data. To ensure consistency of the data, the Division of Water Quality prepared a technical guidance manual

(N.C. DWQ, 2002) and conducted a series of five training workshops which were intended to instruct private consultants on standard operating procedures for collection of data.

Technical Guidance Manual. Survey protocols, including sample collection and processing mimic those described in the Standard Operating Procedure of the Biological Assessment Unit of DWQ (NCEHNR 1997). Copies of this document can be obtained from DWQ's web site (http://www.esb.enr.state.nc.us/BAU.html). Standard qualitative collection methods were recommended for surveys conducted in all wadable streams that are 3rd order or larger. This collection method consists of two kick net samples, three sweep net samples, one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections (Lenat 1988). Insects are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol. Organisms are picked roughly in proportion to their abundance, but no attempt is make to remove all organisms from the samples. If an organism can be reliably identified as a single taxon in the field (an example would be Isonychia), then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera, and all Hemiptera except Naucoridae, Belostomatidae, Corixidae and Nepidae. These are not picked either because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. The hemipteran families that are included can spend long periods below the water surface.

Stream mitigation projects are frequently conducted in small perennial streams having catchment sizes of less than one square mile (640 acres). Standard qualitative collection methods for these small 1st and 2nd order streams are inappropriate. Therefore, an abbreviated collection technique be used (EPT collection method). This technique is a modification of the standard method in which only four samples are collected (rather than ten): one kick net sample, one sweep net sample, one leaf-pack and "visuals" and only Ephemeroptera, Plecoptera and Trichoptera are collected and identified. However, during these surveys all organisms are collected and processed not just EPT taxa. This collection method is referred to in this guidance as a Qual-4 technique. Analytical methods include the comparisons of taxa richness (total and EPT), abundance and NC biotic index values (lower biotic index values indicate better water quality) between investigations. It is recognized that Ephemeroptera, Plecoptera and Trichoptera (or EPT) are generally not considered early colonizers and would not be appropriate indicator organisms for restoration projects (Merritt and Cummins 1984, Palmer et al. 1997).

Collection Protocols Training. A series of two-day training sessions were conducted in the Raleigh area to instruct individuals in standard operating procedures recommended by the Division of Water Quality for the collection of benthic macroinvertebrates. The first day was devoted to instruction/demonstration of collection methods, insect recognition and general concepts of water pollution biology. The second day consisted of a written test and a field validation exercise. To date, personnel from 36 private consulting firms and approximately 120 students have successfully completed this training and were awarded certificates of completion.

RESULTS AND DISCUSSION

It was not possible to select monitoring projects, evenly among all ecoregions by watershed size and land use. Table 1 lists the number of projects by watershed size (small streams are defined as those having less that one square mile catchment) and general land use patterns and Figure 4 illustrates the number of stream restorations by county in North Carolina. Most projects were selected from small, rural watersheds and were skewed to the western and eastern piedmont ecoregions. This selection process was based primarily on need and it's obvious that most of the restoration projects in North Carolina were associated with regions of impact. Development, including road construction, is concentrated in the piedmont of North Carolina and most mitigation projects associated with this development also were in the western and eastern piedmont ecoregions.

Table 1. Stream Restoration Projects by watershed size and land use.

	Watershed Size		**General Land Use**	
Ecoregion	Small	Large	Rural	Urban
Mountain	3	3	4	2
New River	6	0	5	1
Western Piedmont	15	2	10	7
Slate Belt	2	0	2	0
Triassic Basin	2	1	3	0
Eastern Piedmont	9	0	4	5
Sand Hills	0	1	0	1
Coastal Plain	2	4	5	1
Subtotals	39	11	33	17
Total # Projects	50		50	

All of the restoration projects, which have biological monitoring components are listed in Appendix 1 with supporting information on stream size, general land use as well as dates of construction and a monitoring schedule. At this point in time only 14 of the 50 projects listed have both pre- and post-construction data and each of these 14 projects are summarized in this section by ecoregion. In addition, biological monitoring will be required by DWQ for a limited number of stream restoration projects in order to provide additional data for more ecoregions. Currently most of the stream restoration projects only have pre-construction data (36 projects). The biological data from these projects are listed in Appendix 2 by ecoregion.

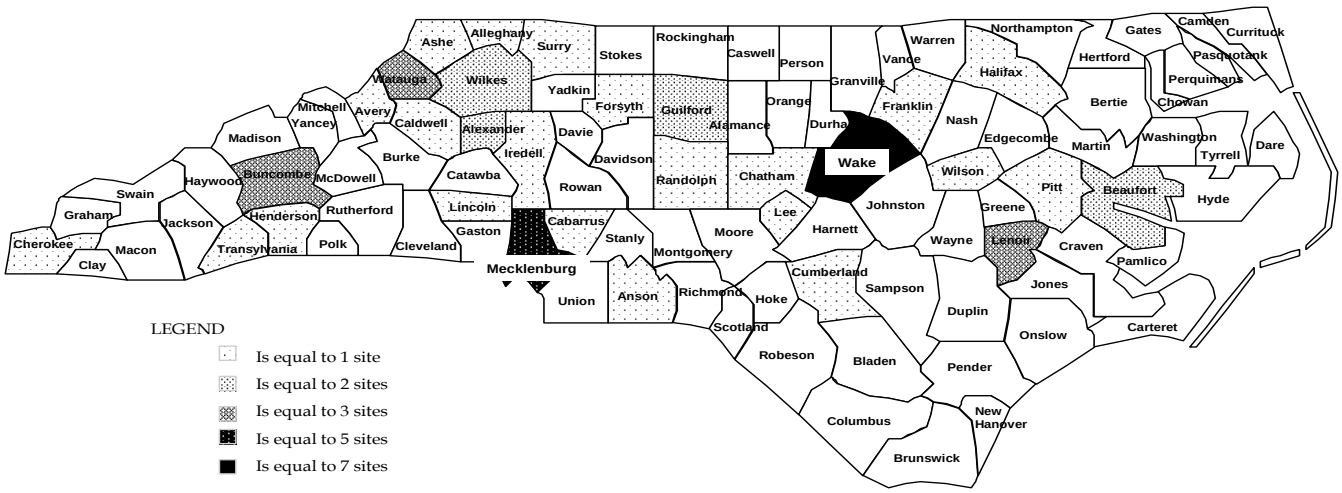
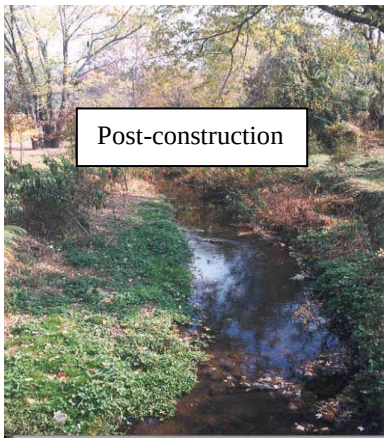


Table Format. Collection protocols (N.C. DWQ 2002) recommend that a pre-construction survey be conducted followed by three annual, post-construction surveys. Generally biological monitoring during the first year following construction is not necessary. It is also strongly recommended that all surveys be conducted during similar seasons to avoid unnecessary variability within the data for a particular site. For the purposes of this report, data summaries for all investigations adhere to a standardized format. Site 1 for each investigation is located on the test stream but above the stream reach that is being restored and is generally considered as background condition. In most instances, this location is more stable than the restored reach and may represent heterotrophic conditions with a mature riparian canopy. Site 2 is within the restored reach. In addition to these two locations, investigations also may have data from Site 3 which in most cases represents a recovery site below the reach of stream being restored. It is often assumed that the restoration project will improve the connection between the stream reach being restored and it's catchment. Data from Site 3 (which is not mandatory per 401 Certification Program protocols) may help to determine if there are any downstream improvements in water quality. Also in some instances, regional reference information was collected ("reference" columns in the tables). Again this was not a mandatory requirement for these projects; however, these data often are useful for comparisons between sites and/or for seasonal data corrections. If data were not collected from any of these locations during the investigations, then the sections within the summary tables were intentionally left blank.

Mountain Ecoregions, including New River
(Ecoregion # 66 from Figure 3)

1. Reed Creek - Asheville, Buncombe County; Constructed March 1998,

Reed Creek is located within Weaver Park, which is in a suburban section of Asheville and receives urban non-point source and stormwater runoff. Benthic macroinvertebrate and fish community structure samples were collected from one location (site 2) within the restoration reach of this stream prior to construction (January 1998) and three times since construction (October 1998, October 1999 and October 2000). The site was selected for mitigation as part of the proposed widening of US 74 from I-40 to SR 2775 in Buncombe County. The DOT biologists collected qualitative data (using DWQ protocols) and quantitative data using Surber samplers. Surber samples collect all of the organisms from one square foot of substrate and all taxa are collected and enumerated. This summary includes both the qualitative data and quantitative information from this one location. Biological data were not collected from an upstream reference reach (Site 1), a regional reference location nor from a downstream location (Site 3). DWQ policy for stream mitigation projects was not developed at that time and it was assumed that the pre-construction data from this stream would act as the reference information.



It is clear from these data that Reed Creek has severe water quality problems, probably associated with urban stormwater runoff. Taxa richness values (especially EPT taxa richness values) did not change substantially during the course of this investigation. The EPT fauna was dominated by tolerant hydropsychid caddisflies (Hydropsyche betteni and Symphitopsyche sparna) during both pre and post-construction surveys. However, there were some fairly significant differences in EPT abundance values between surveys as noted in the qualitative samples. For example, much lower EPT numbers were noted at this location during the first post-construction survey and again during the most recent investigation. These data suggest that the benthic fauna of Reed Creek may be responding to the effects of urban stormwater runoff or hydrology and that if ecological improvements to this urban channel are desired, that stormwater management in the catchment may be necessary.

Table 2. Benthic Marcoinvertebrate summary statistics from Reed Creek, Asheville.

Reed Creek, Asheville (NC Department of Transportation)																
Site Location	Reference				Site 2, Qualitative				Site 2, Surbers				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					12	14	7	C/I**	7	10	9	5				
EPT taxa (SEPT)					3	2	2	C/I**	2	2	2	2				
EPT abundance (EPTn)					21	20	20	C/I**	94	38	106	17				
Biotic Index (BI)					NA*	NA*	NA*	NA*	NA*	NA*	NA*	NA*				
EPT Biotic Index (EPTBI)					NA*	NA*	NA*	NA*	NA*	NA*	NA*	NA*				
Total Abundance (Sn)					-	-	-	NA*	139	132	124	21				

*NA-Biotic Indices were not calculated, **C/I- samples have been collected but not enumerated

Very few fish species were collected from this reach of Reed Creek. The creek chub (Semotilus atromaculatus) was the only fish species collected during the pre-construction survey. During the October 1999 post-construction survey creek chub, blacknose dace (Rhinichthys atratulus), and one specimen of the central stoneroller (Campostoma anomalum) were found.

2. UT Peak Creek (Bare Site) – Ashe County; Construction September 2001,

Biological data were collected (benthic macroinvertebrates by the DWQ and fish community by the NCWRC) from this location, although the project is a stream enhancement, in which stream banks are revegeted and instream structures are placed in the channel, while the stream's pattern, dimension and profile left unchanged. It was suggested that these data might provide a useful comparison between stream restoration and enhancement. Benthic macroinvertebrates were collected from one location near the lower end of the enhanced reach prior to (August 2001) and after construction. Tables 3 and 4 summarize the fish community and benthic macroinvertebrate data, respectively. Table 3 indicates that the number of brook trout were higher at both locations following construction but that the number of non-trout species were slightly lower, although representing the majority of fish collected, at both locations following construction. It appears that the enhancement structures places in this stream provided habitat for brook trout and that these fish have begun to repopulate this reach of stream.

Table 3. Fish community structure from UT Peak Creek prior to and post construction.

UT Peak Creek, Fish Community Structure pre- and post-construction				
	2001, Pre-construction		2002, Post-construction	
Metric/Station	Upstream	Downstream	Upstream	Downstream
No. Brook Trout/ Acre	45	0	126	37
No. Non-trout/Acre	17,199	24,897	17,049	21,127

Table 4 lists the results from the benthic macroinvertebrate survey conducted at this project. These data indicate that there has been very little noticeable change in the taxa richness values for benthic insect fauna before and after construction to date. In addition most of the abundant taxa collected from this stream prior to enhancement remained abundant following the construction, suggesting that the construction had little impact to the aquatic insect fauna. However, EPT abundance values following construction during the 2002 survey were somewhat higher. The abundance of EPT taxa may be in response to the improvement in habitat stability and/or reduction in erosion rates within this reach of UT Peak Creek.

Table 4. Benthic macroinvertebrate summary statistics, UT Peak Creek.

UT Peak Creek, Benthic macroinvertebrates pre- and post-construction		
Metric/Survey	August, 2001	August, 2002
Total Taxa (ST)	52	51
EPT Taxa (SEPT)	26	25
EPT abundance (EPTn)	107	140
Biotic Index (BI)	NA	NA
EPT Biotic Index (EPTBI)	NA	NA

NA-Biotic Indices were not calculated

Western Piedmont Ecoregion
(Ecoregions 45e and 45b from Figure 3)

1. Stone Mountain State Park, E Pr of the Roaring River – Wilkes County; Constructed November 2000

Studies have indicated that stream bank erosion along downstream reaches of the East Prong of the Roaring River was severe due to past agricultural practices. Restoration of the East Prong, within Stone Mountain State Park, included stabilization of the eroding banks and provision of instream habitat as well as reestablishment of pattern, dimension and profile. The total length of the project was 10,633 linear feet in two major reaches of the river. Biological samples were collected from three locations. Reference data (site 1) were collected from a site above the restored reaches within a stable section of the East Prong (see photo below). Two downstream stations were also sampled. Site 2 is within the upper restoration reach and Site 3 is near the lower end of the most downstream section of the restoration. Data were collected during the months of September or October during all surveys.


East Prong Roaring River, Stone Mt. State Park

Table 5. Benthic Macroinvertebrate summary statistics, Stone Mt. State Park.

Stone Mountain State Park (Division of Water Quality)																
Site Location	Reference				Site 1				Site 2				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					73	61	73		75	67	75		66	61	73	
EPT taxa (SEPT)					39	37	37		38	36	35		36	28	32	
EPT abundance (EPTn)					165	173	202		170	154	183		194	109	126	
Biotic Index (BI)					4.05	NA*	NA*		3.97	NA*	NA*		4.38	NA*	NA*	
EPT Biotic Index (EPTBI)					2.70	NA*	NA*		2.60	NA*	NA*		3.10	NA*	NA*	
Dominants in Common						-	-		-	76%	78%		-	34%	48%	

*NA-Biotic Indices were not calculated

Data from the investigations at Stone Mountain State Park are summarized in Table 5. Results of the benthic macroinvertebrate investigations resulted in Good bioclassifications at all locations during each survey (DWQ classification criteria). Slightly lower taxa richness values were recorded from all of the locations during the first post-construction survey, although the differences in EPT taxa richness between the pre and post construction surveys was larger at the most downstream location (site3). However, there were some significant differences in EPT abundance values between surveys. EPT abundance values increased progressively downstream during the pre-construction survey; however this trend was reversed during the first and second post-construction investigations. During these surveys EPT abundance numbers declined progressively downstream. The primary difference between surveys at this lower location was in the number and richness of the caddisfly population. Apparently caddisfly species that could drift and repopulate the downstream reach did so. However, there were several taxa that are poor drifters that have not repopulated this reach (Goera, Brachycentrus, Neophylax) as well as other caddisflies (Diplectrona and Dolophilodes). Many of the insects that were collected at upstream location are habitat specialists and many of the microhabits found at the reference reach are not yet present in the newly created stream sections. A list of keystone species for this project should include these caddisfly taxa. Therefore, these results suggest that repopulation of

the lower reaches of the East Prong of the Roaring River by benthic macroinvertebrates may depend on the establishment of microhabitats, such as macrophytes (Podostemum) on stable habitat material or growth of fine root hairs along the stream banks. The dominants in common metric calculated for the first and second year of post-construction information suggest that biological recovery has taken place at station 2 (DIC = 76 and 78%), but that recovery and recolonization of station 3 has not occurred (DIC = 34 and 48%). The dominants in common were higher at both locations during the second post-construction investigation, suggesting that recolonization/recovery is improving.

