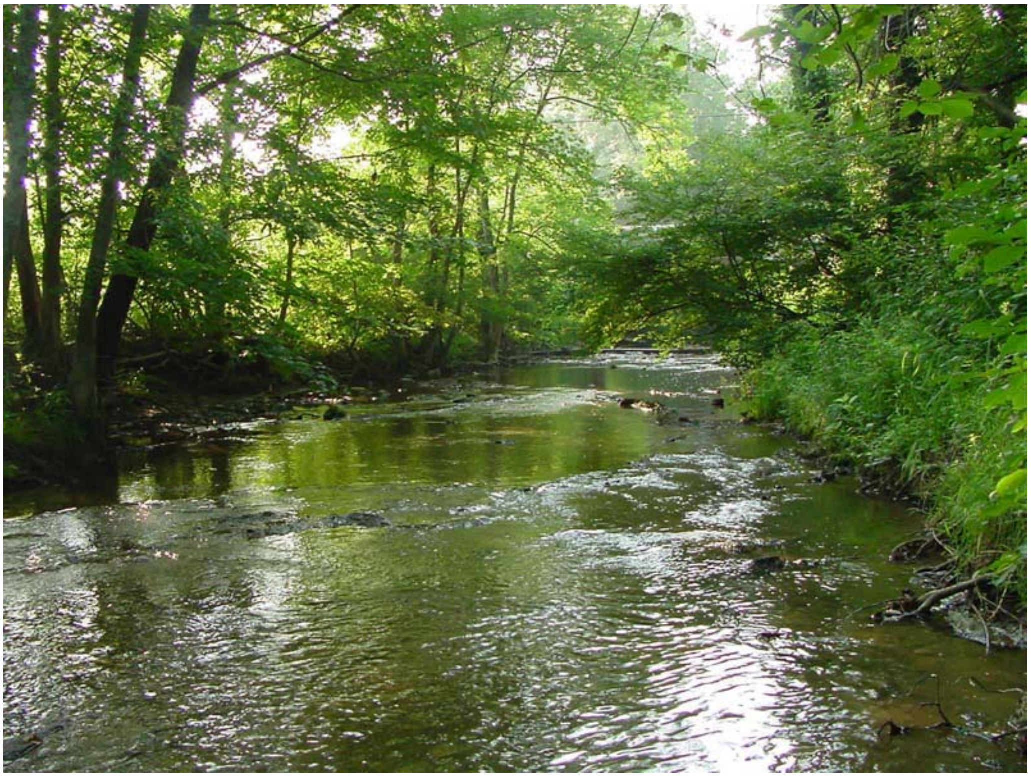
The Quality of Virginia Non-Tidal Streams: First Year Report



Water Quality Monitoring, and

Water Quality Assessment Programs

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EXECUTIVE SUMMARY

The Commonwealth of Virginia is rich in water resources with a wide variety of aquatic environments from fresh to salt, and montane to coastal plain. But the quality of a resource gives it value. So, the question that needs to be asked is "How good is Virginia's water quality, and does it vary across the State?" The Virginia General Assembly, national committees, environmentalists, citizens, and the USEPA have encouraged the Virginia Department of Environmental Quality (VDEQ) to answer this question. VDEQ answers this question through the biennial 305(b) Report (VDEQ 2002). This thorough report is based on tens of thousands of bits of data collected from more than a thousand stations in streams, lakes, and estuaries of the Commonwealth. It provides a comprehensive assessment of the monitored waters. However, it is based on sample locations selected through the observer's understanding of what samples are needed and knowledge of where to best collect them. This targeted sampling has great utility for monitoring regulatory compliance of sources of pollution, and for tracking local pollution events. While point estimates of water quality are made with these data, it is difficult to extrapolate the estimates to other, unsampled waterbodies or to a geographic area of the Commonwealth for two reasons. First, the sample locations were not randomly determined. Second, the target population is the individual sites themselves and not a region or stream type where all points had an equal chance of being sampled. Consequently, one cannot generalize beyond the sample sites.

In response to the need to evaluate water quality in whole river basins, or the Commonwealth in general, VDEQ added probabilistic monitoring to its biological monitoring program in 2001. The monitoring and assessment program is called ProbMon. The aim is to provide an accurate assessment of regional chemical, physical, and biological conditions of Virginia's water resources. The station locations have been selected randomly to allow the expression of water quality conditions in statistical terms. That is, a point value can be generated with an estimate of its precision. For example, it is possible to determine the true percent of streams having good water quality with 95% probability.

ProbMon's goal is to statistically assess the condition of all non-tidal perennial streams in Virginia. The survey is evenly spread over the period 2001-2005 to incorporate wet, dry, and normal years in the database. In the end the survey will provide policy-makers and the public with estimates of the status of Virginia's aquatic resources with statistical confidence. It will also describe associations between indicators of natural and anthropogenic stress and aquatic resources. Finally, it will be used to generate statistical summaries and assessments of the Commonwealth's water resources.

This report is the first assessment of ProbMon data. It contains an analysis of ProbMon spring benthic community and habitat data, and autumn water chemistry from 2001, the first year of the survey. It also presents the methodology of probabilistic data collection and demonstrates the utility of this data. The first year of monitoring only provided enough data to generally assess Commonwealth-wide conditions although it has been possible in some cases to extrapolate to a smaller scale. As more data is collected during the next four years the assessments will become specific for subsets of the Commonwealth's water resources including stream order, river basin, and ecoregion. Although many questions about Virginia's waters can be answered with ProbMon data, not all can be. The reason is, we only get a good estimate of a parameter for some portion of the aquatic resource if the sample size is sufficient. The design focus on stream order and on non-tidal streams has also put limits on the questions that can be answered. However, as ProbMon provides answers to long unanswered questions, we may find a future that demands a more thorough undertaking that can answer even more questions. Time and the results expressed in ProbMon reports will help guide that future.

ACKNOWLEDGEMENTS

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Mary Dail (WCRO) – Chemistry section, Appendix D & F, appendix technical editor
George Devlin (WCRO) – Benthic and Habitat sections
Jason Hill (WCRO) – report organization and first draft, land cover data, technology transfer of probabilistic methods from USEPA, CDF curve figures, State ecoregion maps, and data retrievals from CEDS.
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Dr. Michael Scanlan (WCRO) – general editor, executive summary, and conclusions.
Bill Van Wart (VRO) – Benthic database management, 1st draft Benthic section.
Dr. Lawrence Willis (WCRO) – Standard Operating Procedures (Appendix A) and technique founder along with others (Mark Alling (PRO), Roger Stewart (CO), and Don Smith (CO)).

Survey teams:

This report could not have been written without the data collected by the survey teams. By VDEQ Regional Office and responsibility the teams were as follows.

- Northern Virginia: Greg Brown (Regional Biologist)
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- Valley: Bill Van Wart (Regional Biologist), Michelle Titman, R. Ted Turner, Marcus Richardson, and Rick Anderson
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Logistic support:

Alex Barron (CO) – Biological Program Coordinator.
David Lazarus (CO) – publication funding.
Tony Olsen (EPA) – random site selection, weighting, and CDF curve support.

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1. INTRODUCTION

This is the first report on VDEQ's probabilistic monitoring and analysis of water quality for non-tidal streams of Virginia. The purpose of this report is to 1) inform Virginians that a probabilistic survey of water quality has been initiated, 2) establish VDEQ's methodological baseline for assessments of this type, and 3) present an analysis of the first year's data. ProbMon, short for Probabilistic Monitoring, was conceived in 1999, and the groundwork laid and protocols established in 2000. In 2001, the first survey year, field teams measured the habitat and benthic communities in the spring and fall, and stream chemistry in the fall. This report is based on the spring habitat and benthic data, and the autumn chemistry data. Because of the small data set, only general water quality conditions can be described for the Commonwealth. However, this report lays the foundation by documenting ProbMon data collection methods, QA/QC, database management procedures, and analytical protocols.

What is ProbMon?

ProbMon is a monitoring and assessment program that provides statistically based information about water quality in Virginia. It differs dramatically from traditional VDEQ monitoring by the random selection of sample sites. The target population is all non-tidal perennial rivers and streams in Virginia. ProbMon is based on EPA's Environmental Monitoring and Assessment Program (EMAP) techniques (Olsen 1999). EMAP is a long-term research program that seeks to provide sound information to environmental decision-makers on the current ecological status of a region. At VDEQ's request, ProbMon sampling locations were generated in a fashion similar to EMAP sites by EPA's Office of Research and Development in Corvallis, Oregon.

What Information will the Survey Provide?

ProbMon's goal is to assess the condition of Virginia's non-tidal streams and rivers. The survey provides policy-makers and the public with 1) estimates of the geographic coverage and extent of the aquatic resource conditions with known confidence; 2) estimates of the current status, trends, and changes in indictors of Virginia's aquatic resources with known confidence; 3) statistical summaries and assessments of Virginia's aquatic resources; and 4) a description of associations between indicators of natural and anthropogenic stressors and the condition of aquatic resources.

What are the Survey's Goals?

ProbMon was designed in part to meet requirements of the Water Quality Monitoring and Information Act (WQMIRA 1997) and the JLARC Review (1996). JLARC and WQMIRA specifically encouraged an increase in chemical and biological monitoring, statistical analysis of monitoring data, and statewide comparisons and sampling for all water quality criteria. ProbMon specifically provides the foundation for meeting all of these requests. The sampling design allows for answering a wide variety of questions with statistical accuracy including the basic ones in the following list. The list is by no means complete. However, it demonstrates the kinds of questions that can be answered. The study design allows for both specific and general questions. General questions might be of most interest to decision-makers and managers in the development of new initiatives and in allocating workloads. More specific questions are appropriate for the management of a resource or for determining the variables that most affect the aquatic environment. The ProbMon survey seeks to answer the following questions.

General questions characterizing the Commonwealth's aquatic resources:

Policy:

1. What water quality issues do policy makers need to address?
2. How effective are current management strategies at protecting resources?
3. How can efforts be redirected to better protect the most threatened resources?
4. Where is more stream protection needed?

Science:

1. What is the current statewide water quality?
2. What impairments exist and how wide spread are they?
3. What types of streams are most threatened and what are the threats?
4. What are the statewide and regional water quality trends?

Specific questions concerning the Commonwealth's aquatic resources:

1. How do streams vary by ecoregion across the Commonwealth?
2. How many river kilometers meet water quality standards?
3. How do land uses relate to aquatic resource quality?
4. What habitat characteristics are important for good water quality?

5. What percent of stream kilometers with degraded water quality are associated with the measured habitat indices?
6. For pollutants that are expensive to analyze, to what degree do they impair waters across the Commonwealth, and where are the areas of concern?

General questions concerning the benthic macroinvertebrate community:

1. What are the best available conditions for the biological community?
2. What are the stressors to the biological community?
3. How do biological indicators correlate with stressors?
4. To what degree do non-tidal waters have balanced indigenous macroinvertebrate communities based on the benthic metrics?
5. What are the critical habitat characteristics for healthy macroinvertebrate communities?
6. How do regional reference sites perform compared to historical reference sites?

Specific questions concerning the benthic macroinvertebrate community:

1. Which biological metrics are indicative of specific stressors?
2. Can a matrix of ProbMon data be developed to identify reference sites in Level III ecoregions?
3. Where are these Level III ecoregion reference sites?

Why Use Probabilistic Survey Techniques?

There are several ways to evaluate the quality of streams in Virginia. One method is to census all the streams in each basin, which would be extremely time-consuming with about 80,000 kilometers (50,000 miles) of streams in Virginia. A second method is to use an empirical model for the water quality in each river basin. Models have to be calibrated and verified based on historical water chemistry records. Such models are also time-consuming and expensive, and currently are ineffective in determining the biological integrity of waters. A third way is to collect data using targeted methods. Targeted monitoring networks have been in place in most States for decades and significant funds have been invested in collecting data from them. The stations are strategically located at places suspected of having degraded water quality. Examples are above and below the outfall of a wastewater treatment plant or manufacturing facility. Traditional monitoring stations have also been placed where it is easy to sample. For example, most of the Virginia's ambient monitoring stations are at bridges. Data collected in this manner can be used to answer questions such as "Is a manufacturing facility in compliance with its wastewater permit?" or "Should the stream segment be on the Impaired Waters (303(d)) List?" While targeted monitoring is excellent at answering these critical questions, it cannot be used to speculate on the overall condition of the Commonwealth's water resources. The reason is that the ratio of degraded to non degraded waters is unknown. The final monitoring option considered is the probabilistic method.

The probabilistic method allows VDEQ to establish baseline water quality information for river basins, stream types, and geographic areas in the Commonwealth. If the probabilistic study is repeated at a later time, trends in the quality of the resources can also be estimated. Probabilistic monitoring can address regional questions such as "What percent of Piedmont Virginia steams have a pH lower than 6.5?" Most important, the estimates can be made with statistical confidence. VDEQ's ProbMon survey will collect data from 300 stream locations over a five-year period. This will provide estimates for each sample parameter with 5% precision.

Why is it Important to Sample Randomly?

This section contains modified text from EPA's Answers to Commonly Asked Questions about R-EMAP Sampling Designs and Analyzes (Volstad et al. 1995).

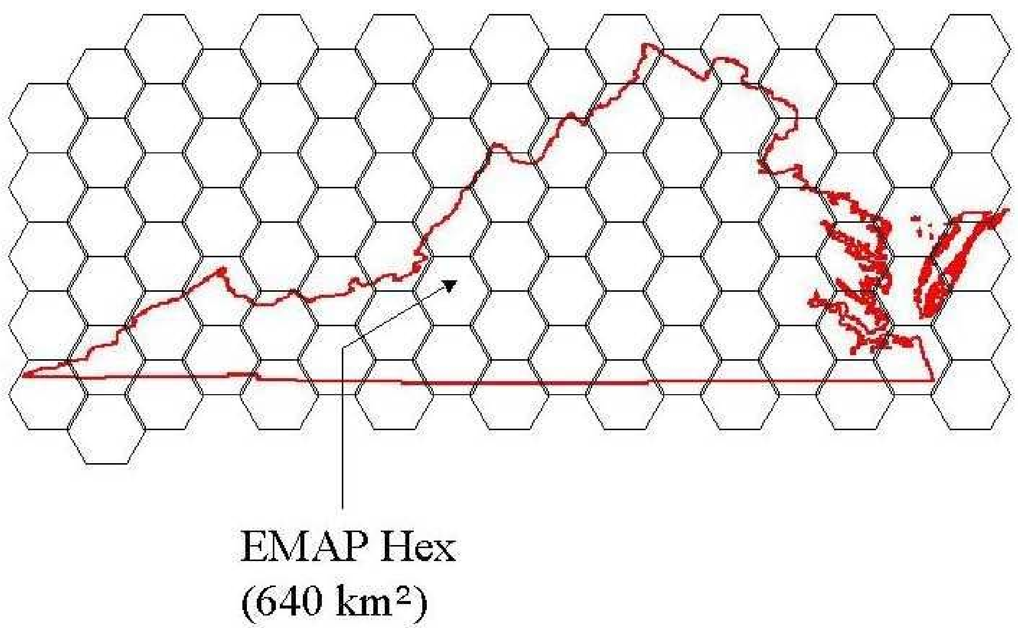
The way we select a sample is crucial for obtaining accurate estimates of the parameters of interest. We clearly would not get a good estimate of the percentage of polluted streams in a watershed if we only sampled downstream of dairy farms. If dairies affect only a small percentage of the total stream length, this preferential sample would include a much higher proportion of nutrients, sediment, and bacteria than the general population of streams. This kind of sampling provides useful information about conditions downstream of dairies, but it does not produce estimates that accurately represent the whole watershed.

The natural tendency is to extrapolate subjectively selected data to holistic conditions for which they are unsuited. Preferential selection can be avoided by taking random samples. Simple random sampling ensures that no particular portion of the sampling universe (i.e., kinds of river reaches) is favored. By this method the chance of selecting a sampling unit with degraded ecology is proportional to the number of sampling units in the target population that have degraded conditions. For example, if 20% of the target population has degraded conditions, then on average 20% of the (randomly selected) units in the sample will exhibit degraded conditions. This property of random sampling allows estimates to be used to draw conclusions about the target population as a whole.

How were ProbMon Stations Selected?

ProbMon used a random tessellation stratified survey design to select stream sample sites (Stevens 1997). In this method an EMAP grid of hexagons was placed over the Commonwealth of Virginia (Figure 1). This grid ensures randomization and spatial distribution of sampling locations. The base density is one grid point per 640 km^2. This was intensified to allow regional analyses.

Figure 1. Base hex grid for the Commonwealth of Virginia.



In Figure 2, the 640 km^2 hexagons are subdivided into 7 hexagons of 90 km^2 each. The 90 km^2 hexagons are subdivided into 7 hexagons that each cover 13 km^2. Finally, within the 13 km^2 hexals there are 7 hexagons that cover 1.8 km^2 of land surface. In Virginia, the sample areas were the 13 km^2 hexals whose edges are defined by the 1.8 km^2 hexagons. This why we say that Virginia's ProbMon used a 7 x 7 x 7 fold enhancement to randomly select stream reaches (Olsen 1999).

The sampling frame for the Virginia survey was constructed by overlaying the EMAP grid onto United States Geological Survey 1:100,000-scale digitized stream maps. These are also referred to as USEPA River Reach File Version 3, or RF3, stream traces. Stream size is reflected in its aquatic community, chemistry, and habitat conditions. So, stream segments were number coded using the Strahler ordering system to reflect their size. The small, initial segment that begins a stream is a Strahler 1st order stream. Two 1st order segments join to form a 2nd order stream and so on. Within the 640 km^2 hexagons, three 13 km^2 hexals were randomly selected as demonstrated in Figure 2. Inside each 13 km^2 hexal the stream segments were designated by Strahler stream order and each segment was assigned a unique code. A stream segment is a stretch of stream between its union with a tributary and the next union upstream. These segments were randomly arranged onto a line as demonstrated in Figure 3. The final line represents the length of all streams from inside the seven 1.8 km^2 hexagons. Sampling locations were randomly chosen along this final line. The stations sampled in 2001 are listed in Appendix B. The benthic community and stream habitat were sampled at each randomly selected site in the spring of 2001. They were again visited in the autumn during which the water quality parameters listed in Appendix C were sampled.

Figure 2. Randomly selected 13 km^2 hexals from 640 km^2 hexagons. Virginia stream segments were selected from the 13 km^2 hexals.

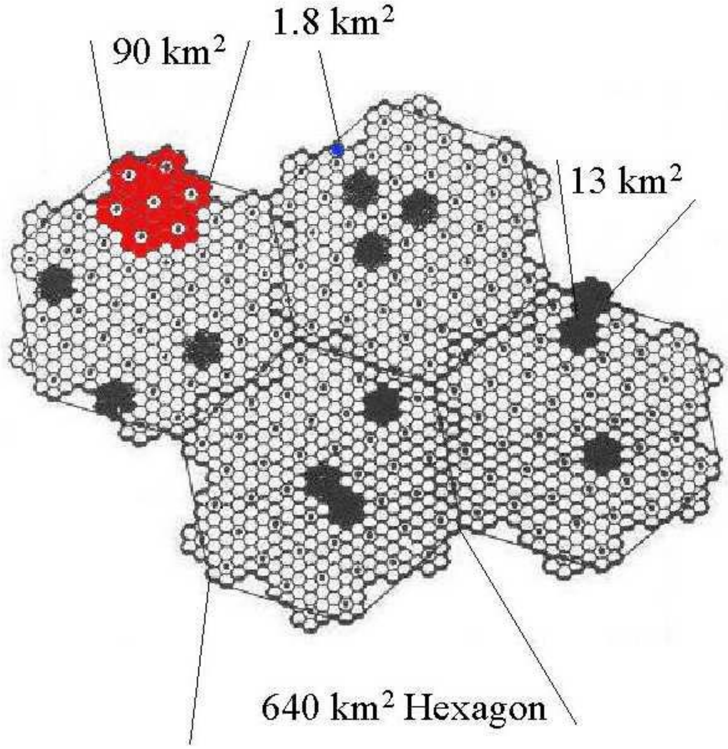
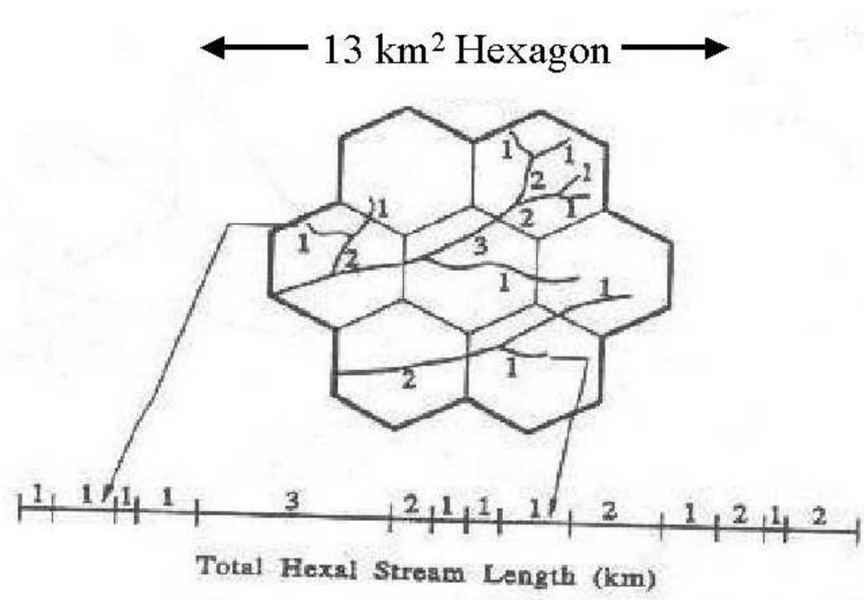


Figure 3. Example stream length for stream orders within a 13 km^2 hexal.



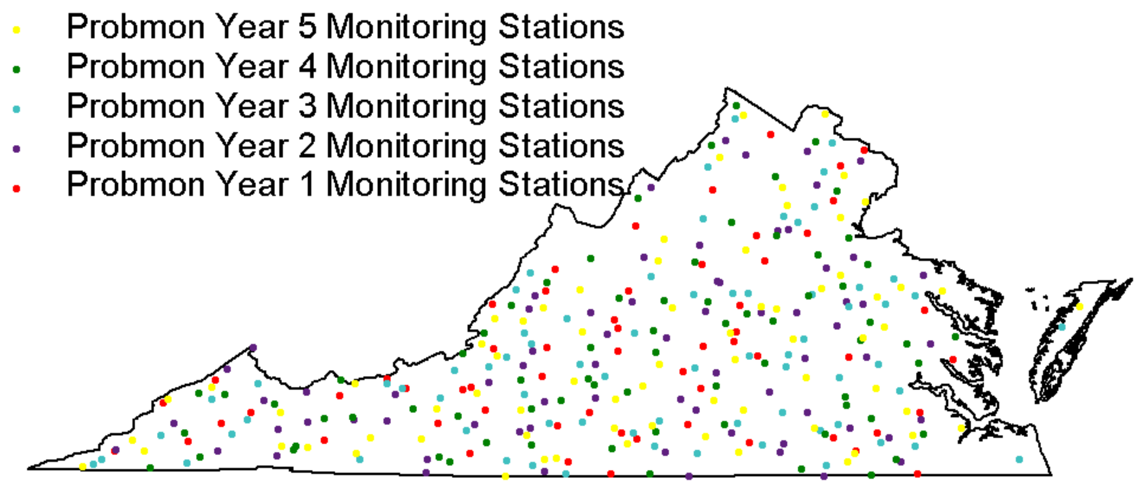
ProbMon is an unequal probability survey meaning that the elements of the target population are not sampled with equal frequency. The target population is all non-tidal perennial streams in Virginia, and the elements are stream orders. The size or order of a stream was selected as the basic selection element because it affects the type of biotic community present and the stream's capacity to handle both point and non point source pollutants. Very small streams are often quite clear, shaded by trees, and dominated by aquatic insects typical of low productivity. Large streams are often muddy, canopy covered only along the banks, and populated by aquatic communities adapted for slow-moving, productive systems.

In ProbMon, Strahler stream order is used to assign the probability of selection to each stream segment to avoid over selecting the more common stream sizes. For example, because 1^{st} order streams make up 65% of Virginia stream kilometers and are four times as common as 2^{nd} order streams, 1^{st} order streams are four times as likely to be randomly selected by a simple random design. Because high order streams are rare, they could be so under sampled that their statistics would be meaningless. Thus, the commonness of stream orders 1 through 4, and orders 5-7 combined was used to weight the choice of samples so that all orders were approximately equally sampled. This markedly increases the precision of the estimated parameters for each element of the target population (USEPA 2002). The statistical analysis from this type of survey is thereby complicated. It is further complicated because the sampling success rate affects the weights. See Appendix G for details on adjusting weights prior to analysis.

How many ProbMon Stations were Sampled during the First Year?

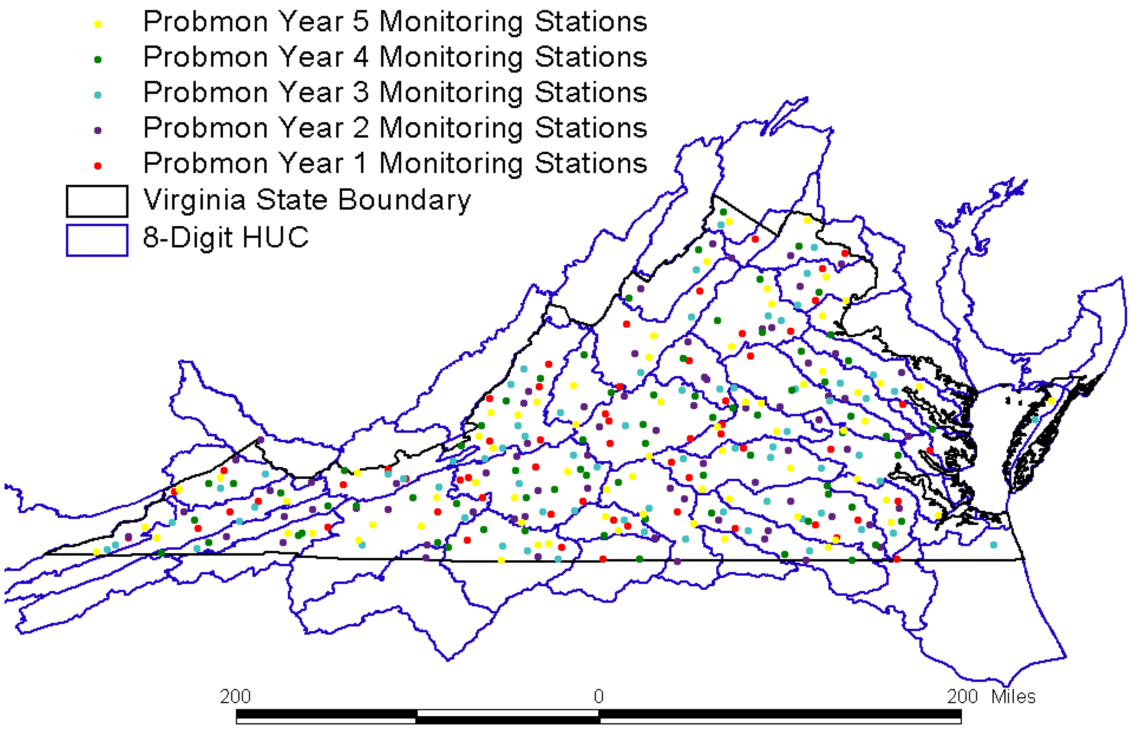
During 2001, 63 sites were monitored in the spring (Figure 4, Figure 7, Appendix E and F) and 58 of these sites were monitored in the fall (Figure 8, Appendix B). To achieve a sample size of 60 sites per year over the five-year period, 70 random sampling locations were provided for each study year by EPA's Office of Research and Development (T. Olsen, personal communication 2001). The extra ten samples provide alternate sites in case some were inaccessible. The results in Section III are based on the data from the first year sites.

Figure 4. ProbMon statewide coverage over five years (n=300).



From the Commonwealth's perspective, the comparative water quality of its river basins is of high interest. In the next figure the ProbMon stations are plotted in the USGS hydrologic units (HUCs) which are river basin subunits. The nine major river basins in Virginia are each composed of several adjoining HUCs. It appears there will be sufficient random stations in each basin to define the water quality and test for differences between and within major basins by the end of the study. Because the HUCs define watershed boundaries, those along the margins of the Commonwealth usually overlap into adjacent state territories.

Figure 5. ProbMon statewide coverage over hydrologic units.



One of the important ecological perspectives of the Commonwealth is the ecoregions as shown in the next figure. The figure outlines areas of Level III Ecoregions.

Figure 6. Level III ecoregions in the Commonwealth.

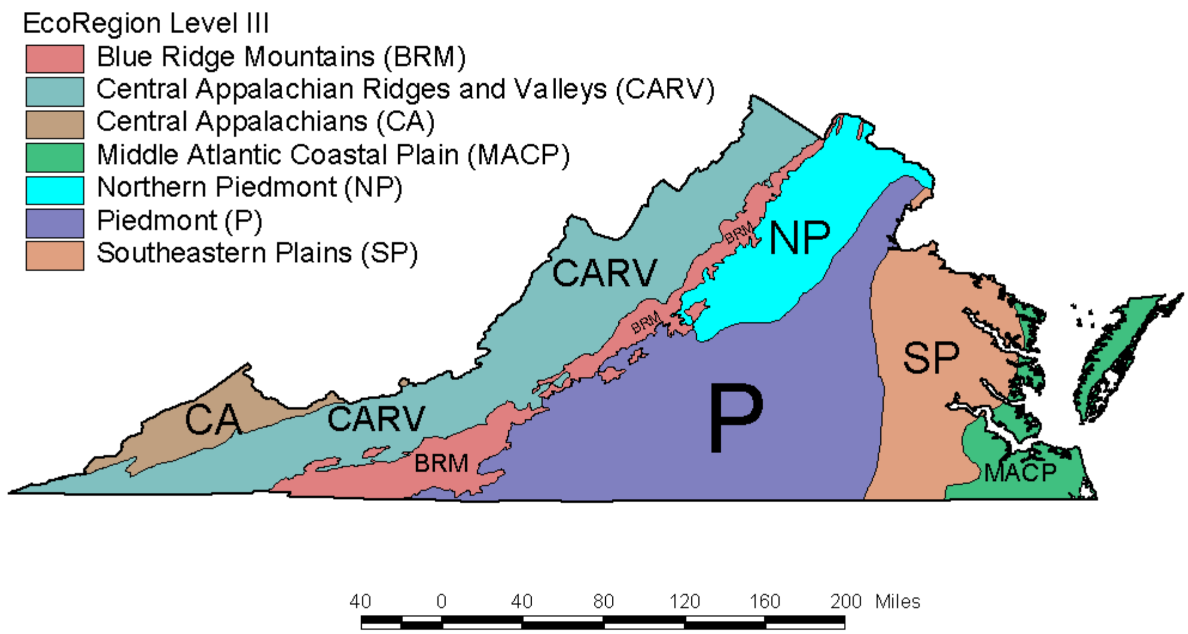


Figure 7. ProbMon stations sampled during spring 2001 (n=63) and the ecoregions of Virginia.

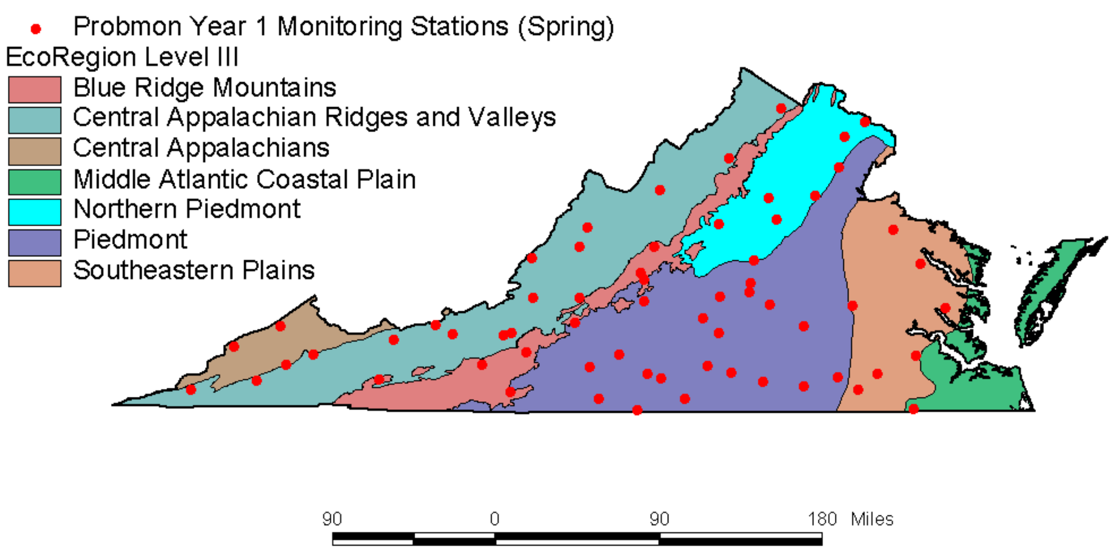
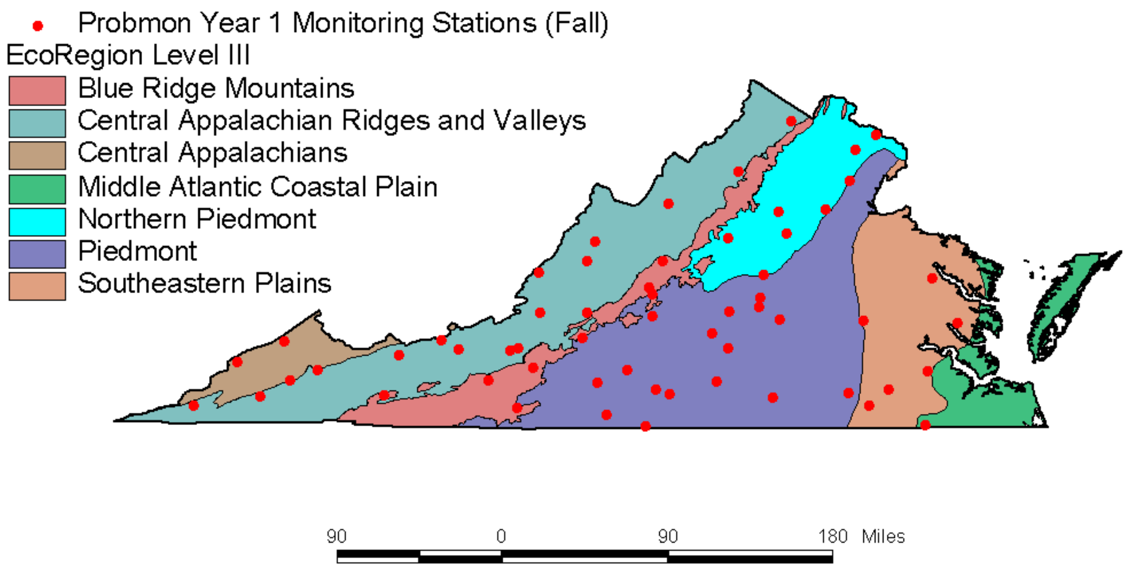
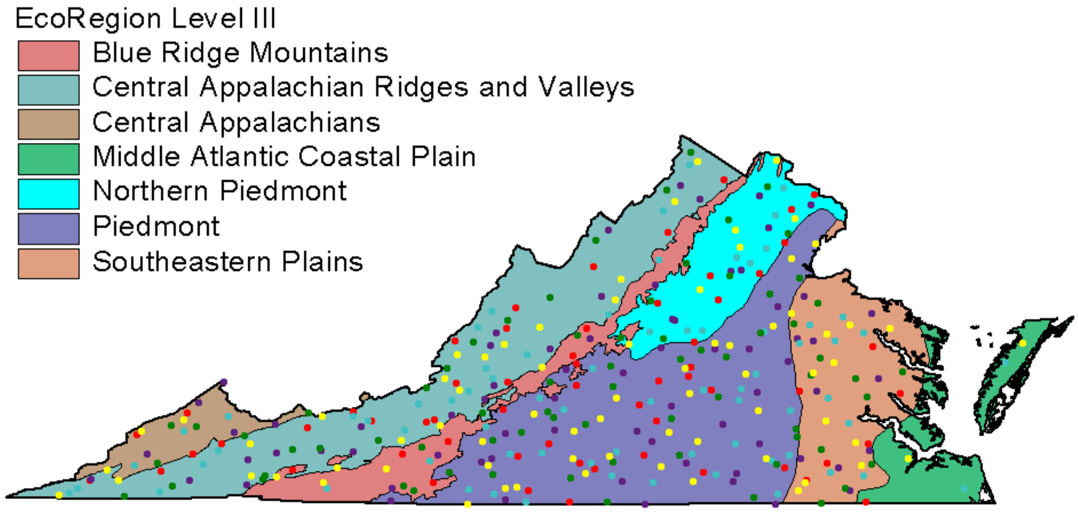


Figure 8. ProbMon stations sampled during fall 2001 (n=58) and the Ecoregions of Virginia.



One of the ProbMon survey goals is to identify trends and patterns by ecoregion (Figure 9). An ecoregion is the region of relative homogeneity, of similar land surface form, soils, land uses, and potential natural vegetation, in an ecological system (Omernik 1987, Bailey 1976). There are sufficient samples in most ecoregions to accomplish this goal by the end of the study. However, no bias was used to ensure equal ecoregion representation. So, station coverage by ecoregion will be in proportion to the aerial coverage by each ecoregion in the State. Then the accuracy of statistical estimates for water quality by ecoregion will depend on the ultimate sample size in each ecoregion and the variability in the data. The ecoregions of stations sampled in 2001 are noted in Appendix B.

Figure 9. ProbMon coverage of Level III ecoregions after five years.



2. METHODS

The following three sections describe the methodologies used to collect, store, and analyze ProbMon data. A fourth section describes the acquisition of land use data.

Data Collection

All field sampling follows standard operating procedures in the ProbMon QA/QC guidelines (Appendix A). Benthic macroinvertebrate sampling and physical habitat assessments follow EPA's Rapid Bioassessment Protocols (RBP II; Barbour et al. 1999).

Data Storage and Management

All water chemistry data is stored in VDEQ's Comprehensive Environmental Data System (CEDS). Using Oracle Discoverer, the water chemistry data was retrieved as an Access database file and put into an ArcView 3.2 Geographic Information System (GIS) database to generate the maps. All biological and physical habitat data is stored in the Ecological Data Application System (EDAS), an Access database developed by TetraTech (1998). The ProbMon data in EDAS was queried and merged into the GIS database with the chemical data. Migration of the data to GIS makes it possible to identify the ecoregion of stations, adjacent land use, and spatial patterns. All data was combined in an Access database to facilitate importing to STATISTICA for box plots, and exporting to text files for the CDF curves.

Data Analysis

Boxplots were created through STATISTICA 5.1 to permit the comparison of ProbMon variables by Strahler order. Many of the parameters are not normally distributed so the median was uniformly used to compare results across stream orders. Based on reasonable algorithms STATISTICA boxplots provide the identification of outliers versus extreme values, which are helpful in making comparisons between stream orders.

Maps of relative values are a second method employed to detect patterns. Because samples were collected across Virginia, any geographic patterns might best appear in maps showing relative values at the collection sites.

The third method of analysis involved the manipulation of the data to generate the cumulative distribution function (CDF) for key variables. The CDF is a statistical function that has been under utilized in environmental studies. Formally, it estimates the probability that a variable is less than or equal to some value. This function is most useful when displayed graphically. Then the viewer is able to determine the likelihood that a variable would be less than a particular threshold. However, it can also provide the probability that a variable would be above a threshold or that it would be within a certain range. For VDEQ's ProbMon, these probabilities apply to the target universe, all non-tidal streams in the Commonwealth.

CDF development begins with the probabilities used in the random selection of sample sites. These probabilities were provided by T. Olsen based on VDEQ's request that a GRTS survey be designed for the network of all non-tidal streams in Virginia (A. Olsen personal communication 2000). An unequal probability survey design was requested such that Strahler stream orders 1, 2, 3, 4, and ≥ 5 had equal probability of being sampled. The sample probability, also called the inclusion probability and symbolized by $\boldsymbol{\pi_i}$, was different for each $\mathbf{i}^{th}$ Strahler order. The inverse of the inclusion probability, the initial design weight, is listed for each Strahler order in Table G2 of Appendix G.

In a probabilistic survey the population parameter to be estimated is the total of the variable over the target universe. For example, for pH we seek to estimate the sum of pH observations over all non-tidal streams in the Commonwealth. For a discrete resource the total is as follows.

$$\hat{z}_T = \sum_{i=1}^{n} \frac{I_R(s_i) z(s_i)}{\pi(s_i)}$$

This is a general population parameter that can be used to estimate the mean, variance, and distribution functions for each sampled variable over the target universe because each statistic depends on the total or sum of **z**.

The distribution of the parameter of interest may be characterized with known inclusion probabilities through a Cumulative Distribution Function (CDF) curve using the Horvitz-Thompson Estimator (Diaz et al. 1996). The CDF curves in this report were calculated on this basis using SAS routines available at the EMAP web address and from Virginia Engels of the USEPA. The mathematical description of the CDF function $\hat{F}_{th}(z)$ for generating the curve for parameter **z** in stratum **h** and in year **t** is represented as follows (USEPA Nov. 2002).

$$\hat{F}_{th}(z) = \frac{1}{n_{th}} \sum_{i;1}^{n_{th}} I\{z_{thi} \le z\}$$

Here, $\mathbf{z_{thi}}$ is the measurement on the parameter in year **t** from stratum **h** at sample site **i**, and $\mathbf{n_{th}}$ denotes the number of observations in year **t** from stratum **h** (Rathbun et al. 1996). In this report, the stratum is a constant because there was no stratification necessary. The variance of $\hat{F}_{th}(z)$ is approximately the following (USEPA Nov. 2002).

$$\hat{V}_{HT}(\hat{z}_T) = \sum_{s_i \in R} \frac{z^2(s_i)}{\pi^2(s_i)} + \sum_{s_i \in R} \sum_{\substack{s_j \in R \\ j \ne i}} \left[\frac{\pi(s_i, s_j) - \pi(s_i)\pi(s_j)}{\pi(s_i, s_j)\pi(s_i)\pi(s_j)} \right] z(s_i) z(s_j)$$

For the CDF curve to provide accurate probabilities, the statistics used to support its calculation must be appropriate, and the data must be collected properly. The USEPA has developed applications for producing the CDF function for probabilistic data. The statistical details can be found in the EMAP Statistical Methods Manual (Diaz-Ramos et al. 1996). This manual does not explain how to weight observations. The necessary details are covered comprehensively by Tony Olsen's document "Adjusting Weights" (A. Olsen, draft 3/25/2002). For information on adjusting design weights (inclusion probabilities) see Appendix G. For CDF background information the reader is referred to the EMAP web site at http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm. It provides example probabilistic studies, applications, and the EMAP methods manual. It also provides software for adjusting site weights, generating CDFs, and producing summary statistics based on probabilistic environmental data.

Land Cover Data

The land cover in watersheds upstream of ProbMon locations was derived using ArcView 3.2, Spatial Analyst, and BASINS 3.0. Upstream watersheds were delineated using the BASINS automatic delineation extension. The automatic delineation extension required Spatial Analyst software and Digital Elevation Model data (90 meter resolution). However, when watershed delineation results did not appear accurate when comparing the resulting coverage to the National Hydrological Dataset (NHD) and Department of Conservation and Recreation (VDCR) subwatershed delineations, a different method was used. Several of the smaller watersheds were delineated using BASINS 3.0 manual delineation extension using a combination of existing Hydrologic Unit Code coverages, NHD coverages, DCR subwatershed coverages, and best professional judgement of VDEQ's GIS specialist. Delineated watershed coverages were used to clip the desired land cover information from the National Land Characterization Data (NLCD) land cover data series (USEPA 1999). Land cover acreage was calculated from the clipped land cover grids. The NLCD was compiled using Landsat thematic mapper imagery from the mid 1990s with a spatial resolution of 30 meters. The major land cover categories used to relate land cover and water quality are in Table 1. The land cover for the entire Commonwealth is mapped in Figure 10.

Table 1. Land cover classes in Virginia's National Land Characterization Data series (USGS 1998). All cover classes listed were mapped for the sampled watersheds.

Water
Open Water (11) – areas of open water, generally with less than 25 percent or greater cover of water (per pixel)

Developed
Low intensity Residential (21) – Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Populations densities will be lower than in high intensity residential areas. **High Intensity Residential (22)** – Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover. **Commercial/ Industrial/Transportation (23)** – Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classifies as High Intensity Residential.
Barren
Bare Rock/Sand/Clay (31) – Perennially barren areas of bedrock, desert, pavement, scraps, talus, slides, volcanic material, glacial debris, and other accumulations of earthen material. **Quarries/Strip Mines/Gravel Pits (32)** – Areas of extractive mining with significant surface expression. **Transitional (33)** – Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clear cuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Vegetated; Natural Forested Upland
Deciduous Forest (41) – Areas dominated by tress where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change. **Evergreen Forest (42)** – Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage. **Mixed Forest (43)** – Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Herbaceous Planted/Cultivated
Pasture/Hay (81) – Areas of grasses, legumes, or grass legume mixtures planted for livestock grazing or the production of seed or hay crops. **Row Crops (82)** – Areas for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton. **Urban/Recreational Grasses (85)** – Vegetation (primarily grasses) planted in developed setting for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.
Wetlands
Woody Wetlands (91) – Areas where forest or shrub land vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water. **Emergent Herbaceous Wetlands (92)** – Areas where perennial herbaceous vegetation accounts for 75-100

percent of the cover and the soil or substrate is periodically saturated with or covered with water.

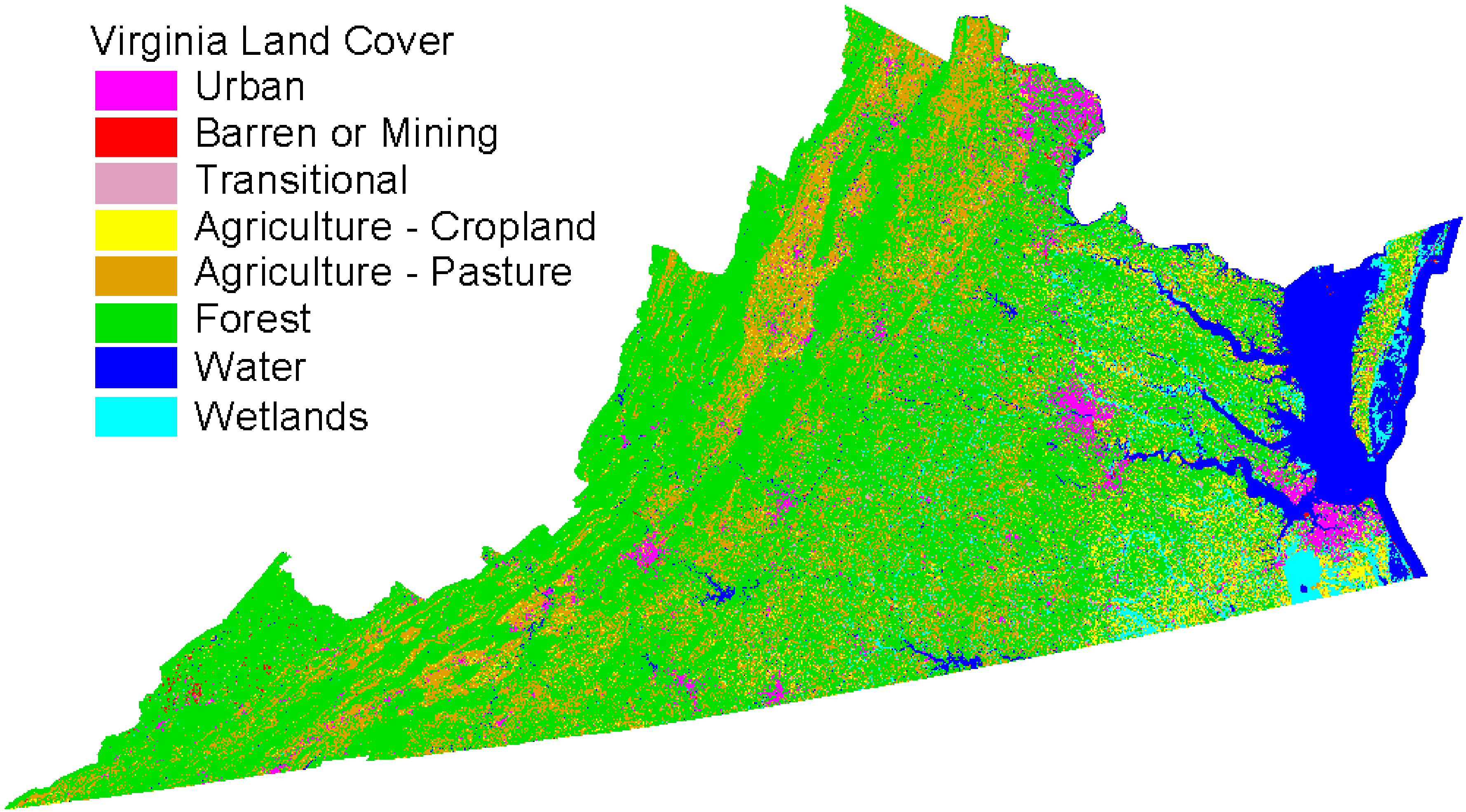


Figure 10. Land cover of the Commonwealth based on Landsat data from the 1990s.

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3. CHEMICAL DATA

To obtain an idea of the water quality chemistry across the Commonwealth, field and chemical data was collected at each ProbMon site following VDEQ's Standard Operating Procedures (see VADEQ SOP). Dissolved oxygen, pH, specific conductance, and temperature were measuremed in mid-stream and 0.3 m below the stream surface. Water and sediment samples were collected and sent to the Virginia Division of Consolidated Laboratory Services in Richmond, Virginia for analysis (Appendix C). In all, 65 chemical and physical parameters were measured at each site along with four field parameters. Selected parameters are discussed in Section 3.1 and the results are presented in Section 3.2.

3.1 CHEMICAL BACKGROUND

pH Background

One of the primary indicators used to evaluate surface water quality is pH. pH measures the concentration of hydrogen ions in water or, the amount of acidity present. Since the pH scale is logarithmic to base 10, a decline in pH by one unit indicates a tenfold increase in Hydrogen ions. At pH 7, a solution is neutral while pH values below 7 indicate acidic conditions and values above 7 indicate basic conditions.

Stream pH depends on local ecology, the presence of inorganic and organic acids, and anthropogenic influences. For example, if a stream has poor buffering capacity as is the case for a stream flowing over granite or shale, it may be naturally acidic. Then, if inorganic acids such as sulfuric or nitric acid are introduced via rain, the low buffering capacity can be rapidly exhausted so that the pH plunges. The resulting low pH may be detrimental to unadapted aquatic biota.

Most aquatic organisms can withstand a pH as low as 6, but prefer a range between 7 and 8.5 (Barker et al. 1990). pH values harmful to aquatic life-use are the extremes; below 5 or above 9. This is reflected in Virginia's water quality standards, where all waters must have a pH range from 6 to 9, or 6.5 to 9.5 in certain streams (Table 2). pH standards can be determined on a case-by-case basis if pH deviates due to natural conditions as in swamps and other wetlands (Commonwealth of Virginia 1997).

Dissolved Oxygen

Dissolved Oxygen (DO) is one of the most important determinants of habitat suitability for aerobic organisms. DO is a fundamental requirement for aquatic life. In streams the concentration is altered by photosynthesis, respiration, nutrient input, reaeration, and temperature, all of which have seasonal cycles. These factors change gradually with the rise in elevation westward across Virginia. There are also micro patterns to these factors confined to certain watersheds, bedrock, and stream order. This natural variability is reflected in the water classes in Virginia's Water Quality Standards (Commonwealth of Virginia 1997). For example, a high-energy mountain stream is expected to have higher DO than a low-gradient, warm water stream (Class III in Table 2) for reasons addressed later. Although expectations for DO concentration vary, all waters in Virginia are required to have a DO concentration of 4 mg/L or above. Streams that support stocked trout or naturally reproducing trout must have DO concentrations of at least 5 mg/L and 6 mg/L, respectively.

Table 2. DO and temperature standards in Virginia by water class (Commonwealth of Virginia 1997).

9 VAC 25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature.***

CLASS OF WATERS	DO (mg/l) Min.	DO (mg/l) Daily Avg.	pH	Maximum Temp. (°C)
I Open Ocean	5.0	--	6.0-9.0	--
II Estuarine Waters (Tidal Water- Coastal Zone to Fall Line)	4.0	5.0	6.0-9.0	--
III Nontidal Waters (Coastal and Piedmont Zones)	4.0	5.0	6.0-9.0	32
IV Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
V Stockable Trout Waters	5.0	6.0	6.0-9.0	21
VI Natural Trout Waters	6.0	7.0	6.0-9.0	20
VII Wetlands	*	*	*	**

*This classification recognizes that the natural quality of these waters may fall outside of the ranges for D.O. and pH set forth above as water quality criteria; therefore, on a case-by-case basis, criteria for specific wetlands can be developed which reflect the natural quality of the waterbody.
**Maximum temperature will be the same as that for Classes I through VI waters as appropriate.
***The water quality criteria in 9 VAC 25-260-50 do not apply below the lowest flow averaged (arithmetic mean) over a period

Seasonal variations in DO concentration are directly related to temperature. Higher summer temperatures tend to bring lower DO concentrations because DO solubility is inversely proportion to temperature. During the winter months, most aquatic organisms have a lower metabolism and many leafy aquatic plants have died back so the demand for oxygen is less.

When streams are under partial or complete ice cover, reaeration is greatly reduced. But fish and microbes still require oxygen and may suffocate under prolonged ice cover. In the summer many fish require an adequate level of DO for feeding, growth, and spawning. Aquatic insects require oxygen in the summer as they undergo changes in life stages, feeding, and reproduction. In addition, in the summer aquatic plants flourish and elevate DO levels in sunlight and depress them in the dark.

Daily fluctuations in DO can be linked to algae and leafy aquatic plants. Photosynthesis, which is fueled by sunlight, will increase the DO concentration in the water in the daytime. Meanwhile, respiration uses oxygen at night. Highly productive streams have higher daytime oxygen production and higher nighttime respiration use. In extremely productive systems, algal blooms may block sunlight from submerged aquatic vegetation thereby decreasing their oxygen production and altering the oxygen balance in the system.

Pollution plays an important role in dissolved oxygen concentration. Human and animal waste released into streams act as fertilizers. As microbes break down the organic matter, their respiration depletes the available DO so that aquatic animals may become stressed and die.

Temperature

Temperature affects water quality by imposing a heat burden on aquatic life, and by limiting the level of dissolved gases in water. Temperature in streams varies in relation to seasonal and daily changes. Sunlight is the primary source of temperature change. However, stream temperature is also influenced by the temperature of the stream bed, groundwater inputs, and air in contact with the water surface. Temperature is inversely related to bank vegetation cover; less cover implies more exposure to the sun and higher temperature. Also, water temperature reflects the seasonal changes in air temperature. Winter air yields colder water temperatures compared to summer. Deviations from this trend occur especially in springs or in small streams. Also, runoff from impervious surfaces in urban areas may increase water temperature. Finally, the effluent from dischargers tends to be higher than the receiving stream and may elevate water temperature.

Stream temperature has a major effect on aquatic organisms. It can directly influence the types of organisms found in an aquatic system as well as their growth, behavior, metabolism, reproduction and feeding habits. Virginia's standards for temperature reflect the upper limit for the support of different forms of aquatic life (Table 2).

Specific Conductance

Specific conductance is the amount of dissolved ions in the water. It indicates the electrical conductance of water by detecting the electrically charged ions. Calcium, magnesium, potassium, sodium, chlorine, and carbonate ions are common in streams. Generally, high specific conductance is indicative of highly productive streams, whereas low specific conductance streams have low productivity. Where the local geology is predominantly limestone the streams have naturally high specific conductance. There is no surface water standard for specific conductance in Virginia.

In terms of aquatic organisms, specific conductance is not indicative of any specific water quality condition. Rather, it is used in combination with other chemical and biological parameters to make general statements about dissolved chemicals in the water.

Hardness

Hardness measures the amount of Calcium and Magnesium salts in water. Calcium and magnesium cations form insoluble compounds with soap. Hardness is not to be confused with alkalinity, as they are not strongly correlated. Calcium and Magnesium ions are commonly found with bicarbonate, sulfate and chloride which are primary players in alkalinity. It is possible however, to have high alkalinity without the presence of much calcium or magnesium. Often water is described as 'hard' or 'soft.' Hard water has an ionic concentration over 25 mg/L while soft water has less than that value.

Aquatic organisms require ions in the waters in which they dwell. However, the specific concentrations needed are imperfectly known. Generally, low concentrations have limited abundance and variety of aquatic organisms. Finally, mollusks, crustaceans, and leeches tend to be more sensitive to changes in ionic concentrations than aquatic insects (Hynes 1970; Macan 1974).

Turbidity

In streams, turbidity mainly reflects the amount of suspended sediment. These sediments originate from eroding banks where streamside vegetation has been removed. Runoff from crop fields with little vegetation also adds to turbidity. Turbidity tends to be low in forested areas and high in urban and agricultural areas (Robertson & Saad 1996).

Turbidity usually has negative effects on aquatic organisms. It can collect on the gills of some aquatic insects or smother fish eggs. Turbid waters may also degrade the habitat by filling interstitial spaces between rocks occupied by aquatic insects. Finally, certain species of fish and aquatic insects are intolerant of substrate dominated by sediment and so are absent from sites with constantly turbid waters.

Nitrate

Nitrogen is common in the air as nitrogen gas. But in terrestrial and aquatic settings it must be present in forms such as nitrate (NO_3) before plants and animals can use it. High nitrate concentration is an indicator of anthropogenic inputs such as agricultural runoff containing fertilizer or manure. Aquatic nitrate can also come from point sources and the atmosphere. The relationship between nitrate and stream flow is highly variable. In some streams the concentrations of nutrients such as nitrate and phosphorus are higher during high flow and lower during low flow (Clark et al. 2000; Murdoch and Stoddard 1992; Mueller et al. 1995). In other streams, nutrient concentrations are elevated at low flow and higher flows tend to dilute them except in the first runoff after a storm (Allan 1995). The frequency of algal blooms is directly proportional to nitrate concentration. These blooms can consume so much DO at night that it is unavailable for fish, macroinvertebrates, and other aquatic organisms.

Total Phosphorus

Phosphorus is one of the most important nutrients for primary production in streams. Algae require nutrients in order to grow and reproduce. Phosphorus is important to plants because it is an essential component of ADP and ATP (energy molecules), nucleic acids, some coenzymes, phospholipids and in the phosphorylation of sugars (Steinman & Mulholland 1996). In streams where nitrogen and phosphorus are excessive, algae and macrophytes may become so abundant that they have a negative effect on the aquatic community. This situation is encouraged where riparian vegetation is depleted and the stream surface is frequently exposed to sunlight.

