

INTERIM, INTERNAL TECHNICAL GUIDE

BENTHIC MACROINVERTEBRATE MONITORING PROTOCOLS FOR COMPENSATORY STREAM RESTORATION PROJECTS

**North Carolina Division of Water Quality
401/Wetlands Unit
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1. Purpose of the Document

Section 401 of the Clean Water Act delegates authority to the States to issue a 401 Water Quality Certification for all development that require a Federal Permit (such as a Section 404 Permit). The “401 Certification” is essentially a verification by the State that a given project will not

Biological restoration of streams and rivers includes restoration of the structure, function and diversity of aquatic biota.

degrade Waters of the State or otherwise violate water quality standards. In many instances, this Certification requires applicants to mitigate for stream impact and also may involve relocation and restoration of stream channels.

There are four major purposes of biological monitoring programs for stream restoration efforts. First, to restore or enhance the ecological function of streams. Monitoring is the only means available to demonstrate whether the attempted mitigation has successfully replaced the ecological function, which has been unavoidably lost. Second, monitoring for a wide variety of projects should reveal which stream restoration and enhancement techniques result in biological benefit. The information will allow the regulated community and the regulators to test and refine stream restoration efforts across North Carolina. Third, since benthic macroinvertebrates respond differently to various pollutants these data will help DWQ and local water pollution control staff to identify any watershed-scale problems in the stream and thereby aid in

stream restoration. Fourth, these data may aid in the development of numeric success criteria for stream restoration. This process could give specific guidelines for stream success to regulators and the regulated community.

The use of benthic macroinvertebrate information is a relatively new concept as it applies to stream mitigation and restoration. This information will be an important tool to measure the success (both short and long term) of these mitigation projects. However, the information also will be used in several other ways. For example, information can be used by students for research projects such as discussing range distribution of aquatic insects or ecosystem function of small stream systems. Specimens and collection records will provide important data for researchers at the N.C. Museum of Natural Sciences and the N.C. Natural Heritage Program. In addition, the DWQ Wetland/401 Unit may conduct long-term surveys of restored stream reaches and QA/QCed information is essential for these comparisons.

Applicants are required to clearly define specific goals and objectives to be accomplished during the implementation process. Overall goals of restoration projects may include construction of stable stream channels to eliminate loss of property, reduce aggradation or other effects of sedimentation, restore fish habitat and productivity, or to restore ecological diversity. Biological restoration of streams and rivers includes restoration of the structure, function and diversity of aquatic biota. Specific monitoring requirements can be written

into each 401 Certification and can be used by regulatory agencies to determine the ecological functions or recovery of these streams reaches. At this point, the use of these monitoring protocols will not be used to specifically determine the success or failure of restoration projects. Biological monitoring to assess the effects of point and nonpoint sources of water pollution is a well-recognized monitoring tool frequently used by regulatory agencies. However, the use of biological monitoring as a tool to determine the recovery of stream functions following restoration projects is a relatively new concept. This guidance document describes the basic principles of benthic macroinvertebrate (or aquatic insects) ecology as a monitoring tool and how this tool will be used in stream restoration projects.

Sections two through five of this document discuss general concepts as they apply to Biological Monitoring using benthic macroinvertebrates, Stream and Habitat Classification, Water Quality and Ecoregions of North Carolina. Chapters six through fifteen are intended to offer specific suggestions for monitoring plans as they relate to Station Selection (including reference reaches), Collection Methods for benthic macroinvertebrates, Taxonomic Considerations, Data Analyses and Quality Control Objectives and Report Writing Considerations. Chapter sixteen

presents two case studies of biological monitoring projects as they relate to stream restoration projects.

It should be noted that all collection and taxonomic analyses of benthic macroinvertebrates for 401 permit required projects, including restoration mitigation projects must be performed and reported by qualified ecologists in accordance with their quality assurance plans as approved the Director or his designate. All taxonomic identifications should be made using the most up-to-date, regional taxonomic keys. A list of taxonomic keys for the United States has been included in the revised Rapid Bioassessment Protocols document (Barbour et.al., 1999). In order to ensure that all biological data collected during stream restoration projects are of a known quality, DWQ Wetlands/401 Unit has established specific requirements for the development of a quality assurance plan. The quality assurance plan must include standard operating procedures and clearly demonstrate the ability of those involved with collection, taxonomic analyses, and reporting of results. Work conducted should adhere to those standard operating procedures and the quality assurance plan. Those interested in conducting biological monitoring for these purposes should contact Mr. Dave Penrose at the NC Division of Water Quality.

2. Concept of Biological Monitoring

The concept of biological integrity in streams was first explicitly defined in the Water Pollution Control Act Amendments of 1972. Since then several revisions of the 1972 Act have been written. This concept and the use of biological monitoring have become an integral part of State and Federal water quality monitoring programs. Biological monitoring programs are being used by most State water quality agencies to

Restoring lost community structure and function of biological communities without considering basinwide processes or river continuum is a short-term fix to a long-term problem.

defining narrative or numeric biocriteria, to water quality standards, to aid in the interpretation of aquatic life use attainment, and to aid with regulatory decisions related to water resource

management. In North Carolina, benthic macroinvertebrate information also has been used to help define reference conditions in several ecoregions and also to reclassify streams as High Quality or Outstanding Resource Waters.

Benthic macroinvertebrates, or aquatic insects, are effective assessment tools for many reasons (Plafkin et al. 1989). This community of aquatic organisms is found in all aquatic habitats including very small perennial stream systems (1st and 2nd order), which normally support a very limited fish fauna. The temporal and spatial patterns of this group of organisms is less studied in intermittent stream systems, however, research has demonstrated that intermittency is

important in shaping patterns in perennial stream systems (Stanley and Fisher 1992). Benthic macroinvertebrates are easily and inexpensively collected, and these communities integrate the effects of short-term environmental perturbations. Sensitive species respond quickly to stress, while community shifts are generally more long-term. In addition, benthic macroinvertebrate communities respond to the various types of water pollution in predictable fashions (Hocutt 1975) and are important in the diets of most fish species.

Listed below are five general definitions and/or descriptions. These definitions/descriptions were added to give those unfamiliar with biological monitoring concepts some basic information as it might relate to stream mitigation/restoration monitoring.

a. Benthic Macroinvertebrates

Benthic invertebrates comprise a heterogeneous assemblage of taxa that inhabit the sediment or live on or in other bottom substrates in the aquatic environment (Klemm et al. 1990). They vary in size from forms small and difficult to see without magnification to other

individuals large enough to see without difficulty. The benthic invertebrates that are large enough to be seen without

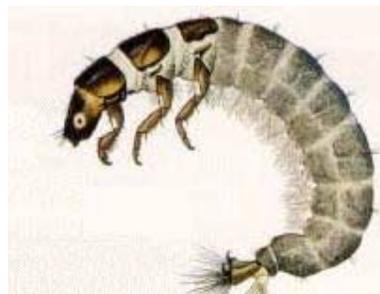


Figure 1. Caddisfly (Trichoptera).

magnification and can be retained by

a U.S. Standard No. 30 sieve and live at least part of their life cycles within or on

the substrate are defined as macroinvertebrates.

b. General effects of Water Pollution.

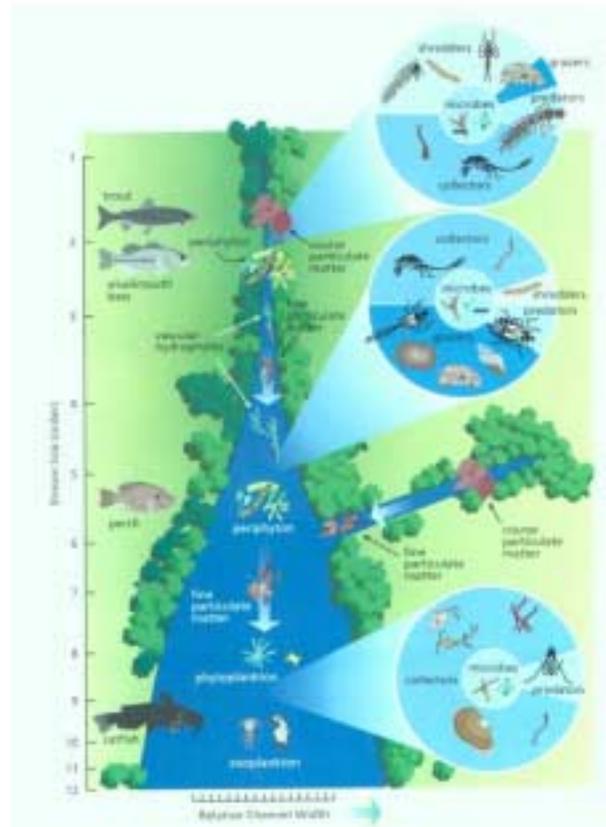
Unstressed streams and rivers will support greater diversity and biological integrity than polluted systems. As water pollution is introduced into a stream system, intolerant taxa (i.e. mayflies, stoneflies and caddisflies) disappear and are replaced by tolerant species (i.e. tubificidae, some chironomidae). The spatial and temporal effects of both point and nonpoint sources of water pollution are affected by flow regimes. During high flow periods, nonpoint source runoff is increased and the effects of point sources are minimized because of dilution. During low flow or drought conditions, the opposite is observed such that point source pollution often is much greater and the effects of nonpoint sources are negligible at lower flows.

c. Feeding Guilds.

Benthic macroinvertebrates exploit the physical characteristics of streams to obtain their food (Wallace and Webster 1996, Cummins and Klug 1979, Merritt and Cummins 1981). In addition, there exists a relationship between a stream's riparian corridor and functional feeding groups of its resident biota (i.e. grazers, shredders, gatherers, filter-feeders and predators). Analyses of functional feeding groups can be used to assess the overall health of a stream. For example, shredders are important components of forested areas of streams from 1st through 4th orders (Minshall et. al. 1985). The absence of shredders from restored stream reaches may be an indication of incomplete recolonization within that reach or unstable, poorly retentive headwater streams.

d. River Continuum.

The River Continuum Concept was originally proposed by Vannote et.al. (1980). This concept suggests that a river ecosystem is comprised of a series of biological communities which merge into one another as the biota respond to gradients in physical conditions along the river (Crunkilton and Duchrow 1991). This is an important concept to consider when designing river restoration projects which, in effect, can disrupt the continuum of a river. Restoring lost community structure and function of biological communities without considering basinwide processes or river continuum is a short-term fix to a long-term problem. Figure 2 represents a hypothetical image of the river continuum concept.



e. Recolonization.