2. Concord Mills – Cabarrus County; Constructed July 1999

In 1997 and 1998 a mitigation plan was prepared to provide full functional replacement for wetland and stream impacts associated with the construction of the Concord Mills Mall (EcoScience 2001). The mitigation site is an unnamed tributary of the Rocky River and its associated floodplains. The mitigation plan proposed approximately 3000 linear feet of stream restoration, 3.0 acres of wetland restoration and 5.4 acres of wetland enhancement within the site. Some discrepancies were noted in the monitoring protocols. During the pre-construction survey (April 1999) data were collected from two locations within the restoration reach of this stream using quantitative methods (grabs) and were not compared to reference conditions. During the first post-construction survey (July 2001) Qual-4 collection methods were used to collect samples from the now restored reach and from a reference reach (Mill Run). During the second post-construction survey (August 2002), Qual-4 samples were collected from a stable reach within the same stream (site 1) but above the restored reach and from the same site within the restored reach (site 2). Benthic macroinvertebrate samples were not collected from the reference stream, since it was completely dry due to the extreme drought experienced in NC during 2002. Many of the collection discrepancies were probably due to the lack of stream restoration monitoring protocols by DWQ early in this initiative.

Table 6. Benthic macroinvertebrate summary statistics from the Concord Mills stream restoration project.

Concord Mills (EcoScience)																
Site Location	Reference				Site 1				Site 2				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)		27	dry				37		25		32		26	16	Sed.	
EPT taxa (SEPT)		7	dry				9		2		8		0	4	Sed	
EPT abundance (EPTn)		31	dry				39		20		23		0	17	Sed	
Biotic Index (BI)		NA*	dry				NA*		NA*		NA*		NA*	NA*	Sed	
EPT Biotic Index (BIEPT)		NA*	dry				NA*		NA*		NA*		NA*	NA*	Sed	
Dominants in Common							-				35%					

* NA-Biotic Indices were not calculated. Sed.-no sample was collected at this site due to heavy sedimentation and lack of water.

Accurate trend analyses of these data, is difficult due to the differences in collection methods and station locations between surveys. However, some interesting results are evident from these data. During the most recent post-construction investigation (July 2002) samples were collected from a relatively stable, but incised, reach of this tributary (site 1) and from the upper station within the restoration reach (site 2). A dominants in common comparison of these data resulting in 32%. Data were not collected from the lower site within the restoration reach (site 3). The stream at this point was not flowing due to heavy sedimentation, perhaps due to erosion from upstream activities that did not impact site 1. In fact, flow was reduced to a point that significant differences in the structure of the benthic macroinvertebrate community were seen between sites 1 and 2. Site 1 was dominated by Heptageniid mayflies (Stenonema) and rheophilic caddisflies

(hydropsychidae, Chimarra aterrima and Neophylax), while most of these organisms were not collected from site 2 and may be considered keystone. The benthic fauna at site 2 was dominated by pulmonate snails (Physella), Caenis, beetles (mostly Peltodytes) and Baetis. These data suggest that the restored reach of this stream is not effectively processing sediment from upstream reaches to a point where the hydology of this stream has changed and this has resulted in a modified benthic macroinvertebrate community downstream. DWQ plans to visit and evaluate this project.

3. Fiddlers Creek - Winston-Salem (Forsyth County); Constructed May 1999

Approximately 580 linear feet of a UT to Fiddler's Branch were relocated (May 1999) to accommodate construction of a housing development. Benthic macroinvertebrates were collected from four locations prior to construction and during three post-construction investigations. Sites were selected above the restored reach in a relatively stable reference reach, within the restored channel (site 1), below the restored channel (site 2) and in Fiddler's Creek below the confluence with the UT. Data from these investigations are summarized in Table 7.

Table 7. Benthic macroinvertebrate summary statistics from UT Fiddler's Creek stream restoration project.

Fiddlers Creek, Winston-Salem (KCl)																
Site Location	Reference				Site 1				Site 2				Fiddler's Creek			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)	19	25	19	12	28	16	14	7	18	4	19	4	21	15	26	11
EPT taxa (SEPT)	3	4	4	1	12	1	1	0	3	0	3	0	10	3	10	1
EPT abundance (EPTn)	30	6	6	10	38	3	1	0	16	0	3	0	43	3	34	1
Biotic Index (BI)	5.59	5.98	6.52	4.49	5.69	6.84	6.31	5.99	5.02	8.21	6.82	7.26	5.34	7.14	5.06	7.47
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

The reference reach for this project is a very small, perennial channel and results suggest that this section of the UT is susceptible to drying. Dominant taxa collected from each investigation included mayflies in the family Leptophlebiidae and crustacea that are common in small stream systems. Results from the impact area (site 1) indicate an adverse impact of construction and no recovery during all subsequent investigations. Taxa richness and abundance values continue to decline at this location. Somewhat more variable data are noted at the downstream site (site 2) and at Fiddler's Creek below the confluence of the UT. Note the elevated biotic index value following construction. Reductions in taxa richness and abundance were seen at these two locations during the first post-construction survey, but a limited recovery was noted during the second post-construction survey (including decreases (better water quality) in biotic index values). Data from the third post-construction survey again noted decreased taxa richness and abundance values that were similar to those recorded from the first year following construction. EPT taxa were eliminated from the impact (site 2) and downstream (site 3) collection locations on the UT. These data indicate that construction activity, or perhaps additional construction activities in the catchment, impacted the benthic fauna of this stream and that attempts to restore the community structure have not been successful.

4. Starmount Park – Greensboro, Guilford County; Restored February 2001

Two investigations have been conducted at this project (March 2000 and March 2001). During the March 2000 survey, benthos were collected from only two locations and during the 2001 survey data were collected from three sites. Qual-4 methods were used at all locations during

both investigations. An additional location was analyzed in 2001 downstream from a recently restored reach. The upstream location (site 1) is located within a residential area, although the riparian zone was intact and forested. The stream at this point appears to be relatively stable with good instream habitat. Bedrock outcrops were noted in several areas within this reach. Site 2 is located within the reach that has been restored. This reach is within the Starmount Country Club and golf course and has little riparian vegetation. The stream at this point is essentially a straight channel.

Very little new sinuosity was added to this reach during restoration due to lateral constraints of the golf course. Little new habitat was constructed. There were no undercut banks, riffle material appeared to be undersized and the banks consisted exclusively of coconut matting logs. In addition to these observations, there also appeared to be some nutrient enrichment. Site 3 is located above Market Street at the lower end of this project. This reach was recently constructed approximately one month before the March 2001 investigation and, as expected, very little recolonization has occurred at this site to date. Banks were constructed exclusively of coir-fiber logs and the bottom of the stream was lined with large rocks. The substrate was unstable (fine sand/clay material was immediately below the rocks) and very little sweep areas were found for collection. No riparian canopy was noted at this station as well.

Table 8. Benthic macroinvertebrate summary statistics from the Starmount Park stream restoration project.

Starmount Park, Greensboro (Division of Water Quality)																
Site Location	Reference				Site 1				Site 2				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					26	24			31	25				6		
EPT taxa (SEPT)					2	2			3	2				1		
EPT abundance (EPTn)					13	13			21	20				1		
Biotic Index (BI)					NA*	NA*			NA*	NA*				NA*		
EPT Biotic Index (EPTBI)					NA*	NA*			NA*	NA*				NA*		

*NA-Biotic Indices were not calculated

It is apparent that this UT to North Buffalo Creek is impaired, since the upstream reference location, which appeared to be relatively stable, and has a very tolerant benthic population. Physella and Cheumatopsyche are the two dominant taxa collected during both surveys at this location. EPT taxa richness numbers are extremely low for this reach perhaps responding to stormwater runoff. However, there does appear to be subtle differences in the community structure here compared to downstream reaches. For example, during the March 2000 survey a stonefly (Perlesta) was common at this site and was not collected at the downstream location and during the 2001 survey Ectopria and Ferissia at this location and not from the downstream sites. These taxa may be considered keystone taxa for this project. Interestingly, Crangonyx and Physella were both abundant at this site during both surveys and were not collected or had

reduced abundance at downstream reaches. Data also were collected from Site 2 during surveys conducted there in 2000 and 2001. The benthic fauna at this site was dominated by Cheumatopsyche and Hydropsyche betteni during both investigations suggesting that the restoration of this reach of stream has not changed the environmental conditions necessary for these tolerant taxa. Numbers of these two taxa were much higher here than at the upstream site apparently responding to enrichment or autotrophic conditions of the catchment at this point. Numbers of Argia and Enallagma also were much higher here that at the upstream location. Station 3 has been recently constructed and so far has a very depauperate community. A survey was not conducted during the 2002 survey period; however; follow up investigations will be conducted.

5. Payne Dairy – Taylorsville, Alexander County; Constructed February 2001

Benthic macroinvertebrates samples were collected from three locations to assess the restoration of Jumping Run Creek. Qual-4 collections were used at all locations. Station 1 is located above the restoration project in a relatively stable reach of Jumping Run Creek (approximately 3-4 riffles above fence that marks property line), although there is some sedimentation and bank erosion at this location. The catchment above this location contains mostly pasture and has some stormwater from residential development. Station 2 is located approximately 50 meters above SR 1614. The stream was very unstable at this point with cattle access. Prior to construction the substrate was primarily sand and fine silt. Bank erosion was severe and the canopy has been reduced or eliminated in some places. Also it appears that this reach of Jumping Run Creek has been channelized in the past. Station 3 is below a UT of Jumping Run Creek on the property which is being enhanced. Jumping Run Creek at this point appeared to be more stable and had a much wider riparian zone. Cattle have access to this reach prior to restoration and the benthos was dominated by Physella suggesting accumulation of FPOM and occasional low DO values. The data in table 9 summarize the data from these three locations.

Table 9. Benthic macroinvertebrate summary statistics at the Payne Dairy stream restoration project.

Payne Dairy, Taylorsville (Division of Water Quality)																
Site Location	Reference				Site 1				Site 2				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					43	37			38	12			31	28		
EPT taxa (SEPT)					19	20			8	3			9	7		
EPT abundance (EPTn)					67	88			39	7			47	36		
Biotic Index (BI)					4.07	C/I**			5.92	C/I**			6.32	C/I**		
EPT Biotic Index (EPTBI)					3.22	C/I**			5.48	C/I**			5.48	C/I**		
Dominants in Common					-	-			25%	6%			25%	21%		

C/I**- Samples have been collected by haven't been enumerated.


Jumping Run Creek

Nineteen EPT taxa were collected from station 1 during the pre-construction and 20 during the first post-construction survey; many of these keystone taxa were eliminated at both downstream locations (most notably Psilotreata, Diplectrona modesta, Baetis tricaudatus, Eccoptura xanthenes, Acroneuria abnormis and Perlesta). The number of filter-feeding taxa increased at station 2, presumably responding to the input of fine particulate organic matter. These taxa include Hydropsyche betteni and Simulium. Other, also tolerant, organisms increased at the two downstream locations. Interestingly, the pulmonate snail Physella was not collected at

Station 2, but was very abundant at Station 3. Decline in total taxa richness and progressively higher Biotic Index values were noted from Station 1 to Station 3, suggesting that water quality declines with increasing downstream distance.

Samples have been collected following restoration. These data indicate that reestablishment of keystone species has not occurred within the restoration reach (site #2) and that the number and diversity of benthic macroinvertebrates has declined significantly from the pre-construction investigation. The benthos at this site following restoration is currently dominated by blackflies and tolerant chironomidae (Cricotopus bicinctus). In addition a dominants in common analyses resulted in a 6% similarity at site 2.

6. A, H and W Farm (Big Warrior Creek) – Boomer, Wilkes County; Construction November 2001

Qualitative-4 samples were collected from 3 locations on Big Warrior and from one location on Little Warrior Creek. The reference site is located on the test stream above the farm property and in a relatively undisturbed forest. The Big Warrior stations at 1 and 2 are located below a feedlot and near the lower reach of the restoration project. The canopy at these two locations is open and cattle have direct access to the stream (see photos below prior to restoration. Filamentous algae and streamside grasses were very prolific at both locations. Data from Little Warrior Creek were collected from a site approximately ¼ mile below NC 18 and within the restoration reach of this catchment.

Table 10. Benthic macroinvertebrate summary statistics from the Big Warrior Creek stream restoration project.

Big Warrior Creek, Boomer (Division of Water Quality)																
Site Location	Reference				Site 1				Site 2				Little Warrior Creek			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)	42	30			46	27			39	26			28	24		
EPT taxa (SEPT)	23	18			14	13			15	13			8	9		
EPT abundance (EPTn)	95	75			38	59			77	64			46	31		
Biotic Index (BI)	2.96	NA			6.21	NA			6.09	NA			7.36	NA		
EPT Biotic Index (EPTBI)	2.20	NA			4.91	NA			4.98	NA			5.74	NA		
Dominants in Common	-	-			27%	19%			18%	0%			10%	0%		

NA, Biotic indices have not been calculated

The numbers of EPT taxa, which are generally considered intolerant compared to other groups of aquatic insects, declined from 23 at the reference site on Big Warrior to 14 and 15 at Big Warrior 1 and 2, respectively. Only 8 EPT taxa were collected from the Little Warrior Creek location. It is possible the headwater reaches of Big Warrior Creek are providing recruitment for downstream reaches of this system, whereas headwater reaches of Little Warrior Creek are stressed. In addition to the decline in EPT taxa richness at Big Warrior 1 and 2, there is a tremendous shift in the community structure. In fact 16 intolerant EPT taxa at station 1 were eliminated at downstream locations and replaced by more tolerant insects. For example mayflies (Epeorus rubidus, Paraleptophlebia, and Dannella simplex), caddisflies (Diplectrona modesta, Dolophilodes, Glossosoma) and stoneflies (Allonarcys) were all common or abundant at Big Warrior 1 but were not collected at all at the downstream locations. Stonefly numbers were much reduced at station 2 and eliminated from station 3. Biotic Index values support these observations. Lower numbers reflect better water quality as seen at the Big Warrior reference site and much higher numbers (poorer water quality) at all other locations. In addition there is a shift in feeding type assembles as well. Many of the dominant taxa at the upstream reference

site are shredder organisms (Merritt and Cummins 1984) such as Tallaperla and represent heterotrophic conditions. As Big Warrior Creek loses the riparian canopy, feeding types with the benthos shift to one dominated by grazing organisms and autotrophic conditions. As the riparian canopy at these downstream locations develops we should expect to see the community shift back to heterotrophic conditions.



Samples have been collected following restoration. The above photographs illustrate the pre-construction, construction and post-construction conditions of Big Warrior Creek at Station 1. The post-construction samples represent approximately one year following construction at site 1, approximately six months at site 2, and very recent construction at the Little Warrior Creek location. Taxa richness values were lower at all of the stations during the first post-construction investigation, including the upstream reference location and the dominants in common numbers also declined. EPT abundance values were slightly higher at station 2 within the restoration reach and many more intolerant taxa were collected from this site compared to the pre-construction investigation (especially Dolophilodes and Serratella deficians). Dominants in common analyses were 27% and 19%, respectively. However, the colonization of keystone species are encouraging and suggest that reestablishment of ecological functions in this reach of Big Warrior Creek are developing. The percent dominants in common are reduced to 0% at site 3, which may reflect the more recent construction. The benthic population at the most downstream location was dominated by baetid mayflies and hydropsychid caddisflies.

