An Ecological Assessment of the Potomac River Direct Drains Watershed

Report number - 02070004 - January 2005

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Summary

In June of 1998, the West Virginia Department of Environmental Protection conducted an assessment of the Potomac River Direct Drains watershed, located in the eastern panhandle of the state. The watershed includes all West Virginia tributaries to the river between the South Branch and Shenandoah River exclusive of those two rivers and Cacapon River. Water quality, benthic macroinvertebrate community health, and habitat condition were evaluated at 67 sites. Of these sites, 63 produced comparable benthic macroinvertebrate samples and therefore allowed use of the West Virginia Stream Condition Index (WVSCI) to rate the benthological condition of these sites. Four duplicate samples were collected, bringing the total number of comparable benthic samples to 67.

Most of the watershed was covered by forest during the assessment period. The Opequon Creek sub-watershed, the largest sub-watershed of the Potomac Direct Drains watershed, is a notable exception. The drainage basins of 10 of the 15 sites sampled in the Opequon Creek sub-watershed had less than 50% areal coverage by forest, and 3 sites had the greatest percentage of urban coverage of all sites sampled in the entire Potomac Direct Drains watershed. The majority of land use coverage in the Opequon Creek sub-watershed was by agriculture. However, new residential construction and other urbanization developments were rapidly converting both forest land and farm land into more urban environments. A large percentage of the Opequon Creek sub-watershed is karst. Karst is a relatively flat or rolling landform underlain by limestone and characterized by numerous water sinkholes and springs, as well as caves and caverns. Karstic upland soils are relatively dry. The limestone in this region is intensely fractured, resulting in nutrients and pollutants applied to the landscape readily entering underground watercourses and eventually emerging as tainted surface waters. A few smaller sub-watersheds within the Potomac Direct Drains watershed are covered with large percentages of karst, but the second and third largest Potomac Direct Drains sub-watersheds, Sleepy Creek and Back Creek, drain only minor areas of karst.

Of the 67 comparable samples, 21 produced WVSCI scores below the impairment threshold of 60.60. Of these 21 impaired samples, 18 (~85%) were from the Opequon Creek sub-watershed. WVSCI scores indicating relatively unimpaired benthological communities were generated from 41 (61%) of the comparable benthic samples. All but 4 of the sites that produced these samples are within either the Sleepy Creek or Back Creek sub-watersheds. The other 4 sites are in miscellaneous sub-watersheds, but no unimpaired samples were collected within the Opequon Creek sub-watershed.

Approximately 27% of the samples were in violation of the appropriate WV water quality criterion for fecal coliform bacteria (i.e., 400/100 mL). The Opequon Creek sub-watershed produced 65% of these violations. This high percentage of violations was due partly to karstic drainage patterns, intensive agricultural activities, and intensive urbanization of portions of the Opequon Creek sub-watershed relative to the other 2 major sub-watersheds sampled, Sleepy Creek and Back Creek. Livestock waste was implicated as the source of high bacteria concentrations in some streams, and most of these are in the Opequon Creek sub-watershed and other karstic areas. Although livestock access is not usually as great a human health threat as poor sewage treatment, certainly it is a widespread problem within the Opequon Creek sub-watershed. It is recommended that future research should target both sewage and livestock waste problems in order to help prioritize enforcement

activities and monetary assistance to pollution abatement projects.

For purposes of comparison, Watershed Assessment Program personnel utilized 1.0 mg/L of nitrite+nitrate-nitrogen (NO2+NO3-N) as a “flag” value to call attention to streams that may have had nutrient loading problems. Of the 51 samples analyzed for NO2+NO3-N in the Potomac Direct Drains watershed, 15 had concentrations above 1 mg/L. All 15 samples were taken from streams that drain karst, and 12 of the streams are located in the Opequon Creek sub-watershed. NO2+NO3-N concentrations from the Opequon Creek sub-watershed were typically 1 to 2 orders of magnitude greater than most of those from the other sub-watersheds studied.

The Sleepy Creek and Back Creek sub-watersheds appeared to have relatively good stream health. Both forested headwater tributaries and main stem sites supported diverse benthic communities rated as unimpaired on the WVSCI. Water quality was relatively good at almost all of the sampling sites. Within these sub-watersheds, the *UNT/Back Creek*, *Little Brush Creek*, and *South Fork/Indian Creek* sites met criteria for inclusion on the West Virginia reference stream list.

A recent increase in second home development in the Sleepy Creek and Back Creek sub-watersheds raises traditional concerns about inadequate sewage treatment, increased erosion, diminished vegetated riparian zones, and increased soil imperviousness. However, many of the new homeowners were attracted to the area because of clean air, clean water, forestland recreation opportunities, and friendly neighbors. These new citizens may join forces with local farmers to prevent the environmental degradation that usually follows suburbanization of rural landscapes. This potential alliance, if properly fostered by conservation-oriented agencies and organizations, may serve to demonstrate to other citizens in rapidly developing regions how the habitat needs of humans can be met with minimal negative impact to aquatic resources.

Acknowledgements

Funding for this watershed assessment was provided by the U.S. Environmental Protection Agency's 319 and 104(b)(3) programs and by the West Virginia Division of Environmental Protection.

Jeffrey Bailey, Perry Casto, Alvan Gale, Karen Maes, Christina Moore, Mike Puckett, Charles Surbaugh, John Wirts, and Doug Wood collected samples and assessed sampling sites. Karen Maes and Christina Moore processed some of the benthic macroinvertebrate samples, but Marshall University students, under the supervision of Dr. Donald Tarter and Jeffrey Bailey, processed the bulk of the benthic samples. Jeffrey Bailey, Janice Smithson, and John Wirts identified the macroinvertebrates. Karen Maes, Christina Moore, and Charles Surbaugh (retired since) entered the raw data into the database. John Wirts, Doug Wood, and Kim Smith created tables and figures. Michael Arcuri, Patrick Campbell, Judith Lyons, Steve Young, and John Wirts reviewed various drafts of this report. Doug Wood interpreted the results and is the primary author of this report.

Watersheds And Their Assessment

In 1959, the West Virginia Legislature created the State Water Commission, which was the predecessor of the Division of Water Resources, and later, the Division of Water and Waste Management (DWWM). The DWWM, like its predecessor agencies, is charged with balancing the state's needs of economic development and water consumption with the restoration and maintenance of water quality in the state's waters.

At the federal level, the U.S. Congress enacted the Clean Water Act of 1972 and subsequent amendments in order to restore the quality of our nation's waters. For more than 25 years, the Act's National Pollutant Discharge Elimination System (NPDES) has caused reductions in pollutants discharged from point sources to surface waters. There is broad agreement that implementation of the NPDES permit system has reduced the amount of contaminants in point source discharges, and this reduction has resulted in significant improvement in the water quality of many of our nation's streams.

Under the federal law, each state was given the option of managing NPDES permits within its borders or deferring that management role to the federal government. When West Virginia assumed primacy over NPDES permits in 1982, the state's Water Resources Board - renamed the Environmental Quality Board (EQB) in 1994 - began developing water quality criteria for each kind of use designated for the state's waters (see box on this page). In addition, the West Virginia Department of Environmental Protection's (DEP) water protection activities are guided by the EQB's anti-degradation policy, which charges the DWWM with maintaining surface waters at sufficient quality to support existing uses, regardless of whether or not the uses are specifically designated by the EQB.

Even with significant progress, by the early 1990s many streams still did not support their designated uses. Consequently, environmental managers began to examine pollutants flushing off of the landscape from a broad array of sources. Recognition of the negative impacts of these nonpoint sources (NPS) of pollution, was a conceptual step that served as a catalyst for today's holistic watershed approach to improving water quality.

Several DEP units, including the Watershed Assessment Section, are currently implementing a variety of watershed projects. Located within the DWWM, the Section's scientists are charged with evaluating the health

WATER QUALITY CRITERIA - The concentrations of water quality parameters and the stream conditions that are required to be maintained by the Code of State Regulations, Title 46, Series 1 (Requirements Governing Water Quality Standards).

DESIGNATED USES - For each water body, those uses specified in the water quality standards, whether or not those uses are being attained. Unless otherwise designated by the rules, all waters of the state are designated for:

- the propagation and maintenance of fish and other aquatic life, and
- water contact recreation.

Other types of designated uses include:

- public water supply,
- agriculture and wildlife uses, and
- industrial uses.

of West Virginia's watersheds. The Watershed Assessment Section is guided, in part, by the Interagency Watershed Management Steering Committee (see box on this page).

The Watershed Assessment Section uses the U.S. Geological Survey's (USGS) scheme of hydrologic units to divide the state into 32 watersheds. Some of these watersheds are entire stream basins with natural hydrologic divides (e.g., Gauley River watershed). Three other types of watershed units were devised for manageability: (1) clusters of small tributaries that drain directly into a larger mainstem stream (e.g., Potomac River Direct Drains watershed); (2) the West Virginia portions of interstate basins (e.g., Tug Fork watershed); and (3) divisions of large watersheds (e.g., Upper and Lower Kanawha River watersheds).

THE INTERAGENCY WATERSHED MANAGEMENT STEERING COMMITTEE consists of representatives from each agency that participates in the Watershed Management Framework. Its function is to coordinate the operations of the existing water quality programs and activities within West Virginia to better achieve shared water resource management goals and objectives.

The Watershed Basin Coordinator serves as the day-to-day contact for the committee. The Coordinator's responsibilities are to organize and facilitate the steering committee meetings, to maintain the watershed management schedule, to assist with public outreach, and to be the primary contact for watershed management related issues.

General Watershed Assessment Strategy

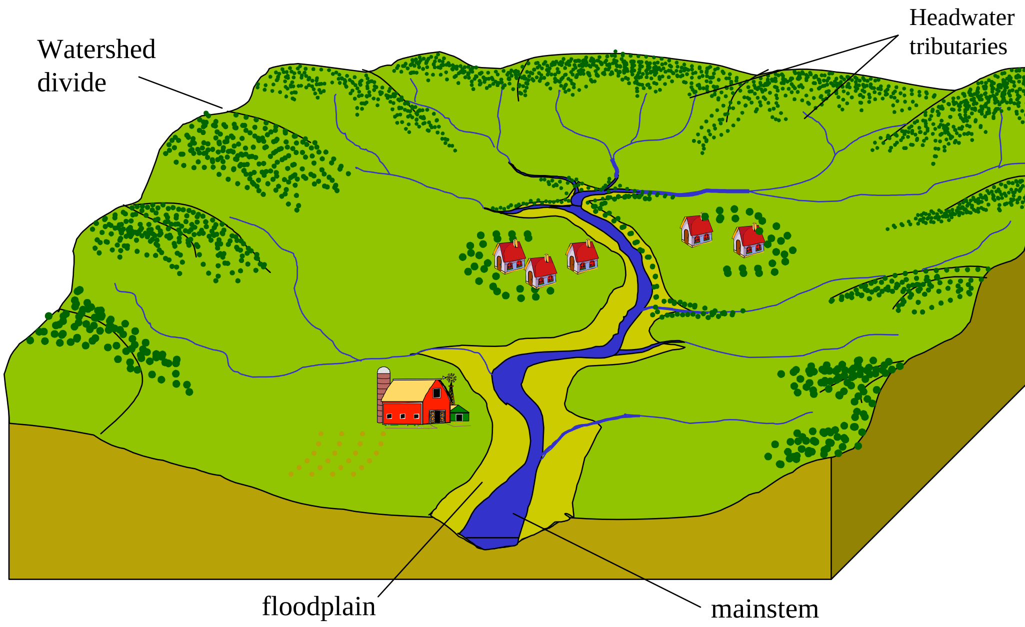
A watershed may be envisioned as an aquatic tree, that is, a network of upwardly branching, successively smaller streams (See Figure 1). An ideal assessment of a watershed would be one that documented changes in the quantity and quality of water flowing down every stream, at all water levels, in all seasons, from headwater reaches to the downstream boundary of the watershed. Land uses throughout the watershed would be quantified also. However, this approach would require more time and resources than are available.

The Watershed Assessment Section assesses the health of a watershed by evaluating the aquatic integrity of as many streams as possible near their mouths. The general sampling strategy can be broken into several steps:

- The names of streams within the watershed are retrieved from the U.S. Environmental Protection Agency's (EPA) Waterbody System database.

- A list of streams is developed that consists of several sublists, including:
    1. Severely impaired streams,
    2. Slightly or moderately impaired streams,
    3. Unimpaired streams,
    4. Unassessed streams, and
    5. Streams of particular concern to citizens.

Figure 1. A Generalized Watershed



In this report, "watershed" refers to all the land that drains to a certain point on a river. The Potomac River Direct Drains watershed includes all the West Virginia land (722.63 sq. miles) that drains into Potomac River between its South Branch and Shenandoah River, excluding the Cacapon River sub-watershed.

- Assessment teams visit as many listed streams as possible and sample as close to the streams' mouths as allowed by road access and sample site suitability.

Long streams may be sampled at additional sites further upstream. In general if a stream is 15 to 30 miles (25-50 km) long, 2 sites are sampled; 30-50 miles (50-89 km) long, 3 sites are sampled; 50-100 miles (80-160 km) long, 4 sites are sampled or; longer than 100 miles (160 km), 5 sites are sampled. If inaccessible or unsuitable sites are dropped from the list, they are replaced with previously determined alternate sites.

An exception to this general investigative strategy is the sampling methodology developed to produce statistically valid summaries that allow the comparison of watersheds to one another. This methodology is detailed in the Watershed Assessment Section titled “Probabilistic or Random Sampling.”

The Watershed Assessment Section has scheduled the assessment of each watershed during a specific year of a 5-year cycle. Advantages of this preset timetable include: (1) synchronizing study dates with permit cycles, (2) facilitating stakeholder input in the information gathering process, (3) insuring assessment of all watersheds, and (4) improving the DWWM’s ability to plan. The data collected thus far from the Section’s watershed assessment efforts have assisted immensely with identifying impaired streams and calculating total maximum daily loads of pollutants that cause impairment (see the box titled “Total Maximum Daily Load and the 303(d) List”).

This document, which reports an ecological assessment of 1 watershed, has been prepared for a wide variety of users, including elected officials, environmental consultants, educators, watershed associations, and natural resources managers.

Probabilistic (Random) Sampling

The nonrandom sampling component of the watershed assessment process is very useful in targeting problem sites, potential reference sites, and little known streams. However, the data generated from nonrandom sampling have limited usefulness in making statistical comparisons between watersheds.

In 1997, in order to improve the evaluation process, the Watershed Assessment Section began to incorporate random sampling into the watershed assessment strategy. The sample sites are randomly selected by computer and may require an assessment at any point along the length of the stream. Random sampling allows researchers to make statistically valid inferences about stream conditions within each watershed. Randomization also improves comparisons between watersheds. EPA personnel provide computer-generated locations for about 40 random sites within each watershed. Because there are many more miles of first-order and second-order headwater streams than there are of higher ordered streams, stream miles are statistically weighted so that an adequate number of larger stream sites are selected by the computer.

Section field crews visit the sites and verify locations with Global Positioning System (GPS) units. If a site is wadeable and has riffle/run habitat, it is assessed using the same protocols as those used at nonrandom sites with the addition of extra water quality constituents to the analysis list.

The results of random sampling are reported herein mixed with nonrandom data. The DEP, with support from the EPA, will report the results of statewide random sampling at a later date.

TOTAL MAXIMUM DAILY LOAD AND THE 303(d) LIST - The term “total maximum daily load” (TMDL) originates in the federal Clean Water Act, which requires that degraded streams be restored to support their designated uses.

Every 2 years, a list of water quality limited streams, called the 303(d) list after the Clean Water Act section number wherein the list is described, is prepared. In a case of severe impairment, it is relatively easy to determine that a stream should be placed on the 303(d) list. However, the determination is more difficult to make for most streams due to a lack of data or data that are conflicting, of questionable quality, or too old. Any stream that would not support its designated uses, even after technology-based pollution controls were applied, would be considered for inclusion on the list. West Virginia’s 303(d) list includes streams affected by a number of stressors including mine drainage, acid deposition, metals, and siltation.

Mathematically, a TMDL is the sum of the allocations of a particular pollutant (from point and nonpoint sources) into a particular stream, plus a margin of safety. Restoration of a 303(d) list stream begins by calculating a TMDL, which involves several steps:

- Define when a water quality problem is occurring (e.g., at base flow, during the hottest part of the day, or throughout the winter ski season),
- Calculate how much of a particular contaminant must be reduced in a stream in order to meet the appropriate water quality criterion,
- Calculate the total maximum daily load from flow values during the problem period and the concentration allowed by the criterion,
- Divide the total load allocation between point and nonpoint sources (e.g., 70% point and 30% nonpoint), and
- Recommend pollution reduction controls to meet designated uses (e.g., install best management practices, reduce permit limits, or prohibit discharges during problem periods). A TMDL cannot be approved unless the proposed controls are reasonable and able to be implemented.

Watershed Assessment Methods

In 1989, the EPA published a document titled *Rapid Bioassessment Protocols for Use in Streams and Rivers - Benthic Macroinvertebrates and Fish* (Plafkin et al. 1989). This document was intended to provide water quality monitoring programs, such as the Section's Watershed Assessment Program, with a practical technical reference for conducting cost-effective biological assessments of flowing waters.

Originally, the Rapid Bioassessment Protocols (RBPs) were intended to be inexpensive screening tools to determine if a stream was supporting a designated aquatic life use. However, the current consensus is that the RBPs also can be applied to other program areas, such as:

- Characterizing the existence and severity of use impairment
- Helping to identify sources and causes of impairments in watershed studies
- Evaluating the effectiveness of control actions
- Supporting use-attainability studies
- Characterizing regional biological components.

The diversity of applications provided by the RBPs was the primary reason they were adopted by the Watershed Assessment Section for use in assessing watersheds. In 1999, the EPA published a second edition of the RBP manual (Barbour, et. al.,1999). Before this publication date, a draft revision was circulated among the states and the Watershed Assessment Section was able to incorporate many of the recommended changes to protocol prior to the 1998 sampling season. Because the vast majority of stream miles in the state have riffle/run habitat, the "Single Habitat Approach" was the benthic collection method adopted by the Watershed Assessment Section.

The following sections summarize the procedures used to assess the streams in this watershed. A more detailed description of assessment procedures is found in the Watershed Assessment Section's *Standard Operating Procedures* manual.

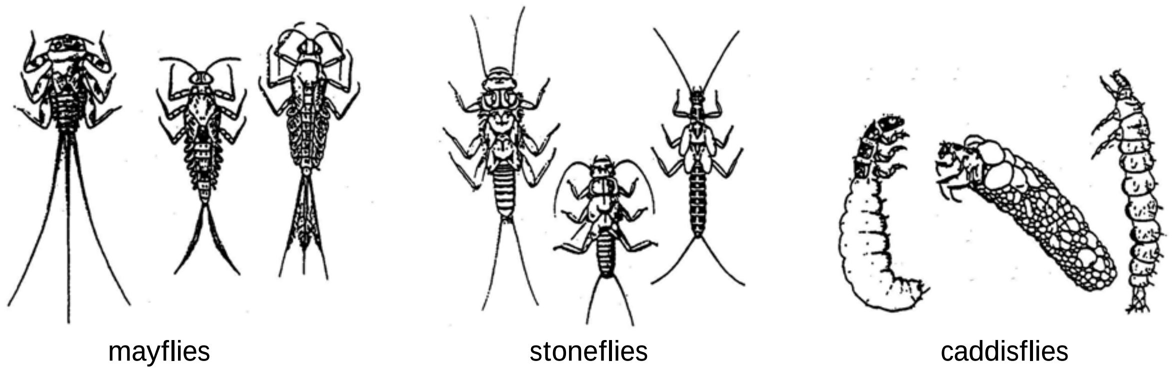
Biological Monitoring — Benthic Macroinvertebrates

Benthic macroinvertebrates are small animals that live on the bottoms of streams, rivers, and lakes. Insects comprise the largest diversity of these animals and include mayflies, stoneflies, caddisflies, beetles, midges, crane flies, dragonflies, and others. Snails, mussels, aquatic worms, and crayfish also are members of the benthic macroinvertebrate community. Benthic macroinvertebrates are important in the processing and cycling of nutrients, and are major food sources for fish and other aquatic animals. In general, a clean stream has a diverse array of benthic organisms that occupy a variety of ecological niches. Polluted streams generally have a lower diversity and often are devoid of pollution sensitive species. Figure 2 shows several of the most common macroinvertebrate organisms found in West Virginia's streams.