The only form of inorganic phosphate usable by aquatic plants is orthophosphate. When the concentration of a nutrient is below that needed to support plant growth, it is considered to be limiting. Most eastern US streams are phosphorus limited because they contain more nitrogen than the plants can metabolize given the low orthophosphate concentration. ProbMon water samples collected in the fall were analyzed for both total and orthophosphate (as phosphorus; Appendix C).

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the fecal matter of warm-blooded animals. High counts of fecal coliform bacteria in a stream indicate that feces have entered the stream presenting the risk of disease from pathogenic organisms. By the Virginia water quality standard, a stream cannot exceed a geometric mean of 200 colony forming units (cfu) per 100 ml when sampled two or more times over a calendar month. The instantaneous standard is no more than 10 % of the samples in a calendar month can exceed 400 cfu/100 ml. *Escherichia coli* is the new pathogen indicator for freshwater in Virginia and will replace the fecal coliform standard by 2008. The standard for *E. coli* is a geometric mean of 126 cfu/100ml and an instantaneous maximum of 235 cfu/100ml (State Water Control Board 2002).

3.2 CHEMICAL RESULTS

The water quality chemistry results presented in this section are based on data collected in the autumn of 2001. The sample station information is in Appendix B and the parameter list is in Appendix C. The full chemical data set is listed in Tables 1-6 in Appendix D. Although benthic macroinvertebrates and habitat were sampled at 63 sites in the spring (Figure 11), six of those sites could not be sampled for chemistry in the fall. Five were too dry to obtain water for chemistry samples and a sixth went unsampled. That left 57 sites plus a new site not sampled in the spring to be sampled for chemistry in the autumn; 58 chemistry sites. Thus, for comparisons between spring and autumn variables, only 57 stations can be used. The seasonal station count by stream order is noted in Table 3. Nine physical-chemical parameters are discussed in this section.

Figure 11. There were 63 stations sampled in the spring for macroinvertebrates and habitat, 58 sampled in the autumn for water chemistry, and 57 sampled in both seasons.

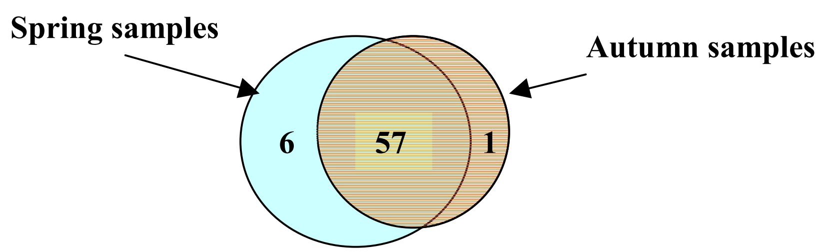


Table 3. Station count by sample season and Strahler stream order.

Strahler Stream Order	2001 Sample Sites			
	Spring Benthos & Habitat	Autumn Chemistry	Spring Benthos & Habitat only	Autumn Chemistry only
1	17	12	6	1
2	13	13	0	0
3	14	14	0	0
4	7	7	0	0
5	11	11	0	0
6	1	1	0	0
Totals:	**63**	**58**	**6**	**1**

pH Results

An efficient way to summarize data is the box plot. In this report the style used is a small square marking the median or middle value of the data. A large rectangle shows the range occupied by the middle 50% of the data; the range from the 25^{th} percentile to the 75^{th} percentile. Data within reasonable range of the median is marked by whiskers (Non-Outlier Max/Min). Finally, extreme observations and outliers are marked by special symbols.

Box plots for pH by stream order are graphed in Figure 12. Note that only one order 6 stream was sampled so its plotted value is the median. Also, only one value in the entire data set is an outlier, 4.9 SU in order 2. Because the max-min whiskers for all orders overlap, there is no statistical difference in pH between streams of different order. However, the medians suggest that pH increases from order 1 through order 4 streams and declines at higher orders. Future samples will help determine whether this is a consistent pattern.

The regulatory pH limit for most Virginia waterbodies is 6.0 – 9.0 SU. For some waters the limits are 6.5 – 9.5 SU. These boundaries are indicated with the box plots in Figure 12. Based on the data collected thus far, pH violations are rare in Virginia streams. Because the low order streams tend to have a whisker (Min) within the 6 – 6.5 SU zone, violations are more likely to be on the acid side and in low order streams.

CDF curves are designed to summarize data in a way that predictions can be made. In Figure 13 the pH data are summarized to facilitate generalizations about all non-tidal streams in Virginia. Based on the CDF curve, only 2% of sites sampled in the fall of 2001 had a pH below the lower regulatory limit of 6.0 and no streams exceeded the upper limit of 9.0 (Figure 13). The two sites with the lowest pH were in blackwater streams in southeastern Virginia where the pH is naturally low due to the leaching of tannins and other organics in these wetland-influenced streams. Recall that because the stations were selected randomly, the interpretation can just as well be in terms of the target population, all non-tidal streams in Virginia. That is, based on the data at hand, we could correctly estimate that in the fall only 2% of non-tidal streams have a pH below 6.0.

Figure 12. Boxplot of fall 2001 pH by Strahler Stream Order.

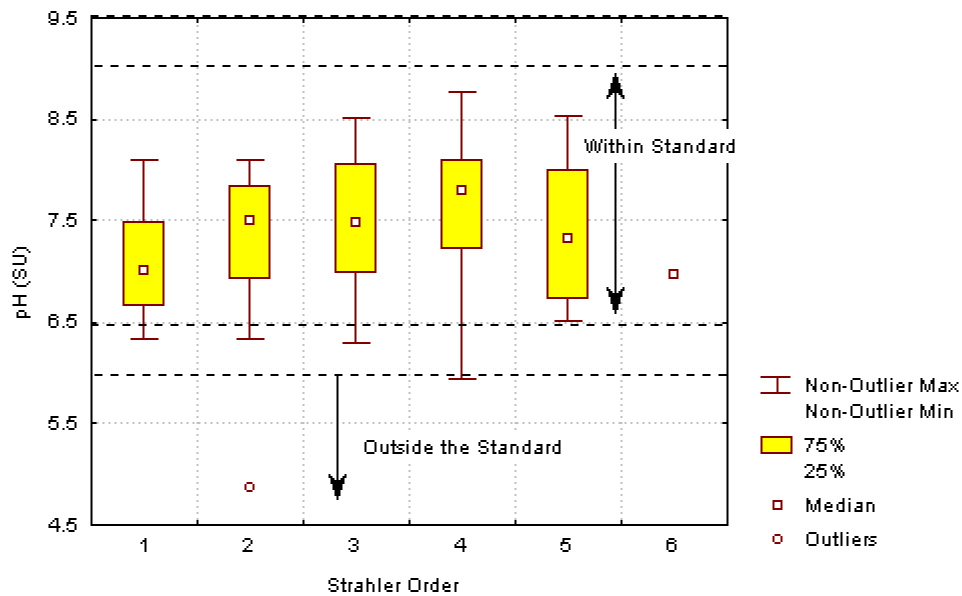
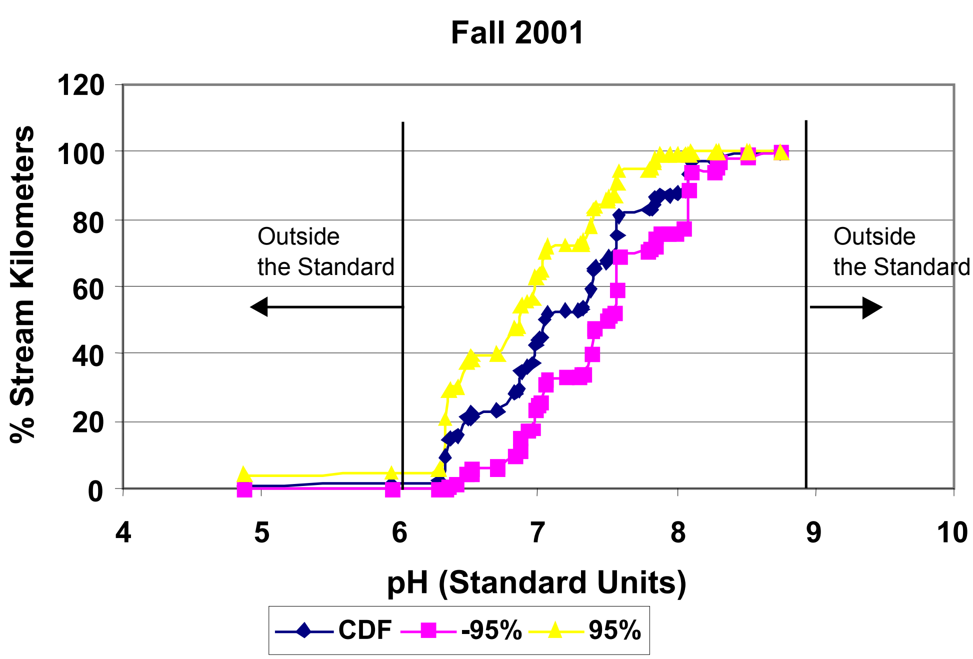


Figure 13. CDF curve of pH. The CDF curve is graphed as blue diamonds, the upper 95% confidence interval is the yellow triangles and the lower 95% confidence interval is the pink (red) squares. The typical water quality standards range for pH, 6-9, is shown.



The utility of the CDF curve is that probabilities can be directly determined from the figure because the vertical axis is a cumulative probability. That is, it shows the chance of a pH value being the same size or smaller than that listed on the horizontal axis. Assuming the data in Figure 13 is representative of all Virginia non-tidal streams, we can pose questions such as "What percent of Virginia non-tidal streams have a pH below the neutral pH value of 7.0?" To answer the question, on the figure draw a line up from the pH value of 7.0. Where the line intersects the diamond-symbol CDF curve, draw a horizontal line to the vertical axis. The value on the vertical axis is approximately 44%. Then, the answer to the above question is, "44% of Virginia non-tidal streams have a pH less than 7.0." Because the data set contains only 58 chemical measurements, there is error associated with the answer. The error can be found using the +/- 95% confidence interval in Figure 13. A vertical line drawn on the figure at a pH of 7.0 crosses the confidence interval lines at approximately 25% and 63%. This means the precise answer to the above question is between 25% and 63% of the streams have a pH less than or equal to 7.0 with 95% confidence.[2] Another way to express the answer is "We can be 95% confident that the percent of streams with a pH less than or equal to 7.0 is between 25% and 63%." This is a wide confidence interval; it is not very precise. As additional data are collected the interval should narrow significantly.

While the boxplots in Figure 12 reflect the distribution of pH in each stream order, from a regulatory standpoint one needs to focus on the results in terms of the standards. This focus is partially provided by Figure 14 where the pH measured in waters of each order is compared to the range 6.0 - 9.0 SU, the standard for most waters in Virginia. Importantly, no violations of the upper limit were measured in the fall of 2001. On a percent rank basis, violations were observed, especially in 2nd order streams. The right-most pair of bars in the figure represent the overall rank percentage exceedances weighted by stream order sample size. Overall, only a 1.52 rank percent of the streams exhibited a pH exceedance. In summary, pH violations in non-tidal waters are very infrequent in the fall and tend to occur on the acid end of the range.

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[2] When setting upper and lower limits for a statistic, a certain percent of the time the parametric value of the statistic will be contained within those limits. Thus, a 95% confidence interval in the figure suggests that in 95 out of 100 times we collect data and construct the intervals, they will cover the statistic. It is incorrect to say the statistic is contained in the interval 95% of the time; the interval changes, not the statistic (Sokal & Rohlf 1981).

Figure 14. pH values outside of Virginia's typical pH standards range. The right-most category is the overall estimate based on a weighted average of the values for the orders.

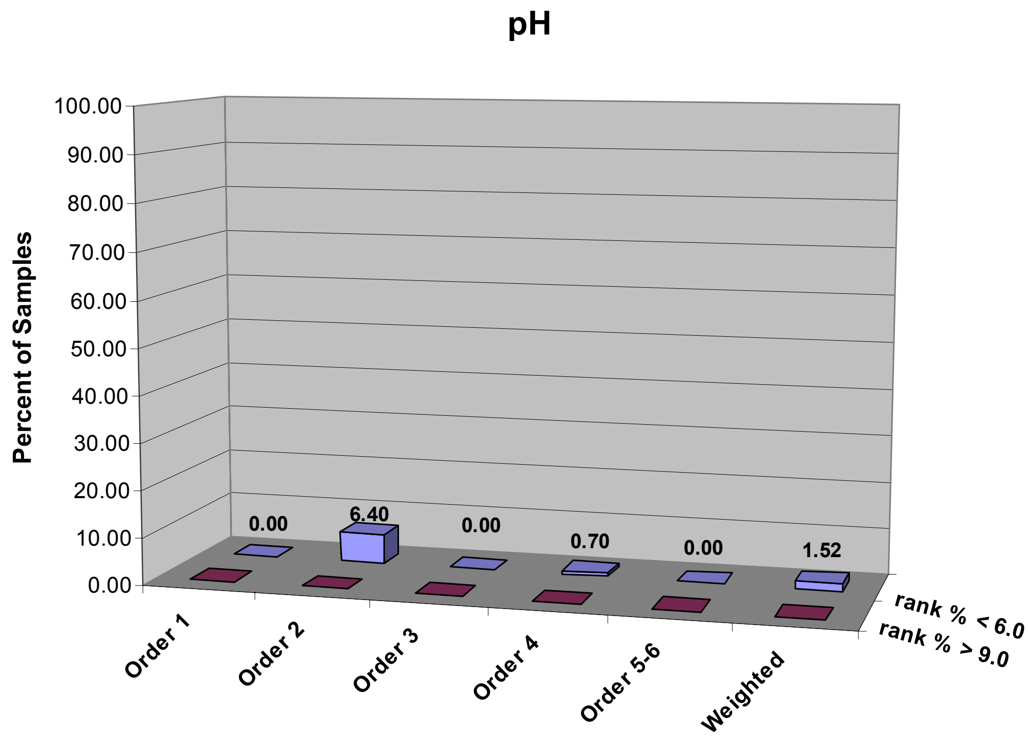
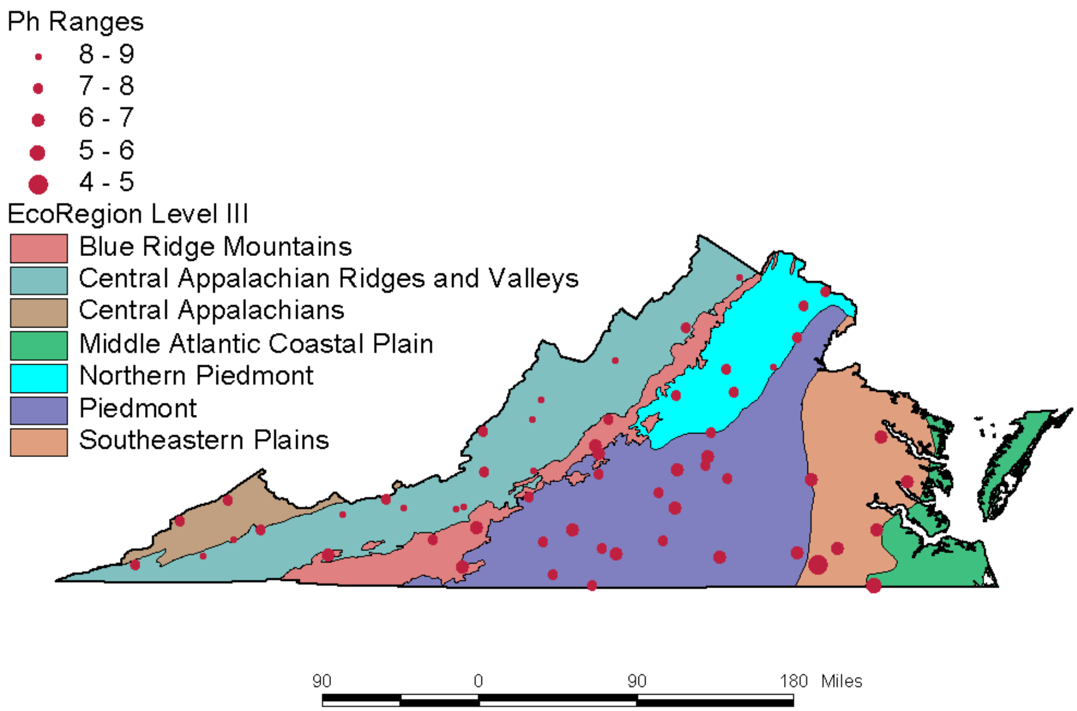


Figure 15 shows the spatial distribution of pH. The map suggests there may be more acidic streams in the coastal and Piedmont ecoregions and more basic streams in the Central Appalachian Ridges and Valleys ecoregion. The basic streams appear to be related to the basic nature of the bedrock in those ecoregions.

Dissolved Oxygen Results

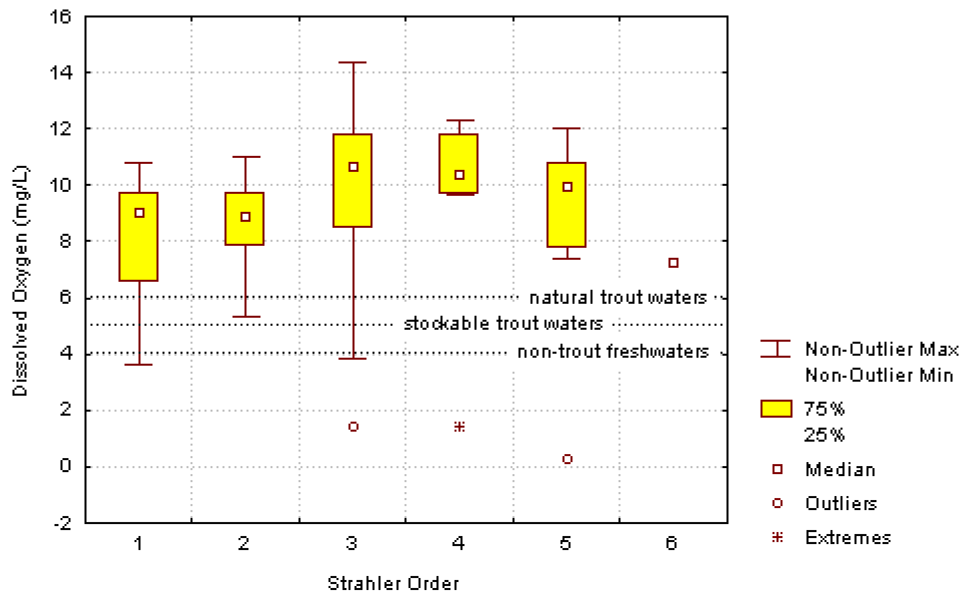
Box plots for DO by stream order are graphed in Figure 16. Note that there are two outliers and one extreme value, all on the low DO side. Only one 6th order stream was sampled, so in all box plots its position on the figure is represented by a median. Because the Max-Min whiskers for all orders overlap, there is no statistical difference in DO between streams of different order. However, excepting order 6, 1st and 2nd order streams exhibited the lowest median DO in the fall of 2001, a drought year. These small streams appear to be affected more than higher order streams by the current extreme drought and resulting reduced reaeration.

Figure 15. Spatial distribution of pH.



In terms of range, 3rd order streams exhibit the largest DO variation while 4th order streams varied the least. From low to high stream order the water surface area is progressively smaller smaller compared to the volume so that reaeration is less effective in replacing consumed oxygen. This may explain the decrease in median DO from 3rd to 6th order streams. A possibility discussed in the Temperature Results section is that the larger streams also have less overhead canopy leading to higher temperature from insolation and decreased DO solubility.

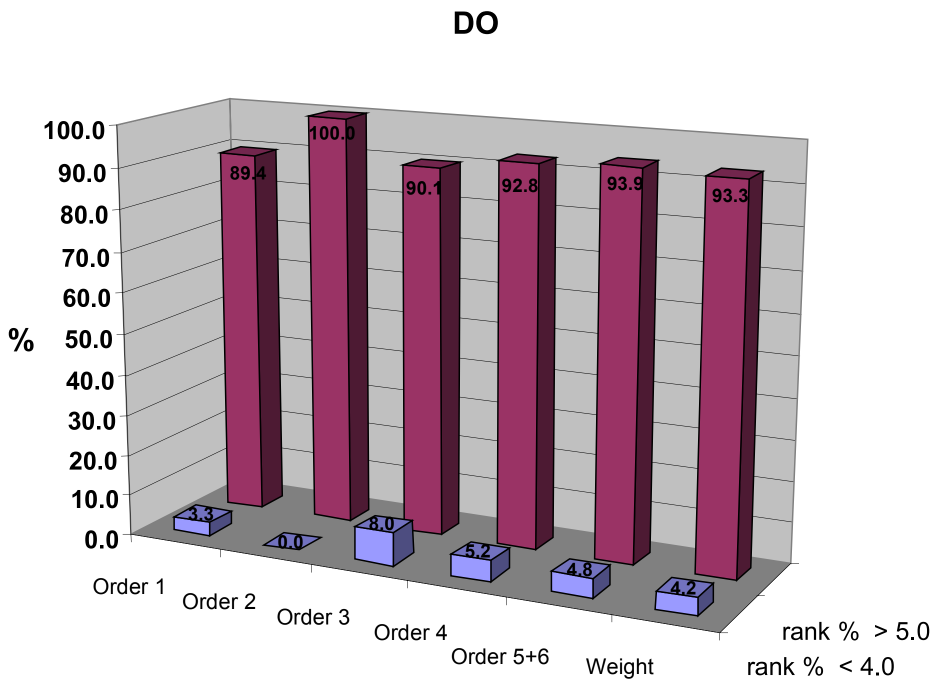
Figure 16. Boxplot of fall 2001 dissolved oxygen data by Strahler Stream Order showing the minimum instantaneous DO threshold for three classes of Virginia waters.



Three regulatory limits for DO are shown as dotted lines in Figure 16. Based on data collected thus far, occasional DO excursions are expected in all waters regardless of stream order. On a kilometer-length basis, 65% of Virginia's streams are 1st order (Appendix G, Table G1). So it is of concern that the DO minimum for 1st order streams extends outside the acceptable zone. If this pattern is maintained in the future, it will be possible to estimate the percent of order 1 streams that exceed the standard. Meanwhile, standards excursions were recorded in most stream orders.

While the boxplots in Figure 16 focus on the distribution of DO by stream order, from a regulatory standpoint one needs to focus on potential standards violations. This is partly satisfied by Figure 17 where the DO measured in waters of each order are compared to the DO thresholds 4.0 and 5.0 mg/L. A DO of 4.0 mg/L is the lowest value permitted in streams of the Commonwealth (Table 2). The front row of bars indicate the rank percent of non-tidal waters that exceed this threshold. On this basis we can say, for example, that at least 3.3% of 1st order streams violate the instantaneous standard. We make the qualification 'at least' because some 1st order streams have a higher water quality standard than 4.0 mg/L. The back row of bars in the graph relate to stockable trout waters which must have DOs of 5.0 mg/L or better. From the figure, 88% of 1st order streams meet that requirement. Now, if all the data making up a bar came from stockable trout streams, we could say the height of a bar represented the percent meeting the standard. But, streams with DO standards of 5.0 mg/L or higher are much less common in Virginia than classes with a lower DO standard. Thus, for each stream order, the percent meeting the instantaneous DO standard is probably higher than that listed in Figure 17.

Figure 17. Rank percent of waters with DO below 4.0 mg/L or above 5.0 mg/L.



An estimate of overall exceedance of the DO standards is sought through the CDF curve. The CDF curve in Figure 18 suggests that approximately 9% of Virginia stream kilometers have fall DO concentrations below 4 mg/L. The 95% confidence interval for that estimate is 0% to 18%. In other words, we can be 95% certain that this range includes the real percent. The range will narrow as more data is collected. Another kind of question that can be answered using the figure is "What fraction of the streams have a DO concentration of 7.0 or better?" The answer depends on realizing that the vertical axis probabilities in Figure 18 are cumulative probabilities. Then, from the figure, if 27% have a DO of 7.0 or less, 100%-27% or 73% have a DO of 7.0 or more. The answer is "In the fall, 73% of the streams have a DO of 7.0 or greater." The answer relative to a DO of 7.0 has importance in that the DO fluctuation during a 24 hour period is generally no more than 2 mg/L. If the daytime DO is 7.0, the early morning minimum is probably not below 5.0, the minimum for stockable trout waters. Thus, based on the daytime fall temperatures measured at ProbMon sites in 2001, 73% of the streams will have a daytime DO of 7.0 or greater and will probably not violate the DO standard for stockable trout waters any time during a 24 hour period.

Figure 18. CDF curve of dissolved oxygen.

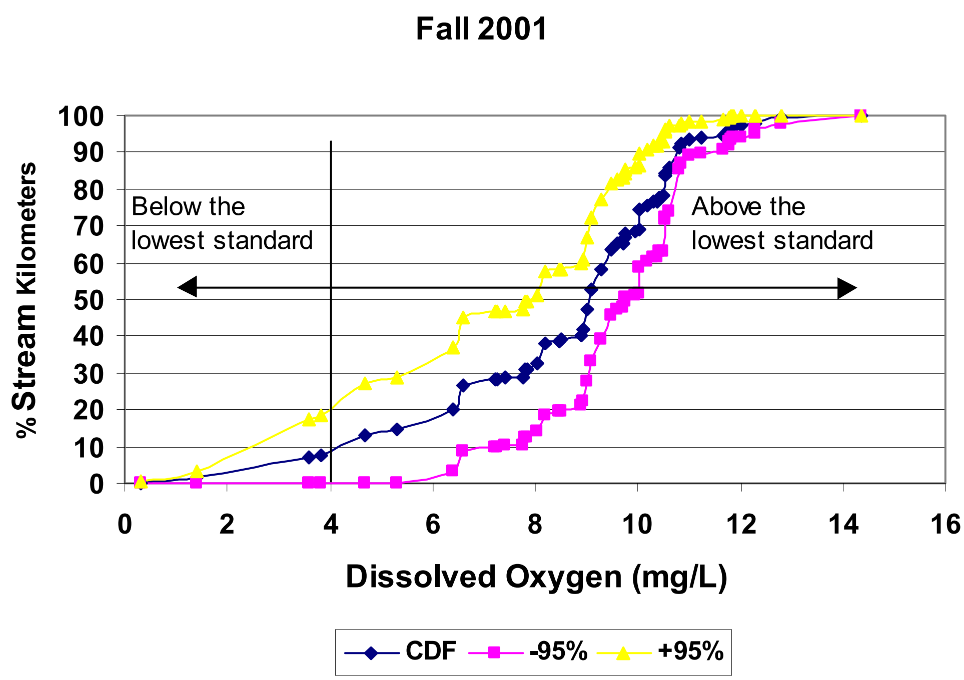
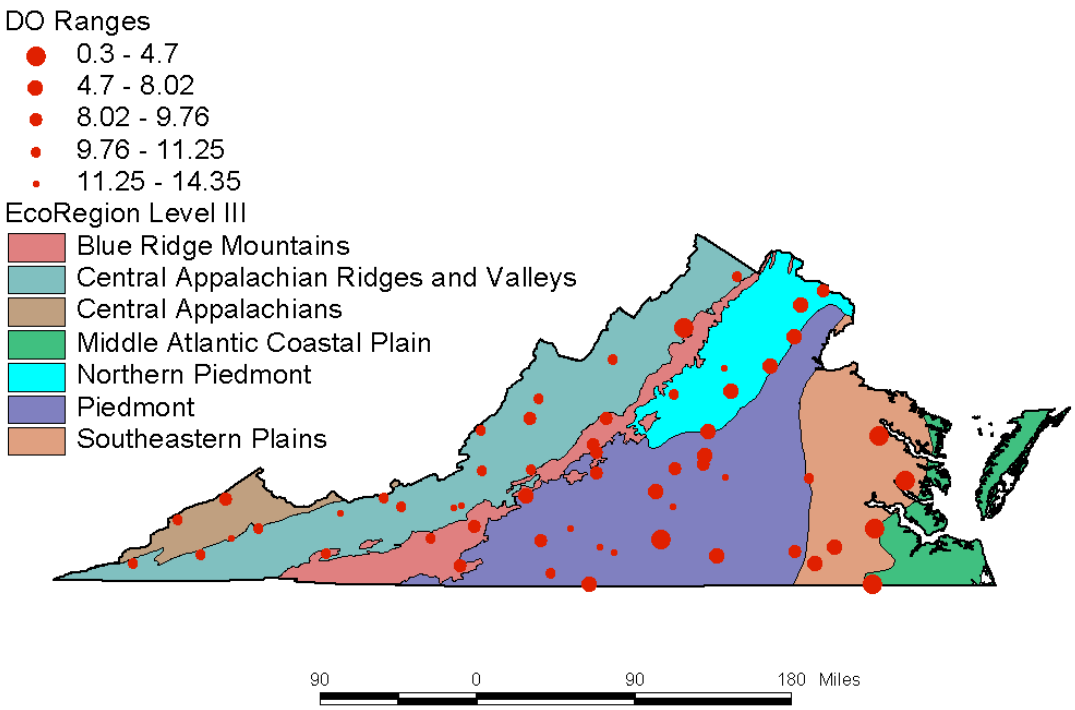


Figure 19 displays the DOs measured across Virginia where larger dots signify lower DO. Several low concentrations occur in the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions. The few extremes are from the piedmont and tidewater areas. Streams in the east typically have a lower gradient so that snags, leaf packs, and fine sediments dominate the habitat. Lower gradient streams are slower moving and therefore have lower reaeration and DOs. In addition, as noted in the next section, median temperatures are higher in the Piedmont and Southeastern Plains ecoregions. Because these eastern waters have lower DO solubility they are expected to have lower DO concentrations.

Figure 19. Spatial distribution of dissolved oxygen.



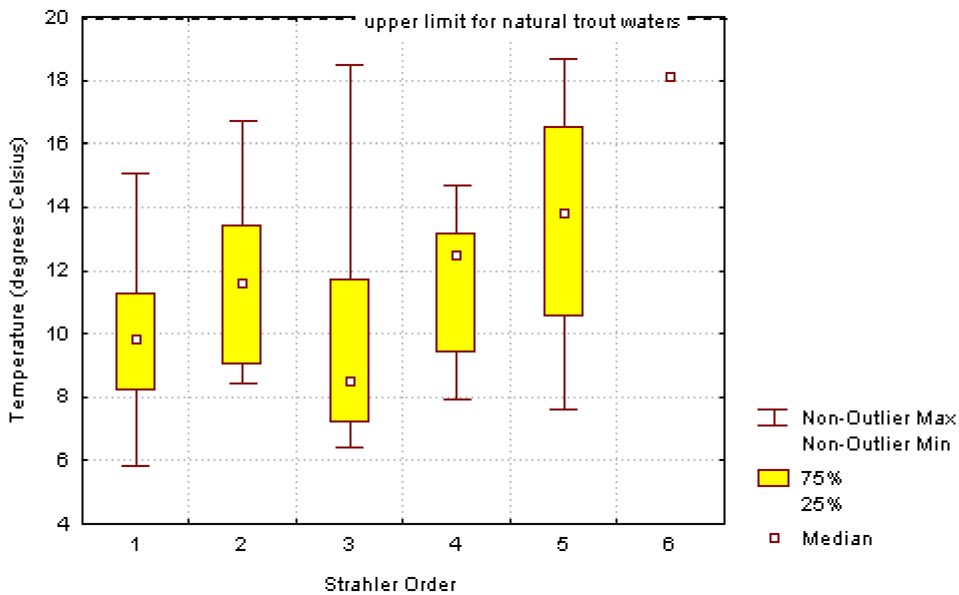
Temperature Results

Boxplots of temperature by stream order are presented in Figure 20. The figure suggests there is an increasing gradient of temperature with increasing stream order. The results were not unexpected given the geographic location of the stations and the season. The highest temperatures were recorded in 6th order streams. This is expected for reasons similar to those for DO such as less cover and therefore less shelter from insolation. Also, the groundwater supply to these streams is cooler than the air in the fall. Thus, stream waters are likely to be warmer farther from their source; in higher order streams. Again, as for DO, 3rd order streams have high variation. Whatever the cause, the wide temperature variation corresponds to and may drive the wide DO variation in 3rd order streams. Additionally, the variability shown in Figure 20 is expected to be high relative to that in the summer or winter when temperature plateaus. Similar variation patterns may be expected in DO.

Virginia's instantaneous temperature standards are maximums. That is, a violation occurs when the waters exceed the values listed in Table 2. The lowest temperature threshold is

20°C, the maximum for natural trout waters in Virginia. Based on the boxplot, none of the stream orders exceeded the 20°C threshold although 3rd and 5th order streams have maxima in that neighborhood. These results are summarized by the CDF curve.

Figure 20. Boxplot of fall 2001 temperature data by Strahler Stream Order.



Based on the CDF curve in Figure 21, all ProbMon sites had fall temperatures below 20°C. Thus at this time of the year non-tidal streams in Virginia are expected to meet all instantaneous temperature standards including that for natural trout streams (Table 2). It is important to note that the measurements were made in September and October when stream temperature is declining from the summer maximum. Meanwhile, the temperature standards were established to protect aquatic life during extreme conditions that, for stream temperature, usually occur between June and September. Thus the absence of temperature violations is not surprising.

Figure 22 is a display of relative temperatures across the State. Large dots indicate locations where water temperature was higher in the fall of 2001. Based on Figure 22, higher temperatures are found in the Piedmont and Southeastern Plains ecoregions. Stream temperatures are expected to be higher in these areas based mainly on land use. The mountainous ecoregions, that is, the Central Appalachians and Appalachian Ridges and Valleys, tend to have lower temperatures because the streams are more rural or forested with more natural inputs.

Figure 21. CDF curve of temperature.

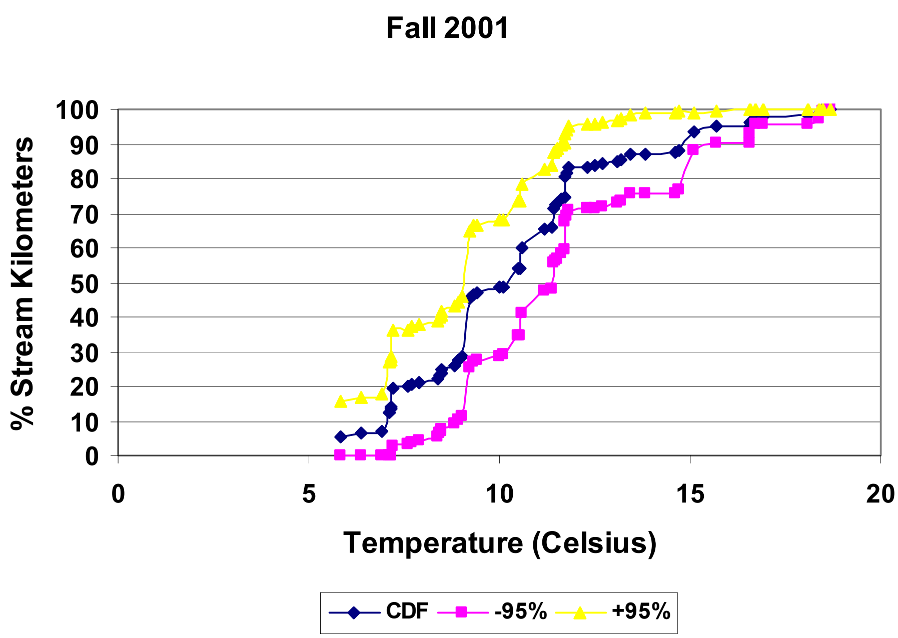
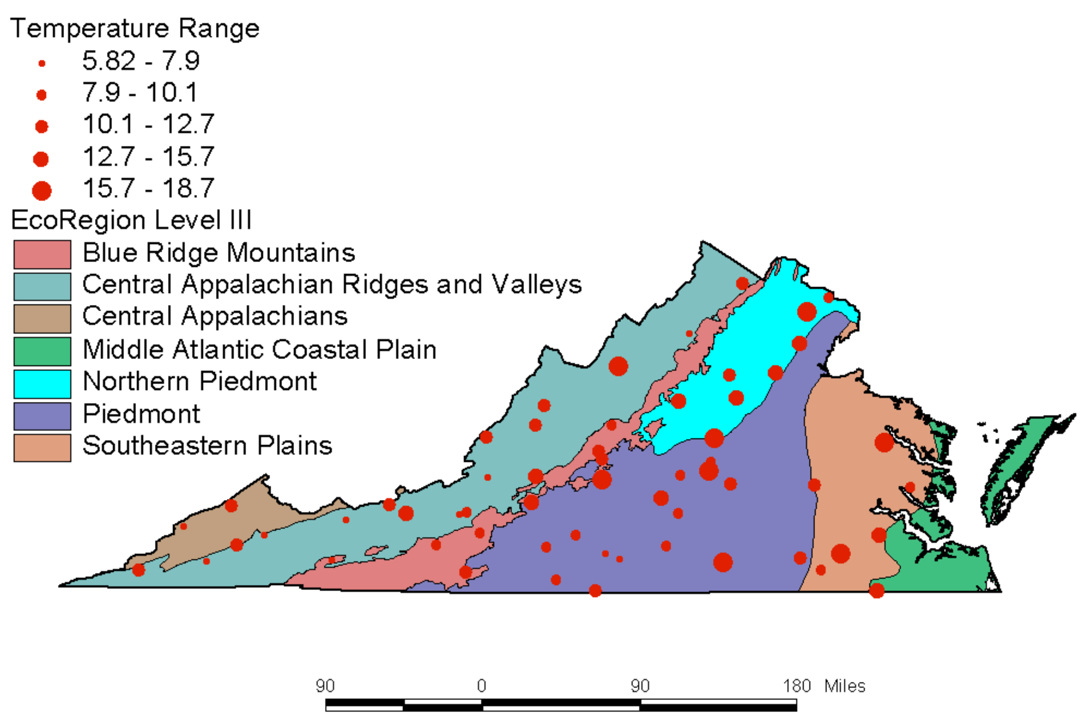


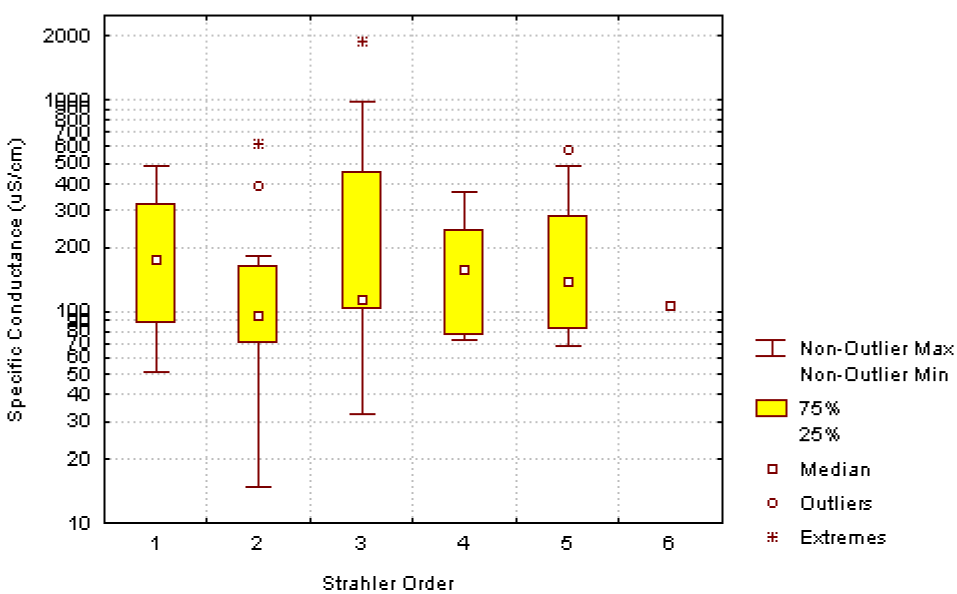
Figure 22. Spatial distribution of temperature.



Specific Conductance Results

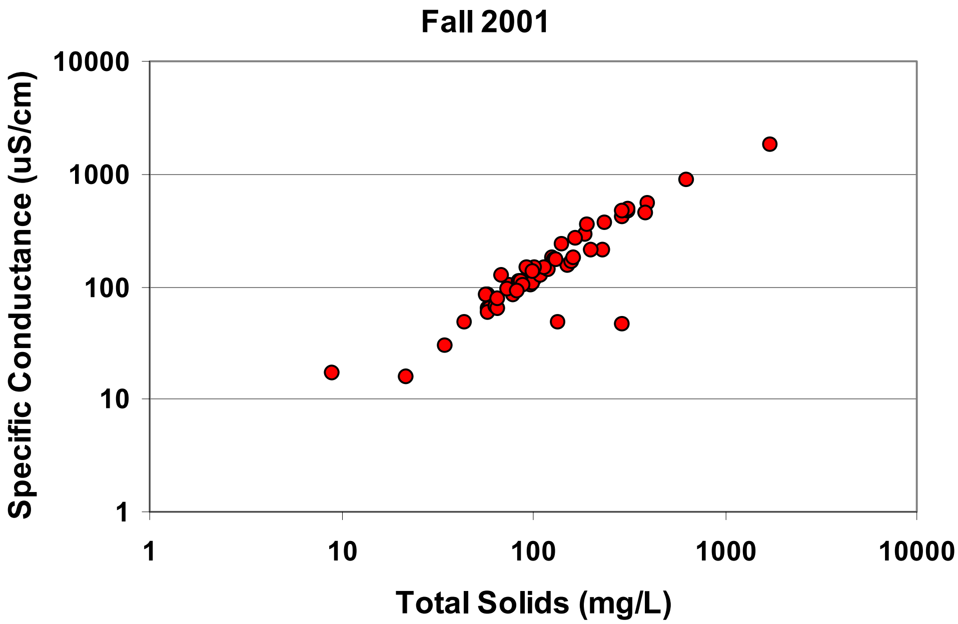
The specific conductance data from fall 2001 are summarized by stream order in Figure 23. Note that the vertical axis is logarithmic so a small vertical change in the upper part of the figure represents a large change in specific conductance compared to the lower part of the figure. A few outliers and extremes were measured including the two highest values 1,891.0 and 979.0 µS/cm. There is some difference in range of values with 3rd order streams having the broadest range as was true for DO and temperature. Overall, Virginia's non-tidal streams have relatively low specific conductance. Not unexpectedly, sites with high specific conductance usually had high total solids (Figure 24).

Figure 23. Boxplot of the logarithm of specific conductance by Strahler Stream Order.



There is no specific conductance standard for surface waters in Virginia to compare to the results. However, as mentioned in 3.1 Chemical Background, specific conductance tends to be related to productivity. Thus, the least productive streams in the Commonwealth may typically be 2nd order.

Figure 24. Correspondence of specific conductance and total solids in non-tidal streams.



The CDF curve for specific conductance in Figure 25 initially ascends steeply and then flattens out. This is due to two values being markedly higher than the others. The two extremes are the right-most points in the graph. The figure also shows that nearly 100% of Virginia's stream miles have specific conductance below 700 µS/cm.

Figure 25. CDF curve of specific conductance.

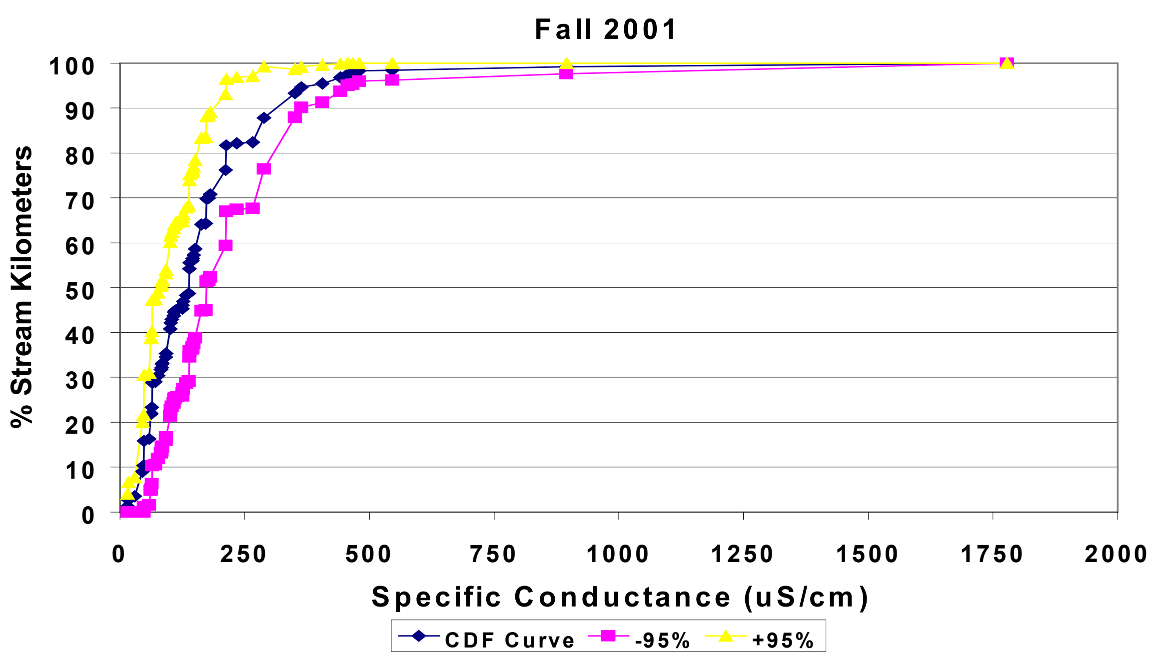
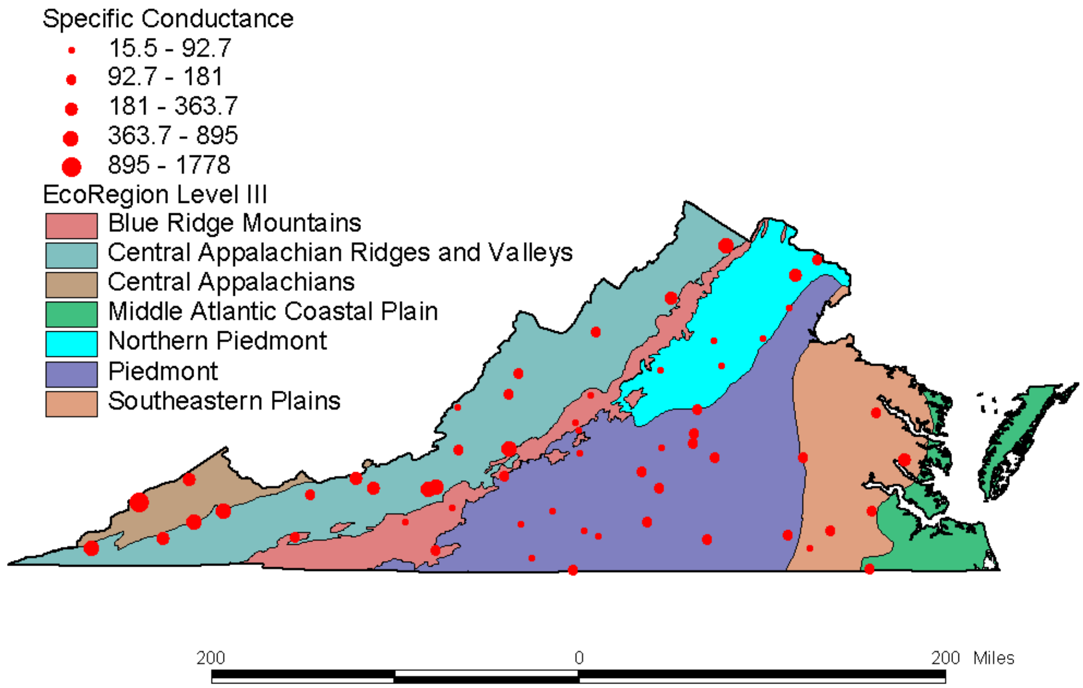


Figure 26. Spatial distribution of specific conductance.

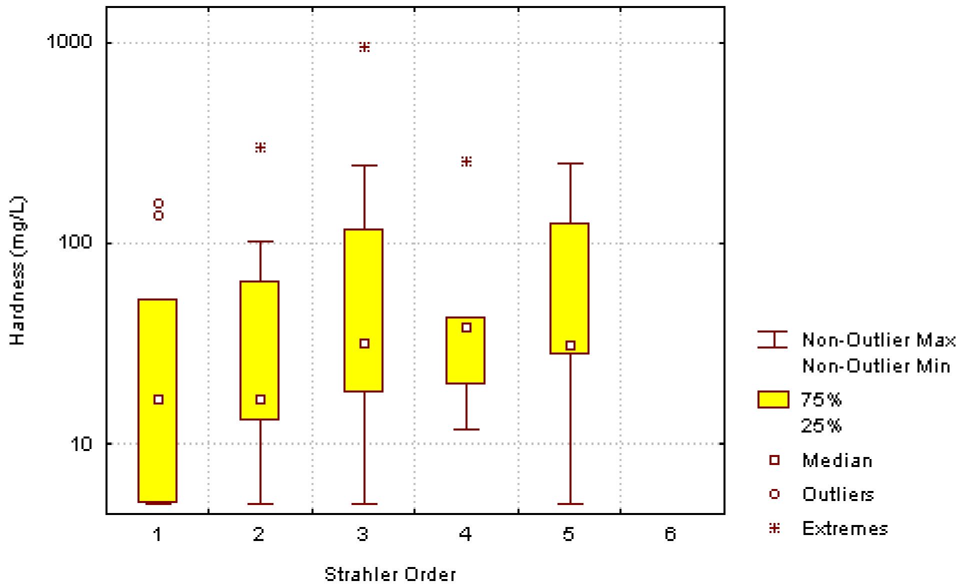


The distribution of specific conductance across the Commonwealth is shown in Figure 26. The concentration of high specific conductance sites in the Central Appalachians and Central Appalachian Ridges and Valleys ecoregions suggests a geologic uniqueness in those areas. Streams flowing over limestone and or through karst topography tend to have high specific conductance. So the large dots in the figure may signify these lithologies. There may be some relation to land use as well although there is insufficient information to form conclusions.

Hardness Results

The difference in hardness by stream order is indicated in Figure 27. Because of the wide variation in the data a logarithmic scale is used on the vertical axis. There are no surface water standards for hardness in Virginia. But there are groundwater standards dependent on physiographic area. The upper limits are 120 mg/L for the Coastal Plain, Piedmont, and Blue Ridge Mountains, 300 mg/L for the Valley and Ridge complex, and 180 mg/L for the Cumberland Plateau. Although these standards do not apply to the ProbMon stream measurements, they may be used to suggest whether the source has appropriate water quality.

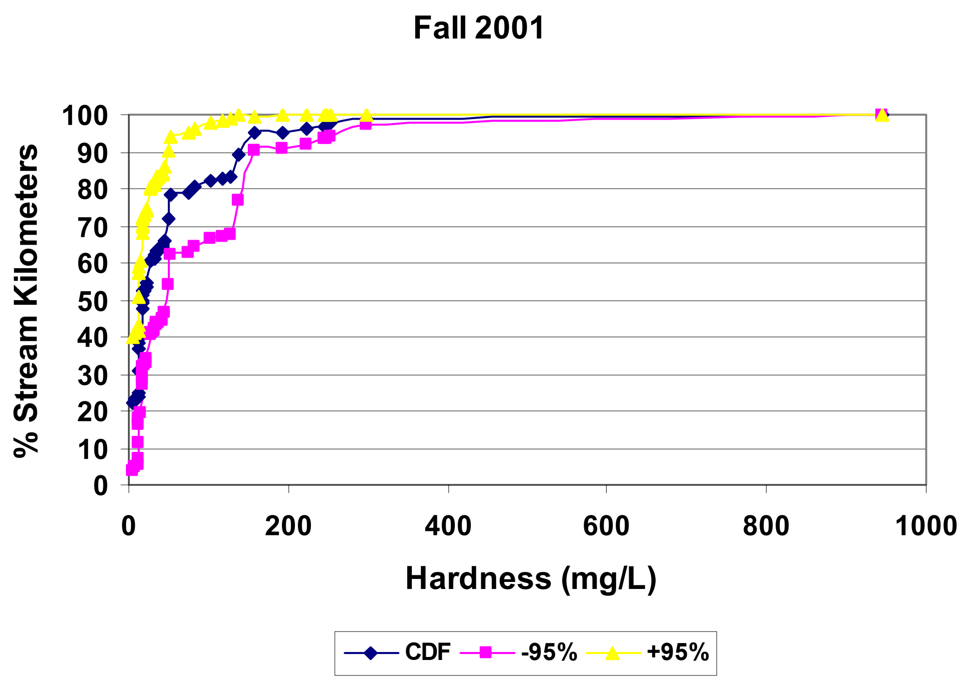
Figure 27. Boxplot of the logarithm of fall 2001 hardness by Strahler Stream Order.



During a drought such as the one in the sample year, nearly all stream water originates from groundwater. Then, especially in first order streams where the natural chemical alteration of the water has been minor, stream hardness can indicate whether the groundwater standard is likely to be met in the source. From Figure 27, 1st order non-tidal streams rarely exceed the groundwater hardness standards suggesting that non-tidal groundwater sources usually meet the hardness standard. In terms of variability, 3rd and 5th order streams have the widest hardness range. Also, following the median across orders suggests a trend of rising hardness with stream order.

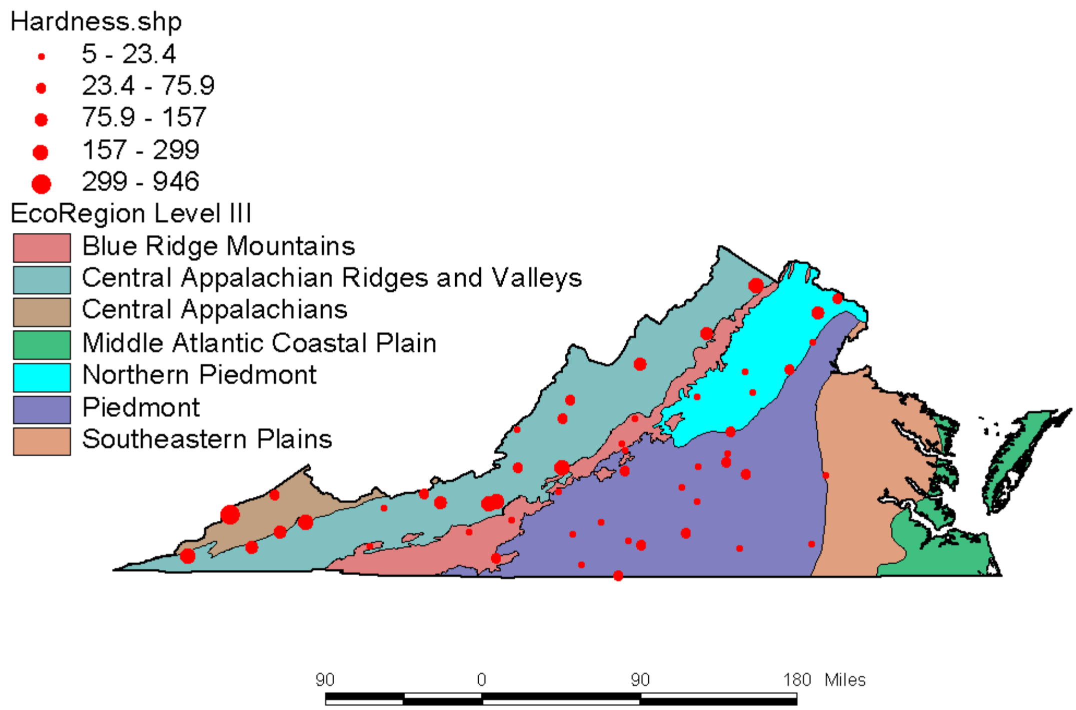
Hardness has importance in terms of domestic and commercial use. By one convention, 25 mg/L is the break between soft and hard waters. Based on this break, the CDF graph in Figure 28 suggests that 54% of non-tidal streams are soft (≤ 25 mg/L) and the remainder are hard; an approximate 50:50 ratio. The 95% confidence interval for 25 mg/L hardness indicates that the actual percent of soft streams is between 34% and 75% with 95% confidence. This is a rather wide range that will narrow as more data is collected.

Figure 28. CDF curve of hardness.



Stream hardness is mapped across Virginia in Figure 29. Waters in the western third of the State (Central Appalachians and Central Appalachian Ridges and Valleys) which have high specific conductance are also hard waters.

Figure 29. Spatial distribution of hardness data.

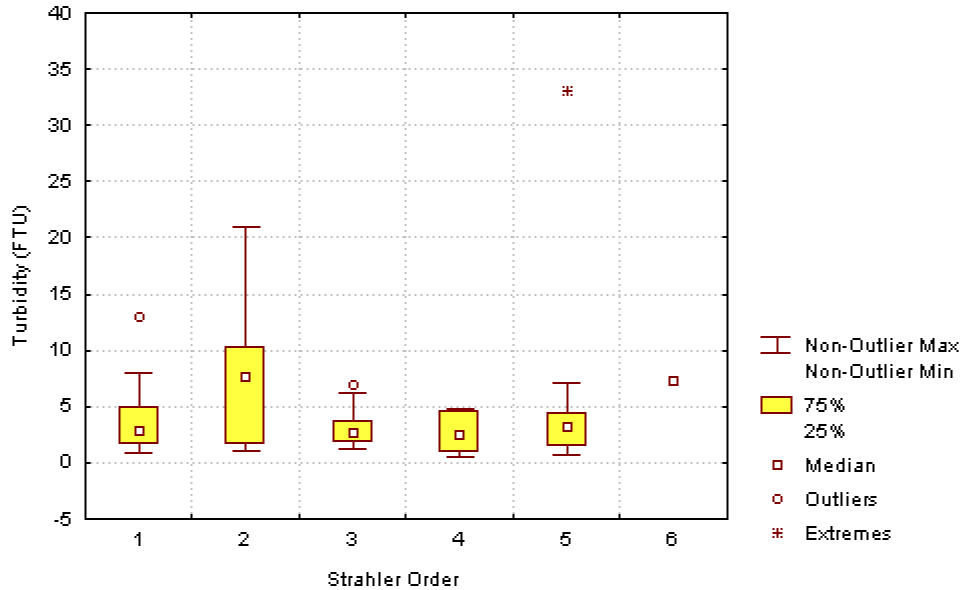


Turbidity Results

The boxplot for turbidity shows one unusual feature: order 2 streams have relatively high turbidity and the broadest turbidity range. The median is more than twice that of stream orders one through five. It is expected that there are more crop fields and eroding banks devoid of riparian vegetation bordering order 2 streams. Although the high turbidity may be a symptom of the land use bordering 2nd order streams, the proof is left to future reports.