7. Meridian Drive – Charlotte, Mecklenburg County; Construction July 2000

The Meridian Drive stream restoration project is from an UT of McIntyre Creek within an urban catchment of Charlotte. The catchment is dominated by low-density residential development and receives stormwater runoff. Biological samples were collected and analyzed by the Mecklenburg County Department of Environmental Protection from two locations for this project (Roux 2000). Site 1 is located at Edinborough Drive upstream of the wetland area that marks the upper limit of the project and site 2 is located near the lower end of the project.

Table 11. Benthic macroinvertebrate summary statistics from the Meridian Drive stream restoration project.

Meridian Drive, Charlotte (LAW Engineering)																
Site Location	Reference				Site 1 (B6502)				Site 2 (B6501)				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					21	14			21	23						
EPT taxa (SEPT)					3	2			3	2						
EPT abundance (EPTn)					21	2			23	6						
Biotic Index (BI)					6.52	7.02			7.36	6.55						
EPT Biotic Index (EPTBI)					NA*	NA*			NA*	NA*						

NA*-data were not calculated.

Three EPT species and a total of 21 taxa were found at each of the locations prior to construction. The fauna at both sites were dominated by pollution tolerant taxa including chironomidae (Conchapelopia group and Phaenopsectra), Sialis, Enallagma and filter-feeding hydropsychids (Cheumatopsyche). Construction of this project occurred in July 2000 and the first post-construction survey was conducted in June 2002. Lower taxa richness and abundance values and a higher biotic index value were noted at site 1 following construction, which indicates that water quality conditions have declined following construction. This may be partially due to extremely low flow conditions during the post-construction investigation. Additional data will be collected from this project.

8. Edsel Place – Charlotte, Mecklenburg County; Constructed May 2001

The City of Charlotte identified an UT to Briar Creek (Edsel Place) for stream restoration due to increasing problems of erosion-related damage to public and private infrastucture, loss of instream habitat, floodplain encroachment, channel incision, bank erosion and periodic flooding (CSWS 2001). The project consists of approximately 2750 linear feet of perennial stream. Three monitoring stations were established and standard qualitative collection methods were used for benthic macroinvertebrates.

Table 12. Benthic macroinvertebrate summary statistics from the Edsel Place stream restoration project.

Edsel Place, Charlotte (LAW Engineering)																
Site Location	Reference				Site 1 (B0710)				Site 2 (B0711)				Site 3 (B0712)			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					14	24			19	27			22	21		
EPT taxa (SEPT)					2	2			3	3			3	2		
EPT abundance (EPTn)					20	14			21	21			12	20		
Biotic Index (BI)					6.92	7.56			7.10	7.53			6.30	7.64		
EPT Biotic Index (EPTBI)					NA*	NA*			NA*	NA*			NA*	NA*		

NA*-data were not calculated.

The data from all three monitoring locations during both surveys illustrates poor water quality with very little difference in the community structure of the benthos following construction. The community is dominated by chironomidae, blackflies and hydropsychidae (Cheumatopsyche). Many fewer Cheumatopsyche were collected from the most downstream (recovery) location. In addition to collecting benthic macroinvertebrates the Mecklenburg County staff also collect fecal coliform bacteria samples and noted that the numbers decrease significantly downstream. These data suggest that the numbers of Cheumatopsyche may be related to the high number of fecal coliform at the two upstream monitoring locations. The success of the restoration project may in part depend on the identification and elimination of the source of bacterial contamination.

Eastern Piedmont Ecoregion
(Ecoregion 45f from Figure 3)

1. Rochester Heights – Raleigh, Wake County; Constructed April 2000

Benthic macroinvertebrate samples have been collected from one location, within the restoration reach of a UT of Walnut Creek, prior to construction and two times following construction. The UT Walnut Creek catchment is urban/suburban and receives stormwater runoff from largely impervious land use.

Table 13. Benthic macroinvertebrate summary statistics from the Rochester Heights stream restoration project.

Rochester Heights, Raleigh (City of Raleigh)																
Site Location	Reference				Site 1				Site 2				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					6	8	11									
EPT taxa (SEPT)					0	1	1									
EPT abundance (EPTn)					0	3	10									
Biotic Index (BI)					NA*	NA*	6.60									
EPT Biotic Index (EPTBI)					NA*	NA*	NA*									

NA*-data were not calculated.

Table 13 summarizes the benthic macroinvertebrate data from this project. The stream restoration construction took place in April 2000 and biological surveys were conducted October 1999 prior to construction and September 2001 and 2002 following construction. These data indicate an improvement in the benthic fauna of this channel following restoration. During each post-construction survey, one mayfly taxa (Baetis in 2001 and Isonychia in 2002) were collected (Ellis Aquatic Services 2002) whereas no mayflies were collected during the pre-construction survey.

Sand Hills Ecoregion
(Ecoregion 65c from Figure 3)

1. Buckhead Creek – Fayetteville, Cumberland County; Construction July 2000

In 1998, channel hardening was done in an unnamed tributary of Buckhead Creek to increase stormwater runoff conveyance from existing medical, residential and commercial properties that were experiencing flooding. The mitigation plan associated with this project specified that 1,400 linear feet of stream and riparian restoration along the UT downstream of the hard improvements and along 985 linear feet of Buckhead Creek were necessary (Blue Land Water Infrastucture 2000).

Construction of this project was completed in July 2000. Benthic macroinvertebrate samples were collected in September 1999 prior to construction and then during surveys in October 2000 and 2001 following construction as specified in the 401 Certification for the project. Standard qualitative methods were used at two locations: Buckhead Creek (lower end of the mitigation) and a site on a tributary of Buckhead Creek (lower end of mitigation). Data from these three surveys are summarized on table 14.

Table 14. Benthic macroinvertebrate summary statistics from the Buckhead Creek stream restoration project.

Buckhead Creek, Fayetteville (Blue Land and Water Infrastructure)																
Site Location	Reference				Buckhead Creek				UT Buckhead Creek				Site 3			
Metric/Survey	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3	PreC	Post1	Post2	Post3
Total Taxa (ST)					40	28	29		39	23	14					
EPT taxa (SEPT)					2	4	3		0	1	1					
EPT abundance (EPTn)					6	40	16		0	10	1					
Biotic Index (BI)					6.73	7.11	7.18		8.34	7.42	6.51					
EPT Biotic Index (EPTBI)					NA*	NA*	NA*		NA*	NA*	NA*					
Total Abundance					157	1799	1439		465	3186	691					

NA*-Biotic indices not calculated.

Much lower benthic organism abundance values were recorded during the pre-construction survey following extremely high flows following Hurricanes Dennis and Floyd (September 2000). Density was 157 in 1999, 1799 and 1439 in 2000 and 2001, respectively at the Buckhead Creek location and 465 in 1999, 3186 in 2000 at the UT Buckhead Creek location. Variability in total density is expected in unstable urban streams that receive stormwater runoff. Total taxa richness values at both locations declined following the construction, but the numbers continue to decline at the UT Buckhead Creek location suggesting that water quality conditions or perhaps habitat have continued to decline.

Most of the dominant taxa collected from the Buckhead Creek location during the post-construction surveys are facultative organisms; such as Stenonema and Eurylophella, Enallagma, Dubiraphia and Tribelos. These organisms are not generally considered early colonizers and their abundance at this location following construction is somewhat surprising. Enallagma (a damselfly) accounted for nearly 1/3 of the total number of organisms collected. This organism is commonly collected from bank areas during sweep samples.

The abundance of very tolerant taxa from the UT Buckhead location following construction suggests that there are perhaps some perturbations in the catchment not accounted for as part of this project. The dominance of tubificidae (65% of all animals collected), Physella and Chironomus generally suggests that this stream is receiving some sort of enrichment. This perturbation may not have been apparent during the pre-construction survey due to extremely high flows.

Coastal Plain Ecoregion
(Ecoregions 65 and 63 from Figure 3)

1. Upper Whitehurst Creek – Aurora, Beaufort County; Construction October 1992 and October 1995

Upper Whitehurst Creek stream restoration project is approximately 5,000 linear feet from the outlet of a sediment basin to its confluence with Whitehurst Creek. In 1995, 3,200 feet additional feet of the upper channel were rerouted to allow for the advancement of mining activities. Benthic macroinvertebrates have been collected from two sites using swamp methods (9 sweep-net samples supplemented with washes and visuals). Baseline surveys were conducted in the winter and summer of 1992 and 7 surveys have been conducted post-construction. Baseline and post-construction information is illustrated in figure 5 for data within the mitigation channel that

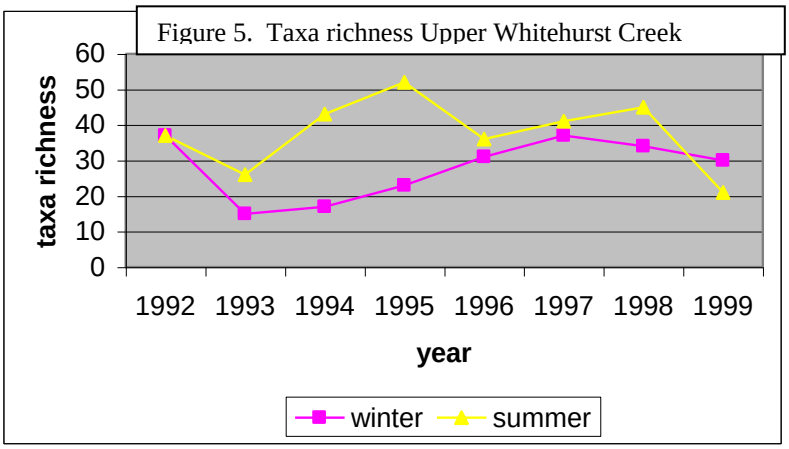
includes both stations 1 and 2. The only difference between stations is the length of time for recolonization. These data illustrate that there were declines in taxa

Table 15. Benthic macroinvertebrate summary statistics for the Upper Whitehurst Creek stream restoration

Upper Whitehurst Creek, Aurora (CZR, Inc.)																
	1992 PreC		1993 post1		1994 post2		1995 post3		1996 post4		1997post5		1998 post6		1999 post7	
Metric/sea	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Total taxa	37	37	15	26	17	43	23	52	31	36	37	41	34	45	30	21
EPT taxa	3	1	0	1	1	2	2	4	2	2	4	3	2	2	2	1
EPT abund.	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A
Biotic Index	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

W=winter, S=summer; P/A indicates presence/absence data only, NA-biotic index values not calculated.

richness 1993 following the construction and that conditions improved, although at different rates for summer and winter surveys following the construction. These data also illustrate that the taxa richness totals are somewhat more unstable during summer months at which large decreases in taxa richness were seen in 1996 and particularly 1999. Unfortunately, the data from both stations 1 and 2 were combined as mitigation reach data and all taxa are listed in the Appendix as present/absent only (CZR, Inc. 2000). This makes between year analyses of the data difficult. However,some interesting shifts in the presence/absence data for many taxa are noted during the investigation. For example three caddisfly taxa (Cheumatopsyche, Ptilostomis and Ironoquia punctatissima) and a megaloptera (Sialis) were collected during the pre-construction survey, but were not found during any of the post-construction investigations. There are increases in other taxa following the first and, in some cases, the second year of restoration (Naididae, Callibaetis, and some caddisfly (Limnephilus, Micrasema and Oecetis)). Also, three mollusca were primarily collected during the 1996 to 1999 surveys (Ferrissia hendersoni, Gyraulus parvus and Physella). These shifts in community structure may be related to the evolution of the Upper Whitehurst Creek channel following restoration. These data suggest that there has been some limited improvement in the biological condition (increase in the number of taxa) of this channel up to the 1997 and 1998 investigations but that this improvement declined in 1999. At this point there is no explanation for the reduced values during the 1999 investigation since mitigation monitoring for this project has been completed.



2. Bailey Creek – Aurora, Beaufort County; Constructed September 1996

The sampling design and methodology for this mitigation project is very similar to the Whitehurst Creek project. Construction occurred May through September 1996. At this point there have been four years of post-construction analyses. Once again, the data from stations 1 and 2 are combined for each survey by season and all taxa are listed as present or absent during each of the surveys. These data are illustrated below. The number of taxa have increased each year and many taxa (Crustacea, mayflies (Baetis, Caenis and Callibaetis), Odonata and Trichoptera)

have become abundant. Increases in taxa richness have been consistent for the surveys conducted in the winter and somewhat less so for summer surveys.

Table 16. Benthic marcroinvertebrate summary statistics for Bailey Creek Stream Restoration

Bailey Creek, Aurora (CZR, Inc.)									
	1995	1997 post1		1998 post2		1999 post3		2000 post4	
Metric/sea	summer	winter	summer	winter	summer	winter	summer	winter	summer
Total taxa	31	15	23	16	32	36	40	42	35
EPT taxa	0	0	0	0	5	3	2	3	3
EPT abund.	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A	P/A
Biotic Index	NA	NA	NA	NA	NA	NA	NA	NA	NA

W=winter, S=Summer; P/A indicates presence/absence data only, NA-biotic index values not calculated.

These data represent an improvement in the condition of the biological community of this stream channel and therefore a trend towards successful mitigation. Mitigation monitoring has been discontinued at these locations.

SUMMARY

This report summarizes benthic macroinvertebrate data from fifty (50) stream restoration projects in North Carolina. During the initial planning process of this grant it was decided to select, for monitoring purposes, 80 stream restoration projects that were to be evenly distributed among eight major ecoregion groups in North Carolina. To date, the total number of projects is short of the goal and projects are not evenly distributed among the ecoregions. This selection process was based primarily on need and availability, therefore most of the restoration projects summarized in this grant report were associated with regions of impact. Development, including road construction, is concentrated in the piedmont of North Carolina and most mitigation projects associated with this development also were in the western and eastern piedmont ecoregions. Also most of the projects were selected from small, rural watersheds. Other projects will be selected from understudied ecoregions where possible in during the next fiscal year to attempt to meet project goals.

To date, only 14 of the 50 projects summarized in this report have post-construction information and only seven of these projects have more than one year of post-construction data. This represents a very small proportion of the total projects. Therefore the results of this document should be considered preliminary.

Collection protocols for these investigations were established early in the granting process. These protocols suggested that pre-construction data should be collected, then allow stream conditions approximately one year to equilibrate followed by three annual and consecutive surveys (a total of 5 year monitoring period). All surveys should limit the effects of seasonal variability and use collection protocols established by the NC Division of Water Quality. The protocols also recommended that a minimum of two stations per project be established: an upstream monitoring location above the restoration reach and one site within the section of stream receiving restoration. Other stations such as an ecoregional reference location, or recovery location below the restoration reach are optional.

Preliminary results and observations of these data suggest that some ecological functions of restored streams (using benthic macroinvertebrates as indicators) are reestablished relatively soon after construction. For example, data from the restoration project at Stone Mountain indicates that there is a suite of benthic macroinvertebrates that are capable of moving into restored reaches and colonizing newly created microhabitats early in the restoration process (two years following construction). However, these data also indicate that there are many other taxa that have not recolonized from upstream reference reaches and that movement of these taxa (primarily cased caddisflies, and some Ephemerelidae) into restored reaches will take more time due to specific habitat requirements. Also preliminary observations from Big Warrior and Bailey Creek also indicate that limited ecological recovery can take place relatively soon after construction although these encouraging observations were not noted at other rural restoration projects (i.e. Payne Dairy).