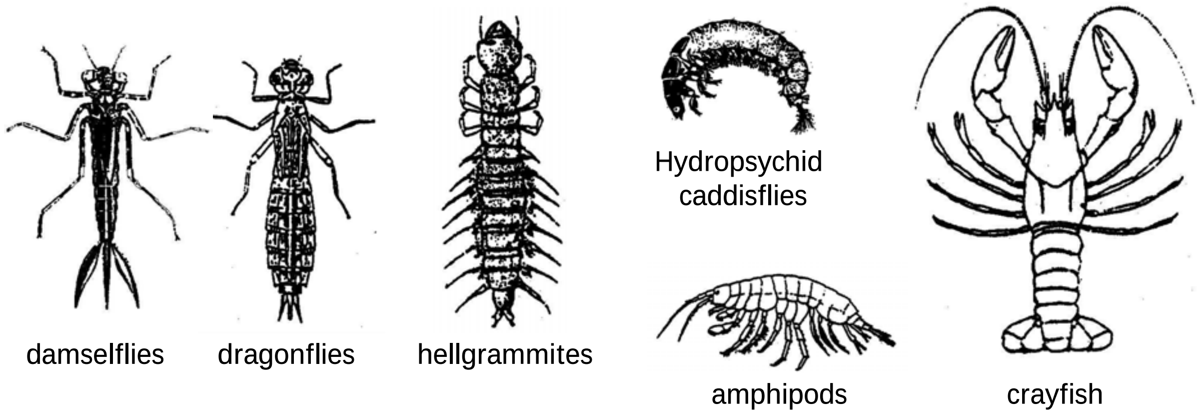
Benthic macroinvertebrate data have been used for several decades as tools for conducting

Figure 2. Common Benthic Macroinvertebrate Organisms

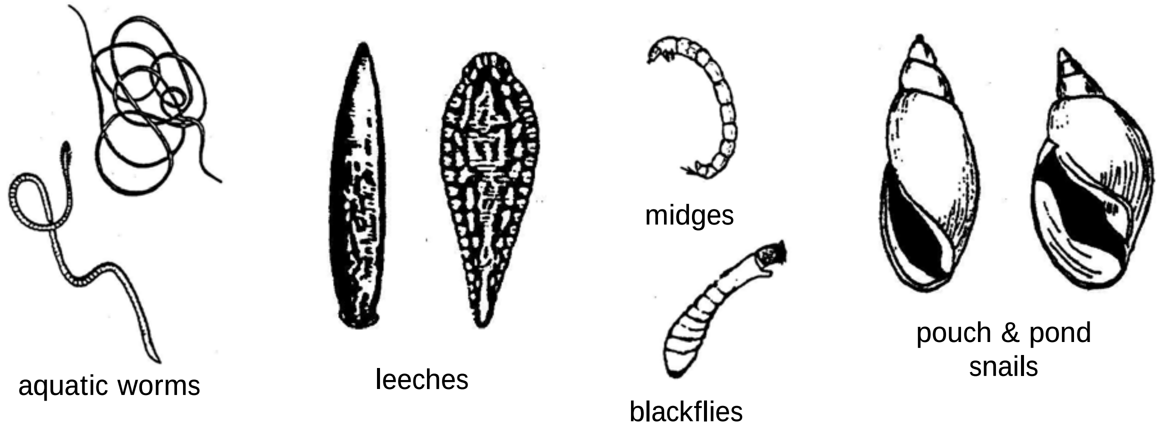
Pollution Sensitive Groups



Moderately Sensitive Groups



Pollution Tolerant Groups

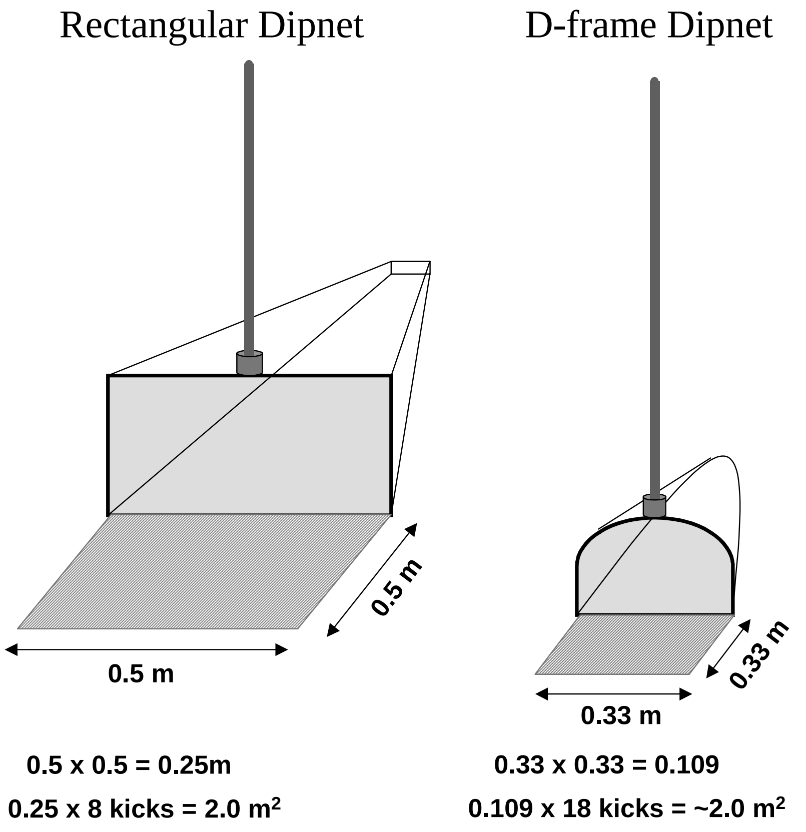


ecological assessments of streams. Many federal, state, and private organizations use this group of animals as part of their biological monitoring programs and the advantages are myriad. The most recognized benefit is that benthic macroinvertebrate communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). They provide a holistic measure of environmental conditions by integrating responses to stresses over time, and the public better understands them (as opposed to chemical conditions) as measures of environmental health (Plafkin et al. 1989).

Benthic macroinvertebrates can be collected using several techniques. The Watershed Assessment Section used the EPA's RBP II with some modifications. The 2-man kick net used in the original RBP was replaced with a kick net modified for use by 1 person. In streams having adequate riffle/run habitat, the Watershed Assessment Section used a rectangular dipnet to capture organisms dislodged by kicking the stream bottom substrate and by brushing large rocks and sticks. In streams too small to accommodate the rectangular dipnet, a smaller net called a D-frame was used to collect dislodged organisms (See Figure 3). Riffle/run streams with low flow that did not have enough water to sample with either net were sampled using a procedure called hand picking. This procedure involved picking and washing stream substrate materials in a bucket of water. Field crews attempted to sample 2 square meters of stream substrate (an area equal to 8 kicks with a rectangular net and 18 with a D-frame net) regardless of the device or technique employed.

The D-frame net was also used to collect macroinvertebrates in slow flowing (glide/pool dominated) streams that did not have sufficient riffle/run habitat. Macroinvertebrate sampling in glide/pool streams was accomplished using a procedure developed for use in Mid-Atlantic state coastal plain streams (the MACS technique) but applied to slow-moving streams in West Virginia.

Figure 3. Benthos Collection Nets



Benthic samples were preserved and delivered to the Department of Biological Sciences at Marshall University for processing. Processing involved removing a 200-organism subsample from the composite sample following RBP II protocols. The subsample was returned to

Section biologists who counted and identified the specimens to the family level or the lowest possible level of classification. The samples were kept for future reference and for identification to lower taxonomic levels if necessary.

Fish specimens inadvertently collected during macroinvertebrate sampling were transferred to the West Virginia Department of Natural Resources (DNR) office in Elkins where they became part of the permanent fish collection. Salamanders inadvertently collected were donated to the Marshall University Biological Museum in care of Dr. Tom Pauley.

The Section's primary goal in collecting macroinvertebrate data was to determine the biological conditions of the selected stream assessment sites. Determining the biological condition of each site involved calculating and summarizing 6 community metrics based upon the benthic macroinvertebrate data. The following benthic community metrics were used for each assessment site:

Richness Metrics

1. Total Taxa - measures the total number of different macroinvertebrate taxa collected in the sample. In general, the total number of taxa increases with improving water quality.

Benthic Community Metrics

Metrics are calculations that numerically describe the benthic communities of streams. Some metrics are simple summations such as Taxa Richness; a measure of the total number of different kinds of organisms in a sample.

Other metrics are more complex such as Hilsenhoff's Biotic Index, which incorporates the pollution tolerance values of collected organisms to provide a number that assesses organic pollution in streams.

The Watershed Assessment Section currently uses 6 metrics to determine the integrity of benthic macroinvertebrate communities. The use of several metrics, instead of only 1 or 2, provides greater assurance that valid assessments of integrity are made.

2. EPT Index - measures the total number of distinct taxa within the generally pollution sensitive orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies). In general, this index increases with improving water quality.

Community Composition Metrics

3. Percent Contribution of 2 Dominant Taxa - measures the abundance of the 2 numerically dominant taxa relative to the total number of organisms in the sample. Generally, this index decreases with improving water quality.

4. Percent EPT - measures the relative abundance of mayfly, stonefly, and caddisfly individuals to the total number of organisms in the sample. In general, this index increases with improving water quality.

5. Percent *Chironomidae* - measures the abundance of chironomid (midge) individuals relative to the total number of individuals in the sample. Generally, chironomids are considered tolerant of

many pollutants. This metric generally decreases in value with improving water quality.

Tolerance/Intolerance Metric

6. HBI (Hilsenhoff's Biotic Index - modified) - summarizes tolerances of the benthic community to organic pollution. Tolerance values range from 0 to 10 and generally decrease with improving water quality.

Of the many metrics available, these 6 metrics were used because (1) they provide the best discrimination between impaired and unimpaired sites, (2) they represent different community attributes, and (3) they minimize redundancy.

West Virginia Stream Condition Index

The 6 benthic community metrics were combined into a single index, the West Virginia Stream Condition Index (WVSCI). The WVSCI was developed by Tetra Tech Inc. (Gerritsen et. al. 2000) using the DEP's watershed assessment data and the EPA's Environmental Monitoring and Assessment Program data collected from riffle/run habitats in wadeable streams.

The WVSCI score is determined by calculating the average of the standardized score of each metric. The standardized score for each metric is determined by comparing an individual metric value to the "best standard value." This value represents either the 95th or 5th percentile (depending on whether the metric registers high or low for healthy streams) of all sites sampled via comparable methods. In general terms, all metrics values are converted to a standard, 0 to 100 (worst to best) scale. An average of the 6 standardized metric scores is calculated for each benthic sample site resulting in a final index score that ranges from 0 to 100.

In order to interpret the WVSCI score, the Watershed Assessment Section needed to establish reference conditions (see box on page 17). In a few previous assessments, the Watershed Assessment Section used either a single least-impaired site or a set of sites categorized by both stream width and ecoregional location as the reference conditions. However, it soon became clear that it is difficult to identify a single reference site that has both (1) minimal impairment and (2) the type of biological community that provides defensible conclusions about the impairment of assessed sites.

As a result of this revelation, the Watershed Assessment Section began defining reference conditions by using a collection of sites that met predetermined minimum impairment criteria. A site's suitability as a reference site was established by comparing the site's habitat and physicochemical data to a list of minimum degradation criteria or "reference site" criteria. Assessment sites that met all of the minimum criteria were given reference site status. The Watershed Assessment Section developed the minimum degradation criteria with the assumption that sites meeting these criteria would provide a reasonable approximation of least disturbed conditions.

Originally, the Watershed Assessment Section was using a set of reference sites limited to the watershed being studied. Subsequent research showed that a single reference set for wadeable streams is sufficient for statewide assessments (Tetra Tech, 2000). The researchers found that partitioning streams into ecoregions did not significantly improve the accuracy of assessments. The Watershed Assessment Section began using 107 reference sites to describe reference conditions. The reference conditions were then used to establish a threshold for biological impairment. These reference conditions can be used statewide, in all wadeable streams, and throughout the established sampling period of April through October.

The 5th percentile of the range of WVSCI scores for all the reference sites was selected as the impairment threshold. For the 107 reference sites used in this study, the 5th percentile score is 68. Initially, a site that received a WVSCI score equal to or less than 68 was considered impaired. However, because the final WVSCI score can be affected by a number of factors (collector, microhabitat variables, subsampling, etc.) the Watershed Assessment Section sampled 26 sites in duplicate to determine the precision of the scoring. Following an analysis of the duplicate data, the Watershed Assessment Section determined the precision estimate to be 7.4 WVSCI points. The Watershed Assessment Section then subtracted 7.4 points from the impaired threshold of 68 and generated what is termed the gray zone that ranges from >60.6 to 68.0. If a non-reference site has a WVSCI score within the “gray zone”, a single kick sample is considered insufficient for classifying it as impaired. If a site produces a WVSCI score equal to or less than 60.6, the Watershed Assessment Section is confident that the site was truly biologically impaired during the assessment period based on the single benthic macroinvertebrate sample. Accordingly, sites receiving the lowest WVSCI scores are the most impaired.

Reference Conditions

Reference conditions describe the characteristics of waterbody segments least-impaired by human activities, and are used to define attainable biological and habitat conditions. Selection of reference sites depends on an evaluation of the physicochemical and habitat data collected during each site’s assessment.

These data must meet minimum degradation criteria established by the Watershed Assessment Section before a site can be given reference site status. In general, the following parameters are examined: dissolved oxygen, pH, conductivity, fecal coliform bacteria, violations of water quality standards, nonpoint sources of pollution, benthic substrate, channel alteration, sediment deposition, streambank vegetation, riparian zone vegetation, overall habitat condition, human disturbances, point sources of pollution, and land use.

The information from sites that meet the defined criteria is used to establish reference conditions. Benthic macroinvertebrate data from each assessment site can then be compared to the reference conditions to produce a WVSCI score.

The impairment categories developed within the WVSCI are important tools the Watershed Assessment Section uses in making management decisions and in allocating limited resources to the streams that need them most. For the purposes of this report, the Watershed Assessment Section considered impaired sites and sites with WVSCI scores in the gray zone to be in need of further investigation and/or corrective action.

The WVSCI has proven itself as a useful and cost effective tool for assessing the health of the streams of West Virginia. However, like all biological assessment tools, it has its relative strengths and weaknesses. In some situations it is less applicable than in others. For most categories of streams found within West Virginia it appears to be a very reliable mechanism for measuring relative benthic community condition.

One shortfall seems to be its weakness in distinguishing differences in benthic community conditions between streams impacted by acidic deposition (rain, snow, fog, etc.) and unimpaired streams. Many atmospherically acidified streams have produced high WVSCI scores as long as there were no other sources of pollution present. Aquatic entomologists can often readily distinguish between benthic communities from deposition-impacted streams and unimpaired, non-acidified streams. Such clues as taxa composition and total numbers of organisms reveal the differences to the trained eye. Although the WVSCI also depends upon these clues, a family-level index is not sensitive enough to distinguish between the communities in the 2 categories of streams. This weakness in the WVSCI may also be partially due to its relative insensitivity to differences in total numbers of organisms collected. Often, acid deposition impacted sample sites do not produce enough individuals to require subsampling in the laboratory. The limitations of the current WVSCI are expected to diminish as genus-level and species-level indices are developed. These refinements of the WVSCI are expected to improve its sensitivity to benthic community changes brought about by problems like acid deposition.

The WVSCI is a helpful tool in assessing small watershed streams, but influences such as seasonal no-flow conditions and difficulty using consistent sampling methodologies, may result in low WVSCI scores that would indicate “impairment” in circumstances that are entirely natural. For this reason, it is imperative for assessment teams to record information adequate to determine the comparability of benthic collections.

Fecal Coliform Bacteria

Numerous disease-causing organisms may accompany fecal coliform bacteria, which is released to the environment in feces. Therefore, the presence of such bacteria in a water sample indicates the potential presence of human pathogens.

A fecal coliform bacteria sample was collected at each assessment site. EPA sampling guidelines limit the field holding time for such samples to 6 hours. Due to the distance to laboratories, personnel limitations, and time constraints, a 24-hour limit was utilized during this sampling effort. All bacteria samples were packed in wet ice until delivered to the laboratory for analysis.

Physicochemical Sampling

Physicochemical samples were collected at each site to help determine what types of stressors, if

Table 1. Water Quality Parameters

All numbered references to analytical methods are from *EPA: Methods for Chemical Analysis of Water and Wastes; March 1983*, unless otherwise noted.

Parameter	Minimum Detection Limit or Instrument Accuracy	Analytical Method	Maximum Holding Time
Acidity	1 mg/L	305.1	14 days
Alkalinity	1 mg/L	310.1	14 days
Sulfate	5 mg/L	375.4	28 days
Iron	50 µg/L	200.7	6 months
Aluminum	50 µg/L	200.7	6 months
Manganese	10 µg/L	200.7	6 months
Fecal Coliform Bacteria	Not Applicable	9222 D[1]	24 hours[2]
Conductance	1% of range[3]	Hydrolab™	Instant
pH	± 0.2 units[3]	Hydrolab™	Instant
Temperature	± 0.15 C[3]	Hydrolab™	Instant
Dissolved Oxygen	± 0.2 mg/L[3]	Hydrolab™	Instant
Total Phosphorus	0.02 mg/L	4500-PE[1]	28 days
Nitrite+Nitrate-N	0.05 mg/L	353.2	28 days
Ammonia-N	0.5 mg/L	350.2	28 days
Unionized Amm-N	0.5 mg/L	350.2	28 days
Suspended Solids	5 mg/L	160.2	28 days
Chloride	1 mg/L	325.2	28 days

[1] Standard Methods For The Examination Of Water And Wastewater, 18th Edition, 1992.

[2] U.S. EPA guidelines limit the holding time for these samples to 6 hours. Due to laboratory location, personnel limitations, and time constraints, 24 hours was the limit utilized during this sampling effort.

[3] Explanations of and variations in these accuracies are noted in Hydrolab Corporation's Reporter ™ Water Quality Multiprobe Operating Manual, May 1995, Application Note #109.

any, were negatively impacting each benthic macroinvertebrate community. The physicochemical data were helpful in providing clues about the sources of stressors.

Field analyses for pH, temperature, dissolved oxygen, and conductivity were performed. The manufacturer's calibration guidelines for each measurement instrument were followed with minimal variation.

Samples were collected at many sites for analysis of specific water quality constituents. A list of these constituents, preservation procedures, and analytical methods is included in Table 1.

In areas where mine drainage was present, assessment teams collected water samples for the analyses of aluminum (Al), iron (Fe), and manganese (Mn). In a few cases, samples were analyzed for hot acidity (mg/L), alkalinity (mg/L), and sulfate (mg/L). If excess nutrients were suspected, total phosphorus, nitrate-nitrite nitrogen, and ammonia were included in the analyses.

Assessment teams measured stream flow in cubic feet per second (cfs) when field readings indicated there was mine drainage impacting the stream. A current meter was used to measure velocity at multiple points across a stream transect and the discharge was calculated with the sum-of-partial-discharges method.

Procedures to ensure that samples are collected in a consistent manner and results are reliable are described in a standard operating procedures manual that is updated annually. These procedures include the collection of duplicate samples and field blanks.