Recovery of biological diversity and integrity within restored stream reaches is dependent upon rates of recolonization. This process is dependent on many factors, but most importantly is the proximity of refugia for aquatic organisms and heterotrophic sources of energy. Headwater stream reaches or unaltered tributary systems are usually considered primary refugia. Benthic organisms will drift in from these refugia to colonize restored reaches. Rates of recolonization within mitigation reaches, including numbers of taxa and diversity relative to reference locations, will be used as an indication ecological function and restoration.

3. Stream and Habitat Classification

a. Stream Classification.

The concept of classifying stream systems using physical or chemical characteristics is not a new concept. For example Davis (1899) first classified streams into three types based on age of adjustment: youthful, mature, and old age. Since then many other classification systems have been used to categorize stream types. Most recently, Rosgen (1996) describes a hierarchical classification system that uses river dimension, pattern and profile to delineate geomorphic types. Rosgen lists the specific objectives of this classification system as follows:

- ❖ Predict a river's behavior from its appearance.
- ❖ Develop specific hydraulic and sediment relationships for a given stream type and its state.
- ❖ Provide a mechanism to extrapolate site-specific data to stream reaches having similar characteristics.
- ❖ Provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines and interested parties.

This classification system has formed the basis for stream restoration initiatives nationwide. The Wetlands/401 Unit of DWQ recommends that the Level II Rosgen stream classification system be used to classify existing and proposed stream reaches during restoration projects. Stream types should be assigned to all monitoring locations. It is generally assumed that aquatic biota will respond to restoration efforts in a predictable fashion and this will be driven by stream type. A modified Rosgen stream classification system was an effective classification variable for partitioning variation among benthic macroinvertebrate communities in a study conducted in the Susquehanna River Basin (McGarrell 1998).

b. Habitat Classification.

The overall assessment of ecological condition first focuses on the evaluation of habitat quality and then the analysis of the biological components of the system (Plafkin et. al. 1989). Habitat quality is a dominant factor used to define the biological potential of the stream and is therefore a critical factor in any evaluation of ecological integrity (Karr et. al. 1986). Numerous habitat classification systems have been used by State and Federal water quality monitoring agencies. However, each classification system will have parameters that rank or discuss watershed scale quality (i.e. land use), riparian and bank structure, channel morphology, and instream habitat characteristics (Gibson 1996).

The Biological Assessment Unit of the North Carolina Division of Water Quality

Habitat quality is a dominant factor used to define the biological potential of the stream and is therefore a critical factor in any evaluation of ecological integrity (Karr et. al. 1986).

has developed and is still refining a habitat classification form (NCEHNR 1997). This habitat classification form is specific for mountain/piedmont streams and for coastal plain streams and contains eight assessment categories (riffle habitat quality is not included in the coastal plain form). Each category is given a subjective score and then all scores are totaled. One hundred (100) is the maximum score for

each of the forms, but no criteria have been developed to describe habitat degradation. These forms are included in this document as Appendix 2. Applicants

are encouraged to regularly check the DWQ websites for changes in protocols as they are developed.

4. Water Quality Considerations

Benthic macroinvertebrate community structure will respond to water quality perturbations in a predictable fashion. (Figure 3). This figure illustrates how taxa richness and abundance of benthic macroinvertebrates will respond to toxic pollution, sedimentation and nutrient enrichment.

During the collection of biological samples, water quality samples also should be collected at each location.

Water quality considerations of the catchment are important to consider during the initial design of the mitigation project. In addition, water quality

of the catchment upstream of the mitigation reach will affect the potential recovery rates and/or success of the project.

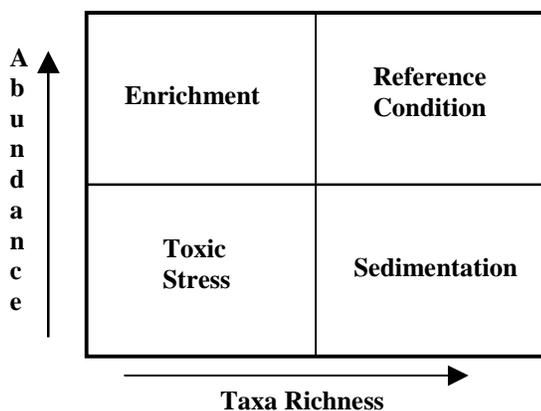


Figure 3. Typical Reactions of Benthic Macroinvertebrate Populations to Water Pollution (Hocutt, C.H. 1975).

Toxic pollutants result in a very characteristic benthic macroinvertebrate community (Penrose et. al. 1980). Toxic stress can include urban runoff (metals), agricultural runoff (pesticides) or discharge from point sources. One of the more common point source impacts to stream benthos are the effects of overchlorination of municipal effluents. Toxic stress can reduce both taxa richness and abundance often resulting in stream communities extremely devoid of life and dominated by very tolerant taxa. Chironomidae (such as Polypedilum and the Conchapelopia group) frequently will be the dominant taxa in these streams.

b. Sedimentation

Sediment and the effects of sedimentation are thought to be the most widespread water quality problem in North Carolina (NCENR 1999). The reduction of viable habitat for the colonization of benthic macroinvertebrates and cover or breeding areas for fish are the most obvious results of excessive sedimentation. The capacity of stream systems to tolerate sedimentation is a function of gradient and flow. Frequently, high quality riffles are the only habitat from which benthic insects are commonly collected. The overall result of excessive sediment in streams is that taxa richness is generally not affected, while abundance is reduced. Several benthic macroinvertebrates are tolerant to the effects of sedimentation and are frequently abundant in these streams (Penrose et. al. 1980). These taxa include several species of Baetis, Progomphus,

a. Toxic Pollution

and several chironomidae (esp. Eukiefferiella and Cricotopus). Benthic insect populations of sediment stressed streams often have extremes in abundance values. These abundance values are related to the unstable nature of sediment as a habitat type and stream flow. Population numbers can be extremely high during low flow periods (many of these insects are surface grazers and respond to increases in algal populations), but are eliminated during high flow periods (Waters 1995).

c. Nutrient Enrichment

The effects of organic enrichment on stream communities has been repeatedly studied (Hynes 1974). The most important effect is due to the exertion of biochemical oxygen demand, often resulting in severe dissolved oxygen depletion. Dissolved phosphorus and nitrogen promote algal growths (especially in areas with little canopy cover), which in turn decay and contribute to oxygen depletion. Total density of aquatic invertebrates will increase, as the organic material constitute a considerable food source. Taxa richness declines as only those organisms tolerant of low dissolved oxygen can survive. Tubificidae (esp. Limnodrilus hoffmeisteri

and Tubifex tubifex) and Chironomidae (esp. Chironomus) often become dominant (Penrose et. al. 1980).

d. Reference Condition

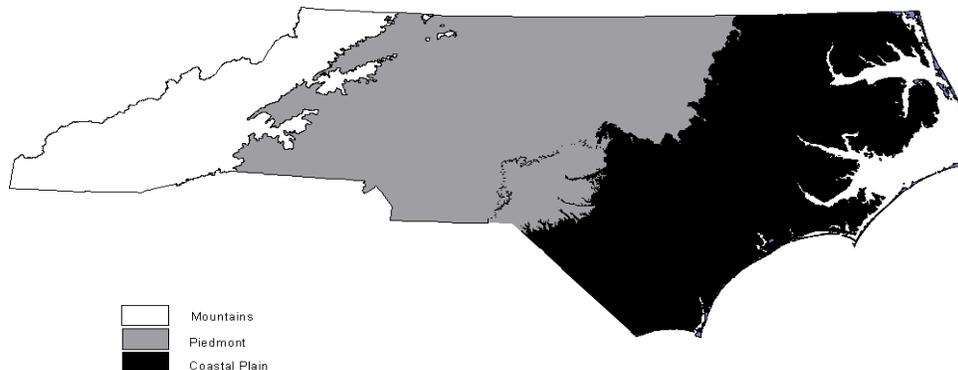
In unstressed streams and rivers higher numbers of taxa would be collected and the fauna would contain many more intolerant taxa than stressed streams. In addition, the abundance of intolerant taxa will be much greater in this stream type. The reference condition is discussed in more detail in Section 6, Station Locations. Additional water quality assessment parameters, which are commonly collected, include water temperature ($^{\circ}\text{C}$), dissolved oxygen (DO), pH (units), and conductivity ($\mu\text{mhos}/\text{cm}^2$). Other water quality parameters may need to be collected, but on a case-by-case basis at the discretion of the applicant. For example, heavy metal samples may need to be collected from highly urbanized catchments, and nutrients from monitoring locations downstream of sewage treatment facilities or agricultural catchments. This type of monitoring protocol is particularly relevant during investigations of an entire watershed.

5. Ecoregions of North Carolina

Ecoregions are generally considered to be geographic regions of relative homogeneity in ecological systems or in relationships between organisms and their environment (Omernik and Gallant 1986). The climate, geology, and soil of an area determine the substrate, seasonal discharge, channel morphology, and chemical properties of the catchments (Bryce and Clarke 1996). These concepts have provided water quality managers with an ecological framework for effective management of aquatic ecosystems (Hughes and Larsen 1988, Hughes et. al. 1990). Descriptions of ecological conditions (i.e. taxa richness) are obtained from regional reference locations and are most applicable from reference catchments that are completely contained within an ecoregion. Although, it should be noted that streams, or stream segments may have characteristics atypical of an ecoregion.

Ecoregion delineation has been conducted at the national level (Omernik 1987) and within most States. North Carolina can be divided into three distinct physiographic areas based on topography, climate, and geology, soils and naturally occurring vegetation. These three areas are the mountains, piedmont and coastal plain (Figure 4). Bioclassification criteria have been developed for wadable, freshwater streams in these three major regions of North Carolina (NCEHNR 1997). Subregions within these major ecoregions in North Carolina do exist (i.e. Slate Belt, Triassic Basin, and Sandhills) and efforts have been initiated to delineate these regions (personal comm., J. Omernik). In addition, draft criteria are being developed to evaluate low-flow swamp streams in the coastal plain. It is recommended that all restoration-mitigation projects specify which ecoregion all monitoring locations are located within.

Figure 4. Major Ecoregions of North Carolina.



6. Sampling Design and Regulatory Guidelines

An important consideration should be how any mitigation project will affect downstream reaches or receiving catchments.