Preliminary data from many of the restoration projects that are within urban catchments (Reed Creek, Concord Mills, Fiddlers Creek, Starmount Park, Meridian Drive and Buckhead Creek) suggest that stormwater or urban nonpoint runoff has an overriding impact on the biological integrity of restored reaches. These data also indicate the importance of having stable, upstream reference reaches for comparison to restored reaches. In many of the earlier restoration projects, these stations were not investigated and only pre-construction data were used as reference. Charbonneau and Resh (1992) studied an urban stream restoration project on the University of

California-Berkeley Campus and noted that water quality improved from poor to good and that included improved biotic index values, and increased taxa richness values. However, the project included significant stormwater treatment as well as habitat restoration. Many more recent urban stream restoration projects, which have only pre-construction data do have stormwater management plans (Rocky Branch, Edwards Branch, Edsel Place, and Adkins Branch). Part of future analysis of these data will examine whether stormwater management of restored urban streams is beneficial to the biology of these systems.

Based on the preliminary observations and data collected from these stream restoration projects, possible biological success criteria have been developed. These criteria will be further tested and modified as more data are collected. These criteria are listed below and are based the type of reference information collected (i.e. upstream site, ecoregional reference or neither).

Category 1. Upstream Reference Data are Available:

- Biological success will be defined as occurring when the benthic macroinvertebrate community within the restored channel includes a viable population (common or abundance specimens) of keystone species. Keystone aquatic insect species are those taxa whose presence in the restored stream are dependent upon stable microhabitats. The presence of keystone species, or habitat specialists, is an indication that the restored stream channel contains productive microhabitats. These taxa must be collected from the upstream reference site and during any of the post-construction investigations from within the restored reach. Examples of keystone species include Tallaperla (leafpack), leptocerid caddisflies (streambank root hairs), elmid beetles or some limnephilid caddisflies (large woody material), heptageniid mayflies and hydropsychid caddisflies (flow).

And

- The composition of the dominant taxa between the reference reach and the restored channel must be at least 75% similar. The dominants in common is defined as the number of dominant taxa common to the reference and restored reach regardless of their order of their abundance (ADPC&E 1987). Dominants are defined as all abundant or common taxa if use DWQ collection criteria are use or the ten most dominant taxa if quantitative methods or complete counts are used in the analyses. The 75% similarity criteria can be demonstrated during any of the post-construction investigations.

Category 2. Ecoregional Reference Data are Available:

- Comparisons between the restored channel and the ecoregional reference location must be made between similar catchment types and stream order. The composition of the benthic fauna must be at least 50% similar (using a dominants in common analyses) between the ecoregional reference location and the restored channel. The 50% similarity criteria can be demonstrated during any of the post-construction investigations. The 50% similarity threshold is less restrictive than projects with upstream reference reaches because it is assumed that the biological integrity of the ecoregional reference streams is greater than streams selected for restoration. The ecoregional reference location must be approved by staff of the DWQ.

Category 3. Upstream Reference nor Ecoregional Reference Data are Available:

- These types of monitoring projects are strongly discouraged by the DWQ and will not be approved for all future projects. The value of having reference data is critical for the determination of success. Unfortunately, some earlier projects were approved using this approach. If comparisons between pre- and post-construction investigations within restored channels are done, biological success is defined as having at least a 25% increases in taxa richness of EPT or 25% increase in the abundance of intolerant taxa (as defined by having a NC Biotic Index value of 3.50 or less), or a decrease in the NC Biotic Index value of one pollution category (excellent, good, good-fair, fair or poor) during any post-construction survey.

Table 17 summarizes each of the stream restoration projects that have post-construction biological monitoring components to them and discusses the application of the possible success criteria.

Table 17. Possible Biological Success of Stream Restoration Projects in North Carolina: Benthic Macroinvertebrates				
Category 1 (upstream Reference locations)				
Project/Stream	**Ecoregion**	**Land Use**	**Constr Completed**	**Comments**
Stone Mountain	Western Piedmont	Rural	November 2000	Two post-construction surveys have been conducted. The data indicates that the Dominants in Common Index are above the 75% Threshold at the upstream monitoring location and that several keystone species have recolonized there. Data from the downstream monitoring location indicates that the Dominants in Common Index is well below the 75% threshold for success (but improving) and keystone species have not reestablished at this site
Payne Dairy	Western Piedmont	Rural	February 2001	A single post-construction survey has been conducted at this project. The Dominants in Common Index was very low (6%) within the restored reach of Jumping Run Creek and the fauna dominated by tolerant chironomidae. Keystone species were not collected from this monitoring location. Very little difference in summary statistics between surveys were noted from station 3 which was selected as a downstream recovery site.
Big Warrior Creek	Western Piedmont	Rural	November 2001	Taxa richness values were lower at all of the stations during the first post-construction investigation, including the upstream reference location and the dominants in common numbers also declined. EPT abundance values were slightly higher at station 2 which is within the restoration reach and many more intolerant taxa were collected from this site compared to the pre-construction investigation (especially Dolophilodes and Serratella deficians). Dominants in common analyses are below the proposed 75% similarity criteria (27% and 19%). However, the colonization of keystone species are encouraging and suggest that reestablishment of ecological functions in this reach of Big Warrior Creek are developing. The percent dominants in common are reduced to 0% at site 3, which may reflect the more recent construction.
Concord Mills	Western Piedmont	Urban	July 1999	Two post-construction surveys have been conducted at this project; however, there were some discrepancies in monitoring protocols noted between surveys. Many of these discrepancies were potentially due to the lack of monitoring protocols by DWQ early in this initiative. However, during the most recent survey (2002) data were collected from an upstream reference reach and compared to the test reach of this stream. A dominants in common comparison of these data resulting in 32% similarity, which is much less than the 75% criteria for success and many of the keystone species found upstream were not collected at the downstream location (Stenonema, Neophylax, and Chimarra).

Starmount Park	Western Piedmont	Urban	February 2001	A single post-construction survey was conducted at this project. These data indicate that water quality conditions were poor at both locations (Dominants in Common Index of 65%) perhaps responding to urban stormwater runoff. The fauna at both locations were dominated by hydropsychid caddisflies. There are subtle differences in the fauna and some potential keystone species (Perlesta, Ferrissia) were collected from the reference location and were eliminated from the restored section. High numbers of hydropsychid caddisflies at the site 2 may be responding to enrichment or autotrophic conditions of the catchment at this reach.
Meridian Drive	Western Piedmont	Urban	July 2000	Benthic macroinvertebrates were collected from two stations (upstream reference and test locations) pre and during one post-construction survey. The fauna at both sites were dominated by pollution tolerant taxa including chironomidae (Conchapelopia group and Phaenopsectra), Sialis, Enallagma and filter-feeding hydropsychids (Cheumatopsyche). None of these taxa are keystone. Lower taxa richness and abundance values and a higher biotic index value were noted at site 1 following construction, which indicates that water quality conditions have declined following construction. This may be partially due to extremely low flow conditions or urban runoff during the post-construction investigation.
Edsel Place	Western Piedmont	Urban	May 2001	The data from all three monitoring locations during both surveys illustrates poor water quality with very little difference in the community structure of the benthos following construction. The community is dominated by chironomidae, blackflies and hydropsychidae (Cheumatopsyche). Many fewer Cheumatopsyche were collected from the most downstream (recovery) location. Fecal coliform bacteria samples were also collected and the data noted that the numbers decrease significantly downstream. These data suggest that the numbers of Cheumatopsyche may be related to the high number of fecal coliform at the two upstream monitoring locations.

Category 2 (Ecoregional Reference locations)				
Project/Stream	**Ecoregion**	**Land Use**	**Constr Completed**	**Comments**
Fiddler's Creek	Western Piedmont	Urban	May 1999	Results from the restoration reach (site 1) indicate an adverse impact of the construction and no recovery during all subsequent investigations. Taxa richness and abundance values continue to decline at this location. Somewhat more variable data are noted at the downstream site (site 2) and at Fiddler's Creek below the confluence of the UT. Note the elevated biotic index value following construction. Reductions in taxa richness and abundance were seen at these two locations during the first post-construction survey, but a limited recovery was noted during the second post-construction survey (including decreases (better water quality) in biotic index values). Data from the third post-construction survey again noted decreased taxa richness and abundance values that were similar to those recorded from the first year following construction. EPT taxa were eliminated from the impact (site 2) and downstream (site 3) collection locations on the UT. These data indicate that construction activity, or perhaps additional construction activities in the catchment, impacted the benthic fauna of this stream and that attempts to restore the community structure have not been successful.
Category 3 (No Reference locations)				
Project/Stream	**Ecoregion**	**Land Use**	**Constr Completed**	**Comments**
UT Peak Creek (enhancement)	Mountain	Rural	September 2001	Only one station was surveyed as part of this investigation as this was only a stream enhancement project rather than a restoration. The results of the first post-construction investigation noted that there was very little change in taxa richness values between surveys and that abundant taxa remained abundant, but that the Dominants in Common Index between years was only 59%.
Upper Whitehurst Creek	Coastal Plain	Rural	October 1992	Data were collected from two stations within the restoration channel. These data illustrate that there were declines in taxa richness in 1993 following the construction and that conditions improved, although at different rates for summer and winter surveys following the construction. These data also illustrate that the taxa richness totals are somewhat more unstable during summer months at which large decreases in taxa richness were seen in 1996 and particularly 1999. Unfortunately, the data from both stations 1 and 2 were combined as mitigation reach data and all taxa are listed in the Appendix as present/absent only.

Bailey Creek	Coastal Plain	Rural	September 1996	Data were collected from two locations within the restoration reach of the project. The number of taxa have increased each year and many taxa (Crustacea, mayflies (Baetis, Caenis and Callibaetis), Odonata and Trichoptera) have become abundant. Increases in taxa richness have been consistent for the surveys conducted in the winter and somewhat less so for summer surveys. These data represent an improvement in the condition of the biological community of this stream channel and therefore a trend towards successful mitigation**.**
Reed Creek	Mountains	Urban	March 1998	Taxa richness values (especially EPT taxa richness values) did not change substantially during the course of this investigation. The EPT fauna was dominated by tolerant hydropsychid caddisflies (Hydropsyche betteni and Symphitopsyche sparna) during both pre and post-construction surveys. However, there were some fairly significant differences in EPT abundance values between surveys as noted in the qualitative samples. For example, much lower EPT numbers were noted at this location during the first post-construction survey and again during the most recent investigation. These data suggest that the benthic fauna of Reed Creek may be responding to the effects of urban stormwater runoff or hydrology and that if ecological improvements to this urban channel are desired, that stormwater management in the catchment is necessary. The Dominants in Common index declined from 56% during the first post-construction survey to 33% during the second post-construction survey using the qualitative information.
Rochester Heights	Eastern Piedmont	Urban	April 2000	Two post-construction surveys have been conducted at one location within the restored channel of this project. Very few taxa were collected during each of these investigations; however, the number of total taxa have increased each year of analyses and a mayfly taxa was collected during each post-construction survey (Baetis in 2001 and Isonychia in 2002). These data suggest that limited reestablishment of ecological functions of this stream has occurred.
Buckhead Creek	Sandhills	Urban	July 2000	Much lower benthic organism abundance values were recorded during the pre-construction survey following extremely high flows following Hurricanes Dennis and Floyd (September 2000). Variability in total density is expected in unstable urban streams that receive stormwater runoff. Total taxa richness values at both locations declined following the construction, and the numbers continue to decline at the UT Buckhead Creek location suggesting that water quality conditions or perhaps habitat have continued to decline. The abundance of very tolerant taxa from the UT Buckhead location following construction suggests that there are perhaps some perturbations in the catchment not accounted for as part of this project. The dominance of tubificidae (65% of all animals collected), Physella and Chironomus generally suggests that this stream is receiving some sort of enrichment.

RECOMMENDATIONS

- Restoration activities should be conducted on a large enough scale to include all significant portions of the catchment (NRC 1992). Therefore basinwide or contiguous restoration projects rather than a patch-in-place scenario would be preferred. Under these scenarios, restored reaches would have better access to refugia.
- The data generated thus far from urban stream restoration projects (Reed Creek, Fiddler's Creek, Concord Mills, Starmount Park) indicated that restored reaches have generally not improved beyond background or upstream reference conditions. These data imply that stormwater or nonpoint source urban runoff may be an overriding source of degradation in these projects. Therefore restoration in urban streams should include active stormwater management. Biological monitoring data should be collected prior to stream selection in urban catchments and if the data suggest that poor or very poor conditions exist that we would recommend stormwater management.
- One potential aspect of "success" may be to look at the recolonization of keystone species such as cased caddis (Neophylax) at Stone Mountain, Lepidostoma at Kings Creek and Stenonema at Concord Mills. These taxa are indicators of the reintroduction of proper habitat and flow conditions in restored reaches. The use of keystone species will be based on a case by case basis. Much more additional information will need to be collected to determine acceptable keystone species for indicators of success.
- It is strongly recommended that collection protocols as described in the Technical Guidance for Stream Restoration Projects (N.C. DWQ 2002) be followed. This includes collection of reference data (rather than relying on pre-construction information as reference). Preliminary observations also suggest that the seasonality of data collection may affect the results of these investigations. Based on these preliminary observations, and if possible because of construction schedules, benthic macroinvertebrate samples from mountain ecoregions should be collected during summer months. This collection period represents worst case scenarios (low dissolved oxygen, high water temperature) for streams in these ecoregions and the impacts of anthropomorphic perturbations are more pronounced. On the other hand biological samples from sites in the Triassic Basin and Coastal Plain ecoregions should be collected during winter months to optimize flow and water temperature conditions. Summer surveys in these ecoregions may mask potential improvements to stream health.
- Long-term monitoring at selected projects is recommended. Restoration efforts also need to be long-term to ensure that restoration project goals have been achieved and that restored ecosystems can endure stressful episodic natural events such as bankfull flows, droughts or invasion of exotic species (NRC 1992). Therefore monitoring beyond five years maybe warranted at selected sites.
- Erosion control and fencing practices of animals from the stream should be done on all projects where relevant.
- Additional data from other stream restoration projects in understudied ecoregions will be conducted as a follow-up to this grant.
- Biological success criteria will be further tested and improved as data storage and manipulation capabilities are improved within the Unit.

ADDITIONAL RESEARCH OPPORTUNITIES

- A possible research project associated with restoration could be to conduct topographic mapping of channel morphology (Frothingham et al. 2001, Gore 2001) and include on the map locations of microhabitats (living riparian rootlets, macrophytes such as Podostomum, large woody debris). This could also include the enhancement capabilities to capture organic detritus and *Aufwuchs*. The application of habitat simulation models may be useful to predict how a stream will respond to restoration (Gore 2001). These models include IFIM (Instream Flow Incremental Methodology) and PHABSIM (Physical Habitat Simulation).
- Research to examine the habitat needs for species at reference reaches and compare these to predictions of habitat at restored reaches (Merritt and Cummins 1996) would be useful. For example, how would the increase in average pebble size (D50) following restoration affect the abundance of taxa that need stable habitat (such as Heptageniid mayflies)?
- More studies are needed to look at the benefits of priority one (in which pattern, dimension and profile are corrected) versus other types of restoration projects in which only one or two of these stream characteristics are improved; also to compare the benefits of stream enhancement projects versus restoration.
- One aspect of channel construction that may be considered as a research project would be to look at the potential of disturbed soil as a contributor to chronic toxicity. Aluminum and iron are common in piedmont soils and may be released from newly relocated channels.
- The monitoring protocols of the DWQ are semi-qualitative, yet the responses within the benthic community may be related to taxa abundance values. More investigations are needed to look at how stream restoration affect abundance of benthic macroinvertebrates. This may involve using collection devices such as Surbers or Hess samplers in addition to the collection methods commonly used by DWQ.