Habitat Assessment

An 8-page Stream Assessment Form was completed at each site. A 100 meter section of stream and the land in its immediate vicinity were qualitatively evaluated for instream and streamside habitat conditions. Each assessment team recorded the location of each site, utilizing a GPS unit when possible, and recorded detailed travel directions so future researchers might return to the same site. The assessed stream section was sketched. The team recorded physical stream measurements, erosion potential, possible point and nonpoint sources of pollution, and any anthropogenic activities and disturbances. It also recorded observations about the substrate, water, and riparian zone.

An important part of each assessment was the completion of a 2-page Rapid Habitat Assessment form (from EPA's RBP manual by Barbour et. al. 1999). On this form, habitat conditions that were most likely to affect aquatic life were scored. Information from this form provided insight into the condition of the benthic macroinvertebrate community that might be expected at the sample site due to the recorded habitat conditions. Physical impairments to the stream habitat encountered during the assessment also were recorded on the form. The following 10 parameters were evaluated:

- Epifaunal substrate/fish cover
- Embeddedness
- Velocity/Depth regimes
- Channel alteration
- Sediment deposition
- Riffle frequency
- Channel flow status
- Bank stability
- Bank vegetative protection
- Width of undisturbed vegetation zone

A Rapid Habitat Assessment data set is valuable because it provides a consistent means of comparing sites to one another. Each parameter on the assessment form was given a score ranging from 0 to 20. Table 2 describes the categories that are used to rate each parameter. The 10 individual scores for each parameter were added together and this sum was the final habitat condition score for each assessment site (maximum possible = 200).

Table 2. Scoring For Rapid Habitat Assessment

Optimal (score 16-20)	Habitat quality meets natural expectations
Suboptimal (score 11-15)	Habitat quality less than desirable but satisfies expectations in most areas
Marginal (score 6-10)	Habitat quality has a moderate level of degradation; severe degradation at frequent intervals.
Poor (score 0-5)	Habitat is substantially altered; severe degradation

Although all the habitat parameters measure important aspects of stream habitat, some affect the benthic community more than others; *Embeddedness* and *sediment deposition* are 2 such parameters. Both of these parameters are measurements of the percentage of substrate affected by small particle deposits. Heavy deposits of small particles (silt and sand), especially in the spaces between cobbles and boulders in riffle/run habitats, restrict populations of benthic organisms. See Figure 4 for an illustration of substrate embeddedness.

Another important habitat parameter is the *riparian buffer zone width*. The condition of the land next to a stream has a direct and important affect on the instream conditions (see Figure 5). An intact riparian zone, (i.e., one with a combination of mature trees, saplings, and ground cover), serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and appropriate nutrient input into the stream.

Figure 4. Illustration of embeddedness

The view on the left is heavily embedded with sand and silt. Notice the different amounts of interstitial space (the space between the rocks and gravel).

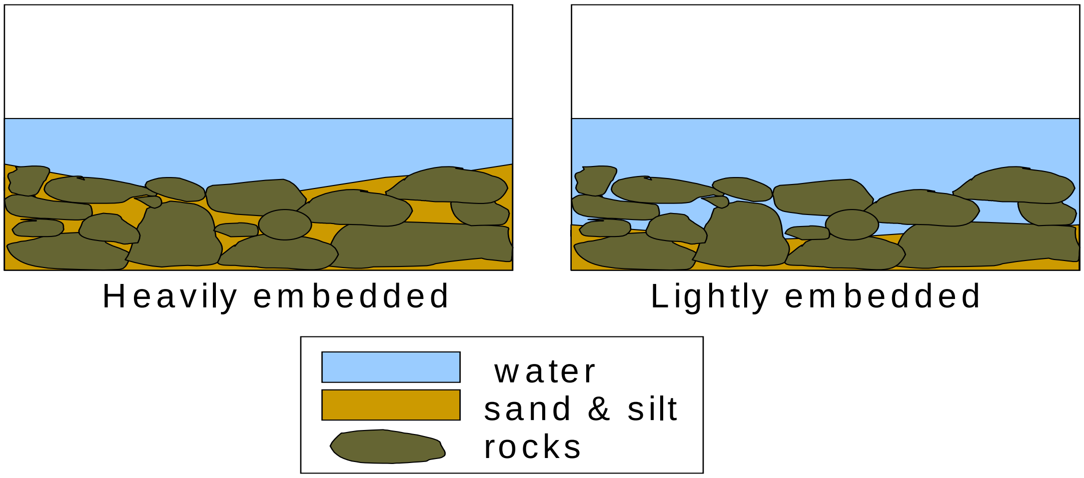
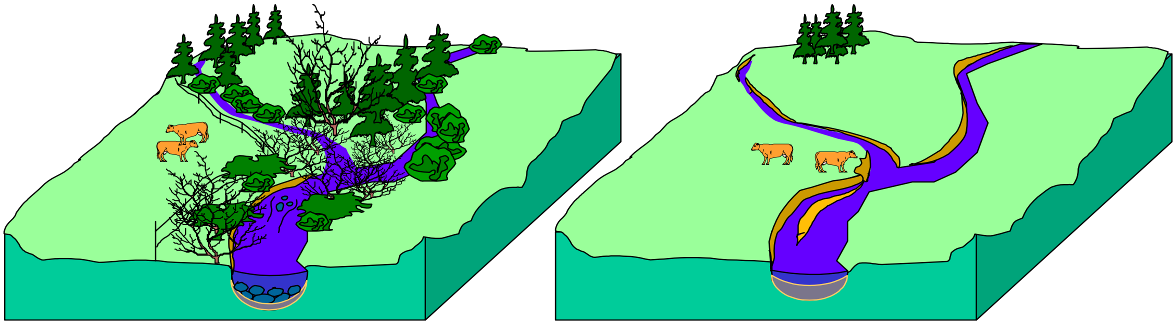


Figure 5. Stream with and without riparian buffer zone



Data Interpretation

When all of the aforementioned sets of data (i.e., biological, habitat, and physicochemical) are compiled, they must be interpreted by experienced scientists in order to make them useful for purposes set forth in various legislative rules regarding water quality. One of the interpretive tools, the WVSCI, has already been explained. Visual tools, such as graphs and tables, can aid the scientist-interpreter in

Figure 6. Example Sub-watershed

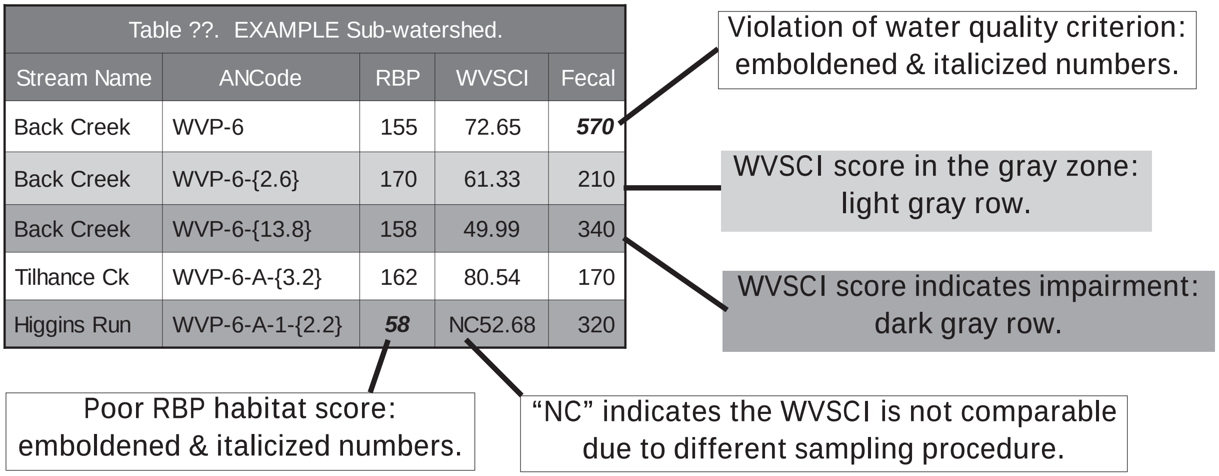


Table ??. EXAMPLE Sub-watershed.

Stream Name	ANCode	RBP	WVSCI	Fecal
Back Creek	WVP-6	155	72.65	***570***
Back Creek	WVP-6-{2.6}	170	61.33	210
Back Creek	WVP-6-{13.8}	158	49.99	340
Tilhance Ck	WVP-6-A-{3.2}	162	80.54	170
Higgins Run	WVP-6-A-1-{2.2}	***58***	NC52.68	320

Violation of water quality criterion: emboldened & italicized numbers.

WVSCI score in the gray zone: light gray row.

WVSCI score indicates impairment: dark gray row.

Poor RBP habitat score: emboldened & italicized numbers.

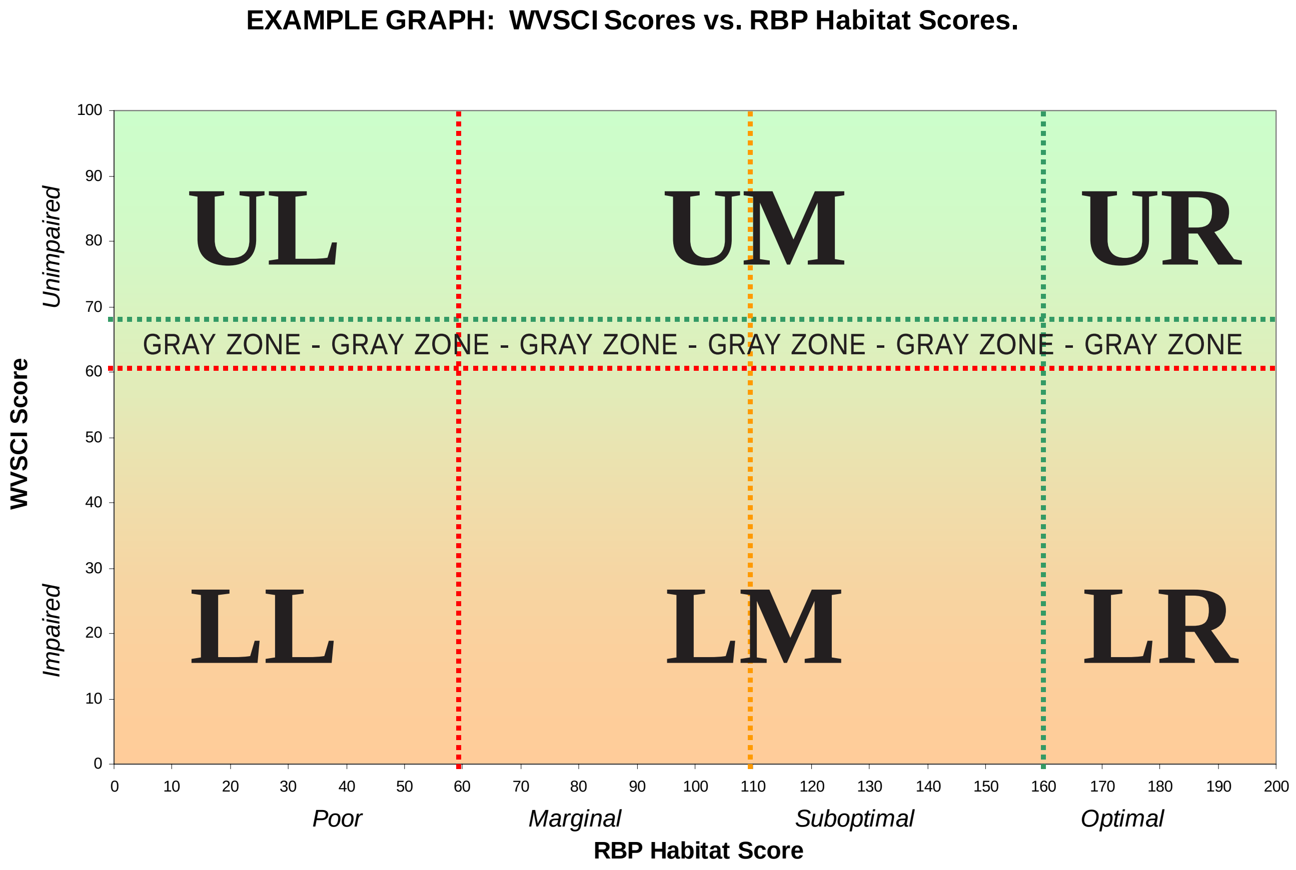
“NC” indicates the WVSCI is not comparable due to different sampling procedure.

the translation of these data to the interested citizen. In the following sections, 2 visual aids will be used often to help in understanding the general biological condition of the sampled sites; the sub-watershed general information table and the RBP habitat vs.WVSCI X-Y graph. The sub-watersheds are smaller units of the larger watershed considered in this study. All watersheds within the United States and its territories have been categorized into a Hydrologic Unit Code System (HUCS) by the USGS. Each sub-watershed discussed herein is identified by an 8-digit numeric HUCS code.

Each sub-watershed table (see Figure 6) provides a quick reference to the stream sites sampled in a particular sub-watershed during the assessment survey. The stream name and the alpha-numeric code (AN code) for each site are given. Each AN code provides a little information about the sampling site location relative to the watershed mainstem stream. For instance, *Higgins Run* has been assigned the AN code **WVP-6-A-1-{2.2}**. The “**WV**” tells us the site has been designated by the state of **W**est **V**irginia and the “**P**” indicates it is within the **P**otomac River Direct Drains watershed. The alternating series of numbers and letters that follow indicate the stream is a tributary of a tributary of a tributary of *Potomac River*. Each number and letter corresponds to another branching of the stream. Generally, these numbers and letters refer to the branching sequence as a person travels upstream. While traveling up *Potomac River*, the **6**th named tributary we encounter is *Back Creek*. If we turn up *Back Creek*, the first (the letter “**A**” is the first letter in the Roman alphabet) named tributary we encounter is *Tilhance Branch*. Up *Tilhance Branch*, the **1**st named tributary we encounter is *Higgins Run*. At milepoint **2.2** on *Higgins Run* we find the sampling site. The coding system is not exact, so occasionally strange code particles like “.1B” and “A.5” show up. Usually, the absence of a bracketed milepoint suffix indicates the sample site is at or very near the mouth of the stream. Within each table, the upstream sequence of tributaries is usually ordered from top to bottom.

Also included in each general information table are the WVSCI score, the RBP habitat score, and the fecal coliform concentration of each sample site. The example table (Figure 6) deciphers the information provided by various font and color schemes.

Figure 7. Example X-Y Graph.



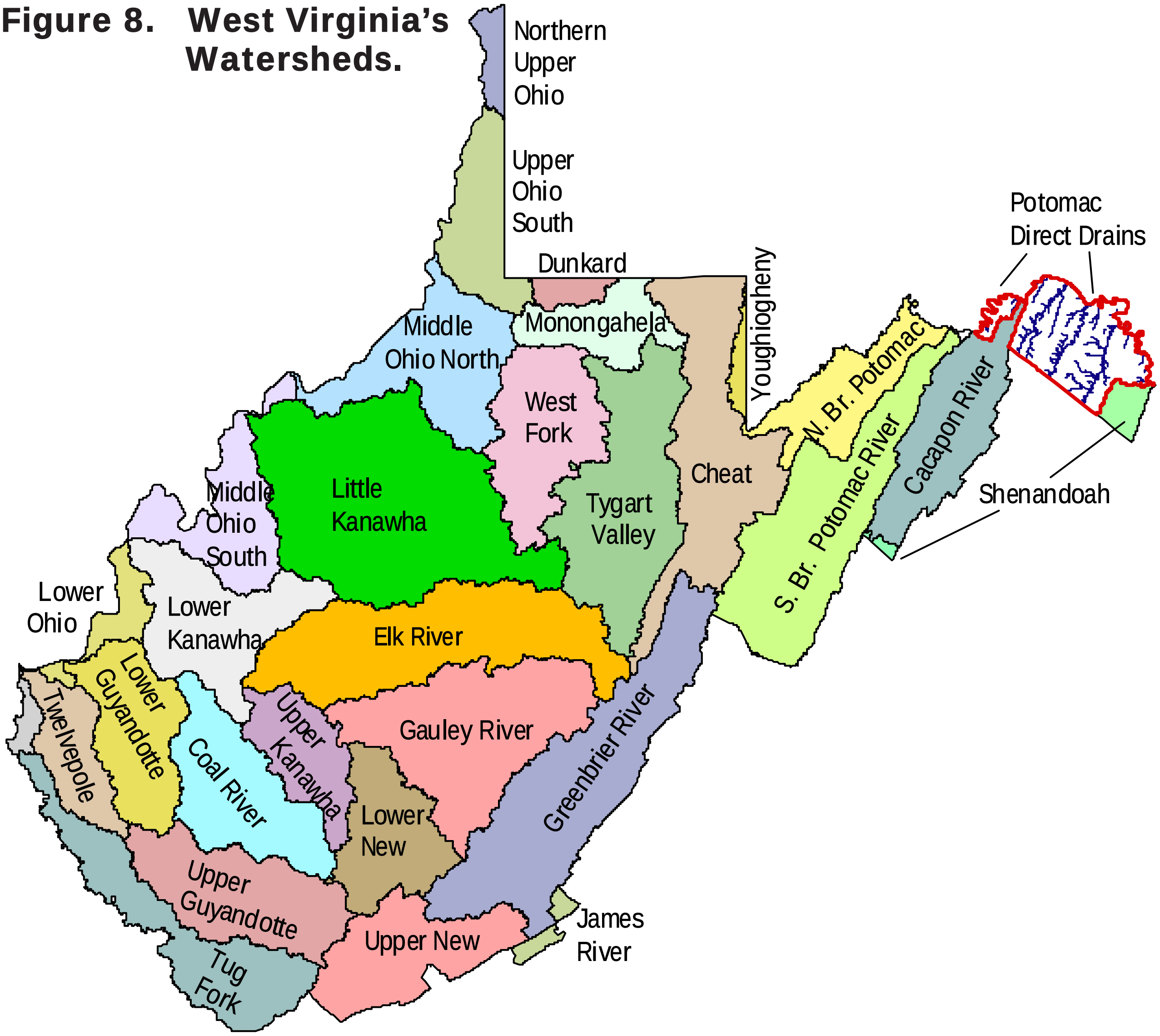
An example RBP habitat vs. WVSCI X-Y graph is shown in Figure 7. On the X-axis, the dividing lines between the RBP habitat score ranges are shown in colored, dotted lines. Poor total habitat scores fall below 60. Marginal scores include 60 through 109.9. Total RBP habitat scores from 110 through 159.9 are considered suboptimal, while those equal to or above 160 are optimal. On the Y-axis, the WVSCI score ranges are similarly delineated. Each sample site's paired score is represented by a mark on the graph, usually a large dot. Sites with dots in the upper right (UR) region of the graph generally have water quality and habitat conducive to producing diverse benthic macroinvertebrate communities. Dots that lie in the lower left (LL) portion of the graph represent sites with benthic communities that are almost certainly impaired by poor habitat along with other possible causes. Benthic communities at the sites represented by dots in the lower right (LR) sextant often are those that reside in high quality habitat, but are impaired by poor water quality. Sites that fall in all other sextants of the graph require more in-depth analysis to understand community condition and/or potential causes of impairment.

As mentioned previously, each site represented in the "gray zone" is one in which the benthic macroinvertebrate community may have been slightly impaired, but the single kick sample was considered insufficient evidence for classifying it as such.

The Potomac River Direct Drains Watershed

The Potomac River Direct Drains watershed is located in the eastern panhandle of West Virginia (see Figure 8). The watershed area covers all of Berkeley County, parts of Morgan and Jefferson Counties, and a very small portion of Hampshire County. Martinsburg, Shepherdstown, and Berkeley Springs are the largest towns in the watershed. The watershed is defined by both natural features and

Figure 8. West Virginia's Watersheds.



The **Potomac River Direct Drains Watershed** includes 3 major sub-watersheds (Opequon Creek, Back Creek, and Sleepy Creek) and a few small streams that drain directly into the River between the Shenandoah River and Cacapon River Watersheds, and between the Cacapon River and South Branch/Potomac River Watersheds.

political boundaries. Over two thirds of the watershed area are made up of the West Virginia portions of 3 tributary sub-watersheds: Opequon Creek, Sleepy Creek, and Back Creek. Significant portions of the Opequon Creek and Back Creek sub-watersheds are in Virginia.