Sampling stations must be carefully selected to ensure habitat comparability between sites. Unless habitats between sampling stations are comparable, differences in community structure attributed to degraded habitat will be difficult to separate from those attributed to water quality degradation (Plafkin et. al. 1989). Monitoring locations should not be located immediately

downstream of point source discharges, storm drains or obvious non-point sources. Additionally, monitoring locations for restoration projects near the mouths of tributaries, which flow into larger streams, should be avoided, as these areas will have characteristics of the larger stream (Karr et. al. 1986).

a. Reference Reach

The reference condition establishes the basis for making comparisons and for detecting water quality impairment (Gibson 1996). Data collected from minimally impaired reference reaches will be used in restoration projects to establish the functional capacity of the stream and to denote benchmark, or representative, conditions. Reference reaches must be established upstream of each restoration reach. These data will be used to test the potential impact and recovery of the restoration reach. In addition, a regional reference reach also may need to be sampled. The regional reference reach essentially defines the best-case, least-impaired scenario for each mitigation project. Surveys at regional reference

locations should be conducted on a case-by-case basis. In many instances only Wetlands/401 Unit investigations will require the use of regional reference locations. These monitoring reaches are established in similar sized catchments. In other words, if the restoration is being conducted on a second order stream, then the regional reference data may need to be collected from another second order stream with similar attributes. Factors that need to be considered when selecting a regional reference reach include the following (from Gibson 1996):

- ❖ The entire catchment should be within the ecoregion of interest
- ❖ No upstream impoundments
- ❖ No known discharges (NPDES) or contaminants in place
- ❖ No known spills or other pollutant incidents
- ❖ Low human population density
- ❖ Low agricultural activity
- ❖ Low road and highway density
- ❖ Drainage area on public land
- ❖ Minimal non-point source problems

In some instances, data from a single regional reference reach can be used for several mitigation projects. Regional reference data are useful in investigations that are conducted in non-summer seasons to account for variability of taxa richness (especially EPT taxa).

b. Test Locations.

Test locations are those sites found within and below the restoration reach. One of these monitoring locations should be within the mitigation reach, preferably near the lower end of the reach. This monitoring site needs to be sampled

whenever possible within the existing channel prior to relocation and within the relocated channel during all subsequent surveys. In addition, a monitoring reach also may be established downstream of the mitigation reach. Data from this location may be used to assess recovery and/or changes in the biological integrity of the stream system following restoration. Again the collection of data from this location will be conducted on a case-by-case basis and may include only DWQ Wetlands/401 Unit investigations.

There may be exceptions to this general monitoring scheme that will be determined on a case-by-case basis. Final approval of the monitoring plans will be conducted by biologists with DWQ Wetlands Unit during the 401 Certification process. An important consideration should be how any mitigation project will affect downstream reaches or receiving catchments. Monitoring stations may need to be established in receiving streams to assess catchment-wide impacts.

Monitoring should be conducted prior to stream disturbance followed by at least three years of biological monitoring starting one year after the stream is restored. All samples need to be collected during similar seasonal periods each year of analysis. These requirements enable the monitoring investigation to adequately assess the recovery and recolonization of the aquatic community. However, it should be noted that in some instances, recovery of restored reaches may take longer than three years following disturbance. For example, restoration may include headwater reaches that would reduce recolonization potential from upstream refugia. In these instances success criteria will be reevaluated by DWQ Wetland/401 Unit biologists.

c. Regulatory Guidelines

The use of biological indicators are appropriate for all stream restoration projects. However, as a regulatory tool for determining ecological recovery, biological surveys will be recommended on a case-by-case basis for projects having linear feet measurements of greater than 500 and less than 1000 feet, and will be required for all projects that have more than 1000 linear feet of restoration. Monitoring plans may be required for restoration projects having 500 to 1000 linear feet in water supply watershed or catchments that have been given special designations such as High Quality or Outstanding Resource Waters. Biological

Benthic Macroinvertebrate samples will collected from all locations before disturbance and for at least three years following disturbance and will be required for all projects having 1000 linear feet or more of restoration.

monitoring will not be a mandatory requirement for projects having 500 or less linear feet. It should be noted that some physical monitoring of the substrate and riparian areas may be required on a case-by-case basis.

7. Collection Methods for Benthic Macroinvertebrates

Survey protocols, including sample collection and processing, as defined in this technical guide, mimic to a large degree, 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>). Excerpts from this document have been copied in this guide as they may apply to stream mitigation and restoration projects and a complete description of all collection techniques is included as Appendix 1. A partial list of biological supply companies is listed in Appendix 4. These companies can provide applicants with collecting equipment. Applicants are encouraged to regularly check the DWQ websites for changes in protocols as they are developed.

a. Large Streams and Rivers

Standard qualitative collection methods are recommended for surveys conducted in all wadable streams that are 3rd order or larger. Each sampling technique (kick net, etc) is described in detail in Appendix 1. 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 made 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.

b. Small Streams

Stream mitigation and restoration 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, it is recommended that an abbreviated collection technique is used. 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". It is recommended that all organisms are collected and processed during using this survey type. This collection method is referred to in this guidance as a Qual-4 technique. 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.

c. Swamp Streams

The swamp, or slowflowing stream, collection method utilizes a variety of collection techniques to inventory the macroinvertebrate fauna at a site. A total of nine sweep samples (one series of three by each of the field team) are collected from each of the following habitat types: macrophytes, root mats/undercut banks, and detritus deposits. If one of these habitat types is not present, a sweep from one of the other habitats should be substituted. A sweep for the swamp method is defined as the area that can be reached from a given standing location. Three log/debris washes also are collected. Visual collections are the final method used at each location.

Samples are picked on site as described for the collection methods. The primary output for this collection technique is a taxa list with a relative abundance (Rare, Common or Abundant) for each taxon. DWQ biologists are in the process of refining the metrics for evaluating swamp streams.

d. Stream Ordering

Stream ordering is a method used to establish the natural hierarchy of stream channels. The Strahler method (1957) is perhaps the most popular method (Figure 5). In this method headwater channels are designated as first order down to their first confluence. A second order stream is formed by the confluence of two first order streams. A third order stream is formed by the confluence of two second order streams and so. The confluence of a channel with another channel of lower order does not raise the order of the stream below the confluence. Knowing what order a stream is can provide clues concerning relative channel size and depth

(US EPA 1998). For mitigation purposes it is recommended that only solid blue lines be used to assign stream order.

Figure 5. Stream Ordering Process

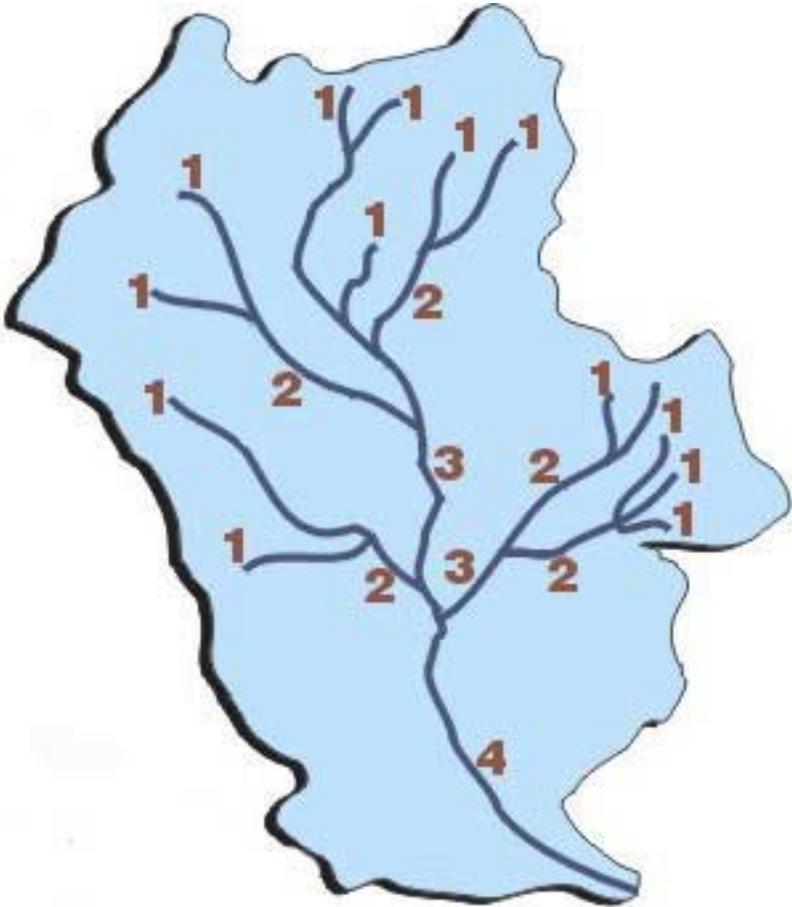
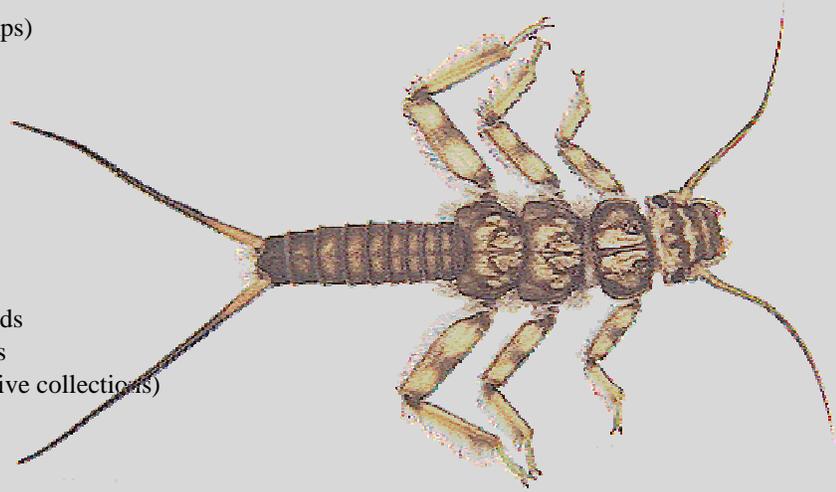


Table 1. Field Equipment needed for Benthic Macroinvertebrate Collections (see Appendix 1 for collecting procedures).

- Kick nets (riffles)
- Sweep nets (banks, swamps)
- Sand bag sampler
- Wash tub
- Sieve buckets
- Plastic picking trays
- 6 dram vials
- Collection containers
- Alcohol (95% ethanol)
- Forceps
- Labels and Collection cards
- Habitat Assessment forms
- Surber sampler (quantitative collections)
- Camera
- GPS unit
- First Aid Kit
- Cell Phone
- Waders
- Rain Gear



8. Qualitative and Quantitative Collection Methods.

The collection protocols described in the previous section that are used by biologists with DWQ are semi-qualitative methods. The results of these surveys are lists of taxa and relative abundance values (DWQ assigns Rare, Common and Abundant value to 1-2, 3-9 and 10 or more specimens, respectively). One of the primary objectives of semi-qualitative surveys is to make within or between site comparisons and to determine the presence or absence of benthic macroinvertebrate species with various tolerances to water pollution (Klemm et. al. 1990). When conducting these types of surveys, attempts are made to collect as many taxa as possible in an allotted time period and usually requires some experience to select the most productive habitat. A disadvantage of semi-qualitative methods

is that no information on standing crop or biomass can be generated.