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Appendix 1. Stream Restoration Projects with Biological Monitoring Components by Ecoregion, October 2002

Mountain Ecoregion

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency*	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Reed Cr., Asheville	Large	Urban	DOT	Jan-98	Mar-98	Oct-98	Oct-99	Oct-00
Tallula Cr., Murphy	Large	Rural	DOT	Mar-98	Aug-02	Mar-04	Mar-05	Mar-06
High Vista, Asheville	Small	Rural	DWQ	Dec-01	Jul-02	Dec-03	Dec-04	Dec-05
TC Roberson, Hendersonville	Small	Rural	Appalachian Env.	Jun-02	Not Completed	Jun-04	Jun-05	Jun-06
Warren Wilson College	Small	Rural	AES, Wisconsin	Sep-02	Nov-Dec 02	Sep-03	Sep-04	Sep-05
Kings Creek, Brevard	Large	Urban	DWQ	Aug-02	Aug-02	Aug-04	Aug-05	Aug-06

New River Ecoregion

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Lynnhaven, Boone	Small	Rural	Appalachian Env.	Sept-97	Dec-01	Nov 02		
Trillium, Boone	Small	Rural	ENV	Mar-01	May-01	Mar-03	Mar-04	Mar-05
Brush and Little Pine, Sparta	Small	Rural	DWQ	Apr-01	Jul-01	Apr-03	Apr-04	Apr-05
Bare Site (enhancement only)	Small	Rural	DWQ	Aug-01	Sep-01	Aug-02	Aug-03	Aug-04
Charleston Forge, Boone	Small	Urban	S & EC	Aug-01	?	Aug-03	Aug-04	Aug-05
Hanging Rock Cr., Banner Elk	Small	Rural	Buck Eng.	Apr 01, May 02	Not Completed	May-04	May-05	May-06

Western Piedmont

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Stone Mt. State Park	Large	Rural	DWQ	Oct-98	Nov-00	Sep-01	Sep-02	Sep-03
Concord Mills	Small	Rural	EcoScience	Apr-99	Jul-99	Jul-01	Jul-02	Jul-03
Fiddlers Branch, Winston-Salem	Small	Rural	KCI	May-99	May-99	May-00	May-01	May-02
Starmount Pk, Greensboro	Small	Urban	DWQ	Mar-00	Feb-01	Mar-01	Mar-03	Mar-04
Edwards Br., Charlotte	Small	Urban	MCDEP	Jul-01, Jul-02	Phase 1 only	Jul-04	Jul-05	Jul-06
Payne Dairy, Taylorsville	Small	Rural	DWQ	Oct-00	Feb-01	Oct-02	Oct-03	Oct-04
Big Warrior Cr., Boomer	Small	Rural	DWQ	Oct-00	Nov-01	Oct-02	Oct-03	Oct-04
Price Park, Greensboro	Small	Urban	DWQ	May-01	Jul-01	May-03	May-04	May-05
Sheppard's Tree, Statesville	Small	Rural	DWQ	Jul-01	Apr-03	Jul-04	Jul-05	Jul-06
Edsel Place, Charlotte	Small	Urban	Law Engineering	May 00	May-01	May-03	May-04	May-05
Lyle Creek (Wike Prop), Newton	Small	Rural	DWQ	Dec-01	Jun-02	Dec-03	Dec-04	Dec-05
Brown Branch, Lenoir	Small	Rural	DWQ	Apr-02	Sep-02	Apr-04	Apr-05	Apr-06
Beaver Creek, Surry County	Large	Rural	DWQ	Apr-02	Jul-02	Apr-04	Apr-05	Apr-06
Pott Creek, Lincoln County	Small	Rural	RKK	Nov-01	Mar-02	Nov-03	Nov-04	Nov-05
Meridan Drive, Charlotte	Small	Urban	Law Engineering	Sept99, Apr00	Jul-00	Jun-02	Jun-03	Jun-04
Magnolia/Kirkwood, Charlotte	Small	Urban	Law Engineering	5-01, 6-01,7-02	Phase 1 complete	Jun-04	Jun-05	Jun-06
Hope Park Branch, Charlotte	Small	Urban	Law Engineering	Sept-01	Sept-02	Sept-03	Sept-04	Sept-05

Slate Belt Ecoregion

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Randolph/Chatham County Sites	Small	Rural	DWQ	Aug-01	Oct-02	Aug-04	Aug-05	Aug-06
Mt. Vernon Springs	Small	Rural	S & EC	Jul-01	Jul-02	Jul-04	Jul-05	Jul-06

Triassic Basin

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Anson County Landfill, Monroe	Small	Rural	EcoScience	Mar-01	Apr-01	Mar-03	Mar-04	Mar-05
3M, Moncure	Small	Rural	KCI	Sep-01	Jul-02	Sep-03	Sep-04	Sep-05
Morrisville Community Park	Large	Rural	S and EC	May-02	Jun-02	May-04	May-05	May-06

Eastern Piedmont

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Chavis Park, Raleigh	Small	Urban	G. Pasacreta	Aug-99	Jul-02	Aug-03	Aug-04	Aug-05
Rochester Heights, Raleigh	Small	Urban	City of Raleigh	Sep-99	Apr-00	Sep-01	Sep-02	Sep-03
Rocky Branch, Raleigh	Small	Urban	DWQ	Dec-00	Spring 03?	Dec-04	Dec-05	Dec-06
Randolph Park, Enfield	Small	Rural	Buck Eng.	Jan-01	Not Completed			
Hominy Swamp, Wilson	Small	Urban	Buck Eng.	May-01	Jan-02	May-03	May-04	May-05
Smith-Austin Crks., Wake Forest	Small	Urban	DWQ	Aug-01	Jul-02	Aug-03	Aug-04	Aug-05
Murphy Farm, Louisburg	Small	Rural	DWQ	Dec-01	Jul-02	Dec-03	Dec-04	Dec-05
Yates Mill, Raleigh	Small	Rural	DWQ	Mar-02	Apr-02	Mar-03	Mar-04	Mar-05
Marks Creek, Knightdale	Small	Rural	Stantec	May-02	Sept 02	May-04	May-05	May-06

Sand Hills Ecoregion

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Buckhead Cr., Fayetteville	Large	Urban	BLWI	Sep-99	Jul-00	Oct-00	Oct-01	Oct-02

Coastal Plain Ecoregion

Project or Stream Name, location	Catchment Size	Rural or Urban	Collection Agency	PreC - Survey	Constr Date	Post-Construction Monitoring Year 1	Year 2	Year 3
Whitehurst Cr., Aurora	Large	Rural	CZR	w & s 92	Oct 92 & 95	w & s 93	w & s 94	w & s 95
Bailey Cr., Aurora	Small	Rural	CZR	Jul-95	Sep-96	w & s 97	w & s 98	w & s 99
Mill Branch, Greenville	Small	Rural	DWQ	Jul-01	Not Completed			
Global Transpark, Kinston	Large	Rural	EcoScience	Jun-02	Not Completed			
Adkins Branch, Kinston	Large	Urban	DWQ	Apr-02	Not Completed			
Crescent Road, Kinston	Large	Rural	Buck Engin.	none done	Apr-02	Feb-02	Feb-03	Feb-04

*Collecting Agencies; DWQ-Division of Water Quality, DOT-Department of Transportation, MCDEP-Mecklenburg County Department of Environmental Protection. All other collecting agencies are private consulting firms.

Appendix 2. Benthic Macroinvertebrate Data for Pre-construction Conditions.

Mountain Ecoregion

High Vista, Buncombe County (NC Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	34	34	29		
EPT taxa (SEPT)	21	19	5		
EPT abundance (EPTn)	85	62	18		
Biotic Index (BI)	NA	NA	NA		
EPT Biotic Index (EPTBI)	NA	NA	NA		

NA-Biotic indices were not calculated.

Qual-4 samples were collected from three locations prior to construction. Station 1 is located below the confluence of a spring seep and the ponds at the headwaters of this stream. This site is located at 7+50. The habitat at this site looked more stable than at the downstream reaches and probably has a greater D50 value. The benthos were more diverse with many Heptageniids and stonefly species present. Station 2 is at 26+50 near the downstream reach of the project. The stream at this point is very unstable with a sandy/gray looking substrate. The benthos was dominated by blackflies and hydropsychids. No Heptageniids or stoneflies were collected at this location which may suggest that the golf course is having a negative effect on the fauna of this stream. In addition to these two locations data were also collected from a UT to Bolyston Creek at Turkey Pen Gap (Reference).

TC Roberson High School, Henderson County (Appalachian Environ. Services)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	21	19			
EPT taxa (SEPT)	2	0			
EPT abundance (EPTn)	4	0			
Biotic Index (BI)	6.06	8.01			
EPT Biotic Index (EPTBI)	NA	NA			

NA-EPT Biotic indices were not calculated.

This stream restoration project is mitigation for the North Windy Ridge Elementary School. The project will restore a 1200 foot reach of the UT and will include 240 linear feet of daylighting the exiting stream, creating 579 linear feet of “B” stream type on the upper section of the stream and 637 linear feet of “E” channel on the lower section. Qual-4 benthos samples were collected from a reference reach located in a nearby catchment (approximately the same drainage area 0.2-0.3 square miles) and from a site on the lower reach of the mitigation channel.

Lynn Haven-Boone, Watauga County (Appalachian Environmental Sciences)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	48	49	51		
EPT taxa (SEPT)	18	25	18		
EPT abundance (EPTn)	152	137	160		
Biotic Index (BI)	3.92	3.39	3.65		
EPT Biotic Index (EPTBI)	1.89	1.98	1.65		

This project relocated 470 linear feet of a small existing UT of the East Fork of the New River and culverted another 378 linear feet of this channel. In addition sections of this UT were repaired to

stay in compliance with the 401 Certification. The pre-construction survey for this project was done in September 1997 (Pennington and Associates 1997) and the first post-construction survey was conducted. However, the data at this point have not been enumerated. Data were collected from two locations in the original channel; an upstream reference location above the Lynn Haven facility and site 1 near the confluence of this original channel and another stream. A third station, site 2 is located above the confluence with the mitigation channel.
Pre-construction data from these three stations indicate good to excellent water quality conditions. The benthic fauna was dominated by intolerant taxa, which resulted in low biotic index values for both total and EPT taxa. These taxa include mayflies (Epeorus, Paraleptophlebia), stoneflies (Leuctra, Amphinemura and Malirekus hastatus) and caddisfly (Diplectrona modesta Parapsyche cardis). Construction was conducted in December 2001, which included culverting and relocating sections of these catchments. Additional investigations will be conducted on these streams.

Warren Wilson College, Buncombe County (Applied Ecological Services)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)					
EPT taxa (SEPT)					
EPT abundance (EPTn)					
Biotic Index (BI)					
EPT Biotic Index (EPTBI)					

This project is providing mitigation for the Canton Motor Speedway project in Heywood County. Benthic macroinvertebrates were collected from four locations using protocols established by the NC DWQ. Samples were collected from two sites on Pigpen Creek (one reference and one site at the lower end of the restoration reach) and two sites on Alexander Branch. The upstream location is within the Berea pasture and will be restored and the downstream site is near the confluence with the Swananoa River. At this point data have not been enumerated.

Tallula Creek-Murphy, Cherokee County (NC Department of Transportation)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	31	14			
EPT taxa (SEPT)	22	8			
EPT abundance (EPTn)	76	43			
Biotic Index (BI)	NA	NA			
EPT Biotic Index (EPTBI)	NA	NA			

The NC Department of Transportation collected fish and benthic macroinvertebrates from two sites on Tallula Creek on 26 March 1998. Tallula Creek was disturbed and channelized due to construction of a golf course during the 1980's. Construction of the golf course was abandoned before completion. The reference site is located in the vicinity of where Tallula Creek enters the site. This was selected as a reference location above the golf course. Station 2 is located approximately 2000 feet downstream of the reference. Qualitative benthos collections were conducted according to DWQ's SOP and in addition, three Surber samples from each location were also collected. The substrate changes substantially between locations. The reference site is dominated by gravel (40%) but has some boulder and rubble, while the substrate at Station 1 is dominated by sand (75%) and silt.

Quantitative Data (Surbers)

	EPT Taxa Richness	EPT Abundance	EPT Biotic Index	Biotic Index	Total Taxa Richness
Reference	12	31	Not calculated	Not calculated	21
Station 1	2	5	Not calculated	Not calculated	5

Both taxa richness and abundance values were much lower at Station 1 for both the qualitative and quantitative investigations. These data reflect the obvious change in habitat between locations. The elimination or reduction in abundance of several abundant taxa at Station 1 (i.e. Acroneuria abnormis, Tallaperla, Elimia) was apparent as was the increase in other taxa (i.e. Cordulegaster). Very few Chironomidae were collected.

Significant reductions in the fish community also were noted at the downstream monitoring location. Interestingly, all sculpin were eliminated from Station 1, perhaps due to the nature of the sandy habitat at this location.

Kings Creek-Brevard, Transylvania County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	52	53	54		
EPT taxa (SEPT)	26	24	23		
EPT abundance (EPTn)	116	89	69		
Biotic Index (BI)	NA	NA	NA		
EPT Biotic Index (EPTBI)	NA	NA	NA		

NA-Biotic indices were not calculated.

Benthic marcroinvertebrate collections were made at three locations at this project. Full scale surveys were done at all locations. Station 1 is immediately upstream from NC 64 behind the Sub and Pub. The stream at this point receives runoff from suburban areas and perhaps stormwater from a number of small industries but has a decent riparian zone and appears to be stable. The stream at this point has a well-developed riffle pool sequence and pool to pool spacing. Despite these potential impacts the benthic fauna appeared to be relatively diverse. Station 2 is just above the restoration reach. This site is on the Brevard College campus and has been impacted due to channelization in the past as well as the removal of riparian canopy. Station 3 is at the lower end of the restoration project at transect 23+50. The stream at this point is very unstable with severely eroding banks and increased width/depth ratios. It was interesting to note the change in the benthic community from the upstream location to the site at Station 3. Many taxa were collected at Station 1 and were eliminated at Station 3 (esp. Lepidostoma) and replaced by baetids and chironomids. It appears that as the stream become more unstable downstream that many taxa were eliminated. The replacement of “keystone” species such as Lepidostoma may be an indication of success.

New River Ecoregion

Trillium-Boone, Watauga County (Environmental Consulting Services)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	25	19			
EPT taxa (SEPT)	9	4			
EPT abundance (EPTn)	215	40			
Biotic Index (BI)	2.90	4.82			
EPT Biotic Index (EPTBI)	NA	NA			

NA-EPT Biotic indices were not calculated.

This project provided on-site mitigation for the Trillium residential development and involves the relocation and restoration of a small unnamed tributary of the East Fork of the South Fork of the New River. This tributary is a first order stream with a drainage area of approximately 100 acres. The reference reach is located approximately 300 meters above the impact area. Qual-4 collection methods were used at both locations. Many of the taxa collected from the upstream reference site are intolerant EPT taxa (Diplectrona modesta, Leuctra, Neophlax) while the fauna at the downstream site prior to construction is represented mostly by chironomidae.