Of these 3 main tributaries, only *Opequon Creek* drains land with significant amounts of limestone (see Figure 9), although some of the headwater streams of the Virginia portion of the Back Creek sub-watershed drain a small amount of karst. Karst is a landform, found in areas underlain by limestone, that is characterized by relatively flat or rolling terrain, numerous water sinkholes and springs, and relatively dry upland soils. Caves and caverns are common in karstic regions. Most of the Sleepy Creek and Back Creek sub-watersheds are surfaced with soils developed from shales and sandstones. There are a few sandstone ridges located within these 2 sub-watersheds. The Opequon Creek mainstem within West Virginia flows through a shale-surfaced valley, but as stated previously, much of the watershed drains karst.

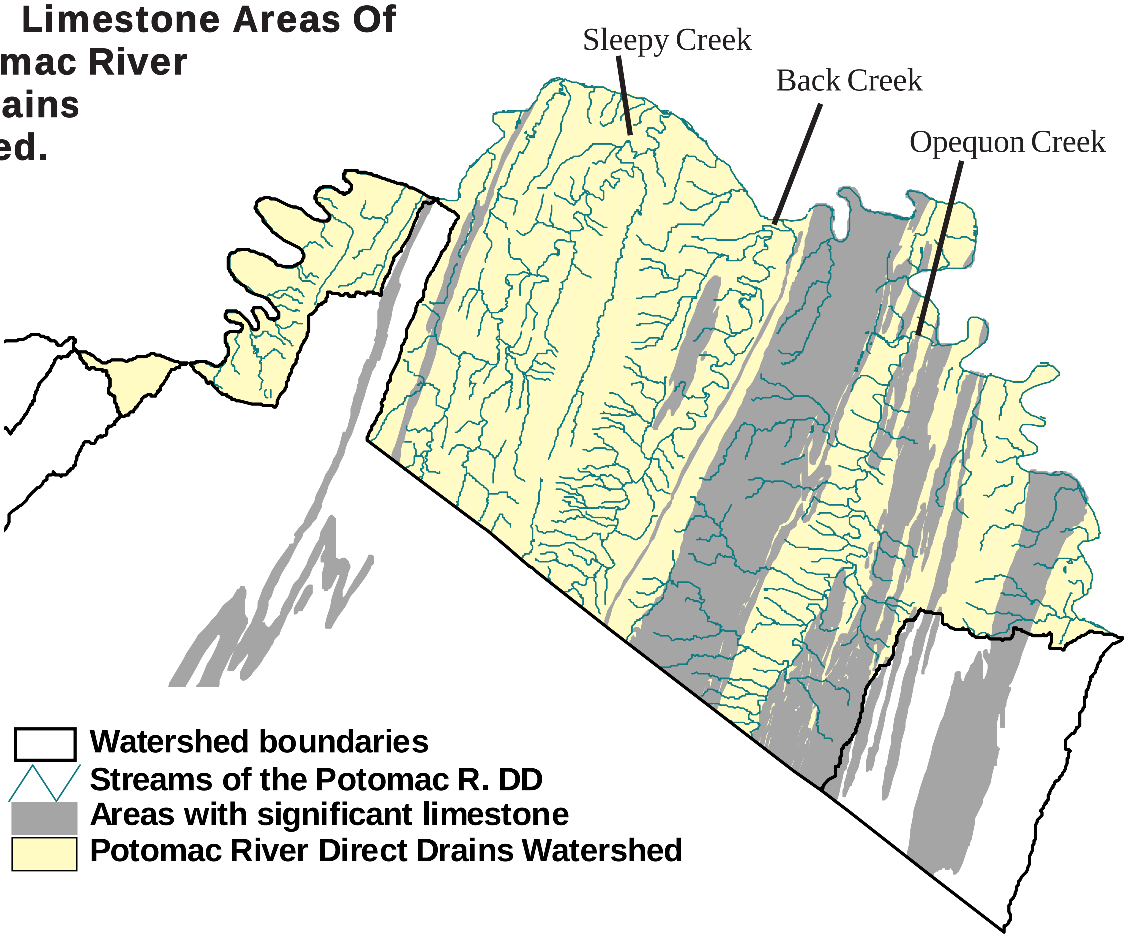
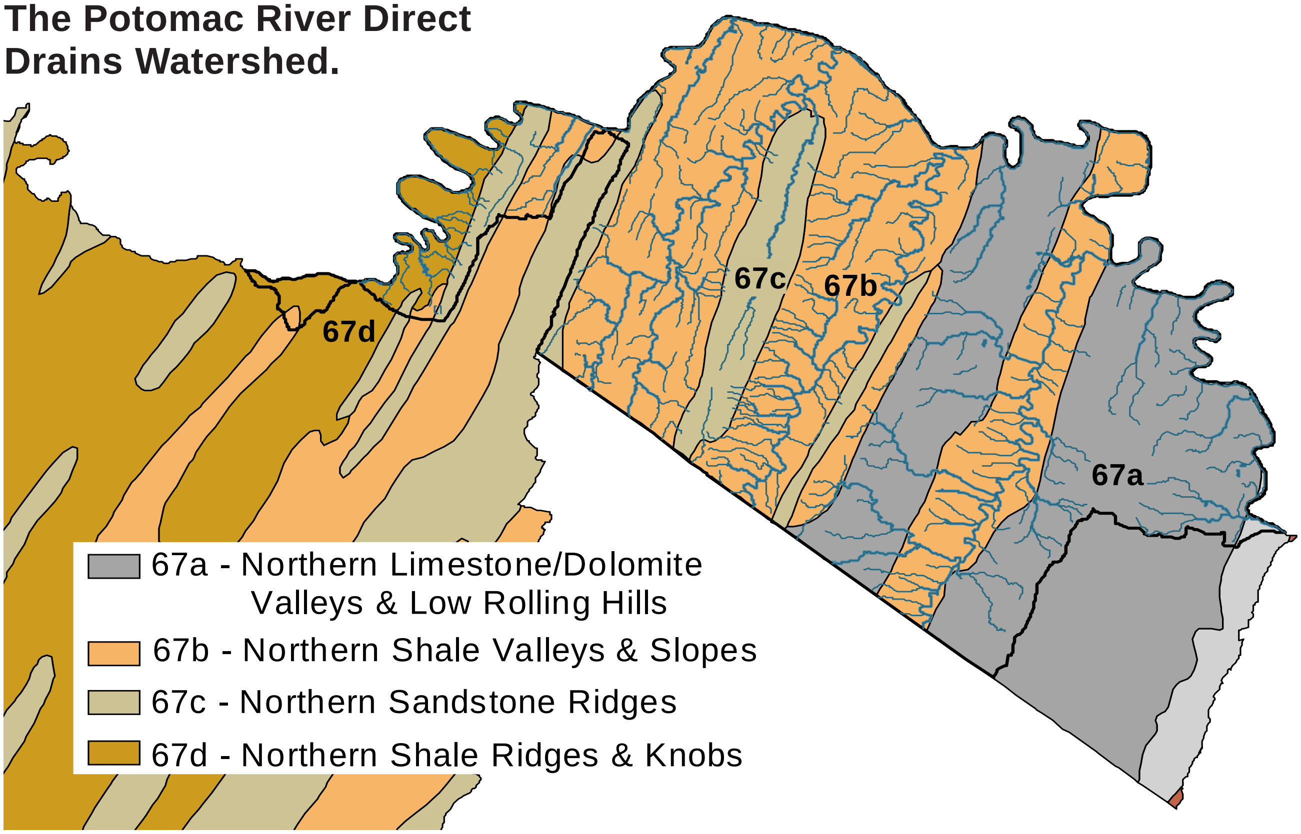


Figure 9. Limestone Areas Of The Potomac River Direct Drains Watershed.

Four Level IV sub-ecoregions (Omernik et. al., 1992) are represented within the watershed; Northern Limestone/Dolomite Valleys & Low Rolling Hills, Northern Shale Valleys & Slopes, Northern Sandstone Ridges, and Northern Shale Ridges & Knobs (see Figure 10). Only 1 sample site

Figure 10. Ecoregions Of The Potomac River Direct Drains Watershed.



is located within the latter ecoregion, *Rockwell Run* (WVP-16-{0.1}), but much of the stream's watershed area drains the Northern Sandstone Ridges ecoregion.

At the beginning of the historic period, the karstic region of this watershed was covered by numerous open grasslands and savannahs. In his book, *A History Of The Valley Of Virginia* (copyrighted 1833, second edition printed 1850), Samuel Kercheval gave a well-researched picture of the region wherein our present watershed of concern lies. The eastern branch of "the great war road" between the northern and southern Indians passed across the karst draining into Shenandoah River and Opequon Creek. As Europeans and Euro-Americans began following this trail up the valleys to farm the grasslands, sporadic conflicts arose between Amerindian war parties and farmers. This caused the Six Nations Confederacy to move the war road westward to the "back side" of North Mountain, hence the name of Back Creek was given to the stream that flowed along the western flank of the mountain.

Generally speaking, small immigrations of Scotch-Irish, German, and English homesteaders moving onto lands not yet negotiated for by either Crown or Colony, spawned these sporadic conflicts. This typically led to treaty negotiations between allied Amerindians and various colonies and the resulting treaties defined new colonial settlement boundaries. The new boundaries usually led to large immigrations of Euro-Americans onto the purchased lands and smaller immigrations onto unpurchased lands further to the west.

However, from around 1730 until 1753, both Euro-Americans and Amerindians lived together in the region, practicing a very similar form of agriculture, called today “slash and burn.” The primary difference between the 2 cultures’ agricultural practices was larger scale animal husbandry, introduced by the Europeans. While Amerindians would occasionally fatten a bear or eat their dogs, no native practice came close to the hog, horse, and cattle rearing that set the Euro-American communities apart from those of their native neighbors. Some Amerindians quickly adopted livestock farming, but the majority living away from Euro-American settlements continued to provide meat to their families primarily through hunting. The grasslands provided excellent forage for native grazers, like buffalo and elk, as well as for imported livestock. Conflict between the 2 cultures over which grazing species should have the run of the grasslands was inevitable.

Excerpts from Kercheval’s book hint at the importance of human activities in maintaining the grasslands first encountered by white settlers in the region: “Much of the greater part of the country between what is called the Little North Mountain and the Shenandoah River, at the first settling of the valley was one vast prairie, and like the rich prairies of the west, afforded the finest possible pasturage for wild animals...There are several aged individuals now living [1833], who recollect when there were large bodies of land in the counties of Berkeley, Jefferson and Frederick, barren of timber. The barren land is now covered with the best of forest trees.” (Kercheval 1850:44).

A switch from slash and burn agriculture to intensive soil and field management led to the establishment of forests (likely on only marginally productive land) described by Kercheval in 1833. Field to forest ratios have fluctuated since Kercheval’s time, responding to various cultural pressures, but both land uses resulted in some sort of vegetative soil cover. However, today the region is experiencing a new land use that results in losses of normal ecological functions of both vegetation and soil. That destructive land use is urbanization. The increases in impervious surfaces (pavement, roof tops, etc.) in the vicinities of Martinsburg, Charlestown, Inwood, Harpers Ferry, and Shepherdstown in the last 20 years is alarming. Stream degradation is ensured. Suburban developments of retirement homes and vacation homes in the Sleepy Creek and Back Creek sub-watersheds have rapidly increased within the past 3 decades. Failing communal sewage treatment systems are frequent sources of pollutants in small streams scattered throughout the watershed.

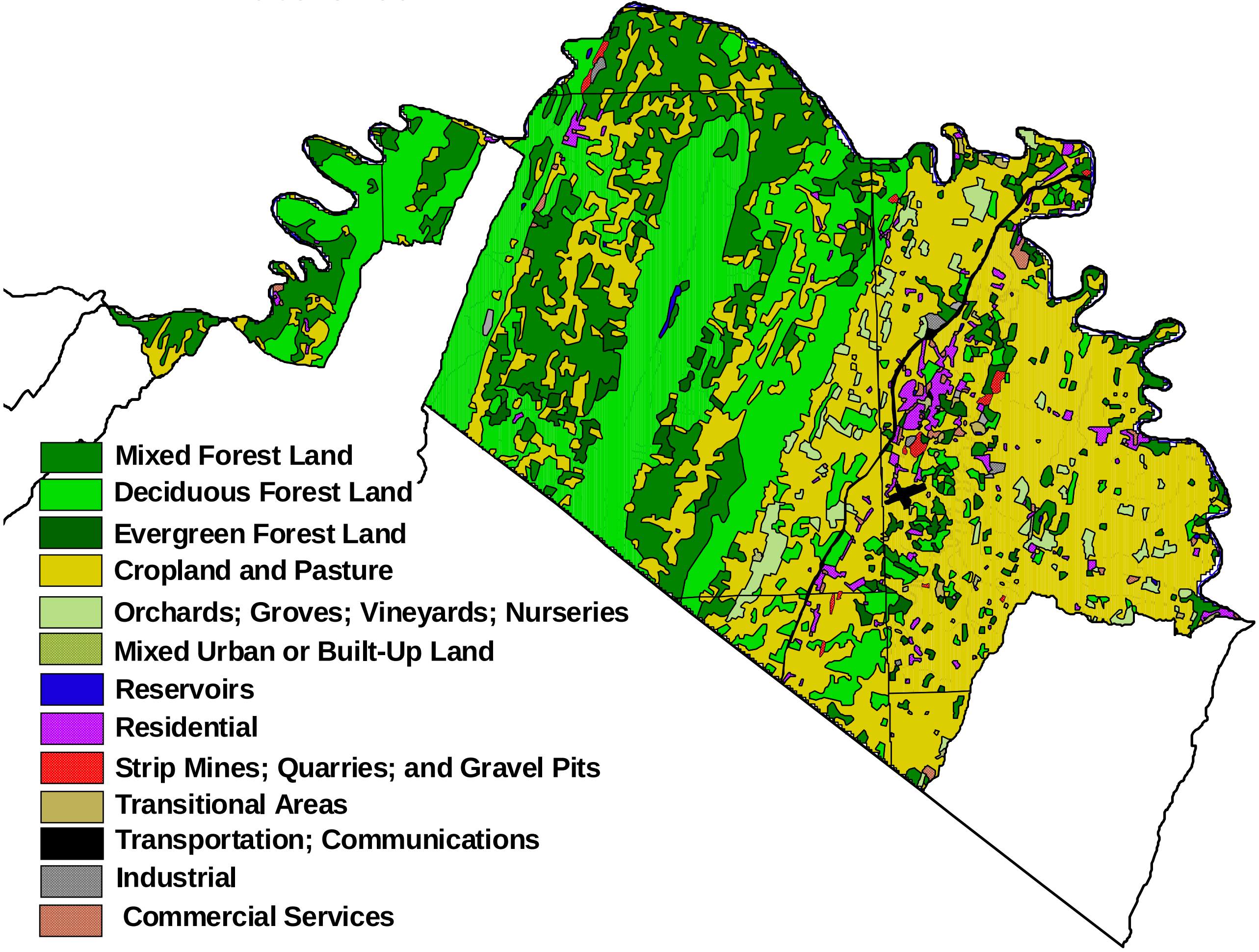
Maryland’s Biological Stream Survey (Boward et. al. 1999:27 & 31) found that when watershed imperviousness exceeds 25%, only hardy, pollution tolerant reptiles and amphibians can thrive, while more pollution sensitive species are eliminated. They found that brook trout are never found when upstream impervious land cover is greater than 2%.

Despite the looming shadow of these urban pollution problems, water quality in much of the watershed appears to be quite good. This is especially true of the Sleepy Creek and Back Creek sub-watersheds. There are 15 stream segments within the watershed included on the 2002 303(d) list of water quality limited streams (Table 3), but none of these are in the Sleepy Creek and Back Creek sub-watersheds. A challenge will be to guide the inevitable urban development so that it’s negative impacts upon aquatic ecosystems are minimal.

Currently, the land in this watershed is being developed more rapidly than in any other part of the state. Its proximity to Washington and Baltimore make it a desired location for many people trying to get away from the congestion of the cities. Many farms are being purchased and residential developments are being built in their places. Some politicians and citizens in this area have been concerned with this growth and are trying to deal with the potential problems that others in this state have not addressed. Figure 11 shows the land use in the watershed. The data are several years old and therefore do not accurately depict the current conditions. However, the major modern trends in land use change in the Back Creek, Sleepy Creek, and Opequon Creek sub-watersheds are evident from this figure.

The Potomac Direct Drains watershed is located within the drainage basin of the largest estuary in the eastern United States, Chesapeake Bay. The bay's aquatic life has suffered severely in the last 200 years due to many affronts, perhaps the most pervasive of which is chronic nutrient overloading. Fishery resources in the bay have plummeted and so have fishing related jobs. A number of interstate and intergovernmental agreements legally define a cooperative effort to improve the biological condition of the bay. The EPA administers a special program dedicated to this improvement and other goals for the bay. West Virginia participates in this cooperative effort. Sub-watersheds that contribute disproportionate amounts of nutrients to the bay are being targeted for special nutrient reduction efforts. The assessment reported herein provides insight into the relative nutrient loads carried by

Figure 11. Landuses In The Potomac River Direct Drains Watershed.



Potomac Direct Drains tributary sub-watersheds.

It is difficult to positively identify some causes of benthic impairments in this watershed because major changes in land use coincide closely with ecoregional boundaries (see Figures 9, 10, and 11) and because there are few historical benthological data to accurately assess trends. This dilemma begs such questions as; “If a stream in the eastern part of the watershed appears to be impaired relative to streams in the western watershed area, is this due to recent increases in human disturbances or is it due to natural differences in geology and/or topography?”

One answer to this question was proposed in a study reported upon in the *Journal Of The North American Benthological Society* (Waite, 2000). After sampling 259 sites scattered across 3 Level IV sub-ecoregions (including limestone/dolomite valleys), the researchers concluded that ecoregional differences were not reflected in benthic assemblages. Peering more closely at limestone vs. non-limestone streams, one of the researchers concluded “there’s not a strong case for looking at Limestone streams as a separate group. Watershed size and human disturbance seem to be stronger drivers of biological assemblages than ecoregion.” (Herlihy, 1999).

Table 3 shows the 15 streams placed on the 2002 303(d) list. The actual list informs that the aquatic life use of the full length of each stream was impaired by unknown causes during the evaluation period. Also, *Opequon Creek* had its human health use impaired by elevated fecal coliform bacteria concentrations. Data collected during the assessment reported herein were largely responsible for placing these streams on the 303(d) list. Further study scheduled for 2003 & 2004 may better distinguish between impaired segments of these streams and those that are unimpaired.

Note that all but 3 of these streams are within the Opequon Creek sub-watershed (AN code WVP-4...). Also of note is that most of these streams drain karstic lands. Table 4 shows streams that are on both the 303(d) List and the DNR High Quality Streams List. These 2 lists have different qualification criteria, but including streams on both lists calls attention to the need to simplify stream quality classification schemes. The qualification criteria for inclusion on the DNR list are: (1) the streams are stocked with trout or contain native trout populations, or (2) the streams are warmwater of over 5 miles in length and supporting desirable fish populations that support public utilization. To summarize and paraphrase; the streams must support game fisheries. The inclusion of these 5 streams on the 303(d) list indicates that the game fisheries therein may be threatened.

Those streams found in Table 5 are included in the 2002 Special Waters Presumptive List. Explicit anti-degradation protection will be given waters of special concern, also known as Tier 2.5 waters. Candidate waters for Tier 2.5 designation are those with naturally reproducing trout populations, those utilized by the DEP as reference streams, or those determined to have biological scores indicative of high water quality. Such streams will be protected from human activities that would reduce their pollutant assimilation capacities by more than 10%. *Rockwell Run* and *South Fork/Indian Creek* were added to the list partly due to their suitability as reference streams for WVSCI calculations.

Table 3. Potomac Direct Drains 2002 303(d) list streams.