Biologists with DWQ Wetlands/401 Unit have proposed, and will be testing, the use of quantitative collection methods as they apply to stream mitigation and restoration projects. Quantitative methods essentially provide an estimation of the numbers or biomass of the benthic macroinvertebrate community per unit area (Klemm et. al. 1990). Quantitative data are obtained by using collection devices that sample a unit area. Surber samplers are a popular quantitative collection device. Major considerations when conducting this type of survey are how many samples should be collected to accurately estimate population structure (the number of samples will vary with stream size) and which habitat to sample.

9. Sample Processing

DWQ protocols for processing benthic macroinvertebrate samples are discussed in the Standard Operating Procedures manual (NCEHNR 1997). Benthic macroinvertebrate samples collected by DWQ biologists are “picked” and preserved in the field. It is not necessary to know the total number of organisms from a specific habitat type when qualitative or semi-qualitative samples are collected. It is only necessary to know if those taxa are present and if they are rare, common or abundant. Specimens are “picked” from the sample and preserved in 6 dram vials using 95% ethanol. Larger organisms (dragonflies, crayfish, Megaloptera) are preserved in larger containers. Standard qualitative collection methods will take approximately 1 ½ to 2 hours for a team of three biologists to collect and Qual-4 collection methods will

take approximately one hour per site. Field processing samples in this fashion minimizes laboratory processing.

Quantitative samples, such as Surber samples, must be processed in the laboratory. The entire sample, including organic debris and particulate material, are preserved in the field using 95% ethanol. All organisms are picked from this type of sample and identified and counted.

Appropriate sample labeling protocols should be consistent between surveys. Labels should contain information regarding stream name and location, date, sample number, collectors. In addition, habitat data and chemical information should be recorded at each location.

10. EPT (Ephemeroptera, Plecoptera and Trichoptera)

Perhaps one of the most widely accepted biological metrics used to assess the integrity of streams and rivers is EPT. This metric is, quite simply, the total number of mayflies (or Ephemeroptera) plus stoneflies (or Plecoptera) and caddisflies (or Trichoptera) collected during a survey. The use of the EPT metric was described in the EPA Rapid



Figure 6. Mayfly

Bioassessment Protocol (Plafkin et. al. 1989) and recently endorsed by Wallace et. al. (1996). Wallace noted that the EPT metric was easy to use, it was stable at reference locations and it effectively tracked changes in water quality. The EPT metric had its origin in nonpoint studies conducted in North Carolina in the late 1970's (Penrose et. al. 1980). However, recognition of many

EPT taxa as intolerant to the effects of water pollution was reported much earlier (Gaufin and Tarzwell 1952). During this period, investigations started to classify organisms as tolerant, facultative or intolerant (Surber 1953, Beck 1953, Weber 1973) and eventually lead to the use of biotic indices (Chutter 1972 and Hilsenhoff 1977).



Figure 7. Stonefly

The use of EPT taxa as a metric for assessing the effectiveness of stream restoration-mitigation projects is described in this report. In addition, case studies are included which describe the use of the EPT metric.



Figure 8. Caddisfly

11. Seasonality

The ideal sampling procedure is to conduct surveys during each change of season (Gibson 1996). This sampling scheme ensures that ecological disturbance will be monitored and trends in community structure documented. However, benthic macroinvertebrates do integrate the effects of stress over the entire year and monitoring programs should be as cost effective as possible. Therefore, a single index period can be selected for biological monitoring programs as it applies to mitigation projects.

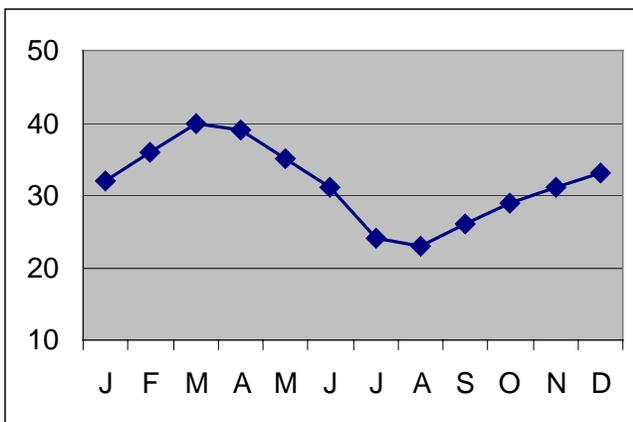


Figure 9. Hypothetical Seasonal Pattern of EPT

Population structures are seasonally variable within all biological communities. Peak emergence and reproduction are typically during the spring and fall time periods for most benthic macroinvertebrate communities and is due to the abundance of food supply during these two periods (Cummins and Klug 1979). Thus one would expect to collect more taxa during the spring and fall from stream sites than

during winter and summer collection periods (Figure 9). DWQ classification criteria for benthic macroinvertebrates were developed using data primarily from summer (worst-case conditions) collection periods. Restoration investigations should be conducted during summer periods. However, if this is not practical, seasonal consistency needs to be maintained. Samples should be collected in similar seasons (months) for the entire monitoring period for each stream restoration program.

It is recommended that benthic macroinvertebrate samples be collected during the summer (June – September) for mitigation projects in the mountain and piedmont (including the Sand Hills) ecoregions. Information collected from these projects can then be compared to data in the DWQ benthos database, where appropriate. However DWQ classification criteria have not yet been proposed for small streams. In addition, it is also recommended that benthic macroinvertebrate samples be collected during the winter (January - March) for mitigation projects in coastal plain swamp streams (including Triassic Basin streams). Benthic macroinvertebrate survey work conducted by DWQ suggests that the winter time period is optimal to detect water quality perturbations from swamp streams and data from summer surveys are difficult to interpret.

12. Taxonomic Considerations

Taxonomic identifications should be conducted to the lowest possible level and should be consistent throughout the survey period. Although family level taxonomy is often sufficient for determinations of non-impaired, moderately-impaired or

Accurate genus/species level taxonomic identification is essential to assess recovery of these lotic communities.

severely-impaired water quality conditions, subtle differences in community composition will not be determined except by genus/species identification (Resh and Unzicker 1975, Klemm et. al. 1990). It is anticipated that recovery (primary succession) of the benthic macroinvertebrate fauna within restored reaches will be subtle.

Accurate genus/species level taxonomic identification is essential to assess recovery of these lotic communities. Recovery following disturbance can be complete within a relatively short period of time (Yount and Niemi 1990). However, this will be dependent upon the accessibility of unaffected upstream and internal refugia, which serve as sources of organisms for repopulating.

Investigations have shown that the use of family level taxonomy had limited utility as a water pollution assessment tool. When DWQ data were back-identified to family level taxonomy versus genus/species levels results indicated that family level misclassified approximately 40% of the excellent monitoring locations. Similarly family level data did not identify trends at about 30% of the fixed sites at which trends were found (Lenat and Resh, in preparation). In addition, many taxonomic families have wide ranges of tolerance (i.e. Hydropsychidae, Chironomidae).

All identifications should be made using the most up-to-date, regional taxonomic keys. A list of taxonomic keys for the United States has been included in the revised Rapid Bioassessment Protocols document (Barbour et. al. 1999). Most organisms may be identified using only a dissection microscope, but Oligochaeta and Chironomidae must be slide mounted and identified with a compound microscope. As organisms are identified, the individuals in each taxonomic unit are counted and recorded on bench sheets.

The North American Benthological Society (web site, www.benthos.org) maintains a list of specialists for most invertebrate groups.

13. Data Analyses and Metrics

a. Standard Qualitative Metrics

Analytical methods and metrics used by DWQ in the biological monitoring programs are described in the Standard Operating Procedures (NCEHNR 1997). This document also is available for review on the DWQ website (<http://www.esb.enr.state.nc.us/BAU.html>). Applicants are encouraged to regularly check the DWQ websites for changes in protocols as they are developed.

Several data-analysis summaries (metrics) are used from standard qualitative (semi-qualitative) samples to detect water quality problems. These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index. Recall that standard qualitative samples are only collected during stream mitigation projects from 3rd order streams that have drainage areas of 1 square mile or more. Calculation of bioclassifications are not required as part of this procedure.

b. Qual-4 Metrics

Qual-4 collection methods are recommended for small streams, which have catchments of one square mile, or less (1st and 2nd order streams). All taxa should be picked and identified, rather than just EPT taxa, during this type of survey. The primary output for this sampling method will be a taxa list with an

indication of relative abundance (Rare, Common, Abundant) for each taxon. The calculation of metrics from a Qual-4 method is similar to those conducted for a standard qualitative collection method. These metrics include total and EPT taxa richness, EPT abundance and biotic index values. Currently, DWQ does not have classification criteria for small streams. Therefore applicants are not required to calculate bioclassification ratings of these stream systems.

c. Swamp Metrics

Classification criteria used to assess swamp streams are being developed by DWQ. Investigations have been conducted in swamp streams to determine the natural variability of least impacted catchments. The macroinvertebrate data collected during these studies indicated that although swamp streams are subject to natural stresses, their macroinvertebrate communities can be affected by anthropogenic related impacts. It is recommended that applicants use the NC Biotic Index to assess restoration projects in swamp streams. However, methods to determine impacts are being developed. Applicants are encouraged to regularly check the DWQ websites for changes in protocols as they are developed. In addition, field and laboratory methods and metrics testing also were conducted during a study of low-gradient, non-tidal streams mid-Atlantic coastal plain (US EPA 1997). This study established standard procedures for collecting and quantifying biological and physical habitat data from low-gradient, nontidal coastal plain streams. These protocols offer applicants additional information for assessing swamp streams.

d. Quantitative Metrics

Data from quantitative samples can be used to obtain many metrics that cannot be accurately calculated using qualitative or semi-qualitative collection methods. In addition, data collected from this type of sample can be analyzed using a suite of statistical evaluation techniques (Klemm et. al. 1990). These metrics and statistical techniques include among many others, total standing crop of individuals (i.e. # of individuals / square meters), biotic index values, biomass estimates or species (taxa) diversity (Shannon and Weaver 1963). The application of these metrics to stream restoration projects will be tested by biologists with DWQ prior to being recommended as an assessment tool.

e. Pebble Counts

An inventory or assessment of channel materials is essential to understanding the biological function of a stream. Excessive levels of fine sediments will fill interstitial spaces between streambed particles and reduce the intergravel flow of oxygen. Excessive levels of fine sediments will thereby reduce the biological productivity of streams including the abundance of benthic macroinvertebrates. The pebble count method of sampling channel bed materials has been widely used in

geomorphic studies. This method was initially proposed by Wolman (1954), and has been advocated for impact assessment by others (Kondolf 1997 and Rosgen 1996). A quantitative description of the bed material (pebble counts) and the association of this material (dominant and average particle size) to the benthic macroinvertebrate community will give regulators an additional tool to assess the recovery of restoration projects and to use to correlate to the benthic macroinvertebrate data. Comparisons of pebble count data from reference reaches can be used to determine, with statistical reliability, if there has been a shift to finer sized material or if there has been a change over time.