Brush and Little Pine Crks-Sparta, Alleghany County (Division of Water Quality)					
metric/site	Little Pine 1	Little Pine 2	Brush 3	Brush 4	Brush 5
Total Taxa (ST)	47	64	75	63	79
EPT taxa (SEPT)	22	29	38	38	39
EPT abundance (EPTn)	110	135	166	129	199
Biotic Index (BI)	4.28	3.66	2.50	3.39	3.58
EPT Biotic Index (EPTBI)	2.88	2.52	2.50	2.66	2.41

Full scale benthic macroinvertebrate samples were collected from 5 locations during the pre-construction survey. These samples were collected from two sites on Little Pine Creek above (station 1) and within (station 2) the restoration area and from three stations on Brush Creek. Brush Creek station 3 is above the confluence with Little Pine, station 4 is in the unstable reach that will receive enhancement and Brush Creek station 5 is the most downstream and stable reach we surveyed. Priority 1 restoration has been conducted on a 950-foot reach of Little Pine Creek.

Interestingly taxa richness and EPT abundance was greater at station 2 on Little Pine Creek than at the upstream location. The channel at station 2 was artificially straightened and deepened in 1969. However, the stream banks appeared to be stable and there was a riffle-pool sequence. The benthos data may be a reflection of water quality conditions in the catchment as it appears that Little Pine Creek above the restoration reach has also been straightened in the past. Cattle have been excluded from the lower reach at Station 2 but have access to the stream at the upper reach at Station 1. The apparent increase in diversity at the lower reach of Little Pine Creek may be due to the exclusion of cattle. The canopy upstream at station 1 has also been removed and provides even less cover that the canopy at the downstream reach. Many of the benthic taxa more abundant at the downstream location are generally considered slow-water taxa or edge species (Stenacron carolina, Ephemera, Paraleptophlebia, and Gomphus) or are more tolerant (especially C/O sp 1 and 6). It will be interesting to see how restoration will change what appears to be a subtle shift in the composition of the fauna.

The EPT taxa richness totals from Brush Creek did not change much at all (38 and 39); however, EPT abundance values and total taxa richness did change between locations. These two metrics were much lower in the unstable reach of Brush Creek below the confluence with Little Pine. Also there appeared to be major shifts in community structure between locations. Many taxa were much more abundant at station 5 in the stable reach (Epeorus dispar, Isonychia, Pycnopsyche, Brachycentus spinae, Symphitopsyche sparna, Pteronarcys, Acroneuria abnormis, Antocha) or were only collected at this site (Rhyacophila fuscula). Perhaps these organisms are good indicators of stream stability in mountain streams. Issues to consider are habitat stability and the presence of organic matter within the substrate allowing for this community to exist.

There were many more Symphitopsyche bronta at stations 4 and 5 below the confluence with Little Pine that at station 3 above Little Pine.

Charleston Forge-Boone, Watauga County (Soil and Environmental Consultants)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	73	70			
EPT taxa (SEPT)	7	5			
EPT abundance (EPTn)	30	17			
Biotic Index (BI)	4.48	4.42			
EPT Biotic Index (EPTBI)	NA	NA			

NA-EPT Biotic indices were not calculated.

Pre-construction data were collected from two locations as part of this on-site mitigation project. The reference reach is approximately 200 feet upstream of the impacted reach and site 1 is located near the downstream end of the proposed restored channel. Low numbers of EPT taxa were collected from both locations, although somewhat higher abundance values were found at the reference reach.

Hanging Rock Creek-Banner Elk, Avery County (Buck Engineering)					
metric/site	Reference	Reference	Site 1	Site 1	Other sites
	April, 2001	May 2002	April, 2001	May 2002	
Total Taxa (ST)	43	65	44	78	
EPT taxa (SEPT)	23	38	25	33	
EPT abundance (EPTn)	123	162	115	173	
Biotic Index (BI)	2.98	NA	3.93	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Benthic macroinvertebrates samples were collected twice at these two locations: 2001 by Buck Engineering and 2002 by DWQ. It was felt that the data from the initial survey did not suggest that there was enough of a difference in community structure to warrant a restoration project.

Reference Location. The stream at this point is relatively stable with a good canopy. However, upstream reaches are very unstable which has probably impacted the fauna at this location some. It was noted that when the substrate was disturbed loads, of fine sediment were released suggesting that some embeddednes has occurred. Much of the stream above this point is in pasture. Also there is a pond at the confluence of the two branches, which may create some eutrophication problems in the stream. Despite the potential upstream perturbations, Hanging Rock Creek at this point did have good habitat for the benthos including some good sweep areas (esp. Triaenodes), leaf packs (esp. Tallaperla) and had lots of coarse organic material.

Hanging Rock 1. This is the downstream reach within the restoration section. This site had very little canopy and the substrates in many of the sections were prolific with Elodea during the 2002 investigation. Apparently the Elodea was not found during the 2001 investigation, which may be due to differences in water temperature between investigations. The community appeared to still be somewhat diverse (Chimarra, Psilotreata, Hydropsychids) but it was dominated by midges and blackflies. These data indicate that the benthic macroinvertebrate population shifts from a heterotrophic community at the reference site to an autotrophic one at the impacted reach. Many fewer shredder organisms were collected at the downstream location.

Western Piedmont Ecoregion

Edwards Branch-Charlotte, Mecklenburg County (NC Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	UT Edwards Br
Total Taxa (ST)		13	14		0
EPT taxa (SEPT)		3	3		0
EPT abundance (EPTn)		14	7		-
Biotic Index (BI)		7.78	7.82		7.18
EPT Biotic Index (EPTBI)		7.50	6.78		-

Qualitative 4 samples were collected from 3 locations within the Edwards Branch watershed. These samples were collected to assess the water quality conditions of Edwards Branch prior to the implementation of watershed-level, stormwater BMPs. Samples were collected from a site near the downstream (Station 2) end of the project and at an upstream site near Campbell Street (Station 1). In addition a survey was conducted from a UT to Edwards Branch near Sheffield Park. Data from all locations reflect poor to very poor water quality conditions.

Very similar faunas exist at both Edwards Branch locations (identical EPT taxa) suggesting that water quality conditions are uniformly poor throughout the entire catchment perhaps responding to stormwater. The data from the UT is interesting in that there were no EPT taxa at all and the bank habitat looked productive. The substrate at the UT site was dominated by sand. Numerous fish kills have been reported from this catchment due to sewage spills.

Price Park-Greensboro, Guilford County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	35	34			
EPT taxa (SEPT)	7	7			
EPT abundance (EPTn)	27	13			
Biotic Index (BI)	NA	NA			
EPT Biotic Index (EPTBI)	NA	NA			

NA-Biotic indices were not calculated.

Qual-4 samples were collected from two sites on this stream. The reference site was selected above the proposed restoration and station 1 is within the restoration reach just below a walkway/road over the stream. The reference site is located at the end of a paved walkway at a fence line marking a property line. The stream at this point appeared relatively stable with good habitat. Rocky riffles and undercut banks provided good habit. A few relatively intolerant taxa were collected from this site and not at the downstream location (Paraleptophlebia, Triaenodes tardus, Brillia, Stylogomphus and Gomphus) and many more taxa were abundant here and reduced in abundance at the downstream site. These taxa include Stenonema modestum, Cheumatopsyche, Simulium. There appeared to be a shift in abundance of tolerant species at the downstream site. Baetis flavistrega, Hydropsyche betteni, Ilyodrilus templetoni, Paratendipes were all found downstream at not at the upstream location. Part of the difference in taxa richness is likely due to the loss of riparian canopy and habitat at the downstream location (heterotrophic vs. autotrophic conditions. Taxa richness values did not change between sites (EPT and total), although there was a shift in the composition of the fauna and EPT abundance was much lower at station 1 as noted above. Construction and nonpoint source runoff is prevalent in the developed catchment.

Sheppard's Tree-Statesville, Iredell County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	43	29	23		
EPT taxa (SEPT)	19	8	2		
EPT abundance (EPTn)	67	27	13		
Biotic Index (BI)	NA	NA	NA		
EPT Biotic Index (EPTBI)	NA	NA	NA		

NA-Biotic indices were not calculated.

Samples were collected from only two locations at the Sheppard's Tree mitigation location. Qualitative 4 collection methods were used at both locations. However, the data from these two locations are compared, for this discussion, to the data collected from the Payne Dairy Restoration project in Alexander County. Jumping Run Creek at the upstream location is approximately the same size, but the data for the Payne Dairy Project were collected in October so there may be some seasonality effects. It is evident from these data that the water quality conditions of the UT Third Creek are much worse than the conditions from Jumping Run Creek. The UT Third Creek is not hydrologically connected to the historical UT channel. Rather is has been move and connected to Third Creek upstream of the historical confluence. The restoration will reconnect this channel. It appears that Station 1 is above the channelized reach although the stream at this point is deeply incised and impacted by sediment. The upstream location is less than one meter wide, but has perennial flow. Most of the catchment appears to be agricultural. Station 2 is on the UT Third Creek approximately 50 meters above the confluence. Access to this location was along the berm between the UT and Third Creek. Samples were not collected from the reach between station 1 and 2. However, the stream in this reach had no flow and comparisons to other sites would have been difficult. Data should be collected from within this reach following restoration.

Water quality problems are present at both of the UT Third Creek locations as reflected by the significant differences in the composition of the fauna. For example Heptageniid mayflies were collected abundantly at station 1 but were completely absent from the downstream location. The only mayfly collected downstream was the burrowing mayfly Hexagenia. This fact suggests sediment deposition in this reach. It was also interesting to note the abundance of Elimia at the downstream location. It is apparent that the elimination of the hydrologic connection has changed the benthic fauna from upstream conditions.

Lyle Cr (Wike Property)-Newton, Alexander County (Division of Water Quality)					
metric/site	UT Catawba	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	39	44	51	18	
EPT taxa (SEPT)	18	16	17	3	
EPT abundance (EPTn)	66	94	84	30	
Biotic Index (BI)	NA	NA	NA	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Qual-4 collections were made at four locations prior to construction on this project. The reference site is located above the restoration reach at transect 140. The stream at this point was fairly incised but had some decent habitat including some bank habitat. The catchment appeared to be mostly forest at this point. This reach has a fairly sandy substrate but some gravel/cobble riffles were noted. UT Lyle Creek 1 is located near transect 110 at the lower reach of the restoration section and within a pastured reach of this UT. Cattle obviously have access to

this reach of the stream as the banks were eroding and the substrate was more sandy/muddy. UT Lyle Creek is a very small stream, that probably stops flowing during many times of the year, and is near transect 202. The substrate was extremely sandy and the EPTS numbers were very low. The only mayflies collected ware Ameletus and Leptophlebia. Benthos samples also were collected from a UT to the Catawba River that was selected for design purposes for this project. This stream appeared to be fairly stable and is a good choice for restoration design. The catchment appeared to be completely forested; however, the substrate was extremely sandy which suggests some perturbations in the past or sources of sediment upstream from the collection location.

Greater taxa richness values were found at the downstream site (UT Lyle Creek 2) compared to the upstream reference location (station 1), although EPT abundance was greater at the upstream location. There were differences in the structure of the community between these two locations. It was interesting to note that, even though this reach appeared to be moderately enriched, that Chimarra was very dominant at UT 2 and not collected at the upstream location. Chimarra is usually considered a fairly intolerant taxa, but its numbers at this site are perhaps responding to the enrichment. Hydropsyche betteni was also collected at this site and not at the upstream location, its presence is more typical of the effects of enrichment. Another interesting shift in the composition of the community was that Pycnopsyche and Diplectrona modesta were collected upstream and not at the downstream location and that the blackfly Prosimulium and mollusks were much more abundant downstream.

The reference reach for this project is a UT of the Catawba River. Despite the fact that the stream appeared to be more stable than the UT Lyle Creek, the substrate was mostly sand suggesting that there have been disturbances in the past or that there are sources on nonpoint runoff in the catchment that are affecting this reach. The EPT taxa richness value is very similar to the UT Lyle Creek locations but EPT abundance and total taxa richness values were less than the Lyle Creek location. Many of the same taxa were collected from this location, although there were many fewer Chironomidae at this site.

Brown Branch-Lenoir, Caldwell County (Division of Water Quality)					
metric/site	Christian Cr	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	109	57	57	67	
EPT taxa (SEPT)	48	33	31	33	
EPT abundance (EPTn)	213	133	87	119	
Biotic Index (BI)	NA	NA	NA	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Samples were collected from three locations on Brown Branch. Stations were located at the reference reach above the restoration reach. This site (site #1) was located above the project start point (52 + 87) but below the confluence of a small tributary. It was felt that this site was a better candidate reference reach because it was closer in size to the section of Brown Branch which is being restored. Sedimentation is apparent within this reach since most of the pools are at least partially filled in with sand. However, there is a good riparian canopy and lots of large woody debris (LWD). The LWD offers substantial habitat for aquatic insects, as many Limnephilid caddisflies were very abundant. These taxa include Pycnopsyche (2 or 3 species), Heteroplectron and Anisocentropus. Interestingly there were very few mayflies were collected

from this reach. This includes Heptageniids (including Epeorus) or Ephemerelids. This may due to the sedimentation or pH may be chronically low.

The next downstream site was located immediately below a farm pond on the property. Brown Branch at this point is much different then at station 1. The width/depth ratio appears to have increased substantially and most of the canopy has been eliminated. In addition LWD was scarce, as was fine organic matter in the substrate. This physical change in the structure of Brown Branch has impacted the benthic fauna. Many fewer Limnephilids were collected and we started to see Ephemerelids and Heptageniids. Embeddedness also has increased significantly between these two locations.

Station 3 (the most downstream location) was located near the confluence with Mulberry Creek. The site is directly across the pasture from the owner's home. The stream at this point appears to have incised some and there is evidence of enrichment. Macrophytes are common and cattle have direct access to the stream. EPT abundance values appear to have increased from site 2. Another interesting observation is the shift in the structure of the snail population. The upstream location was dominated by Elimia, but as soon as the canopy opened up, the number of Elimia dropped off and they were replaced by some Physella and Planorbula at the downstream locations.

Benthic macroinvertebrates also were also collected from Christian Creek. These data can be used as an ecoregional reference information.

Beaver Creek, Surry County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	98	111			
EPT taxa (SEPT)	42	40			
EPT abundance (EPTn)	195	147			
Biotic Index (BI)	NA	NA			
EPT Biotic Index (EPTBI)	NA	NA			

NA-Biotic indices were not calculated.

Two full scale samples were collected from Beaver Creek to assess this restoration project. An upstream site (reference) was located approximately 50 meters above the restoration reach and a downstream site (Station 1) was located near the end of the restoration reach. Both stations had a well-developed riparian canopy (somewhat less so downstream) and fairly stable banks. There were some areas where the banks were eroding, but overall both stations looked pretty good. The reference was in a more stable reach with large bedrock outcrops but had lots of fine sediments in the pools, which suggests that there are catchment-wide problems with erosion. The stability of this site was reflected in the higher abundance values of many EPT taxa (Epeorus, other Heptageniids, Isonychia) and Elimia. Station 1 is at transect 20 + 14 near an old wooden bridge. The EPT taxa richness and abundance values were very high at this location as well. Which suggests that there will be little improvement in the quality of the benthic fauna following restoration.

UT Pott Creek, Lincoln County (Rummel, Klepper, and Kahl)					
metric/site	UT Catawba	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	37	13	30		
EPT taxa (SEPT)	17	1	5		
EPT abundance (EPTn)	65	1	44		
Biotic Index (BI)	4.20	7.86	6.13		
EPT Biotic Index (EPTBI)	NA	NA	NA		

NA-EPT Biotic indices were not calculated.

This restoration project will construct approximately 4,300 linear feet of new channel of the UT to Pott Creek. Benthic macroinvertebrates were collected from two locations in the Pott Creek catchment: station 1 is located downstream of the UT flowing directly into Pott Creek and station 2 is located within the stream channel on the eastern portion of the site. Reference data were collected from a nearby similar-sized catchment (UT Catawba River). UT Pott Creek 1 has been channelized and although cattle have been excluded from this reach, there still is a great deal of bank erosion and cattle has access to upstream reaches of Pott Creek. Station 2 appears to be somewhat more stable than station 1 and has some facultative to intolerant taxa (exp. Diplectrona modesta, Stenonema terminatum and Leptophlebia). Poor water quality is evident at both UT Pott Creek locations. Taxa richness is reduced at both locations. Chironomidae were abundant from both sites.