Stream name	AN code
Elks Br/Elks Rn	WVP-1-A
UNT/Potomac Rv a.k.a. Teagues Rn	WVP-2.2
Opequon Ck	WVP-4
Eagle Rn	WVP-4-B
Tuscarora Ck	WVP-4-C
Dry Rn/Tuscarora Ck	WVP-4-C-1
Evans Rn	WVP-4-D
Hopewell Rn	WVP-4-I
Middle Ck	WVP-4-J
Goose Ck	WVP-4-J-1
Mill Ck/Opequon Ck	WVP-4-M
Sylvan Rn	WVP-4-M-1
Torytown Rn	WVP-4-M-2
Silver Spring Rn	WVP-4-P
Harlan Rn	WVP-5

Table 4. Potomac Direct Drains streams on both the 303(d) list and the WVDNR high quality streams list.

Stream name	AN code
Opequon Ck	WVP-4
Eagle Rn	WVP-4-B
Tuscarora Ck	WVP-4-C
Middle Ck	WVP-4-J
Mill Ck	WVP-4-M
Harlan Rn	WVP-5

Table 5. Potomac Direct Drains streams on the Proposed Special Waters list (Tier 2.5).

Stream name	AN code
North Fk/ Indian Ck	P-9-G-1
South Fk/ Indian Ck	P-9-G-2
Rockwell Rn	P-16

Assessment Results

General Overview

In June of 1998, DEP field teams visited 67 sites on 42 streams in the Potomac River Direct Drains Watershed (see Figure 12). The larger streams were sampled at multiple locations. Three sites were sampled in duplicate as part of the Program's quality control plan. Another 3 sites were inadvertently sampled twice by different sampling teams on different days.

One site did not have enough habitat to allow collection of a macrobenthic sample. Another 4 sites did not have enough suitable riffle/run habitat, so the MACS sampling protocol (see the *Watershed Assessment Methods* section) was used.

A water quality meter was not working properly during part of the sampling effort, so 7 sites were sampled without obtaining temperature, pH, dissolved oxygen, and conductivity data. All other aspects of these 7 sites were assessed.

Benthic Macroinvertebrates

Comparable Sites

Of the 67 comparable benthic macroinvertebrate samples collected, 21 produced WVSCI scores below the impairment threshold of 60.60. Of these 21 impaired samples, 18 were from the Opequon Creek sub-watershed, and the other 3 were from adjacent sub-watersheds. Table A-5 (all tables with an "A" prefix are found in the appendix) shows the benthic macroinvertebrate community metrics and the WVSCI scores for these sites. Table A-6 lists the taxa and counts for each of the 21 samples.

Forty-one of the comparable benthic samples produced WVSCI scores indicative of relatively unimpaired benthological communities (the green dots in Figure 12). None of the sites that these samples were collected from are within the Opequon Creek sub-watershed. All but 4 of the sites are within either the Sleepy Creek or Back Creek sub-watersheds.

Figures 13-16 show the relationship between the WVSCI score and the total score from the RBP habitat assessment. Many sites that had relatively high habitat scores, but poor WVSCI scores had at least 1 observable water quality problem. Sites with poor WVSCI scores and no obvious problems with habitat or water quality may have been affected by episodic events, such as spills or cyclical discharges, not detected at the time of sampling.

There were 67 distinct family level taxa identified from the benthic samples. The most frequently encountered taxa were *Chironomidae*, *Hydropsychidae*, *Elmidae*, *Baetidae*, and *Tipulidae*.

Non-comparable Sites

Only 4 sites sampled for benthic macroinvertebrates were considered non-comparable. *Tullis Branch* (WVP-5-A-{1.4}), 1 *Tuscarora Creek* site (WVP-4-C-{1.5}), and 2 *Opequon Creek* sites (WVP-4-{17.8} & {18.8}) were sampled using the MACS protocol. Generally, the samples from the *Opequon Creek* site at mile point 18.8 and from *Tullis Branch* appeared to have relatively diverse benthos, while those from *Opequon Creek* at mile point 17.8 and *Tuscarora Creek* at mile point 1.5 did not.

TABLE 6: SAMPLING SUMMARY

Named streams	**113**
Streams visited	**42**
Sites visited	**67**
Habitat assessment sites	**67**
Water quality sampling sites	**67**
Comparable benthic sites	**63**
Comparable benthic samples	**67**
MACS-samples	**4**

Fecal Coliform Bacteria

Approximately 27% of the samples were in violation of the appropriate WV water quality criterion for fecal coliform bacteria (i.e., 400/100 mL, see Fig. 17). None of these violating samples were collected in the Back Creek sub-watershed and only 3 were from the Sleepy Creek sub-watershed. Fully 65% of these violations were from the Opequon Creek sub-watershed. This phenomenon is due partly to karstic drainage patterns, intensive agricultural activities, and intensive urbanization of portions of the Opequon Creek sub-watershed relative to the other 2 sub-watersheds.

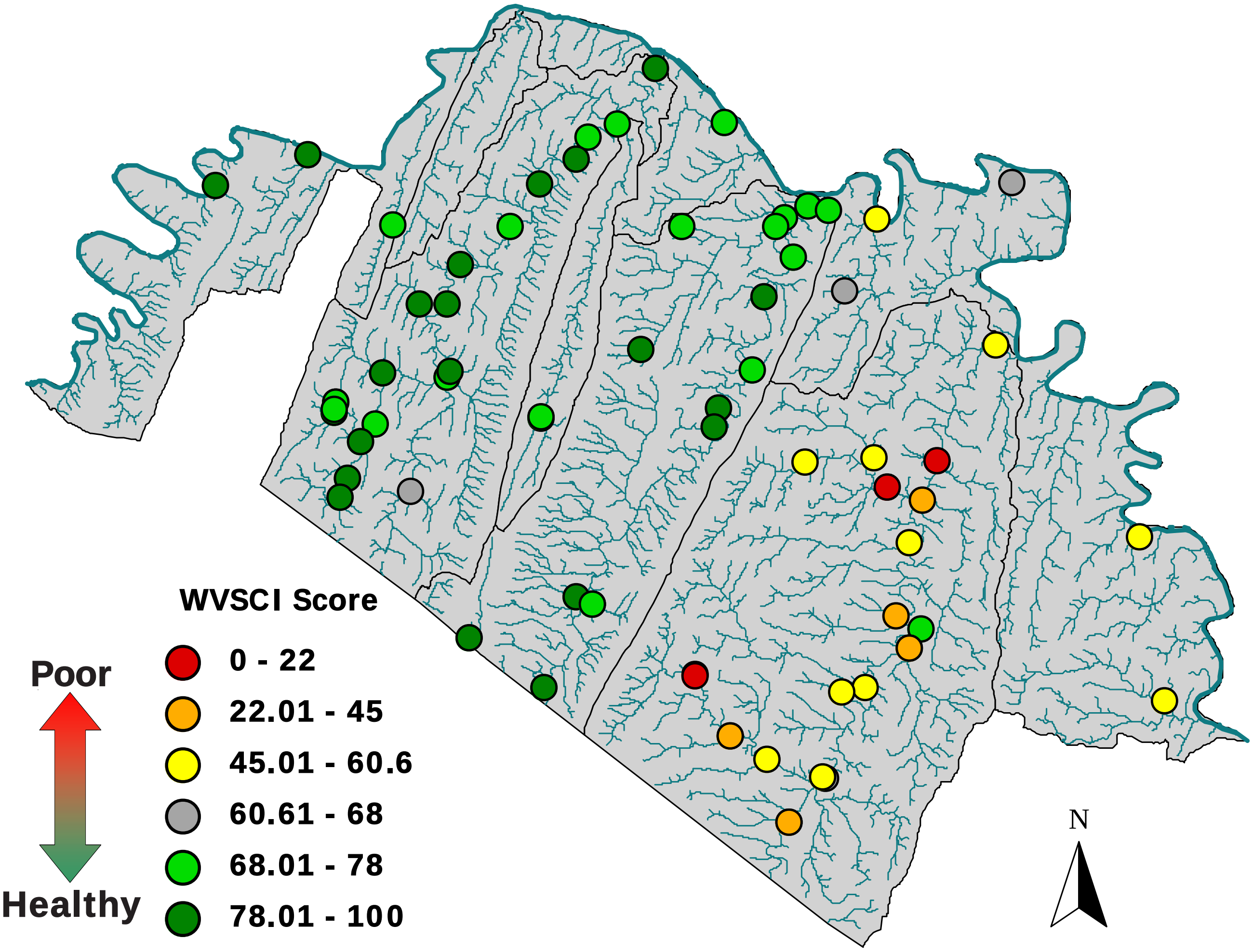
Notes on the habitat assessment forms from most of the other sites that produced violations of the bacteria criterion, implicated agricultural or urban activities as potential sources of the bacteria.

Physicochemical Water Quality

Excessive nutrient concentrations in aquatic ecosystems cause changes to the biological communities that reside therein. Nutrient-sensitive taxa decrease and nutrient-tolerant taxa increase. Such taxa as *Chironomidae* midges, *Hydropsychidae* caddisflies, *Baetidae* and *Philopotamidae* mayflies, and *Oligochaeta* worms, often have increased numbers in nutrient laden waters. Algae often increase in abundance and macroinvertebrates classed in the functional feeding group known as “grazers” increase accordingly. Results of biometric measurements change in response to the altered communities, and indices, such as the WVSCI, result in scores that indicate greater impairment.

Currently, there are no “aquatic life” water quality criteria for nitrate-nitrogen in the West Virginia water quality standards. However, for purposes of comparison, Watershed Assessment Program personnel often utilize 1.0 mg/L as a “flag” value to call attention to streams that may have nutrient loading problems. This flag value is utilized for results of nitrate-N and nitrite+nitrate-N

Figure 12. WVSCI scores at each sample site



(NO2+NO3-N) analyses. In the following discussion, sampling sites are discriminated by the 1.0 mg/L flag value. This does not imply certainty of chronic nutrient problems in those streams with values greater than the flag value, but it does indicate which streams may need further study to detect such problems.

Of the 51 samples analyzed for NO2+NO3-N, only 15 had concentrations above 1 mg/L. Table 7 shows these 15 sampling sites in order of highest to lowest concentrations of NO2+NO3-N. All 15 samples were taken from streams that drain karst, and 12 of the streams are located in the Opequon Creek sub-watershed. Of the remaining 36 samples, only 1 (the 1 from *Goose Creek*) was collected from within the Opequon Creek sub-watershed. However, the *Goose Creek* drainage basin lies entirely within shale rock layers and receives no drainage from limestone or dolomite. Consequently, the lower NO2+NO3-N concentration is expected from this stream.

Samples for NO2+NO3-N from the Opequon Creek sub-watershed were typically 1 to 2 orders of magnitude greater than most of those from the other sub-watersheds studied. *Eagle Run* had 21 mg/L of this constituent. Total phosphorus was also relatively high in the Opequon Creek sub-watershed.

Figure 13. Back Creek WVSCI Scores vs. RBP Habitat Scores.

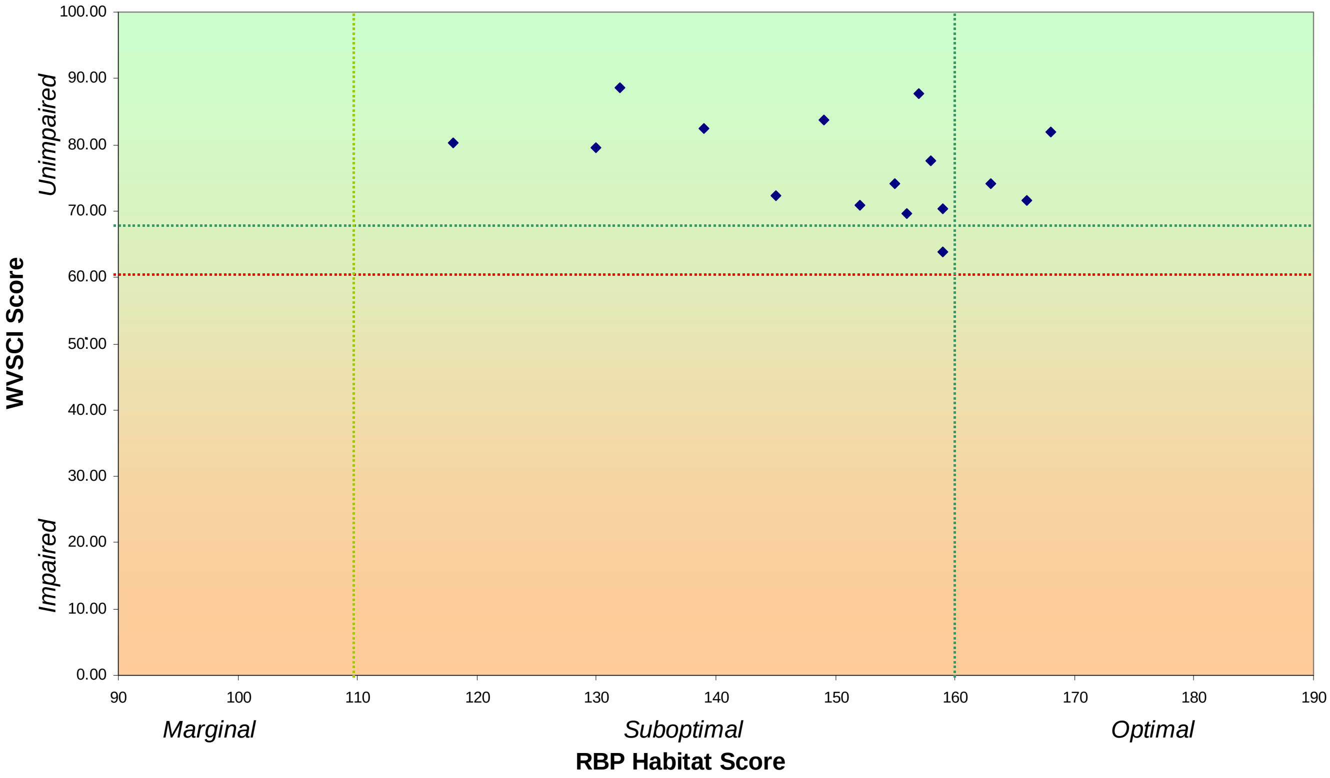


Figure 14. Sleepy Creek WVSCI Scores vs. RBP Habitat Scores.

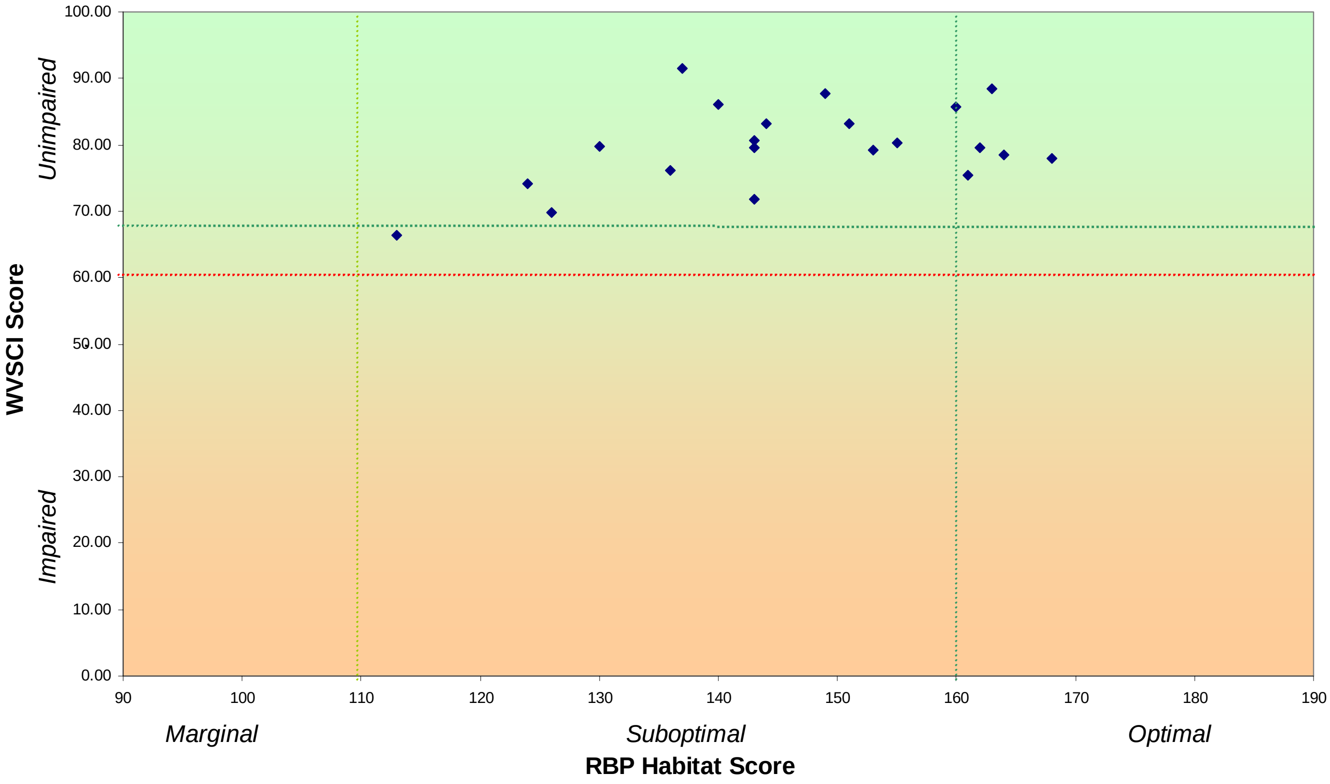


Figure 15. Opequon Creek WVSCI Scores vs. RBP Habitat Scores.