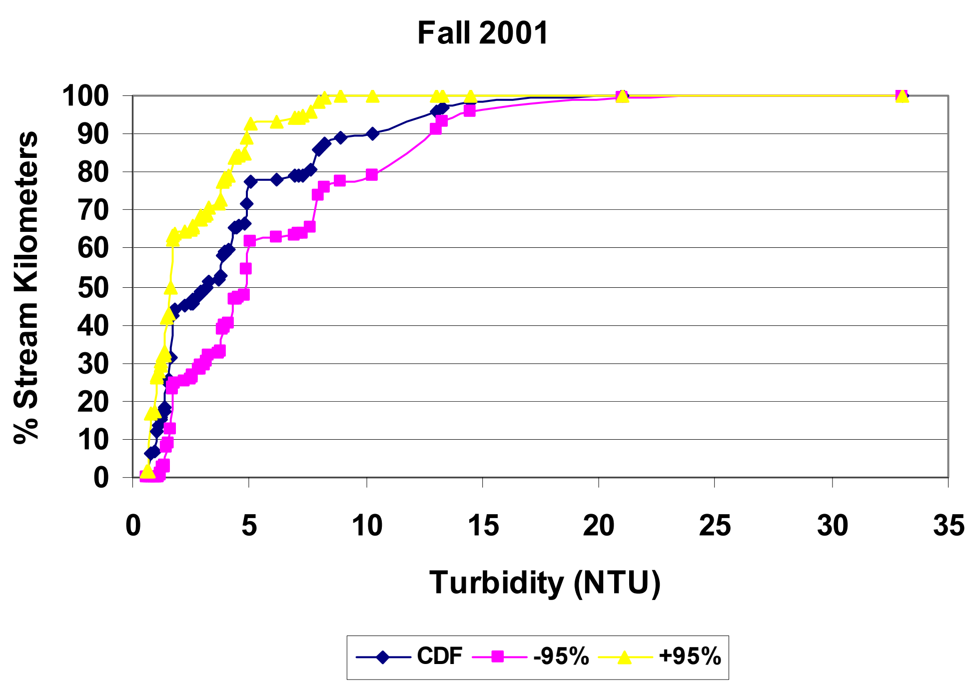
Virginia does not currently have a water quality standard for turbidity. The USEPA may incorporate it into a future standard for water clarity. Meanwhile, if Virginia waters exhibit turbidity problems they are mainly in 2nd order streams.

Figure 30. Boxplot of fall 2001 turbidity data by Strahler Stream Order.



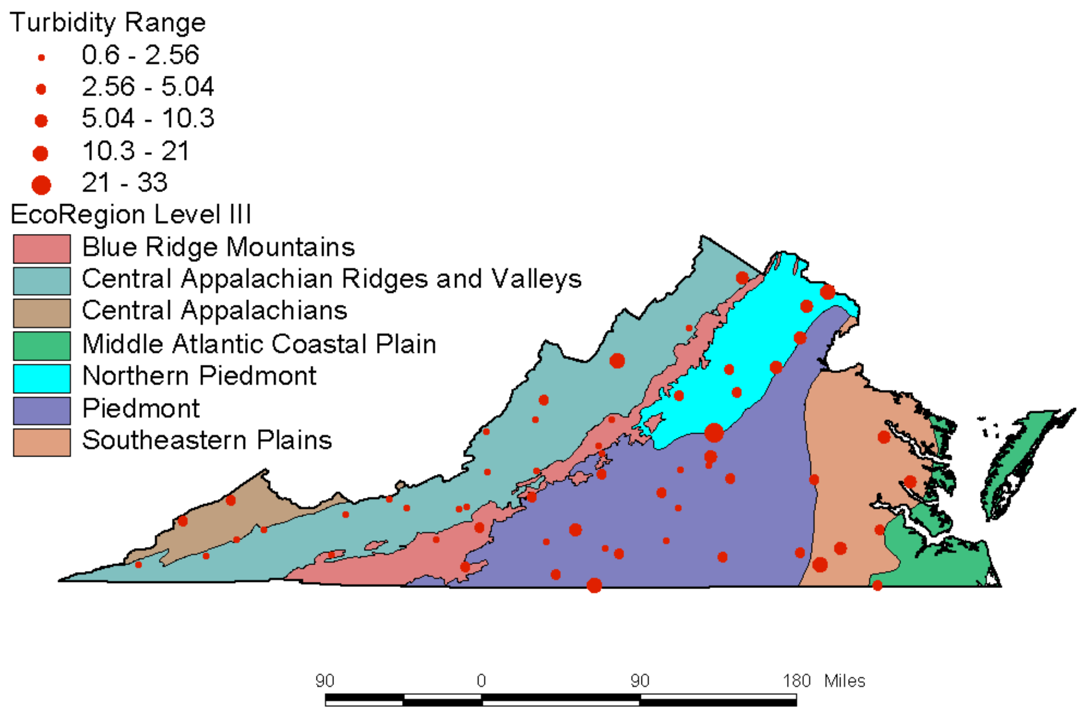
The overall distribution of turbidity in non-tidal waters is graphed in Figure 31. The figure supports the contention that turbidities above 12 NTU are rare; only 5% of Virginia non-tidal streams have turbidities higher than 12 NTU. Graphs such as Figure 31 have utility if a turbidity standard is considered for Virginia's streams in the future.

Figure 31. CDF curve of turbidity data.



Based on Figure 32, there is no clear geographic concentration of turbidity. High and low values are scattered across the Commonwealth irrespective of ecoregion and geography.

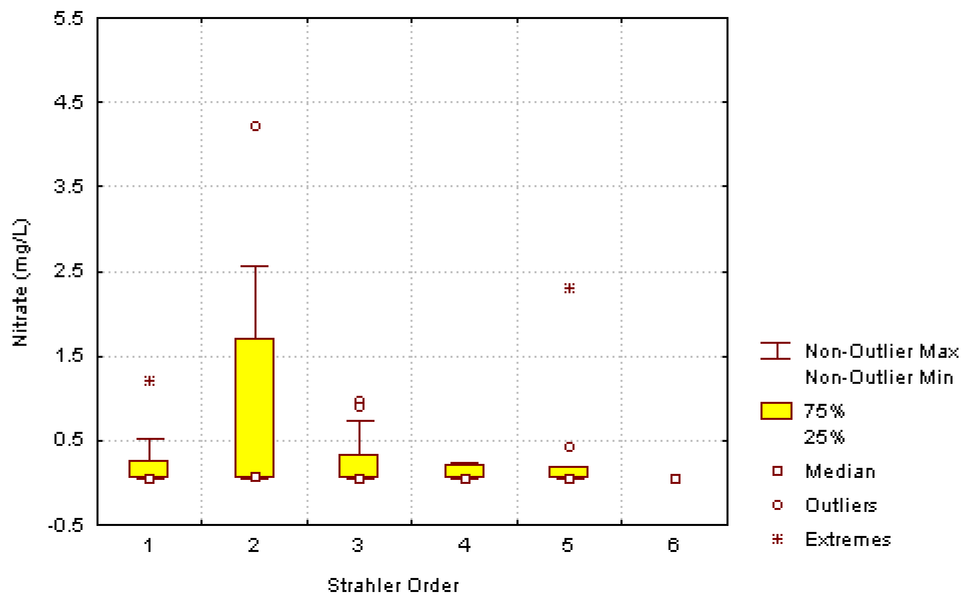
Figure 32. Spatial distribution of turbidity data.



Nitrate Results

Nitrate was chosen as the parameter to describe nitrogen conditions in streams of the Commonwealth. Several other nitrogen forms were sampled. Similar to turbidity, nitrate is much more variable in 2^{nd} order streams than in other orders (Figure 33). Because nutrients and sediments wash off landscapes after a rain event, the high variability for nitrate and turbidity in 2^{nd} order streams suggests streams of that size are especially affected by non point source runoff. In general, higher order streams appear to be buffered from nitrate inputs.

Figure 33. Boxplot of fall 2001 nitrate data by Strahler Stream Order.

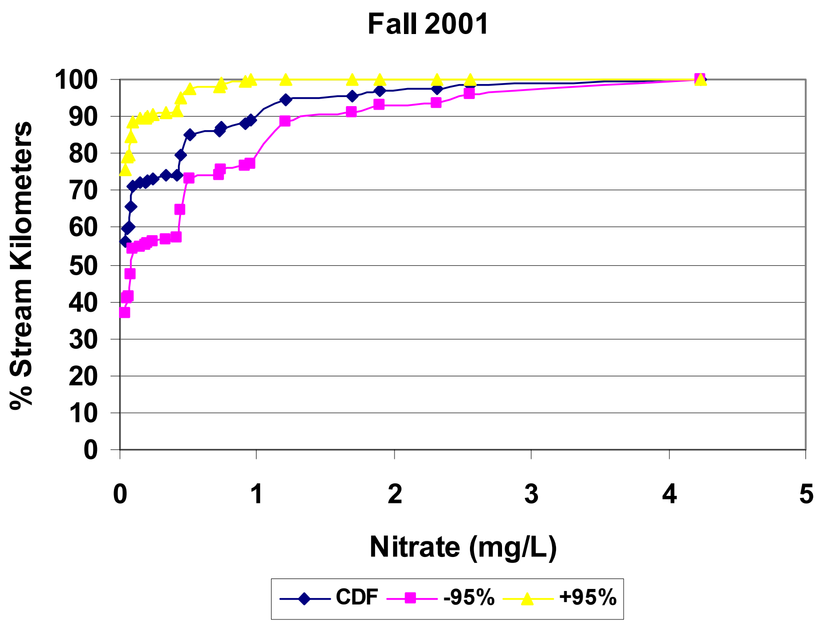


The nitrate standard for public water supplies (PWS) is 10.0 mg/L in Virginia. In general, waters classified as PWS are 5-mile stretches of water and occur infrequently. Then, though it is unlikely that a ProbMon station occurred in a PWS, we can still observe that non-tidal streams entirely meet the PWS criterion.

The overall distribution of nitrate values is graphed in Figure 34. The initial steep rise in the CDF curve represents about 50% of the data that were at or below the analytical method limit of detection (0.04 mg/L). Only 15% exceeded a nitrate value of 0.5 mg/L, and 11% (6 samples) exceeded 1.0 mg/L. If stations with concentrations above 1.0 mg/L are bordered by agricultural land use, it would be interesting to sample them in the spring season after the fields have been fertilized.

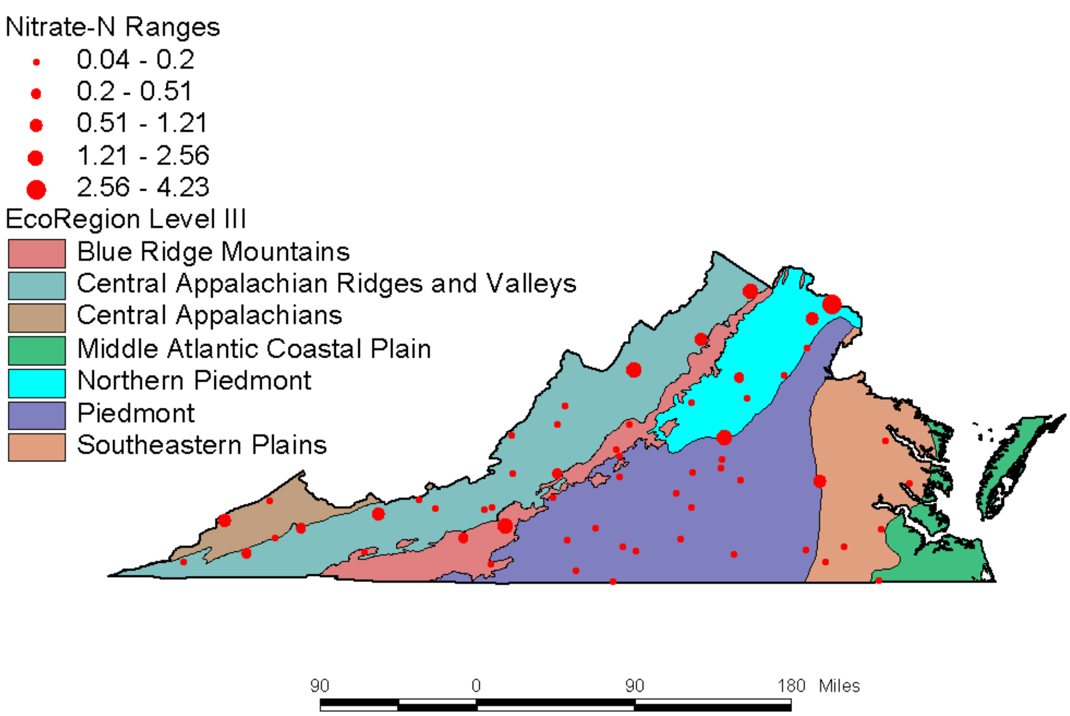
There is no nitrate or nitrogen standard for non-PWS surface water segments in Virginia. But the CDF curve and boxplots for nitrate provide useful perspectives should Virginia consider establishing limits for waters in general. The box plots indicate the high nitrate concentrations will more often be in 2nd order streams, the scale at which controls would have to be used. It is important to emphasize that the nitrate measurements herein represent ambient, base flow concentrations during a drought year. Concentrations in wet years may be very different, and values immediately after a storm can be much higher.

Figure 34. CDF curve of nitrate data.



Based on the map in Figure 35, nitrate concentrations do not exhibit a geographic pattern across the State.

Figure 35. Spatial distribution of nitrate data.

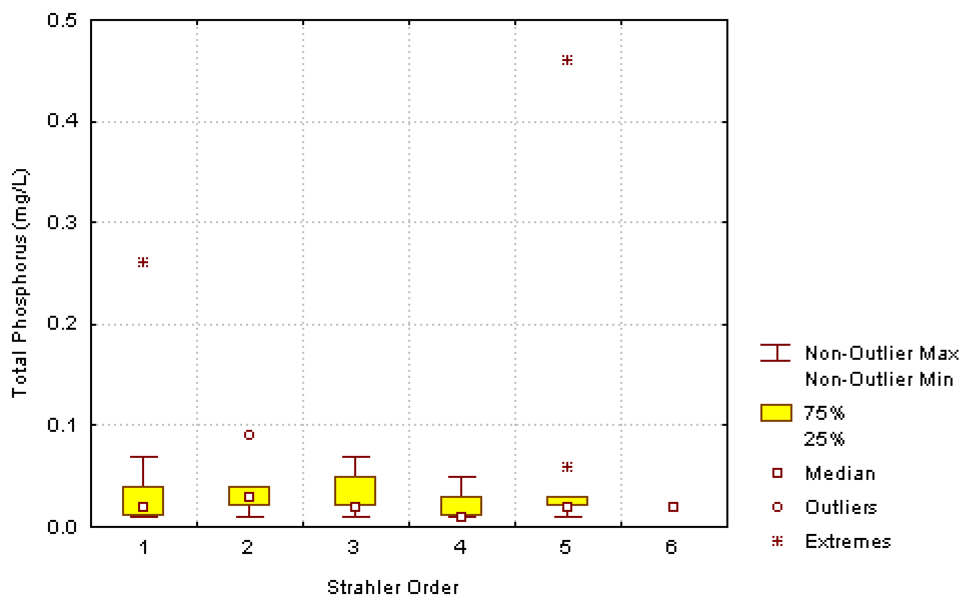


Total Phosphorus Results

Both total phosphorus and orthophosphate were measured in ProbMon chemistry samples collected in the fall of 2001. Based on the discussion section orthophosphate is the important form to evaluate. However, most values were at the detection level of 0.02 mg/L. Consequently, the results for total phosphorus are discussed here (Appendix D, Table 3).

In the biennial 305(b) assessment of State waters the VDEQ uses a total phosphorus threshold of 0.20 mg/L in the absence of a State-wide standard for free-flowing streams (VDEQ 2002). Waters exceeding the threshold meet water quality standards but are considered threatened to some degree by upstream sources of nutrients. For the autumn data there were only three instances of total phosphorus concentrations above the threshold (Figure 36). The remaining 55 waters had autumn values well below the threshold.

Figure 36. Boxplot of fall 2001 total phosphorus data by Strahler Stream Order. To show detail, a 3.05 mg/L extreme in an order 2 stream was not plotted.



The CDF curve for total phosphorus rises steeply and then levels off to the three highest measurements (Figure 37). In other words, all but a few streams have total low total phosphorus. Based on the data, 93% of Virginia's non-tidal streams carry 0.09 mg/L or less of total

Figure 37. CDF curve of total phosphorus data. To show the detail on the left end of the graph a 3.05 mg/L value was not plotted.

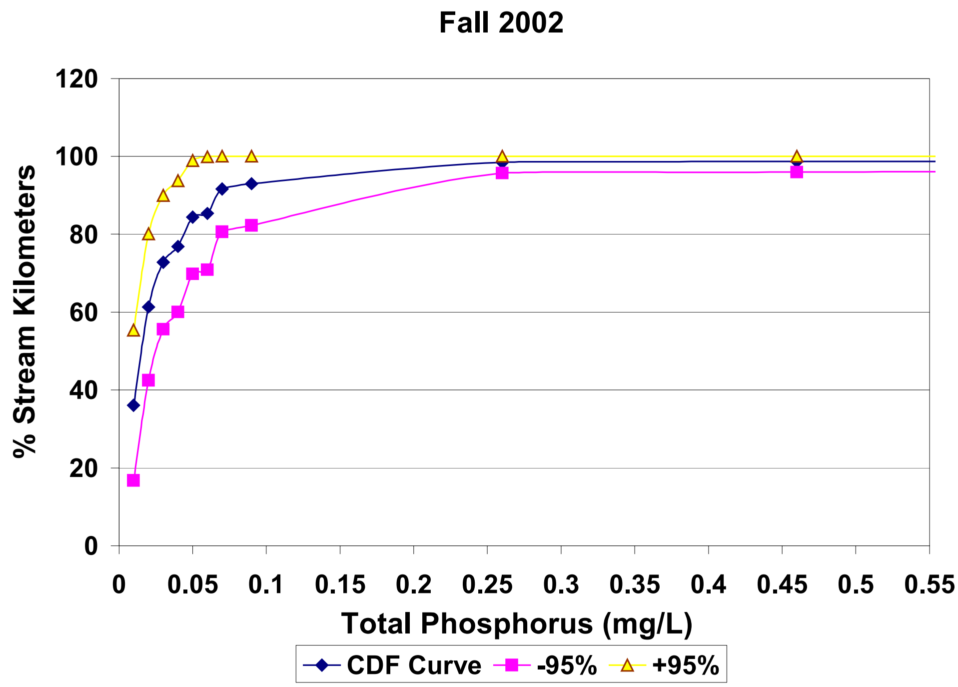
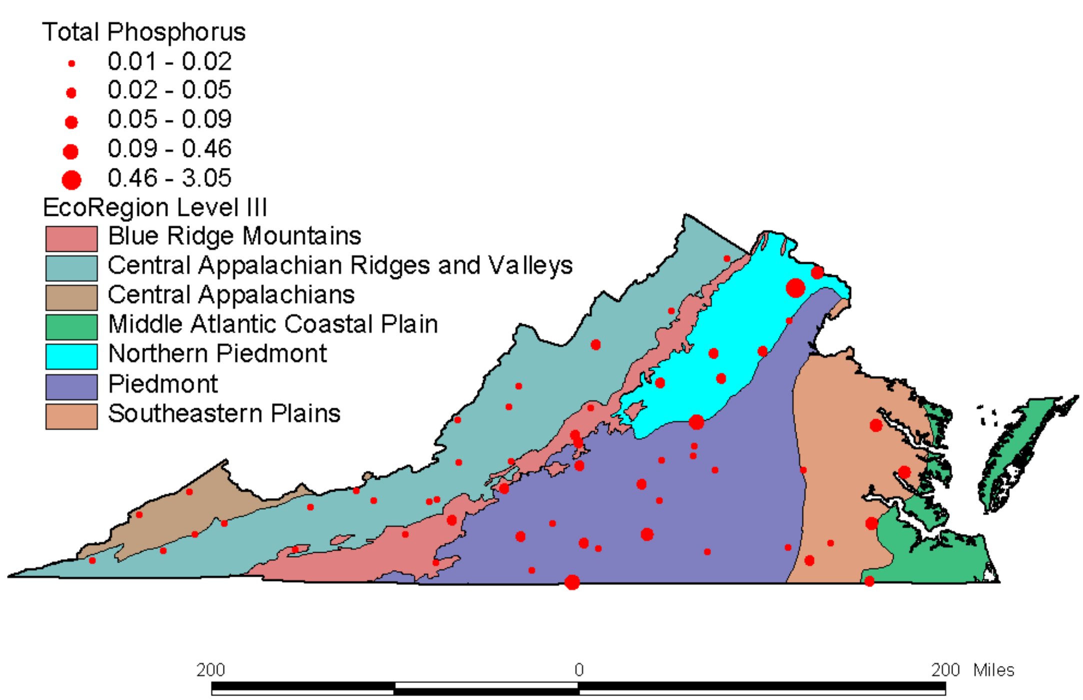


Figure 38. Spatial distribution of total phosphorus data.

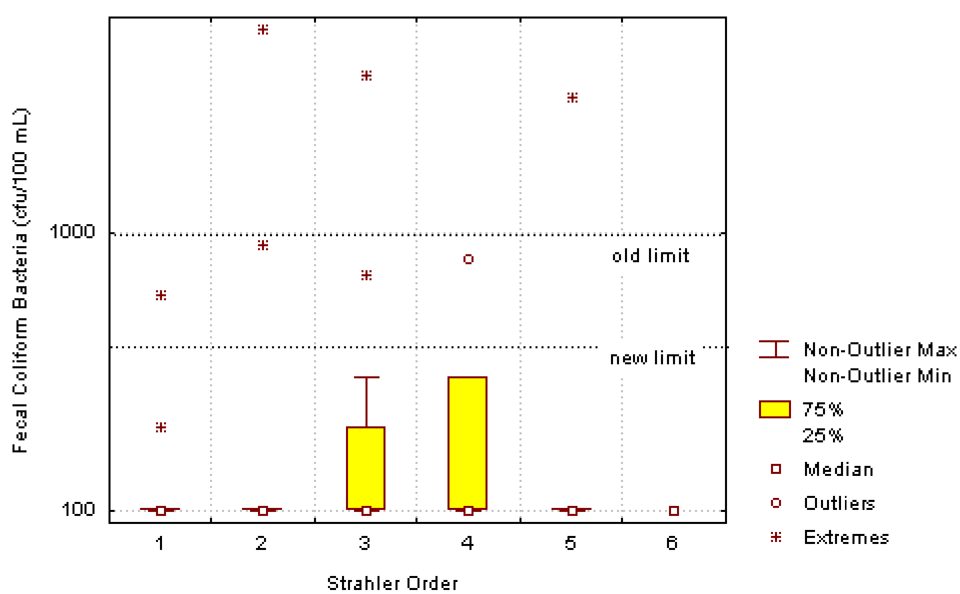


phosphorus. The 95% confidence interval for this estimate extends from 82% - 100%. Additional data will narrow this estimate. Unlike nitrate, high phosphorus concentrations tend to occur in the eastern half of the Commonwealth in the piedmont and Southeastern Plains Ecoregions (Figure 38).

Fecal Coliform Bacteria Results

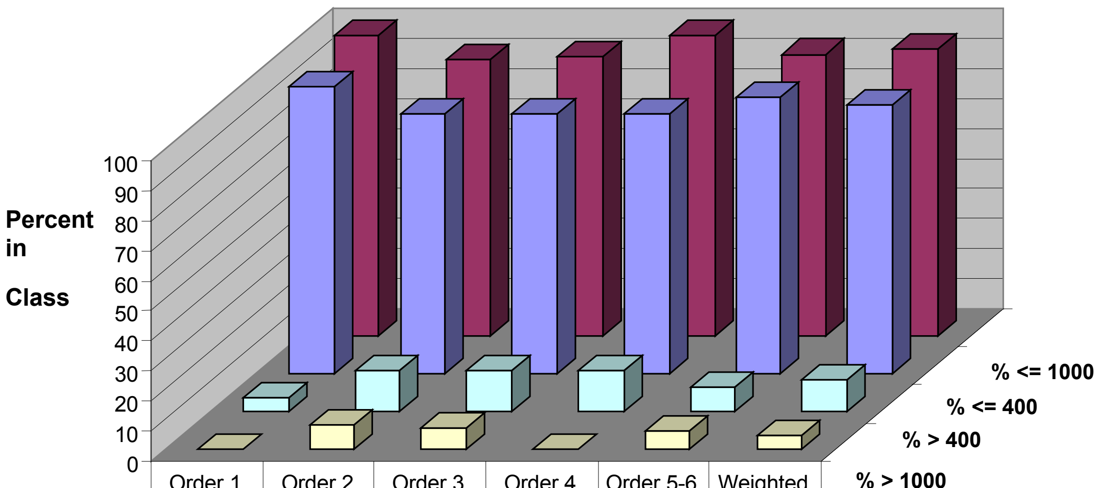
In Figure 39, the bacterial counts are graphed on a logarithmic scale. Bacterial counts are consistent across stream orders in terms of the median count although extremes occur in most stream orders. Also, in order 3 and 4 streams the counts are highly variable.

Figure 39. Boxplot of the logarithm of fecal coliform bacteria counts for fall 2001 by Strahler Stream Order, and with respect to the new and old instantaneous upper limits.



As noted in the background discussion, Virginia developed new instantaneous standards for fecal coliform bacteria in 2002. The percent of ProbMon samples relative to the old and new bacterial standards can be compared using the 3-D graph in Figure 40. Only three exceedances of the old 1,000 cfu/100 mL standard occurred with one each in stream orders 2, 3, and 5+6. No exceedances occurred in orders 1 and 4. The overall weighted rank percent exceedance of the old standard is 4.9%. Based on the second rank of bars in the histogram all stream orders exhibited one to two exceedances of the new 400 cfu/100mL instantaneous standard. The overall weighted rank percent exceedance of the new standard is 10%. Thus, exceedances of the bacterial standard in non-tidal streams are not restricted to a particular stream order. Future sampling will provide counts of *E. coli*, the new bacteria replacing fecal coliforms as an indicator of pathogens in surface waters, *E. coli*. It will be interesting to see whether *E. coli* exhibits the same patterns apparent for fecal coliform bacteria.

Figure 40. Rank percent of fecal coliform bacteria counts relative to the old and new instantaneous standard, partitioned by stream order.

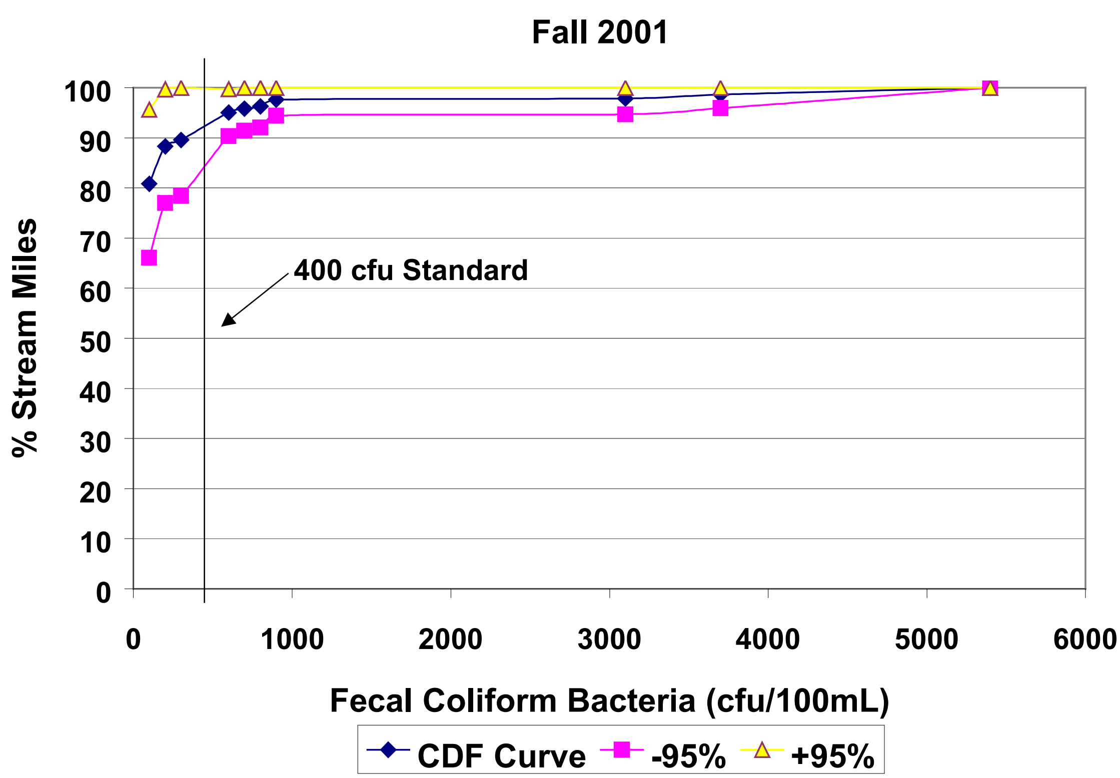


	Order 1	Order 2	Order 3	Order 4	Order 5-6	Weighted
% > 1000	0.0	8.2	7.0	0.0	6.4	4.9
% > 400	4.6	13.6	13.5	13.4	8.2	10.6
% <= 400	95.4	86.4	86.5	86.6	91.8	89.4
% <= 1000	100.0	91.8	93.0	100.0	93.6	95.1

It is important to note that the overall rank percent estimates for fecal coliform bacteria in Figure 40 do not exactly agree with estimates derived from the CDF curve for fecal coliform bacteria (Figure 41). For example, the estimated exceedance of the old standard is 4.9% by rank percent and 2.4% ± 5.6% by CDF. The estimated exceedance of the new standard is 10.6% by rank percent and 10% ± 12% by CDF. The lack of correspondence occurs in part because the former are derived through simple weighted averaging, while the latter are derived through a more exact weighting method. The CDF curve estimates are more useful because they have 95% confidence bounds on them. However, because the CDF confidence intervals include the rank percent estimates, the weighted rank estimates are not considered significantly different from the more rigorously derived CDF estimates.

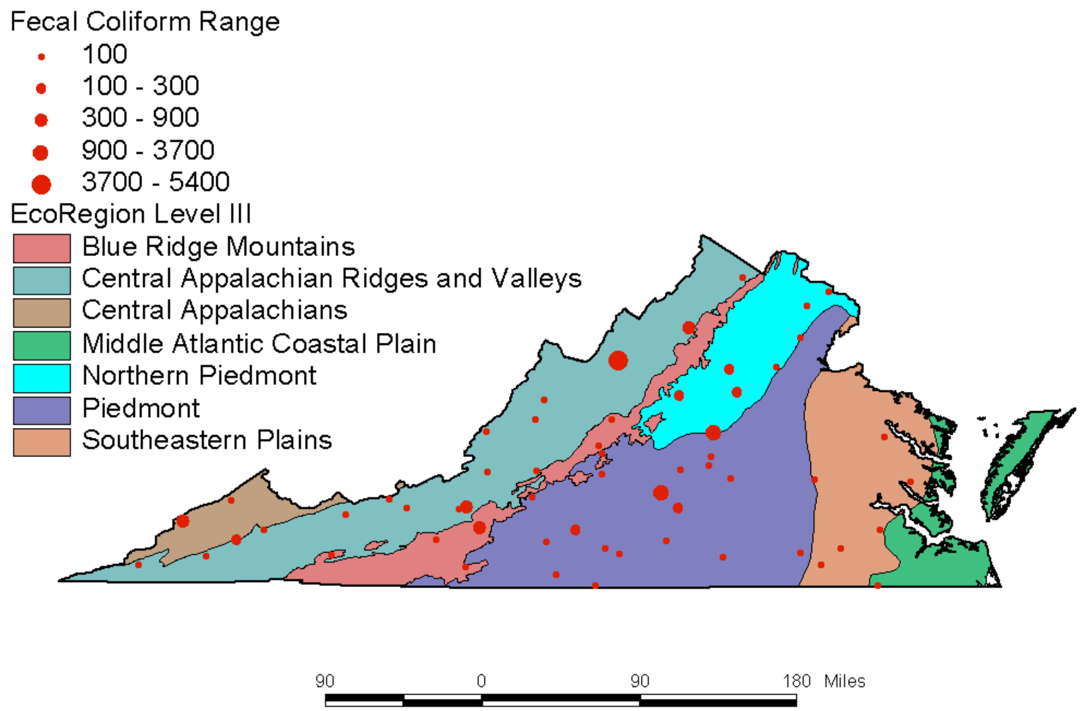
The bacterial count cumulative distribution is graphed in Figure 41. Similar to the nitrate data, the steep initial rise along the vertical axis is due to 81% of the counts being at or below the detection limit of 100 cfu/100 mL. Finally, based on Figure 41, only about 10% ± 12% of the stream miles exceed the new 400 cfu/100 mL standard for fecal coliform bacteria.

Figure 41. CDF curve of fecal coliform bacteria. The vertical line marks the new regulatory limit of 400 cfu/100mL for Virginia waters.



Based on the map of the Commonwealth and its ecoregions in Figure 42, there is no relationship between bacterial counts and ecoregion except that high counts tend to occur in the middle and western parts of Virginia. Part of the reason for the absence of a pattern may be the few values above the detection limit (100 cfu/100 mL). Given the high proportion of detection limit values it may take several years of sampling to detect any geographic patterns.

Figure 42. Spatial distribution of fecal coliform bacteria.



4. BIOLOGICAL DATA

Biological monitoring is a tool for determining the 'health' of a stream ecosystem. To this end VDEQ biologists surveyed the benthic macroinvertebrate community at each wadeable ProbMon site. The organisms surveyed in biomonitoring are primarily aquatic insects which live on or near the bottom of the stream, most of which ultimately emerge into terrestrial forms. Other invertebrates including crayfish, clams, and snails are also collected and included in data analyses. Because most of these organisms persist over several seasons, they are excellent for gauging the presence and extent of aquatic pollution. Measurements on these organisms are here referred to as biological data.

Monitoring the biological community can help detect environmental stresses that are too subtle or short-lived to be detected by ambient chemical monitoring. Stream communities retain the effect of an environmental impact, such as a toxic chemical spill, for an extended time. Likewise, these communities will show if an impacted stream has recovered. Benthic community composition and structure is dramatically altered in specific ways by different kinds of pollution. Consequently, quantitative metrics have been developed to reflect the degree to which the community, and therefore the aquatic environment, has been impacted by pollution or other forms of disturbance.

VDEQ has been conducting biological monitoring since the early 1970's. It has been using EPA's Rapid Bioassessment Protocols since 1990, and used them in ProbMon as well. Biological data collection for ProbMon followed the SOP in Appendix A. ProbMon biomonitoring differs dramatically from VDEQ's historical approach in which monitored sites were paired with a single reference site characterizing the expected condition of undisturbed biota. A goal of VDEQ's biomonitoring program is to increase the number of reference sites across the State so that reference conditions can be developed and implemented into a multi metric index for macroinvertebrate communities. The data collected at random sites in the ProbMon program will accelerate this process and help determine reference conditions throughout the commonwealth.

4.1 BENTHIC COMMUNITY BACKGROUND

Benthic metrics are numerical characterizations of a population, community, or other organism groups that reflect equilibrium among the physical, chemical and biological components of the environment. Pollution or other environmental stressors such as habitat degradation can alter one or more components of the environment causing an impact to the inhabiting organisms. When the equilibrium is upset, changes in the metrics are often predictable.

Metrics can be categorized based on the particular aspect of the environment they describe. Categories relevant to ProbMon biological data include Richness, Composition, and Tolerance metrics. In this report, all metrics are based on counts of organisms identified to the Family taxonomic level. Richness metrics represent the diversity of the benthic macroinvertebrate community at a given site (Resh et al. 1995). Richness metrics usually decrease with increasing perturbation (Barbour et al. 1999). Composition metrics, frequently expressed as a percent, are a ratio of the abundance of certain taxa to the total number of individuals in a sample. Essentially, composition is a measure of relative abundance. As habitat disturbance and environmental impact increase, composition metrics either decrease or increase depending on the tolerance of the group measured. Tolerant Families increase and sensitive Families decrease as impacts increase. Finally, Tolerance metrics are applied in situations where the sensitivity of an organism or group of organisms to specific or nonspecific stressors is of interest. For example, MFBI is specific to organic pollution. Tolerance measures may be expressed as either numbers of pollution tolerant or intolerant taxa, percent composition, or as a weighted metric such as MFBI (Barbour et al. 1995). The response to stressors for Tolerance metrics is variable and depends on the taxa that are included in the metric. In this section, seven of the nine metrics produced for ProbMon data are discussed.

Taxa Richness

Taxa richness is the number of taxonomic groups in a sample. In ProbMon's biological monitoring, macroinvertebrate taxa are identified to the Family level. Thus taxa richness is the number of Families in a sample. High taxa richness typically indicates a variety of habitats, stable and normal water chemistry, and other conditions that support a diverse community. In contrast, a stream that has been channeled may be dominated by a few Families that are tolerant of sedimentation and flushing flows, thus resulting in a low taxa richness score. Environmental stressors and taxa richness are often inversely related. Taxa richness is a fundamental metric that is included in multimetric indices commonly applied by state and federal agencies and academia researching benthic macroinvertebrates. It is especially useful for detecting situations when certain taxa are missing from a stream.

EPT Index

EPT is an abbreviation for the aquatic insect Orders Ephemeroptera, Plecoptera, and Trichoptera. The EPT Index is the number of Families in the three Orders. The majority of the Families in the EPT orders are intolerant of pollution and other environmental stressors. The EPT Index yields results similar to the %EPT-H metric described below, but is a better measure of the diversity of sensitive taxa in a sample. Unlike %EPT-H, it does not relate the number of sensitive taxa to the total number of organisms. That is, the EPT Index is a Richness metric rather than a relative abundance metric.

%EPT - H

The %EPT – H index is an abbreviation for 'percent Ephemeroptera, Plecoptera, and Trichoptera, minus Hydropsychidae.' %EPT – H is a Composition metric that estimates the proportion of individuals in a community that are mayflies, stoneflies, or caddisflies, excluding hydropsychid caddisflies. These aquatic insects are the first to be extirpated by environmental stressors such as organic waste, habitat degradation, and low DO concentration. Thus, %EPT – H decreases with increasing pollution and environmental stress. Insects of the Hydropsychidae Family are excluded from the metric because of their tolerance of moderate organic pollution (Voshell 2002). In fact, an overabundance of Hydropsychidae usually indicates excess organic pollution or nutrient enrichment. Thus, %EPT – H measures the relative abundance of sensitive organisms in a sample and translates to the degree of normal, unpolluted conditions the community has been exposed to.

MFBI

The Modified Family Biotic Index (MFBI) is Hilsenhoff's Biotic Index (HBI) adapted for Virginia's aquatic macroinvertebrate communities where the organisms are identified to the Family level. This is a Tolerance metric originally designed to measure a community's tolerance to organic pollution in Wisconsin streams (Hilsenhoff 1987). Each Family has an assigned tolerance value that is used to weight abundance for incorporation into the MFBI (Barbour et al. 1992, Hayslip 1993, Kerans and Karr 1994). The weighting is performed as follows.

$$MFBI = \sum_{i=1}^{S} \frac{x_i t_i}{n}$$

x_i = number of individuals in taxon

t_i = tolerance value of taxon

n = total abundance of sample

S = number of taxa

MFBI scoring is on a scale from 0 to 10 and measures the average pollution tolerance of the organisms in a sample with 0 indicating unpolluted conditions. Table 4 shows the HBI water quality score ranges relative to the degree of organic pollution in a stream and the implied water quality.

Table 4. Relationship between HBI score, water quality condition, and degree of organic pollution (Hilsenhoff 1987).

HBI	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

% Dominant Family

The % Dominant Family index is the proportion of the community occupied by the most abundant taxon (Family). This is another measure of community balance that is a Tolerance metric. As noted for Taxa Richness, a community will often be dominated by a few taxa in polluted streams. The more constraining the conditions, the more one Family that is tolerant of that situation will dominate the community. For instance, a stream that has a steady inflow of raw sewage will support very few taxa of macroinvertebrates and may be completely dominated by the Family Tubificidae, an organism tolerant of low dissolved oxygen and high organic waste. Thus, % Dominant Taxa will increase with increasing pollution and environmental stressors.

% Chironomidae

This metric focuses on midge larvae which are tolerant of many stressors. It is a Composition metric that estimates the ratio of midge larvae to the total number of macroinvertebrates in a sample. This metric is expected to increase with increasing pollution and environmental stress (Barbour et al. 1994). Some members of Family Chironomidae are unique in their tolerance of altered environmental conditions. Hemoglobin is found in their blood meaning that they can transport oxygen much like vertebrates (Voshell 2002). Due to this extraordinary adaptation, some midges can reside in streams that are practically anoxic. Some taxa in Family Chironomidae are very tolerant of toxic and petroleum substances whereas others can survive heavy sedimentation and organic and nutrient inputs (Voshell 2002). Their tolerance to a wide variety of pollutants makes % Chironomidae an excellent indicator of degraded water quality.

Simpson's Diversity Index

Simpson's Diversity Index is a Composition metric that reflects the number and variety of organisms in a community. Unlike taxa richness, this index takes the relative abundance of each taxon into account and reflects the taxonomic balance a community. Unlike MFBI, this index does not describe the community tolerance to a pollutant. The index is calculated as follows:

$$D = \frac{1}{\sum_{i=1}^{S} (x_i / n)^2}$$

x_i = number of individuals in taxon

n = total abundance of sample

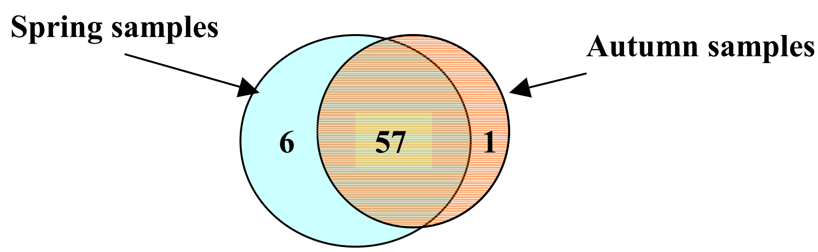
S = number of taxa

Scores for this index range from zero for communities devoid of life to approximately 3.0 for the most diverse communities. Although there is no mathematical upper limit for the index, scores upward of 0.80 reflect good diversity.

4.2 BENTHIC COMMUNITY RESULTS

The benthic community results presented in this section are based on data collected in the spring of 2001. The full data set is listed in Table 2 of Appendix E and the calculated metrics are in Table 1 of Appendix E. The station information is in Appendix B. Although macroinvertebrates and habitat were sampled at 63 sites in the spring, only 57 of these sites were resampled in the fall for chemistry (Figure 43). Thus, for comparisons between spring and autumn variables, only 57 stations can be used. The breakdown of stations between spring and fall sampling seasons is shown in Figure 43. The seasonal station count by stream order is noted in Table 3 in the 3.2 Chemical Results section. The following section presents the results for seven of the nine biological community metrics.

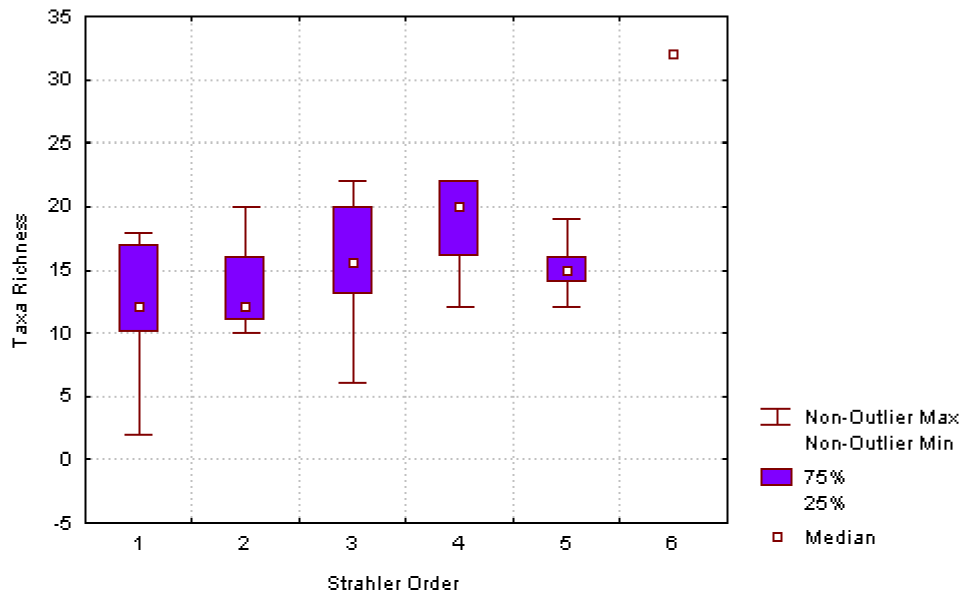
Figure 43. There were 63 stations sampled in the spring for benthic macroinvertebrates and habitat, 58 in the autumn for water chemistry, and 57 sampled for all three components.



Taxa Richness Results

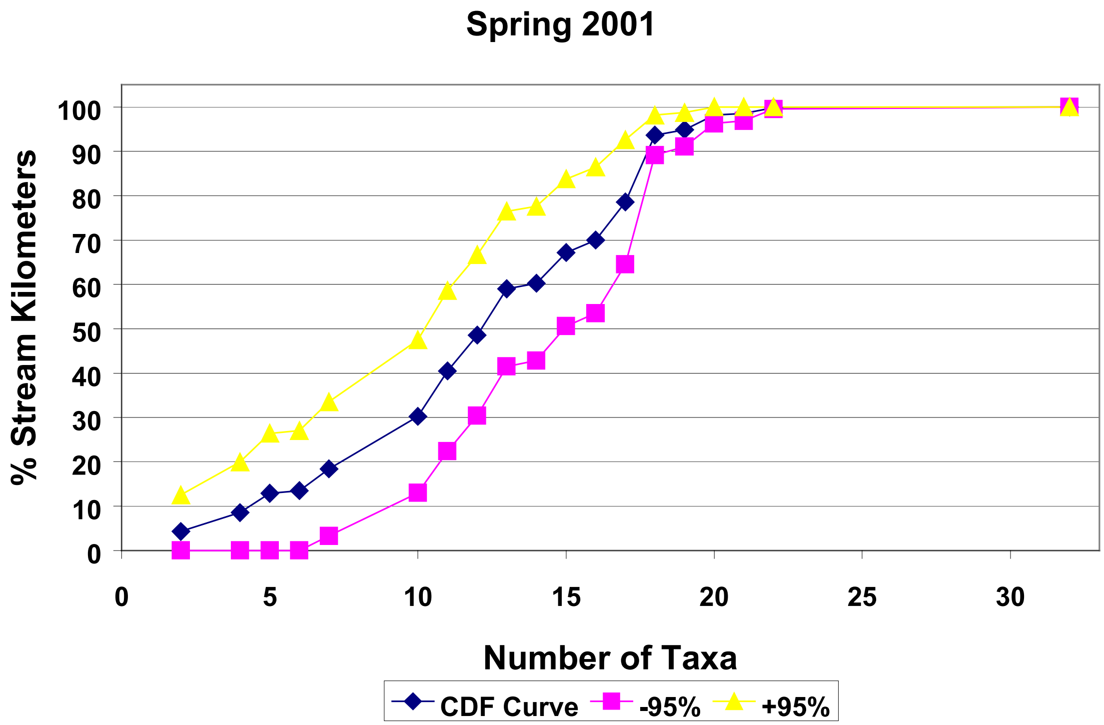
In Virginia's biomonitoring program, macroinvertebrate taxa are identified to the Family level. Thus, taxa richness equates to the number of Families collected in one sample at a site. Taxa richness ranged from 2 to 32 Families and increased from small to large streams (Figure 44). General application of these results apply to 1^{st} – 5^{th} order streams since larger streams are typically wider, deeper, and more ecologically complex and the sample size at 6^{th} order streams is limited. This was expected due to the lower number of niches found in headwater streams that typically are less diverse in habitat and available food for benthic macroinvertebrates. The single sixth order stream in the data set had an unusually high number of Families, 32, with the next most numerous sample having 22 taxa.

Figure 44. Boxplot of Taxa Richness.



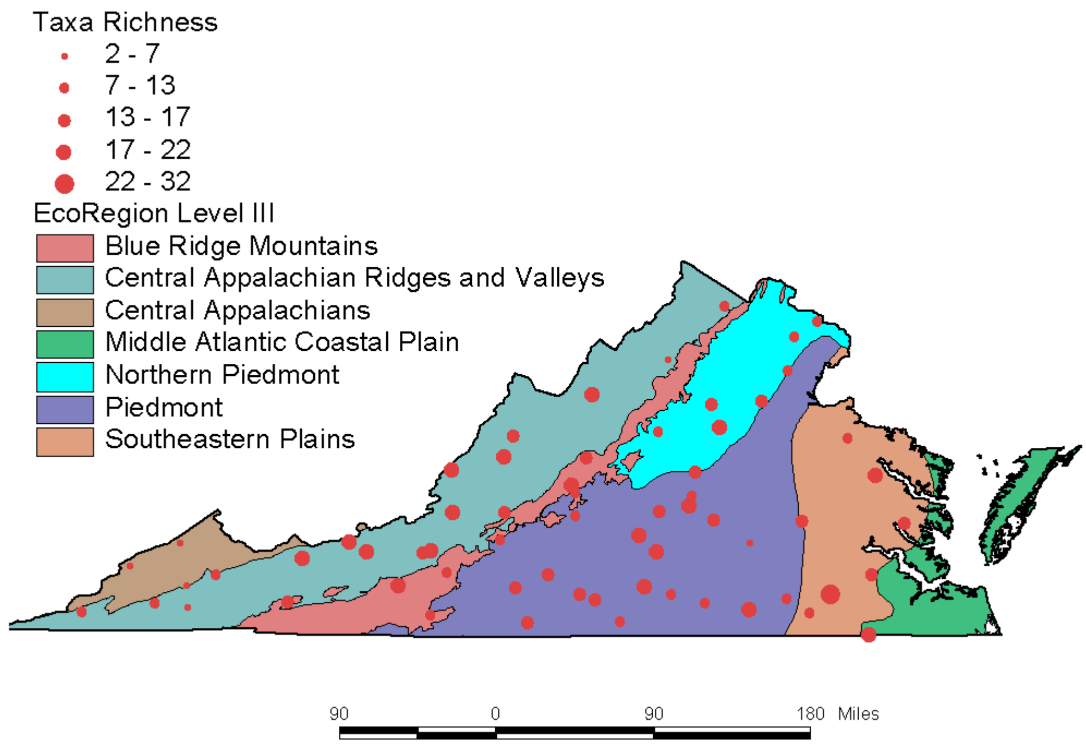
Approximately half of Virginia's stream kilometers had 12 or fewer taxa (Figure 45). Thirty percent of stream kilometers had 10 or fewer taxa which is considered very low richness for most stream types.

Figure 45. CDF curve of Taxa Richness.



The mean number of Families collected across the 63 sites was 14.63 (Appendix E, Table 1). The Nottoway River in the Southeastern Plains had far more taxa than all other streams (Figure 46). The Nottoway River sample is the large dot in southeastern Virginia near the State border.

Figure 46. Spatial distribution of taxa richness.



Despite having high richness the Nottoway River also had a high MFBI score (6.15), low %EPT-H (6.71), and high %Dominant Family (41.16% Gammaridae, a type of Amphipod). So, although the Nottoway River site had an exceptionally high number of taxa, it happened to consist of mostly pollution-tolerant taxa.

Most sites with high taxa richness are in the Central Appalachian Ridges and Valleys and Blue Ridge Mountains ecoregions. However, several streams in the southwestern part of the State are potentially impacted by mining, logging, and drought and display low taxonomic diversity (Figure 46).

EPT Index Results

Similar to taxa richness, the median number of mayfly-stonefly-caddisfly taxa (EPT index) increased with stream order (Figure 47). This trend is possibly related to the increase in habitat diversity and food niches with stream size. As with taxa richness, this applies to 1st – 5th order streams.

Figure 47. Boxplot of EPT Index.

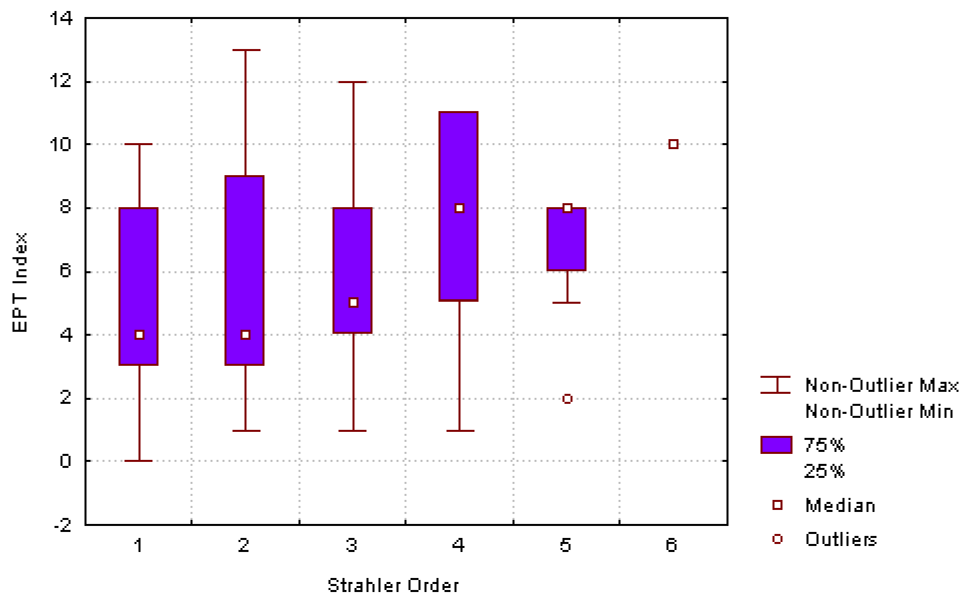
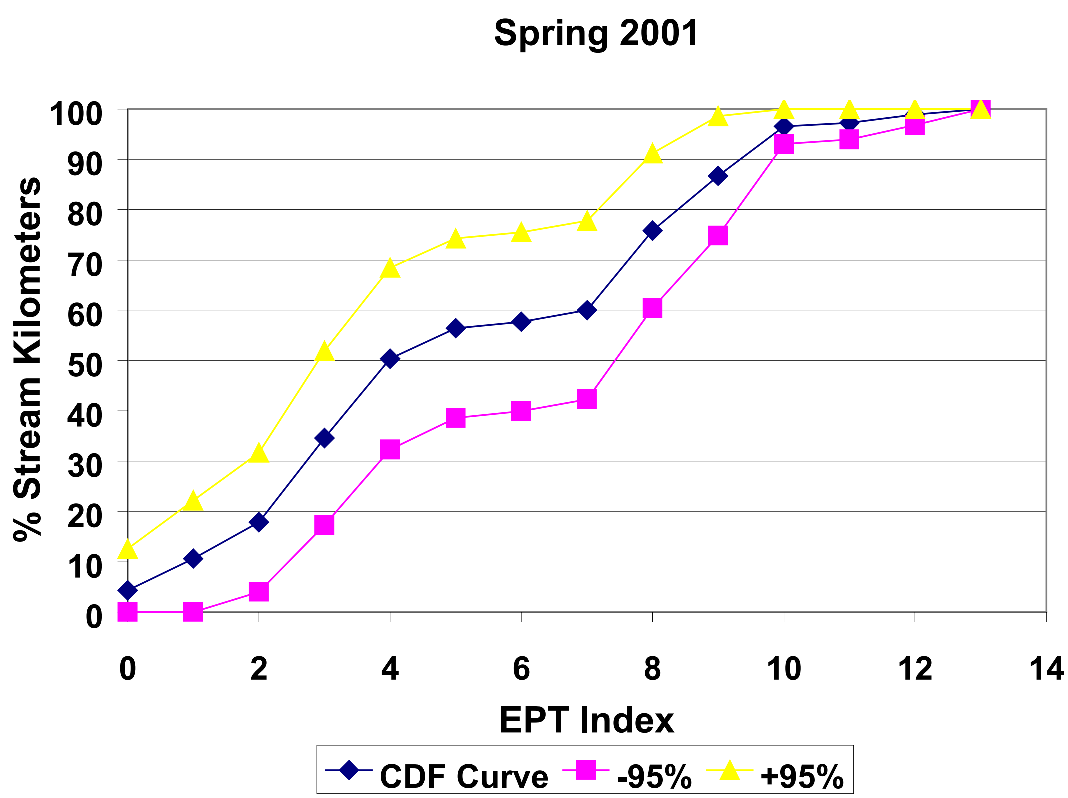


Figure 48. CDF curve of EPT Index.

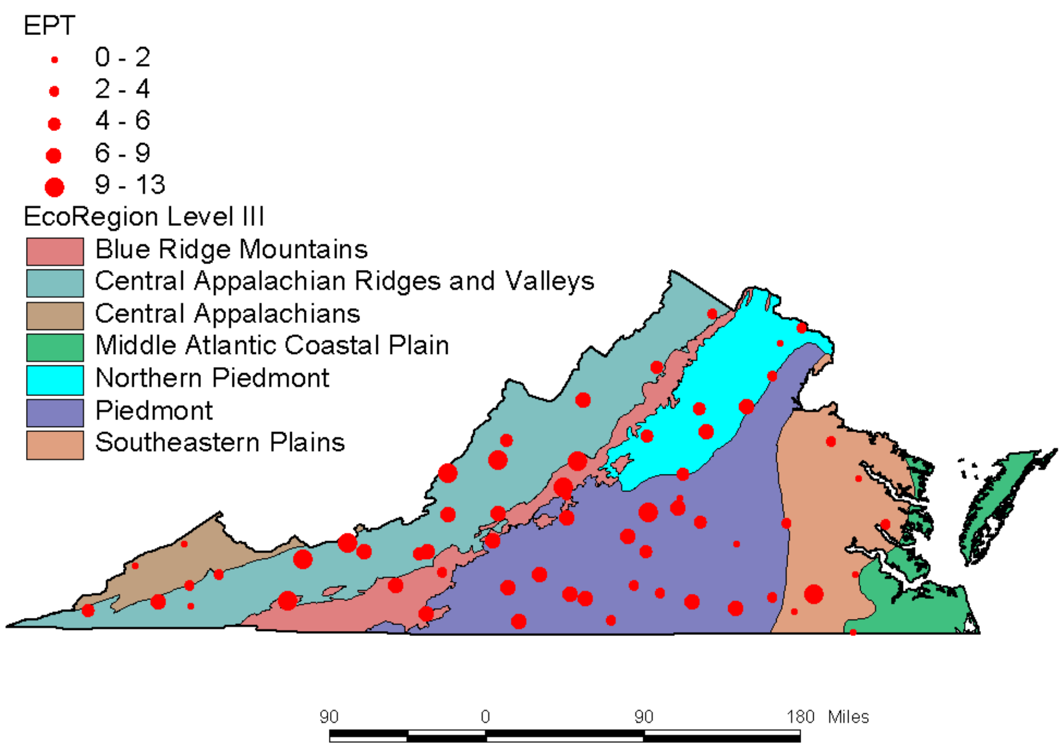


The number of EPT Families collected at all sites ranged from zero to thirteen with an overall mean of six Families (Appendix E, Table 1). Based on Figure 48 it is estimated that 35%

of non-tidal stream kilometers have eight or more EPT taxa indicating communities with a diversity of pollution intolerant taxa. Meanwhile, 50% of the stream lengths had four or fewer EPT families, indicating a low diversity of sensitive taxa.