Methods for conducting pebble counts have been recently described in Rosgen (1996), Kondolf (1997) and Harrelson et. al. (1994). Pebble counting techniques are used when conducting Rosgen Level II stream classification analyses. This technique uses a modified sampling method which is based on the frequency of pools/riffles occurring within a channel reach that is approximately 20-30 bankfull widths in length. This method selects the sampling locations based on bed features proportionally along the stream reach. Pebble count data are plotted on a log-normal graph as a cumulative percent.

14. Data Quality Objectives

In order to ensure that all biological data collected during stream restoration projects are of a known quality, DWQ Wetlands/401 Unit has established specific requirements for the development of a quality assurance plan. A current list (Spring 2000) of certified laboratories is included in this document as Appendix 3. An updated list is available on the Wetlands/401 web site (<http://h2o.enr.state.nc.us/ncwetlands/>).

Taxonomic identification and specimen verification are critical data quality objectives (Plafkin et. al. 1989, US EPA 1995). A general guide is that all specimens be identified to the lowest possible taxonomic level using the most current literature available. In most instances this level should be genus or species level of identification. If there are concerns as to which level is appropriate for identification, DWQ's master species list (NCEHNR 1997) or the biological certification requirements should be consulted. Verification of questionable taxa can be accomplished by comparison with established reference collections or

expert opinion. The North American Benthological Society (web site, www.benthos.org) maintains a list of specialists for most invertebrate groups.

DWQ Wetlands/401 Unit recommends that one sample of six samples collected be reidentified by other taxonomists within each laboratory and that results of these analyses be included as part of the written report summarizing the data. Accuracy or comparability rates between taxonomists need to be greater than 90% during these quality control audits. In instances where only one taxonomist is conducting benthic macroinvertebrate identifications, one sample of six samples collected must be reidentified by subcontractors or by DWQ Wetlands/401 Unit biologists. These results also are included in the written report. During the recertification process each laboratory must identify a standard collection of taxa (25-30 specimens). Accuracy rates must be in excess of 90% to genus/species level of identification or to the lowest practical taxonomic level.

15. Report Writing Considerations

Reports summarizing survey results shall be submitted to DWQ/Wetlands Unit within 60 days following survey completion. Each report should summarize all data collected to date, including between-year changes in the data and results of performance audits. Accurate maps should be included with the report illustrating station location with respect to the restoration reach. Each

summary report shall contain a list of all taxa collected from each collection location and all summary statistics (taxa richness, abundance, biotic index values and pebble counts). In addition, attempts should be made to discuss changes in community structure with respect to status of the project, changes in water quality or stream flow between years.

16. Case Studies

a. Upper Whitehurst Creek (Beaufort Co., NC)

Benthic macroinvertebrates and fish were collected from two monitoring sites in Upper Whitehurst Creek as part of a stream relocation project (CZR Inc. 1999). PCS Phosphate rerouted a large section of the stream due to the advancement of mining in the area during 1992/1993. Baseline samples were collected prior to relocation of the stream in 1992 and following mitigation in winters and summers of 1993 to 1997. Due to the rerouting of the mitigation channel, the downstream monitoring location was moved in February 1996 and is now located within the new portion of the channel.

Whitehurst Creek is a large tributary of South Creek in Beaufort County, North Carolina. The headwater reaches of this catchment are channelized and drain agricultural land. Most of the riparian canopy has been removed as part of the site preparation process. The substrate of Whitehurst Creek is very silty, with prolific macrophyte growths during growing seasons and flow is restricted to very short sections between long non-flowing reaches. Numerous tributary side channels and ditches flow into this reach of the stream. Benthic macroinvertebrate samples were collected using methods described in the DWQ Standard Operating Procedures manual for coastal plain and swamp streams (NCEHNR 1997). This method essentially consists of collecting 9 bank sweeps from common habitat types, three epifaunal samples and conducting visual inspections.

In its 1998 mitigation report to PCS Phosphate, CZR Incorporated noted that 57% of the benthic macroinvertebrates collected during the 1992 baseline survey have been documented within the mitigation channel. In addition, 114 benthic macroinvertebrate taxa not initially found in the 1992 survey have been collected from the upper Whitehurst Creek mitigation channel in the six years since its construction. It is evident that water quality conditions in Whitehurst Creek are stressed and variability of taxa richness was seen at Station 1 which is located above the mitigation reach. Altered channel morphology and land use, lack of riparian zone characteristics and water quality conditions (mean conductivity in 1998 = 360 μ mhos, DO = 2.8 mg/l in September) have impacted the biological integrity of this system. The benthic macroinvertebrate fauna is dominated by tolerant taxa such as



Figure 8. Upper Whitehurst Creek, Beaufort County

chironomids (esp. Procladius), pulmonate snails (i.e. Physella), and a tolerant mayfly (Caenis) each year of analysis. However, representative taxa from each of ten common benthic macroinvertebrate groups have been found recolonizing the upper Whitehurst Creek mitigation channel. Data from all surveys are summarized in the 1998 mitigation report.

b. Reed Creek (Buncombe Co., NC)

Reed Creek was selected as a mitigation stream for the US 74 widening project in Buncombe County (NC DOT 1999). A 1300-foot reach of Reed Creek in Weaver Park in Asheville was selected for restoration including bank stabilization and re-vegetation. A primary goal of the project is to improve water quality conditions of Reed Creek below the project by reducing sediment, turbidity and thermal impacts. All stream restoration work was completed in March 1998.



Figure 9. Reed Creek, Buncombe County

Benthic macroinvertebrate samples were collected from a single location within the mitigation reach prior to construction (January 1998) and seven months after

construction (October 1998). Qualitative samples were collected using DWQ protocols (NCEHNR 1997) and, in addition, quantitative samples also were collected using Surber samples from the same location. Three Surber samples (3.0 ft² or 0.28 m²) were collected from riffle habitats within the collection area.

Elevated concentrations of several water quality parameters, including phosphorus and nitrogen compounds, have been collected from Reed Creek (Maas 1998). These concentrations resulted in prolific growths of filamentous algae (Spirogyra sp.) during the October survey and have likely affected the structure of the benthic macroinvertebrate fauna. Results of these two investigations found that the benthic fauna was comprised of taxa tolerant to the effects of enrichment. Organisms such as filter-feeding caddisflies (Hydropsyche betteni and Symphitopsyche sparna), Oligochaetes (primarily Lumbriculidae), tolerant chironomidae, and a pulmonate snail (Physella) were dominant.

Table 2 compares the data collected from each survey using Surber and qualitative collection techniques. The total number of taxa were less in each of the Surber samples, probably reflecting the loss of edge species or those organisms not commonly collected in the riffle habitats. EPT abundance samples were very dissimilar using the Surber sampler between surveys possibly reflected the loss of habitat or water quality conditions in October, compared to the EPT abundance data using the qualitative collection methods. Additionally, note the increase in species diversity in October. This increase is possibly due to the increase in numbers of Diptera associated with the increase in filamentous algae.

The data collected from Reed Creek should be considered preliminary and there are seasonal differences in the community structure. Post-restoration samples will be collected for 4 years. In order to adequately assess the effects of this restoration project benthic macroinvertebrate data also should have been collected from a monitoring location above the mitigation reach.

Table 2. Benthic Macroinvertebrates collected from Reed Creek, 1998

| | January 1998 (<i>before restoration</i>) | | October 1998(<i>after restoration</i>) | |
|---------------------|--|-------------|--|-------------|
| | Surber | Qualitative | Surber | Qualitative |
| Total Taxa Richness | 7 | 12 | 10 | 14 |
| EPT Taxa Richness | 2 | 3 | 2 | 2 |
| EPT Abundance* | 92 | 21 | 38 | 20 |
| Shannon Diversity | | | | |

*Abundance values are based on the number of specimens collected with Surbers and are subjective (1, 3, 10 for rare, common and abundant) for qualitative samples.

17. Summary and Recommendations

This document presents some basic concepts as they apply to the use of biological monitoring techniques for stream restoration/mitigation projects in North Carolina. Such concepts as river continuum, ecoregions in North Carolina, recolonization of instream habitats, and the general effects of water pollution to benthic macroinvertebrates were briefly discussed. This document then discusses monitoring protocols that need to be followed by applicants conducting restoration/mitigation projects. These protocols include selection of monitoring locations, sample collection procedures and analytical methods. Finally, this report briefly discusses data quality objectives and report writing considerations for these projects.

Monitoring Locations. It is required that monitoring locations be established above, and within the relocation reach. In addition, data also may be collected from a monitoring location below the restoration reach and at a regional reference location with similar catchment characteristics. Data from the regional reference location establishes best-case, least-impaired scenario for each mitigation project. DWQ Wetlands/401 Unit recommends that data be collected from each monitoring reach prior to disturbance and for three years following disturbance starting one year after the stream is restored. Samples need to be collected during similar seasons and flow regimes each year of analysis.

Regulatory Guidelines. The use of benthic macroinvertebrates will be used on a case-by-case basis for projects having linear feet measurements of greater than 500 and

less than 1000 feet (such as water supply watersheds or High Quality or Outstanding Resource Waters), and will be required for all projects that have more than 1000 linear feet of restoration. Biological monitoring will not be a mandatory requirement for projects having 500 or less linear feet. However, it should be noted that physical monitoring of the substrate and riparian zones will be required. At this point, these protocols will not be used to determine the success or failure of the restoration project. However, these protocols will be used by regulatory agencies to determine the ecological functions or recovery of these streams reaches.

Collection Methods. Standard qualitative samples will be collected from mountain and piedmont streams having catchments of at least one square mile and are 3rd order or larger. Protocols in this document for this collection technique should be followed, including sample collection and data interpretation. A list of all taxa collected, taxa richness values (total and EPT), EPT abundance and biotic index values should be given for each sample collected. The Qual-4 collection method be used to collect samples from small mountain or piedmont streams having a catchment size of less than one square mile and are 1st or 2nd order streams. All taxa are collected and analyzed. A list of all taxa collected, taxa richness values (total and EPT), EPT abundance and biotic index values should be given for each sample collected using this method. Streams within the Sandhills ecoregion should be considered most similar to Piedmont streams and protocols for data collection and interpretation are similar.

It is also recommended that DWQ swamp sampling methods be followed when conducting surveys in low-gradient, nontidal coastal plain streams. This includes sample collection (winter surveys) and analytical procedures. It is recognized by DWQ that metrics are being developed for these stream systems. Streams within the Triassic Basin ecoregion also stop flowing for part of the year. Therefore, sample program from streams within this ecoregion should be conducted during winter months.