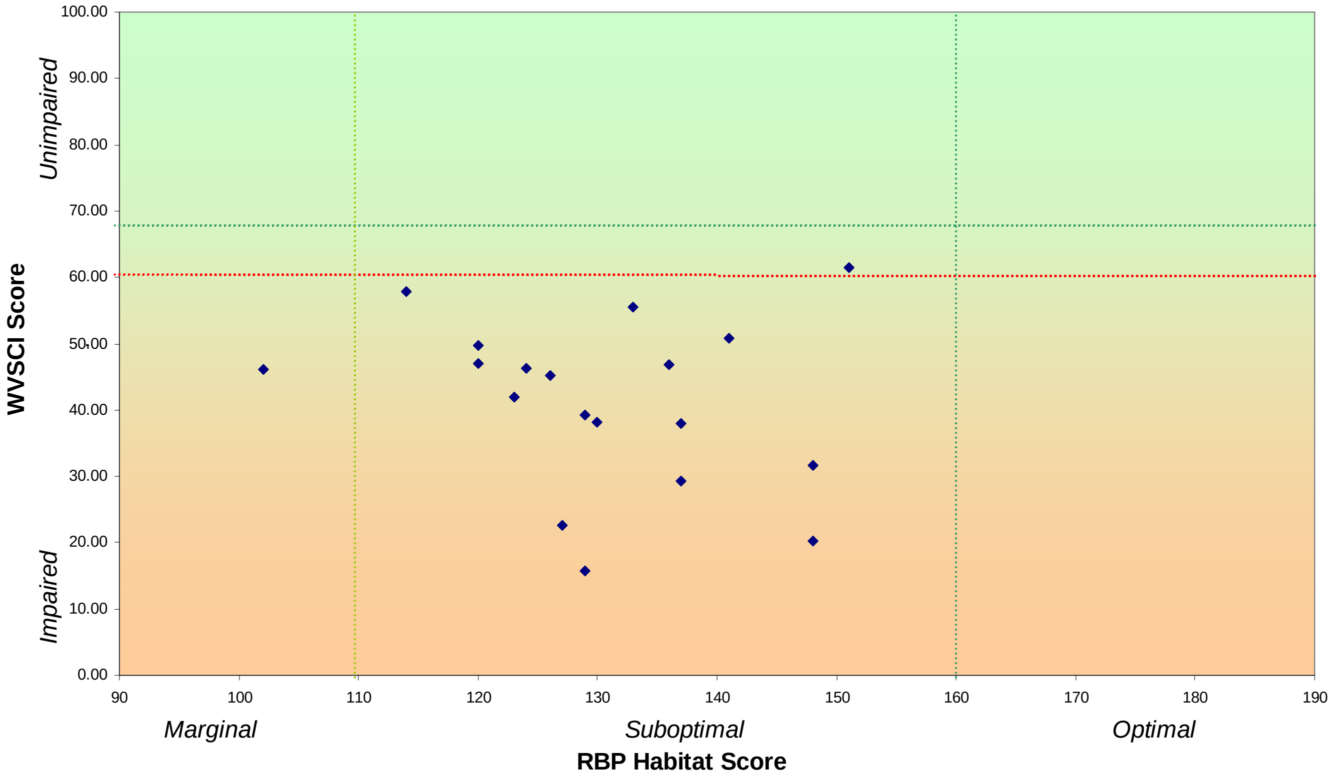
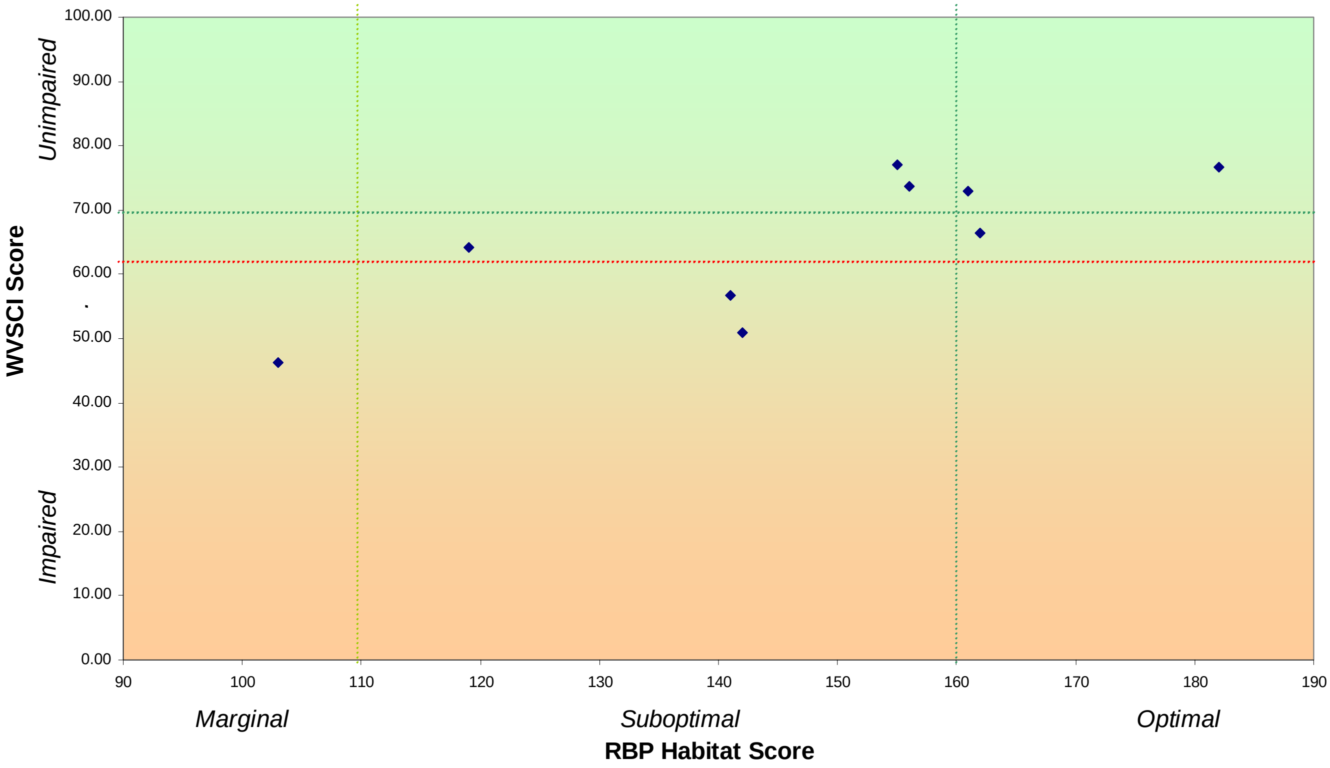


Figure 16. Misc. Streams WVSCI Scores vs. RBP Habitat Scores.

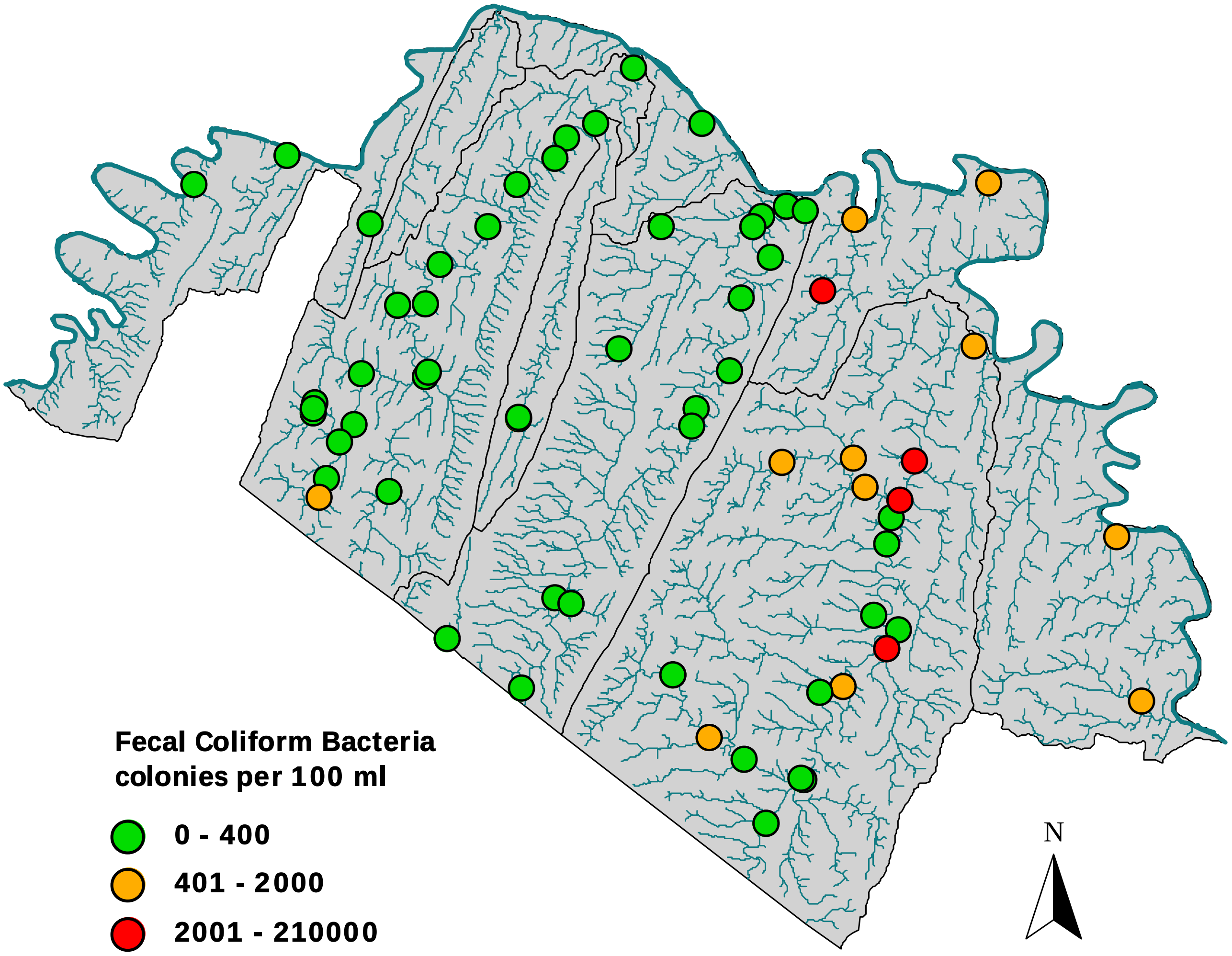


Many of the sub-watershed’s samples had detectable concentrations of phosphorus while only 1 each from the Sleepy Creek and Back Creek sub-watersheds registered above the detection limit of 0.02 mg/L.

Relatively high nutrient concentrations are expected from karstic regions because of agricultural activities combined with unusual drainage patterns. The relatively flat topography and generally alkaline soils that characterize such regions have resulted in their agricultural usage since the first Euro-Americans settled in North America. Artificial fertilization with manure, compost, or chemical additives is the usual practice on pastures, hayfields, and row croplands. Rock strata fractures, abundant in karstic land, allow for quick passage of nutrients from the soil to groundwater. Groundwater in karst regions is typically found in underground streams and often makes its way to the surface via springs. With short residence time in rock strata, groundwater remains highly nutrient-laden when it discharges into surface streams.

Another phenomenon associated specifically with the nitrate portion of karstic groundwater nutrient loads is the prolific activity of cavern-dwelling, nitrogen-fixing bacteria. These troglodytic bacteria contribute significantly to the nitrate load of limestone-influenced groundwater. Such bacteria

Figure 17. Fecal coliform bacteria levels



convert atmospheric nitrogen to readily water-soluble nitrate.

There were 2 violations of the iron water quality standard detected during this study. However, the samples from *Sleepy Creek* at mile point 10.0 (WVP-9-{10.0}) and *Meadow Branch* at mile point 12.8 (WVP-9-B-{12.8}) may not really have been in violation of the standard. Both values reported by the laboratory appear to be transcription errors. The reported iron value for *Sleepy Creek* (3,590 mg/L) appears to be a copy of the reported value for magnesium and the reported iron value for *Meadow Branch* (1,550 mg/L) appears to be an accidental transposition with the value given for magnesium (924 mg/L). At no other sample site was the magnesium concentration lower than the iron concentration. Indeed, this phenomenon occurs only rarely in some streams impacted by mine drainage. These analytical results for iron are suspect and should not be used to determine water quality at these sites.

Physical Habitat

While there is no clear correlation between WVSCI and total habitat scores within the 3 major sub-watersheds, it is noteworthy that habitat scores were slightly worse in the Opequon Creek sub-watershed than in the other 2 major sub-watersheds. The Back Creek sub-watershed had nearly 19% of its comparable sites' habitat scores within the optimal range (160 or greater). Approximately 16% of Sleepy Creek sub-watershed's comparable sites were considered optimal, while no Opequon Creek sub-watershed comparable site produced a total habitat score higher than 151.

The miscellaneous streams sub-watershed X-Y graph shows some correlation between the WVSCI and RBP habitat scores. It is interesting to note that the lowest habitat scores are from the sites that drain karstic land. Perhaps a combination of higher nutrients often associated with karst streams and poorer habitat found at these 5 sites caused the lower WVSCI scores.

Table 7. Sites with nitrite+nitrate-nitrogen >1.0 mg/L.

Stream Name	ANCode	WVSCI	P	N
Eagle Run	WVP-4-B	15.69	1.55	21.0
UNT/Potomac R (Teague's Run)	WVP-2.2-{0.3}	50.95	0.0222	6.60
Tuscarora Creek	WVP-4-C-{0.2}	22.59	0.305	3.94
Tuscarora Creek	WVP-4-C-{1.5}	22.06	0.366	3.91
Elk Branch	WVP-1-A-{0.8}	46.33	0.0402	3.22
Tuscarora Creek	WVP-4-C-{6.0}	49.79	0.0312	3.00
Opequon Creek	WVP-4-{29.2}	61.50	0.175	2.81
Opequon Creek	WVP-4-{17.8}	33.55	0.162	2.80
Mill Creek	WVP-4-M-{7.8}	20.22	0.0357	2.69
Mill Creek	WVP-4-M-{7.8}	31.60	<0.02	2.49
Opequon Creek	WVP-4-{1.3}	46.97	0.123	2.15
Opequon Creek	WVP-4-{18.8}	69.02	0.101	2.15
Opequon Creek	WVP-4-{9.8}		0.0919	2.02
Tullis Br (Tulisus)	WVP-5-A-{1.4}	66.15	0.099	1.82
Torytown Run	WVP-4-M-2	29.31	<0.02	1.25

Results by sub-watershed

The following discussions focus on the biologically impaired streams and those with scores that indicate further data collection is warranted to determine whether or not they should be considered impaired. Known causes and sources of impairment are presented, and probable causes and sources are discussed. A few non-benthically sampled sites are discussed also. The discussions are grouped into sub-watersheds. The maps show sample site locations. The tables present a few results from each of the sites within each sub-watershed. See the example table (Figure 6) illustrated previously in the report section titled *Data Interpretation*.

Table 8. Back Creek Sub-watershed.

Stream Name	ANCode	RBP	WVSCI	Fecal
Back Creek	WVP-6-(1.2)	158	77.66	41
Back Creek	WVP-6-(9.1)	118	80.34	161
Back Creek	WVP-6-(17.3)	139	82.48	100
Back Creek	WVP-6-(18.4)	130	79.59	106
Back Creek	WVP-6-(33.8)	149	83.68	13
Tilhance Ck	WVP-6-A-(0.5)	166	71.58	71
Tilhance Ck	WVP-6-A-(1.3)	163	74.17	65
Tilhance Ck	WVP-6-A-(9.4)	132	88.59	50
UNT/Back Ck	WVP-6-A.1	145	72.28	240
Kates Run	WVP-6-A.2	159	70.28	217
UNT/Back Ck	WVP-6-A.5-(0.2)	152	70.81	360
Higgins Run	WVP-6-A-1-(1.6)	155	74.05	270
UNT/Back Ck	WVP-6-C.8-(0.6)	157	87.76	156
Sawmill Run	WVP-6-D	159	63.9	300
Sawmill Run	WVP-6-D	156	69.7	250
Little Brush Ck	WVP-6-G-1	168	81.92	30

Back Creek Sub-watershed

Figure 13 presents the WVSCI vs. total RBP habitat score graph for the Back Creek sub-watershed. The scores and bacteria concentrations are shown in Table 8. Note that all WVSCI scores except 1 are in the unimpaired category. One of *Sawmill Run's* samples, duplicate no. 1 (WVP-6-D Dup#1), fell within the "gray zone." There is no clear correlation between WVSCI and habitat scores.

Nothing on either of the habitat assessment forms for *Sawmill Run* indicate what might have been the causes of impairment to the sample collected from Duplicate #1. This stream should be sampled again during the next assessment cycle.

It is relatively surprising that not 1 of the sites sampled in the Back Creek sub-watershed produced a fecal coliform bacteria concentration greater than the 400/100 mL water quality criterion, because there were a number of cattle rearing operations within the sub-watershed.

Figure 18. Back Ck.

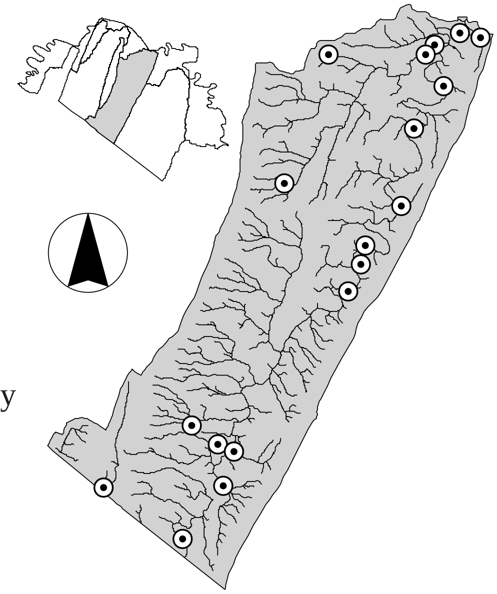


Table 9. Sleepy Creek Sub-watershed.

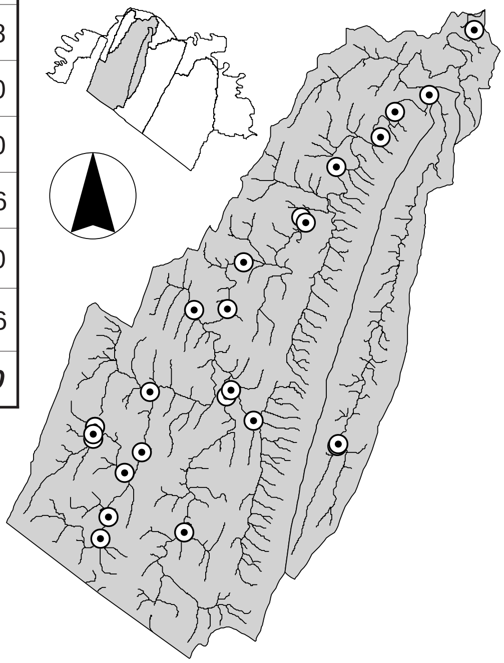
Stream Name	ANCode	RBP	WVSCI	Fecal
Sleepy Creek	WVP-9-(1.0)	164	78.54	80
Sleepy Creek	WVP-9-(10.0)	168	78.02	71
Sleepy Creek	WVP-9-(12.2)	153	79.21	7
Sleepy Creek	WVP-9-(15.2)	160	85.76	150
Sleepy Creek	WVP-9-(18.2)	126	69.86	124
Sleepy Creek	WVP-9-(21.6)	143	80.66	160
Sleepy Creek	WVP-9-(23.6)	149	87.67	167
Sleepy Creek	WVP-9-(33.2)	161	75.33	75
Sleepy Creek	WVP-9-(35.6)	162	79.63	290
Sleepy Creek	WVP-9-(36.8)	155	80.36	***560***
Meadow Branch	WVP-9-B-(0.0)	161	72.99	66
Meadow Branch	WVP-9-B-(12.8)	162	66.34	***420***
Roaring Run	WVP-9-B-1-A-(0.1)	182	76.66	10
Lick Run	WVP-9-D.8-(0.5)	143	79.61	18
Middle Fk/Sleepy Ck	WVP-9-E-(1.5)	143	71.84	44
Middle Fk/Sleepy Ck	WVP-9-E-(7.0)	113	66.41	230
South Fk/Sleepy Ck	WVP-9-E-1	140	86.01	280
Rock Gap Run	WVP-9-F	144	83.14	28
Indian Run	WVP-9-G-(0.25)	151	83.23	80
North Fork Run	WVP-9-G-1	130	79.69	40
North Fork Run	WVP-9-G-1	124	74.22	66
South Fk/Indian Ck	WVP-9-G-2-(0.0)	163	88.34	10
Middle Fk/Indian Rn	WVP-9-G-3	136	76.09	66
Hands Run	WVP-9-I	137	91.53	***1100***

Sleepy Creek Sub-watershed

The WVSCI vs. total habitat score graph for the Sleepy Creek sub-watershed (Figure 14) shows the scores for each sample. The spread of these data is very similar to that from the Back Creek sub-watershed. As in the Back Creek sub-watershed graph, there is no clear correlation between WVSCI and habitat scores. Only 2 samples produced WVSCI scores within the "gray zone." All other WVSCI scores are considered unimpaired.

Nothing recorded on the habitat assessment form indicates what may have been the causes of impairment to the benthic community at milepoint 12.8 on *Meadow Branch*. The same can be said for *Middle Fork/Sleepy Creek* at milepoint 7.0. These streams should be sampled again during the next assessment cycle.

Figure 19. Sleepy Ck.



Only 3 bacteria samples had concentrations above the 400/100 mL criterion. The 1 collected at the upper Meadow

Branch site is the most surprising. However, there is a large population of deer in the Sleepy Creek Wildlife Management Area wherein the site is located. A note on the assessment form indicated that within the past 24 hours, rain had fallen. It is possible that deer scat contributed to the bacteria concentration detected at the site. It should be noted that the bacteria concentration was barely above the appropriate water quality criterion.

Opequon Creek Sub-watershed

Of the 19 comparably-sampled benthic samples, 18 produced samples with WVSCI scores in the "impaired" category. *Eagle Run* (WVP-4-B) produced the lowest WVSCI score of all samples collected during the study. The highest concentration of bacteria detected during this study (210,000/100 mL) was found in *Eagle Run*. Notes on the assessment form make clear that a sewage treatment plant on a tributary of the run was the likely source of bacteria.