High numbers of EPT Families are observed in the Central Appalachian Ridges and Valleys, Blue Ridge Mountains, and some parts of the Piedmont Ecoregions (Figure 49). Excluding the Nottoway River, the Southeastern Plains have few EPT taxa.

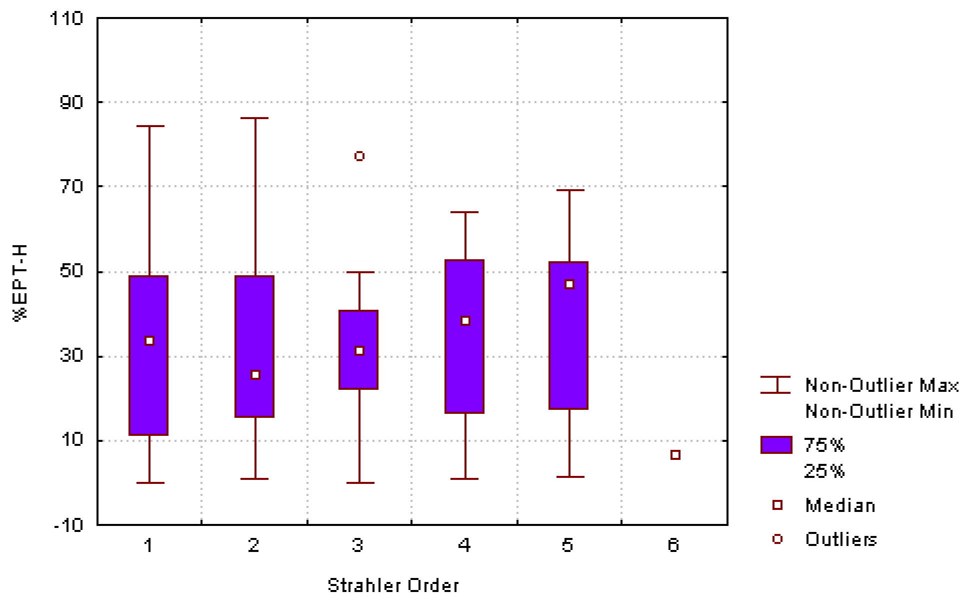
Figure 49. Spatial distribution of EPT.



%EPT-H Results

While the EPT index is a simple Richness metric, the %EPT-H index relates the abundance of the group to the community as a whole. Nevertheless, the %EPT-H index yielded results similar to the EPT index with a general rise in score with stream order (Figure 50).

Figure 50. Boxplot of %EPT-H.



Percent EPT-H ranged from zero in nearly all sizes of streams to greater than 80% in small streams (Appendix E, Table 1). Based on the CDF curve in Figure 51, approximately 40% of Virginia stream kilometers have benthic communities consisting of zero to 20% individuals from the EPT-H Families. Only 20% of the stream kilometers have 55% or greater %EPT-H.

Many of the streams with few EPT-H individuals were wetland systems (swamps) in the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions. Several of these sites were dominated by midge larvae (Chironomidae), aquatic sow bugs (Asellidae), and scuds (Grammaridae). As expected, the mountain and Piedmont regions have higher percentages of EPT-H individuals.

Figure 51. CDF curve of %EPT-H.

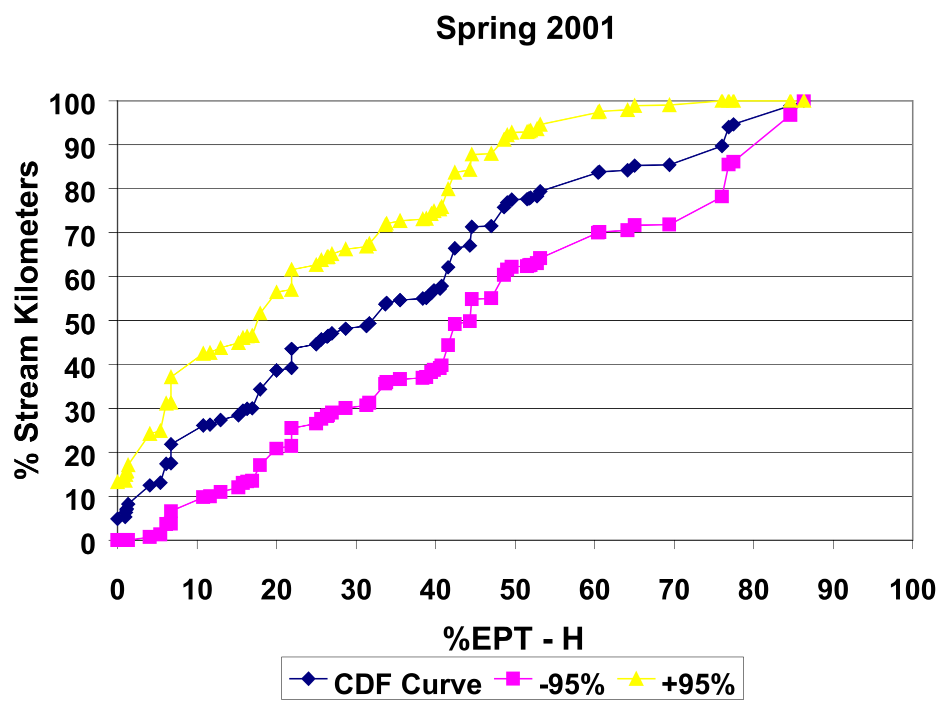
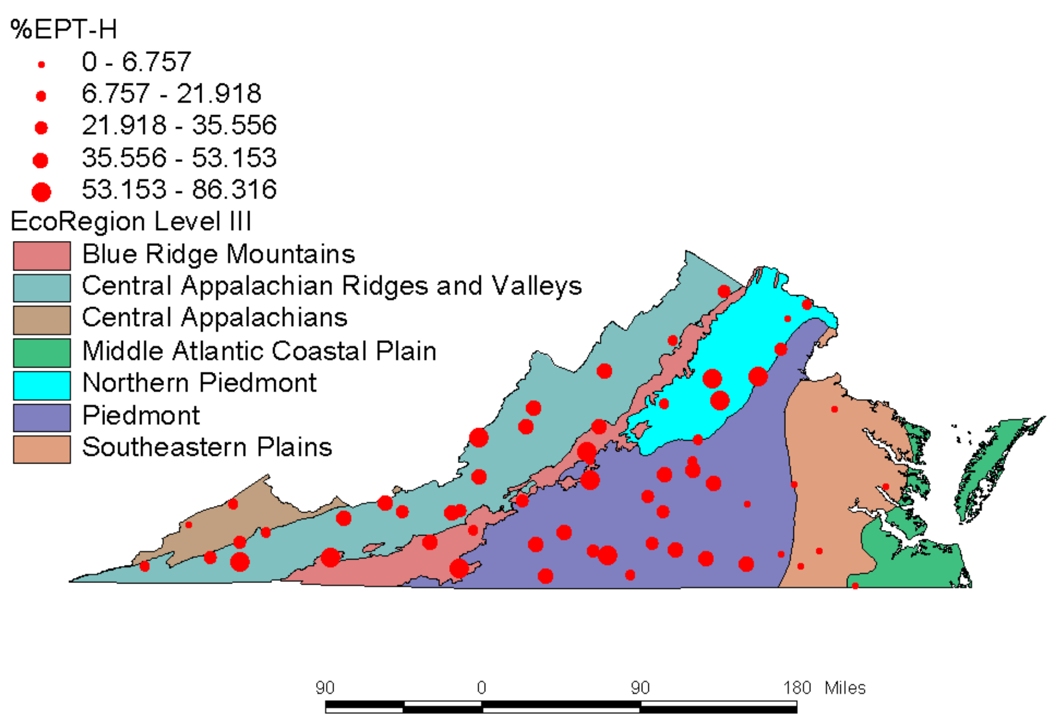


Figure 52. Spatial distribution of %EPT-H.



Based on Figure 52, high %EPT-H scores are found in most areas except eastern Virginia. However, the apparent relationship to ecoregion is an artifact of the index. It was expected that sites in the low gradient Southeastern Plains and Middle Atlantic Coastal Plain would exhibit a low proportion of EPT-H. No sites in either ecoregion score above 10% for %EPT-H.

MFBI Results

Scores for MFBI (Modified Family Biotic Index) ranged from 2.62 to 7.29 indicating communities with a variety of tolerance for organic pollution (Appendix E, Table 1). Forty-four percent (28 sites) had scores ≤ 4.5 indicating very good to excellent water quality (Table 4, page 24***??***). Twenty-four percent (15) had scores between 5.5 and 6.5 indicating fairly significant organic pollution. Only one site had a score > 6.50 indicating significant organic pollution. Based on the MFBI medians, communities in lower order streams typically have more tolerance to organic pollution (Figure 53).

Figure 53. Boxplot of MFBI by stream order.

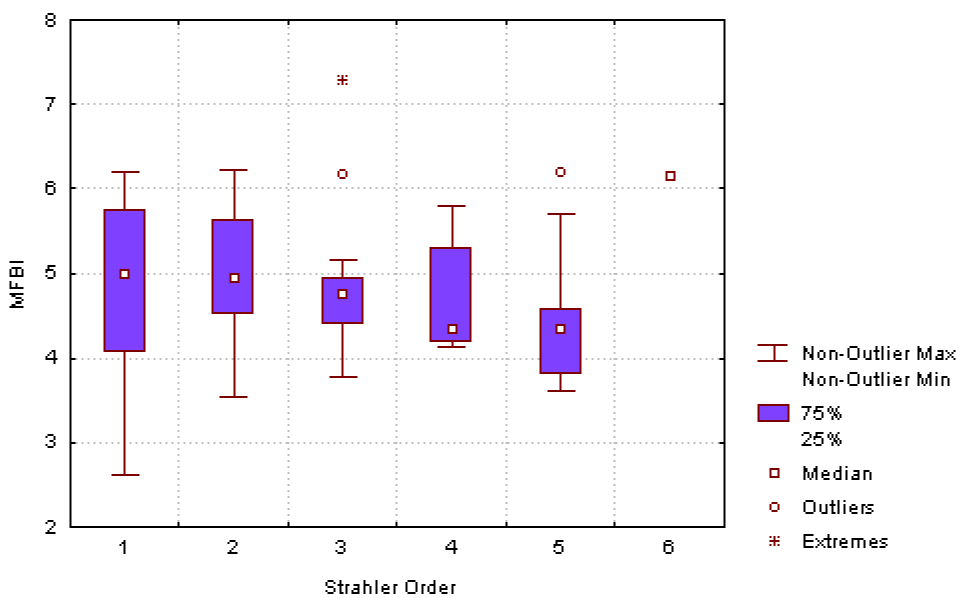


Figure 54. CDF curve of MFBI scores.

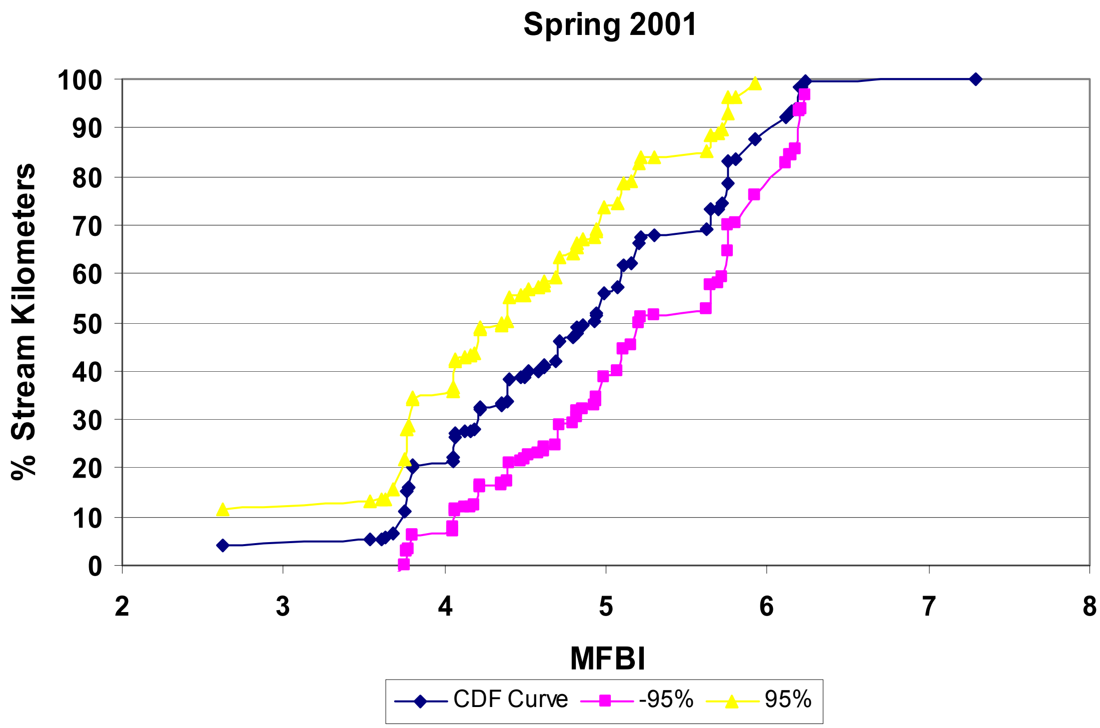
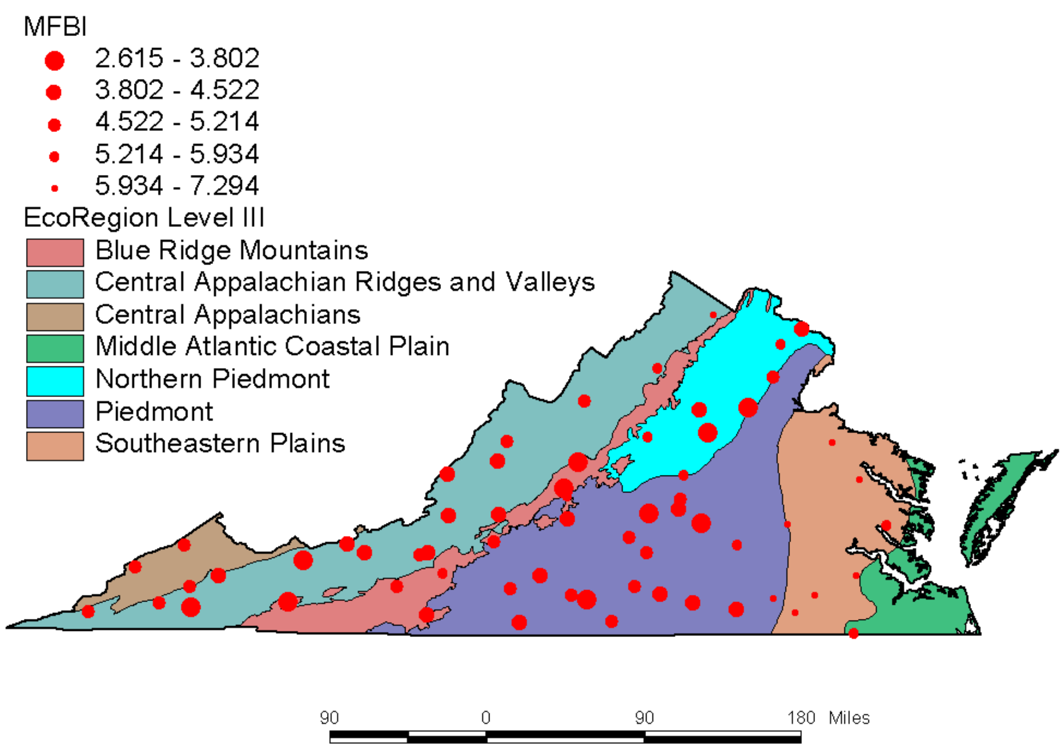


Figure 55. Spatial distribution of MFBI scores.



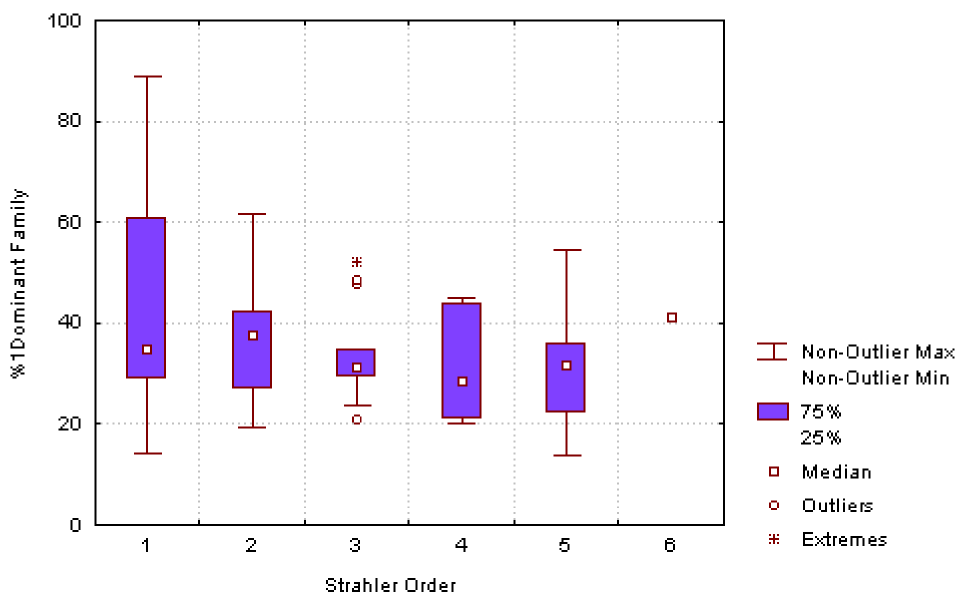
Approximately 40% of Virginia's stream kilometers have benthic communities that display none or only slight organic pollution (scores ≤4.5; Figure 54). Only about 10% have significant organic pollution with scores ≥ 6.0.

A spatial trend is evident in the geographic distribution of MFBI scores (Figure 55). All streams east of the piedmont ecoregions have communities with scores that indicate significant organic pollution. Many of these streams are associated with swamps. Elsewhere in the State there is a mix of low and moderate organic pollution.

%Dominant Family Results

Percent Dominant Family scores ranged from 13.73 to 88.79 with an average of 36% (Appendix E, Table 1). The most common dominant taxon was the pollution tolerant midge Family Chironomidae which dominates 41% of non-tidal streams. Many of these midge-dominant sites are in the eastern ecoregions where streams have naturally higher amounts of sediment for substrate. The few mountain and valley sites in which Chironomidae dominate are potential sites of human induced sedimentation from land uses such as logging, agriculture, and urbanization. The next most dominant Family was the mayfly Ephemerellidae which dominates 9.5% of the time. Intolerant taxa including EPT-H and other families such as Elmidae (riffle beetles) and Psephenidae (water pennies) dominate 38% of the non-tidal streams.

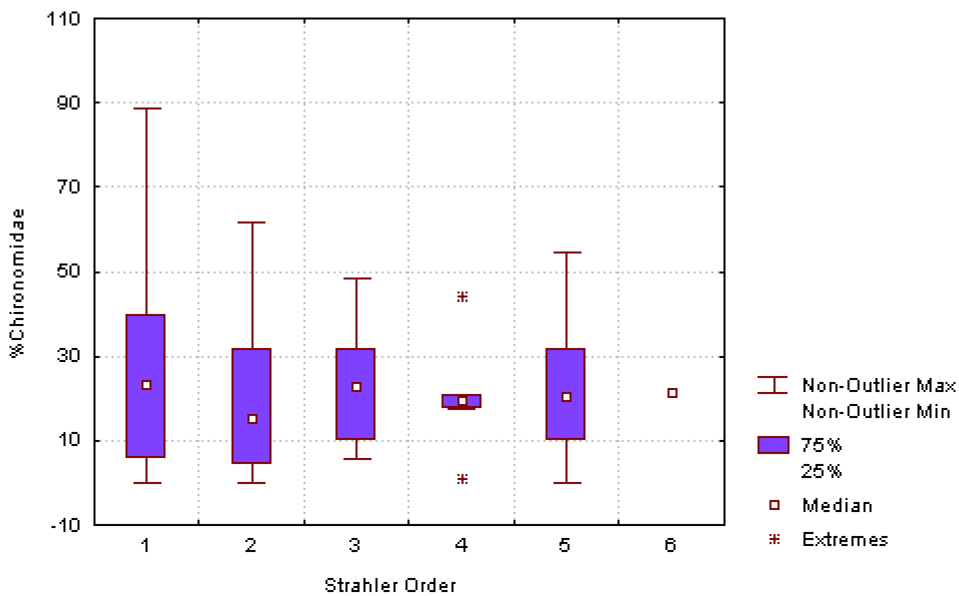
Figure 56. Boxplots of %Dominant Family.



%Chironomidae Results

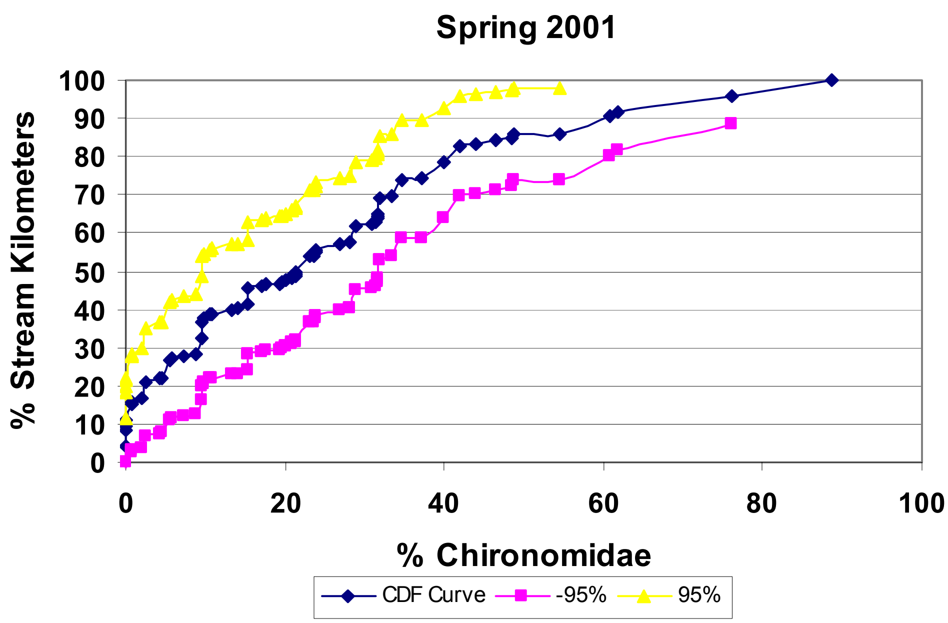
The %Chironomidae index averaged 23% ranging from 0 to 89% (Appendix E, Table 1). Most samples with low numbers of Chironomidae also had few organic pollution-tolerant organisms as indicated by the MFBI scores. Only 8% of non-tidal streams lack Chironomid midges. Thus, this organism is very common in these streams. All stream orders had a similar median %Chironomidae (Figure 57). But there was a wide range of scores in all but 4th and 6th order streams. One interesting feature is that 4th order stream communities consist of approximately 20% Chironomidae.

Figure 57. Boxplot of %Chironomidae.



Approximately half of the stream kilometers in Virginia have communities consisting of 20% or less Chironomidae larvae (Figure 58). Only 20% of the stream kilometers had 40% or greater %Chironomidae. Benthic abundance metrics often exhibit a distribution known as the beta distribution. For example, in the EPA Mid-Atlantic Highlands Streams Assessment study, %Chironomid show a beta distribution (USEPA 2000). The CDF for the beta is S-shaped, unlike Figure 58, suggesting that here **%**Chironomidae is not beta distributed. Neither does it fit other well known distributions. Thus, a theoretical distribution cannot be used to aid prediction in this case. Regardless of whether the CDF matches a theoretical distribution, the empirical CDF curve

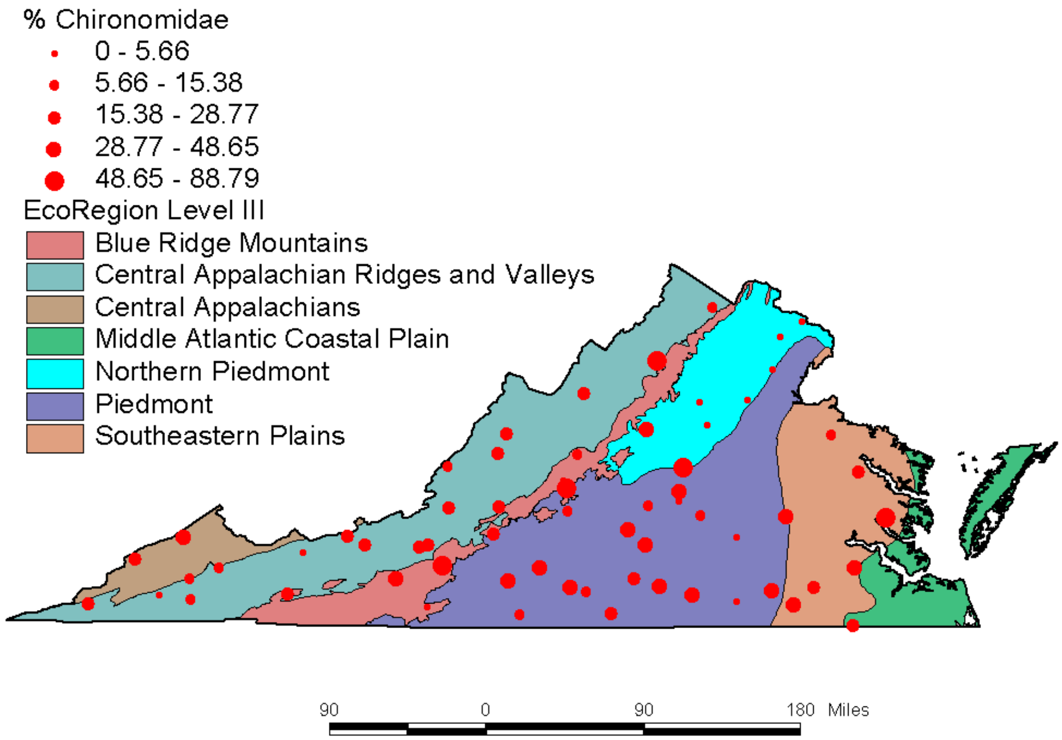
Figure 58. CDF curve of %Chironomidae.



is still useful for deriving probabilities. For example, assume the current ProbMon benthic data set is representative of all Virginia non-tidal streams. Then, we can pose the question, "Based on the data collected so far, how likely is a non-tidal stream to have a community with between 20% and 80% Chironomidae?" To answer this, we draw vertical lines up from 20% and 80% Chironomidae in Figure 58. Based on the intersection of these lines at the CDF curve, 47% and 96% of stream kilometers, respectively, we know that 47% of the sample population has a %Chironomidae less than or equal to 20%, and 96% of the population has a %Chironomidae less than or equal to 80%. Then, the likelihood that a community would have a %Chironomidae index between 20% and 80% is the difference between their cumulative probabilities; 96% – 47% = 49%. So, about 49% of the time we would expect a Virginia benthic community to have between 20% and 80% Chironomidae. This prediction has a wide confidence interval. As data are added to the survey each year, these intervals should become narrower and provide a better prediction for planning purposes.

There was no clear spatial pattern for %Chironomidae. There are sites with high and low values of the metric in all ecoregions. The Northern Piedmont is the only area with mostly low scores. High Chironomidae abundance can be related to low dissolved oxygen, high organic pollution, and high sediment and other fine materials. The few mountain and valley sites dominated by Chironomidae were sites potentially affected by sedimentation from anthropogenic land use.

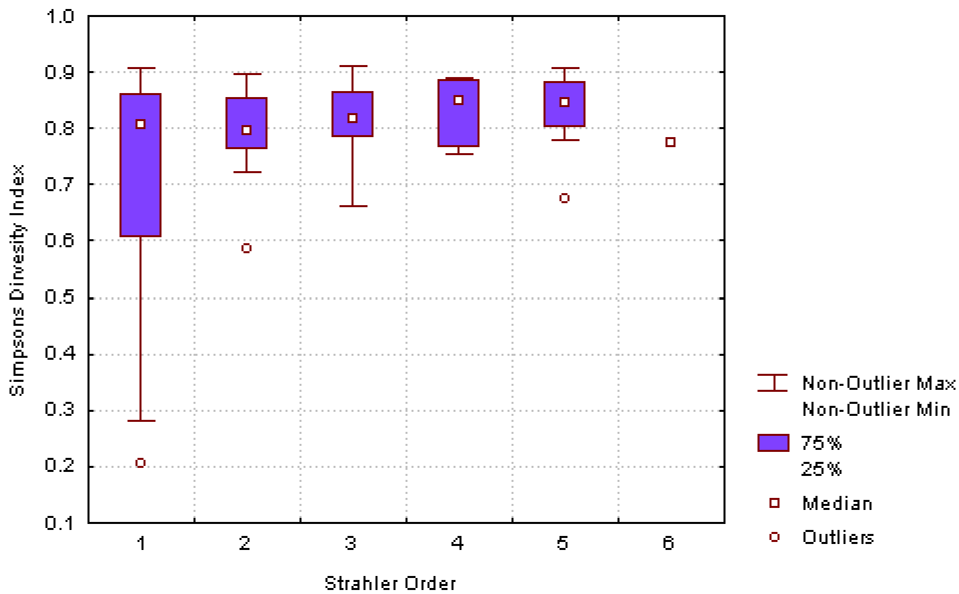
Figure 59. Spatial distribution of %Chironomidae.



Simpson's Diversity Index Results

Simpson's Diversity index ranged 0.21 to 0.91 with an average of 0.79 (Appendix E, Table 1). The high average and the high median diversity across all orders indicates good taxa richness and evenness statewide. Only seven sites had scores indicating poor conditions for this metric (≤ 0.66). On the other hand, 32 sites (51%) had scores ≥ 0.82, indicating good benthic community diversity. Because of the expected reduced habitat variety and food availability in 1st order streams, macroinvertebrate diversity should be low in these streams.

Figure 60. Boxplots of Simpson's Diversity Index.



5. PHYSICAL HABITAT DATA

Habitat quality is an expression of the physical conditions in a stream channel, the surrounding riparian zone, and the watershed land use. The quality and quantity of available habitat can have a large influence on the ecological integrity of a stream. The benthic macroinvertebrates surveyed in ProbMon and the fish that depend on them for food are both affected by stream habitat. Recent surveys of stream resources in Maryland and North Carolina linked physical habitat quality with biological communities (NC DENR 2002, Roth et al. 1998). Therefore, the Virginia ProbMon survey includes a habitat assessment component to determine the percent of non-tidal streams that are degraded, as well as the percent that have exceptional quality. Habitat data were collected using the RBP visual habitat assessment methods (Barbour et al. 1999). These methods use qualitative scoring that is subjective but comparable state wide when performed by trained biologists. In some regions of the State, biologists collected additional quantitative and qualitative habitat data to describe stream substrate and surrounding land use in greater detail and will be summarized in a future report. As ProbMon evolves, the quantity and variety of habitat data collected will expand to better define the range of physical habitat, and to allow the detection of relationships between physical habitat, biological communities, and water quality.

This chapter presents the background and results of physical habitat data collected during the first year of the five-year survey. All observations are based on data collected during the spring of 2001 with the benthic data.

5.1 PHYSICAL HABITAT BACKGROUND

Historically, the majority of VDEQ's biological sampling stations were selected with a bias towards sites impacted by anthropogenic sources (impact site). To gauge the degree of impact, a nearby unimpacted (reference) site was also sampled. Thus, the historical database has few stations with exceptional habitat. In ProbMon, sample sites were chosen randomly and are expected to yield habitat scores that may be variable among sites, but will produce a more accurate assessment of overall habitat quality in Virginia than the historical samples.

The habitat quality at each ProbMon site was judged through ten Rapid Bioassessment Protocol (RBP) habitat parameters adapted from Barbour et al. (1999). Each field site was given a score between zero and 20 for each parameter, with zero being the poorest quality and 20 the best. Scores for each parameter can be translated into four qualitative categories ranging from optimal or least disturbed, to poor or very disturbed (Appendix F, Table 1).

Channel Alteration

Stream channel alteration has been described as one of the most damaging forms of degradation to stream ecosystems and over 26,550 km of rivers in the United States have been altered (Brookes 1988). Natural alteration can be the result of beaver dams that flood riparian zones and alter stream flow. Likewise, man-made dams convert flowing water into reservoir and pond habitat resulting in unnatural flow patterns, nutrient and silt compartmentalization, and temperature alterations (Cushman 1985). Even bridge pilings act as artificial stream banks that deflect water and cause unnatural scouring, erosion, and sediment deposition. Many stream altering structures also serve as barriers to fish migration. Another form of alteration is ditching, or the straightening of stream channels. Removing meanders and deepening stream channels reduce habitat diversity and result in lower plant and animal diversity in the stream and riparian zone. In ProbMon, channel alteration is evaluated on a zero to 20 scale with zero being the most altered.

Instream Condition

The quality and quantity of habitat in the immediate stream channel plays a large role in determining the numbers and kinds of species in the stream (Hawkins et al. 1982, Platts et al. 1983, Rankin 1991, Reice 1980). In the EPA RBP assessment method, four parameters describe the quantity and variety of habitat available to fish and macroinvertebrates. Each was scored separately in the field at ProbMon sites. For this report the four parameters were averaged into one metric to qualitatively assess the habitat in the stream channel as follows.

$$\textbf{Instream Condition}_{\text{high gradient}} = \{(\textbf{epifaunal substrate/available cover}) + (\textbf{velocity/depth regime}) + \textbf{channel flow status} + \textbf{riffle frequency}\} / 4$$

Instream Condition reflects the variety of stable habitat available for macroinvertebrate colonization and for fish spawning, nursery, feeding, and refuge. Optimal cover has a habitat mix of cobbles, boulders, large woody debris (LWD), and undercut banks. Poor cover lacks habitat diversity and is frequently disturbed by variable flows, or human activity in or near the stream channel. In low gradient streams, the ‘velocity/depth regime’ and ‘riffle frequency’ components were replaced with ‘pool variability’ and ‘channel sinuosity’, respectively, in the above equation. This replacement provides an alternate, meaningful estimate of Instream Condition in low gradient streams.

Bank Condition

Bank vegetation provides shade for streams through canopy cover. Wesche et al. (1987) found that trout population size was positively correlated to the amount of overhead bank cover. Rootwads of mature trees provide cover for fish and substrate for macroinvertebrates. Erosion of stream banks is lessened by the root structure of trees and shrubs. Leaf matter from bank vegetation also provides energy to stream ecosystems (Reice 1980).

In the field, bank stability and vegetative protection were scored separately, each on a scale of zero to 20. Stream bank condition was arrived at by averaging bank stability and vegetative protection into one metric as follows.

Bank Condition = (bank stability + vegetative protection) / 2

Bank stability refers to the level of past erosion and the potential for future erosion based on bank slope and evidence of bare soil. Vegetative protection is the percent of the stream bank covered by vegetation from the bankfull (high flow mark) area to the immediate riparian zone. The variety of plant classes on the bank as well as the level of disruption from grazing or mowing affect vegetative protection. For example, stream banks with a majority of exposed bare soil and unstable, sloughed material would be rated low or in poor condition.

Riparian Vegetation

Riparian vegetation buffers a stream from detrimental effects of the immediate land use. Livestock grazing of the riparian zone leads to a loss of riparian vegetation, bank disruption, and sedimentation of the stream (Platts 1991). Riparian plants reduce sedimentation where loose soil flows overland into streams during rain events. Riparian vegetation also prevents excess nutrients of agricultural and suburban areas from reaching surface waters. Shading of streams by riparian vegetation helps maintain cool stream temperatures and high DO levels. A 20-point scale was used for this metric with zero indicating human activity sufficient to remove most or all of the riparian vegetation and 20 for unimpacted riparian zones $\geq$ 18 meters wide.

Embeddedness/Pool Substrate

Embeddedness indicates the extent to which the interstitial spaces between rocks (boulders, cobbles, and gravel) in a stream bed have been clogged by silt, sand, or mud. Generally, more interstitial space allows for higher diversity and numbers of benthic macroinvertebrates (Lemly 1982). As substrate becomes embedded, the fish habitat for spawning, feeding, and shelter also decreases. In high-gradient streams, embeddedness was evaluated in the riffle and run areas. In the low-gradient streams of the Piedmont and Coastal Plain, pool substrate characterization was used to evaluate stream substrate quality. Typically, diverse pool substrate (gravel, sand, and rooted aquatic vegetation) supports a diverse macroinvertebrate community (Beschta and Platts 1986). Pool substrate consisting of mud, loose sand, and little vegetation support a low diversity of organisms. Embeddedness was measured on a 20-point scale with zero being more than 75% embedded.

Sedimentation

Sediment deposition, or sedimentation, is the greatest single water pollutant in the United States in terms of quantity and resulting economic and ecological impact (Waters 1995). Sedimentation, like embeddedness, is the result of large-scale particle movement from local and distant upstream sources. Natural erosion occurs when rain events move loose soil into streams and when high flows scour the stream banks. Sedimentation can degrade ecosystem integrity through impacts to benthic macroinvertebrates and fish (NC DENR June 2002). Fines and other particles may also fill in small pools when they settle out. Sedimentation can be exacerbated by drought when the seasonal flushing of fines does not occur. Seasonally heavy rains normally push sediments downstream to large pool habitats. Optimal scores indicate streams with little enlargement of islands and point bars, whereas streams with heavy deposits of fine material were given a poor rating.

Total Habitat Score

This parameter is used to rate each stream site based on all ten parameters assessed in the field. Total habitat score was calculated for each site by adding the ten scores (possible range 0 – 200), then dividing by 200 and multiplying by 100% to get the percent of the score range to be between 0 and 100. Lower scores represent degraded habitat and high scores (≥ 75%) indicate sites with habitat conditions favorable for macroinvertebrate and fish communities.

5.2 PHYSICAL HABITAT RESULTS

The stream habitat results presented in this section are based on data collected in the spring of 2001. Ten habitat parameters were measured in the field at each sample site, and an eleventh metric total habitat score was calculated from the ten scores. The full data set is listed in Table 2 of Appendix F and the sample site information is in Appendix B. The habitat scores for each site were generated by the biologist using the guide in Table 1 of Appendix F. Although 63 stations were sampled for habitat and benthic macroinvertebrates in the spring, water chemistry was sampled in the fall at only 57 of the benthic/habitat sites (Figure 61). The habitat results and figures in this section are based on 63 data points.

Figure 61. There were 63 stations sampled in the spring for habitat and benthic macroinvertebrates, 58 in the autumn for water chemistry, and 57 sampled for all three components.

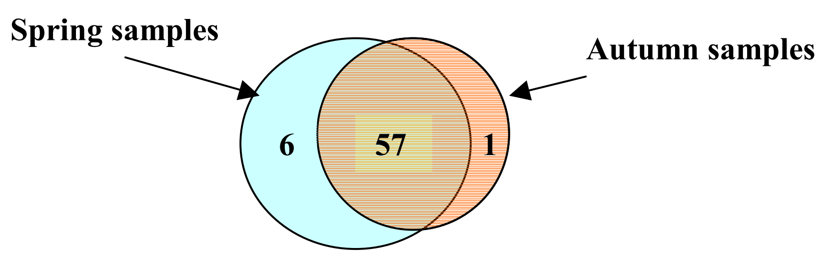
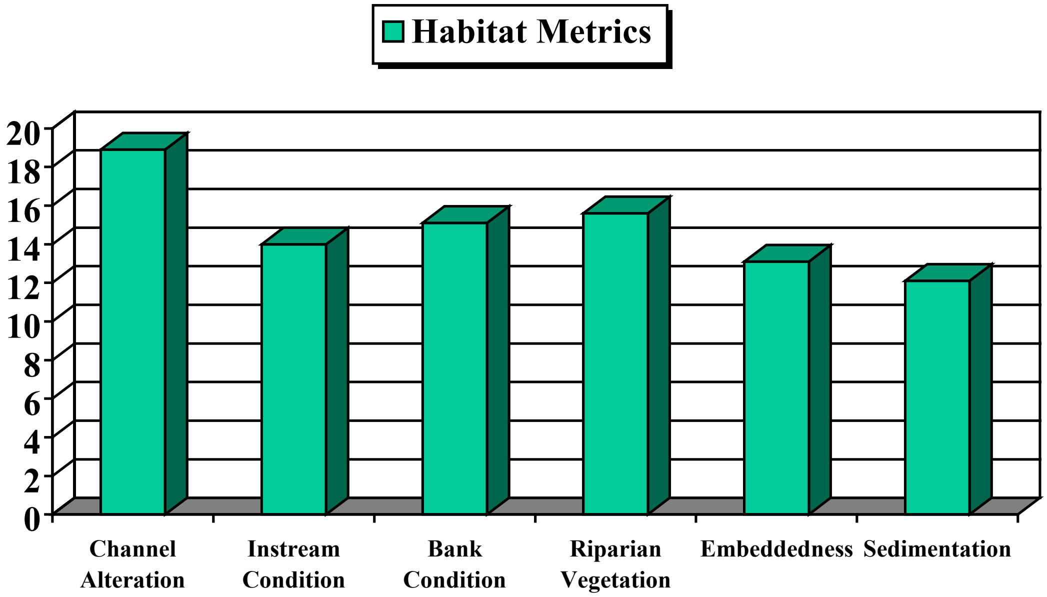


Figure 62 summarizes the average scores (range 0 – 20) for the six primary metrics from all ProbMon sites sampled in spring 2001. Channel alteration was the least impacted parameter (mean = 18.9), whereas sedimentation had the lowest score (mean = 12.1). Qualitative rankings of the scores from Optimal to Poor based on RBP-II methodology are presented in detail in Table 1 of Appendix F. Statewide, no metric averaged in the Poor or Marginal categories while Channel Alteration, Bank Condition, and Riparian Vegetation averaged in the Optimal range.

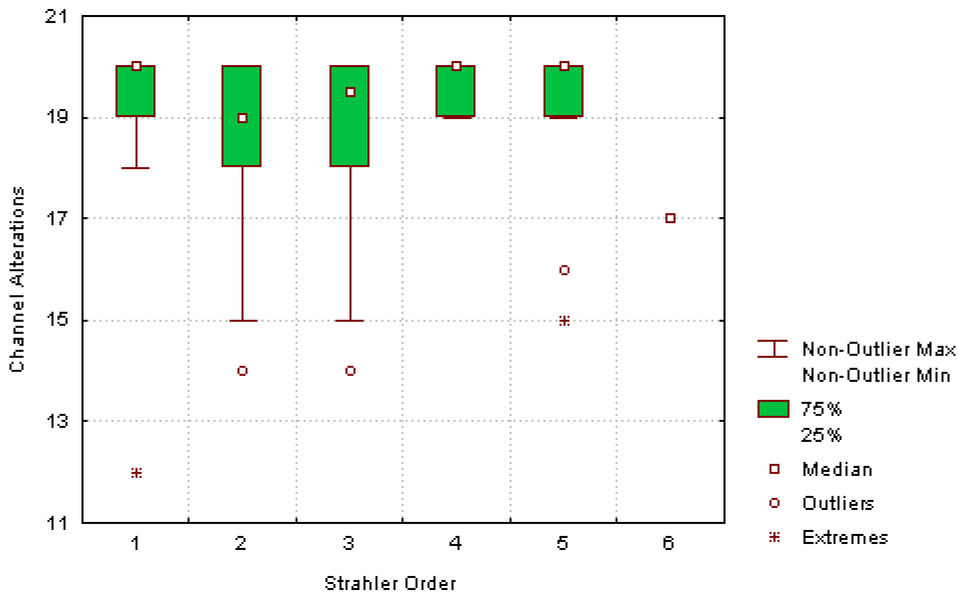
Figure 62. Bar graph of average scores for each habitat metric at ProbMon sites (n = 63). A score of 20 is optimal. The Instream Condition and Bank Condition metrics are combinations of two or more field parameters.



Channel Alteration Results

Based on Figure 63, with the exception of 6th order streams, the median channel alteration score was 19 or 20, showing that most sites had no evidence of an altered stream channel. Stream orders 2 and 3 also have greater variation in channel alteration than other orders and included some sub-optimal channel conditions.

Figure 63. Boxplot of channel alteration score by Strahler Stream Order.



In the CDF curve, channel alteration scores are again concentrated at the upper or optimal end of the range (Figure 64). From the figure one can estimate that 95% of all non-tidal streams in Virginia have unaltered channels. This suggests the metric will not be very useful for explaining chemical or biotic variation although it is a good indicator of the degree to which stream channels have been manipulated. The scatter of high channel alteration scores across the Commonwealth in Figure 65 reinforces the idea that most channels are unaltered. One might argue that, because sites were randomly chosen, many were in remote areas where the stream was not affected by bridges, dredging, or other channel altering processes. But, all sites had an equal chance of being chosen. To summarize, first year results show that in Virginia's non-tidal streams channel are primarily natural or unaltered.

Figure 64. CDF curve of channel alteration.

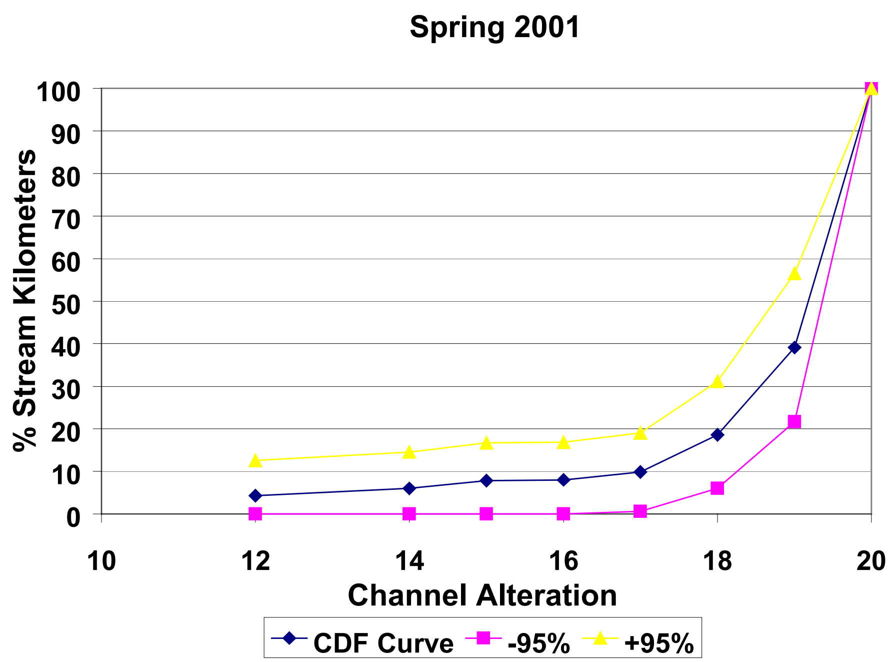
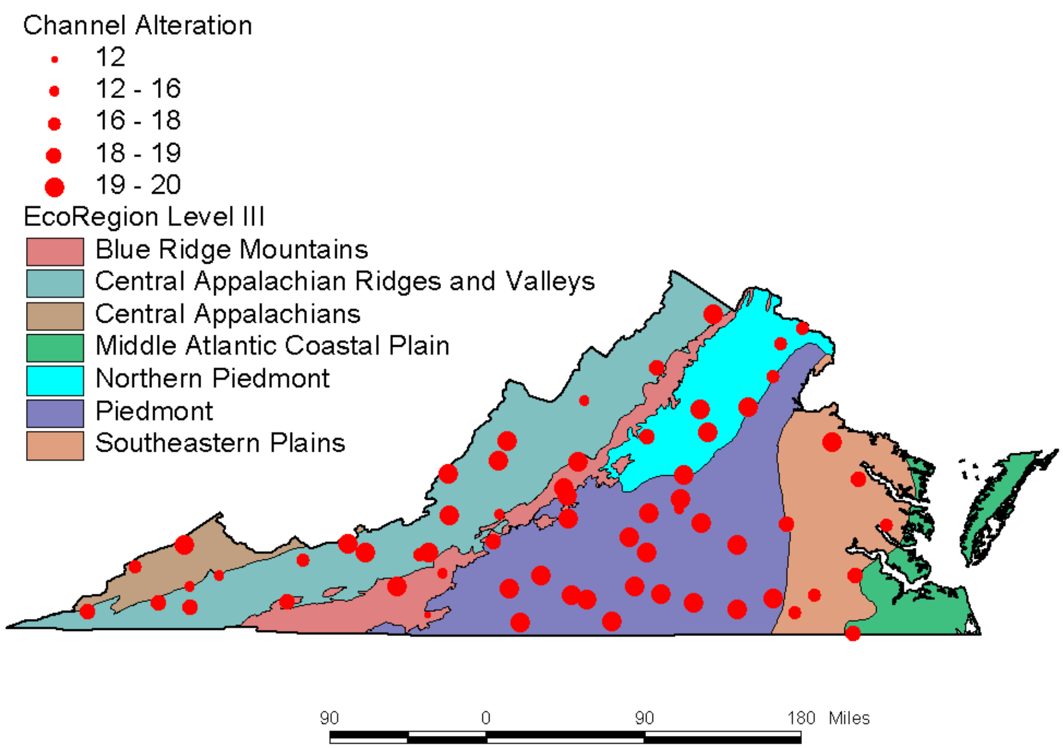


Figure 65. Spatial distribution of channel alteration scores.



Instream Condition Results

For instream condition, four field parameters were averaged so that the score ranged from zero to 20 with higher scores being optimal. Scores ranged from marginal to optimal (5.8 to 19.8). Low scores appear to be clustered in the Piedmont and Southeast Plains ecoregions with the individual cover, flow, and pool variability scores being major determinants of instream condition. Most scores for the mountainous regions were in the optimal to suboptimal range. Several of the parameters in this metric relate to the amount of water in the stream channel and can be influenced by rainfall. During the last three years Virginia has experienced a drought. The drought impact on instream condition has possibly been greater in the eastern part of the Commonwealth.

Bank Condition Results

Bank condition is the average of bank stability and bank vegetation protection which were estimated in the field. It ranged from marginal to optimal; 6.0 to 20.0. The overall mean score was 15.1 indicating that stream banks across the state are in relatively good condition. The few sites with low scores were distributed around the state and among various stream orders. Possible negative impacts to bank condition were disruption from livestock, crop fields located near stream banks, roadways and mowing of vegetation. In addition, where soils are highly erodible, streams can be prone to natural bank failure.

Riparian Vegetation Results

Based on Figure 66, the median riparian vegetation scores are lowest in 2nd and 3rd order streams. These stream orders are potentially more susceptible to human activities such as urbanization and agriculture. For example, a first order site that received a vegetation score of zero was located in the front yard of a home where the owner maintained a lawn to the stream edge.

Figure 66. Boxplot of riparian vegetation scores by Strahler Stream Order.

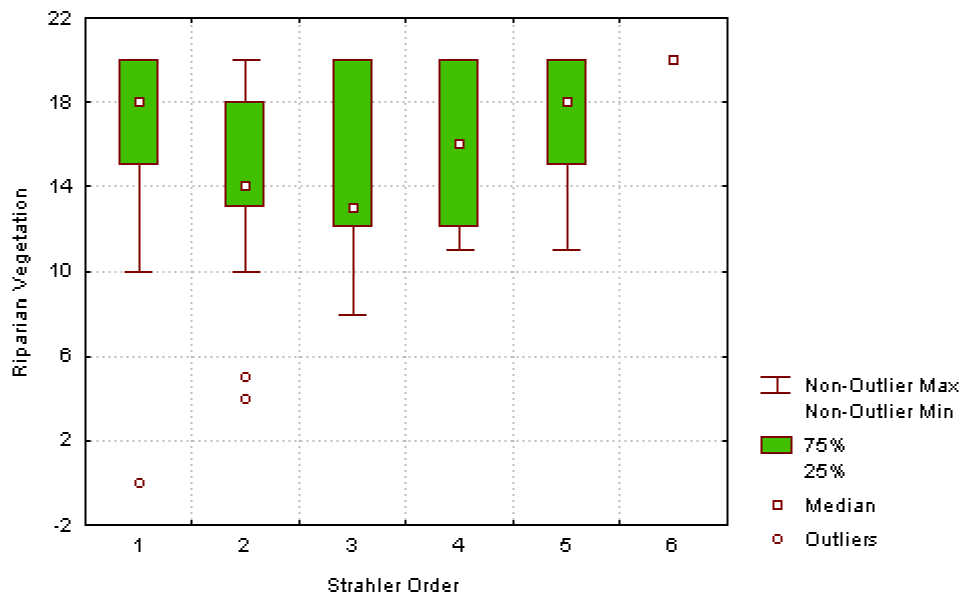
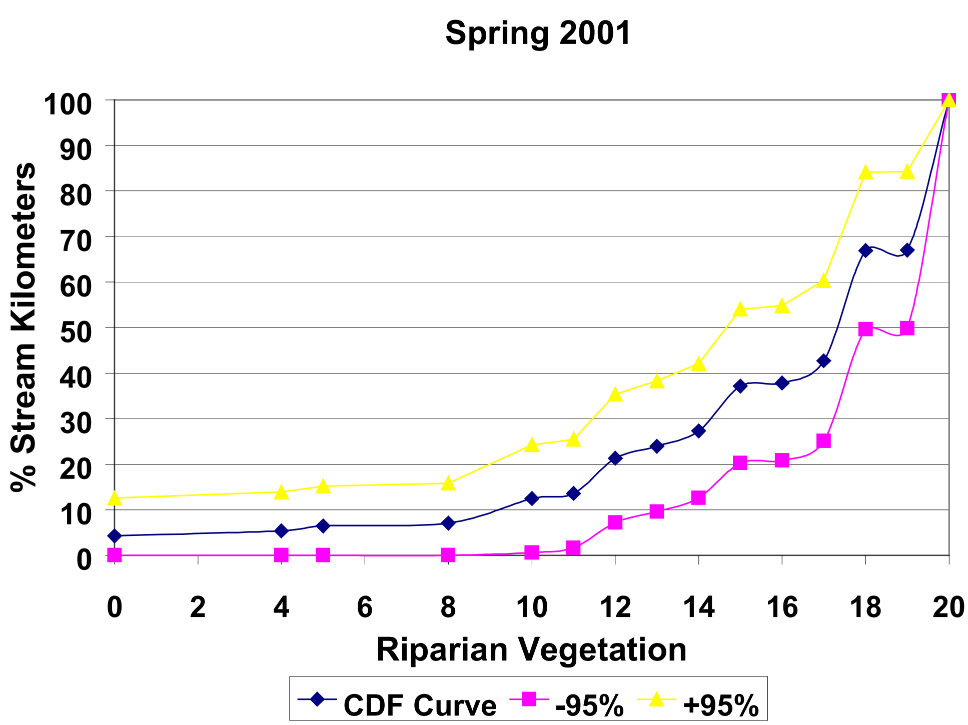


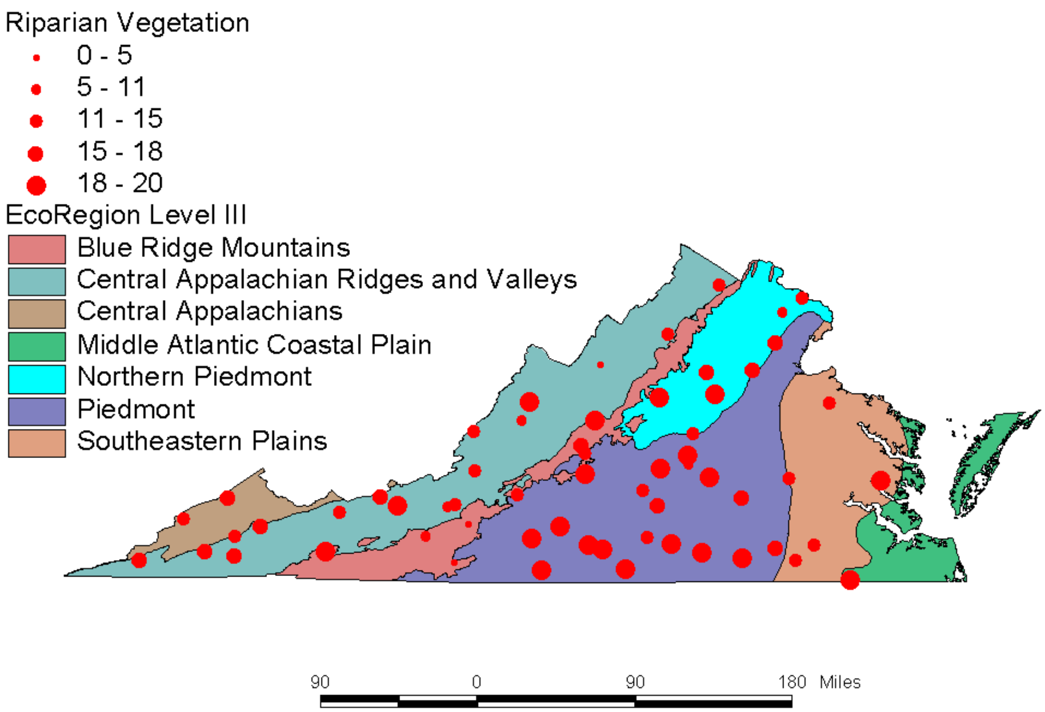
Figure 67. CDF curve of riparian vegetation score by Strahler Stream Order.



As with channel alteration, the riparian vegetation scores tend to be concentrated in the optimal category (Figure 67). But, human activities have reduced the riparian zone in about 38% of non-tidal streams in the Commonwealth. Also, 50% have a score of 18 or better.

Optimal riparian vegetation is found in all ecoregions although the Piedmont ecoregion has predominately high scores (Figure 68). Overall the non-tidal streams in the Commonwealth have substantial riparian vegetation.

Figure 68. Spatial distribution of riparian vegetation scores.



Embeddedness/Pool Substrate Results

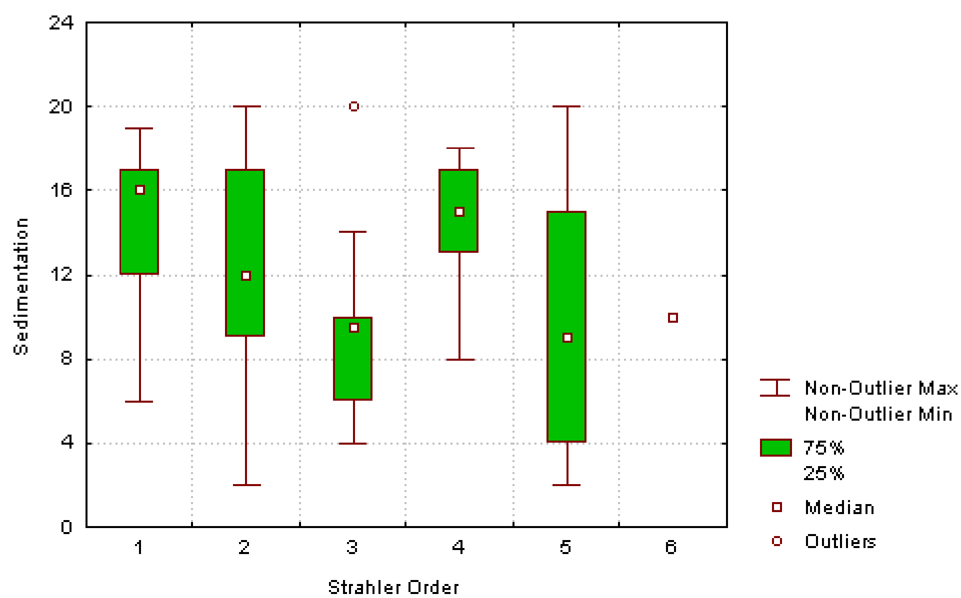
Embeddedness and pool substrate measure similar habitat values in high gradient versus low gradient streams, respectively. Thus, these two scores were used as a single metric across the 63 sites (Table 2 & 3, Appendix F). Scores ranged from zero to 20 with a combined mean score of 13.1. Several factors may explain the level of substrate impacts around the Commonwealth. Low embeddedness scores are most likely due to high agricultural or logging uses surrounding and upstream of the site. The current drought could also be a factor. Some watersheds have not experienced normal heavy rainfall in the spring, and base flows do not have enough power to move fine sediment out of riffle and run habitats. Embeddedness and pool substrate scores appear to be lower in the Piedmont and Southeastern Plains ecoregions, which are typically dominated by low gradient streams.