At the current time only DWQ protocols should be followed and only qualitative samples be collected and processed. However, DWQ Wetlands/401 Unit biologists will be conducting field surveys which will compare qualitative collections with quantitative collections (Surber samplers). Results of these comparisons will be incorporated in future editions of this guidance manual.

Taxonomic Considerations and Choice of Metrics. Taxonomic identifications should be conducted to the lowest practical level and be consistent throughout the survey period.

The diversity of the benthic macroinvertebrate fauna is evaluated using taxa richness counts (total and EPT) and biotic index values are used to determine community tolerance ranges. Lists of taxa for each project and survey should include relative abundance values and discussions of trends in the data.

Data Quality Objectives and Report Writing Considerations. It should be emphasized that collection and processing of biological samples should be conducted by experienced biologists familiar with stream ecology. DWQ Wetlands/401 Unit recommends that one of six samples collected be reidentified by other taxonomists within each laboratory and that results of the analyses be included as part of the written report summarizing the data. Data summaries shall be submitted to DWQ/Wetlands Unit within 60 days following survey completion. Each report shall contain a list of all taxa collected from each location and all summary statistics (taxa richness, abundance, biotic index values and results of pebble counts). In addition, attempts should be made to discuss changes in community structure with respect to status of the project, changes in water quality or stream flow between years.

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APPENDIX 1. SAMPLING TECHNIQUES FOR BENTHIC MACROINVERTEBRATES.

Kick Net. A kick net is an easily constructed and versatile sampling device. It consists of a double layer of flexible nylon door or window screening between two poles. The screening is reinforced with denim along the edges and has lead weights sewn into the bottom edge.

The net is positioned upright on the stream bed, while the area upstream is physically disrupted. The debris and organisms in the kick net are then washed down into a sieve bucket with a US Standard No. 30 mesh (0.600 mm opening) bottom, and larger leaves and debris are removed. Many investigators have found that this simple technique gives very consistent results (Hornig and Pollard 1978, Armitage 1978). If too coarse a mesh is used for the kick net, many animals will not be retained. If too fine a mesh is employed, the net clogs easily and washout becomes a problem.

Two kicks are taken from riffle areas. The two samples should be collected from areas of differing current speed. In very small streams, or in sandy areas lacking riffles, kicks should be taken from root masses, "snags", or bank areas. All types of benthic macroinvertebrates can be collected by this sampling device, but emphasis is placed on Ephemeroptera, Plecoptera and Trichoptera.

Sweep Net. A long-handled triangular sweep net is another versatile sampling device. Three samples are taken by physically disrupting an area and then vigorously sweeping through the disturbed area. Sweeps are usually taken from bank areas, including mud banks and root masses, and macrophyte beds. Bank samples are particularly important for the collection of "edge" species which prefer low current environments. Look for Chironomina (red chironomids), Oligochaeta, Odonata, mobile cased Trichoptera, Sialis, Crustacea, and certain Ephemeroptera. A sweep net also can be used to sample gravel riffle areas where stone-cased Trichoptera may be abundant.

Fine-Mesh Sampler. Since the kick and sweep nets utilize a relatively coarse mesh size, an alternate sampling technique was devised to sample the smaller invertebrates (especially the Chironomidae). The resulting sampler is known as a "chironomid-getter". A cylinder is cut from four inch PVC pipe. Fine nitex mesh (300 microns) is placed between PVC pipe fittings that are designed to screw together. The exact dimensions are not critical, but the cylinder should fit inside another container, usually a one quart plastic container. This device can be used in a variety of ways.

The simplest technique is to wash down rocks or logs in a large plastic tub partially filled with water. Rocks are selected which have visible growths of periphyton, Podostemum, or moss. Any large particulate material (leaves, etc.) is washed down and discarded. A single composite sample can be made from several rocks and/or logs. The material remaining in the basin is poured through the fine mesh sampler and the water allowed to drain out completely. The residue is preserved in 95% ethanol. This is accomplished by placing the fine mesh sampler into another container which is half filled with alcohol. The sample is allowed to sit for several minutes and then backwashed into a picking tray. Note that this method of field preservation

requires only a small amount of alcohol, and it may be reused several times. Usually 2-3 of the fine mesh samplers are used, so that one may be soaking while another is being picked.

Field preservation makes small chironomids and oligochaetes more visible, and easier to pick up with forceps. This technique is also good for Baetidae, Hydroptilidae and other grazers. The "pour-and-preserve" technique also can be used in conjunction with other sampling methods. For example, the elutriate from a kick or sweep sample can be processed in this manner. It is also used in conjunction with sand samples (see below).

Sand Samples. Sandy habitats often contain a distinct fauna, but extraction of this fauna by means of dredge-type sampling can be tedious. Sandy substrates (in areas with definite flow, if possible) are sampled with a large bag constructed of fine mesh (200 microns) Nitex netting. It can be quickly constructed from a one meter square piece of netting, folded in half and sewn together on the opposite side and the bottom. This bag is employed like a Surber sampler, but the lack of a rigid frame allows for easy storage when folded.

The bag is held (open) near the substrate, and the sand is vigorously disturbed by the collector's hands or feet. The material collected (a lot of sand and a few organisms) is emptied into a large plastic container half-filled with water. A "stir and pour" elutriation technique is used in conjunction with the fine mesh sampler. After field preservation, the elutriate is picked, looking especially for Chironomidae (*Rheosmittia*, *Harnischia* group, *Polypedilum* spp.), Oligochaeta, Gomphidae, and Baetidae. The remaining sand can be picked quickly for large or heavy organisms.

Leaf-Pack Samples. Leaf-packs, sticks and small logs are washed down in a seive bucket with a U.S. Standard No. 30 seive (0.600 mm openings) bottom, and then discarded. Generally, three to four leaf packs are collected from rocks or snags in fast current areas. The best leaf packs consist of older leaves (not freshly fallen) that have begun to decay. Piles of leaves in pool areas should not be collected. Leaf-pack and small log samples are particularly useful in large sandy rivers. In such habitats, many of the species are confined to "snags" (Benke et. al. 1984, Neuswanger et. al. 1982). Look for "shredders", especially Tipulidae, Plecoptera, and Trichoptera.

Visual Search. Visual inspection of large rocks and logs (the larger, the better) often adds to the species list. Large rocks and logs are a preferred microhabitat because of their stability during floods. Always look in a number of different areas (not just riffles). Rocks and logs in pools often yield additional species, as this habitat is not well sampled by either kicks or sweeps.

The top of rocks is a specialized microhabitat with a number of characteristic taxa. Both *Psychomyia* and *Petrophila* build retreats on the top of rocks. These are often made more visible by lightly washing off any silt which has accumulated on the top of the rock. Decaying logs should be picked apart to look for chironomids, and many taxa can be found under loose bark. Rocks near the shore (in negligible current) will harbor certain Ephemeroptera, and leaves near the shore may be the primary habitat for some Gastropoda.

Certain caddisflies (*Nyctiophylax* and related genera) select crevices in rocks or logs, often along the edge, and cover them over with silk strands. The silk becomes covered with silt and

periphyton and is hard to see. There is usually a faint opening on each end of this retreat. If the tip of forceps is inserted into one opening, the larvae usually will come out the other opening. Microcaddisflies make small (2-4 millimeters) cases found attached to rocks and logs, usually on the top or along an edge. Polycentropodid caddisflies build funnel-shaped silken retreats (up to six inches in length) in areas of relatively slow current. Out of water, the case collapses and resembles a gelatinous brown glob. The larvae will often crawl out if left out of the water for several minutes. It's a good idea to recheck some logs during visuals for these caddisflies. In sandy coastal plain rivers, look for a log out in the current, with some portion raised above the substrate. This is a good place to look for hydropsychids and other filter-feeders. The net may be the only visible evidence of these organisms, and they must be dug out of their retreats with forceps. Aquatic macrophytes and sponges are other habitats to be closely examined. Mussel species can be obtained by careful visual inspection of the bottom. A mussel search should be conducted if dead shells are evident along the shore; look for midden heaps resulting from the feeding of muskrats and other vertebrates. However, only live specimens should be added to the species list. During periods of receding water levels, many species will move to deeper water, leaving a visible "track". The bases of aquatic weeds (especially water willow) may contain many mussel species and must be searched by hand. If possible, mussels should be identified in the field and returned (alive) to the stream. Approximately 10 minutes is allocated for these visual searches. In general, look for attached cases of Trichoptera, for Turbellaria (flatworms), Coleoptera (beetles), Odonata (dragonflies, especially on large logs), Gastropoda (snails), Hirudinea (leeches) and Megaloptera.

APPENDIX 2. HABITAT ASSESSMENT FORMS: MOUNTAIN/PIEDMONT AND COASTAL PLAIN.

**Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams**

Directions for use of this Assessment: The observer is to survey a minimum of 100 meters of stream, preferably in an upstream direction starting above the bridge pool and the road right-of-way. The stream segment which is assessed should represent average stream conditions. In order to perform a proper habitat evaluation the observer needs to get into the stream. All meter readings need to be performed prior to walking the stream. When working the habitat index, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. There are eight different metrics in this index and a final habitat score is determined by adding the results from the different metrics.

Stream _____ Location/Road _____ County _____

Date _____ CC# _____ Basin _____ Subbasin _____

Observer(s) _____ Office Location _____ Agency _____

Type of Study: Fish Benthos Basinwide Special Study (Describe) _____

Latitude _____ Longitude _____ Ecoregion (circle one) MT P Distance Surveyed _____ meters

Physical Characterization: Land use refers to immediate area that you can see from sampling location - include what you see driving thru the watershed in the remarks section. Also use the remarks section for such descriptions as "deeply incised" or "exposed bedrock" or other unusual conditions.

Land use: Forest _____% Active Pasture _____% Active Crops _____% Fallow Fields _____% Commercial _____%
Industrial _____% Residential _____% Other _____% - Describe _____

Width: (meters) Stream _____ Channel _____ Average Stream Depth: (m) _____ Velocity _____ m/sec

Flow conditions (circle one): High Normal Low

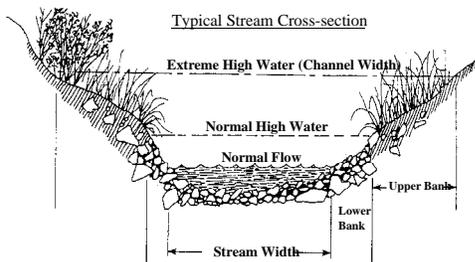
Manmade Stabilization: Y[] N[] Describe _____

Water Quality: Temperature _____ °C Dissolved Oxygen _____ mg/l Conductivity _____ μmhos/cm pH _____

Turbidity: (circle) Clear Slightly Turbid Turbid Tannic

Weather Conditions: _____ Photo # _____

Remarks: _____



| | |
|---|--------------|
| I. Channel Modification (Use Topo map as an additional aid for this parameter) | <u>Score</u> |
| A. channel natural, frequent bends (good diversity of bends or falls)..... | 5 |
| B. channel natural, infrequent bends..... | 4 |
| C. some channelization present..... | 3 |
| D. more extensive channelization, >40% of stream disrupted..... | 2 |
| E. no bends, completely channelized or rip rapped or gabioned, etc..... | 0 |

Remarks _____ Subtotal _____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. Circle the habitats which occur- (Rocks) (Macrophytes) (sticks and leaf packs) (snags and logs) (undercut banks or root mats) Definition: leafpacks consist of older leaves that are packed together and have begun to decay. Piles of leaves in pool areas are not considered leaf packs. EXAMPLE: If >70% of the reach is rocks, 1 type is present, circle the score of 17.