Mill Creek at milepoint 7.8 was accidentally sampled twice (once each by 2 different teams) and 1 of the samples produced the second lowest WVSCI score detected during the study. The other 2 *Mill Creek* samples (1 from duplicate milepoint 7.8 and 1 from near the mouth) also scored in the "impaired" category.

Fourteen samples from 10 other sites scored in the "impaired" category. One of the sites, *Silver Spring Run* was inadvertently sampled twice, and each sample produced a WVSCI score within the "impaired" category.

Torytown Run also was sampled twice by mistake and both samples scored in the "impaired" category.

Table 10. Opequon Creek Sub-watershed.

Stream Name	ANCode	RBP	WVSCI	Fecal
Opequon Ck	WVP-4-(1.3)	120	46.97	***420***
Opequon Ck	WVP-4-(9.8)	114		106
Opequon Ck	WVP-4-(17.8)	102	NC33.55	167
Opequon Ck	WVP-4-(18.8)	108	NC69.02	300
Opequon Ck	WVP-4-(29.2)	151	61.50	172
Eagle Run	WVP-4-B	129	15.69	***210000***
Tuscarora Ck	WVP-4-C-(0.2)	127	22.59	***2750***
Tuscarora Ck	WVP-4-C-(1.5)	122	NC22.06	**1660**
Tuscarora Ck	WVP-4-C-(6.0)	120	49.79	***1850***
Dry Run	WVP-4-C-1	102	46.05	***1200***
Evans Run	WVP-4-D	124	46.34	100
Hopewell Run	WVP-4-I	137	37.91	***3200***
Hopewell Run	WVP-4-I	123	42.02	***2550***
Middle Creek	WVP-4-J	133	55.53	***680***
Goose Creek	WVP-4-J-(1.2)	141	50.76	135
Mill Creek	WVP-4-M	114	57.85	350
Mill Creek	WVP-4-M-(7.8)	148	31.6	***870***
Mill Creek	WVP-4-M-(7.8)	148	20.22	290
Sylvan Run	WVP-4-M-1	136	46.77	105
Torytown Run	WVP-4-M-2	137	29.31	***600***
Torytown Run	WVP-4-M-2	126	45.18	***410***
Silver Spring Rn	WVP-4-P	130	38.23	62
Silver Spring Rn	WVP-4-P	129	39.24	250

Opequon Creek at mile point 29.2 was categorized in the “gray zone.”

Many of the macroinvertebrate samples that scored poorly, did so partly because of an overabundance of 1 taxon, most generally the family of midges, *Chironomidae*. Other overabundant taxa from some of these samples include the caddisfly family *Hydropsychidae* and the scud family *Gammaridae*. All 3 of these taxa are considered tolerant of nutrient pollution and the scuds are usually partial to highly alkaline streams. The discussion of physicochemical results presented above in the section titled *Physicochemical Water Quality*, gives greater insight into the likelihood that nutrient pollution within the Opequon Creek sub-watershed resulted in the depressed WVSCI scores.

As previously noted, *Eagle Run* produced the lowest scoring macroinvertebrate sample during the entire study. The WVSCI was an incredibly low 15.69. The habitat score was relatively low, but several other sites had poorer habitat yet produced diverse and healthy-looking benthic communities. The major problems at *Eagle Run* appear to have been water quality related. For instance, the highest NO2+NO3-N concentration detected (21.0 mg/L) was from the *Eagle Run* sample. The highest bacteria concentration (210,000/100 mL) was produced from *Eagle Run* as well. The 1.55 mg/L concentration of total phosphorus from the sample was also the highest detected. Notes on the assessment form indicate that sewage sludge was abundant in the 100 meter sampling reach. A sewage treatment facility on a tributary of *Eagle Run* was the likely culprit.

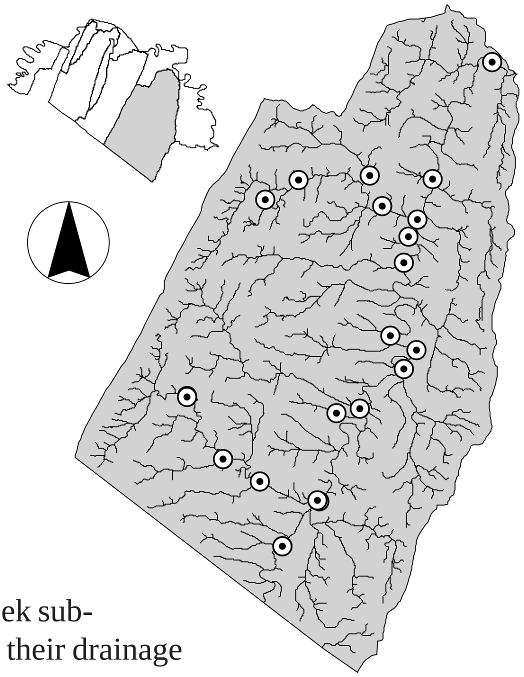
Improperly treated sewage was also implicated as the cause of the poor WVSCI score of the lower *Tuscarora Creek* sample (WVP-4-C-{0.2}). The Martinsburg sewage treatment system has been plagued with infiltration/inflow problems for years. The high fecal coliform bacteria, NO2+NO3-N, and total P concentrations (2,750/100mL, 3.94 mg/L, & 0.305 mg/L) provide evidence that problems still existed during the study. Sewage sludge was present within the 100 meter sampling reach.

Tuscarora Creek produced bacteria values higher than 1,000/100 mL at each of the 3 sites sampled. The upstream site (WVP-4-C-{6.0}) is located in a pasture with “many cattle trails in and along the stream,” according to a note on the habitat assessment form. The lower 2 sites (WVP-4-C-{1.5} & {0.2}) are located below the Martinsburg sewage treatment plant discharge. Sediment was described at both lower sites as smelling “septic.”

Both of the *Hopewell Run* duplicate samples exhibited high bacteria concentrations (2,550/100 mL & 3,200/100 mL). One note described the sediment as having a “cow-pie odor” yet neither assessment form indicated pasture or livestock access within the 100 meter sampling reach.

Of the 15 sites comparably sampled in the Opequon Creek sub-watershed, only 5 had forest coverage greater than 50% over their drainage

Figure 20. Opequon Ck.



basins and only 1 of these had forest coverage over 60%. One of the 5 sites, *Goose Creek*, was sampled in a manner that may not have been comparable. Notes on the assessment form said, “8 kicks were taken from mostly slow runs [...] also involved hand pick [...] Extremely difficult to sample [...] Stream bed composed mainly of bedrock shale”. *Eagle Run* had the highest percentage in urban landuse (17.37%). This was the highest urban coverage of all sites in the entire Potomac River Direct Drains watershed. The only other sites in the entire watershed with more than 10% urban coverage over their basins are 2 Tuscarora Creek sites (milepoints 0.2 & 1.5).

Miscellaneous Streams

Eight comparably sampled sites are not located within the previously discussed sub-watersheds. These sites plus MACS-sampled Tullis Branch make up a small, noncontiguous “pseudo-watershed.” Four of these sites drain karstic land; *Elk Branch*, *Teagues Run*, *Harlan Run*, and *Jordan Run* (drains karst and shale). *Tullis Branch* drains karst also, but was sampled using the MACS protocol. The other sites, *Big Run*, *Sir Johns Run*, *Willet Run*, and *Rockwell Run* drain watersheds underlain primarily by sandstones and shales.

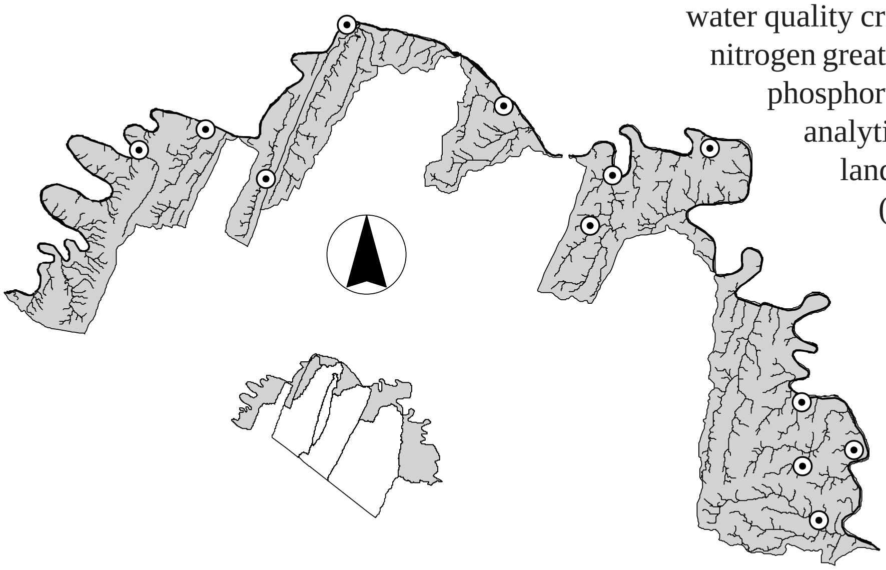
The second highest fecal coliform bacteria concentration (11,000/100 mL) detected in the Potomac Direct Drains watershed came from *Tullis Branch* (locally called *Tulisus Branch*). This sample was collected approximately 12 hours after a violent thunderstorm poured rain on the basin, making it impossible to sample the swollen stream for benthos immediately afterwards. Even though the sample was collected the following day, the water was still turbid, so the bacteria value was likely abnormally elevated above baseflow values. This concentration should not be considered comparable to others from streams sampled during more normal flow conditions.

Table 11. Miscellaneous streams.

Stream Name	ANCode	RBP	WVSCI	Fecal	NO2+-NO3-N (mg/L)
Elk Branch	WVP-1-A-(0.8)	103	46.33	***774***	***3.22***
UNT/Potomac R (Teague's Rn)	WVP-2.2-(0.3)	142	50.95	***880***	***6.60***
Jordan Run	WVP-4.5	119	64.26	***1200***	
Harlan Run	WVP-5	141	56.8	***840***	
Tullis Branch	WVP-5-A-(1.4)	106	NC66.15	***11000***	***1.82***
Big Run	WVP-8	156	73.74	160	
Sir Johns Run	WVP-12-(5.2)	155	77.12	100	0.07
Willet Run	WVP-15-(0.4)	162	91.29	72	0.11
Rockwell Run	WVP-16-(0.1)	166	92.75	6	0.10

Note that all the karst-draining streams produced violations of the bacteria criterion, relatively high nitrite+nitrate-nitrogen concentrations, and relatively low WVSCI scores (either within the “gray zone” or “impaired” range). Table 12 shows various aspects of the sample sites and their drainage areas. Emboldened, italicized numbers call attention to specific key points for consideration. These numbers include (1) fecal coliform

Figure 21. Miscellaneous Streams



bacteria concentrations above the appropriate water quality criterion, (2) nitrite+nitrate-nitrogen greater than 1.0 mg/L, (3) total phosphorus above the 0.02 mg/L analytical detection limit, (4) forested land coverage less than 50%, and (5) open or brushy land (including hay and pasture lands) greater than 50% coverage. The table clearly shows that each of the karst-draining streams has at least 1 of these aspects highlighted.

Jordan Run is the only comparably sampled, karst-draining stream that did not produce a WVSCI score in the impaired range. Keep in mind that this stream drains some land underlain by shale geology and that its watershed area was slightly over 50% forested, while less than 50% was covered in open or brushy land. These characteristics make Jordan Run somewhat similar to the sites that drain no karst.

In one sense, within this "pseudo" sub-watershed is seen a microcosm of the entire Potomac River Direct Drains watershed as studied during this assessment. The karst streams (like most of the Opequon Creek sub-watershed sampling sites) did poorly in a number of categories (e.g., WVSCI scores, nutrient pollution, and bacteria concentrations), while most of the non-karst streams (like most

Table 12. Miscellaneous streams sub-watershed landuse area percentages.

								Landuse percentages				
Stream Name	ANCode	WVSCI	Fecal	NO2+ NO3-- N (mg/L)	Total P (mg/L)	Stream order	Ann. 30-yr. avg. flow (cfs)	Forest	Open or Brushy	Row crop	Urban	Barren
Elk Branch	WVP-1-A	46.33	***774***	***3.22***	***0.0402***	2	15.11	***17.93***	***72.56***	6.73	1.89	0.04
UNT/Potomac R (Teague's Rn)	WVP-2.2	50.95	***880***	***6.60***	***0.0222***	1	3.06	***21.72***	***70.77***	7.39	0.06	0.00
Jordan Run	WVP-4.5	64.26	***1200***			1	2.22	50.24	32.41	12.29	4.44	0.00
Harlan Run	WVP-5	56.80	***840***			2	30.71	***33.03***	***58.08***	6.55	1.39	0.24
Tullis Br (Tulisus)	WVP-5-A	NC66.15	***11000***	***1.82***	***0.099***	1	6.24	***41.24***	***50.33***	5.42	1.52	0.12
Big Run	WVP-8	73.74	160			1	7.07	76.08	17.57	6.12	0.02	0.00
Sir Johns Run	WVP-12	77.12	100	0.07	<0.02	1	7.11	96.69	1.74	0.20	0.17	0.04
Willet Run	WVP-15	91.29	72	0.110	<0.02	2	7.86	94.09	0.84	0.06	0.02	4.93
Rockwell Run	WVP-16	92.75	6	0.109	<0.02	1	5.55	99.76	0.06	0.17	0.01	0.00

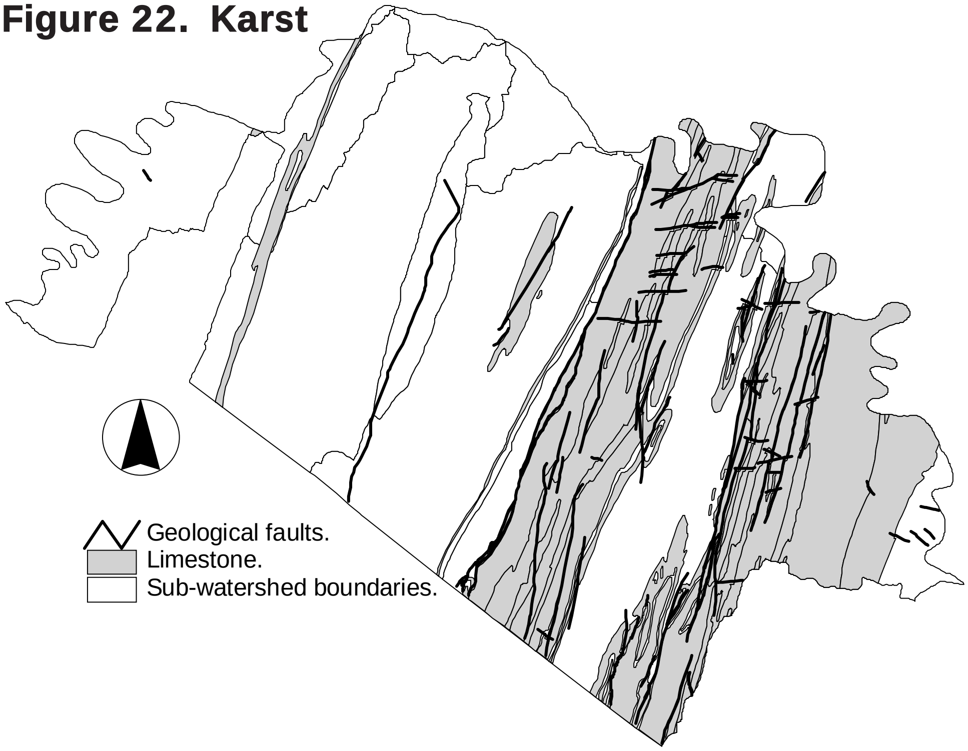
of the Sleepy Creek and Back Creek sub-watershed sites) did much better in the same categories. Table 13 shows the noticeable differences in landuse coverage percentages between the Sleepy Creek and Back Creek (minus *Meadow Branch*) sub-watersheds on the one hand, and the Opequon Creek sub-watershed on the other. Compare these to those of the Miscellaneous streams sub-watershed (Table 12) and it becomes readily apparent that landuse coverages in the karst-draining streams' basins are very similar to one another, but very different from those in the basins that do not drain karstic lands.

Table 13. Major sub-watershed landuses.

Sub-watershed	% Forest	% Hay/Pasture	% Row crops
Back Creek	81.10	16.00	1.91
Sleepy Creek	84.44	12.84	1.30
Opequon Ck	38.88	51.21	3.52

Karstic land is, by definition, relatively level and underlain with limestone, making it suitable for agricultural production. As can be seen from Figure 22, the karst region of the Opequon Creek sub-watershed is riddled with faults. These faults cause even faster rates of infiltration of pollutant laden waters from the agricultural and urban lands above them than would occur if the karst were not fractured. Consequently, spring-fed waters in such faulted karst are usually nutrient rich and relatively heavily laden with bacteria, metals, and other pollutants.

Figure 22. Karst



IMPLICATIONS

Sleepy Creek and Back Creek sub-watersheds appeared to have relatively good stream health based upon the results from the sites sampled during this assessment effort. The data show that not only were forested headwater tributaries supporting diverse benthic communities, but also the main stems over their entire West Virginia lengths produced benthic samples rated as unimpaired. Water quality was relatively good throughout the sample population. Four other comparably-sampled sites outside of the 2 sub-watersheds also received "unimpaired" WVSCI scores; *Big Run*, *Sir Johns Run*, *Rockwell Run*, and *Willet Run*. The *Rockwell Run*, *UNT/Back Creek*, *Little Brush Creek*, and *South Fork/Indian Creek* sites met criteria for reference streams, highly valued by water quality researchers because of their importance in comparative analyses. These 4 streams are part of the West Virginia reference stream list, against which other sampling sites statewide are compared via the WVSCI. Two of these streams (*Rockwell Run* and *South Fork/Indian Creek*) were placed on the Tier 2.5 Waters presumptive list to afford them special protection. The other 2 reference streams were left off of the proposed list accidentally and therefore will have a lower level of protection. They should be considered for nomination to the Tier 2.5 stream list.

The recent second home development phenomenon in the Sleepy Creek and Back Creek sub-watersheds may have a potential positive impact on local water quality. The newest homeowners largely are drawn to the area because of the presence of such amenities as clean air, clean water, forestland recreation opportunities and friendly neighbors. These characteristics of "place" do not meet the oft quoted urban-industrial paradigm of "desirable location." This urban-industrial view places such things as readily extractable natural resources, highly developed transportation facilities, cheap labor, and easily influenced local political control high on the list of desirables. New citizens moving into the sub-watersheds may find common ground with local farmers, and join forces to prevent the wholesale destruction of land by unchecked industrial development and urban sprawl that often follows suburbanization. At the very least, the newcomers can be expected to respond positively to agencies which encourage them to form watershed associations for the long-term protection of water resources even as suburban development continues. However, the potential benefits from second home construction, may also be packaged with the traditional environmental degradation that usually accompanies residential development (i.e., inadequate sewage treatment, increased erosion, diminished vegetated riparian zones, and increased soil imperviousness).

In stark contrast to the Sleepy Creek and Back Creek sub-watersheds, that of Opequon Creek seems to call not so much for protection as for restoration. Restoration is more costly than protection per unit outcome, so the wisdom of expending precious public and private resources on degraded streams while continuing to allow the degradation of healthy waters is questionable. Therefore, restoration activities should be guided by well-researched input/outcome analyses. In this way severely limited funds can be appropriated where the return in improved stream health is likely to be the greatest for the amount of money expended.