Sedimentation Results

Based on Figure 69, 1st order streams have the least sedimentation followed in succession by 4th, 2nd, 3rd, 6th, and 5th orders. With a maximum score of 20, sedimentation appears to be a moderate problem in streams of all orders. In all orders, up to 50% of the stream bottom is affected by sediment. So, instead of the sediment flushing through the monitored sites it is accumulating, creating bars, and filling pool habitats.

In Figure 69 the highest sediment scores are primarily in 1st, 4th, and 2nd order streams.

Figure 69. Boxplot of sedimentation scores by Strahler Stream Order.



In the CDF curve in Figure 70, about 55% of the streams exhibit a sedimentation score of 15 or greater; they are optimal.

Based on Figure 71 streams in all ecoregions experience moderate sedimentation with the Piedmont ecoregion having a slightly higher percentage of affected streams. Like embeddedness, sediment deposition is affected by stream gradient and the amount of water available to move the sediment load. Sandy soils and low gradient streams characterize the Piedmont ecoregion. Thus, streams in this area are more prone to sediment deposition.

Figure 70. CDF curve of sedimentation.

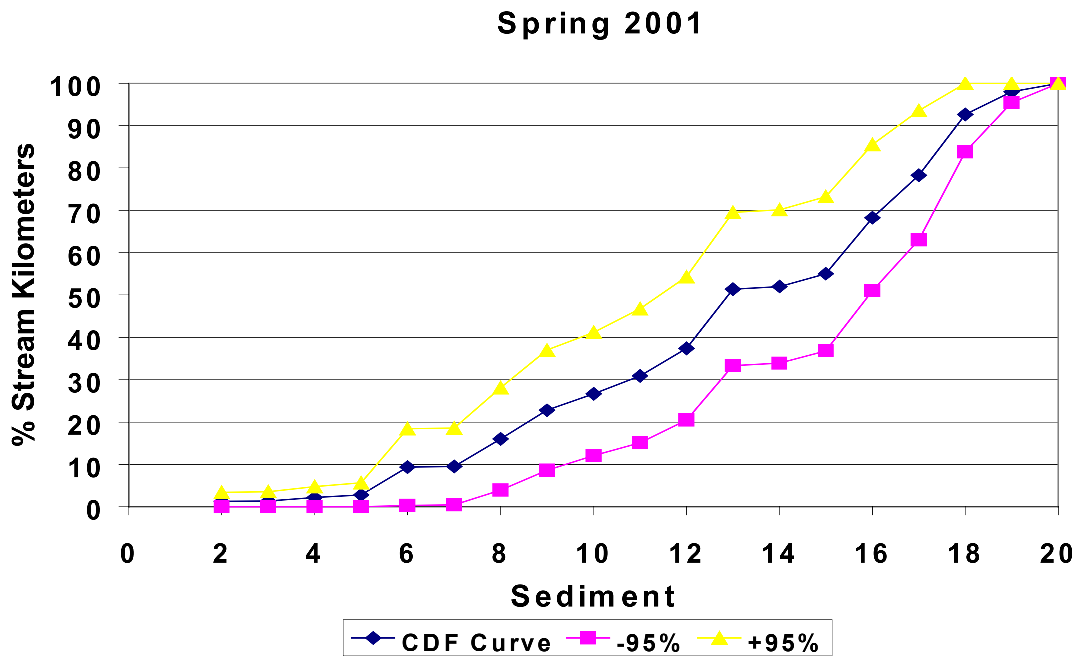
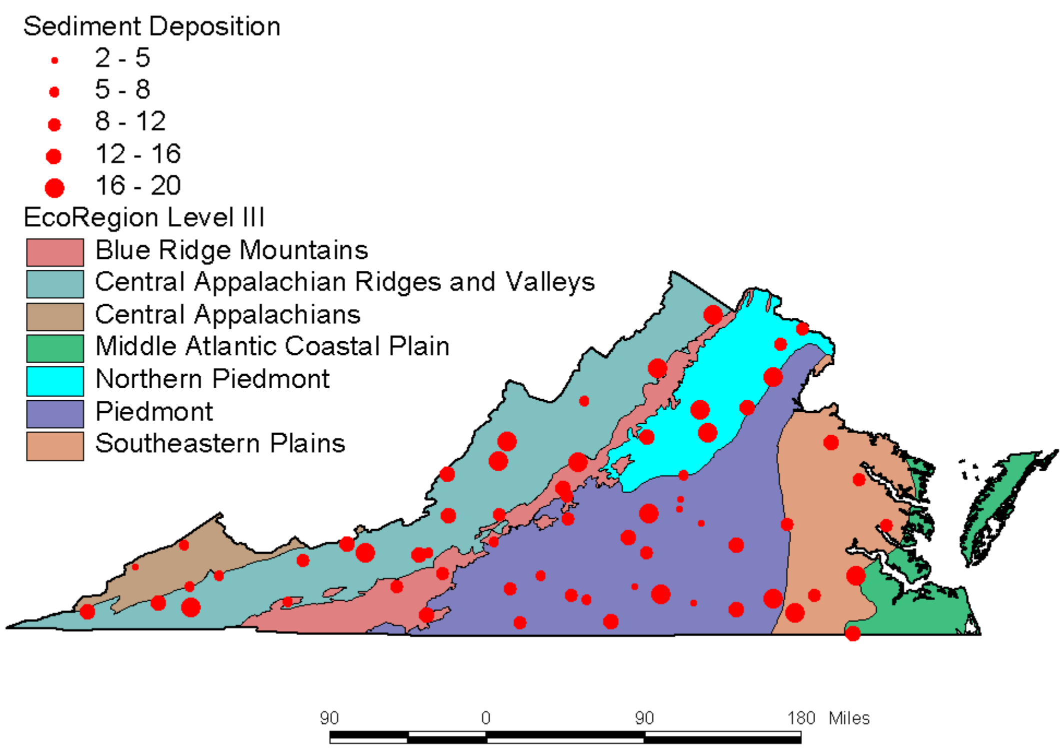


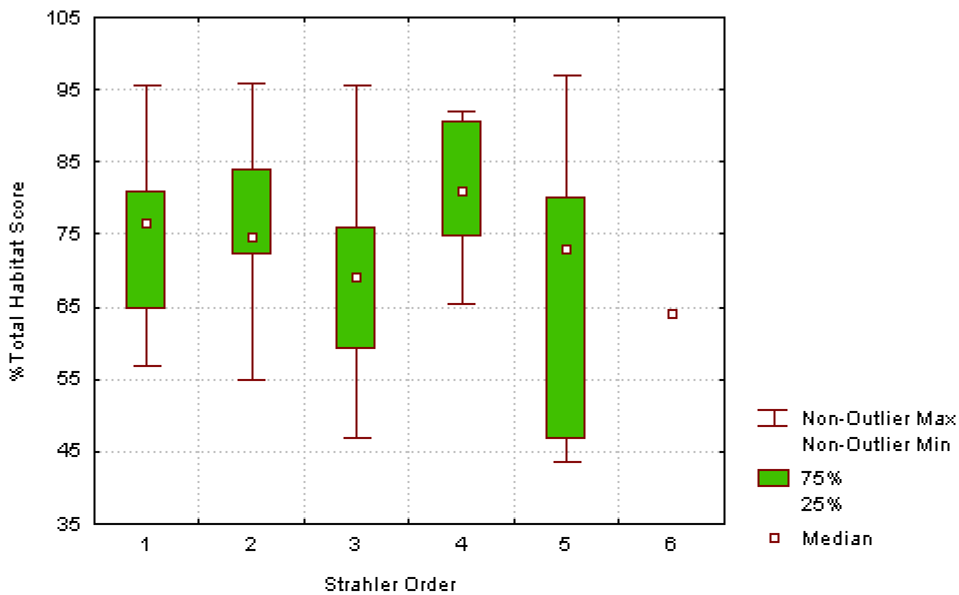
Figure 71. Spatial distribution of sedimentation scores.



Total Habitat Scores Results

Total habitat scores ranged from about 43% to 97% with more variable scores in 3rd and 5th order streams than other size streams (Figure 72). Overall, 4th order streams had less variability.

Figure 72. Boxplot of percent total habitat scores by Strahler Stream Order. The maximum possible score is 100%.



Only one percent of all stream kilometers in Virginia were rated as poor or marginal when combining all habitat parameters (Figure 73). About 50% of stream kilometers were assessed as having optimal habitat. An interesting feature of the CDF curve for total habitat scores is the flat versus rise portions of the graph. At approximately 60% and 75% there are groups of stations with the same percentage. Between the points, there are groups of stations that show a broader range of %Total Habitat.

Figure 74 shows that low and high total habitat scores are distributed throughout the Commonwealth. The Piedmont ecoregion appears to have more low scores than other ecoregions. This is probably related to the lower sediment (see Figure 71) and embeddedness scores in this ecoregion.

Figure 73. CDF curve of percent total habitat.

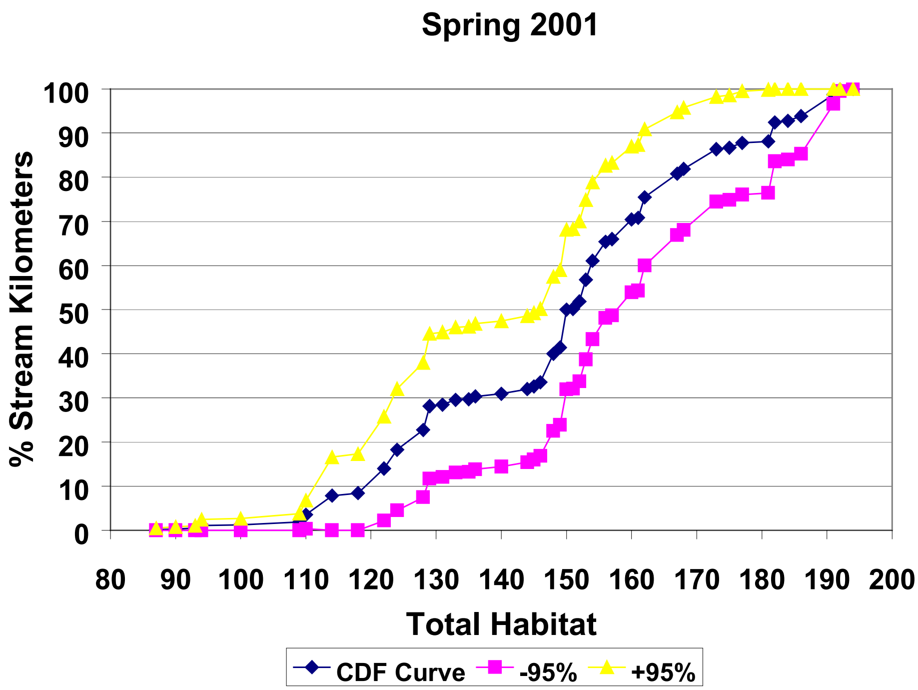
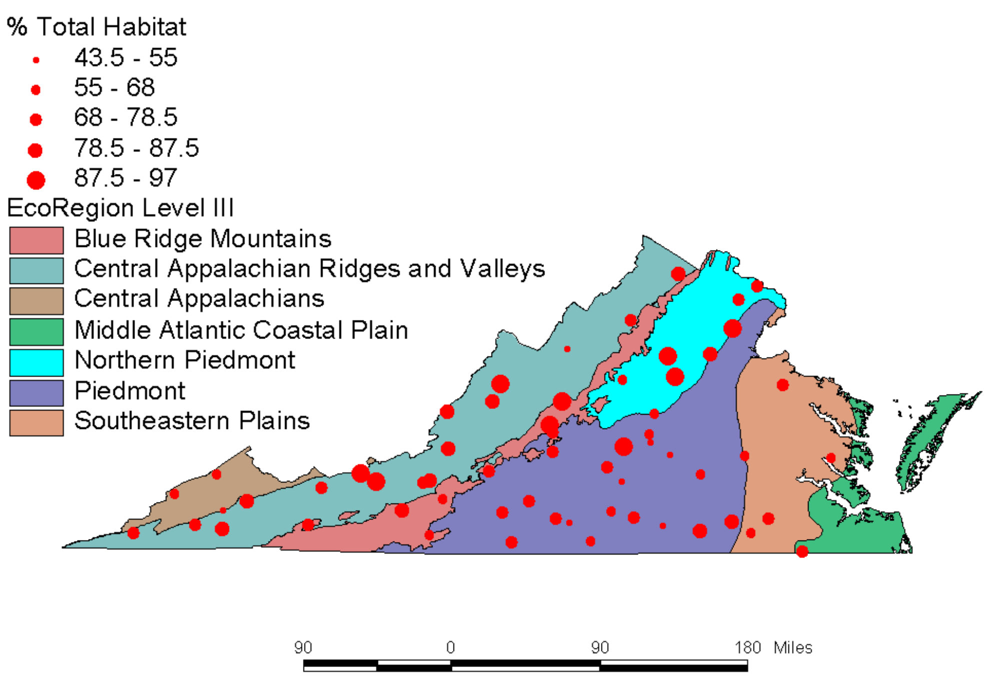


Figure 74. Spatial distribution of percent total habitat scores.



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6. LAND COVER DATA

The land surrounding a water body can significantly impact the in-stream water quality, altering the physical habitat and biological community. Several areas of Virginia are experiencing rapid urban expansion while other areas are reforesting. By calculating land cover upstream of ProbMon sites, VDEQ can explore the impact of different land covers on stream conditions. If land cover can be used to predict stream conditions then an immediate use of land cover data is to help VDEQ biologists identify reference sites. Reference sites are stream segments that have exceptionally good conditions for benthic macroinvertebrates. Reference sites are especially rare in the Piedmont Province of Virginia. By comparing land cover data to biological metrics, VDEQ can create a filtering matrix (which includes habitat and chemical data) to identify potential reference sites. A sample reference watershed matrix for the Central Appalachian Ridges and Valleys ecoregion is shown in Table 5. The matrix is an example of how land cover data can help identify reference watersheds. The matrix is based on literature examples (Rohm et al. 2002; Stepenuck et al. 2002) and personal communication with VDEQ biologists. Land cover also has a potential role in aiding water quality management decisions.

Table 5. Example reference site matrix for the Central Appalachian Ridges and Valleys Ecoregion. See Table 1 on page 24 for land cover type definitions.

Reference Site Selection Matrix	
Land Cover	**Include if**
Urban	< 8%
Agriculture	< 35%
Barren/Mining	< 2%
Physical Habitat Data	**Include if**
Sedimentation	> 16
Riparian Zone	> 18
% Habitat	> 75 %
Chemical Data	**Include if**
Nitrate	< 0.1 mg/L
Total Phosphorus	< 0.02 mg/L
ANC	< 50 ueq/L

After several years of probabilistic data collection VDEQ will refine the matrix for each ecoregion to aid the selection of ecoregion reference sites across the Commonwealth.

Selected Examples of Watershed Land Cover

Land cover is not compared to chemical, physical habitat or biological data in this report. However, the availability of recent digital land coverages for Virginia holds great potential for explaining the chemical, habitat, and biological conditions observed at sample points across the Commonwealth. To provide a foundation for thought on the utility of land cover data, in this section we delineate and map the land cover for the watershed above five ProbMon stations. The stations were chosen from stream orders 1 through 5. The entire watershed above a station was first delineated using a 90 meter Digital Elevation Model based on DEM information. Then the most recent land cover for the watershed was summarized into eight categories. The land cover spatial resolution was 30 meters meaning that each 30M x 30M surface area in Virginia was designated one land use. Finally, the land cover was mapped using ArcView. The resulting maps are presented in the next five figures by ascending stream order. Note that these maps do not have the footprint of an NRCS or VDEQ watershed but are the hydrologic outline of all land upstream of a sample point.

Figure 75. Land cover map for Little Indian Creek Watershed above station 9-LIC004.73, Strahler Order 1.

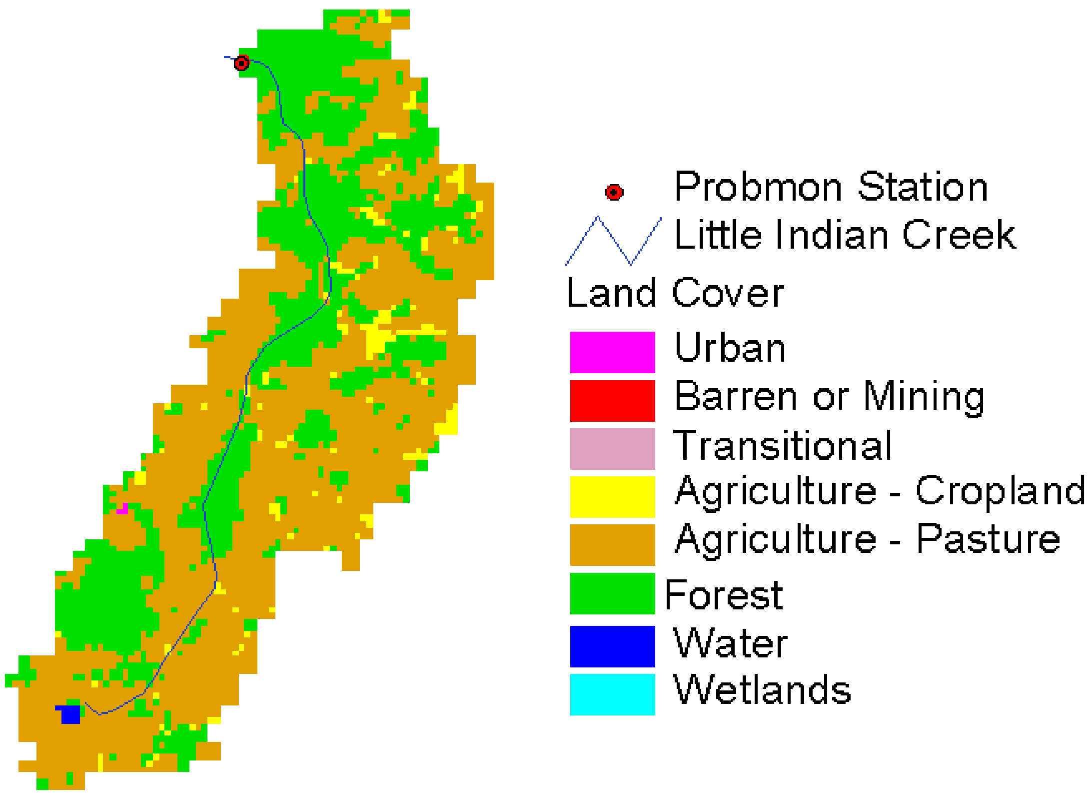


Table 6. Detailed land cover by major land use category for the map of Little Indian Creek Watershed, station 9-LIC004.73, in the New River Basin.

Land Cover	%
Open water	0.22
Urban	0.07
Agriculture	64.85
Forest	34.87
Wetland	0.00
Other	0.00
Total square miles	1.60
Total hectares	413.32

Figure 76. Land cover map for Ogle Creek Watershed above station 2-OGL005.53, Strahler Order 2.

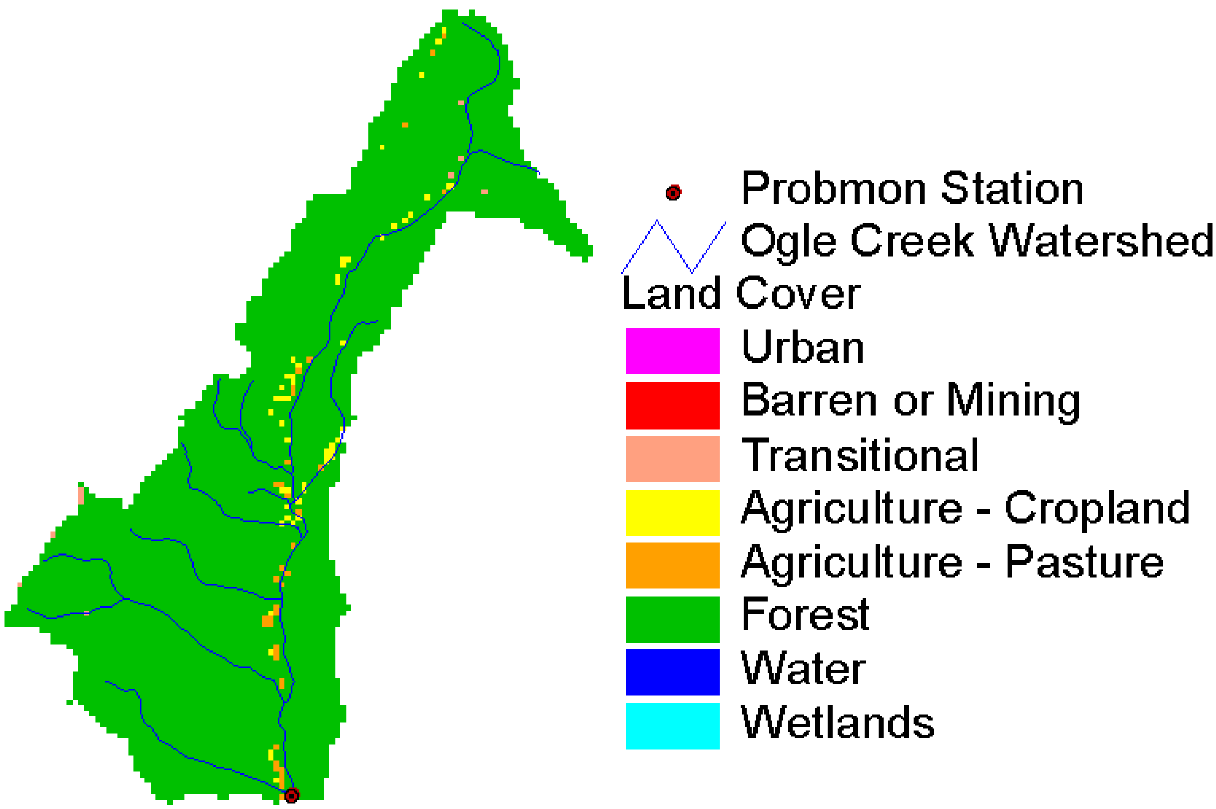


Figure 77. Land cover map for Horsepen Creek Watershed above station 4AHEN004.74, Strahler Order 3.

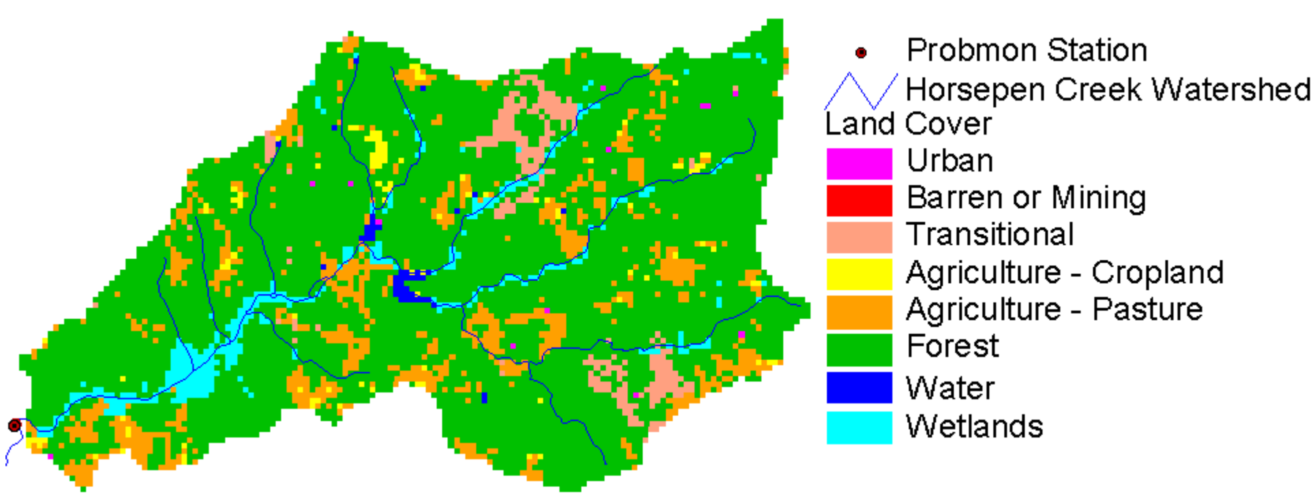


Figure 78. Land cover map for Wolf Creek Watershed above station 9-WFC010.66, Strahler Order 4.

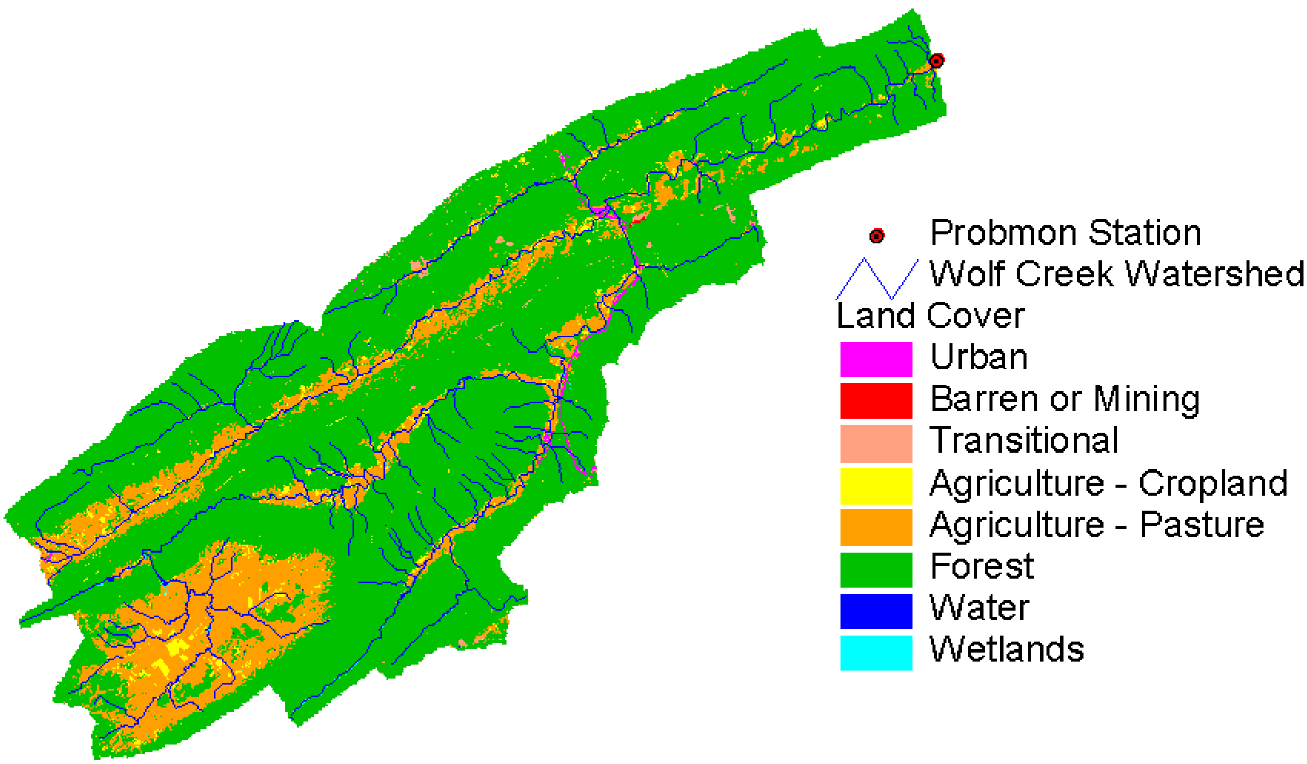
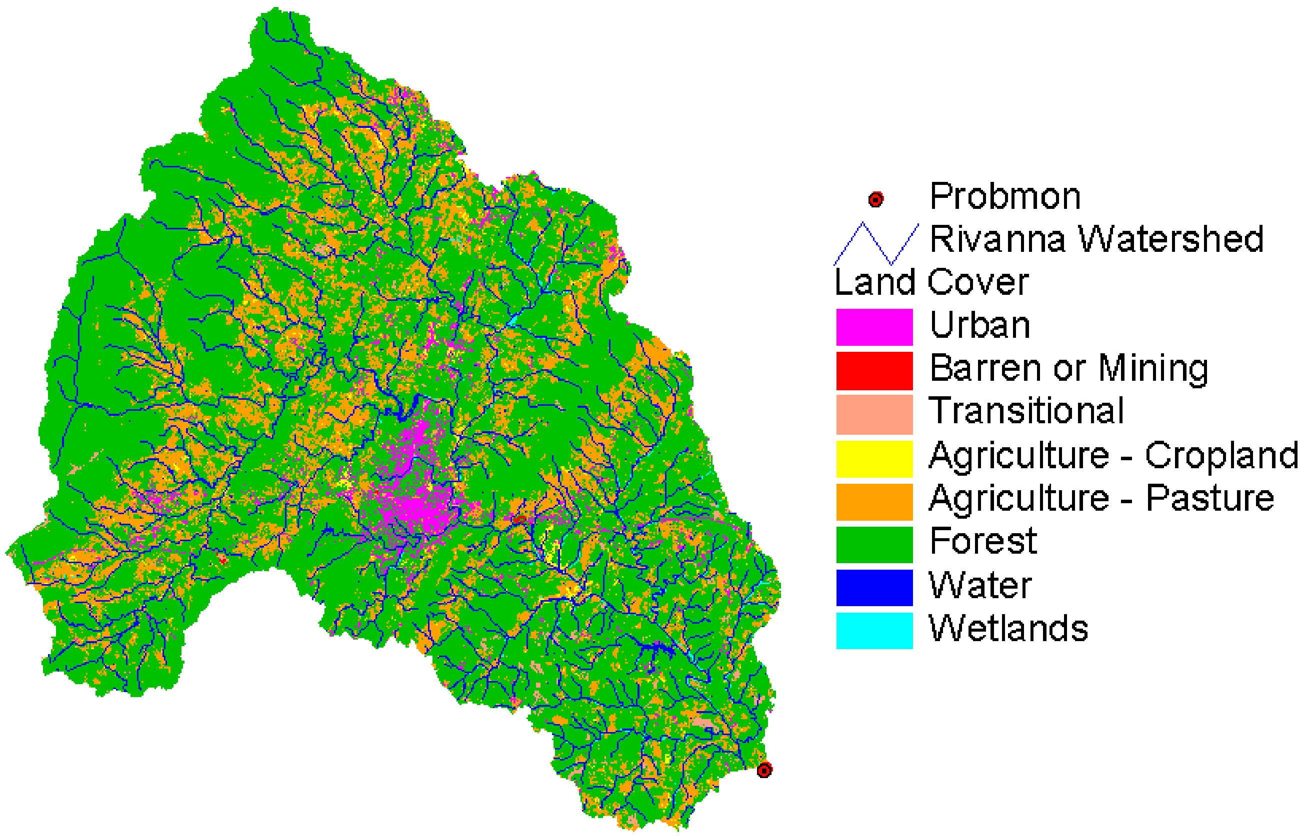


Figure 79. Land cover map for Rivanna River Watershed above station 2-RVN012.05, Strahler Order 5.



Detailed Land Cover Information by Ecoregion.

In this section the land cover information is presented for each of the 58 ProbMon stations that have chemical data. Unlike the previous section, for ecoregion analysis the agricultural land use is totaled as a single category. The stations are grouped by ecoregion because we will ultimately generalize the land cover by ecoregion. The predominant land cover for each watershed is shaded to draw attention to similarities and differences between watersheds in an ecoregion. Finally, the size of each watershed is presented in the last two columns. GIS coverages for the individual stations along with the watershed shapefiles and grids are available from J. Hill (personal communication December 2002).

The land cover information in tables 7-13 is presented in six categories: % Open Water, % Urban, % Agriculture, % Forest, % Wetland, and % Other. These categories were created by merging similar categories found in Table 1. The % Urban category contains Low intensity

Residential (21), High intensity Residential (22), Commercial/Industrial/Transportation (23), and Urban/Recreational Grasses (85). % Agriculture is made up of Pasture/Hay (81) and Row Crops (82). % Forest is formed by Deciduous Forest (41), Evergreen Forest (42), and Mixed Forest (43). % Wetland contains Woody Wetlands (91) and Emergent Herbaceous Wetlands (92). The % Open Water is just Open Water (11). Finally, the % Other category contains, Bare Rock/Sand/Clay (31), Quarries/Strip Mines/Gravel Pits (32), and Transitional (33).

Blue Ridge Mountains Ecoregion

Based on six delineated watersheds, the dominant land cover in the Blue Ridge Mountains Ecoregion is forest (Table 7). Where agriculture is dominant, a third of the watershed is also forested. The largest watershed, 1.60 mi^2 in size, is two-thirds agriculture and one third forest.

Table 7. Land cover for 6 stations in the Blue Ridge Mountains Ecoregion. The dominant land cover for each station's watershed is shaded.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
4ASNF007.64	1	Roanoke	0.00	0.00	1.65	96.69	0.83	0.83	0.04	10.87
6CSLM002.11	1	Holston	0.00	0.00	0.00	100.00	0.00	0.00	0.02	6.29
9-LIC004.73	1	New	0.22	0.07	64.85	34.87	0.00	0.00	1.60	413.32
2-BNF003.52	2	James	0.00	0.00	0.20	99.51	0.00	0.29	0.71	184.02
2-SMR004.80	2	James	0.00	0.00	0.33	99.67	0.00	0.00	0.41	107.37
9-MDR003.60	2	New	0.11	0.05	60.82	39.02	0.00	0.00	0.65	169.46

Central Appalachian Ridges and Valleys Ecoregion

The second largest concentration of ProbMon stations, 16, was in the Central Appalachian Ridges and Valleys Ecoregion (Table 8). As was true for the Piedmont Ecoregion, forest is the dominant land cover although agriculture occupies more than 10% cover in most watersheds. Stream orders 1 through 5 were sampled in this ecoregion. The largest watershed was on an order 4 stream with a 207 mi^2 extent.

Table 8. Land cover for 16 stations in the Central Appalachian Ridges and Valleys Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
1BDRI000.21	1	Shen	0.53	6.87	29.35	62.81	0.34	0.08	14.57	4144.65
6BXDJ000.15	1	Tenn	0.00	0.00	8.32	91.68	0.00	0.00	0.21	55.08
1BBVR000.84	2	Shen	0.14	0.22	33.61	65.60	0.18	0.24	1.72	444.86
1BCPL002.83	2	Shen	0.03	0.05	78.17	21.25	0.48	0.02	5.08	1314.82
2-OGL005.53	2	James	0.00	0.00	1.84	97.95	0.00	0.20	1.69	438.57
2-CWP053.78	3	James	0.22	0.03	13.90	85.32	0.18	0.35	28.88	7480.80
4ARNF015.50	3	Roanoke	0.03	0.67	26.33	72.95	0.00	0.01	48.07	12448.41
6BLWS003.88	3	Tenn	0.25	0.02	8.77	87.12	0.00	3.85	1.97	509.29
9-WFC044.15	3	New	0.16	0.00	50.74	48.80	0.30	0.00	38.68	10018.06
2-CWP023.28	4	James	0.32	0.09	12.22	86.87	0.21	0.29	49.97	12942.24
2-JOB001.02	4	James	0.33	0.01	12.22	93.21	0.14	0.21	13.09	3391.14
4ARNF009.01	4	Roanoke	0.05	2.21	21.74	75.25	0.01	0.74	76.46	19803.05
9-WFC010.66	4	New	0.08	0.39	19.56	79.45	0.15	0.36	207.11	53638.70
2-LMC001.15	5	James	0.10	3.04	37.00	59.68	0.01	0.17	7.62	1973.26
6BPOW156.57	5	Tenn	0.20	2.13	4.27	90.38	0.13	2.88	36.64	9488.38
9-WLK024.17	5	New	0.12	0.31	23.12	76.20	0.03	0.22	192.95	49971.62

Central Appalachians Ecoregion

The dominant land cover for the three watersheds in the Central Appalachian Ecoregion is forest (Table 9). Stream orders range from 1 to 3 with the largest area being 3.92 mi^2.

Table 9. Land cover for 3 stations in the Central Appalachians Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
6AXBF000.40	1	Big Sandy	0.00	0.00	0.00	97.07	0.00	2.93	0.09	24.53
6APNS003.94	3	Big Sandy	0.22	0.08	5.21	77.55	0.05	16.89	1.28	331.38
6BDUM000.23	3	Tenn	0.64	0.50	1.50	90.71	0.17	6.48	3.92	1014.89

Middle Atlantic Coastal Plain

The single watershed sampled in the Middle Atlantic Coastal Plain in eastern Virginia was mainly forest and agricultural although wetlands covered a third of what was covered by forest (Table 10).

Table 10. Land cover for 1 station in the Middle Atlantic Coastal Plain Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
5ASTN002.43	4	Chowan	1.09	1.86	38.04	43.25	14.50	1.26	109.35	28319.49

Northern Piedmont Ecoregion

Seven stations were sampled in the Northern Piedmont. The land cover of the largest stream orders sampled, orders 4 and 5, are so large that their cover dictates cover dominance (Table 11). Forest was the leading cover type with agriculture making up a third to half of that. In the second order watersheds, urban cover was substantial and made up over half the cover in one watershed. The largest watershed covered 656 mi^2, containing a 5th order stream.

Table 11. Land cover for 7 stations in the Northern Piedmont Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
8-BRC002.70	1	York	0.15	0.02	2.39	90.96	2.22	4.26	1.86	481.16
1ACAH001.82	2	Potomac	1.27	9.28	45.99	42.29	0.96	0.21	1.01	262.37
1AFLL000.62	2	Potomac	0.59	52.78	13.74	27.55	1.55	3.78	7.63	1975.78
1ALUC000.95	2	Potomac	0.00	20.78	4.79	72.71	0.02	1.70	3.04	788.37
2-RRS010.30	4	James	0.54	0.93	21.58	76.28	0.09	0.58	215.42	55790.95
3-ROB005.42	4	Rappah	0.27	1.26	31.67	66.35	0.22	0.23	151.35	39197.72
3-RAP008.71	5	Rappah	0.41	1.17	35.88	61.32	0.37	0.85	656.12	169929.71

Piedmont Ecoregion

The greatest number of ProbMon stations were situated in the Piedmont Ecoregion. Sampled stream orders ranged from 1 to 5 (Table 12). Although stream order generally reflects watershed size there is great variation in watershed size even within a stream order. The largest watershed sampled in the Piedmont Ecoregion was 771 mi^2, above a 5th order stream in the James River Basin. The dominant land use in the ecoregion is forest although agricultural use is a strong second in most watersheds.

Table 12. Land cover for 19 stations in the Piedmont Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
2-COO002.35	1	James	0.15	0.05	12.52	85.43	0.00	1.85	0.70	180.07
2-LOB000.15	1	James	0.00	0.11	10.08	89.50	0.00	0.32	0.33	85.54
4AXME001.19	1	Roanoke	0.00	0.00	54.03	45.16	0.00	0.81	0.04	11.14
5AXEJ001.73	1	Chowan	0.00	0.00	41.18	51.10	7.72	0.00	0.09	24.44
2-RND003.57	2	James	0.17	0.19	15.92	79.10	3.19	1.42	14.12	3658.18
4ABDA011.79	2	Roanoke	0.28	2.03	36.82	60.83	0.00	0.05	2.86	739.49
4APAA000.24	2	Roanoke	1.05	0.00	38.10	56.73	0.07	4.05	1.42	368.40
2-BFL016.79	3	James	1.21	0.03	21.58	73.94	2.66	0.58	13.30	3443.61
2-HAZ006.80	3	James	0.43	2.23	23.20	73.91	0.01	0.23	5.59	1446.54
2-SUA001.55	3	James	0.30	1.10	9.99	80.27	3.35	4.99	9.59	2483.63
4AEKH003.18	3	Roanoke	1.28	0.23	18.51	76.50	0.01	3.46	2.41	622.95
4AHEN004.74	3	Roanoke	0.59	0.91	13.02	77.52	4.44	3.52	2.72	703.91
4AOWC004.74	3	Roanoke	0.18	0.04	19.81	74.41	0.00	5.56	0.77	200.46
2-APP082.00	5	James	0.78	1.13	19.11	72.47	4.39	2.11	629.71	163089.65
2-RVN012.05	5	James	0.79	3.01	20.37	70.08	4.78	0.97	770.80	199630.06
2-WLS024.61	5	James	0.64	0.57	16.95	75.24	4.49	2.11	174.09	45087.22
4ABAN022.24	5	Roanoke	0.49	0.60	30.04	65.33	1.36	2.18	63.03	16324.12
4ASRV012.19	5	Roanoke	0.27	0.63	26.80	70.08	0.38	1.86	10.26	2656.86
5AMHN105.36	5	Chowan	0.29	0.49	18.93	74.90	2.42	2.97	309.41	80135.17

Southeastern Plains Ecoregion

For the six ProbMon watersheds in the Southeastern Plains Ecoregion, the dominant land cover was forest with agriculture a strong second cover type (Table 13). The single order 6 watershed sampled by ProbMon was in this ecoregion and covered 1,095 mi^2.

Table 13. Land cover for 6 stations in the Southeastern Plains Ecoregion.

Station	Stream Order	River Basin	% Open Water	% Urban	% Agriculture	% Forest	% Wetland	% Other	Total Square Miles	Hectares
8-XEA000.12	1	York	0.00	0.00	41.66	55.77	2.58	0.00	0.77	198.66
5AAPW001.04	2	Chowan	0.22	0.00	18.23	57.07	12.39	12.09	6.49	1681.60
2-CEL001.00	3	James	0.42	20.07	44.18	33.53	0.47	1.34	10.51	2721.38
7-DRN027.96	3	ChesBay	0.41	0.16	26.57	66.29	5.15	1.42	22.65	5867.31
5ABLW055.26	5	Chowan	0.46	1.81	24.99	65.21	5.28	2.25	287.23	74389.16
5ANTW045.12	6	Chowan	0.68	1.51	20.09	69.37	5.68	2.68	1095.34	283681.10

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7. SUMMARY AND CONCLUSIONS

The first sample year of the Probabilistic Monitoring Program (ProbMon) in the Commonwealth was 2001, the year covered by this report. All sites were randomly selected by the USEPA using a stratification method developed in the EMAP program. The great value of random sites is that the estimates from the data apply to the entire population. Here, the population is non-tidal waters of Virginia. The habitat and benthic macroinvertebrates were sampled both spring and fall, at 63 sites. Only the spring data was analyzed in this report because macroinvertebrate communities are in their best interpretive condition in that season. Water chemistry was sampled in the autumn at 58 sites. Because Strahler stream order is expected to be an important determinant of aquatic condition, the random selection of sites was arranged so that approximately equal numbers were chosen from 1^{st} - 4^{th} and 5^{th}+7^{th} order streams each year. Because of the random selection process, the numbers were not exactly equal this year, a condition which is expected to even out over the five years of the study.

The cumulative distribution function (CDF) was used with the chemical, benthic macroinvertebrate, and habitat data to generate probabilities. In this report a graph of the CDF is used to determine the chance of a value being smaller or larger than a selected value. The method also provides confidence limits that are important gages of the precision of the statistic. For this first year of data, the estimated confidence limits for environmental conditions are fairly wide. That is, they are imprecise. As more data points are collected in future years of the study the confidence limits will narrow to provide tight estimates. This will allow good estimates of parameters of interest as well and facilitate the intelligent management of Virginia's aquatic resources.

The results for each of the three major parameter categories are summarized below.

CHEMISTRY:

The physical-chemical results are based on data from 58 sites sampled in the autumn of 2001. A large number of parameters were collected. Only nine were examined closely in this report. The data for all parameters is listed in Table 1 of Appendix C and in Tables 1-6 of Appendix D.

pH: There is no statistical difference in pH between streams of different order. However, the medians suggest that pH increases from order 1 through order 4 streams and declines at higher orders. pH violations appear to be rare in Virginia streams. Based on the data at hand, in the fall only 2% of non-tidal streams have a pH below 6.0. With 95% confidence the percent of streams with a pH less than or equal to 7.0, the neutral value, is between 24% and 63%; the point estimate is 44%. This fairly imprecise confidence interval should narrow significantly as additional data are collected. No violations of the upper pH limits were found in the fall of 2001. On a percent rank basis, violations on the acid end of the acceptable range were observed, especially in 2nd order streams. There appear to be more acidic streams in the coastal and Piedmont ecoregions and more basic streams in the Central Appalachian Ridges and Valleys ecoregion. The regional differences likely reflect differences in bedrock chemistry. In summary, pH violations in non-tidal waters are infrequent in the fall and tend to occur on the acid end of the range.

Dissolved Oxygen (DO): 1st and 2nd order streams exhibited the lowest median DO in the fall of 2001, a drought year. Small streams appear to be affected more by the current extreme drought and resulting reduced reaeration. Third order streams exhibit the largest variation in several chemical measures including DO. This needs to be examined closer as data accumulate in future years. Larger streams have less overhead canopy leading to higher temperature from insolation and decreased DO solubility. Occasional DO excursions occur in all waters regardless of stream order. At least 3% of 1st order streams show excursions of the instantaneous standard. Approximately 9% of Virginia stream kilometers have fall DOs below 4 mg/L, the lowest instantaneous standard. The 95% confidence interval for that estimate is 0% to 18%. Low DOs occur in the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions. Median temperatures are higher in the Piedmont and Southeastern Plains ecoregions. Because these waters have lower DO solubility they are expected to have lower DO concentrations. In the fall, 73% of non-tidal streams have a DO of 7.0 or better and will probably not violate the DO standard for stockable trout waters any time during a 24 hour period.

Temperature: There is an increase in stream temperature across stream order with the highest temperatures in 6th order streams. Wide temperature variation in 3rd order streams corresponds to and may drive their wide DO variation. None of the stream orders exceeded the most stringent threshold (20°C) although 3rd and 5th order streams have maxima in that neighborhood. At this time of the year non-tidal streams in Virginia are expected to meet all instantaneous temperature standards including the most demanding, that for natural trout streams. Higher temperatures tend to be found in the Piedmont and Southeastern Plains ecoregions.

Specific Conductance: Third order streams having the broadest specific conductance range as was true for DO and temperature. If specific conductance is a yardstick for productivity then the least productive streams in the Commonwealth are 2^{nd} order. Nearly 100% of Virginia's stream miles have specific conductance below 700 uS/cm. High specific conductance at sites in the Central Appalachians and Central Appalachian Ridges and Valleys ecoregions suggests those areas are geologically unique.

Hardness: 1st order non-tidal streams rarely exceed the groundwater hardness standard suggesting that groundwater sources for non-tidal streams usually meet the hardness standard. In terms of variability, 3rd and 5th order streams have the widest hardness range. Some 54% of non-tidal streams are soft (≤ 25 mg/L) and the remainder are hard; an approximate 50:50 ratio. But, there is a trend of rising hardness with stream order. Also, waters in the western third of the State which tend to have high specific conductance also tend to be hard.

Turbidity: Order 2 streams have relatively high turbidity and the broadest turbidity range. The median is more than twice that of stream orders one through five. Thus, any turbidity problems observed in Virginia's waters are likely to be in 2^{nd} order streams. Turbidities above 12 NTU are rare and high values are scattered across the State irrespective of geography. Because turbidity is being considered nationally as a standard for water clarity, this data may be helpful in setting expectations for non-tidal streams.

Nitrate: Nitrate was one of two parameters chosen to represent nutrient conditions in the Commonwealth. High variability for both nitrate and turbidity in 2nd order streams suggests streams of that size may be specifically affected by non point source runoff. In general, higher order streams tend to have low nitrates. Non-tidal streams comply with the public water supply (PWS) limit of 10.0 mg/L. Only about 11% (6 samples) exceeded a nitrate value of 1.0 mg/L, and 50% were below the detection limit. Nitrate concentrations do not exhibit a geographic pattern across the Commonwealth.

Total Phosphorus: For the autumn 2001 data only 5.2% of the sites had total phosphorus concentrations above the 0.20 mg/L advisory threshold. Ninety-three percent of the stations had concentrations less than or equal to 0.09 mg/L. Also, total phosphorus tends to be more abundant in the eastern half of the Commonwealth and is opposite the nitrate pattern. The majority of total phosphorus and ortho phosphorus concentrations were at the method level of detection.

Fecal Coliform Bacteria: The median bacterial count is consistent across stream orders and extremes occur in each order. In order 3 and 4 streams the counts are highly variable. Still, eighty-one percent of the counts were at or below the detection limit of 100 cfu/100 mL. The only exceedances of the old 1,000 cfu/100 mL standard were single occurrences in stream orders 2, 3, and 5-6. Non-tidal stream exceedances of the new bacterial standard of 400 cfu/100 mL are not restricted to a particular stream order. The overall CDF-estimated exceedance of the old standard is 2.4% ± 5%. The estimated exceedance of the new standard is 10% ± 12%. There is no strong relationship between bacterial count and ecoregion but high counts tend to occur in the middle and western parts of Virginia.

BENTHICS:

Benthic community results are based on data from 63 sties sampled in the spring of 2001. The communities were evaluated through ten parameters or categories of which seven were examined in detail. The collection information and community metric scores are in Table 1 of Appendix E. The abundance by taxa and station are listed in Table 2.

Taxa Richness: Taxa Richness varied from 2 to 32 Families and increased from small to large streams. Larger streams have a higher number of niches and available food. The Nottowar River in the Southeastern Plains where it is 6^{th} order had 32 taxa, far more than the next closest site with 22 Families. However, 30% of the stream lengths had ten or fewer taxa which is very low richness for a stream. Most sites with high richness are in the Central Appalachian Ridges and Valleys and Blue Ridge Mountains ecoregions.

EPT Index: EPT taxa which are sensitive to pollution became more abundant with stream size. The increase is possibly related to the increase in habitat diversity and food niches. Thirty-five percent of non-tidal stream kilometers have eight or more EPT taxa implying communities with a diversity of pollution intolerant taxa. High EPT Family counts are found in the Central Appalachian Ridges and Valleys, Blue Ridge Mountains, and some parts of the Piedmont Ecoregions.

%EPT-H: This index reflects the proportion of organisms present that are pollution intolerant. The results were similar to those for the EPT index. The index rose with stream size and the range was 0% - 80%. Approximately 40% of Virginia streams have benthic communities consisting of 20% or fewer EPT-H organisms. Streams with low %EPT-H were often in eastern wetland swamps.

MFBI: This index ranged from 2.62 to 7.29 indicating a variety of tolerance for organic pollution. But the medians for all orders are in the good range. Forty-four percent had scores less than or equal to 4.5 indicating very good to excellent water quality, but 24% indicated fairly significant organic pollution. Communities in lower order streams typically have more tolerance for organic pollution. In terms of spatial pattern, streams east of the Piedmont Ecoregions have communities with MFBI scores reflecting significant organic pollution. Elsewhere the scores suggest that pollution is low to moderate.

%Dominant Family: The %Dominant Family scores ranged from 8.79 to 13.73. The most common dominant Family was Chironomidae, pollution tolerant modges, which dominate 41% of non-tidal streams. Many of these midge-dominated communities are in the eastern ecoregions where streams have naturally higher amounts of sediment substrate. Intolerant EPT-H and other Families dominate 38% of the non-tidal streams.

%Chironomidae: This index averaged 23% and only 8% of non-tidal streams lack chironomid midges. All stream orders had a similar median. Approximately half of the stream kilometers have communities with 20% or less midge larvae. There were no clear geographic patterns. %Chironomidae scores are not beta distributed nor do they have any other well known distribution.

Simpson's Diversity Index: The diversity index ranged from 0.21 to 0.91 with an average of 0.79. The high average and median diversity across all stream orders indicates good taxa richness and evenness statewide. A wide diversity range in 1st order streams relates to the reduced habitat variety and food availability in small streams.

PHYSICAL HABITAT:

Physical habitat data were collected in the spring of 2001 using ten parameters. Results are available for 58 sites of which 47 were high gradient and 16 were low gradient streams. Overall, channel alteration had the highest score while sedimentation had the lowest. Statewide no metric averaged in the poor or marginal categories while channel alteration, bank condition, and riparian vegetation all averaged in the optimal range.

Channel Alteration: 95% of all non-tidal stream kilometers have unaltered channels. When poor channel conditions were found they were primarily in the lower stream orders.

Instream Condition: This index is an average of four field parameters. The range of scores showed marginal to optimal instream conditions. Low scores were geographically clustered in the Piedmont and Southeastern Plains ecoregions. It is suggested that the instream condition impact of the drought has possibly been greater in the eastern part of the Commonwealth.

Bank Condition: This is an average of the scores for bank stability and bank vegetation protection. The score ranged from 6 to 20. The overall score was 15.1 out of a possible maximum score of 20. Thus, stream banks are in good condition.

Riparian Vegetation: These scores were lowest in 2nd and 3rd order streams. Riparian vegetation was reduced in 38% of the non-tidal stream kilometers in the Commonwealth. Optimal riparian vegetation is found in all ecoregions although the Piedmont ecoregion has a predominance of high scores.

Embeddedness/Pool Substrate: This is a combination of measures from high and low gradient streams. Scores were measured across the full range from zero to 20. Scores appear to be lower in the Piedmont and Southeastern Plains ecoregions which are dominated by low gradient streams. Low scores are likely due to agricultural and logging uses around and upstream of the site. The drought may also have been a factor.

Sedimentation: Sediment is a moderate problem in streams of all orders. Although 1st order streams have the least sedimentation, up to 50% of stream bottoms are at least slightly altered. About 55% of the streams have optimal sedimentation scores. Still, sediment appears to be accumulating, creating bars, and filling pool habitats in a number of streams, with a slightly higher impact in Piedmont ecoregion streams.

Total Habitat: The range on these scores was 43% to 97% with the highest variability in 5th order streams. About 50% of the streams had optimal habitat scores. Low and high scores are distributed throughout the Commonwealth.

LAND COVER:

Land cover can significantly impact stream water quality, physical habitat, and biological community. It has been recognized that land cover may aid the search for reference sites by VDEQ biologists. A matrix that includes land cover parameters is proposed to that end. It is expected the matrix will take several years to mature. The watershed and land cover were delineated for five example streams of orders 1 through 5. Also, the detailed land cover for the seven ecoregions was determined for 58 ProbMon chemical stations and grouped by ecoregion.

The plan is to identify the relationships between land use and other ProbMon variables as more data accumulate.

To sum up, box plots were useful in detection differences in variance and median value for parameters across stream order. The CDF curves were helpful in finding the probability of conditions including the likelihood of standards violations. The 95% confidence intervals developed in this report are in most cases too wide to be useful for defining conditions by stream order. But, as data accumulate over the next four sample years the intervals will become narrow providing precise estimates. The Virginia ecoregion maps have been useful in detecting geographic patterns, some of which are already clear. A problem with USEPA's and our focus on ecoregions is the samples were selected irrespective of ecoregion. So, when the five-year survey is complete, we may have good condition estimates for only some ecoregions. There should, however, be sufficient data to make inter and intra river basin comparisons. This can help focus remediation efforts across the Commonwealth. The data collected so far promise to provide critical baselines for future development of water quality standards. Land use is believed to be a fertile source of explanatory variables for the observed chemistry and biology. That area remains untilled until a future report.

A problem in terms of chemistry is timing. The best time of year to measure the benthic macroinvertebrate community is spring while the best time of year to detect physicochemical problems is often another season. For example, spring is often the best time to monitor nutrients while summer is best for measuring DO and temperature. It is hoped a solution that maximizes chemical detection through reasonable manpower demands can be suggested by perceptive readers.

One major assessment area not covered by this report is the interrelationship between variables, especially between the parameter categories. For example, it is expected that some benthic metrics relate to or depend on chemical and habitat conditions. Likewise, it is expected that certain chemical conditions will occur in company with selected habitat features. Since the sample sites were randomly selected, this is an excellent data base with which to explore those relationships. It is suggested that there may be too few samples at this point to get a good fix on the relationships. Thus, this examination is postponed until a larger sample size is available.

8. RECOMMENDATIONS

The following recommendations represent the combined input of the authors. The recommendations, in order of decreasing priority, are presented under headings for the reader's convenience.

1. Ecoregion analysis: In future reports, analytical effort must be directed towards assessing the conditions of Level III ecoregions. The authors consider this a weakness in the current report that can be addressed with additional data.

2. Fecal coliform bacteria: In the first year of ProbMon fecal coliform bacteria were monitored. In 2002, the Virginia water quality standard for bacteria in freshwater streams began a transition to *E. coli*. Despite this change, it will be critical to continue collecting fecal coliforms for the life of the ProbMon survey. It is strongly advised that *E. coli* also be collected in the remaining survey years.

3. Physical habitat: The new intensive habitat methodology added in the autumn of 2002 needs to be incorporated into the SOP in the next report.

4. Virtual fish: Also known as semipermeable membrane devices (SPMDs), these grant-funded devices will provide data on a variety of regulated chemicals in the water column. The ProbMon survey is the most cost-efficient method of estimating the degree to which Virginia waters are at risk in terms of these chemicals. SPMDs will be deployed in the spring of 2003 at all ProbMon sites. Future reports should summarize the information from the SPMDs and the field and analytical methods incorporated into the SOP.

5. New parameters: While the list of parameters monitored by the ProbMon survey has been established, effort should be made to add parameters that would substantially bolster the analytical strength of the data set. Of particular interest is the acid neutralizing capacity (ANC) of streams. A method is needed for this parameter and its utility needs to be established. Fisheries biologists who find the parameter critical for certain fish species need to be queried for advisable methods and interpretations.

6. Percent saturation for DO: In the next report it is highly desirable to obtain, and incorporate as a parameter, percent saturation for field DO.

7. Boxplots: In future reports, these plots for ProbMon data should be presented with matching figures for targeted data to identify parameters for which ProbMon provides better estimates.

8. Presentation of Results: The technical information generated by ProbMon is of high interest to those directly involved in the program. However, some means is needed for translating these results into a form easily understood by managers, legislators, and citizens. There are good examples on EPA, USGS, and other web sites. Color-coded results should be investigated as a possible method of clear and concise summarization.