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

| | >70% | 40-70% | 20-40% | <20% |
|---------------------------|--------------|--------------|--------------|--------------|
| | <u>Score</u> | <u>Score</u> | <u>Score</u> | <u>Score</u> |
| 4 or 5 types present..... | 20 | 16 | 12 | 8 |
| 3 types present..... | 19 | 15 | 11 | 7 |
| 2 types present..... | 18 | 14 | 10 | 6 |
| 1 type present..... | 17 | 13 | 9 | 5 |
| No types present..... | | | | |

Remarks _____ Subtotal _____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) look at entire reach for substrate scoring, but only look at riffle for embeddedness.

| | |
|--|--------------|
| A. substrate with good mix of gravel cobble and boulders | <u>Score</u> |
| 1. embeddedness <20% (very little sand, usually only behind large boulders)..... | 15 |
| 2. embeddedness 20-40%..... | 12 |
| 3. embeddedness 40-80%..... | 8 |
| 4. embeddedness >80%..... | 3 |
| B. substrate gravel and cobble | |
| 1. embeddedness <20%..... | 14 |
| 2. embeddedness 20-40%..... | 11 |
| 3. embeddedness 40-80%..... | 6 |
| 4. embeddedness >80%..... | 2 |
| C. substrate mostly gravel | |
| 1. embeddedness <50%..... | 8 |
| 2. embeddedness >50%..... | 2 |
| D. substrate homogeneous | |
| 1. substrate nearly all bedrock..... | 3 |
| 2. substrate nearly all sand..... | 3 |
| 3. substrate nearly all detritus..... | 2 |
| 4. substrate nearly all silt/ clay..... | 1 |

Remarks _____ Subtotal _____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams.

| | |
|--|--------------|
| A. Pools present | <u>Score</u> |
| 1. Pools Frequent (>30% of 100m area surveyed) | |
| a. variety of pool sizes..... | 10 |
| b. pools same size..... | 8 |
| 2. Pools Infrequent (<30% of the 100m area surveyed) | |
| a. variety of pool sizes..... | 6 |
| b. pools same size..... | 4 |
| B. Pools absent | |
| 1. Runs present..... | 3 |
| 2. Runs absent..... | 0 |

Remarks _____ Page Total _____

V. Riffle Habitats

| | <u>Frequent</u> <u>Score</u> | <u>Infrequent</u> <u>Score</u> |
|---|---------------------------------|-----------------------------------|
| A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream.... | 16 | 12 |
| B. riffle as wide as stream but riffle length is not 2X stream width | 14 | 7 |
| C. riffle not as wide as stream and riffle length is not 2X stream width | 10 | 3 |
| D. riffles absent..... | 0 | |

Subtotal _____

VI. Bank Stability and Vegetation

| | <u>Left Bank</u> <u>Score</u> | <u>Right Bank</u> <u>Score</u> |
|---|----------------------------------|-----------------------------------|
| A. Banks stable | | |
| 1. no evidence of erosion or bank failure, little potential for erosion | 7 | 7 |
| B. Erosion areas present | | |
| 1. diverse trees, shrubs, grass; plants healthy with good root systems..... | 6 | 6 |
| 2. few trees or small trees and shrubs; vegetation appears generally healthy..... | 5 | 5 |
| 3. sparse vegetation; plant types and conditions suggest poorer soil binding..... | 3 | 3 |
| 4. mostly grasses, few if any trees and shrubs, high erosion and failure potential at high flow | 2 | 2 |
| 5. no bank vegetation, mass erosion and bank failure evident..... | 0 | 0 |
| | Total _____ | |

Remarks _____

VII. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

| | <u>Score</u> |
|---|--------------|
| A. Stream with good shading with some breaks for light penetration | 10 |
| B. Stream with full canopy - breaks for light penetration absent..... | 8 |
| C. Stream with partial shading - sunlight and shading are essentially equal..... | 7 |
| D. Stream with minimal shading - full sun in all but a few areas..... | 2 |
| E. No shading | 0 |

Remarks _____

VIII. Riparian Vegetative Zone Width

Definition: A break in the riparian zone is any area which allows sediment to enter the stream. Breaks refer to the near-stream portion of the riparian zone (banks); places where pollutants can directly enter the stream.

| | Right Bank <u>Score</u> | Left Bank <u>Score</u> |
|---|----------------------------|---------------------------|
| A. Riparian zone intact (no breaks) | | |
| 1. zone width > 18 meters..... | 5 | 5 |
| 2. zone width 12-18 meters..... | 4 | 4 |
| 3. zone width 6-12 meters..... | 3 | 3 |
| 4. zone width < 6 meters..... | 2 | 2 |
| B. Riparian zone not intact (breaks) | | |
| 1. breaks rare | | |
| a. zone width > 18 meters..... | 4 | 4 |
| b. zone width 12-18 meters..... | 3 | 3 |
| c. zone width 6-12 meters..... | 2 | 2 |
| d. zone width < 6 meters..... | 1 | 1 |
| 2. breaks common | | |
| a. zone width > 18 meters..... | 3 | 3 |
| b. zone width 12-18 meters..... | 2 | 2 |
| c. zone width 6-12 meters..... | 1 | 1 |
| d. zone width < 6 meters..... | 0 | 0 |

Remarks _____ Total _____

TOTAL SCORE _____

ADD COMMENTS, DRAWINGS:

**Habitat Assessment Field Data Sheet
Coastal Plain Streams**

Directions for use of this Assessment: The observer is to survey a minimum of 100 meters of stream, preferably in an upstream direction starting above the bridge pool and the road right-of-way. The stream segment which is assessed should represent average stream conditions. In order to perform a proper habitat evaluation the observer needs to get into the stream. All meter readings need to be performed prior to walking the stream. When working the habitat index, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. There are seven different metrics in this index and a final habitat score is determined by adding the results from the different metrics.

Stream _____ Location/Road _____ County _____ Date _____
 _____ CC# _____ Subbasin _____ Basin _____

Observer(s): _____ Office Location _____ Agency _____

Type of Study: Fish Benthos Basinwide Special Study (Describe) _____

Latitude _____ Longitude _____ Ecoregion (circle one) CA CB Swamp Distance Surveyed _____ meters

Physical Characterization: Land use refers to immediate area that you can see from sampling location - include what you see driving thru the watershed in the remarks section.

Land use: Forest _____% Active Pasture _____% Active Crops _____% Fallow Fields _____% Commercial _____%
 Industrial _____% Residential _____% Other _____%. Describe: _____

Width: (meters) Stream _____ Channel _____ Average Stream Depth: (m) _____ Velocity _____ m/sec

Flow conditions (circle one): High Normal Low

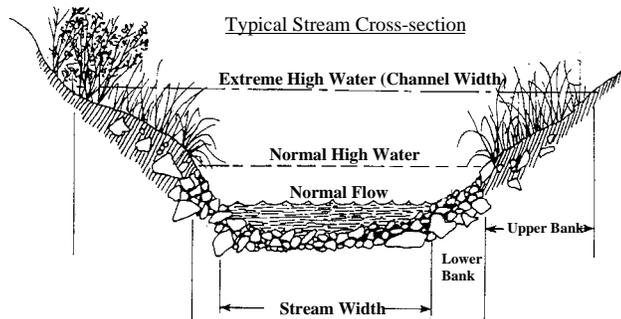
Manmade Stabilization: Y[] N[] Describe: _____

Water Quality: Temperature _____°C Dissolved Oxygen _____mg/l Conductivity _____µmhos/cm pH _____

Turbidity: (circle) Clear Slightly Turbid Turbid Tannic

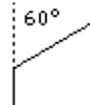
Weather Conditions: _____ **Photo #** _____

Remarks: _____



I. Channel Modification (Use topo map as an additional aid for this parameter)

| | Natural Channel | Modified Channel |
|---------------------|-----------------|------------------|
| A. Frequent bends | <u>Score</u> | <u>Score</u> |
| 1. bends > 60°..... | 15..... | 12 |
| 2. bends < 60°..... | 13..... | 10 |
| B. Infrequent bends | | |
| 1. bends > 60°..... | 11..... | 7 |
| 2. bends < 60°..... | 8..... | 5 |
| Remarks _____ | Subtotal _____ | |



II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover.

Circle the habitats which occur- **(Rocks) (Macrophytes) (sticks and leaf packs) (snags and logs) (undercut banks or root mats)** Definition: leafpacks consist of older leaves that are packed together and have begun to decay. Piles of leaves in pool areas are not considered leaf packs. EXAMPLE: If >70% of the reach is rocks, 1 type is present, circle the score of 17.