Magnolia/Kirkwood-Charlotte, Mecklenburg County (LAW Engineering)												
metric/site	Site 0402		Site 0410		Site 0411		Site 0419		Site 0418		Site 0417	
	6/01	7/02	6/01	7/02	6/01	7/02	6/01	7/02	5/01	7/02	5/01	7/02
Total Taxa (ST)	18	14	25	13	16	11	14	11	18	10	17	11
EPT taxa (SEPT)	5	4	4	3	3	1	2	2	4	2	3	3
EPT abundance (EPTn)	33	12	24	3	9	3	4	13	24	4	12	9
Biotic Index (BI)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPT Biotic Index (EPTBI)	6.95	6.38	7.66	6.76	7.49	7.62	7.96	6.61	6.88	7.09	7.82	7.31

NA-EPT Biotic indices were not calculated.

The City of Charlotte has proposed approximately 6,685 linear feet of stream restoration on five segments of Dairy Branch and three segments of Sedgefield Park. Water quality and stream habitat data collected at the six monitoring locations indicate that the primary contributor to water quality degradation are stream bank erosion, a streambed consisting primarily of sand and littered with trash creating poor habitat, a narrow riparian zone with adjacent parking lots and roads, and unknown sources (s) causing high levels of fecal coliform bacteria.

Pre-construction surveys were conducted at 6 locations on two different occasions. Results of these investigations indicate that water quality conditions at all locations are poor and that the fauna is dominated by tolerant taxa including chironomidae, diptera and gastopods.

Hope Park Branch-Charlotte, Mecklenburg County (LAW Engineering)					
metric/site	Reference	HPB 4	HPB 3	HPB 2	HPB 1
Total Taxa (ST)		7	6	8	11
EPT taxa (SEPT)		0	1	0	1
EPT abundance (EPTn)		0	1	0	1
Biotic Index (BI)		NA	NA	NA	NA
EPT Biotic Index (EPTBI)		8.85	8.03	8.03	8.82

NA-EPT Biotic indices were not calculated.

The City of Charlotte has identified a second order stream tributary to Briar Creek for stream restoration due to increasing problems with erosion-related damage to public and private infrastructure, loss of stream habitat, floodplain encroachment, channel incision, bank erosion and periodic flooding. A pre-construction benthic macroinvertebrate survey was conducted in September of 2001 and recorded poor water quality conditions in the stream. These poor water quality conditions are a likely response to stormwater runoff.

Slate Belt Ecoregion

Randolph/Chatham County (Division of Water Quality)									
metric/site	Amick	Deaton Site				Caviness Site		Thomas Site	
	reference	D1	D2	D3	D4	C1	C2	T1	T2
Total Taxa (ST)	35	36	19	10	30	42	30	22	11
EPT taxa (SEPT)	15	9	1	0	3	14	7	0	1
EPT abundance (EPTn)	81	42	3	0	5	57	11	0	1
Biotic Index (BI)	3.85	5.17	8.39	8.39	7.56	5.44	6.85	7.62	7.08
EPT Biotic Index (EPTBI)	3.61	3.23	9.84	-	6.58	4.25	5.61	-	6.58

Deaton Site. Samples were collected from four locations associated with this project. Station D1 is the upstream location on the North Branch and was selected as a reference reach. This site appears to be relatively stable with a well-developed riparian canopy and normal width/depth ratios and riffle/pool sequence typical of slate belt stream systems. Station D2 also is on the North Branch but is within the reach due to receive level one restoration. The stream at this point has been channelized in the past and the entire riparian canopy has been eliminated. Flow was very reduced during this survey and the substrate is composed primarily of sand and silt. Cattle have direct access to this reach. Station D3 is located on the West Branch and also has been channelized, and hydrologically altered. Flow was eliminated at this location, reduced to only a series of cattle-septic pools. The collection method was altered slightly to account for the lack of flow. Unlike the North Branch, this branch is altered to it's headwaters, which may affect recolonization following restoration. However, this site will make a good comparison with the North Branch. A downstream recovery location at SR 1002 (Randolph County) was also sampled. This site (Station D4) was selected to monitor any downstream recovery following restoration and there is a possibility that DOT may purchase the adjoining land as part of this mitigation project.

Thomas Site. Qual-4 samples were collected from two locations at this project. Station T1 is located above the reference reach and Station T2 is located within the reach. Both locations are unstable with extremely sandy substrates. It should be interesting to compare these data to the Deaton Site because the land use (pasture) above this location will not be altered and may impact the reach that is restored

Caviness Site Two collection locations also were selected at this project. The upstream location (Station C1) is located above the project in an area that has been recently logged. The substrate appeared to be somewhat embedded. However, there still was some fairly stable habitat and a good diversity of insects. Station C2 is located at the lower end of the construction reach just below a culvert. The stream at this point is deeply incised to a grade control point and has a sand/silt substrate. Cattle have direct access to this reach of the stream.

Amick Site Selected as a reference location for all three of the projects. This site is located on a private hunt club.

Mt. Vernon Springs, Chatham County (Soil and Environmental Consultants)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		35	25	27	
EPT taxa (SEPT)		3	3	2	
EPT abundance (EPTn)		4	9	2	
Biotic Index (BI)		6.97	6.38	7.53	
EPT Biotic Index (EPTBI)		NA	NA	NA	

NA-EPT Biotic indices were not calculated.

Qual-4 collections were conducted at three locations at this project in July 2001 prior to construction. All three of these locations were on the project stream; site 1 is above the reach being restored, site 2 within the restoration reach and site 3 slightly below the restoration reach. Samples were collected during a prolonged drought in this area of North Carolina, which may have affected the results. Data from all three locations indicate fair to poor water quality conditions. Biotic indices were all elevated and EPT taxa richness and abundance values at all three locations were very low. No abundant taxa were collected from either of the sites and both heptageniid mayflies (esp. Stenonema) and hydropsychid caddisflies (esp. Cheumatopsyche), which are normally considered very prevalent taxa, were eliminated from site 3. Construction has been completed at this project.

Triassic Basin Ecoregion

Anson County Landfill-Monroe (EcoScience)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	35	14			
EPT taxa (SEPT)	13	0			
EPT abundance (EPTn)	50	0			
Biotic Index (BI)	4.10	7.15			
EPT Biotic Index (EPTBI)	NA	-			

NA-EPT Biotic indices were not calculated.

A compensatory stream and wetland mitigation project was conducted at this location as a result of unavoidable impacts to jurisdictional waters for landfill construction. Approximately 2,000 linear feet of stream channel was restored to design specifications. Benthic macroinvertebrates were collected from one location within the lower section of the restored reach and compared to data from a nearby reference stream. The mitigation stream is very depauperate and most of the taxa include tolerant amphipods and chironomidae. Whereas data from the reference stream indicates a diverse population of intolerant to facultative taxa.

3M Stream Restoration-Moncure, Lee County (KCI)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		22			
EPT taxa (SEPT)		4			
EPT abundance (EPTn)		15			
Biotic Index (BI)		6.12			
EPT Biotic Index (EPTBI)		3.17			

One benthic macroinvertebrate collection site has been surveyed prior to construction of this project. This location is near the lower end of the proposed restoration site. Other sites, including a reference location, were proposed but were completely dry during intended survey dates. These conditions are typical for Triassic Basin streams, particularly during the summer. It is recommended that all surveys in this ecoregion be conducted during the winter collection season.

Morrisville Community Park, Wake County (Soil and Environmental Consultants)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		28	24	14	
EPT taxa (SEPT)		3	2	2	
EPT abundance (EPTn)		14	4	11	
Biotic Index (BI)		6.98	7.80	6.36	
EPT Biotic Index (EPTBI)		NA	NA	NA	

NA-EPT Biotic indices were not calculated.

Qual-4 samples were collected from three sites at this project. Samples were collected from an upstream location above the restoration reach (site 1); a site within the restoration reach (site 2) and a site below the restoration reach (site 3). Very low taxa richness and abundance values were recorded from all three locations and NC biotic index values were also elevated suggesting poor water quality conditions. Interestingly much lower numbers of filter-feeding taxa (esp. Cheumatopsyche) were found at site 2, while higher numbers of tolerant taxa were collected at this site (Physella, Tubificidae, Caenis, Chironomus). This information suggests that water quality conditions or perhaps flow patterns are worse at this site.

Eastern Piedmont Ecoregion

Chavis Park-Raleigh, Wake County (Ecological Consultants)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		28	17	31	
Total Abundance		143	43	128	
EPT taxa (SEPT)		2	2	4	
EPT abundance (EPTn)		11	9	24	
Biotic Index (BI)		7.86	7.62	6.18	
EPT Biotic Index (EPTBI)		NA	NA	NA	

NA –EPT Biotic indices were not calculated.

Benthic macroinvertebrate samples were collected from three monitoring locations as part of this project (Upper, Mid and Lower reaches). Standard qualitative collections were made at each location. Poor water quality conditions were recorded at each location.

Rocky Branch-Raleigh, Wake County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		13	15	13	
EPT taxa (SEPT)		1	1	1	
EPT abundance (EPTn)		1	1	1	
Biotic Index (BI)		7.76	6.62	7.60	
EPT Biotic Index (EPTBI)		7.00	6.22	6.22	

Benthic macroinvertebrates were collected using a Qualitative 4 collection method from three locations on Rocky Branch during a survey conducted in December 2000. Station 1 is located just below Gorman Road. The stream at this point is perennial and has a width of 1-2 meters. The riparian zone was fairly mature and the canopy was nearly complete. This reach of Rocky Branch appears to be relatively stable although there are sources of stormwater and other nonpoint source runoff above this location. The substrate here is comprised primarily of rubble (2.5 – 10") and gravel (0.08 – 2.5") sized material. The substrate was coated with an iron oxidizing bacteria suggesting a fairly strong groundwater influence at this site. The benthic macroinvertebrate fauna was dominated by tolerant chironomidae primarily Conchapelopia and Cricotopus varipes group. The abundance of these taxa and very little else suggests the effects of toxicity, most likely from stormwater runoff.

Station 2 is located above the bridge at Dan Allen Drive. This reach is within the Phase I portion of the project. Rocky Branch at this point is very deeply entrenched and has severe problems with bank erosion. The effects of stormwater and nonpoint source runoff exasperate the problem. Again the benthos is very depauperate dominated primarily by tolerant chironomidae. The benthic macroinvertebrates are again dominated by Cricotopus varipes group and Conchapelopia although Eukiefferielia sp. 6 was also abundant.

Station 3 is the most downstream location for this project and is located above Pullen Road near the athletic fields at North Carolina State University. The stream at this point again is deeply entrenched although there are numerous grade control structures that may be forcing the stream here to widen. This reach of Rocky Branch has very deep pools although fish were not observed. There also appeared to be a stable riffle/pool sequence. The benthic fauna is dominated by tolerant chironomidae. Conchapelopia, Cricotopus varipes group and Polypedilum fallax were very numerous. Their tubes were covering all of the stable substrate material.

Randolph Park-Enfield, Halifax County (Buck Engineering)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	38	24	27	27	
EPT taxa (SEPT)	13	1	1	1	
EPT abundance (EPTn)	94	3	10	10	
Biotic Index (BI)	4.70	7.39	7.13	7.01	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA –EPT Biotic indices were not calculated.

Four benthic macroinvertebrate samples were collected from streams associated with this project. These include a site above the restoration reach (site 1), and below the restoration reach (site 2). Site 3 is the most downstream location the same tributary. The stream at station 1 has a predominantly sandy substrate with a thin riparian zone with a few trees near the stream but a maintained lawn on the outer zones. The benthos at this location suggested poor water quality, perhaps due to the effects of stormwater. Site 2 is within the reach that will be restored and has poor habitat and benthic fauna. The low taxa richness and high biotic index values calculated for this reach of stream are indicative of a highly stressed stream. Land use at station 3 is primarily rural agriculture. This site was selected because of its relatively wide riparian zone that may provide some adequate habitat for the benthos. Much higher habitat scores (using the DWQ habitat evaluation form, NC DWQ 2002) were recorded from this location. These data also include data from a regional reference location for comparison. This site, Bear Swamp, is within Medoc Mountain State Park and has a much healthier benthic macroinvertebrate community.

Hominy Swamp-Wilson, Wilson County (Buck Engineering)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		26	23		
EPT taxa (SEPT)		1	1		
EPT abundance (EPTn)		10	10		
Biotic Index (BI)		NA	NA		
EPT Biotic Index (EPTBI)		NA	NA		

NA -Biotic indices were not calculated.

Qual-4 samples were collected from two sites on this stream. Station 1 is located above the restoration project near the intersection of Canal and Pine Wood streets. The stream at this point has been channelized and appears to be stormwater driven. Riffle areas at this site are comprised primarily of chunks of asphalt. Station 2 is within the restoration reach near the tennis courts/swimming pool. The stream at this point appears to be much less stable. Root mats that were common at the upstream location have been eliminated at station 2 and replaced by emergent vegetation due to the lack of canopy at the lower site. The benthos at station 1 is dominated by Cheumatopsyche, Physella and Polypedilum illinoense. There are only very subtle differences in the fauna between these two locations. Many more midges and few Physella were collected at the downstream location. Even though the emergent vegetation is providing great habitat for damselflies only two specimens of Enallagma were collected from station 2. This suggests that the water quality is very poor.

Smith/Austin Creeks-Wake Forest, Wake County (Division of Water Quality)					
metric/site	Smith 1	Smith 2	Austin 1	Austin 2	Other sites
Total Taxa (ST)	34	42	35	26	
EPT taxa (SEPT)	11	12	11	7	
EPT abundance (EPTn)	68	43	55	29	
Biotic Index (BI)	NA	NA	NA	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Full scale surveys were conducted at four locations associated with this project. Samples were collected from two locations on Smith Creek; station 1 within the restoration reach near the lower end of the construction and station 2 below the confluence with Austin Creek. Two stations were also established on Austin Creek: station 1 at Jones Dairy Road was used as the reference reach for this project and station 2 within the restoration reach. Smith Creek #1 had a very unstable reach and a substrate composed primarily of shifting sand. Macrophytes along the bank were very common. Smith Creek #2 is below the confluence with Austin Creek. Smith Creek at this point also was channelized in the past and had excessive amounts of sediment. Despite some fairly decent habitat EPT numbers were pretty low (12) and dominated by tolerant taxa (S. modestum, Cheumatopsyche and Tricorythodes).

Austin Creek at Jones Dairy Road was selected as the reference reach. Unfortunately EPT taxa richness and abundance values are not substantially different from the two sites on Smith Creek, although there may be some differences in the biotic index values. The stream at this point appears to be relatively stable. Triaenodes and Serratella were collected at this site which probably is related to the microhabitat presence for these two taxa (stable banks and moss on rocks). This was the only site with any stoneflies. The downstream station on Austin Creek did appear to be relatively stable with a decent riparian zone however EPT taxa richness and abundance values were much lower at this site than all others.