9. Land cover: As advanced digital coverage and methods of delineating watersheds become available, the existing data set and methods should be updated.

10. Land cover: Future reports should consider where to place the break point for relating land cover to the variables at a stream station. Also, is the land cover of the full watershed meaningful?

11. SAS programs for Program R from Tony Olsen: Routines developed or being developed in SAS by A. Olsen should be employed for analyzing future data.

12. Total nitrogen: This parameter is being considered on the national level as an indication of overall nitrogen concentrations in a waterbody. It is advised total nitrogen, which is being considered for use in VDEQ's ambient monitoring program, be collected in ProbMon as well.

13. Multimetric Index: It is advised the multimetric index being developed for VDEQ's biomonitoring assessment be examined for ProbMon data.

14. Impoundment Sample Data: It is advised that the water quality data for impoundments not be included in the statistical assessment for these free-flowing streams. Standing waters may have uncharacteristically high nutrients and values of other parameters that can confound the assessment of free-flowing streams.

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APPENDIX A.

PROBABILISTIC MONITORING PROTOCOL

Standard Operating Procedure Manual

January 15, 2003

[Note: To provide current protocols for future monitoring activities, the latest methods have been incorporated into this appendix. Methods which were not employed in the 2001 sample year, or that were not employed exactly as described, have been shaded.]

Table of contents

1. INTRODUCTION

The ProbMon network is a set of randomly chosen stations used to make statistically-based assessments of Virginia's streams. This approach differs from traditional monitoring programs by selecting stations randomly rather than with biases for access or specific data needs. Data from randomly selected stations represents an unbiased distribution of statewide conditions and allows a measure of the accuracy of these data. Because the stations are randomly chosen, statistical tests can be performed to identify differences between types of streams or Ecoregions within the Commonwealth. This method provides statistical certainty in water quality assessments and allows better communication of environmental conditions and monitoring and restoration needs to policy makers.

Why a Statistical Approach is Necessary

In the past, monitoring programs have focused on specific sites. These sites were selected because of a need for information at a specific location such as above or below a discharge, or to monitor known problems. The data represent ambient conditions at these specific sites. These are still valid reasons for monitoring. However, stations chosen with such biases should not be combined for averages of statewide conditions because they are not representative of statewide conditions. Ideally, to answer questions about statewide conditions we would sample every segment of every stream but resources are not available for such intensive sampling. Given limited resources the best way to sample a large population like this is with a statistical design. Recently, several new techniques have been developed for this application. One of the techniques is the EPA developed EMAP design. This method was chosen because of the methodological assistance available from EPA.

Beyond Chemical Parameters in Water Quality Monitoring

Another traditional approach to environmental monitoring has emphasized chemical attributes of the environment through direct measurement of water chemistry. This has been particularly useful for relating instream conditions to 'end of pipe' discharge limits. However, today most water quality problems are not related to permitted discharges but rather to non-point source (NPS) problems. Unlike point source discharges, NPS discharges are not constant and are often not present when samples are taken. Because the purpose of management programs is to protect human life and wildlife it makes sense to use an indicator that directly measures how well stream biota are being protected. Biological monitoring is a direct measure of the biological community.

The quality of the physical habitat is another important aspect of biological monitoring programs. ProbMon includes a physical habitat monitoring component to assess both the distribution of natural habitat conditions and habitat perturbations. Of course simply monitoring environmental quality without also identifying potential sources of problems leaves many unanswered questions. Therefore, ProbMon includes a land use survey (section 3.3.2), that will help identify local causes of stream impacts and will provide information on land use practices related to exceptional water quality.

2. EXPERIMENTAL DESIGN OVERVIEW

2.1. Site Selection

The ProbMon network design, is a generalized random tessellation stratified (GRTS) survey design (Stevens 1997, Stevens and Olsen 1999), developed by EPA statisticians for water quality monitoring programs. The design ensures sites are spatially balanced across the state. The target population is all non-tidal, perennial streams in Virginia with all possible points on the streams as potential sample points. If sites were picked completely randomly, few large rivers would be sampled because approximately 94% of the river miles in the state are small headwater streams. While small streams are by far the most common in terms of river kilometers, large rivers are valuable resources that would be under-sampled if not weighted for inclusion in the sampling. To ensure larger rivers were included, station selection was biased by Strahler Order. This results in approximately equal number of sites sampled in 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and $\geq 5^{th}$ stream orders. This bias becomes an important factor during statistical analysis.

Stations were selected for the five year sample period 2001-2005 with the help of EPA statisticians. They used USEPA RF3 reach files, based on ~~a~~ 1:100,000-scale topographic maps. Approximately 50 stations are needed in each category tested to obtain accurate confidence intervals (95%C.I.=12%). This allows the assessment of statewide conditions. Assessments of more specific types of streams such as large rivers, piedmont streams, trout streams, and so on, will also require 50 stations sampled in those kinds of streams.   After five years, enough data will be collected and analyzed in order to address many questions

The five-year study is designed to sample a minimum of 50 stations each year. This will allow general, statewide estimates of water quality to be made in the first year. In successive years, the estimates will improve because the confidence intervals will become narrower providing more confidence in the data. Each year, we expect that some sites will be inaccessible. Therefore, 70 sites have been chosen each year to insure a minimum sample size of 50 stations.

2.2. Selection of Revisit Sites

Each year, one station per VDEQ Region will be revisited for a total of seven stations each year. By the end of the survey there will be a total of 28 revisited stations. This is done to satisfy QA/QC requirements and to observe how conditions change over time. The stations will be chosen randomly by the Project Manager from the stations each region has sampled up to that point.

2.3. Data Analysis

The statistical analysis of the data requires that weighting and stratification variables be used. Otherwise, incorrect estimates for the target population will occur. See Data Analysis in Section 2 of the report and Appendix G for estimation procedures. Results from data analysis software developed by EPA will be included in future reports.

3. FIELD METHODS

Five data sheets are provided to guide the ProbMon field activities. The sheets are listed below and attached at the end of the appendix.

Table A-3. Site Description Form

Table A-4. Biological Monitoring Form

Table A-5. Fall Habitat Form

Table A-6. Field Chemistry Form

Table A-7. Spring Habitat Form

The data sheets prompt the user for required information and list the work to be accomplished at each visit.   Directions for each data entry are presented below. All information must be filled out completely. Stations with incomplete data sheets will be excluded from analyses.

Site Documentation

Before going into the field several important steps need to be taken.   These include finding the site on a topographical map, making several measurements from the map and acquiring landowner permission.   The information is to be entered onto the form titled “Site Information” and entered into EDAS.

3.1.1. Finding location on the map

The easiest way to locate the site on a map is to use a computerized mapping program such as MapTech or TopoZone.   TopoZone is available on the internet at http://www.Topozone.com. Note that significant errors have been found in the DeLorme 3-D TopoQuads. Both MapTech and TopoZone are based on USGS maps and allow you to input a latitude and longitude to look up. ProbMon stations were originally chosen from 1:100,000-scale maps. However, USGS 1:24,000-scale maps should be used for all measurements because of the added detail they provide.

3.1.2. Landowner permission

Obtaining landowner permission before the spring field season will save time by omitting sites where permission is denied. Often the easiest method is to visit the site and ask permission from resident landowner. But, the landowner may not be home or live at the site. Another useful technique is to search tax records for the owner and address. Tax records are at County Courthouses and may be on line.

If access is denied, record the reason for denial on the Site Documentation form. Denial of access and the reason for it has statistical ramifications. It is useful to have a record of the landowners’ concerns so we can change our methods in the future. If access is granted, the landowner contact information and directions to the site are recorded on the Site Documentation Form.

3.1.3. Station ID

The Station ID is the primary site identifier and field that will link tables in the database. Therefore, station ID will be associated with each data form. Regional Planners calculate the river miles and provide the stream and basin codes. They require the original EPA latitude and longitude to obtain river miles from the VDEQ GIS database.

Station ID is a 10-character code in the format, XXYYYnnn.nn. XX is a two character code for the river basin that begins with a number followed by a letter, number or hyphen. YYY is a unique, three-letter code designating the stream name. The final five numbers nnn.nn represent the distance in miles from the mouth of the stream as determined by the Regional Planners. For example, 2-OGL005.53 represents Ogle Creek (OGL) in the James River basin (2-) at river mile 5.53 (005.53).

3.1.4. Latitude and longitude record and conversions

The latitudes and longitudes furnished by EPA should correspond well to the VDEQ GIS system because both originated from the same database. In the event of discrepancies, record the new latitude and longitude in the comments section of the Site Description data sheet and communicate the problem to the Project Manager. Discrepancies in locations on MapTech or Topozone are less of a problem as long as the samples are collected near the point as mapped on the GIS. During the field visit the GPS latitude and longitude should be recorded along with a measure of the signal strength. GPS units have different measures of signal strength such as number of satellites or other measures. Record both the strength and the method of measurement.

ProbMon uses latitude and longitude measures in decimal degrees. All measures should be recorded in this format. The Regional Planners have programs for converting coordinates to and from decimal degrees.

3.1.5. Information from topographical maps [and GIS]

All topographical information should be obtained from 1:24,000 scale topographical maps that are available both on line and in the Regional Offices.

3.1.6. Strahler Order Measured from 1:100,000

Strahler stream order is a hierarchical system of measuring relative stream size based on links of stream segments between tributaries. The farthest upstream segments, from the source to the first tributaries, are termed 1st order. First order streams go from the origin to the first connection with another stream. When two first order streams come together they form a 2nd order stream. Likewise when two 2nd order streams come together they form a 3rd order stream. In this scheme, order is not affected by the addition of lower order tributaries. Strahler order was included with the EPA station list. If errors are discovered, record them on the field sheet.

3.1.7. Elevation

Elevation is measured at the nearest contour line to the site location 'X'.

3.1.8. Gradient

Gradient will be measured from topographic maps by finding the closest contour line below the sample location and measure upstream to the contour interval that is closest to 1 mile away. Determine the change in elevation and the distance and record on the Site Description form.

3.1.9. Sinuosity (channel length/ valley length)

Sinuosity is a measure of how the stream meanders within its valley. Measure the main stem length upstream of the sample location for five miles and mark the point. Measure the length of the stream valley and record. Valley length may be a straight line, or, if the valley curves, it will be a broken line.

3.1.10 Remoteness

Remoteness is measured as the nearest distance to one of a variety of human influences. Distance to the nearest road is the straight-line distance in miles from the sample location to the nearest road on the topographic map. This is in any direction. Note the type of road. Distance to nearest upstream crossing is the river mile distance upstream to the nearest crossing. Note the type of crossing. Distance to upstream influences is based on the observer's best professional judgement as to what might be having an influence on the site. This is measured in river miles to the source. Describe what the source is. Upstream influences may include impoundments, discharges, mines, or other human activities that affect the site.

Some of this information cannot be gained from maps in the office. For example, we cannot determine if the adjacent land use is a high-density pasture that has a large impact on the stream, or crop fields with substantial riparian vegetation protecting the banks without a field visit. Thus, the biologist needs to bring this form to the site to fill in details and unmapped changes such as new bridges, fords, and so on.

Field Visit

Fieldwork is divided into three categories: chemical, biological, and physical habitat sampling. Before sampling for any parameter, sampleability must be determined. Sampleability will determine which of the three categories will be sampled. Chemical samples should be collected at all sites where they can be obtained. Reaches with wadeable habitat will be sampled chemically and biologically. Reaches that are ≥70% wadeable will also be sampled during the fall physical habitat assessment.

Stations will be visited twice each year and sampled for specific parameters on each visit. The spring sampling window is March through April and sampling includes an assessment of sampleability, a reach size determination and setting of the downstream reach limit, map (optional), biological, chemical and the RBP physical habitat assessment. The fall sampling window is September through October and includes a more extensive reach layout and physical habitat sampling as well as biological sampling. These are discussed below.

3.2.1. Determining accessibility, sampleability and wadeability

Accessibility: In some instances sites may not be safely accessed due to physical barriers such as swamps, underground diversions or impoundments. Inaccessible streams must be documented and communicated to the Project Manager as soon as possible.

Sampleability: Sometimes a stream will be dry due to drought, or will be non-existent because of an error on the topographic map. In these cases no sample can be collected. If the stream is accessible and sampleable then, at a minimum, chemical samples are collected. Streams that are not sampleable should be communicated to the Project Manager as soon as possible.

Wadeability: Wadeability is necessary for biological and habitat sampling. Biological data collection requires access to the most productive biological habitat which will generally be a riffle, snag or stream bank. The biologist uses discretion as to safety and ability to collect a sample. During the fall visit, the stream must be wadeable in a majority of the reach to accomplish the bed substrate stability survey. This is defined as ≥70% of the transects can be sampled. Fifteen of the 21 transects (71%) should be shallower than an arm's length to collect the physical habitat samples. In marginal situations this should be determined in the fall. However, during the spring visit, if >71% of the stream is estimated to be unwadeable, do not make a fall visit unless biological samples can be safely collected. In this case the Project Manager should be notified. If the stream is wadeable for biological samples a fall visit is required.

Another issue in sampleability is the time it takes to complete the sampling. In some cases the stream may be wadeable but extremely wide which significantly adds to the time it takes to do the work. When two people cannot complete sampling in a single day, the station is unsampleable for the physical habitat parameters.

Field documentation of site

Each site location will be documented with GPS-measured latitude and longitude measured at **X**. It is important to also record some measure of GPS signal strength. Some GPS units give this in terms of the number of satellites while others use other measures of signal strength. Record the appropriate measure for the GPS used and the units of the measure.

Site Map: An optional site map may be drawn. This may be helpful in laying out the reach and for returning to the site in the fall. The EPA RBP manual provides forms and direction for sketching maps.

Digital photos should be taken once from a location as close to the actual sampling location as possible looking both upstream and downstream. The location where the photo is taken should be described so that future photos can be taken from the same location to document changes in habitat, land use, and so on. It would also be useful to photograph prominent stream features within the reach such as dams, waterfalls, etc. These photos should be taken with a digital camera and sent to the Project Manager electronically. Naming these files should consist of the Station ID followed by 'US' for upstream photos, 'DS' for downstream photos and consecutive letters 'A', 'B', 'C', and so on for conspicuous landmarks.

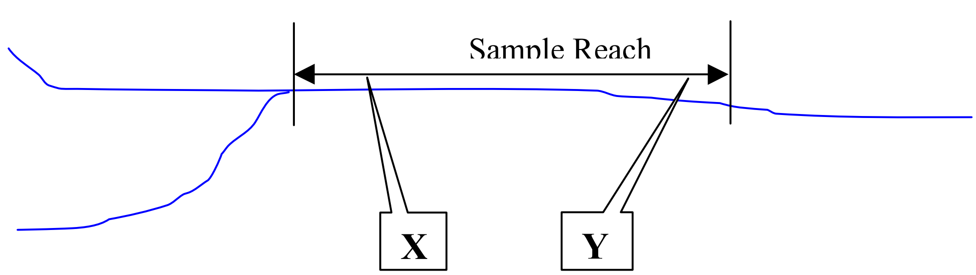
3.3.1. Laying out the reach and benthic sample site for spring

The location (**X**) is the randomly selected latitude and longitude that falls on the RF3 GIS layer. From this point, a length of stream will be selected as the sample reach based on the size of the stream. For a 1st to 3rd order stream, a reach of 30 times the stream width will be selected; however, the stream reach can not be less than 30 meters or more than 100 meters. For a stream of 4th order or greater, the stream reach will be 30 times the stream width with a maximum length of 400 meters.

The selected stream reach must fall within an area representative of point **X**. There may not be any permitted discharges or major tributaries within the stream reach. If point **X** falls within an impounded area of the stream, the site will be listed as unwadeable, and no benthic sample will be taken at the site. However, the site will still be sampled for chemical and physical parameters.

The sampling location (Y) must be within the downstream half of the reach. The number of riffles sampled depends upon the characteristics of the location. For instance, in very narrow streams, only one kick per riffle can be taken. In very large streams, all of the kicks may be taken within one riffle. Benthic and ambient water samples should be confined to the lower half of the stream reach; whereas, the habitat assessment should characterize the entire sample reach.

Figure A1. Example of sample reach and site location.



3.3.2. Adjacent land use

Most land use information will be obtained from GIS databases (to be described later). But for field truthing and to get a correct representation of the reach land use a checklist characterization is to be completed. The checklist is divided into five categories, residential, recreational, agricultural, industrial, and stream management. Within each of these categories are several uses. Each land use that occurs within the reach or by your judgement is having an influence on the reach should be circled. Most of the uses are self-explanatory. One important designation is livestock on pasture and animal feeding operations. An animal feeding operation is any operation that confines animals and manages waste. Dairies qualify as animal feeding operations even if the cows are on a pasture while you are there. Intensity of use is measured on a relative scale of Low, Moderate and High. Leaving an intensity category uncircled indicates the use is not present. The intensities are relative to the sampler's experience.

3.3.3. GIS parameters

Several watershed and site characteristics may be obtained from GIS databases when it is determined that a GIS would provide ~~a~~ more accurate site description information. An example of this is Ecoregion determination. At sites near ecoregion borders, GIS may be more accurate than using a topographic map to assign the ecoregion. However, GIS-derived attributes must be verified. The GIS Manager will provide GIS based information, but the Biologist is responsible for verifying site characteristics during the site visit.

4. CHEMICAL SAMPLING

Chemical sampling for the field parameters dissolved oxygen, specific conductance, temperature and pH will be conducted in both spring and fall. Laboratory analyzed parameters will be sampled in the spring only (2002-2005). Group codes for chemical parameters are in Table A- 1. Parameter details are listed by group code in Appendix C.

Table A- 1. Chemical parameters and analytical group codes.

Lab Group Code	Parameters Analyzed
NME12	Non metals (turbidity, solids)
NUT4	Nutrients

MFEE	Bacteria
HTIT	Hardness
TNUTL	Nutrients
FCHLR	Chlorophyll
TOC	Total organic carbon in water
PART	Sediment particle size (%sand, %silt, %clay) and TOC in sediment
MET1S	Metals in sediments
PES1S	Pesticides in sediments

4.1 Sample Quality Control and Quality Assurance

All samples are to be taken according to methods described in the most recent Chemical Monitoring Standard Operating Procedures.

4.2 Field Measures

WATER QUALITY INSTRUMENTS SHOULD NOT BE USED IF THEY FAIL CALIBRATION CHECKS OR ARE UNSTABLE.

To insure the quality of data, information on meter accuracy is to be recorded as well as the field measures. These QA data are recorded on the field data sheets and will be entered into EDAS forms created by staff. Details on these measures are a part of the ambient monitoring SOP but are summarized below by parameter.

4.2.1 Temperature

Record the last calibration check date (it should be within 30 days), the calibration value (using a traceable thermometer), the meter calibration reading at the standard and the offset. Record the stream temperature in the Field Temp box on the Chemical Monitoring Form.

4.2.2 Specific conductance

Record the last date of the last calibration check (should be within 30 days), the calibration standard value, and the meter reading in the standard. Record the stream specific conductance in the Field Conductivity box of the Chemical Monitoring Form.

4.2.3 Dissolved oxygen

Record the calibration value in either % saturation or barometric pressure according to manufacturer's specifications, the calibration temperature, and the dissolved oxygen reading in air at the calibration temperature. Record the stream dissolved oxygen reading in the Field DO box of the Chemical Monitoring Form. After taking the stream oxygen reading in the field, post check of the DO meter according to the manufacturer's specifications and record applicable data.

4.2.4 pH

A three-point pH calibration is required using 4.00, 7.00, and 10.00 buffer standard solutions. Record the three calibration pH values. Record the stream pH in the Field pH box. Post-check and record the three values in the appropriate boxes.

Chemical/physical samples (both field parameters and water collected for laboratory analyses) should be collected at the lower end of the sample reach and should be collected before the stream is disturbed by biological or physical habitat sampling. Every effort should be made to ice the samples immediately upon collection.

Sample handling and shipping is by standard methods (ambient SOP), and chain-of-custody procedures are not required.

5. PHYSICAL HABITAT SAMPLING

Two different habitat assessment techniques will be utilized. During spring sampling, the physical habitat will be assessed using the EPA RBP habitat techniques (Barbour et al 1999). In the fall, a more quantitative technique will be employed based on the Relative Bed Stability method (Kaufmann et al. 1999) developed by EPA's EMAP program. Both are described below.

5.1.Spring RBP Habitat Sampling

The RBP habitat technique is a subjective measure of 10 physical habitat parameters that are scored from 0 to 20. Three of the metrics are scored 0-10 on the left and right banks for a total of 20 possible points for each metric. Two different scoring techniques are used based on whether the stream is high or low gradient (Appendix F, Table 1). The specific techniques used for scoring these parameters in the RBP manual (Barbour et al., 1999; pp. A-7 through A-10).

- All biologists should use the 10-parameter habitat assessment method that is in the 1999 RBP manual (2nd Edition, pp. A-7 through A-10).

- The two-page Physical Characterization/Water Quality Field Data Sheet from the RBP manual (pp. A-5 and A-6) should also be used to describe each site in detail. The site description will include a sketch of the site indicating the approximate location(s) of areas where benthic samples were collected.

Specific Habitat Features to be noted/measured (optional):

- Estimates of percent riffle, run, and pool habitat in the entire reach (reach length depends on stream order and width, see reach length section). In the Piedmont and Coastal Plain, estimate percent of reach that is snag habitat.

- Estimate (measure when possible) the width of the riparian zone and note the percent of each vegetation type (i.e. trees, shrubs, grasses). Note all man-made structures in the riparian zone and floodplain and show approximate location on site map.

- Note the location/position of all bridges in the reach. Also note each tributary confluence (including culverts/storm drains) in the reach.

- Estimate the percent canopy in the reach.

- Estimate the percent embeddedness in 10 one-square meter sections of the riffle(s) sampled so that an average percent embeddedness can be calculated. Use BPJ when riffle area is too small or too degraded by sediment to estimate embeddedness in 10 sections.

- If large woody debris (LWD) is a substantial part of the stream habitat, estimate the number of pieces of LWD/ft., or, LWD/10-meter section.

Pebble Count (optional):

- When riffles are the type of habitat sampled and when time allows, perform a riffle pebble count (minimum of 50 pieces of substrate, 100 is preferable). This will produce a quantitative estimate of the percent fines, sand, etc. Transects should include the top, middle, and bottom of the riffle(s) sampled. At each transect, start at bankfull width at one side and continue until the bankfull width is reached on the opposite side of the stream. Walking heel to toe, identify the first particle touched at the tip of your boot and measure the intermediate diameter of the particle (the diameter that would limit it from fitting through a sieve). For very large particles (i.e. boulders and bedrock), count the same particle as many times as your toe encounters it. Measurements can be made using calipers, or, a small rule, and a meter stick for large substrate. In wide streams, measure substrate particles at larger intervals (i.e., one-step, or, approximately 1 meter apart), so that the sample covers a minimum of three transects. Complete transects even when the minimum number of particles is reached while in mid-transect.

- Tally the samples by the Udden-Wentworth size classes: less than 2 mm, 2-4 mm, 4-8 mm, 8-16 mm, 16-32 mm, etc. (see attached form). The cumulative percent finer is then calculated for each size class. (Adapted from: Riffle Stability Index: a procedure to evaluate stream reach and watershed equilibrium. Gary B. Kappesser, Forest Hydrologist. USFS. August, 1994)

Note: when more than one riffle is sampled for benthic invertebrates, use the most representative riffle for the pebble count, or, composite pebble samples from several riffles as was done with the benthic sample.

During the spring RBP habitat assessment stream width is measured at five places. To obtain the reach length for the fall habitat assessment these should be representative of the average width of the reach at base flow. Select 5 places within 150m of **X** to measure the width and record these on the data sheet. Calculate the reach length by multiplying the average width by 40. If the width is greater than 12.5m the reach length will be 500m. If the reach is less than 3.75m then the reach length will be 150m. The selected reach should be representative of the point **X** in terms of habitat and **X** should be located in the lower end of the reach. The reach should be positioned so that no major tributaries or natural changes to the habitat occur within the reach. On the other hand, human influences are not to be avoided. In fact, the occurrence of such influences will aid in detecting potential impacts and stressors. Setting the limits of the reach will greatly depend on best professional judgement of the Biologist.

5.2.Fall Habitat Sampling

5.2.1. Reach layout

During fall habitat sampling the spring reach layout is used. Lay out each cross section with surveys flags. Starting at the downstream end of the reach measure the stream cross section, longitudinal profile, and bank height as described below.

5.2.2. Substrate and channel dimension cross sections

Substrate measurements and channel dimensions at channel transects contribute directly to assessments of habitat volume, channel stability, and bed stability. Measure wetted width at 21 channel cross sections, and substrate size and water depth at five locations along each cross section. Substrate and water depth are measured at evenly spaced distances across a transect starting with the first measurement at one bank and measurements at 25% of the distance across the channel, at the mid channel point, 75% of the distance across the channel and at the opposite bank. Mid channel bars are treated normally, and can result in zero depth readings. Substrate sizes are visually estimated according to the classes in Table A- 2.

Table A- 2. Substrate size classes.

5.2.3. Longitudinal profile

Data from the longitudinal profile allows calculation of indices of stream size, residual pool dimensions, and stream power. Knowing stream power allows an estimate to be made of the predicted substrate size which then allows comparisons of observed versus predicted substrate.

The longitudinal profile is a survey of thalweg, wetted width, bankfull height, and elevation change between cross sections. Beginning at the downstream end of the reach, the profile is measured upstream in the middle of the channel. Thalweg measurements refer to the depth of the deepest point on the cross section. The wetted width is described above in measures of channel cross section. The elevation change is measured by stretching a clear, flexible, plastic tube between cross sections, filling the tube completely with water, and keeping the end at the upstream cross section under water. The tube end at the lower cross section is raised out of the water and the elevation of the water in the tube above the stream water level is recorded. This is the elevation change between the two cross sections.

Embeddedness is also visually estimated. Sand and finer substrates are defined as 100% embedded.

5.2.4. Bankfull depth

Bankfull depth is measured at each cross section. This is a subjective measurement and requires experience. Technically, bankfull depth is the total distance from the stream bottom, at the thalweg, to the top of the bank. Since the thalweg is rarely located near the stream bank, it is easiest to obtain this measurement by measuring from the water surface to the bankfull mark, then add it to the thalweg depth. Bankfull discharge occurs just prior to flooding on a rising hydrograph and occurs with an average frequency of once every two years. The challenge in this measurement is recognizing bankfull indicators such as scour lines, vegetation limits, flood-deposited material, or abrupt changes in slope. As with many aspects of stream mapping, sufficient training and experience is necessary to recognize this physical characteristic.

6. BIOLOGICAL SAMPLING

Biological sampling will be conducted in the spring and fall in accordance with the EPA RBP methodology described below (Barbour et al., 1999). Samples should be taken from the same areas in the spring and fall.

6.1 Biological Sample Location Determination

Biological samples will be collected within the sample reach defined earlier in section 3.3.1. In most cases, the biological samples should be collected from the best habitat available in the lower part of the sample reach. Specific sampling locations are left to the Biologists judgement of the available habitat. In streams that have well defined riffle/pool structure, ~~the~~ riffles will be the preferred sample location. In streams with poorly defined riffles or no riffles, other habitats must be sampled such as snags or banks. The type of habitat sampled should noted on the field sheet. In rare situations, multiple habitats may need to be sampled in order to obtain a representative survey of the macroinvertebrate community. In this case, record the percentage of each habitat type sampled.

The quality of the riffle, or other habitat sampled, should be noted on the field sheet as Good, Marginal, Poor or None. This is intended as a measure of biological habitat quality. 'Good' riffles are well developed and have good biological habitat based on the biologist's judgement. 'Marginal' riffles are not as well developed and are not as good biological habitat, but are still the best habitat available. 'Poor' riffles are so poor that the biologist believes other habitat is more productive and therefore does not sample the riffle. The classification 'None' is used when no riffle structure is apparent.

In very narrow streams only one kick per riffle might be taken and the sample may approach 100% of the available habitat in the entire reach. In very large streams, all of the kicks may be taken within one riffle and represent less than 1% of the available habitat.

Once the Biological sample location is determined five measures of depth should be made in the vicinity of the biological samples and recorded on the Biological Monitoring Field Sheet.

6.2 Sampling

Equipment

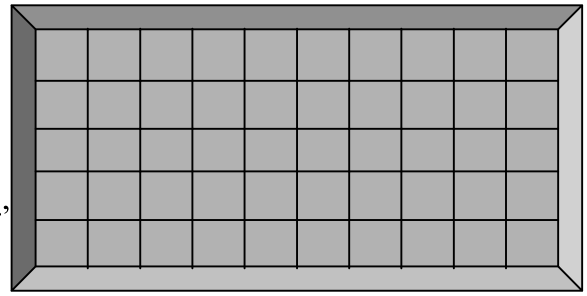
- 600µm mesh nylon D-net
- sieve bottom bucket
- 70% Alcohol (isopropanol or ethanol)
- plastic bags, plastic containers with lids, and buckets

Samples should consist of kicks or jabs with a 0.3 m D-frame kicknet (mesh size No. 30, 595 um) to approximate $2m^2$ of the total area sampled. Sampling should begin at the downstream end of the reach and be done before the stream bottom is disturbed by the habitat survey. Samples are preserved in 70% ethanol or isopropanol. Replicate samples should be collected at 10% of the sites (rounded down).

Processing the Biological Sample

Equipment

- 70% alcohol (isopropanol or ethanol)
- 25 ml scintillation vials
- random numbers table (1 to 50)
- quadrat-sized square metal 'cookie cutter'
- small putty knife
- forceps
- microscope
- 50-quadrat (2-inch square grids) subsampling box with 600µm mesh stainless steel bottom



Subsampling Box

Method

1. Place entire contents of sample (organisms, sand, leaves, debris, etc.) into the sieve box and mix sample thoroughly with box partially submerged in water, then spread the entire sample evenly over the bottom of the box (Tetra Tech 2001).
2. Remove the box from water after sample is evenly spread.
3. Select a quadrat from the box using a random numbers table. Record the number of the quadrat on the bench sheet for that station.
4. Using a microscope, completely remove all macroinvertebrates from the selected quadrat and store organisms in vials with 70% alcohol.
5. Continue selecting and processing randomly selected quadrats until a minimum of 100 organisms are counted or a minimum of 4 quadrats is sorted. If it appears that sorting organisms from 4 grids will result in a sub sample that far exceeds the target number (i.e., 100-120 organisms), then combine with the contents from 3 more randomly selected grids to avoid bias from a clumped distribution. In this event, a second tier of sub sampling will be done on the composited 4-grid sub sample to obtain the target number of organisms. Finish processing the last quadrat.

6. Record the number of quadrats sorted and the number of organisms sorted from each one on the bench sheet.
7. Using a microscope, identify all organisms in the sample to Family and record on the bench sheet.
8. Enter data into EDAS

6.5 Presence/absence Survey for crayfish, mollusks, snails, amphibians, fish, mammals

In addition to the standard RBP protocol an additional survey of the study area will be conducted for presence/absence of a few specific groups. This survey will consist of looking for signs that specific taxa are present by doing a stream walk or while doing the reach layout, mapping and habitat assessment (see RBPI methodologies in Plafkin 1989). The taxa and signs looked for include: Periphyton, Filamentous Algae, Submerged Macrophytes, Emergent Macrophytes, Crayfish, Corbicula, Unionidae, Operculate Snails, Non-operculate Snails, Frogs and Tadpoles, Salamanders, Warm-water fishes, Cold-water fishes, Beavers, Muskrats and Ducks and Geese.

7. LITERATURE CITED

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Stevens, D.L., Jr. 1997. Variable density grid-based sampling designs for continuous spatial populations. Environmetrics, 8, 167-95.

Stevens, D.L., Jr. and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics, 4, 415-28.

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Appendix A: Table A-3. Site Description Form.

ProbMon

Site Decription Form

Page of

(Completed in the office)

Station ID: EPA No.: Basin:
Observers: Region: Topo Quad:
Stream Name: Ecoregion:
Strahler Order: Location: County:

EPA LATITUDE (decimal degrees) __ __ . __ __ __ __ __ __

EPA LONGITUDE (decimal degrees) - .

Access Information

~~Landowner information~~

Name: ____________________ Directions: ____________________

Address: ____________________

Phone: ____________________

DID YOU SAMPLE THIS SITE?			
YES (Check all that apply)		**NO** (check only one)	
CHEMICAL	☐	DRY	☐
BIOLOGICAL	☐	MAP ERROR - No evidence of a channel	☐
HABITAT	☐		
Problems		**NO ACCESS**	
IMPOUNDED	☐	ACCESS PERMISSION DENIED	☐
WETLAND	☐	INACCESSIBLE - Unsafe or unable to reach site	☐
NON-WADEABLE	☐	OTHER	☐
OTHER	☐		

Stream Channel Information (*Measured from 1:24,000 topographic maps*)

Gradient: Elev. Change (ft) ☐ / Stream Length (mi) ☐ = ☐ (ft/mi)

From nearest contour interval below "X" measure to contour interval nearest to 1 mile upstream.

Sinuosity Index: Stream Length (ft) ☐ / Valley Length (ft) ☐ = ☐

Measured over 1 mile of stream distance as measured for gradient.

Remoteness

Distance (in any direction) to a road/trail

Type of road (check one) Trail Dirt/Gravel Paved Highway Interstate Railroad

Distance to upstream crossing

Type of crossing (check one) __Trail __Ford __Low Water Br. __Paved Road __Highway __Interstate __Railroad

Distance to upstream Influence ________

Type of influence ____________________

Distance to upstream Influence ________

Type of Influence ____________________

Comments: ____________________

Upon completion fax to WCRO (540)562-6725

Appendix A: Table A-4. Biological Monitoring Form.

ProbMon

Biological Monitoring Form

Page____of____

(Spring and Fall)

Station ID: EPA No.: Basin:

Observers: Region: Topo Quad:

Stream Name: Ecoregion:

Strahler Order: Location: County:

Date [ ] Start Time [ ] Finish Time [ ]

Riffle Quality (check one) **Good (sampled)** **Marginal (sampled)** **Poor (not sampled)** **None**

Single Most Productive Habitat (check one) **Riffle** **Snags** **Banks** **Rootwads** **Vegetation** **Detritus**

Other? Describe ______________________________

Area Sampled (square meters) [ ]

Notes: ______________________________

____

____

____

____

Biological Observations circle one in each (0=absent, 1=present, 2=common, 3=dominant)

0 1 2 3	Periphyton	**0 1 2 3**	Salamanders
0 1 2 3	Filamentous algae	**0 1 2 3**	Warmwater Fish
0 1 2 3	Submerged Macrophytes	**0 1 2 3**	Coldwater Fish
0 1 2 3	Emergent Macrophytes	**0 1 2 3**	Beavers
0 1 2 3	Crayfish	**0 1 2 3**	Muskrats
0 1 2 3	Corbicula	**0 1 2 3**	Ducks/Geese
0 1 2 3	Unionidae	**0 1 2 3**	Other…
0 1 2 3	Operculate Snails	**0 1 2 3**	
0 1 2 3	Non-operculate Snails	**0 1 2 3**	
0 1 2 3	Frogs/ Tadpoles	**0 1 2 3**	

0 = Absent
1 = Sparse
2 = Common to Abundant
3 = Dominant - abnormally high density where other taxa are insignificant in relation to the dominant taxa. There can be situations where multiple taxa are dominant such algae and snails.

Weather (Check only if recent weather has had an effect on habitat or benthics)

	Now	Past 24 Hrs	Last 7 Days
Clear			
Showers			
Rain			
Storms			
Other			

Upon completion fax to WCRO (540)562-6725

Appendix A: Table A-5. Fall Habitat Form.

ProbMon

Fall Habitat Form

Page____of____

(Use Fall Only)

Station ID: EPA No.: Region: WCRO

Observers:

Stream Name:

Location:

REACH LENGTH ___________________

	Cross section Substrate Size								
TRANSECT	LEFT	LEFT MIDDLE	MIDDLE	RIGHT MIDDLE	RIGHT	BANKFULL HEIGHT (mm)	THALWEG (mm)	SLOPE (mm)	WETTED WIDTH (m)
A1									
A2									
B1									
B2									
C1									
C2									
D1									
D2									
E1									
E2									
F1									
F2									
G1									
G2									
H1									
H2									
I1									
I2									
J1									
J2									
K									

Substrate Classification

Class	Size	Score	Relative size
Bedrock	>4000 mm	6	Bigger than a car
Boulder	250-4000 mm	5	Basketball to car
Cobble	64-250 mm	4	Tennisball to basketball
Coarse Gravel	16-64 mm	3.5	Marble to tennisball
Fine Gravel	2-16 mm	2.5	Ladybug to marble
Sand	0.06-2 mm	2	Gritty between fingers
Fines	<0.06 mm	1	Smooth, not gritty

Upon Completion fax to WCRO (540)562-6825

Appendix A: Table A-6. Field Chemistry Form.

ProbMon

Field Chemistry

Page____of____

(SPRING AND FALL)

Station ID EPA No. Region

Observers

Stream Name

Location

DATE	TIME

DO NOT USE A METER THAT FAILS A CALIBRATION CHECK

TEMPERATURE

Meter Information		Calibration			Field
Meter Brand Name	Meter Number	Date of Last Calibration	Offset		Temp.

CONDUCTIVITY

Meter Information		Calibration			Field
Meter Brand Name	Meter Number	Last Calibration	Offset		Field Cond.

DISSOLVED OXYGEN

Meter Information		Calibration			Field	Post Check		
Meter Brand Name	Meter Number	Calibration Value % or B.P.	Calibration Temp.	Calibration D.O.	Field D.O.	Post Check % or B.P.	Post Check Temp.	Post Check D.O.

pH

Meter Information		Calibration			Field	Post Check		
Meter Brand Name	Meter Number	Calibration Standard 1	Calibration Standard 2	Calibration Standard 3	Field pH	Standard 1 ________	Standard 2 ________	Standard 3 ________

List of spring group codes, containers and preservatives

Group Code	Bottle Type	Preservative
MFEE	100 ML STERILE BOTTLE	ICE
NMEAL	1 GALLON CUBITAINER	ICE
NUT4	250 ML PLASTIC BOTTLE	ICE
TNUTL	250 ML PLASTIC BOTTLE	H2SO4, ICE
HTIT	250 ML PLASTIC BOTTLE	HNO3, ICE
FCHLR	GLASS FIBER FILTER, FOIL	ICE
TOC	40 ML GLASS VIAL W/SEPTA	HCL, ICE
PART	16 OZ WIDEMOUTH JAR	ICE
MET1S	8 OZ WIDEMOUTH JAR	ICE
PES1S	8 OZ WIDEMOUTH JAR	ICE

Upon completion fax to WCRO (540)562-6725

Appendix A: Table A-7. Spring Habitat Form.

ProbMon

Spring Habitat Form

Page____of____

(Spring Only)

Station ID _______________ EPA No. _______________ Region _______________

Observers _______________

Stream Name _______________

Location _______________

DATE		START TIME		FINISH TIME	
GPS LATITUDE (Decimal degrees)	__ __ . __ __ __ __ __ __ __	GPS LONGITUDE (Decimal degrees)	-__ __ . __ __ __ __ __ __ __	GPS Signal Quality	

STREAM WIDTH (Meters)

1 _______________

2 _______________

3 _______________

4 _______________

5 _______________

AVERAGE WIDTH (meters) _______________

REACH LENGTH (meters) _______________

40x average width, 150m minimum, 500m maximum

Transfer number to the Fall Habitat Sheet

LANDUSE CHECKLIST (Blank=Not observed, L=Low, M= Moderate, H=Heavy) (circle all that apply within reach)

Residential	Recreational	Agricultural	Industrial	Stream Management
L M H Residences	L M H Hiking Trails	L M H Crops	L M H Industrial	L M H Liming
L M H Lawns	L M H Parks, Camps	L M H Pasture	L M H Mines/Quarries	L M H Chemical
L M H Construction	L M H Primitive Parks	L M H Livestock on pasture	L M H Oil/Gas	L M H Angling
L M H Pipes, Drains	L M H Trach/Liter	L M H Animal feeding operation	L M H Power Plants	L M H Dredging
L M H Roads	L M H Surface Films	L M H Orchards	L M H Logging	L M H Channelization
L M H Dumping		L M H Irrigation	L M H Fire	L M H Flow Alterations
L M H Bridge Culverts			L M H Odors	L M H Fish Stocking
L M H STPs			L M H Commercial	L M H Dams

RBP HABITAT ASSESSMENT

	High Gradient		Low Gradient	
1	Epifaunal Substrate		Epifaunal Substrate	
2	Embeddedness		Pool Substrate	
3	Velocity/Depth		Pool Variability	
4	Sediment Deposition		Sediment Deposition	
5	Channel Flow Status		Channel Flow Status	
6	Channel Alteration		Channel Alteration	
7	Riffle Frequency		Channel Sinuosity	
8	Bank Stability LDB 1-10		Bank Stability LDB 1-10	
	Bank Stability RDB 1-10		Bank Stability RDB 1-10	
9	Vegetative Protection LDB 1-10		Vegetative Protection LDB 1-10	
	Vegetative Protection RDB 1-10		Vegetative Protection RDB 1-10	
10	Riparian Zone LDB 1-10		Riparian Zone LDB 1-10	
	Riparian Zone RDB 1-10		Riparian Zone RDB 1-10	
	Total:	______		______

Comments _______________

____

____

____

Upon completion fax copy to WCRO (540)562-6725

Photos - rivermileus, rivermileds, rivermilea, rivermileb…

Optional map on back.

APPENDIX B. LIST OF STATIONS SAMPLED SPRING AND FALL 2001.

Appendix B: Table 1. List of Stations Sampled Spring and Fall 2001.

Station ID	Stream Name	Strahler Order	Collection Date: Spring 2001	Collection Date & Time: Fall 2001	River Basin	Ecoregion	DEQ Region
1ACAH001.82	Captain Hickory Run	2	5/29/01	10/29/01 11:30	Potomac	NorPDMT	NRO
1AFLL000.62	Flatlick Branch	2	5/30/01	10/22/01 11:00	Potomac	NorPDMT	NRO
1ALUC000.95	Lucky Run	2	4/12/01	10/1/01 12:30	Potomac	NorPDMT	NRO
1BBVR000.84	Beaver Creek	2	5/17/01	10/4/01 10:00	Shenandoah	CARV	VRO
1BCPL002.83	Chapel Run	2	5/24/01	10/16/01 10:40	Shenandoah	CARV	VRO
1BDRI000.21	Dry Run	1	5/17/01	10/9/01 10:00	Shenandoah	CARV	VRO
2-APP082.00	Appomattox River	5	5/3/01	11/5/01 13:00	James	Piedmont	SCRO
2-BFL016.79	Buffalo Creek	3	5/17/01	10/31/01 11:15	James	Piedmont	SCRO
2-BNF003.52	N.F. Buffalo River	2	4/3/01	10/22/01 10:30	James	BRM	SCRO
2-CEL001.00	Cornelius Creek	3	3/19/01	11/20/01 12:00	James	SEPlains	PRO
2-COO002.35	Cooper Creek	1	4/11/01	11/1/01 10:50	James	Piedmont	SCRO
2-CWP023.28	Cowpasture River	4	5/15/01	10/22/01 10:30	James	CARV	VRO
2-CWP053.78	Cowpasture River	3	5/30/01	10/11/01 10:00	James	CARV	VRO
2-HAZ006.34	Harris Creek	3	5/10/01	10/22/01 15:30	James	Piedmont	SCRO
2-HOI004.08	Horsepen Branch	1	5/18/01	NA	James	Piedmont	PRO
2-JOB001.02	Johns Creek	4	4/20/01	10/9/01 9:45	James	CARV	WCRO
2-LMC001.15	Looney Creek	5	4/9/01	10/10/01 15:00	James	CARV	WCRO
2-LOB000.37	Long Branch	1	6/5/01	10/22/01 13:00	James	Piedmont	SCRO
2-OGL005.53	Ogle Creek	2	5/1/01	10/9/01 13:30	James	CARV	WCRO
2-RND003.57	Randolf Creek	2	4/12/01	10/29/01 11:20	James	Piedmont	SCRO
2-RRS010.30	SF Rivanna River	4	5/22/01	10/1/01 11:00	James	NorPDMT	VRO
2-RVN012.05	Rivanna River	5	5/14/01	10/15/01 10:00	James	Piedmont	VRO
2-SMR004.80	St. Marys River	2	5/29/01	10/17/01 11:00	James	BRM	VRO
2-SUA001.55	Suanee Creek	3	6/11/01	10/23/01 10:30	James	Piedmont	SCRO
2-WLS024.61	Willis River	5	5/2/01	10/29/01 14:00	James	Piedmont	SCRO
3-RAP008.71	Rapidan River	5	4/24/01	10/10/01 13:00	Rappahannock	NorPDMT	NRO
3-ROB005.42	Robinson River	4	4/10/01	10/18/01 11:00	Rappahannock	NorPDMT	NRO
3-XEX000.81	UT to Elmwood Creek	1	3/22/01	NA	Rappahannock	SEPlains	PRO
4ABAN022.24	Banister River	5	5/15/01	11/7/01 12:00	Roanoke	Piedmont	SCRO
4ABDA011.79	Beaverdam Creek	2	4/6/01	10/23/01 15:30	Roanoke	Piedmont	WCRO
4AEKH003.18	Elkhorn Creek	3	5/15/01	10/30/01 10:00	Roanoke	Piedmont	SCRO
4AHEN004.74	Horsepen Creek	3	5/16/01	10/18/01 11:20	Roanoke	Piedmont	SCRO
4AOWC004.37	Old Womans Creek	3	5/15/01	11/7/01 10:30	Roanoke	Piedmont	SCRO
4APAA000.24	Poplar Branch	2	5/31/01	10/17/01 11:00	Roanoke	Piedmont	WCRO
4ARNF009.01	N.F. Roanoke River	4	5/7/01	11/8/01 13:30	Roanoke	CARV	WCRO
4ARNF015.50	N.F. Roanoke River	3	4/11/01	11/8/01 11:45	Roanoke	CARV	WCRO
4ASNF007.64	N.F. South Mayo River	1	5/17/01	11/19/01 10:40	Roanoke	BRM	WCRO
4ASRV012.19	Sandy River	5	6/4/01	10/30/01 14:30	Roanoke	Piedmont	SCRO
4AXME001.19	UT to Dan River	1	NA	10/30/01 12:30	Roanoke	Piedmont	SCRO
4AXMF001.46	UT to Hyco River	1	5/15/01	NA	Roanoke	Piedmont	SCRO
5AAPW001.04	Applewhite Swamp	2	4/9/01	10/18/01 10:10	Chowan	SEPlains	TRO

Appendix B: Table 1. List of Stations Sampled Spring and Fall 2001 (continued)

Station ID	Stream Name	Strahler Order	Collection Date: Spring 2001	Collection Date & Time: Fall 2001	River Basin	Ecoregion	DEQ Region
5ABLW055.26	Blackwater River	5	4/9/01	10/23/01 9:45	Chowan	SEPlains	PRO
5AMHN105.36	Meherrin River	5	5/8/01	10/24/01 11:30	Chowan	Piedmont	SCRO
5ANTW045.12	Nottoway River	6	5/15/01	10/15/01 10:35	Chowan	SEPlains	PRO
5ASTN002.43	Somerton Creek	4	5/3/01	10/11/01 10:50	Chowan	MACP	TRO
5AXEH001.35	UT to Great Creek	1	4/10/01	NA	Chowan	Piedmont	PRO
5AXEI000.27	UT to S. Meherrin River	1	5/16/01	NA	Chowan	Piedmont	SCRO
5AXEJ001.73	UT to Nottoway River	1	4/9/01	10/30/01 12:00	Chowan	SEPlains	PRO
6APNS003.94	S.F. Pound	3	6/18/01	10/29/01 11:30	Big Sandy	CentApp	SWRO
6AXBF000.40	Japa's Fork	1	5/21/01	10/23/01 12:30	Big Sandy	CentApp	SWRO
6BDUM000.23	Dumps Creek	3	4/25/01	10/18/01 13:50	Tennessee	CentApp	SWRO
6BLWS003.88	Lewis Creek	3	4/30/01	10/18/01 11:30	Tennessee	CARV	SWRO
6BPOW156.57	Powell River	5	5/15/01	10/22/01 12:15	Tennessee	CARV	SWRO
6BXDJ000.15	UT to Falls Creek	1	5/30/01	10/29/01 13:30	Tennessee	CARV	SWRO
6CSLM002.11	Slemp Creek	1	5/9/01	10/30/01 12:45	Holston	BRM	SWRO
6CXCH001.34	UT to N.F. Holston River	1	4/16/01	NA	Holston	CARV	SWRO
7-DRN027.96	Dragon Swamp	3	4/25/01	10/25/01 10:30	Chesapeake Bay	SEPlains	PRO
8-BRC002.70	Beaver Creek	1	4/25/01	10/2/01 11:30	York	NorPDMT	NRO
8-XEA000.12	UT to Bland Creek	1	4/25/01	10/29/01 10:30	York	SEPlains	PRO
9-LIC004.73	Little Indian Creek	1	4/18/01	11/5/01 13:30	New	BRM	WCRO
9-MDR003.60	Meadow Run	2	4/18/01	11/1/01 9:50	New	BRM	WCRO
9-WFC010.66	Wolf Creek	4	5/8/01	10/11/01 11:00	New	CARV	WCRO
9-WFC044.15	Wolf Creek	3	4/26/01	11/1/01 11:30	New	CARV	SWRO
9-WLK024.17	Walker Creek	5	6/6/01	10/11/01 13:30	New	CARV	WCRO

Notes:

UT .. Unnamed tributary

NA .. Collection Date is NA if unsampled.

Key to Ecoregion Abbreviations		Sample Season			
Abbreviation	Ecoregion	Spring only	Spring & Fall	Fall only	total
BRM	Blue Ridge Mountains	0	6	0	6
CARV	Central Appalachians Ridges and Valleys	1	16	0	17
CentApp	Central Appalachians	0	3	0	3
MACP	Mid-Atlantic Coastal Plains	0	1	0	1
NorPDMT	Northern Piedmont	0	7	0	7
Piedmont	Piedmont	4	17	1	22
SEPlains	Southeastern Plains	1	7	0	8
	Ecoregion totals:	6	57	1	64

Key to DEQ Region in which the station is located:		Sample Season			
		Spring only	Spring & Fall	Fall only	total
NRO	Northern Virginia Regional Office	0	6	0	6
PRO	Piedmont Regional Office	3	6	0	9
SCRO	South Central Regional Office	2	15	1	18
SWRO	South West Regional Office	1	8	0	9
TRO	Tidewater Regional Office	0	2	0	2
VRO	Valley Regional Office	0	8	0	8
WCRO	West Central Regional Office	0	12	0	12
	DEQ Region totals:	6	57	1	64

APPENDIX C. PARAMETERS SAMPLED AND GROUP CODES.

Appendix C: Table 1. Parameters Sampled and Group Codes.

Parameter	Field	NME12	FCMF	HTIT	TNUTL	NUT4	FCHLR	PES1S	MET1S	PART	TOC	STORET Code	Holding Time (Hours)	Lower Detection Limit	Measure Unit
Aldrin								X				39333	168	10	ppb
Aluminum (MET1S)									X			1108		5	ug/g
Ammonia						X						610	48	0.04	ppm
Antimony (MET1S)									X			1098		5	ug/g
Arsenic (MET1S)									X			1003		5	ug/g
Beryllium (MET1S)									X			1013		5	ug/g
Cadmium (MET1S)									X			1028		1	ug/g
Chlorophyll A (Monochromatic Method)							X					32211		0.5	ug/L
Chlorophyll A (Trichromatic Method)							X					32210		0.5	ug/L
Chlorophyll B (Trichromatic Method)							X					32212		0.5	ug/L
Chlorophyll C (Trichromatic Method)							X					32214		0.5	ug/L
Chlorophyll, 630 b (before HCl)							X					630BX			OD
Chlorophyll, 647 B (before HCl)							X					647BX			OD
Chlorophyll, 664 B (before HCl)							X					664BX			OD
Chlorophyll, 665 A (after HCl)							X					665AX			OD
Chlorophyll, 750 A (after HCl)							X					750AX			OD
Chlorophyll, 750 B (before HCl)							X					750BX			OD
Chlorophyll, B/A Ratio (Monochromatic)							X					32219			
Chlorophyll, Cell Path							X					CELLP			cm
Chlorophyll, Extract Volume							X					EXTVO			mL
Chlorophyll, Volume Filtered							X					71994			L
Chromium (MET1S)									X			1029		5	ug/g
Clay										X		82009		1	% dry wt.
Conductivity		X										95	672	0.05	umhos/c
Copper (MET1S)									X			1043		5	ug/g
Dicofol								X				79799	168	50	ppb
Dieldrin								X				39383	168	10	ppb
Dissolved Oxygen, Field	X											399			mg/L
Endrin								X				39393	168	10	ppb
Fecal Coliform, MF			X									31616	24	100	#/100 mL
Fixed Solids		X										510	168	5	mg/L
Fixed Suspended Solids		X										540	168	3	mg/L
Hardness				X								900	4383	10	mg/L
Heptachlor								X				39413	168	10	ppb
Heptachlor Epoxide								X				75045	168	10	ppb
Iron (MET1S)									X			1170		5	ug/g

Appendix C: Table 1. Parameters Sampled and Group Codes (continued).

Parameter	Field	NME12	FCMF	HTIT	TNUTL	NUT4	FCHLR	PES1S	MET1S	PART	TOC	STORET Code	Holding Time (Hours)	Lower Detection Limit	Measure Unit
Lead (MET1S)									X			1052		5	ug/g
Manganese (MET1S)									X			1053		5	ug/g
Mercury (STORET 71921)									X			71921		0.1	ug/g
Nickel (MET1S)									X			1068		5	ug/g
Nitrate as N						X						620	48	0.04	mg/L
Nitrite as N						X						615	48	0.01	mg/L
Ortho Phosphate as P						X						70507	48	0.02	ppm
Pentachlorophenol								X				39061	168	50	ppb
pH	X														SU
Pheophytin A (Monochromatic Method)							X					32218		0.5	ug/L
Sand										X		82007		1	% dry wt.
Selenium (STORET 01148)									X			1148		1	ug/g
Silt										X		82008		1	% dry wt.
Silver (MET1S)									X			1078		1	ug/g
Specific Conductance, Field	X														uS/cm
Sum of PCB Congeners in Sediment								X				39526	168	10	ppb
Temperature, Field	X											100			Degrees Celsius
Thallium (MET1S)									X			34480		5	ug/g
Total Chlordane								X				39351	168	20	ppb
Total DDD								X				39363	168	10	ppb
Total DDE								X				39368	168	10	ppb
Total DDT								X				39373	168	10	ppb
Total Kjeldahl Nitrogen					X							625	672	0.1	ppm
Total Organic Carbon (sediment)										X		687		2	g/kg
Total Organic Carbon (water column)											X	680		2	mg/L
Total Phosphorus					X							665	672	0.01	ppm
Total Solids		X										500	168	5	mg/L
Total Suspended Solids		X										530	168	3	mg/L
Toxaphene								X				39403	168	50	ppb
Turbidity		X										76	48	0.1	NTU
Volatile Solids		X										505	168	5	mg/L
Volatile Suspended Solids		X										535	168	3	mg/L
Zinc (MET1S)									X			1093		5	ug/g

APPENDIX D. TABLES OF CHEMICAL DATA.

Appendix D: Table 1. Field data from Fall 2001

Station ID	Strahler Order	Ecoregion	Basin	DEQ Region	Collection Date Time	Temp Celcius	Dissolved Oxygen mg/l	pH	Specific Conductance µS/cm
1ACAH001.82	2	NorPDMT	Potomac	NVRO	10/29/01 11:30	10.00	8.90	7.80	151
1AFLL000.62	2	NorPDMT	Potomac	NVRO	10/22/01 11:00	16.57	7.80	7.50	363.7
1ALUC000.95	2	NorPDMT	Potomac	NVRO	10/1/01 12:30	13.42	7.20	7.52	64
1BBVR000.84	2	CARV	Shenandoah	VRO	10/4/01 10:00	16.70	10.20	8.10	140
1BCPL002.83	2	CARV	Shenandoah	VRO	10/16/01 10:40	11.80	11.00	8.10	442
1BDRI000.21	1	CARV	Shenandoah	VRO	10/9/01 10:00	7.20	4.70	7.40	212
2-APP082.00	5	Piedmont	James	SCRO	11/5/01 13:00	10.52	12.00	7.33	110
2-BFL016.79	3	Piedmont	James	SCRO	10/31/01 11:15	8.48	11.78	6.97	109
2-BNF003.52	2	BRM	James	SCRO	10/22/01 10:30	11.77	9.74	6.52	15.5
2-CEL001.00	3	SEPlains	James	PRO	11/20/01 12:00	11.37	10.32	6.42	104
2-COO002.35	1	Piedmont	James	SCRO	11/1/01 10:50	9.20	9.11	6.36	62
2-CWP023.28	4	CARV	James	VRO	10/22/01 10:30	12.50	9.70	8.10	146
2-CWP053.78	3	CARV	James	VRO	10/11/01 10:00	11.70	10.40	8.30	148
2-HAZ006.34	3	Piedmont	James	SCRO	10/22/01 15:30	18.50	8.46	7.31	92.7
2-JOB001.02	4	CARV	James	WCRO	10/9/01 9:45	7.90	11.25	7.81	145.5
2-LMC001.15	5	CARV	James	WCRO	10/10/01 15:00	13.20	10.48	8.53	466.5
2-LOB000.37	1	Piedmont	James	SCRO	10/22/01 13:00	11.72	9.00	6.84	65.1
2-OGL005.53	2	CARV	James	WCRO	10/9/01 13:30	11.60	10.62	7.85	82.7
2-RND003.57	2	Piedmont	James	SCRO	10/29/01 11:20	8.40	6.60	6.33	102
2-RRS010.30	4	NorPDMT	James	VRO	10/1/01 11:00	13.20	10.40	7.20	59
2-RVN012.05	5	Piedmont	James	VRO	10/15/01 10:00	16.90	7.40	7.30	178
2-SMR004.80	2	BRM	James	VRO	10/17/01 11:00	8.90	9.60	7.00	17
2-SUA001.55	3	Piedmont	James	SCRO	10/23/01 10:30	13.10	7.80	7.56	108
2-WLS024.61	5	Piedmont	James	PRO	10/29/01 14:00	18.70	8.50	7.00	115
3-RAP008.71	5	NorPDMT	Rappahannock	NVRO	10/10/01 13:00	14.61	7.75	8.00	71
3-ROB005.42	4	NorPDMT	Rappahannock	NVRO	10/18/01 11:00	11.50	12.30	7.50	84
4ABAN022.24	5	Piedmont	Roanoke	SCRO	11/7/01 12:00	7.60	11.85	6.70	85
4ABDA011.79	2	Piedmont	Roanoke	WCRO	10/23/01 15:30	15.70	8.02	7.84	133
4AEKH003.18	3	Piedmont	Roanoke	SCRO	10/30/01 10:00	6.90	11.68	7.41	84.2
4AHEN004.74	3	Piedmont	Roanoke	SCRO	10/18/01 11:20	8.42	3.83	7.02	125.6
4AOWC004.37	3	Piedmont	Roanoke	SCRO	11/7/01 10:30	8.50	14.35	6.86	29.7
4APAA000.24	2	Piedmont	Roanoke	WCRO	10/17/01 11:00	9.30	8.92	7.06	92.2
4ARNF009.01	4	CARV	Roanoke	WCRO	11/8/01 13:30	9.40	11.81	8.76	479.5
4ARNF015.50	3	CARV	Roanoke	WCRO	11/8/01 11:45	7.70	11.80	8.31	456.6
4ASNF007.64	1	BRM	Roanoke	WCRO	11/19/01 10:40	11.20	8.19	6.98	173.8
4ASRV012.19	5	Piedmont	Roanoke	SCRO	10/30/01 14:30	10.10	10.80	7.33	62.7
4AXME001.19	1	Piedmont	Roanoke	SCRO	10/30/01 12:30	10.60	6.41	7.57	163.5
5AAPW001.04	2	SEPlains	Chowan	TRO	10/18/01 10:10	9.00	5.30	4.87	48
5ABLW055.26	5	SEPlains	Chowan	PRO	10/23/01 9:45	14.70	0.30	6.71	172
5AMHN105.36	5	Piedmont	Chowan	SCRO	10/24/01 11:30	16.55	7.85	6.51	111
5ANTW045.12	6	SEPlains	Chowan	PRO	10/15/01 10:35	18.10	7.26	6.98	125
5ASTN002.43	4	MACP	Chowan	TRO	10/11/01 10:50	14.70	1.40	5.94	138
5AXEJ001.73	1	Piedmont	Chowan	PRO	10/30/01 12:00	10.50	9.48	6.33	101
6APNS003.94	3	CentApp	Big Sandy	SWRO	10/29/01 11:30	6.39	10.83	7.89	1778
6AXBF000.40	1	CentApp	Big Sandy	SWRO	10/23/01 12:30	11.40	9.30	7.05	213
6BDUM000.23	3	CentApp	Tennessee	SWRO	10/18/01 13:50	11.47	12.81	8.51	895
6BLWS003.88	3	CARV	Tennessee	SWRO	10/18/01 11:30	7.15	10.54	7.59	406
6BPOW156.57	5	CARV	Tennessee	SWRO	10/22/01 12:15	12.30	9.96	7.95	546
6BXDJ000.15	1	CARV	Tennessee	SWRO	10/29/01 13:30	7.12	10.80	8.09	289
6CSLM002.11	1	BRM	Holston	SWRO	10/30/01 12:45	5.82	10.53	6.48	139
7-DRN027.96	3	SEPlains	Chesapeake Bay	PRO	10/25/01 10:30	18.40	1.40	6.29	127
8-BRC002.70	1	NorPDMT	York	NVRO	10/2/01 11:30	15.08	6.60	7.38	48.3
8-XEA000.12	1	SEPlains	York	PRO	10/29/01 10:30	9.20	3.60	6.87	351
9-LIC004.73	1	BRM	New	WCRO	11/5/01 13:30	9.20	10.04	7.59	45.2
9-MDR003.60	2	BRM	New	WCRO	11/1/01 9:50	8.80	9.76	6.92	76.3
9-WFC010.66	4	CARV	New	WCRO	10/11/01 11:00	12.70	10.01	7.85	234.4
9-WFC044.15	3	CARV	New	SWRO	11/1/01 11:30	7.16	12.31	8.06	181
9-WLK024.17	5	CARV	New	WCRO	10/11/01 13:30	13.80	10.37	8.28	266.6

Appendix D: Table 2. Non-Metal Analysis 12 (NME12) data from Fall 2001.