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

| | >50% | 30-50% | 10-30% | <10% |
|---------------------------|--------------|--------------|--------------|--------------|
| | <u>Score</u> | <u>Score</u> | <u>Score</u> | <u>Score</u> |
| 4 or 5 types present..... | 20 | 16 | 12 | 8 |
| 3 types present..... | 19 | 15 | 11 | 7 |
| 2 types present..... | 18 | 14 | 10 | 6 |
| 1 type present..... | 17 | 13 | 9 | 5 |
| No types present..... | 0 | | | |

Remarks _____ Subtotal _____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) look at entire reach for substrate scoring, but only look at riffle for embeddedness.

| | |
|---|---------------------|
| A. substrate types mixes | <u>Score</u> |
| 1. gravel/rock dominant..... | 15 |
| 2. sand dominant..... | 13 |
| 3. detritus dominant..... | 7 |
| 4. silt/clay dominant..... | 4 |
| B. substrate homogeneous | |
| 1. substrate nearly all gravel..... | 12 |
| 2. substrate nearly all sand..... | 7 |
| 3. substrate nearly all detritus..... | 4 |
| 4. substrate nearly all silt/ clay..... | 1 |

Remarks _____ Subtotal _____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams.

| | |
|--|--------------|
| A. Pools present | <u>Score</u> |
| 1. Pools Frequent (>30% of 100m area surveyed) | |
| a. variety of pool sizes..... | 10 |
| b.pools same size..... | 8 |
| 2. Pools Infrequent (<30% of the 100m area surveyed) | |
| a. variety of pool sizes..... | 6 |
| b.pools same size..... | 4 |
| B. Pools absent | |
| 1. Runs present..... | 3 |
| 2. Runs absent..... | 0 |
| Remarks _____ | Total _____ |

V. Bank Stability and Vegetation

| | | |
|---|------------------|-------------------|
| | <u>Left Bank</u> | <u>Right Bank</u> |
| A. Banks stable | | |
| 1. no evidence of erosion or bank failure, little potential for erosion | 10 | 10 |
| B. Erosion areas present | | |
| 1. diverse trees, shrubs, grass; plants healthy with good root systems..... | 9 | 9 |
| 2. few trees or small trees and shrubs; vegetation appears generally healthy..... | 7 | 7 |
| 3. sparse vegetation; plant types and conditions suggest poorer soil binding..... | 4 | 4 |
| 4. mostly grasses, few if any trees and shrubs, high erosion and failure potential at high flow | 2 | 2 |
| 5. no bank vegetation, mass erosion and bank failure evident..... | 0 | 0 |

Total _____

Remarks _____

VI. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

| | |
|--|--------------|
| | <u>Score</u> |
| A. Stream with good shading with some breaks for light penetration | 10 |
| B. Stream with full canopy - breaks for light penetration absent..... | 8 |
| C. Stream with partial shading - sunlight and shading are essentially equa..... | 7 |
| D. Stream with minimal shading - full sun in all but a few areas..... | 2 |
| E. No shading | 0 |

Remarks _____

VII. Riparian Vegetative Zone Width

Definition: A break in the riparian zone is any area which allows sediment to enter the stream. Breaks refer to the near-stream portion of the riparian zone (banks); places where pollutants can directly enter the stream.

| | Left Bank | Right Bank |
|---|-----------|------------|
| A. Riparian zone intact (no breaks) | | |
| 1. zone width > 18 meters..... | 5 | 5 |
| 2. zone width 12-18 meters..... | 4 | 4 |
| 3. zone width 6-12 meters..... | 3 | 3 |
| 4. zone width < 6 meters..... | 2 | 2 |
| B. Riparian zone not intact (breaks) | | |
| 1. breaks rare | | |
| a. zone width > 18 meters..... | 4 | 4 |
| b. zone width 12-18 meters..... | 3 | 3 |
| c. zone width 6-12 meters..... | 2 | 2 |
| d. zone width < 6 meters..... | 1 | 1 |
| 2. breaks common | | |
| a. zone width > 18 meters..... | 3 | 3 |
| b. zone width 12-18 meters..... | 2 | 2 |
| c. zone width 6-12 meters..... | 1 | 1 |
| d. zone width < 6 meters..... | 0 | 0 |

Total _____

Remarks _____

TOTAL SCORE _____

COMMENTS, DRAWINGS:

APPENDIX 3. LIST OF NORTH CAROLINA CERTIFIED LABORATORIES FOR THE
IDENTIFICATION OF BENTHIC MACROINVERTEBRATES

Duke Power Company

13339 Hagers Ferry Road
MGO3A
Huntersville, North Carolina 28078-7929
Contact Dr. Arnie Gnilka
704/875-5421
Email agnilka@duke-energy.com

Pennington and Associates, Inc

P.O. Box 2887
Cookeville, Tennessee 38502-2887
Contact Wendell Pennington
931/526-6038
FAX 931/528-4167
Email pai@tnaccess.com

Mecklenburg County Department of Environmental Protection

Water Quality Section
700 North Tryon Street
Charlotte, North Carolina 28202
Contact Tony Roux
704/336-5500
FAX 704/336-4391
Email rouxtj@comecklenburg.nc.us

Law Engineering and Environmental Services, Inc.

2801 Yorkmont Road, Suite 100
Charlotte, NC 28208
Contact Tom Wilda
Phone: 704/357-5599
FAX: 704/357-8638
Email TWilda@kennesaw.Lawco.com

**APPENDIX 4. LIST OF CONSULTING FIRMS CERTIFIED TO COLLECT
BENTHIC MACROINVERTEBRATE SAMPLES AS PART OF
THE 401 CERTIFICATION PROCESS.**

Third Rock Consultants, LLC
2514 Regency Road, Suite 104
Lexington, Kentucky 40503
Mike Floyd, Bert Remley

Fish and Wildlife Associates
P.O. Box 241
Whittier, North Carolina 28789
Pamela Boaze, Stephan Brown

Environmental Assessment and Planning
3714 Spokeshave Lane
Matthews, North Carolina 28105
Len Rindner, Eric Secrist, Patrick Kealy

BLUE: Land, Water Infrastructure, PA
1271 Old Highway #1 South
Southern Pines, North Carolina 28387
Thomas Blue, Brian Smith

E'nV Environmental Consulting Service
3764 Rominger Road
Banner Elk, NC 28604
John Vilas

LandMark Consulting
6512 Six Forks Road, Suite 200,
Raleigh, North Carolina 27615
Michael Eagan

Environmental Services, Inc.
524 South New Hope Road
Raleigh, North Carolina 27610
Kevin Lapp, Eric Renninger, Jennifer Murray
Sally Landaal, Gail Tyner, Lauren Cobb

Rummel, Klepper, and Kahl, LLP
5800 Faringdong Place, Suite 105
Raleigh, North Carolina 27609
Amy Paulson, Nancy Daly, Elizabeth Mack,
William Stafford

LAW Engineering & Environmental Services
3301 Atlantic Avenue
Raleigh, North Carolina 27604
Darrin Peine, Jay Lawson, Rebecca Shanahan

HDR Engineering, Inc. of the Carolinas
128 South Tryon Street
Charlotte, North Carolina 28202
Chris Matthews, Kerri Snyder

Ecological Consultants
4216 Hope Valley Drive
Hillsborough, North Carolina 27278
George Pesacreta, Cynthia Huggett

Buck Engineering
1152 Executive Circle
Cary, North Carolina 27511
Greg Price, Jessica Rohrbach

EcoScience Corporation
1101 Haynes Street, Suite 101
Raleigh, North Carolina 27604
Ward Ellis, Matt Cusack

Skelly and Loy, Inc
18028 Mougans Avenue
Hagerstown, Maryland 21740
Josh Lincoln, Andy Brookens

Soil and Environmental Consultants
11010 Raven Ridge Road
Raleigh, North Carolina 27614
Jim Cooper, Todd Preuninger, Sean Clark,
Brad Suther

Barbara H. Mulkey Engineering, Inc.
559 Jones Franklin Road, Suite 164-A
Raleigh, North Carolina 27606-580
Lisa Warlick, Coy McKenzie

**Mecklenburg County Department of
Environmental Protection**

Charlotte, North Carolina 28202
Jay Wilson, Mark Popinchalk, Crystal Taylor,
Christopher Elmore

Carolina Wetland Services, Inc.

2041 South Blvd., Suite E1
Charlotte, North Carolina 28203
Greg Antemann

City of Greensboro

Stormwater Management Division
201 N. Greene St.
Greensboro, NC 27402
Ron Small

KCI Associates of North Carolina

4601 Six Forks Road, Suite 200
Raleigh, North Carolina 27609-5210
Brad Humber

R.J. Goldstein and Associates

8480 Garvey Drive
Raleigh, North Carolina 27616
Gerald Pottern

East Coast Environmental Consultants

4016 Wood Valley Drive
Aiken, South Carolina 29803
Todd Ball

Heritage Land Associates

1160 Ralph Tuttle Road
Walnut Cove, North Carolina 27052
Ken Bridle

WATER OAK

301 Water Oak Lane
Matthews, North Carolina 28104
Michael Wolf

URS Corporation

3109 Poplarwood Court, Suite 301
Raleigh, North Carolina 27604
Andrea Dvorak-Grantz

HSMM (Hayes, Seay, Mattern & Mattern)

1305 Navaho Drive
Suite 303
Raleigh, North Carolina 27609
Anne Timm

City of Charlotte

Storm Water Services
600 East Forth Street
Charlotte, North Carolina 28202
Chris Estes, Mary C. Murray

ARCADIS Geraghty & Miller

2301 Rexwoods Drive, Suite 102
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Robert Lepsic, Cindy Carr

Earth Tech

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Raleigh, North Carolina 27607
Heather Wallace

City of Durham

Storm Water Services
101 City Hall Plaza
Durham, North Carolina 27701
Bill Hailey, Chris Outlaw

Spangler Environmental

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Raleigh, North Carolina 27602
Scott Linnenburger

US Army Corps of Engineers

Raleigh Regulatory Field Office
6508 Falls of Neuse Road, Suite 120
Raleigh, North Carolina 27615
Todd Tugwell, Amanda Jones

Micheal A. Neal and Associates (MANA)

Engineers, Surveyors, and Planners
2823 Percussion Drive
Hillsborough, North Carolina 27278
CJ Geraci, Sandy Maunz

Independants

Angela Morland, NCSU Water Quality Group

Timothy Milling

**APPENDIX 4. PARTIAL LIST OF
BIOLOGICAL SUPPLY COMPANIES**

Ben Meadows

3589 Broad Street
Atlanta, Georgia 30341
800/241-6401
www.benmeadows.com
Waders, kick nets, dip nets, wash buckets,
forceps.

Carolina Biological Supply Company

2700 York Road
Burlington, NC 27215-3398
800/334-5551
www.carolina.com
Hand lenses, forceps, kick nets, microscopes.

Fisher Scientific

2775 Horizon Drive
Suwanee, Georgia 30024
800/766-7000
www.fishersci.com
Lab equipment, sieves, forceps.

Hach Company

P.O. Box 389
Loveland, Colorado 80539-0389
800/227-4224
www.hach.com
Field and laboratory water testing equipment.

Hydrolab Corporation

8700 Cameron Road, Suite 100
Austin, Texas 78754
800/949-3766
www.hydrolab.com
Water monitoring equipment and supplies.

Lawrence Enterprises

P.O. Box 344
Seal Harbor, Maine 04675
207/276-5746
www.h2oequip@acadia.net
Kick nets, sieve buckets.

Nichols Net and Twine, Inc.

2200 Highway 111
Granite City, Illinois 62040
618/797-0211
Kick nets.

Wards Natural Science, Inc

5100 W Henrietta Road
West Henrietta, NY 14586-9729
716/359-2502
www.wardsci.com
Microscopes.

Wildco Wildlife Supply Company

301 Cass Street
Saginaw, Michigan 48602
517/799-8100
www.wildco.com
Kick nets, wash buckets, field biological
sampling equipment.