Murphy Farm-Louisburg, Franklin County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	50	48	36	46	
EPT taxa (SEPT)	21	16	4	8	
EPT abundance (EPTn)	100	69	8	23	
Biotic Index (BI)	NA	NA	NA	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Approximately 1800 linear feet of this UT to Bear Swamp Creek in Franklin County will be restored at this site. Qual-4 samples were collected from three reaches of this tributary to establish pre-construction conditions. An additional sample was collected from a UT to Crooked Creek, which was selected as the reference reach for the design part of this project. These are all very small streams. Station 1 is above the 1800 linear foot reach on the UT to be restored. The site was selected as an upstream reference reach and receives flow from a series of springs immediately above the site. There's also an instream pond located above this location but did not have flow during this investigation. Two sites were selected within the restoration reach. Station 2 is below Mr. Murphy's driveway near a barn. The stream at this point is severely degraded very little riparian canopy and cattle have direct access. It appears that this reach is degrading and that the abundance of benthic organisms is less than at the next downstream location. Station 3 is located within a forested reach of the stream and appears to be aggrading. Abundance at this location is much greater than at station 2 and there are many more Chironomus were found here. The reference reach at the UT to Crooked Creek appears to be very stable and has a diverse benthic macroinvertebrate population.

A very rapid change in the composition of the benthic fauna occurs between sites 1 and 2. Station 1 is dominated by fairly intolerant taxa including Diplectrona and Chimarra, but their numbers fall off drastically at station 2. These conditions may indicate a shift from heterotrophic to autotrophic conditions. Many organisms that are abundant or common upstream were not collected at the downstream location. Abundance and taxa richness increase slightly at station three, perhaps responding to the increase in canopy cover. However tolerant fauna (Chironomus and Physella) dominated the fauna at this most downstream location. Data also were collected from UT Crooked Creek that was selected as the reach for design. Taxa richness and abundance values were higher at this location. Many more mayflies and stoneflies were collected from this location than the upstream reference reach of UT Bear Swamp.

Yates Mill-Raleigh, Wake County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	26	15	3	24	
EPT taxa (SEPT)	9	3	1	4	
EPT abundance (EPTn)	26	12	3	4	
Biotic Index (BI)	NA	NA	NA	NA	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-Biotic indices were not calculated.

Qual-4 samples (or slight modifications because of the very small size of some sites) were collected from four locations associated with this project. Station 1 is located above a road and culvert and also above an earlier restoration project work on 800 linear feet. The stream at this point is very small bordering on intermittent. A good population of limnephilid caddisfly were collected at this location (plus some Pisidium) which suggests that the stream at this point is

perennial. The riparian zone is mostly forested above this location and there did not appear to have obvious sources of enrichment. There were "typical" riffle pool sequences with substrate materials that would support a benthic fauna. Station 2 is located within the lower reach of the earlies restoration project, that was completed a couple of years ago. This station is approximately 20 yards above the current stream restoration. The stream at this point is heavily enriched with very thick mats of Aufwuchs material. Also it appeared that the riffles were poorly developed in that they did not have the proper materials to support fauna. The substrate appeared to mostly clay-like material rather than rocks. Chironomids dominated the fauna. Station 3 is within the current stream channel near transect 24 00. The stream at this point had good habitat (rocky riffles, and some undercut banks), but the fauna seemed depauperate. There were lot of Aufwuchs material on the substrate materials and the pools looked greenish.

The reference reach selected for this project was Sals Branch. Benthos samples were also collected from this stream. The site is near the US 70 entrance to the Park and behind the visitor's center. The stream at this point was stable with a population of benthos dominated by intolerant taxa (esp. Neophylax).

Marks Creek-Knightdale, Wake County (Stantec)					
metric/site	UT Marks 1	UT Marks 2	UT Marks 3	UT Marks 4	Other sites
Total Taxa (ST)	48	30	37	33	
EPT taxa (SEPT)	11	6	12	12	
EPT abundance (EPTn)	65	15	23	38	
Biotic Index (BI)	4.18	5.23	5.64	5.51	
EPT Biotic Index (EPTBI)	NA	NA	NA	NA	

NA-EPT Biotic indices were not calculated.

Qual 4 samples were collected from four locations at this project. Sites were selected at an upstream reference reach on the West Branch of UT to Marks Creek (site 1) and from a site on this branch at the upstream end of the proposed restoration reach (site 2). This site was selected just below the high water line of the old pond. A sample was also collected from the East Branch above the upper limit to the old pond bed (Site 3). A final site below the confluence of these two branches and in the old pond bed approximately 50 meters above the breached dam also was surveyed (Site 4). Several intolerant taxa were only collected at the upstream reference reach on the West Branch (Neophylax, Anychytarsus bicolor, Mystacides sepulchralus, and Lepidostomatidae) suggesting good water quality at this site. Other, more tolerant organisms were more dominant at the other locations (Cheumatopsyche, Simulium).

Coastal Plain Ecoregion

Mill Branch-Greenville, Pitt County (Division of Water Quality)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)		19	24		
EPT taxa (SEPT)		4	2		
EPT abundance (EPTn)		15	13		
Biotic Index (BI)		NA	NA		
EPT Biotic Index (EPTBI)		NA	NA		

NA-Biotic indices were not calculated.

This is a very small stream system that has mostly residential and agricultural land cover. This restoration is not being done for compensatory mitigation, and is being coordinated by the Natural Resources Conservation Society. In addition, several research projects are being

conducted by researchers at Eastern Carolina University. The upstream reference reach didn't appear to be stable and was located below a culverted road crossing. Qual-4 samples were collected from only two locations; Station 1 is upstream of the restoration reach and Station 2, which is at the downstream reach of the restoration. Station 1 is located in a pretty heavily forested reach of the UT and has a pretty good riffle/pool habitat and good flow. The stream at this point is deeply incised but has relatively stable banks. This site also had good flow but had much more sediment deposition.

The benthic fauna is depauperate at both locations, perhaps due to stormwater at station 1 and stormwater plus agricultural chemicals at Station 2. EPT richness and abundance was low at both stations, although Caenis and Ephemerella were collected at Station 1 and no mayflies at all at Station 2. There also were many more Elmid beetles at the downstream location including Ancyronyx varigatus and Macronychus.

Global Transpark-Kinston, Lenoir County (EcoScience)					
metric/site	Groundnut Creek	Stonyton Creek	Briary Run	Site 3	Other sites
Total Taxa (ST)	32	42	31		
EPT taxa (SEPT)	5	1	1		
EPT abundance (EPTn)	25	3	1		
Biotic Index (BI)	6.30	7.80	7.60		
EPT Biotic Index (EPTBI)	5.70	9.80	7.40		

Biological samples were collected from three locations associated with this project. Surveys were conducted in June during low flow conditions using DWQ methods for swamp streams.

Stonyton Creek nr Highway 58. Samples were collected approximately 100 meters below the bridge at this location, which is within the restoration reach. The stream at this location has been channelized in the past and is deeply entrenched. Flow was extremely limited due to the lack of rain and the geology of this region. Very short reaches of flow were found below long stretches of stagnant water. Midges and several types of snails dominated the fauna at this location. Only one mayfly specimen was collected at this location. There were two large wetlands associated with this reach of Stonyton Creek that will be incorporated into the new restored channel.

Briary Run nr SR 1572. This site was selected as a water quality monitoring location for the GTP project. Flow was essentially not existent at this site. The reach consisted on long isolated pools with very little or no flow between them. Interestingly one of the most dominant taxa at this location was Sphaeridae, which are typically considered filter-feeders and not deposit feeders.

Groundnut Creek at Alridge Store Road. This site was selected as the reference reach for this project based on the size the catchment (very comparable to Stonyton Creek) and is also an abandoned USGS gaging station. A good reference reach on Falling Creek for the Adkins Branch project has been established in the same area. Groundnut Creek has a catchment size of approximately 6.5 square miles. This site had good flow with widely spaced sandy riffles and lots of snag habitat. A fairly diverse fauna was collected at this location, lots of Heptagenids and Hydropsychids were found. We also collected several Perlesta.

Adkins Branch-Kinston, Lenoir County (HSMM, Inc)					
metric/site	Falling Cr	Site 1	Site 2	Site 3	Site 4
Total Taxa (ST)	36	15	16	14	14
EPT taxa (SEPT)	9	0	0	0	0
EPT abundance (EPTn)	40	0	0	0	0
Biotic Index (BI)	5.57	8.67	7.53	7.50	7.30
EPT Biotic Index (EPTBI)	NA	-	-	-	-

NA-EPT Biotic indices were not calculated.

Full scale collections were made at four Adkin Branch stations in April 2002. Three of these locations are within the proposed restoration reach (from upstream to downstream they are MH 29 near the beginning of the project, MH 15 and MH01 near the confluence with the Neuse River). In addition to these locations, a fourth Adkin Branch location was sampled above the restoration reach at Heritage Street near Doctor's Drive and a regional reference site was also sampled. This site is Falling Creek at SR 1001.

Adkin Branch #1. This is the most upstream location in the catchment and was selected above the restoration reach to serve as a reference condition. Adkin Branch at this location appears to be somewhat more stable than the downstream locations although has been channelized in the past and has a substrate dominated by shifting sand. The width/depth ratios are very high and the channel is trying to reform itself with the banks. The substrate does have LWD, organic material and leafpack habitats as well as good sweep areas. The riparian canopy is developed and the streambanks are relatively stable with little active erosion. However, the benthos were very depauperate and dominated by very tolerant taxa. This suggests that there are some upstream impacts, including stormwater that will affect the ecological functions of the stream following restoration.

Adkin Branch #2. This is the most upstream location within the restoration reach. Sampling was close to MH 29 about 50 meters below the 55/11 bridge. The habitat at this location has been completely eliminated. The substrate in dominated by shifting sand, badly eroding stream banks have eliminated sweep habitats and the riparian zone is devoid of canopy allowing increased water temperatures. Oil was also noted in the substrate at this location. Benthos are dominated by tolerant taxa especially chironomidae.

Adkin Branch #3. This site was selected as a midreach location within the restoration and is located at MH 15 near the Cypress Street Bridge. Samples have been collected at this site following a very high flow event (April 2) and during normal flow conditions (April 23). This site appeared to be more enriched than either the upstream location or the downstream location. Polific growths of filamentous algae and more red midges were noted. The channel at this location is confined within hardened structures which has allowed for more confined flow and riffle conditions with a rocky substrate. The benthos again appeared to be dominated by very tolerant taxa, primarily chironomidae.

Adkin Branch #4. This is the most downstream location on Adkin Branch at station MH 01. Samples were collected just below the Lincoln Street Bridge. This is similar to site #3 but will incorporate all of the restoration activities. The benthos again were very depauperate dominated by tolerant taxa.

Falling Creek. This site was selected as a regional reference location at SR 1001. The site had a very sandy substrate but also contained productive snag, leaf pack and sweep habitats. The benthos at this location was dominated by intolerant taxa including nine EPT taxa.

Crescent Road-Kinston, Lenoir County (Buck Engineering)					
metric/site	Reference	Site 1	Site 2	Site 3	Other sites
Total Taxa (ST)	26	24			
EPT taxa (SEPT)	9	2			
EPT abundance (EPTn)	48	4			
Biotic Index (BI)	5.39	7.25			
EPT Biotic Index (EPTBI)	3.74	5.78			

Two collection sites were done as part of this project; within the project area at an ecoregional reference location (Still Creek located in Cliff of the Neuse State Park). Data from the reference reach noted higher total and EPT taxa richness and abundance values. While total taxa richness between the two sites were similar, the project reach had only two EPT taxa (including Cheumatopsyche) compared to nine EPT taxa at the reference reach. Pre-construction data were not collected from this stream; these data therefore represent the first year of post-construction data.

Appendix 3

AQUATIC INSECT COLLECTION PROTOCOLS FOR STREAM MITIGATION AND RESTORATION PROJECTS AS RELATED TO NCDENR DWQ 401 CERTIFICATIONS

The objective of this workshop is to instruct participants in proper collection techniques for benthic macroinvertebrate sampling as related to NCDENR DWQ 401 stream mitigation and restoration projects. A Certificate of Completion will be provided upon successful completion of the course. The main purpose of the course is to instruct participants in benthic macroinvertebrate collection for activities such as monitoring of stream mitigation projects. **We strongly urge all individuals who plan to collect macrobenthos data for this purpose to attend this course.**

AGENDA

First Day

8:30 am	Introductions and Overview: applicants should be prepared to discuss their current/planned mitigation/restoration projects
9:00 am	General Benthos Discussion, Regulatory Requirements and Technical Guidance
10:15 am	Break
10:30 am	Biological Concepts as they apply to the 401 Certification Process, Collection Methods
Noon	Lunch
1:00 pm	Field Visit
5:00 pm	End of Field Visit

Second Day

8:30 am	Review and Questions
9:00 am	Written Evaluation
10:00 am	Field verification/Evaluation
2:00pm	Completion of Course

Each participant should be thoroughly familiar with the following documents and **bring copies to the workshop:**

Technical Guidance Manual (http://h20.enr.state.nc.us/ncwetlands/download.html; (under "Benthic Macroinvertebrate Monitoring Protocols for Stream Mitigation Projects")

Benthos SOP Manual (http://www.esb.enr.state.nc.us/BAU.html)

Participants are responsible for providing **ALL** necessary equipment. Those participants without the necessary equipment will not be allowed to complete the training. Equipment lists are located in both the Benthos SOP (page 21) and the Technical Guidance (page 14).

NO EQUIPMENT WILL BE PROVIDED

A small fee may be charged to offset cost for supplies, transportation, etc (not including staff time). Participants will be informed of the exact cost (if any) before the class begins.

Participants should bring a brown bag lunch on April 11 due to limited time constraints.

This training is applicable ONLY for the 401 Certification Program involving stream mitigation and restoration projects.

Applications will be accepted through the U. S. Mail only. **NO** other applications will be accepted. Additional workshops may be scheduled depending on demand. Please direct questions to Beth Barnes (919) 715-8394 (Beth.Barnes@ncmail.net).

REGISTRATION FORM

NAME: _____ DEPARTMENT/COMPANY: _____

ADDRESS: _____ TELEPHONE NUMBER: _____

(Certificates will be mailed upon evaluation of written and field portions of course)

E-MAIL: _____
(notification of acceptance into the workshop will be via e-mail)

EXPERIENCE (how long have you been collecting aquatic insects and for what purpose): _____

_____

EDUCATIONAL BACKGROUND (degrees, classes in ecology, etc.): _____

_____

Mail application to: Wetlands/401 Unit
NC Division of Water Quality
Attn: BETH BARNES
2331 Crabtree Blvd.
Raleigh, NC 27604-2260

Appendix 4. BIOLOGICAL TRACKING – STREAM RESTORATION PROJECTS

A. Title: A, H, and W Farm Mitigation Site
B. Project/Stream Name: Big and Little Warrior Creeks
C. DWQ Number: US 421, #970616
D. Map Number: 01
E. Ecoregion, County and Location Information:
   Eastern Blueridge Foothills (66l), borders the Northern Inner Piedmont (45e).
   Wilkes County, NC 18 near Boomer
F. Coordinates and USGS Quad Name
   360127/811814 at upstream location
   Boomer, C13SE
G. Rosgen Classification: B type upstream in undisturbed reach transitioning to a C type stream about halfway through the reach. Many reaches have incised to a point that they are now G type streams (including Little Warrior below Andrews Road).
H. Length of Project: app. 14,000 linear feet (may change as plans are finalized)
I. Urban or Rural: Rural
J. Catchment Size at lower end of project: app. 1.25 square mile
K. Who conducted the biological monitoring? DWQ (Dave Penrose)
L. Applicant Information:
   1. Name:
   2. Telephone Number:
   3. Email address:
M. Consultant Information:
   1. Name: Micky Clemmons, Wildlife Resources Commission
   2. Telephone Number: (828) 452-6191
   3. Email Address: Clemmomm@brinet.com
N. Project Status: Easements are being obtained and should be complete by January 1 and the pre-construction biological survey has been completed by DWQ (see attached summary sheet).

upstream, Niki collecting sweep sample

downstream, unstable channel