Station ID	Strahler Order	Collection Date Time	TURBIDITY FTU - Hach Turbidimeter	LAB SPECIFIC CONDUC-TANCE	TOTAL SOLIDS (MG/L)	VOLATILE SOLIDS (MG/L)	FIXED SOLIDS (MG/L)	TOTAL DISSOLVED SOLIDS (MG/L)	TOTAL SUSPENDED SOLIDS (MG/L)	VOLATILE SUSPENDED SOLIDS (MG/L)	FIXED SUSPENDED SOLIDS (MG/L)
1ACAH001.82	2	10/29/01 11:30	14.50	163.40	154	58	96		39	5	34
1AFLL000.62	2	10/22/01 11:00	10.30	388.00	239	69	170		3	3	3
1ALUC000.95	2	10/1/01 12:30	8.25	69.50	59	5	55		3	3	3
1BBVR000.84	2	10/4/01 10:00	13.30	184.00	120	35	85		9	3	6
1BCPL002.83	2	10/16/01 10:40	7.62	613.00	385	35	350		4	3	3
1BDRI000.21	1	10/9/01 10:00	1.70	322.00	203	35	168		3	3	3
2-APP082.00	5	11/5/01 13:00	3.10	127.00	85	28	57	75	3	3	3
2-BFL016.79	3	10/31/01 11:15	2.56	104.60	86	20	66	80	3	3	3
2-BNF003.52	2	10/22/01 10:30	1.10	19.10	22	12	10		3	3	3
2-CEL001.00	3	11/20/01 12:00	3.77	102.00	75	27	48	63	3	3	3
2-COO002.35	1	11/1/01 10:50	1.50	59.50	60	23	37	60	3	3	3
2-CWP023.28	4	10/22/01 10:30	0.91	179.00	103	5	100		3	3	3
2-CWP053.78	3	10/11/01 10:00	2.90	193.00	116	17	99		3	3	3
2-HAZ006.34	3	10/22/01 15:30	3.71	93.20	74	23	51		3	3	3
2-JOB001.02	4	10/9/01 9:45	2.50	156.00	93	14	79		3	3	3
2-LMC001.15	5	10/10/01 15:00	1.33	483.00	317	67	250		3	3	3
2-LOB000.37	1	10/22/01 13:00	1.65	69.60	64	20	44		3	3	3
2-OGL005.53	2	10/9/01 13:30	1.30	86.00	57	10	47		3	3	3
2-RND003.57	2	10/29/01 11:20	8.90	103.90	98	35	63	94	3	3	3
2-RRS010.30	4	10/1/01 11:00	4.82	72.10	58	5	54		3	3	3
2-RVN012.05	5	10/15/01 10:00	33.00	206.00	163	30	133		65	15	50
2-SMR004.80	2	10/17/01 11:00	1.20	14.90	9	5	9		3	3	3
2-SUA001.55	3	10/23/01 10:30	3.96	110.00	100	27	73		3	3	3
2-WLS024.61	5	10/29/01 14:00	2.55	138.20	102	35	67	104	3	3	3
3-RAP008.71	5	10/10/01 13:00	7.10	80.70	64	15	49		11	3	9
3-ROB005.42	4	10/18/01 11:00	4.53	76.80	58	14	44		3	3	3
4ABAN022.24	5	11/7/01 12:00	3.30	73.20	58	25	33	55	3	3	3
4ABDA011.79	2	10/23/01 15:30	2.85	129.00	99	20	79		3	3	3
4AEKH003.18	3	10/30/01 10:00	1.73	84.70	80	23	57		3	3	3
4AHEN004.74	3	10/18/01 11:20	1.84	117.00	110	30	80	100	3	3	3
4AOWC004.37	3	11/7/01 10:30	6.20	32.70	35	25	10		3	3	3
4APAA000.24	2	10/17/01 11:00	1.50	95.70	82	21	61		3	3	3
4ARNF009.01	4	11/8/01 13:30	1.70	367.00	318	97	221		3	3	3
4ARNF015.50	3	11/8/01 11:45	2.20	481.00	295	121	174		3	3	3
4ASNF007.64	1	11/19/01 10:40	5.04	181.00	133	46	87		8	3	5
4ASRV012.19	5	10/30/01 14:30	2.88	67.60	66	23	43		3	3	3
4AXME001.19	1	10/30/01 12:30	13.00	165.00	159	48	111		23	6	17
5AAPW001.04	2	10/18/01 10:10	21.00	36.00	136	68	68		29	14	15
5ABLW055.26	5	10/23/01 9:45	3.95	145.00	130	54	76		10	7	3
5AMHN105.36	5	10/24/01 11:30	4.46	119.00	87	15	72	79	5	3	3
5ANTW045.12	6	10/15/01 10:35	7.33	105.00	69	7	62		3	3	3
5ASTN002.43	4	10/11/01 10:50	4.10	123.00	103	40	63		4	3	3
5AXEJ001.73	1	10/30/01 12:00	4.34	102.60	89	32	57	84	4	3	3
6APNS003.94	3	10/29/01 11:30	3.15	1891.00	1714	182	1532		3	3	3
6AXBF000.40	1	10/23/01 12:30	3.88	316.00	234	23	211		3	3	3
6BDUM000.23	3	10/18/01 13:50	1.36	979.00	637	32	605		3	3	3
6BLWS003.88	3	10/18/01 11:30	1.54	455.00	290	58	232		3	3	3
6BPOW156.57	5	10/22/01 12:15	1.06	585.00	397	75	322		3	3	3
6BXDJ000.15	1	10/29/01 13:30	0.81	329.00	188	50	138		3	3	3
6CSLM002.11	1	10/30/01 12:45	1.03	163.20	96	16	80		3	3	3
7-DRN027.96	3	10/25/01 10:30	6.99	107.00	105	46	59		4	3	3
8-BRC002.70	1	10/2/01 11:30	4.90	51.30	44	13	31		3	3	3
8-XEA000.12	1	10/29/01 10:30	8.00	304.00	192	20	172		5	3	3
9-LIC004.73	1	11/5/01 13:30	1.70	488.00	296	106	190		5	3	3
9-MDR003.60	2	11/1/01 9:50	3.30	83.30	65	18	47		3	3	3
9-WFC010.66	4	10/11/01 11:00	0.60	243.00	141	30	111		3	3	3
9-WFC044.15	3	11/1/01 11:30	1.22	215.00	127	21	106		3	3	3
9-WLK024.17	5	10/11/01 13:30	0.70	279.00	166	40	126		3	3	3

Appendix D: Table 3. Nutrient Data (NUT4, TNUTL, HTIT) from Fall 2001.

Station ID	Strahler Order	Collection Date Time	AMMONIA, TOTAL (MG/L AS N)	NITRITE, TOTAL (MG/L AS N)	NITRATE, TOTAL (MG/L AS N)	NITROGEN, TOTAL KJELDAHL (MG/L AS N)	PHOSPHOR-US, TOTAL (MG/L AS P)	TOTAL ORGANIC CARBON (MG/L AS C)	ORGANIC CARBON, IN BED MATERIAL (GM/KG AS C)	HARDNESS, EDTA (MG/L AS CACO3)
1ACAH001.82	2	10/29/01 11:30	0.04	0.02	4.23	0.70	0.09		2.00	45.80
1AFLL000.62	2	10/22/01 11:00	0.04	0.01	0.74	49.20	3.05		7.80	103.00
1ALUC000.95	2	10/1/01 12:30	0.04	0.01	0.06	0.60	0.02		15.50	13.50
1BBVR000.84	2	10/4/01 10:00	0.04	0.04	1.90	0.20	0.04		2.00	83.80
1BCPL002.83	2	10/16/01 10:40	0.04	0.01	2.56	0.10	0.01		6.30	299.00
1BDRI000.21	1	10/9/01 10:00	0.04	0.01	1.21	0.10	0.02		2.00	157.00
2-APP082.00	5	11/5/01 13:00	0.04	0.01	0.04	0.20	0.02	4.00	3.10	36.90
2-BFL016.79	3	10/31/01 11:15	0.04	0.01	0.04	0.20	0.02	2.30	2.00	6.90
2-BNF003.52	2	10/22/01 10:30	0.04	0.01	0.04	0.10	0.04	2.00	2.00	5.00
2-CEL001.00	3	11/20/01 12:00	0.04	0.01	0.73	0.20	0.02	5.00	2.60	17.90
2-COO002.35	1	11/1/01 10:50	0.04	0.01	0.04	0.20	0.01	2.00	2.00	13.30
2-CWP023.28	4	10/22/01 10:30	0.04	0.01	0.04	0.10	0.01		19.21	41.80
2-CWP053.78	3	10/11/01 10:00	0.04	0.01	0.04	0.10	0.01		9.35	75.90
2-HAZ006.34	3	10/22/01 15:30	0.04	0.01	0.04	0.20	0.05	3.00	2.00	31.70
2-JOB001.02	4	10/9/01 9:45	0.04	0.01	0.04	0.10	0.01	2.00		35.10
2-LMC001.15	5	10/10/01 15:00	0.04	0.01	0.42	0.60	0.02	2.00	21.80	248.00
2-LOB000.15	1	10/22/01 13:00	0.04	0.01	0.04	0.10	0.05	2.40	2.00	5.00
2-OGL005.53	2	10/9/01 13:30	0.04	0.01	0.06	0.20	0.01	2.00	2.00	17.50
2-RND003.57	2	10/29/01 11:20	0.04	0.01	0.04	0.40	0.02	4.80	4.60	16.90
2-RRS010.30	4	10/1/01 11:00	0.04	0.01	0.07	0.20	0.03		16.00	11.80
2-RVN012.05	5	10/15/01 10:00	0.04	0.02	2.31	1.60	0.46		2.00	27.70
2-SMR004.80	2	10/17/01 11:00	0.04	0.01	0.04	0.10	0.01		6.20	5.00
2-SUA001.55	3	10/23/01 10:30	0.04	0.01	0.04	0.50	0.05	5.00	2.00	17.10
2-WLS024.61	5	10/29/01 14:00	0.04	0.01	0.04	0.30	0.02	5.40	52.00	30.90
3-RAP008.71	5	10/10/01 13:00	0.04	0.01	0.04	0.40	0.03		25.40	28.80
3-ROB005.42	4	10/18/01 11:00	0.04	0.01	0.24	0.40	0.03		18.69	19.70
4ABAN022.24	5	11/7/01 12:00	0.04	0.01	0.04	0.20	0.01	2.40	3.30	31.50
4ABDA011.79	2	10/23/01 15:30	0.04	0.01	0.04	0.30	0.03	2.90	11.20	16.50
4AEKH003.18	3	10/30/01 10:00	0.04	0.01	0.04	0.10	0.03	2.80	2.00	23.40
4AHEN004.74	3	10/18/01 11:20	0.04	0.01	0.04	0.20	0.06	8.40	2.70	34.40
4AOWC004.37	3	11/7/01 10:30	0.04	0.01	0.04	0.20	0.01	2.00	16.00	5.00
4APAA000.24	2	10/17/01 11:00	0.04	0.01	0.04	0.20	0.03	4.50	6.80	15.50
4ARNF009.01	4	11/8/01 13:30	0.04	0.01	0.04	0.10	0.01	2.00	44.00	254.00
4ARNF015.50	3	11/8/01 11:45	0.04	0.01	0.15	0.10	0.02	2.00	33.50	246.00
4ASNF007.64	1	11/19/01 10:40	0.04	0.01	0.04	0.10	0.01	2.00	5.90	27.50
4ASRV012.19	5	10/30/01 14:30	0.04	0.01	0.04	0.10	0.02	2.00	2.00	5.00
4AXME001.19	1	10/30/01 12:30	0.04	0.01	0.04	0.60	0.26	3.40	19.20	49.60
5AAPW001.04	2	10/18/01 10:10	0.04	0.01	0.04	0.90	0.04		43.00	
5ABLW055.26	5	10/23/01 9:45	0.04	0.01	0.04	0.80	0.06		71.30	
5AMHN105.36	5	10/24/01 11:30	0.04	0.01	0.04	0.20	0.02	3.60	2.00	7.30
5ANTW045.12	6	10/15/01 10:35	0.04	0.01	0.04	0.10	0.02		2.00	
5ASTN002.43	4	10/11/01 10:50	0.04	0.01	0.04	0.60	0.05		48.10	
5AXEJ001.73	1	10/30/01 12:00	0.04	0.01	0.04	0.20	0.02	3.60	2.00	5.00
6APNS003.94	3	10/29/01 11:30	0.04	0.01	0.91	0.10	0.01		14.51	946.00
6AXBF000.40	1	10/23/01 12:30	0.05	0.01	0.10	0.10	0.01		6.50	52.10
6BDUM000.23	3	10/18/01 13:50	0.04	0.01	0.06	0.10	0.02		11.78	118.00
6BLWS003.88	3	10/18/01 11:30	0.04	0.01	0.33	0.10	0.02		3.16	224.00
6BPOW156.57	5	10/22/01 12:15	0.04	0.01	0.19	0.10	0.02		26.74	194.00
6BXDJ000.15	1	10/29/01 13:30	0.04	0.01	0.51	0.10	0.01		7.09	139.00
6CSLM002.11	1	10/30/01 12:45	0.04	0.01	0.04	0.20	0.01		2.00	5.00
7-DRN027.96	3	10/25/01 10:30	0.04	0.01	0.04	0.60	0.07		168.10	
8-BRC002.70	1	10/2/01 11:30	0.04	0.01	0.08	0.30	0.03		7.40	13.00
8-XEA000.12	1	10/29/01 10:30	0.04	0.02	0.04	0.20	0.07		82.40	
9-LIC004.73	1	11/5/01 13:30	0.04	0.01	0.44	0.20	0.02	2.00	7.20	16.50
9-MDR003.60	2	11/1/01 9:50	0.04	0.01	1.70	0.20	0.03	2.80	49.00	12.40
9-WFC010.66	4	10/11/01 11:00	0.04	0.01	0.20	0.10	0.01	2.00	2.00	42.60
9-WFC044.15	3	11/1/01 11:30	0.04	0.01	0.96	0.10	0.02		12.13	22.30
9-WLK024.17	5	10/11/01 13:30	0.04	0.01	0.04	0.10	0.01	2.10	2.00	127.00

Appendix D: Table 4. Metals (MET1S) Data from Fall 2001.

Station ID	Strahler Order	Collection Date Time	ARSENIC, SEDIMENT (MG/KG DRY WT)	BERYLLIUM, SEDIMENT (MG/KG AS BE DRY WT)	CADMIUM, SEDIMENT (MG/KG DRY WT)	CHROMIUM, SEDIMENT (MG/KG DRY WT)	COPPER, SEDIMENT (MG/KG AS CU DRY WT)	LEAD, SEDIMENT (MG/KG AS PB DRY WT)	MANGENESE, SEDIMENT (MG/KG AS DRY WT)	NICKEL, SEDIMENT (MG/KG DRY WT)	SILVER, SEDIMENT (MG/KG AS AG DRY WT)	ZINC, SEDIMENT (MG/KG AS ZN DRY WT)	ANTIMONY, SEDIMENT (MG/KG AS SB DRY WGT)	ALUMINUM, SEDIMENT (MG/KG AS AL DRY WGT)
1ACAH001.82	2	10/29/01 11:30	5.00	5	1	35.80	14.60	8.50	377.00	25.90	1	42.30	5	5200
1AFLL000.62	2	10/22/01 11:00	5.00	5	1	11.30	11.00	8.40	174.00	7.90	1	33.30	5	4800
1ALUC000.95	2	10/1/01 12:30	5.00	5	1	14.40	6.40	8.10	207.00	6.70	1	16.90	5	4880
1BBVR000.84	2	10/4/01 10:00	5.00	5	1	5.00	5.00	5.00	39.40	5.00	1	7.10	5	1510
1BCPL002.83	2	10/16/01 10:40	5.00	5	1	24.70	7.80	9.70	439.00	11.20	1	17.50	5	10300
1BDRI000.21	1	10/9/01 10:00	5.00	5	1	11.80	5.00	7.90	344.00	5.00	1	21.30	5	3630
2-APP082.00	5	11/5/01 13:00	5.00	5	1	7.40	5.00	5.00	881.00	5.00	1	17.50	5	1280
2-BFL016.79	3	10/31/01 11:15	5.00	5	1	6.20	5.00	5.00	622.00	5.00	1	5.10	5	1660
2-BNF003.52	2	10/22/01 10:30	5.00	5	1	6.40	6.30	14.00	459.00	5.40	1	90.90	5	15000
2-CEL001.00	3	11/20/01 12:00	5.00	5	1	5.00	5.00	5.00	14.30	5.00	1	31.20	5	929
2-COO002.35	1	11/1/01 10:50	5.00	5	1	24.60	5.50	5.00	276.00	6.60	1	17.60	5	4130
2-CWP023.28	4	10/22/01 10:30	6.40	5	1	16.30	22.90	14.50	144.00	33.00	1	87.20	5	8440
2-CWP053.78	3	10/11/01 10:00	7.40	5	1	13.70	19.50	11.70	242.00	25.90	1	69.50	5	6230
2-HAZ006.34	3	10/22/01 15:30	5.00	5	1	16.90	6.60	7.10	557.00	5.00	1	31.00	5	6930
2-JOB001.02	4	10/9/01 9:45	6.57	5	1	8.60	10.90	14.40	470.00	24.90	1	88.00	5	4220
2-LMC001.15	5	10/10/01 15:00	5.00	5	1	24.30	15.30	17.50	292.00	16.50	1	56.90	5	17500
2-LOB000.37	1	10/22/01 13:00	5.00	5	1	6.20	5.00	12.50	261.00	5.00	1	21.40	5	5100
2-OGL005.53	2	10/9/01 13:30	25.90	5	1	26.60	20.30	23.20	408.00	31.30	1	83.40	5	13200
2-RND003.57	2	10/29/01 11:20	5.00	5	1	21.70	15.40	8.50	270.00	7.50	1	30.40	5	13600
2-RRS010.30	4	10/1/01 11:00	5.00	5	1	11.40	8.40	13.10	341.00	5.00	1	56.60	5	11400
2-RVN012.05	5	10/15/01 10:00	5.00	5	1	13.00	10.00	10.20	1045.00	6.68	1	49.50	5	7950
2-SMR004.80	2	10/17/01 11:00	5.00	5	1	5.00	5.00	5.00	100.00	5.00	1	10.40	5	4930
2-SUA001.55	3	10/23/01 10:30	5.00	5	1	20.40	5.00	5.00	95.60	5.00	1	11.30	5	2740
2-WLS024.61	5	10/29/01 14:00	5.00	5	1	15.60	8.90	5.00	376.00	5.50	1	19.30	5	7260
3-RAP008.71	5	10/10/01 13:00	5.00	5	1	36.90	31.90	23.40	919.00	18.60	1	113.00	5	30700
3-ROB005.42	4	10/18/01 11:00	5.00	5	1	17.50	13.40	12.90	526.00	8.12	1	71.00	5	14500
4ABAN022.24	5	11/7/01 12:00	5.00	5	1	7.40	5.00	5.00	1280.00	5.00	1	8.40	5	1120
4ABDA011.79	2	10/23/01 15:30	5.00	5	1	13.70	6.20	21.80	278.00	5.50	1	70.20	5	20300
4AEKH003.18	3	10/30/01 10:00	5.00	5	1	5.20	5.00	5.00	968.00	5.00	1	12.00	5	5670
4AHEN004.74	3	10/18/01 11:20	5.00	5	1	14.20	5.00	5.00	391.00	5.00	1	8.90	5	2240
4AOWC004.37	3	11/7/01 10:30	5.00	5	1	27.00	18.20	17.20	1170.00	17.10	1	42.10	5	16600
4APAA000.24	2	10/17/01 11:00	5.00	5	1	31.10	5.00	5.00	210.00	15.50	1	13.80	5	4090
4ARNF009.01	4	11/8/01 13:30	5.00	5	1	15.40	16.60	16.20	426.00	17.60	1	68.70	5	10500
4ARNF015.50	3	11/8/01 11:45	5.00	5	1	14.00	14.60	13.70	558.00	14.70	1	57.90	5	9260
4ASNF007.64	1	11/19/01 10:40	5.00	5	1	58.40	48.90	9.50	654.00	23.40	1	89.30	5	20000
4ASRV012.19	5	10/30/01 14:30	5.00	5	1	14.40	5.00	5.00	135.00	5.00	1	12.80	5	5340
4AXME001.19	1	10/30/01 12:30	5.00	5	1	115.00	33.80	21.30	725.00	57.10	1	116.00	5	56300
5AAPW001.04	2	10/18/01 10:10	5.00	5	1	8.10	5.00	13.50	26.00	5.00	1	14.30	5	9280
5ABLW055.26	5	10/23/01 9:45	5.00	5	1	19.80	5.30	18.50	312.00	8.50	1	43.60	5	22100
5AMHN105.36	5	10/24/01 11:30	5.00	5	1	23.80	5.00	5.00	975.00	5.00	1	10.80	5	4300
5ANTW045.12	6	10/15/01 10:35	5.00	5	1	5.00	5.00	5.00	937.00	5.00	1	11.60	5	1160
5ASTN002.43	4	10/11/01 10:50	5.00	5	1	10.80	5.00	13.70	54.80	5.00	1	13.30	5	11000
5AXEJ001.73	1	10/30/01 12:00	5.00	5	1	5.00	5.00	5.00	14.10	5.00	1	5.00	5	1210
6APNS003.94	3	10/29/01 11:30	5.00	5	1	6.70	8.00	7.50	2340.00	52.00	1	118.00	5	5730
6AXBF000.40	1	10/23/01 12:30	5.00	5	1	6.30	8.60	7.40	624.00	18.00	1	65.20	5	5540
6BDUM000.23	3	10/18/01 13:50	5.00	5	1	5.30	6.00	5.90	310.00	8.34	1	27.40	5	3520
6BLWS003.88	3	10/18/01 11:30	5.00	5	1	6.00	5.80	6.80	346.00	8.17	1	31.90	5	4810
6BPOW156.57	5	10/22/01 12:15	5.00	5	1	5.00	5.00	9.70	299.00	8.70	1	29.20	5	2080
6BXDJ000.15	1	10/29/01 13:30	7.90	5	1	20.60	6.10	19.00	712.00	10.30	1	21.20	5	5560
6CSLM002.11	1	10/30/01 12:45	5.00	5	1	5.00	5.00	12.60	1680.00	6.50	1	64.10	5	3310
7-DRN027.96	3	10/25/01 10:30	23.40	5	1	20.50	8.10	20.70	2870.00	16.00	1	77.00	5	18900
8-BRC002.70	1	10/2/01 11:30	5.00	5	1	10.30	5.30	11.20	95.30	6.00	1	13.40	5	5140
8-XEA000.12	1	10/29/01 10:30	5.40	5	1	17.90	5.60	14.70	115.00	9.50	1	41.20	5	15900
9-LIC004.73	1	11/5/01 13:30	5.00	5	1	12.60	12.60	13.30	388.00	10.50	1	72.40	5	16700
9-MDR003.60	2	11/1/01 9:50	5.00	5	1	30.90	9.80	21.20	641.00	11.60	1	107.00	5	38100
9-WFC010.66	4	10/11/01 11:00	5.00	5	1	6.00	5.00	10.20	223.00	8.90	1	38.40	5	1300
9-WFC044.15	3	11/1/01 11:30	5.00	5	1	8.10	5.00	8.80	302.00	6.80	1	42.60	5	4010
9-WLK024.17	5	10/11/01 13:30	5.00	5	1	7.20	5.00	7.40	147.00	5.00	1	16.90	5	1310

Appendix D: Table 5. Fecal Coliforms (FCMF), Sediment (PART) and Selected Chlorophyll (FCHLR) Data from Fall 2001.

Station ID	Strahler Order	Collection Date Time	FECAL COLIFORM (MFM-FCBR/100 ML) MEMBRANE FILTER METHOD	CHLORO-PHYLL A, UNCORRECT-ED (UG/L)	CHLORO-PHYLL A, CORRECTED (UG/L)	CHLORO-PHYLL B (trichro-matic)	CHLORO-PHYLL C (trichro-matic)	PERCENT SAND IN SEDIMENT (%DRY WT)	SEDIMENT PARTICLE SIZE SILT (%DRY WT)	SEDIMENT PARTICLE SIZE CLAY (%DRY WT)	ORGANIC CARBON, IN BED MATERIAL (GM/KG AS C)
1ACAH001.82	2	10/29/01 11:30	100	5.662	5.200	1.980	0.500	86.300	10.300	3.400	2.000
1AFLL000.62	2	10/22/01 11:00	100	0.500	0.500	0.500	0.500	72.800	17.600	9.600	7.803
1ALUC000.95	2	10/1/01 12:30	100	0.500	0.500	0.500	0.500	63.600	30.100	6.230	15.500
1BBVR000.84	2	10/4/01 10:00	5400	1.830	1.100	0.500	0.500	96.900	1.490	1.630	2.000
1BCPL002.83	2	10/16/01 10:40	100	0.606	0.730	0.500	0.500	71.800	15.500	12.700	6.300
1BDRI000.21	1	10/9/01 10:00	600	0.998	1.140	0.500	0.500	97.400	1.010	1.550	2.000
2-APP082.00	5	11/5/01 13:00	100	0.500	0.530	0.500	0.500	98.000	1.000	1.370	3.100
2-BFL016.79	3	10/31/01 11:15	300	0.500	0.660	0.500	0.500	95.600	1.650	2.760	2.000
2-BNF003.52	2	10/22/01 10:30	100	0.500	0.500	0.500	0.500	95.600	2.390	2.010	2.000
2-CEL001.00	3	11/20/01 12:00	100	0.500	0.780	0.500	0.500	96.900	1.010	2.140	2.600
2-COO002.35	1	11/1/01 10:50	100	0.500	0.500	0.500	0.500	91.600	5.220	3.170	2.000
2-CWP023.28	4	10/22/01 10:30	100	0.500	0.500	0.500	0.500	69.600	17.600	12.800	19.210
2-CWP053.78	3	10/11/01 10:00	100	0.500	0.500	0.500	0.500	81.600	11.000	7.400	9.350
2-HAZ006.34	3	10/22/01 15:30	100	0.500	0.500	0.500	0.500	95.900	1.720	2.420	2.000
2-JOB001.02	4	10/9/01 9:45	100	0.500	0.500	0.500	0.500				
2-LMC001.15	5	10/10/01 15:00	100	0.500	0.500	0.500	0.500	15.100	35.900	49.000	21.800
2-LOB000.37	1	10/22/01 13:00	100	0.500	0.500	0.500	0.500	95.600	2.270	2.150	2.000
2-OGL005.53	2	10/9/01 13:30	100	0.500	0.500	0.500	0.500	94.800	2.570	2.630	2.000
2-RND003.57	2	10/29/01 11:20	100	0.500	0.660	0.500	0.500	79.600	10.000	10.400	4.600
2-RRS010.30	4	10/1/01 11:00	300	0.582	0.640	0.500	0.500	40.400	33.000	26.600	16.000
2-RVN012.05	5	10/15/01 10:00	3100	34.804	17.620	3.250	2.270	92.100	3.690	4.190	2.000
2-SMR004.80	2	10/17/01 11:00	100	0.500	0.500	0.500	0.500	89.200	5.410	5.360	6.200
2-SUA001.55	3	10/23/01 10:30	3700	1.624	0.610	0.500	0.500	93.300	3.830	2.870	2.000
2-WLS024.61	5	10/29/01 14:00	100	0.500	0.640	0.500	0.500	79.400	12.100	8.540	52.000
3-RAP008.71	5	10/10/01 13:00	100	0.500	0.500	0.500	0.500	5.250	63.400	31.300	25.400
3-ROB005.42	4	10/18/01 11:00	200	0.752	0.890	0.500	0.500	42.900	36.800	20.300	18.690
4ABAN022.24	5	11/7/01 12:00	100	0.500	0.620	0.500	0.500	97.700	1.000	1.610	3.300
4ABDA011.79	2	10/23/01 15:30	100	0.500	0.500	0.500	0.500	64.700	21.100	14.200	11.200
4AEKH003.18	3	10/30/01 10:00	100	0.500	0.500	0.500	0.500	93.700	3.450	2.830	2.000
4AHEN004.74	3	10/18/01 11:20	100	1.911	0.960	0.500	0.500	89.300	5.860	4.860	2.700
4AOWC004.37	3	11/7/01 10:30	200	0.500	0.500	0.500	0.500	59.100	20.800	20.100	16.000
4APAA000.24	2	10/17/01 11:00	100	0.500	0.500	0.500	0.500	91.900	3.330	4.780	6.800
4ARNF009.01	4	11/8/01 13:30	800	0.500	0.530	0.500	0.500	24.000	44.600	31.400	44.000
4ARNF015.50	3	11/8/01 11:45	100	1.259	0.940	0.500	0.500	12.200	42.900	44.800	33.500
4ASNF007.64	1	11/19/01 10:40	100	0.500	0.500	0.500	0.500	86.900	7.650	5.440	5.900
4ASRV012.19	5	10/30/01 14:30	100	0.500	0.500	0.500	0.500	92.000	4.140	3.870	2.000
4AXME001.19	1	10/30/01 12:30	100	4.328	2.950	0.500	0.500	35.700	33.200	31.100	19.200
5AAPW001.04	2	10/18/01 10:10	100	3.639	2.250	0.500	0.500	62.800	19.200	18.000	43.000
5ABLW055.26	5	10/23/01 9:45	100	2.168	2.460	0.500	0.500	47.000	16.100	36.900	71.300
5AMHN105.36	5	10/24/01 11:30	100	0.712	0.680	0.500	0.500	96.200	2.260	1.550	2.000
5ANTW045.12	6	10/15/01 10:35	100	0.500	0.640	0.500	0.500	96.200	1.360	2.440	2.000
5ASTN002.43	4	10/11/01 10:50	100	1.705	1.740	0.500	0.500	57.400	16.700	25.800	48.100
5AXEJ001.73	1	10/30/01 12:00	100	0.500	0.570	0.500	0.500	96.400	1.370	2.260	2.000
6APNS003.94	3	10/29/01 11:30	700	0.577	0.960	0.500	0.500	59.200	27.200	13.600	14.510
6AXBF000.40	1	10/23/01 12:30	100	0.500	0.500	0.500	0.500	84.500	8.760	6.730	6.500
6BDUM000.23	3	10/18/01 13:50	200	0.676	0.870	0.500	0.500	91.800	4.070	4.080	11.780
6BLWS003.88	3	10/18/01 11:30	100	0.500	0.520	0.500	0.500	92.700	4.060	3.240	3.161
6BPOW156.57	5	10/22/01 12:15	100	0.802	0.910	0.500	0.500	90.700	2.970	6.350	26.740
6BXDJ000.15	1	10/29/01 13:30	100	0.500	0.500	0.500	0.500	85.600	7.460	6.990	7.091
6CSLM002.11	1	10/30/01 12:45	100	0.500	0.500	0.500	0.500	94.000	2.170	3.820	2.000
7-DRN027.96	3	10/25/01 10:30	100	1.354	2.170	0.500	0.500	6.980	22.600	70.400	168.100
8-BRC002.70	1	10/2/01 11:30	200	0.500	0.500	0.500	0.500	43.400	40.100	16.500	7.400
8-XEA000.12	1	10/29/01 10:30	100	0.500	0.890	0.500	0.500	27.800	37.200	35.000	82.400
9-LIC004.73	1	11/5/01 13:30	100	0.500	0.500	0.500	0.500	81.400	13.300	5.230	7.200
9-MDR003.60	2	11/1/01 9:50	900	0.606	0.710	0.500	0.500	44.000	35.000	21.000	49.000
9-WFC010.66	4	10/11/01 11:00	100	0.500	0.500	0.500	0.500	96.700	1.100	2.190	2.000
9-WFC044.15	3	11/1/01 11:30	100	0.500	0.500	0.500	0.500	73.800	14.500	13.700	12.130
9-WLK024.17	5	10/11/01 13:30	100	0.500	0.500	0.500	0.500	97.500	1.000	1.990	2.000

Appendix D: Table 6. Pesticide (PES1S) Data from Fall 2001.

Station ID	Strahler Order	Collection Date Time	PENTACHLOROPHENOL, SEDIMENT (UG/KG DRY WT)	ALDRIN, SEDIMENT (UG/KG DRY WT)	CHLORDANE TECH MIX & METABS,SEDIMENT(UG/KG DRY WT)	DDD, SEDIMENT (UG/KG DRY WT)	DDE, SEDIMENT (UG/KG DRY WT)	P-P' DDT, SEDIMENT (UG/KG DRY WT)	DIELDRIN, SEDIMENT (UG/KG DRY WT)	ENDRIN, SEDIMENT (UG/KG DRY WT)	TOXAPHENE, SEDIMENT (ug/Kg)	HEPTACHLOR, SEDIMENT (ug/Kg)	PCBS TOTAL, SEDIMENT (UG/KG DRY WT)	HEPTACHLOR EPOXIDE, SED (UG/KG DRY WT)	DICOFOL (KELTHANE)
1ACAH001.82	2	10/29/01 11:30	70	20	60	20	30	20	20	30	110	20	20	20	70
1AFLL000.62	2	10/22/01 11:00	100	20	80	30	40	20	20	40	160	20	20	20	100
1ALUC000.95	2	10/1/01 12:30	90	20	70	30	40	20	20	40	140	20	20	20	90
1BBVR000.84	2	10/4/01 10:00	80	20	70	30	40	20	20	40	130	20	20	20	80
1BCPL002.83	2	10/16/01 10:40	100	20	80	30	40	20	20	40	160	20	20	20	100
1BDRI000.21	1	10/9/01 10:00	60	20	50	20	30	20	20	30	90	20	20	20	60
2-APP082.00	5	11/5/01 13:00	80	20	60	30	30	20	20	30	120	20	20	20	80
2-BFL016.79	3	10/31/01 11:15	70	20	60	20	30	20	20	30	110	20	20	20	70
2-BNF003.52	2	10/22/01 10:30	90	20	70	30	40	20	20	40	130	20	20	20	90
2-CEL001.00	3	11/20/01 12:00	80	20	70	30	40	20	20	40	130	20	20	20	80
2-COO002.35	1	11/1/01 10:50	70	20	60	20	30	20	20	30	110	20	20	20	70
2-CWP023.28	4	10/22/01 10:30	90	20	70	30	40	20	20	40	130	20	20	20	90
2-CWP053.78	3	10/11/01 10:00	70	20	60	30	30	20	20	30	110	20	20	20	70
2-HAZ006.34	3	10/22/01 15:30	90	20	70	30	40	20	20	40	140	20	20	20	90
2-JOB001.02	4	10/9/01 9:45	70	20	60	30	30	20	20	30	120	20	20	20	70
2-LMC001.15	5	10/10/01 15:00	150	30	120	50	60	30	30	60	240	30	30	30	150
2-LOB000.37	1	10/22/01 13:00	90	20	70	30	40	20	20	40	130	20	20	20	90
2-OGL005.53	2	10/9/01 13:30	70	20	60	20	30	20	20	30	110	20	20	20	70
2-RND003.57	2	10/29/01 11:20	70	20	60	20	30	20	20	30	110	20	20	20	70
2-RRS010.30	4	10/1/01 11:00	80	20	60	30	30	20	20	30	120	20	20	20	80
2-RVN012.05	5	10/15/01 10:00	70	20	60	20	30	20	20	30	110	20	20	20	70
2-SMR004.80	2	10/17/01 11:00	60	20	50	20	30	20	20	30	100	20	20	20	60
2-SUA001.55	3	10/23/01 10:30	800	160	640	240	320	160	160	320	1280	160	160	160	800
2-WLS024.61	5	10/29/01 14:00	120	30	100	40	50	30	30	50	190	30	30	30	120
3-RAP008.71	5	10/10/01 13:00	140	30	1120	50	60	30	30	60	230	30	30	30	140
3-ROB005.42	4	10/18/01 11:00	160	40	130	50	70	40	40	70	250	40	40	40	160
4ABAN022.24	5	11/7/01 12:00	80	20	70	30	40	20	20	40	130	20	20	20	80
4ABDA011.79	2	10/23/01 15:30	120	30	90	40	50	30	30	50	180	30	30	30	120
4AEKH003.18	3	10/30/01 10:00	60	20	50	20	30	20	20	30	100	20	20	20	60
4AHEN004.74	3	10/18/01 11:20	80	20	70	30	40	20	20	40	130	20	20	20	80
4AOWC004.37	3	11/7/01 10:30	90	20	70	30	40	20	20	40	140	20	20	20	90
4APAA000.24	2	10/17/01 11:00	100	20	80	30	40	20	20	40	150	20	20	20	100
4ARNF009.01	4	11/8/01 13:30	160	40	130	50	70	40	40	70	250	40	40	40	160
4ARNF015.50	3	11/8/01 11:45	230	50	180	70	90	50	50	90	360	50	50	50	230
4ASNF007.64	1	11/19/01 10:40	70	20	60	20	30	20	20	30	110	20	20	20	70
4ASRV012.19	5	10/30/01 14:30	70	20	60	20	30	20	20	30	110	20	20	20	70
4AXME001.19	1	10/30/01 12:30	110	30	90	30	50	30	40	50	180	30	30	30	110
5AAPW001.04	2	10/18/01 10:10	190	40	150	60	80	40	40	80	300	40	40	40	190
5ABLW055.26	5	10/23/01 9:45	800	160	640	240	320	160	160	320	1280	160	160	160	800
5AMHN105.36	5	10/24/01 11:30	60	20	50	20	30	20	20	30	100	20	20	20	60
5ANTW045.12	6	10/15/01 10:35	90	20	70	30	40	20	20	40	140	20	20	20	90
5ASTN002.43	4	10/11/01 10:50	130	30	110	40	60	30	30	60	210	30	30	30	130
5AXEJ001.73	1	10/30/01 12:00	70	20	60	30	30	20	20	30	110	20	20	20	70
6APNS003.94	3	10/29/01 11:30	70	20	60	30	30	20	20	30	110	20	20	20	70
6AXBF000.40	1	10/23/01 12:30	70	20	60	30	30	20	20	30	120	20	20	20	70
6BDUM000.23	3	10/18/01 13:50	100	20	80	30	40	20	20	40	150	20	20	20	100
6BLWS003.88	3	10/18/01 11:30	100	20	80	30	40	20	20	40	150	20	20	20	100
6BPOW156.57	5	10/22/01 12:15	90	20	70	30	40	20	20	40	140	20	20	20	90
6BXDJ000.15	1	10/29/01 13:30	70	20	60	20	30	20	20	30	110	20	20	20	70
6CSLM002.11	1	10/30/01 12:45	70	20	60	20	30	20	20	30	110	20	20	20	70
7-DRN027.96	3	10/25/01 10:30	440	90	350	130	180	90	90	180	700	90	90	90	440
8-BRC002.70	1	10/2/01 11:30	80	20	70	30	40	20	20	40	130	20	20	20	80
8-XEA000.12	1	10/29/01 10:30	170	40	140	50	70	40	40	70	270	40	40	40	170
9-LIC004.73	1	11/5/01 13:30	90	20	70	30	40	20	20	40	140	20	20	20	90
9-MDR003.60	2	11/1/01 9:50	130	30	100	40	50	30	30	50	200	30	30	30	130
9-WFC010.66	4	10/11/01 11:05	70	20	60	30	30	20	20	30	110	20	20	20	70
9-WFC044.15	3	11/1/01 11:30	130	30	100	40	50	30	30	50	200	30	30	30	130
9-WLK024.17	5	10/11/01 13:35	90	20	70	30	40	20	20	40	140	20	20	20	90

APPENDIX E. TABLES OF BIOLOGICAL DATA.

Appendix E: Table 1. Benthic macroinvertebrate summary metrics for Spring 2001.

Station ID	StreamName	Strahler Order	Collection Date	DEQ Region	Taxa Rich-ness	EPT Index	%EPT	%EPT-H	%Ephem-eroptera	MFBI	%Dom-Fam	Dominant Family	%Chiron-omidae	Simpsons Diversity Index
1ACAH001.82	Captain Hickory Run	2	5/29/01	NRO	12	3	26.09	15.22	6.98	4.52	19.57	Corydalidae	0.00	0.90
1AFLL000.62	Flatlick Branch	2	5/30/01	NRO	11	2	42.11	1.05	1.05	5.72	41.05	Hydropsychidae	2.11	0.77
1ALUC000.95	Lucky Run	2	4/12/01	NRO	13	4	28.71	28.71	21.78	4.94	37.62	Simuliidae	0.00	0.80
1BBVR000.84	Beaver Creek	2	5/17/01	VRO	19	9	56.86	49.02	43.14	4.82	26.80	Chironomidae (A)	26.80	0.85
1BCPL002.83	Chapel Run	2	5/24/01	VRO	10	3	27.88	25.00	25.00	6.14	39.42	Asellidae	10.58	0.78
1BDRI000.21	Dry Run	1	5/17/01	VRO	7	5	10.78	10.78	10.34	5.76	88.79	Chironomidae (A)	88.79	0.21
2-APP082.00	Appomattox River	5	5/3/01	SCRO	14	6	51.96	51.96	31.37	3.63	13.73	Oligo./Perlidae	9.80	0.91
2-BFL016.79	Buffalo Creek	3	5/17/01	SCRO	20	5	30.00	27.00	15.00	4.79	31.00	Chironomidae (A)	31.00	0.87
2-BNF003.52	N.F. Buffalo River	2	4/3/01	SCRO	18	12	88.42	86.32	69.47	3.68	42.11	Heptageniidae	4.21	0.76
2-CEL001.00	Cornelius Creek	3	3/19/01	PRO	15	4	27.93	5.41	3.60	6.17	30.63	Chironomidae (A)	31.53	0.78
2-COO002.35	Cooper Creek	1	4/11/01	SCRO	17	10	54.72	42.45	19.81	3.75	14.15	Psephenidae	9.43	0.91
2-CWP023.28	Cowpasture River	4	5/15/01	VRO	21	11	55.56	52.78	34.03	4.35	22.22	Heptageniidae	20.14	0.88
2-CWP053.78	Cowpasture River	3	5/30/01	VRO	15	6	60.00	49.57	48.70	4.86	20.87	Chironomidae(A)/ Ephemerellidae	20.87	0.87
2-HAZ006.34	Harris Creek	3	5/10/01	SCRO	13	9	83.33	77.45	72.55	4.06	29.41	Baetidae	9.80	0.82
2-HOI004.08	Horsepen Branch	1	5/18/01	PRO	5	0	0.00	0.00	0.00	5.65	34.78	Gammaridae	0.00	0.81
2-JOB001.02	Johns Creek	4	4/20/01	WCRO	20	8	38.37	38.37	23.84	4.13	20.93	Chironomidae (A)	20.93	0.89
2-LMC001.15	Looney Creek	5	4/9/01	WCRO	15	8	56.57	51.52	46.46	4.35	26.26	Ephemerellidae	20.20	0.85
2-LOB000.37	Long Branch	1	6/5/01	SCRO	10	4	19.66	17.95	17.95	5.75	60.68	Chironomidae (A)	60.68	0.61
2-OGL005.53	Ogle Creek	2	5/1/01	WCRO	20	13	72.58	65.05	50.00	4.05	20.97	Ephemerellidae	13.44	0.89
2-RND003.57	Randolf Creek	2	4/12/01	SCRO	12	2	15.79	15.79	0.00	5.07	31.58	Chironomidae (A)	31.58	0.85
2-RRS010.30	SF Rivanna River	4	5/22/01	VRO	12	5	16.33	16.33	14.29	5.81	43.88	Chironomidae (A)	43.88	0.76
2-RVN012.05	Rivanna River	5	5/14/01	VRO	15	6	29.46	16.96	14.29	5.70	54.46	Chironomidae (A)	54.46	0.68
2-SMR004.80	St. Marys River	2	5/29/01	VRO	16	10	72.97	53.15	9.91	3.54	19.82	Hydropsychidae	15.32	0.88
2-SUA001.55	Suanee Creek	3	6/11/01	SCRO	20	8	42.57	31.68	23.76	4.69	31.68	Chironomidae (A)	31.68	0.86
2-WLS024.61	Willis River	5	5/2/01	SCRO	19	7	62.50	51.79	39.29	4.16	20.53	Heptageniidae	4.46	0.90
3-RAP008.71	Rapidan River	5	4/24/01	NRO	15	8	79.10	69.40	50.75	3.80	43.28	Ephemerellidae	0.00	0.78
3-ROB005.42	Robinson River	4	4/10/01	NRO	16	6	71.67	64.17	60.00	4.18	45.00	Ephemerellidae	0.83	0.76
3-XEX000.81	UT to Elmwood Cr.	1	3/22/01	PRO	11	3	7.02	6.14	5.26	6.20	49.12	Simuliidae	9.65	0.71
4ABAN022.24	Banister River	5	5/15/01	SCRO	15	8	70.87	60.63	34.65	3.61	22.83	Perlidae	14.17	0.88
4ABDA011.79	Beaverdam Creek	2	4/6/01	WCRO	12	7	59.83	25.64	18.80	5.21	34.19	Hydropsychidae	23.93	0.81
4AEKH003.18	Elkhorn Creek	3	5/15/01	SCRO	16	9	38.38	31.31	19.19	4.93	48.48	Chironomidae (A)	48.48	0.75
4AHEN004.74	Horsepen Creek	3	5/16/01	SCRO	18	4	26.36	26.36	11.82	5.16	23.64	Chironomidae (A)	28.18	0.91
4AOWC004.37	Old Womans Creek	3	5/15/01	SCRO	16	8	44.44	39.81	15.74	4.05	33.33	Chironomidae (A)	33.33	0.82
4APAA000.24	Poplar Branch	2	5/31/01	WCRO	14	7	47.37	39.47	15.79	4.82	46.49	Chironomidae (A)	46.49	0.73
4ARNF009.01	N.F. Roanoke River	4	5/7/01	WCRO	18	8	36.84	33.83	31.58	4.47	28.57	Elmidae	19.55	0.85
4ARNF015.50	N.F. Roanoke River	3	4/11/01	WCRO	15	5	44.66	40.78	39.81	4.62	34.95	Ephemerellidae	21.36	0.80
4ASNF007.64	N.F. South Mayo R.	1	5/17/01	WCRO	12	8	80.00	76.00	72.00	4.06	64.80	Ephemerellidae	2.40	0.56
4ASRV012.19	Sandy River	5	6/4/01	SCRO	15	8	71.90	38.84	22.31	4.22	33.06	Hydropsychidae	10.74	0.84
4AXMF001.46	UT to Hyco River	1	5/15/01	SCRO	11	4	21.92	21.92	6.85	4.99	28.77	Chironomidae (A)	28.77	0.85
5AAPW001.04	Applewhite Swamp	2	4/9/01	TRO	10	1	1.35	1.35	0.00	6.23	48.65	Chironomidae (A)	48.65	0.72
5ABLW055.26	Blackwater River	5	4/9/01	PRO	16	2	1.18	1.18	0.29	6.21	35.99	Chironomidae (A)	37.17	0.80
5AMHN105.36	Meherrin River	5	5/8/01	SCRO	13	8	58.12	47.01	27.35	4.50	31.62	Chironomidae (A)	31.62	0.85
5ANTW045.12	Nottoway River	6	5/15/01	PRO	32	10	7.16	6.71	5.15	6.15	41.16	Gammaridae	21.25	0.77
5ASTN002.43	Somerton Creek	4	5/3/01	TRO	22	1	0.97	0.97	0.00	5.30	41.85	Hydrobiidae	19.46	0.77
5AXEH001.35	UT to Great Creek	1	4/10/01	PRO	18	8	59.72	48.61	6.94	4.40	19.44	Leptoceridae	5.56	0.90
5AXEI000.27	UT to S. Meherrin R.	1	5/16/01	SCRO	10	4	44.57	44.57	22.83	4.22	34.78	Chironomidae (A)	34.78	0.80
5AXEJ001.73	UT to Nottoway R.	1	4/9/01	PRO	13	3	22.97	6.76	5.41	6.12	41.89	Chironomidae (A)	41.89	0.79
6APNS003.94	S.F. Pound	3	6/18/01	SWRO	6	1	23.96	0.00	0.00	4.94	47.92	Elmidae	23.96	0.66
6AXBF000.40	Japa's Fork	1	5/21/01	SWRO	4	2	40.00	20.00	0.00	5.20	40.00	Chironomidae (A)	40.00	0.90
6BDUM000.23	Dumps Creek	3	4/25/01	SWRO	7	3	66.67	35.56	13.33	4.62	31.11	Hydropsychidae	8.88	0.82
6BLWS003.88	Lewis Creek	3	4/30/01	SWRO	11	4	28.13	21.88	20.83	4.39	31.25	Elmidae	7.29	0.80
6BPOW156.57	Powell River	5	5/15/01	SWRO	12	5	19.42	11.65	10.68	4.58	22.33	Pleuroceridae	21.36	0.85
6BXDJ000.15	UT to Falls Creek	1	5/30/01	SWRO	13	8	36.96	33.70	20.65	5.11	29.35	Talitridae	0.00	0.84
6CSLM002.11	Slemp Creek	1	5/9/01	SWRO	17	10	60.44	60.44	29.67	3.80	23.08	Chironomidae (A)	23.08	0.86
6CXCH001.34	UT to N.F. Holston R.	1	4/16/01	SWRO	2	1	84.62	84.62	0.00	2.62	84.62	Taeniopterygidae	15.38	0.28

Appendix E: Table 1. Benthic macroinvertebrate summary metrics for Spring 2001 (continued).

7-DRN027.96	Dragon Swamp	3	4/25/01	PRO	22	2	1.12	1.12	1.12	7.29	52.19	Asellidae	17.17	0.68
8-BRC002.70	Beaver Creek	1	4/25/01	NRO	18	9	84.33	76.87	47.76	3.76	22.39	Heptageniidae	0.75	0.87
8-XEA000.12	UT to Bland Creek	1	4/25/01	PRO	15	3	4.10	4.10	1.64	5.93	76.23	Chironomidae (A)	76.23	0.41
9-LIC004.73	Little Indian Creek	1	4/18/01	WCRO	18	9	52.21	41.59	30.97	4.71	31.86	Chironomidae (A)	31.86	0.83
9-MDR003.60	Meadow Run	2	4/18/01	WCRO	10	3	29.01	12.98	12.98	5.62	61.83	Chironomidae (A)	61.83	0.59
9-WFC010.66	Wolf Creek	4	5/8/01	WCRO	22	11	42.66	40.56	32.17	4.22	20.28	Baetidae	17.48	0.89
9-WFC044.15	Wolf Creek	3	4/26/01	SWRO	20	12	47.17	44.34	33.96	3.78	26.42	Psephenidae	5.66	0.88
9-WLK024.17	Walker Creek	5	6/6/01	WCRO	18	8	29.41	26.47	24.51	4.52	33.33	Elmidae	23.53	0.81
			Minimum		2	0	0.00	0.00	0.00	2.62	13.73		0.00	0.21
			Maximum		32	13	88.42	86.32	72.55	7.29	88.79		88.79	0.91
			Mean		14.63	6.05	41.55	33.79	22.15	4.80	36.33		23.24	0.79

Explanation of Metrics

Taxa Richness = total number of families in sample.

EPT Index = total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) Families in sample. Families in these Orders are typically regarded as being intolerant of pollution.

% EPT = percent abundance of EPT individuals.

% EPT-H = percent abundance of EPT individuals minus larvae from the Family Hydropsychidae. Hydropsychidae larvae are semi-tolerant and can be very abundant in nutrient enriched streams.

% Ephemeroptera = percent abundance of individual mayfly larvae. Higher values typically indicate better water quality.

MFBI = Modified Family Biotic Index. The weighted sum of total taxa by organic pollution tolerance. Lower scores are better (values $\geq$ 6.5 typically indicate significant organic pollution).

% 1Dom. Fam. = Percent of the most numerous taxa in the sample. An indicator of community diversity. Less than 20% is very good; greater than 50% is bad.

Dominant Family = the name of the family that numerically dominated the sample.

% Chironomidae = midge fly larvae. Combined Chironomidae (A) and (B). A's occur naturally in most streams. B's are the "bloodworms" that are the "bloodworms" that are found in degraded streams.

Simpsons Diversity Index = an indicator of community balance and eveness.

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001.

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
1	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Aeshnidae	4
2	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Calopterygidae	2
3	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Cambaridae	8
4	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Corydalidae	9
5	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Gerridae	1
6	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Heptageniidae	3
7	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Hydropsychidae	5
8	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Noteridae	1
9	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Philopotamidae	4
10	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Sialidae	1
11	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Tipulidae	6
12	1ACAH001.82	Captain Hickory Run	2	5/29/01	CAH2987	Veliidae	2
13	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Cambaridae	1
14	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Chironomidae (A)	2
15	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Chironomidae (B)	5
16	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Coenagrionidae	3
17	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Corbiculidae	2
18	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Elmidae	17
19	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Heptageniidae	1
20	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Hydropsychidae	39
21	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Planorbidae	3
22	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Simuliidae	15
23	1AFLL000.62	Flatlick Branch	2	5/30/01	FLL2988	Tipulidae	7
24	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Aeshnidae	1
25	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Corydalidae	11
26	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Dryopidae	8
27	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Elmidae	3
28	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Ephemerellidae	1
29	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Gerridae	3
30	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Gyrinidae	5
31	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Heptageniidae	21
32	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Perlidae	6
33	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Philopotamidae	1
34	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Simuliidae	38
35	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Tipulidae	1
36	1ALUC000.95	Lucky Run	2	4/12/01	LUC2990	Veliidae	2
37	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Asellidae	2
38	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Baetidae	18
39	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Chironomidae (A)	41
40	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Elmidae	7
41	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Empididae	9
42	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Ephemerellidae	35
43	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Ephemeridae	1
44	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Glossosomatidae	3
45	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Heptageniidae	9
46	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Hydropsychidae	12
47	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Limnephilidae	4
48	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Lumbriculidae	1
49	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Naididae	1
50	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Oligoneuriidae	3
51	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Philopotamidae	2
52	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Pleuroceridae	1
53	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Simuliidae	1
54	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Tipulidae	2
55	1BBVR000.84	Beaver Creek	2	5/17/01	BVR2886	Tubificidae	1
56	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Asellidae	41
57	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Baetidae	7
58	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Cambaridae	1
59	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Chironomidae (A)	11
60	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Dytiscidae	1
61	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Elmidae	8
62	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Heptageniidae	19
63	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Hydropsychidae	3
64	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Lumbriculidae	1
65	1BCPL002.83	Chapel Run	2	5/24/01	CPL2883	Simuliidae	12
66	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Baetidae	16
67	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Chironomidae (A)	206
68	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Ephemerellidae	3

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
69	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Heptageniidae	3
70	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Hydrophilidae	1
71	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Leptophlebiidae	2
72	1BDRI000.21	Dry Run	1	5/17/01	DRI2885	Philopotamidae	1
73	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Baetiscidae	3
74	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Chironomidae (A)	10
75	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Corbiculidae	4
76	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Corixidae	2
77	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Culicidae	6
78	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Elmidae	12
79	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Ephemerellidae	2
80	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Gomphidae	3
81	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Heptageniidae	13
82	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Hydrophilidae	11
83	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Macromiidae	1
84	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Oligoneuriidae	14
85	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Perlidae	14
86	2-APP082.00	Appomattox River	5	5/3/01	APP6367	Pteronarcyidae	7
87	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Aeshnidae	3
88	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Baetidae	13
89	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Calopterygidae	2
90	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Cambaridae	3
91	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Chironomidae (A)	31
92	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Coenagrionidae	4
93	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Corbiculidae	1
94	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Corixidae	1
95	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Corydalidae	4
96	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Culicidae	4
97	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Elmidae	7
98	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Ephemeridae	1
99	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Gammaridae	1
100	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Gomphidae	2
101	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Gyrinidae	4
102	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Heptageniidae	1
103	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Hydropsychidae	3
104	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Perlidae	12
105	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Tipulidae	2
106	2-BFL016.79	Buffalo Creek	3	5/17/01	BFL6353	Veliidae	1
107	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Brachycentridae	1
108	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Ceratopogonidae	1
109	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Chironomidae (A)	4
110	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Chloroperlidae	2
111	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Corydalidae	1
112	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Elmidae	2
113	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Ephemerellidae	23
114	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Heptageniidae	40
115	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Hydropsychidae	2
116	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Leptophlebiidae	3
117	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Lumbriculidae	2
118	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Peltoperlidae	1
119	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Perlidae	1
120	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Perlodidae	4
121	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Pteronarcyidae	3
122	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Rhyacophilidae	2
123	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Taeniopterygidae	2
124	2-BNF003.52	N. F. Buffalo River	2	4/3/01	BNF1598	Tipulidae	1
125	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Aeshnidae	1
126	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Calopterygidae	1
127	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Cambaridae	1
128	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Chironomidae (A)	34
129	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Chironomidae (B)	1
130	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Corydalidae	1
131	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Culicidae	30
132	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Elmidae	6
133	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Gomphidae	2
134	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Heptageniidae	4
135	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Hydropsychidae	25
136	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Philopotamidae	1

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
137	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Phryganeidae	1
138	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Simuliidae	2
139	2-CEL001.00	Cornelius Creek	3	3/19/01	CEL6375	Tipulidae	1
140	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Baetidae	1
141	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Calamoceratidae	1
142	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Cambaridae	1
143	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Chironomidae (A)	10
144	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Corydalidae	1
145	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Elmidae	7
146	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Ephemerellidae	3
147	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Heptageniidae	12
148	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Hydrophilidae	1
149	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Hydropsychidae	13
150	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Limnephilidae	5
151	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Oligoneuriidae	5
152	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Peltoperlidae	1
153	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Perlidae	14
154	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Psephenidae	15
155	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Taeniopterygidae	3
156	2-COO002.35	Cooper Creek	1	4/11/01	COO6364	Tipulidae	13
157	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Baetidae	7
158	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Chironomidae (A)	29
159	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Coenagrionidae	3
160	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Elmidae	14
161	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Ephemerellidae	7
162	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Gomphidae	2
163	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Heptageniidae	32
164	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Hydropsychidae	4
165	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Hydroptilidae	1
166	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Lepidostomatidae	1
167	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Limnephilidae	1
168	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Lumbriculidae	1
169	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Oligoneuriidae	3
170	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Perlidae	2
171	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Philopotamidae	21
172	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Pleuroceridae	4
173	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Psephenidae	7
174	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Rhyacophilidae	1
175	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Simuliidae	2
176	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Sphaeriidae	1
177	2-CWP023.28	Cowpasture River	4	5/15/01	CWP2884	Tabanidae	1
178	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Baetidae	5
179	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Cambaridae	1
180	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Chironomidae (A)	24
181	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Coenagrionidae	3
182	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Elmidae	1
183	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Ephemerellidae	24
184	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Heptageniidae	15
185	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Hydropsychidae	12
186	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Lumbriculidae	5
187	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Oligoneuriidae	12
188	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Perlidae	1
189	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Psephenidae	1
190	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Simuliidae	8
191	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Sphaeriidae	1
192	2-CWP053.78	Cowpasture River	3	5/30/01	CWP2880	Tipulidae	2
193	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Baetidae	30
194	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Caenidae	1
195	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Chironomidae (A)	10
196	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Corbiculidae	1
197	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Elmidae	2
198	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Ephemerellidae	26
199	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Glossosomatidae	2
200	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Heptageniidae	4
201	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Hydropsychidae	6
202	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Hydroptilidae	1
203	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Oligoneuriidae	13
204	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Perlidae	2

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
205	2-HAZ006.34	Harris Creek	3	5/10/01	HAZ1591	Simuliidae	4
206	2-HOI004.08	Horsepen Branch	1	5/18/01	HOI6352	Asellidae	4
207	2-HOI004.08	Horsepen Branch	1	5/18/01	HOI6352	Cambaridae	4
208	2-HOI004.08	Horsepen Branch	1	5/18/01	HOI6352	Dytiscidae	3
209	2-HOI004.08	Horsepen Branch	1	5/18/01	HOI6352	Gammaridae	8
210	2-HOI004.08	Horsepen Branch	1	5/18/01	HOI6352	Macromiidae	4
211	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Athericidae	3
212	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Baetidae	2
213	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Blephariceridae	2
214	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Brachycentridae	2
215	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Ceratopogonidae	1
216	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Chironomidae (A)	36
217	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Corydalidae	2
218	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Elmidae	28
219	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Ephemerellidae	11
220	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Gomphidae	2
221	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Heptageniidae	26
222	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Hydrophilidae	1
223	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Lumbriculidae	2
224	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Nemouridae	13
225	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Oligoneuriidae	2
226	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Perlidae	6
227	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Philopotamidae	4
228	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Pleuroceridae	10
229	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Psephenidae	11
230	2-JOB001.02	Johns Creek	4	4/20/01	JOB1612	Simuliidae	8
231	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Chironomidae (A)	20
232	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Chloroperlidae	1
233	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Corydalidae	1
234	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Elmidae	12
235	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Empididae	4
236	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Ephemerellidae	26
237	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Heptageniidae	14
238	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Hydropsychidae	5
239	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Oligoneuriidae	6
240	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Philopotamidae	2
241	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Pleuroceridae	1
242	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Psephenidae	4
243	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Rhyacophilidae	1
244	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Taeniopterygidae	1
245	2-LMC001.15	Looney Creek	5	4/9/01	LMC1614	Tipulidae	1
246	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Baetidae	2
247	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Chironomidae (A)	71
248	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Elmidae	1
249	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Ephemerellidae	12
250	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Gomphidae	1
251	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Heptageniidae	7
252	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Hydropsychidae	2
253	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Lumbriculidae	13
254	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Simuliidae	6
255	2-LOB000.37	Long Branch	1	6/5/01	LOB1593	Tipulidae	2
256	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Ancylidae	1
257	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Athericidae	1
258	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Baetidae	10
259	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Brachycentridae	1
260	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Chironomidae (A)	25
261	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Chloroperlidae	1
262	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Elmidae	1
263	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Ephemerellidae	39
264	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Heptageniidae	31
265	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Hydrachnidae	1
266	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Hydropsychidae	14
267	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Leptophlebiidae	7
268	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Limnephilidae	1
269	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Nemouridae	3
270	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Oligoneuriidae	6
271	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Perlidae	5
272	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Perlodidae	5

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
273	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Philopotamidae	12
274	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Psephenidae	21
275	2-OGL005.53	Ogle Creek	2	5/1/01	OGL1596	Stratiomyidae	1
276	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Chironomidae (A)	18
277	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Coenagrionidae	6
278	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Corixidae	3
279	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Elmidae	9
280	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Gammaridae	1
281	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Gomphidae	5
282	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Leptoceridae	5
283	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Lymnaeidae	2
284	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Phryganeidae	4
285	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Tabanidae	1
286	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Tipulidae	1
287	2-RND003.57	Randolf Creek	2	4/12/01	RND6373	Viviparidae	2
288	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Baetidae	8
289	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Ceratopogonidae	5
290	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Chironomidae (A)	43
291	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Elmidae	15
292	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Ephemerellidae	1
293	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Ephemeridae	2
294	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Gomphidae	1
295	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Heptageniidae	3
296	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Perlidae	2
297	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Simuliidae	1
298	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Sphaeriidae	7
299	2-RRS010.30	S. F. Rivanna River	4	5/22/01	RRS2882	Tubificidae	10
300	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Baetidae	3
301	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Chironomidae (A)	61
302	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Corbiculidae	3
303	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Elmidae	6
304	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Ephemerellidae	1
305	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Heptageniidae	12
306	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Hydropsychidae	14
307	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Hydroptilidae	2
308	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Naididae	2
309	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Perlidae	1
310	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Physidae	2
311	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Pleuroceridae	1
312	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Psephenidae	1
313	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Sphaeriidae	2
314	2-RVN012.05	Rivanna River	5	5/14/01	RVN2887	Tanyderidae	1
315	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Capniidae	4
316	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Chironomidae (A)	17
317	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Corydalidae	5
318	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Elmidae	5
319	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Heptageniidae	11
320	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Hydropsychidae	22
321	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Hydroptilidae	1
322	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Leuctridae	18
323	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Limnephilidae	1
324	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Lumbriculidae	1
325	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Nemouridae	14
326	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Perlidae	5
327	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Polycentropodidae	1
328	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Rhyacophilidae	4
329	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Simuliidae	1
330	2-SMR004.80	Saint Marys River	2	5/29/01	SMR2881	Tipulidae	1
331	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Ancylidae	1
332	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Athericidae	2
333	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Baetidae	4
334	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Caenidae	6
335	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Cambaridae	1
336	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Chironomidae (A)	32
337	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Corbiculidae	1
338	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Corydalidae	2
339	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Elmidae	11
340	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Heptageniidae	5

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
341	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Hydropsychidae	11
342	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Leuctridae	1
343	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Lumbriculidae	2
344	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Oligoneuriidae	9
345	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Perlidae	1
346	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Philopotamidae	6
347	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Pleuroceridae	1
348	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Psephenidae	1
349	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Simuliidae	2
350	2-SUA001.55	Suanee Creek	3	6/11/01	SUA1588	Tipulidae	2
351	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Baetidae	15
352	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Chironomidae (A)	5
353	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Coenagrionidae	1
354	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Dytiscidae	2
355	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Elmidae	14
356	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Ephemerellidae	3
357	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Gomphidae	3
358	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Gyrinidae	2
359	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Heptageniidae	23
360	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Hydrophilidae	3
361	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Hydropsychidae	12
362	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Macromiidae	1
363	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Oligoneuriidae	3
364	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Perlidae	7
365	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Philopotamidae	7
366	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Pleuroceridae	2
367	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Simuliidae	1
368	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Sphaeriidae	4
369	2-WLS024.61	Willis River	5	5/2/01	WLL6355	Tipulidae	4
370	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Aeshnidae	1
371	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Corduliidae	1
372	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Corydalidae	1
373	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Dryopidae	5
374	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Elmidae	14
375	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Ephemerellidae	58
376	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Heptageniidae	6
377	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Hydropsychidae	13
378	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Lepidostomatidae	8
379	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Leptoceridae	6
380	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Libellulidae	1
381	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Nemouridae	1
382	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Oligoneuriidae	4
383	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Perlidae	10
384	3-RAP008.71	Rapidan River	5	4/24/01	RAP2991	Pleuroceridae	5
385	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Aeshnidae	1
386	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Chironomidae (A)	2
387	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Coenagrionidae	1
388	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Corbiculidae	1
389	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Corydalidae	29
390	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Dryopidae	7
391	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Elmidae	5
392	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Ephemerellidae	108
393	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Glossosomatidae	1
394	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Gyrinidae	3
395	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Heptageniidae	30
396	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Hydropsychidae	18
397	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Oligoneuriidae	6
398	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Perlidae	9
399	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Pleuroceridae	2
400	3-ROB005.42	Robinson River	4	4/10/01	ROB2986	Psephenidae	17
401	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Asellidae	18
402	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Chironomidae (A)	8
403	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Chironomidae (B)	3
404	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Corbiculidae	3
405	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Gammaridae	16
406	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Hydropsychidae	1
407	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Leptophlebiidae	6
408	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Lumbriculidae	1

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
409	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Philopotamidae	1
410	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Simuliidae	56
411	3-XEX000.81	Ut to Elmwood Creek	1	3/22/01	XEX6372	Tipulidae	1
412	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Aeshnidae	1
413	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Baetidae	4
414	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Brachycentridae	4
415	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Caenidae	8
416	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Chironomidae (A)	18
417	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Corbiculidae	1
418	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Corydalidae	1
419	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Elmidae	12
420	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Heptageniidae	19
421	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Hydrophilidae	3
422	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Hydropsychidae	13
423	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Neoephemeridae	7
424	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Oligoneuriidae	6
425	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Perlidae	29
426	4ABAN022.24	Bannister River	5	5/15/01	BAN6370	Tipulidae	1
427	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Chironomidae (A)	28
428	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Elmidae	6
429	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Empididae	6
430	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Ephemerellidae	14
431	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Glossosomatidae	2
432	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Heptageniidae	8
433	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Hydropsychidae	40
434	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Limnephilidae	4
435	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Perlodidae	1
436	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Philopotamidae	1
437	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Simuliidae	4
438	4ABDA011.79	Beaverdam Creek	2	4/6/01	BDA1616	Tipulidae	3
439	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Ancylidae	1
440	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Baetidae	3
441	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Caenidae	6
442	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Ceratopogonidae	3
443	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Chironomidae (A)	48
444	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Chloroperlidae	2
445	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Corydalidae	2
446	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Elmidae	4
447	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Ephemerellidae	9
448	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Gomphidae	1
449	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Hydropsychidae	7
450	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Oligoneuriidae	1
451	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Perlidae	4
452	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Perlodidae	3
453	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Philopotamidae	3
454	4AEKH003.18	Elkhorn Creek	3	5/15/01	EKH1609	Simuliidae	2
455	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Aeshnidae	3
456	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Baetidae	9
457	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Calopterygidae	4
458	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Cambaridae	6
459	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Chironomidae (A)	26
460	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Chironomidae (B)	5
461	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Coenagrionidae	7
462	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Culicidae	7
463	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Elmidae	5
464	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Gomphidae	6
465	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Gyrinidae	2
466	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Heptageniidae	4
467	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Leptoceridae	7
468	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Macromiidae	4
469	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Phryganeidae	9
470	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Planorbidae	1
471	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Sialidae	3
472	4AHEN004.74	Horsepen Creek	3	5/16/01	HEN6362	Tipulidae	2
473	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Baetidae	2
474	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Capniidae	23
475	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Ceratopogonidae	1
476	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Chironomidae (A)	36

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
477	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Corydalidae	1
478	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Elmidae	15
479	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Ephemerellidae	5
480	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Gomphidae	1
481	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Heptageniidae	5
482	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Hydropsychidae	5
483	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Lumbriculidae	2
484	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Nemouridae	1
485	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Oligoneuriidae	5
486	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Perlidae	2
487	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Simuliidae	2
488	4AOWC004.37	Old Womans Creek	3	5/15/01	OWC1603	Tipulidae	2
489	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Baetidae	1
490	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Cambaridae	1
491	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Capniidae	3
492	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Chironomidae (A)	53
493	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Corydalidae	1
494	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Elmidae	2
495	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Ephemerellidae	1
496	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Heptageniidae	16
497	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Hydropsychidae	9
498	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Lumbriculidae	1
499	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Perlidae	3
500	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Philopotamidae	21
501	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Psephenidae	1
502	4APAA000.24	Poplar Branch	2	5/31/01	PAA1608	Simuliidae	1
503	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Athericidae	3
504	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Baetidae	14
505	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Cambaridae	1
506	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Chironomidae (A)	26
507	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Corydalidae	1
508	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Elmidae	38
509	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Ephemerellidae	16
510	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Heptageniidae	7
511	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Hydrachnidae	2
512	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Hydropsychidae	4
513	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Leptophlebiidae	2
514	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Lumbriculidae	1
515	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Naididae	1
516	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Nemouridae	1
517	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Oligoneuriidae	3
518	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Perlidae	2
519	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Pleuroceridae	4
520	4ARNF009.01	N.F. Roanoke River	4	5/7/01	RNF1605	Simuliidae	7
521	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Athericidae	1
522	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Chironomidae (A)	20
523	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Chironomidae (B)	2
524	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Corydalidae	1
525	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Elmidae	19
526	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Ephemerellidae	36
527	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Heptageniidae	1
528	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Hydropsychidae	4
529	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Hydroptilidae	1
530	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Lumbriculidae	2
531	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Oligoneuriidae	4
532	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Pleuroceridae	7
533	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Psephenidae	1
534	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Simuliidae	3
535	4ARNF015.50	N.F. Roanoke River	3	4/11/01	RNF1621	Tipulidae	1
536	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Baetidae	3
537	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Chironomidae (A)	3
538	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Elmidae	17
539	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Ephemerellidae	81
540	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Heptageniidae	5
541	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Hydropsychidae	5
542	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Nemouridae	2
543	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Peltoperlidae	1
544	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Perlodidae	2

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
545	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Psephenidae	3
546	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Siphlonuridae	1
547	4ASNF007.64	N. F. South Mayo River	1	5/17/01	SNF1613	Tipulidae	2
548	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Baetidae	2
549	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Caenidae	6
550	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Cambaridae	2
551	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Chironomidae (A)	13
552	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Elmidae	7
553	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Gomphidae	1
554	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Heptageniidae	3
555	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Hydropsychidae	40
556	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Lumbriculidae	1
557	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Oligoneuriidae	16
558	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Perlidae	13
559	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Philopotamidae	6
560	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Pleuroceridae	9
561	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Pteronarcyidae	1
562	4ASRV012.19	Sandy River	5	6/4/01	SRV1611	Tipulidae	1
563	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Ancylidae	2
564	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Baetidae	4
565	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Calopterygidae	1
566	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Cambaridae	10
567	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Chironomidae (A)	21
568	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Gerridae	4
569	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Heptageniidae	1
570	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Leptoceridae	1
571	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Limnephilidae	10
572	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Tipulidae	13
573	4AXMF001.46	UT to Hyco River	1	5/15/01	XMF6369	Veliidae	6
574	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Asellidae	9
575	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Calopterygidae	1
576	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Cambaridae	4
577	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Chironomidae (A)	36
578	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Crangonyctidae	12
579	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Dytiscidae	5
580	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Ephydridae	1
581	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Libellulidae	1
582	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Polycentropodidae	1
583	5AAPW001.04	Applewhite Swamp	2	4/9/01	PBAPWTRO1	Simuliidae	4
584	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Ancylidae	1
585	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Asellidae	58
586	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Cambaridae	5
587	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Chironomidae (A)	122
588	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Chironomidae (B)	4
589	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Corixidae	1
590	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Crangonyctidae	30
591	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Dytiscidae	2
592	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Heptageniidae	1
593	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Hydrobiidae	44
594	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Leptoceridae	3
595	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Libellulidae	1
596	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Planorbidae	3
597	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Sphaeriidae	41
598	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Tubificidae	10
599	5ABLW055.26	Blackwater River	5	4/9/01	PBBLWTRO1	Viviparidae	13
600	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Baetidae	11
601	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Chironomidae (A)	37
602	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Corydalidae	4
603	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Culicidae	2
604	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Dytiscidae	3
605	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Ephemerellidae	3
606	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Heptageniidae	14
607	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Hydropsychidae	13
608	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Limnephilidae	2
609	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Oligoneuriidae	4
610	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Perlidae	14
611	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Philopotamidae	7
612	5AMHN105.36	Meherrin River	5	5/8/01	MHN6360	Tipulidae	3

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
613	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Aeshnidae	2
614	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Ancylidae	1
615	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Asellidae	3
616	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Brachycentridae	2
617	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Cambaridae	4
618	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Ceratopogonidae	15
619	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Chironomidae (A)	95
620	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Coenagrionidae	3
621	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Corbiculidae	9
622	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Corixidae	1
623	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Dytiscidae	2
624	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Elmidae	8
625	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Ephemerellidae	7
626	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Ephemeridae	1
627	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Gammaridae	184
628	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Glossiphoniidae	1
629	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Gomphidae	5
630	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Heptageniidae	13
631	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Hydrobiidae	1
632	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Hydropsychidae	2
633	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Leptoceridae	1
634	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Limnephilidae	2
635	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Macromiidae	1
636	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Oligoneuriidae	2
637	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Perlidae	1
638	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Physidae	9
639	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Planorbidae	14
640	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Pleuroceridae	2
641	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Polycentropodidae	1
642	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Sphaeriidae	36
643	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Tubificidae	17
644	5ANTW045.12	Nottaway River	6	5/15/01	PBNTWTRO1	Viviparidae	2
645	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Ancylidae	2
646	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Asellidae	4
647	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Ceratopogonidae	4
648	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Chironomidae (A)	70
649	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Chironomidae (B)	10
650	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Coenagrionidae	3
651	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Corixidae	21
652	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Gammaridae	1
653	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Glossiphoniidae	8
654	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Gyrinidae	4
655	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Hirudinidae	1
656	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Hydrobiidae	172
657	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Leptoceridae	4
658	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Libellulidae	4
659	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Lumbriculidae	2
660	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Lymnaeidae	1
661	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Physidae	21
662	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Planariidae	4
663	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Planorbidae	6
664	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Sphaeriidae	51
665	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Tubificidae	8
666	5ASTN002.43	Somerton Creek	4	5/3/01	PBSTNTRO1	Valvatidae	10
667	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Ancylidae	1
668	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Baetidae	1
669	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Calopterygidae	1
670	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Cambaridae	2
671	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Chironomidae (A)	4
672	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Coenagrionidae	1
673	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Corydalidae	1
674	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Culicidae	3
675	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Dytiscidae	1
676	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Elmidae	3
677	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Ephemerellidae	2
678	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Heptageniidae	2
679	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Hydropsychidae	8
680	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Leptoceridae	14

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
681	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Limnephilidae	8
682	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Perlidae	6
683	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Philopotamidae	2
684	5AXEH001.35	UT to Great Creek	1	4/10/01	XEH6357	Psephenidae	12
685	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Cambaridae	1
686	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Chironomidae (A)	32
687	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Corbiculidae	4
688	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Corydalidae	4
689	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Gomphidae	3
690	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Heptageniidae	18
691	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Perlidae	18
692	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Siphlonuridae	3
693	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Taeniopterygidae	2
694	5AXEI000.27	UT to S. Meherrin River	1	5/16/01	XEI6366	Tipulidae	7
695	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Asellidae	1
696	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Baetidae	4
697	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Calopterygidae	4
698	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Cambaridae	1
699	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Chironomidae (A)	31
700	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Coenagrionidae	2
701	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Corbiculidae	3
702	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Culicidae	5
703	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Hydropsychidae	12
704	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Leptoceridae	1
705	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Physidae	6
706	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Tipulidae	3
707	5AXEJ001.73	UT to Nottaway River	1	4/9/01	XEJ6358	Viviparidae	1
708	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Athericidae	1
709	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Chironomidae (A)	23
710	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Elmidae	46
711	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Hydropsychidae	23
712	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Tipulidae	2
713	6APNS003.94	S. F. Pound River	3	6/18/01	PNS2894	Veliidae	1
714	6AXBF000.40	Japa's Fork	1	5/21/01	XBF2893	Chironomidae (A)	2
715	6AXBF000.40	Japa's Fork	1	5/21/01	XBF2893	Hydropsychidae	1
716	6AXBF000.40	Japa's Fork	1	5/21/01	XBF2893	Nemouridae	1
717	6AXBF000.40	Japa's Fork	1	5/21/01	XBF2893	Simuliidae	1
718	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Baetidae	6
719	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Chironomidae (A)	4
720	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Corbiculidae	2
721	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Elmidae	7
722	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Empididae	2
723	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Hydropsychidae	14
724	6BDUM000.23	Dumps Creek	3	4/25/01	DUM2889	Nemouridae	10
725	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Ancylidae	2
726	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Chironomidae (A)	7
727	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Corydalidae	1
728	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Elmidae	30
729	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Empididae	3
730	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Ephemerellidae	17
731	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Heptageniidae	3
732	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Hydropsychidae	6
733	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Nemouridae	1
734	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Psephenidae	25
735	6BLWS003.88	Lewis Creek	3	4/30/01	LWS2895	Simuliidae	1
736	6BPOW156.57	Powell River	5	5/15/01	POW2888	Baetidae	5
737	6BPOW156.57	Powell River	5	5/15/01	POW2888	Chironomidae (A)	22
738	6BPOW156.57	Powell River	5	5/15/01	POW2888	Corbiculidae	1
739	6BPOW156.57	Powell River	5	5/15/01	POW2888	Corydalidae	1
740	6BPOW156.57	Powell River	5	5/15/01	POW2888	Elmidae	18
741	6BPOW156.57	Powell River	5	5/15/01	POW2888	Ephemerellidae	3
742	6BPOW156.57	Powell River	5	5/15/01	POW2888	Hydropsychidae	8
743	6BPOW156.57	Powell River	5	5/15/01	POW2888	Oligoneuriidae	3
744	6BPOW156.57	Powell River	5	5/15/01	POW2888	Perlidae	1
745	6BPOW156.57	Powell River	5	5/15/01	POW2888	Pleuroceridae	23
746	6BPOW156.57	Powell River	5	5/15/01	POW2888	Psephenidae	16
747	6BPOW156.57	Powell River	5	5/15/01	POW2888	Simuliidae	2
748	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Asellidae	3

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
749	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Baetidae	15
750	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Capniidae	2
751	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Elmidae	19
752	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Ephemerellidae	2
753	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Heptageniidae	2
754	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Hydropsychidae	3
755	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Nemouridae	1
756	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Peltoperlidae	7
757	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Philopotamidae	2
758	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Pleuroceridae	1
759	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Psephenidae	8
760	6BXDJ000.15	UT to Falls Creek	1	5/30/01	XDJ2891	Talitridae	27
761	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Baetidae	4
762	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Chironomidae (A)	21
763	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Chloroperlidae	1
764	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Dixidae	1
765	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Elmidae	6
766	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Empididae	1
767	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Ephemerellidae	18
768	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Gomphidae	1
769	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Heptageniidae	2
770	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Leptophlebiidae	3
771	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Leuctridae	1
772	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Nemouridae	18
773	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Peltoperlidae	2
774	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Perlodidae	5
775	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Simuliidae	5
776	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Taeniopterygidae	1
777	6CSLM002.11	Slemp Creek	1	5/9/01	SLM2897	Tipulidae	1
778	6CXCH001.34	UT to N. F. Holston River	1	4/16/01	XCH2892	Chironomidae (A)	2
779	6CXCH001.34	UT to N. F. Holston River	1	4/16/01	XCH2892	Taeniopterygidae	11
780	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Aeshnidae	3
781	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Ancylidae	2
782	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Asellidae	465
783	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Baetidae	7
784	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Belostomatidae	1
785	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Caenidae	3
786	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Cambaridae	3
787	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Ceratopogonidae	51
788	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Chironomidae (A)	153
789	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Coenagrionidae	15
790	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Corixidae	22
791	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Gammaridae	38
792	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Glossiphoniidae	2
793	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Haliplidae	6
794	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Hirudinidae	1
795	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Libellulidae	2
796	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Lymnaeidae	25
797	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Ptychopteridae	3
798	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Sphaeriidae	3
799	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Tabanidae	1
800	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Talitridae	81
801	7-DRN027.96	Dragon Swamp	3	4/25/01	PBDRNTRO1	Tubificidae	4
802	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Calamoceratidae	1
803	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Calopterygidae	3
804	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Cambaridae	3
805	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Chironomidae (A)	1
806	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Corbiculidae	3
807	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Corydalidae	6
808	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Dryopidae	1
809	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Elmidae	2
810	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Ephemerellidae	29
811	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Heptageniidae	30
812	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Hydrophilidae	1
813	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Hydropsychidae	10
814	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Nemouridae	21
815	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Oligoneuriidae	5
816	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Perlidae	2

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
817	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Perlodidae	5
818	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Philopotamidae	10
819	8-BRC002.70	Beaver Creek	1	4/25/01	BRC2989	Psephenidae	1
820	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Baetidae	2
821	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Calopterygidae	1
822	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Chironomidae (A)	93
823	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Dolichopodidae	1
824	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Dryopidae	2
825	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Gammaridae	8
826	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Gyrinidae	1
827	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Hydrophilidae	1
828	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Lymnaeidae	1
829	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Nemouridae	2
830	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Notonectidae	1
831	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Phryganeidae	1
832	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Physidae	2
833	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Pyralidae	1
834	8-XEA000.12	UT to Bland Creek	1	4/25/01	PBXEATRO1	Sphaeriidae	5
835	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Athericidae	2
836	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Baetidae	3
837	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Ceratopogonidae	1
838	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Chironomidae (A)	36
839	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Elmidae	5
840	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Ephemerellidae	26
841	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Heptageniidae	6
842	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Hydropsychidae	12
843	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Lumbriculidae	2
844	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Perlidae	3
845	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Perlodidae	5
846	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Polycentropodidae	1
847	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Psephenidae	2
848	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Pteronarcyidae	2
849	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Rhyacophilidae	1
850	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Sialidae	1
851	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Simuliidae	4
852	9-LIC004.73	Little Indian Creek	1	4/18/01	LIC1595	Tipulidae	1
853	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Ceratopogonidae	1
854	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Chironomidae (A)	81
855	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Elmidae	3
856	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Ephemerellidae	8
857	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Heptageniidae	9
858	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Hydrobiidae	1
859	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Hydropsychidae	21
860	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Lumbriculidae	1
861	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Simuliidae	3
862	9-MDR003.60	Meadow Run	2	4/18/01	MDR1620	Tipulidae	3
863	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Baetidae	29
864	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Blephariceridae	4
865	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Brachycentridae	2
866	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Chironomidae (A)	25
867	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Corydalidae	2
868	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Elmidae	25
869	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Empididae	3
870	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Ephemerellidae	5
871	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Glossosomatidae	1
872	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Helicopsychidae	6
873	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Heptageniidae	10
874	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Hydrachnidae	2
875	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Hydropsychidae	3
876	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Lumbriculidae	1
877	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Oligoneuriidae	2
878	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Perlodidae	1
879	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Philopotamidae	1
880	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Pleuroceridae	11
881	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Psephenidae	5
882	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Rhyacophilidae	1
883	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Simuliidae	3
884	9-WFC010.66	Wolf Creek	4	5/8/01	WFC1592	Tipulidae	1

Appendix E: Table 2. Benthic macroinvertebrate taxa list for Spring 2001 (continued).

Record	Station ID	Stream Name	Stahler Order	Collection Date	BenSampID	Taxa Name	Count
885	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Baetidae	1
886	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Blephariceridae	3
887	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Chironomidae (A)	6
888	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Elmidae	4
889	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Empididae	1
890	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Ephemerellidae	17
891	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Heptageniidae	7
892	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Hydropsychidae	3
893	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Leptophlebiidae	10
894	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Nemouridae	4
895	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Oligoneuriidae	1
896	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Peltoperlidae	1
897	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Perlidae	1
898	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Perlodidae	1
899	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Pleuroceridae	2
900	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Psephenidae	28
901	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Pteronarcyidae	1
902	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Rhyacophilidae	3
903	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Sialidae	1
904	9-WFC044.15	Wolf Creek	3	4/26/01	WFC2896	Simuliidae	11
905	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Athericidae	1
906	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Baetidae	5
907	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Brachycentridae	1
908	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Caenidae	1
909	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Chironomidae (A)	24
910	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Corydalidae	1
911	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Elmidae	34
912	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Ephemerellidae	14
913	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Gomphidae	1
914	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Heptageniidae	3
915	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Hydropsychidae	3
916	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Lumbriculidae	3
917	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Oligoneuriidae	2
918	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Perlidae	1
919	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Pleuroceridae	2
920	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Psephenidae	4
921	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Simuliidae	1
922	9-WLK024.17	Walker Creek	5	6/6/01	WLK1589	Tipulidae	1

Note: BenSampID .. sample identification code for EDAS database.

APPENDIX F. TABLES OF PHYSICAL HABITAT DATA.

Appendix F: Table 1. RBP II Habitat Assessment Chart.

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5	High Gradient	Low Gradient
Epifaunal Substrate / Available Cover	Greater than 70% (50% for Low Gradient) of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e. logs/snags <u>not</u> new fall and <u>not</u> transient).	40-70% (30-50% for Low Gradient) mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (20-30% for Low Gradient) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for Low Gradient) stable habitat; lack of habitat is obvious; substrate unstable or lacking.	✔	✔
Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity and niche space.	Gravel, Cobble, and boulder particles are 15-50% surrounded by sediment.	Gravel, Cobble, and boulder particles are 50-75% surrounded by sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.	✔	
Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent, root mats and submerged vegetation common.	Mixture of soft sand mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.		✔
Velocity / Depth Regime	All four velocity / depth regimes present (slow-deep, slow-shallow, fast-deep fast-shallow). (Slow is <0.3 m/s, deep is >0.5m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).	✔	
Pool Variability	Even Mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; vary few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.		✔
Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (20% for Low Gradient) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for Low Gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% (50-80% for Low Gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for Low Gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.	✔	✔

Appendix F: Table 1. RBP II Habitat Assessment Chart (continued).

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5	High Gradient	Low Gradient
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas or bridge abutments; evidence of past channelization, I.e., dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.	✔	✔
Frequency of Riffles (or Bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstructions is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 and 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of >25.	✔	
Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.		✔
Bank Stability (score each bank 1-10) Note: determine left or right by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.	✔	✔
Vegetative Protection (score each bank 1-10) Note: determine left or right by facing downstream.	More than 90% of streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5cm or less in average stubble height.	✔	✔

Appendix F: Table 2. High Gradient Stream Habitat Data from Spring 2001.

Station ID	Strahler Order	Sample Date	ALTER (Channel Alteration)	BANKS (Bank stability Left+ Right)	BANKVEG (Vegetative protection: Left + Right)	COVER (Epifaunal substrate/A vailable cover)	EMBED (Embed-dedness)	FLOW (Channel flow status)	RIFFLES (Frequency of riffles or bends)	RIPVEG (Riparian vegetative zone width)	SEDIMENT (Sediment Deposition)	VELOCITY (Velocity/De pth regime)	TotHabSc (Total habitat score)
1ACAH001.82	2	5/29/01	18	16	15	15	14	11	17	13	12	17	148
1AFLL000.62	2	5/30/01	18	16	18	12	14	19	10	10	12	15	144
1ALUC000.95	2	4/12/01	18	18	20	17	17	16	17	18	18	18	177
1BBVR000.84	2	5/17/01	14	10	4	8	10	19	17	4	6	18	110
1BCPL002.83	2	5/24/01	20	14	20	15	13	18	16	14	17	20	167
1BDRI000.21	1	5/17/01	19	17	20	19	11	10	18	15	17	7	153
2-APP082.00	5	5/3/01	20	10	12	3	2	9	1	20	3	10	90
2-BFL016.79	3	5/17/01	20	8	8	4	2	8	10	17	9	8	94
2-BNF003.52	2	4/3/01	20	20	18	20	16	20	20	18	15	19	186
2-COO002.35	1	4/11/01	20	16	16	18	20	16	18	20	19	19	182
2-CWP023.28	4	5/15/01	20	16	15	19	18	15	10	11	18	20	162
2-CWP053.78	3	5/30/01	20	20	20	18	20	20	13	20	20	20	191
2-JOB001.02	4	4/20/01	20	18	17	19	17	19	20	12	15	18	175
2-LMC001.15	5	4/9/01	15	16	17	14	16	17	16	13	9	18	151
2-LOB000.37	1	6/5/01	20	19	15	13	12	15	20	12	9	15	150
2-OGL005.53	2	5/1/01	20	17	18	15	20	14	20	14	15	15	168
2-SMR004.80	2	5/29/01	20	18	20	20	19	17	20	20	19	19	192
2-SUA001.55	3	6/11/01	20	12	14	15	16	13	14	12	13	16	145
2-WLS024.61	5	5/2/01	16	12	14	8	3	9	12	11	4	4	93
3-RAP008.71	5	4/24/01	20	16	18	18	16	16	16	18	15	20	173
3-ROB005.42	4	4/10/01	20	18	18	18	17	18	18	18	17	19	181
4ABAN022.24	5	5/15/01	20	18	6	5	0	7	8	20	7	9	100
4ABDA011.79	2	4/6/01	19	19	18	10	16	17	13	13	8	15	148
4AHEN004.74	3	5/16/01	20	14	16	8	6	7	17	12	4	14	118
4AOWC004.37	3	5/15/01	20	19	20	12	13	13	18	20	8	14	157
4APAA000.24	2	5/31/01	20	10	20	16	18	12	11	20	10	15	152
4ARNF009.01	4	5/7/01	20	16	17	18	20	18	14	13	8	17	161
4ARNF015.50	3	4/11/01	18	15	10	14	19	20	15	11	14	17	153
4ASNF007.64	1	5/17/01	12	20	10	10	15	18	16	0	13	10	124
4AXMF001.46	1	5/15/01	20	14	16	3	16	8	13	20	16	3	129
5AMHN105.36	5	5/8/01	20	8	4	4	2	8	3	20	2	16	87
5AXEH001.35	1	4/10/01	20	18	18	18	18	16	16	20	16	13	173
5AXEI000.27	1	5/16/01	20	14	14	13	17	9	18	20	18	7	150
6APNS003.94	3	6/18/01	17	14	12	13	10	11	12	12	5	16	122
6AXBF000.40	1	5/21/01	20	5	18	12	6	9	19	18	6	9	122
6BDUM000.23	3	4/25/01	14	5	15	12	6	14	8	14	6	16	110
6BLWS003.88	3	4/30/01	15	8	16	15	8	11	8	8	6	14	109
6BPOW156.57	5	5/15/01	19	13	18	18	12	12	7	16	13	18	146
6BXDJ000.15	1	5/30/01	19	12	18	16	16	14	18	18	13	10	154
6CSLM002.11	1	5/9/01	19	5	18	13	13	8	17	18	8	9	128
6CXCH001.34	1	4/16/01	19	18	18	17	16	17	17	18	18	9	167
8-BRC002.70	1	4/25/01	20	20	20	19	19	18	19	20	18	18	191
9-LIC004.73	1	4/18/01	20	20	18	15	12	20	20	10	12	15	162
9-MDR003.60	2	4/18/01	15	16	15	12	12	17	14	5	9	14	129
9-WFC010.66	4	5/8/01	20	20	20	19	18	18	18	16	15	20	184
9-WFC044.15	3	4/26/01	18	15	16	11	9	11	17	14	10	19	140
9-WLK024.17	5	6/6/01	20	20	19	15	20	20	20	20	20	20	194

Appendix F: Table 3. Low Gradient Stream Habitat Data from Spring 2001.

Station ID	Strahler Order	Sample Date	ALTER (Channel Alteration)	BANKS (Bank stability Left+ Right)	BANKVEG (Vegetative protection: Left + Right)	COVER (Epifaunal substrate/Available cover)	FLOW (Channel flow status)	POOLSUB (Pool substrate)	POOLVAR (Pool variability)	RIPVEG (Riparian vegetative zone width)	SEDIMENT (Sediment Deposition)	SINUOSITY (Channel sinuosity)	TotHabSc (Total habitat score)	%TotScore (% Total Score)
2-CEL001.00	3	3/19/01	19	8	11	14	11	16	8	12	10	13	122	61.0
2-HAZ006.34	3	5/10/01	20	12	14	15	15	17	10	20	10	13	146	73.0
2-HOI004.08	1	5/18/01	20	14	12	3	13	8	8	17	13	6	114	57.0
2-RND003.57	2	4/12/01	20	16	16	9	20	7	15	20	2	8	133	66.5
2-RRS010.30	4	5/22/01	19	14	15	2	14	11	13	20	13	10	131	65.5
2-RVN012.05	5	5/14/01	20	10	20	8	9	13	16	15	8	16	135	67.5
3-XEX000.81	1	3/22/01	20	18	18	13	16	14	9	15	16	9	148	74.0
4AEKH003.18	3	5/15/01	20	11	20	19	14	13	10	20	10	15	152	76.0
4ASRV012.19	5	6/4/01	20	9	9	16	18	13	15	19	10	17	146	73.0
5AAPW001.04	2	4/9/01	17	13	14	17	11	14	10	15	20	18	149	74.5
5ABLW055.26	5	4/9/01	19	18	16	17	17	9	13	16	20	15	160	80.0
5ANTW045.12	6	5/15/01	17	8	20	8	17	10	7	20	10	11	128	64.0
5ASTN002.43	4	5/3/01	19	16	16	8	15	11	13	20	16	15	149	74.5
5AXEJ001.73	1	4/9/01	20	14	18	13	20	13	14	18	17	13	160	80.0
7-DRN027.96	3	4/25/01	19	13	12	14	15	15	9	12	9	18	136	68.0
8-XEA000.12	1	4/25/01	18	16	20	17	15	16	9	20	11	14	156	78.0

APPENDIX G. ADJUSTING WEIGHTS FOR ANALYSIS.

In a simple random survey the probability of selection of any site from a stream order is directly proportional to the kilometers of streams of that order among the kilometers of Virginia non-tidal streams. For example, in Virginia because 1st order streams are nearly four times more common than 2nd order streams, a simple random survey would produce a fourth as many 2nd order stream sites as 1st order stream sites. Where we suspect the chemistry, habitat, or biota vary by stream order, it is important to include equal amounts of sites from each order. This is the purpose of the unequal probability survey produced for ProbMon. The selection probability for the elements of the target population was set to the inverse of their abundance to ensure the different elements were sampled with equal frequency. In ProbMon, the site selection design ensured that Strahler stream orders 1-4 and ≥5 had equal probability of selection. This prevented, for example, over selecting 1st order streams which make up 65% of Virginia stream kilometers (Table G1). The selection method ensured that, when encountered, 2nd order stream sites were four times more likely to be randomly selected than those on 1st order streams. In a similar fashion, site selection was higher for sites on higher, more rare orders. This also increases the precision of the estimated parameters for the different stream orders (EPA 2002). However, the analysis of data from this type of survey is more complicated and requires adjusting site weights, the subject of this appendix.

Table G1. The relative commonness of Virginia streams by Strahler Order.

Stream Order	Total Kilometers In Virginia	Percent of Total	Abundance Relative to Next Lower Order
1	51210.000	64.75	3.74
2	13680.000	17.30	1.76
3	7781.080	9.84	1.75
4	4448.257	5.63	2.33
5	1731.302	2.19	2.57
6	163.901	0.21	10.4
7	14.710	0.02	NA
Total:	79085.391	99.94	

Table G2 contains the design weights set by EPA and used by them to randomly select sample sites from each stream order. For ProbMon, a design weight is the stream length represented by a site as if the total stream length in Virginia for that order was evenly divided among the sites sampled from that order. Then 1st order streams have the largest design weight because there are more kilometers of 1st order streams than any other order in Virginia. Table G2 indicates that each 1st order stream sample represents 3,790 km of first order stream, each 2nd order stream sample represents 947 km of second order stream, and so on. The site selection design requested that stream orders be equally represented each annual sampling period. However, as shown in Table G2, due to the random selection process the number of Virginia sites actually sampled in 2001 are not evenly distributed across the stream orders. This further complicates the analysis.

For the generation of CDF curves, the ProbMon design weights in Table G2 are adjusted based on sampling reality. In reality, a 1st order stream site may be dry, access could be dangerous, or a landowner may deny permission to sample the site. This information collected by the biologist at the sample site is categorized and used to adjust the weights prior to analysis (see Table G3). An example of the adjustment process is detailed using a synthetic example and Tables G4 – G6.

Table G2. ProbMon design weights from T. Olsen and Sample sites for Virginia's non-tidal streams in 2001.

Stream Order	Design Weights	Chemical Sites Sampled	Biological and Habitat Sites Sampled
1	3790.5166	12	17
2	947.6292	13	13
3	541.5024	14	14
4	315.8764	7	7
5	140.3895	11	11
6	140.3895	1	1
7	140.3895	0	0

Table G3. ProbMon status codes used to adjust design weights.

Status	Interpretation
TS	Target stream that was sampled for one or more indicators
LD	Landowner denied access and likely that site was a target site
PB	Physical barrier to site making access unsafe and likely that site was a target site
OT	Target stream not sampled for another reason and likely that site was a target site (e.g., the wrong region is asked to sample the site)
NT	Non-target site for any reason (impoundment, no stream course present, dry, and so on)
NN	Site not needed. These are sites that were never evaluated for potential field sampling.

To demonstrate site weight adjustment, assume we had sampled the ten stations listed in Table G4 from an a stream network which had an RF3 stream length of 18,475.258 km of river miles (obtained from USEPA's RF3 digital stream trace file). The listed design weights used for site selection must be adjusted using the ratio of RF3 length to the sum of design weights and the status of the site. The RF3 adjustment forces the sum of the weights to equal the 'known' RF3 km. As a first step, sum the design weights (column C in Table G5) to find the potential kilometers evaluated for sampling. Next, for each cell in column E multiply the 'known' RF3

Table G4. Synthetic example of the status, design weight, and weight category for ten probabilistic stations. Stations with the same stream order have the same weights.

Station ID	Status	Design Weight	Weight Category (Strahler Order)
6CSLM002.11	NT	3790.5166	1
2-COO002.35	NT	3790.5166	1
6AXBF000.40	NT	947.6292	2
5AXEJ001.73	PB	3790.5166	1
9-LIC004.73	PB	947.6292	2
8-XEA000.12	TS	140.3895	5
6BXDJ000.15	TS	140.3895	5
8-BRC002.70	TS	3790.5166	1
4ASNF007.64	TS	3790.5166	1
4AXME001.19	TS	3790.5166	1

Table G5. Excel formulas used to adjust design weights.

A	B	C	D	E	F
Station ID	**Status Code**	**Design Weight**	**Weight Category**	**AdjWgtOSW**	**AdjWgtMAR**
6CSLM002.11	NT	3790.5166	1	=C3*18475.258/SUM($C$3:$C$12)	
2-COO002.35	NT	3790.5166	1	=C4*18475.258/SUM($C$3:$C$12)	
6AXBF000.40	NT	947.6292	2	=C5*18475.258/SUM($C$3:$C$12)	
5AXEJ001.73	PB	3790.5166	1	=C6*18475.258/SUM($C$3:$C$12)	
9-LIC004.73	PB	947.6292	2	=C7*18475.258/SUM($C$3:$C$12)	
8-XEA000.12	TS	140.3895	5	=C8*18475.258/SUM($C$3:$C$12)	=E8*E$14/E$15
6BXDJ000.15	TS	140.3895	5	=C9*18475.258/SUM($C$3:$C$12)	=E9*E$14/E$15
8-BRC002.70	TS	3790.5166	1	=C10*18475.258/SUM($C$3:$C$12)	=E10*E$14/E$15
4ASNF007.64	TS	3790.5166	1	=C11*18475.258/SUM($C$3:$C$12)	=E11*E$14/E$15
4AXME001.19	TS	3790.5166	1	=C12*18475.258/SUM($C$3:$C$12)	=E12*E$14/E$15
	Potential km sampled	=SUM(C3:C12)	Known RF3 km	=SUM(E3:E12)	
			Estimated km sampled	=SUM(E6:E12)	
			Sampled km	=SUM(E8:E12)	

Table G6. Results of design weights adjustment.

A	B	C	D	E	F
Station ID	**Status Code**	**Design Weight**	**Weight Category**	**AdjWgtOSW**	**AdjWgtMAR**
6CSLM002.11	NT	3790.5166	1	2810.32092	
2-COO002.35	NT	3790.5166	1	2810.32092	
6AXBF000.40	NT	947.6292	2	702.580268	
5AXEJ001.73	PB	3790.5166	1	2810.32092	
9-LIC004.73	PB	947.6292	2	702.580268	
8-XEA000.12	TS	140.3895	5	104.085957	146.410067
6BXDJ000.15	TS	140.3895	5	104.085957	146.410067
8-BRC002.70	TS	3790.5166	1	2810.32092	3953.07192
4ASNF007.64	TS	3790.5166	1	2810.32092	3953.07192
4AXME001.19	TS	3790.5166	1	2810.32092	3953.07192
	Potential km sampled	24919.137	Known RF3 km	18475.258	
			Estimated km sampled	12152.0359	
			Sampled km	8639.13469	

length (18,475.258 km in this example) by the design weight for that station, and divide by the potential stream length (the sum of column C). Sum column E to find that it equals total RF3. Sum column E adjusted weights for TS, LD, PB, and OT stations to find the estimate sampled

RF3 length. Sum column E adjusted weights for TS sites to find the 'Sampled'. Finally, in column F for TS sites only, multiply a site's adjusted weight in column E by 'Estimated Sampled' length and divide by 'Sum of Sampled' length. The result in column F is the adjusted design weight that is used to analyse the data. When the formulas in Table G5 are activated, the results appear as in Table G6.

In ProbMon, all parameters measured at the same sites have the same adjusted weights for those sites. Because physical-chemical parameters were measured at 58 sites, all parameters have the final site weights unless there were missing data for a parameter. Thus, the weights for hardness were different because several sites were not monitored for hardness. Because biological and habitat parameters were sampled at the same 63 sites, the biological and habitat parameter sites have the same final design weights as listed in Table G7.

Table G7. Adjusted design weights for ProbMon sites in 2001.

Stream Order	Initial Design Weights	Number of Chemical Stations	Final Adjusted Design Weights	Number of Bio. & Habitat Stations	Final Adjusted Design Weights
1	3790.516600	12	3045.200474	17	3001.017070
2	947.629200	13	761.300159	13	750.254307
3	541.502400	14	435.028662	14	428.716747
4	315.876400	7	253.766720	7	250.084769
5	140.389500	11	112.785200	11	111.148777
6	140.389500	1	112.785200	1	111.148777
7	140.389500	0	0.000000	0	0.000000

In order to memorialize the ProbMon calculations that led to the final site weights the following two tables are presented. Table 8 is an exhibit of the spreadsheet on which design weights were estimated for the physical-chemical parameters discussed in detail in this report. Table 9 exhibits the design weight estimation for all biological and habitat parameters.

Appendix G: Table 8. Physical-Chemical Design Weights.

SITE #	STATION ID	STATUS CODE	DETAILS	Design Weight	Weight Category	Status Decision	AdjWgtOSW	AdjWgtMAR
VAEQ99-010		NT	Impoundment (beaver pond)	3790.5166	1	0	2839.502002	
VAEQ99-015	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-032	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-036	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-055	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-058	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-065	Spring Sample	NT	Dry	3790.5166	1	0	2839.502002	
VAEQ99-049		NT	Tidal (estuary) stream	3790.5166	1	0	2839.502002	
VAEQ99-057		NT	Dry	947.6292	2	0	709.8755379	
VAEQ99-064		OT	Target but Not Sampled, Wrong Region Asked to Sample	3790.5166	1	2	2839.502002	
VAEQ99-069		OT	Target but Not Sampled, Wrong Region Asl	947.6292	2	2	709.8755379	
VAEQ99-024		OT	Target but Not Sampled, Wrong Region Asl	140.3895	5	2	105.166738	
VAEQ99-028		OT	Target but Not Sampled, Wrong Region Asl	140.3895	5	2	105.166738	
VAEQ99-007	6CSLM002.11	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-014	2-COO002.35	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-027	6AXBF000.40	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-040	5AXEJ001.73	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-042	9-LIC004.73	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-043	8-XEA000.12	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-047	6BXDJ000.15	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-048	8-BRC002.70	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-051	4ASNF007.64	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-056	4AXME001.19	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-059	2-LOB000.37	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-070	1BDRI000.21	TS	Sampled	3790.5166	1	1	2839.502002	3045.200474
VAEQ99-001	2-OGL005.53	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-003	2-BNF003.52	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-023	1BBVR000.84	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-025	1ACAH001.82	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-026	9-MDR003.60	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-029	2-RND003.57	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-030	1AFLL000.62	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-033	2-SMR004.80	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-035	5AAPW001.04	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-046	4APAA000.24	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-050	1BCPL002.83	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-053	1ALUC000.95	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-066	4ABDA011.79	TS	Sampled	947.6292	2	1	709.8755379	761.3001586
VAEQ99-004	2-BFL016.79	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-008	7-DRN027.96	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-009	2-HAZ006.34	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-011	4ARNF015.50	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-012	9-WFC044.15	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-016	4AOWC004.37	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-017	6BLWS003.88	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-022	6APNS003.94	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-038	2-CWP053.78	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-039	2-SUA001.55	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-044	4AHEN004.74	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-060	2-CEL001.00	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-061	4AEKH003.18	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-062	6BDUM000.23	TS	Sampled	541.5024	3	1	405.6431645	435.028662
VAEQ99-013	2-CWP023.28	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-021	2-JOB001.02	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-031	4ARNF009.01	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-037	9-WFC010.66	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-063	2-RRS010.30	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-068	3-ROB005.42	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-100	5ASTN002.43	TS	Sampled	315.8764	4	1	236.6251793	253.7667195
VAEQ99-002	9-WLK024.17	TS	Sampled	140.3895	5	1	105.166738	112.7851998
VAEQ99-005	5ABLW055.26	TS	Sampled	140.3895	5	1	105.166738	112.7851998
VAEQ99-006	4ASRV012.19	TS	Sampled	140.3895	5	1	105.166738	112.7851998
VAEQ99-018	2-RVN012.05	TS	Sampled	140.3895	5	1	105.166738	112.7851998
VAEQ99-019	2-APP082.00	TS	Sampled	140.3895	5	1	105.166738	112.7851998
VAEQ99-020	5AMHN105.36	TS	Sampled	140.3895	5	1	105.166738	112.7851998

Appendix G: Table 9. Biological Design Weights.

ECOREGION III Region	STATION ID	STATUS CODE	DETAILS	Design Weight	Weight Category	AdjWgtOSW	AdjWgtMAR
Piedmont	VA56	NT	Impoundment	3790.5166	1	2839.502038	
Southeastern Plain	VA10	NT	Impoundment	3790.5166	1	2839.502038	
Southeastern Plain	VA49	NT	Estuarine River	3790.5166	1	2839.502038	
Central Apppalach	VA57	NT	Dry	947.6292	2	709.8755469	
Piedmont	VA064	OT	Target, Wrong Region Asked to Sample	3790.5166	1	2839.502038	
Piedmont	VA069	OT	Target, Wrong Region Asked to Sample	947.6292	2	709.8755469	
Piedmont	VA028	OT	Target, Wrong Region Asked to Sample	140.3895	5	105.1667394	
Southeastern Plain	VA024	OT	Target, Wrong Region Asked to Sample	140.3895	5	105.1667394	
Blue Ridge	SLM002.11	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Blue Ridge	LIC004.73	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Blue Ridge	SNF007.64	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Central Appalachia	XCH001.34	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Central Appalachia	XDJ000.15	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Central Appalachia	DRI000.21	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Central Appalachia	XBF000.40	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Northern Piedmont	BRC002.70	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	HOI004.08	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	XEH001.35	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	XEI000.27	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	XMF001.46	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	XEJ001.73	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	COO002.35	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Piedmont	LOB000.15	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Southeastern Plain	XEX000.81	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Southeastern Plain	XEA000.12	TS	Sampled	3790.5166	1	2839.502038	3001.01707
Blue Ridge	SMR004.80	TS	Sampled	947.6292	2	709.8755469	750.254307
Blue Ridge	MDR003.60	TS	Sampled	947.6292	2	709.8755469	750.254307
Blue Ridge	BNF003.52	TS	Sampled	947.6292	2	709.8755469	750.254307
Central Appalachia	BVR000.84	TS	Sampled	947.6292	2	709.8755469	750.254307
Central Appalachia	CPL002.83	TS	Sampled	947.6292	2	709.8755469	750.254307
Central Apppalach	OGL005.53	TS	Sampled	947.6292	2	709.8755469	750.254307
Northern Piedmont	CAH001.82	TS	Sampled	947.6292	2	709.8755469	750.254307
Northern Piedmont	FLL000.62	TS	Sampled	947.6292	2	709.8755469	750.254307
Northern Piedmont	LUC000.95	TS	Sampled	947.6292	2	709.8755469	750.254307
Piedmont	RND003.57	TS	Sampled	947.6292	2	709.8755469	750.254307
Piedmont	PAA000.24	TS	Sampled	947.6292	2	709.8755469	750.254307
Piedmont	BDA011.79	TS	Sampled	947.6292	2	709.8755469	750.254307
Southeastern Plain	APW001.04	TS	Sampled	947.6292	2	709.8755469	750.254307
Central Appalachia	LWS003.88	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Appalachia	WFC044.15	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Appalachia	CWP053.78	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Appalachia	DUM000.23	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Appalachia	PNS003.94	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Apppalach	RNF015.50	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	BFL016.79	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	HEN004.74	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	OWC004.37	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	SUA001.55	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	EKH003.18	TS	Sampled	541.5024	3	405.6431697	428.7167468
Piedmont	HAZ006.34	TS	Sampled	541.5024	3	405.6431697	428.7167468
Southeastern Plain	CEL001.00	TS	Sampled	541.5024	3	405.6431697	428.7167468
Southeastern Plain	DRN027.96	TS	Sampled	541.5024	3	405.6431697	428.7167468
Central Appalachia	CWP023.28	TS	Sampled	315.8764	4	236.6251823	250.084769
Central Apppalach	RNF009.01	TS	Sampled	315.8764	4	236.6251823	250.084769
Central Apppalach	WFC010.66	TS	Sampled	315.8764	4	236.6251823	250.084769
Central Apppalach	JOB001.02	TS	Sampled	315.8764	4	236.6251823	250.084769
Mid Atlantic Coasta	STN002.43	TS	Sampled	315.8764	4	236.6251823	250.084769
Northern Piedmont	ROB005.42	TS	Sampled	315.8764	4	236.6251823	250.084769
Northern Piedmont	RRS010.30	TS	Sampled	315.8764	4	236.6251823	250.084769
Central Appalachia	POW156.57	TS	Sampled	140.3895	5	105.1667394	111.1487774
Central Appalachia	LMC001.15	TS	Sampled	140.3895	5	105.1667394	111.1487774
Central Apppalach	WLK024.17	TS	Sampled	140.3895	5	105.1667394	111.1487774
Northern Piedmont	RAP008.71	TS	Sampled	140.3895	5	105.1667394	111.1487774
Piedmont	WLL024.61	TS	Sampled	140.3895	5	105.1667394	111.1487774
Piedmont	MHN105.36	TS	Sampled	140.3895	5	105.1667394	111.1487774
Piedmont	APP082.00	TS	Sampled	140.3895	5	105.1667394	111.1487774

APPENDIX H. SOFTWARE METHODS FOR PROBMON DATA.

Several software packages are available to analyze probabilistic data. EPA's Office of Research and Development programmed analytical routines in SAS and S-Plus. In 2002, EPA also released the shareware statistical program 'R'. An approximate solution is available as Visual Basic routines that were programmed using equations from a Quattro Pro spreadsheet written by FTN Associates (J. Hill personal communication 2002). The CDF curves presented in this report were calculated using the SAS programs.

The two SAS programs used to produce the CDF curves and statistics are named VPwatrCDF.sas and CDF_HT.sas. To begin, SAS is started, the first of the two programs is called into the editor and run. On execution, VPwatrCDF.sas calls the second SAS program. The programs require two input files. The first, STATIONS.sas7bdat, is a special SAS table containing the station name and other location attributes. The second VP_watr.sas7bdat is a SAS table containing the observations for the parameter to be analyzed, the station names for cross-reference to the first file, and the station weights. The CDF curve is generated as an output file that in our application was a text file. This was imported into an Excel spreadsheet where the CDF curves were generated for this report.