Concentrated livestock access and improper sewage treatment are problems that must be dealt with continually in the Opequon Creek sub-watershed. As evidenced by *Eagle Run* and *Tuscarora Creek*, inadequate sewage treatment facilities cause major water quality problems and result in high human health threats. Concentrated livestock stream access usually results in pathogen concentrations lower than those from inadequate sewage treatment facilities. Dairy operations are notable exceptions to this tendency. Although each instance of livestock access is not usually as great a human health threat as each instance of poor sewage treatment, currently within the Opequon Creek sub-watershed livestock waste is a more widespread problem than is sewage. Future studies should target these 2 problems in order to help prioritize enforcement activities and monetary assistance to pollution abatement projects.

The relatively high nutrient concentrations in streams that drain karstic lands are facts of life. Even if no urban areas or agriculture existed on such lands, the nitrogen fixing bacteria inside caverns would likely cause higher background levels of stream nitrate than in areas with no karst. However, nutrients are so abundant in the Opequon Creek sub-watershed that stream health is threatened. Opequon Creek drains into Potomac River, which tumbles toward Chesapeake Bay. One part of West Virginia's responsibility to the East's most significant estuarine resource is to reduce the nutrient load exported to the Bay from tributary sub-watersheds. Agencies with oversight of water quality programs should continue planning vigorous nutrient reduction strategies for the Opequon Creek sub-watershed in particular.

A large percentage of streams were not sampled during this study. In fact, only 37% of the named streams within the watershed were sampled from at least 1 site. Due to random selection procedures not well suited to trellised drainage patterns, a large portion of the random sample population was from sites on the main stems of the 3 large tributaries of the watershed's namesake stream, Potomac River. In future studies, more sites from named and unnamed streams other than *Opequon Creek*, *Back Creek*, and *Sleepy Creek* main stems should be deliberately selected for sampling.

The inclusion of 6 DNR-designated high quality streams on the 303(d) list indicates that the game fisheries therein may be threatened (see Table 4). These streams should receive greater scrutiny in future sampling efforts to determine if special actions should be taken to protect these fisheries. The TMDL development process for these streams should address not only the protection of benthic macroinvertebrate communities, but also that of fish assemblages.

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Glossary

303(d) list -a list of streams that are water quality limited and not expected to meet water quality criteria even after applying technology-based controls. Required by the Clean Water Act and named for the section of the Act in which it appears.

acidity -the capacity of water to donate protons. The abbreviation pH (see definition below) refers to degree of acidity. Higher acidities are more corrosive and harmful to aquatic life.

acid mine drainage (AMD) -acidic water discharged from an active or abandoned mine.

alkalinity -measures water's buffering capacity, or resistance to acidification; often expressed as the concentration of carbonate and bicarbonate.

aluminum -a potentially toxic metallic element often found in mine drainage; when oxidized it forms a white precipitate called "white boy".

ArcView - a brand of Geographic Information System computer software.

benthic macroinvertebrates - small animals without backbones yet still visible to the naked eye, that live on the bottom (the substrate) of a water body and are large enough to be collected with a 595 micron mesh screen. Examples include insects, snails, and worms.

benthic organisms, or benthos - organisms that live on or near the substrate (bottom) of a water body (e.g., algae, mayfly larvae, darters).

buffer -a dissolved substance that maintains a solution's original pH by neutralizing added acid.

canopy -The layer of vegetation that is more than 5 meters from the ground; see understory and ground cover.

cfs - cubic feet per second, a measurement unit of stream discharge.

citizens monitoring team -a group of people that periodically check the ecological health of their local streams.

conductivity (conductance) -the capacity of water to conduct an electrical current, higher conductivities indicate higher concentrations of ions.

CR - County Route.

DEP - Division of Environmental Protection. A unit of the executive branch of West Virginia's state government charged with enforcing environmental laws and monitoring environmental quality.

designated uses -the uses specified in the state water quality standards for each water body or segment (e.g., fish propagation or industrial water supply).

discharge -liquid flowing from a point source; or the volume of water flowing down a stream per unit of time, typically recorded as cfs (cubic feet per second).

discharge permit -a legal document issued by a government regulatory agency specifying the kinds and amounts of pollutants a person or group may discharge into a water body; often called NPDES permit.

dissolved oxygen (DO) - the amount of molecular oxygen dissolved in water, normally expressed in mg/L.

DNR - Department of Natural Resources. A unit of the executive branch of West Virginia state government charged with protecting and regulating the use of wildlife, fish and their habitats.

DWWM - Division of Water and Waste Management. A unit within the DEP that manages a variety of regulatory and voluntary activities to enhance and protect West Virginia's surface and ground waters.

ecoregion -a land area with relative homogeneity in ecosystems that, under unimpaired conditions, contain habitats which should support similar communities of animals (specifically macrobenthos).

ecosystem -the complex of a community and its environment functioning as an ecological unit in nature. A not easily defined aggregation of biotic and abiotic components that are interconnected through various trophic pathways, and that interact systematically in the transfer of nutrients and energy.

effluent -liquid flowing from a point source (e.g., pipe or collection pond).

Environmental Protection Agency (EPA) -a unit in the executive branch of the federal government charged with enforcing environmental laws.

Environmental Quality Board (EQB) -a standing group, whose members are appointed by the governor, that promulgates water quality criteria and judges appeals for relief from water quality regulations.

EPA - Environmental Protection Agency (see definition above).

ephemeral -a stream that carries surface water during only part of the year; a stream that occasionally dries up.

EQB - Environmental Quality Board (see definition above).

eutrophic -a condition of a lake or stream which has higher than normal levels of nutrients, contributing to excessive plant growth. Consequently more food and cover is provided to some macrobenthos than would be provided otherwise. Usually eutrophic waters are seasonally deficient in oxygen.

fecal coliform bacteria -a group of single-celled organisms common in the alimentary tracts of some birds and all mammals, including man; indicates fecal pollution and the potential presence of human pathogens.

GIS - Geographic Information System. Computer programs that allow for the integration and manipulation of spatially anchored data.

GPS - geographic positioning system.

ground cover -vegetation that forms the lowest layer in a plant community defined as less than 0.5 meters high for this assessment .

impaired -as used in this assessment report, a benthic macroinvertebrate community with metric scores substantially worse than those of an appropriate reference site. The total WVSCI score is equal to or less than 60.6.

iron -a metallic element, often found in mine drainage, that is potentially harmful to aquatic life. When oxidized, it forms an orange precipitate called "yellow boy" that can clog fish and macroinvertebrate gills.

karst - a landform in areas underlain by limestone and characterized by relatively flat or rolling terrain, numerous water sinkholes and springs, and relatively dry upland soils. Caves and caverns are common in karstic regions.

lacustrine - of or having to do with a lake or lakes.

MACS -Mid-Atlantic Coastal Streams -macrobenthic sampling methodology used in streams with very low gradient that lack riffle habitat suitable for The Section's preferred procedure.

manganese -a metallic element, often found in mine drainage, that is potentially harmful to aquatic life.

metrics -statistical tools used by ecologists to evaluate biological communities.

MRLC -1993 **M**ulti-**R**esolution **L**and **C**haracteristics coverage in the WCMS.

NO2+NO3-N - nitrite plus nitrate nitrogen.

National Pollutant Discharge Elimination System (NPDES) -a government permitting activity created by section 402 of the federal Clean Water Act of 1972 to control all discharges of pollutants from point sources. In West Virginia this activity is conducted by the Division of Water Resources.

N/C - not comparable.

nonpoint source (NPS) pollution -contaminants that run off a broad landscape area (e.g., plowed field, parking lot, dirt road) and enter a receiving water body.

oligotrophic - a stream, lake or pond which is poor in nutrients.

P - phosphorus.

palustrine - of or having to do with a marsh, swamp or bog.

pH -indicates the concentration of hydrogen ions; a measure of the intensity of acidity of a liquid. Represented on a scale of 0-14, a pH of 1 describes the strongest acid, 14 represents the strongest base, and 7 is neutral. Aquatic life cannot tolerate either extreme.

point source -a specific, discernible site (e.g., pipe, ditch, container) locatable on a map as a point, from which pollution discharges into a water body.

RBP - Rapid Bioassessment Protocol. Relatively quick methods of comparatively assessing biological communities.

reference site -a stream reach that represents an area's (watershed or ecoregion) least impacted condition; used for comparison with other sites within that area. Site must meet the agency's minimum degradation criteria.

SCA -Soil Conservation Agency.

Section - The Watershed Assessment Section of the WV Division of Water Resources.

SPOT image - a geographic information system coverage layer that mimics black and white satellite imagery.

stakeholder -a person or group with a vested interest in a watershed, e.g., landowner, business person, angler.

STORET -**STO**rage and **RET**rieval of U.S. waterways parametric data -a system maintained by EPA and used by DWWM to store and analyze water quality data.

sub-watershed - a smaller drainage area within a watershed.

total maximum daily load (TMDL) -the total amount of a particular pollutant that can enter a water body and not cause a water quality standards violation.

turbidity -the extent to which light passes through water, indicating its clarity; indirect measure of suspended sediment.

understory -the layer of vegetation that form a forest's middle layer (defined as 0.5 to 5 meters high for this assessment).

unimpaired -as used in this assessment report, a benthic community with metric scores similar to those of an appropriate reference site. Total WVSCI score greater than 68.0.

UNT -unnamed tributary.

USGS -United States Geological Survey.

water-contact recreation -the type of designated use in which a person (e.g., angler, swimmer, boater) comes in contact with the stream's water.

watershed -a geographic area from which water drains to a particular point.

Watershed Approach Steering Committee -a task force of federal (e.g., U.S. Environmental Protection Agency, US Geological Survey) and state (e.g., Division of Environmental Protection, Soil Conservation Agency) officers that recommends streams for intense, detailed study.

Watershed Assessment Section -a group of scientists within the DWWM charged with evaluating and reporting on the ecological health of West Virginia's watersheds.

watershed association -a group of diverse stakeholders working via a consensus process to improve water quality in their local streams.

Watershed Network -an informal coalition of federal, state, multi-state, and non-governmental groups cooperating to support local watershed associations.

WCMS - **W**atershed **C**haracterization and **M**odeling **S**ystem, an ArcView-based GIS program developed by the Natural Resource Analysis Center of West Virginia University.

APPENDIX A - DATA TABLES

Table A-1. Sites Sampled.

Stream Name	Stream Code	Date	Latitude			Longitude			County
Elk Branch	WVP-1-A-{0.8}	6/2/1998	39	20	40.41	77	46	52.94	Jefferson
UNT/Potomac River (Teague's Run)	WVP-2.2-{0.3}	6/2/1998	39	25	32.21	77	47	35.66	Berkeley
Opequon Creek	WVP-4-{1.3}	6/2/1998	39	31	18.29	77	52	47.57	Berkeley
Opequon Creek	WVP-4-9.8}	6/2/1998	39	26	18.62	77	56	9.5	Berkeley
Opequon Creek	WVP-4-{17.8}	6/9/1998	39	23	27.23	77	56	56.22	Berkeley
Opequon Creek	WVP-4-{18.8}	6/3/1998	39	23	1.32	77	55	59.25	Berkeley
Opequon Creek	WVP-4-{29.2}	6/9/1998	39	18	42.41	77	59	48.87	Berkeley
Eagle Run	WVP-4-B	6/10/1998	39	27	58	77	55	10	Berkeley
Tuscarora Creek	WVP-4-C-{0.2}	6/10/1998	39	26	49	77	55	47	Berkeley
Tuscarora Creek	WVP-4-C-{1.5}	6/3/1998	39	27	14.51	77	57	5.27	Berkeley
Tuscarora Creek	WVP-4-C-{6}	6/1/1998	39	28	3.94	78	0	12.51	Berkeley
Dry Run	WVP-4-C-1-{0.4}	6/3/1998	39	28	7.78	77	57	32.07	Berkeley
Evans Run	WVP-4-D	6/10/1998	39	25	34	77	56	21.5	Berkeley
Hopewell Run	WVP-4-I	6/9/1998	39	22	28.04	77	56	28.3	Jefferson
Hopewell Run	WVP-4-I	6/9/1998	39	22	28.04	77	56	28.3	Jefferson
Middle Creek	WVP-4-J-{0.1}	6/9/1998	39	21	22.43	77	58	12.09	Berkeley
Goose Creek	WVP-4-J-1-{1.2}	6/8/1998	39	21	15.92	77	59	4.29	Berkeley
Mill Creek	WVP-4-M	6/9/1998	39	18	44.73	77	59	54.12	Berkeley
Mill Creek	WVP-4-M-{7.8}	6/3/1998	39	21	53.91	78	4	37.84	Berkeley
Mill Creek	WVP-4-M-{7.8}	6/10/1998	39	21	53	78	4	38	Berkeley
Sylvan Run	WVP-4-M-1	6/8/1998	39	19	21.17	78	2	1.72	Berkeley
Torytown Run	WVP-4-M-2	6/3/1998	39	20	2.32	78	3	21.39	Berkeley
Torytown Run	WVP-4-M-2	6/10/1998	39	20	2.32	78	3	21.39	Berkeley
Silver Spring Run	WVP-4-P	6/4/1998	39	17	26.69	78	1	16.07	Berkeley
Silver Spring Run	WVP-4-P	6/10/1998	39	17	26.69	78	1	16.07	Berkeley
Jordan Run	WVP-4.5-{0.5}	6/23/1998	39	36	6	77	51	58.5	Berkeley
Harlan Run	WVP-5	6/23/1998	39	35	9	77	57	10	Berkeley
Tullis Branch (Tulisus)	WVP-5-A-{1.4}	6/24/1998	39	33	5.5	77	58	28	Berkeley
Back Creek	WVP-6-{1.2}	6/2/1998	39	35	37.03	77	59	45.16	Berkeley
Back Creek	WVP-6-{9.1}	6/2/1998	39	32	57.78	78	1	32.48	Berkeley
Back Creek	WVP-6-{17.3}	6/3/1998	39	29	43.81	78	3	25.21	Berkeley
Back Creek	WVP-6-{18.4}	6/3/1998	39	29	12	78	3	35.8	Berkeley
Back Creek	WVP-6-{33.8}	6/8/1998	39	21	40.5	78	10	23.1	Berkeley
Tilhance Creek	WVP-6-A-{0.5}	6/9/1998	39	35	18.4	78	0	40.1	Morgan
Tilhance Creek	WVP-6-A-{1.3}	6/9/1998	39	35	2.2	78	1	1	Berkeley
Tilhance Creek	WVP-6-A-{9.4}	6/9/1998	39	31	32.8	78	6	16.7	Berkeley
Higgins Run	WVP-6-A-1-{1.6}	6/2/1998	39	35	7.49	78	4	32.64	Berkeley
UNT/Back Creek	WVP-6-A.1	6/2/1998	39	35	28.18	77	58	59.82	Berkeley
Kates Run	WVP-6-A.2	6/2/1998	39	34	7.39	78	0	23.42	Berkeley
UNT/Back Creek	WVP-6-A.5-{0.2}	6/3/1998	39	30	48.76	78	2	5.31	Berkeley
UNT/Back Creek	WVP-6-C.8-{0.6}	6/3/1998	39	24	18.18	78	9	0.59	Berkeley
Sawmill Run	WVP-6-D	6/3/1998	39	24	4.76	78	8	25.82	Berkeley
Sawmill Run	WVP-6-D	6/3/1998	39	24	4.76	78	8	25.82	Berkeley
Little Brush Creek	WVP-6-G-1	6/2/1998	39	23	11	78	13	10	Berkeley
Big Run	WVP-8	6/2/1998	39	38	8.88	78	2	50.73	Morgan
Sleepy Creek	WVP-9-{1}	6/1/1998	39	39	48.84	78	5	22.41	Morgan
Sleepy Creek	WVP-9-{10}	6/1/1998	39	37	50.94	78	8	0.62	Morgan

Table A-1. Sites Sampled (continued).

Stream Name	Stream Code	Date	Latitude			Longitude			County
Sleepy Creek	WVP-9-{12.2}	6/2/1998	39	37	13.89	78	8	30.2	Morgan
Sleepy Creek	WVP-9-{15.2}	6/2/1998	39	36	31.18	78	9	57.16	Morgan
Sleepy Creek	WVP-9-{18.2}	6/3/1998	39	35	17.51	78	11	6.73	Morgan
Sleepy Creek	WVP-9-{21.6}	6/3/1998	39	34	14.06	78	13	1.26	Morgan
Sleepy Creek	WVP-9-{23.6}	6/3/1998	39	33	4.89	78	13	35.56	Morgan
Sleepy Creek	WVP-9-{33.2}	6/10/1998	39	29	35.5	78	16	28	Morgan
Sleepy Creek	WVP-9-{35.6}	6/10/1998	39	28	0.17	78	17	35.5	Morgan
Sleepy Creek	WVP-9-{36.8}	6/10/1998	39	27	28	78	17	53	Morgan
Meadow Branch	WVP-9-B-{0}	6/1/1998	39	38	14	78	6	53.5	Morgan
Meadow Branch	WVP-9-B-{12.8}	6/3/1998	39	29	36.16	78	10	11.02	Berkeley
Roaring Run	WVP-9-B-1-A-{0.1}	6/3/1998	39	29	38.27	78	10	10.28	Berkeley
Lick Run	WVP-9-D.8-{0.5}	6/3/1998	39	33	4.25	78	14	39.66	Morgan
Middle Fork/Sleepy Creek	WVP-9-E-{1.5}	6/3/1998	39	30	55.05	78	13	41.53	Morgan
Middle Fork/Sleepy Creek	WVP-9-E-{7}	6/10/1998	39	27	33.7	78	15	10.7	Morgan
South Fork/Sleepy Creek	WVP-9-E-1	6/4/1998	39	31	4	78	13	33	Morgan
Rock Gap Run	WVP-9-F	6/2/1998	39	31	5	78	16	8.5	Morgan
Indian Run	WVP-9-G-{0.25}	6/10/1998	39	29	5.6	78	17	2.1	Morgan
North Fork Run	WVP-9-G-1	6/1/1998	39	30	15	78	17	56	Morgan
North Fork Run	WVP-9-G-1	6/1/1998	39	30	15	78	17	56	Morgan
South Fork/Indian Creek	WVP-9-G-2-{0}	6/3/1998	39	29	58.05	78	17	59.92	Morgan
Middle Fork/Indian Run	WVP-9-G-3	6/2/1998	39	30	4	78	18	0	Morgan
Hands Run	WVP-9-I	6/10/1998	39	26	18.1	78	18	30.2	Fredrick, Va.
Sir Johns Run	WVP-12-{5.2}	6/1/1998	39	35	27.88	78	15	35.14	Morgan

Table A-2. Physical characteristics of 100 meter stream reach.

Stream Code	Stream Width (m)	Riffle Depth (m)	Run Depth (m)	Pool Depth (m)
WVP-1-A-{0.8}	2.6	0.15	0.3	
WVP-2.2-{0.3}	1.9	0.05	0.15	0.2
WVP-4-{1.3}	10		1	
WVP-4-{9.8}	17		1	
WVP-4-{17.8}	30		1	
WVP-4-{18.8}	60		1	
WVP-4-{29.2}	25	0.1	0.4	0.7
WVP-4-B	2.8	0.06	0.13	0.35
WVP-4-C-{0.2}	7.5	0.1	0.4	
WVP-4-C-{1.5}	46		0.3	0.3
WVP-4-C-{6}	5.5	0.15	0.3	0.4
WVP-4-C-1-{0.4}	2.9	0.6	0.15	0.2
WVP-4-D	7.4	0.1	0.23	0.6
WVP-4-I	4.5	0.1	0.35	0.7
WVP-4-I	3.7	0.08	0.25	0.6
WVP-4-J-{0.1}	5.5	0.1	0.3	
WVP-4-J-1-{1.2}	2.2	0.02	0.07	0.2
WVP-4-M	8.4	0.15	0.3	0.6
WVP-4-M-{7.8}	5.5	0.1	0.25	
WVP-4-M-{7.8}	5.6	0.15	0.25	
WVP-4-M-1	4.7	0.1	0.2	0.4
WVP-4-M-2	3.3	0.25	0.3	0.6
WVP-4-M-2	5.6	0.15	0.4	0.6
WVP-4-P	1.1	0.05		0.2
WVP-4-P	2.1	0.03	0.08	0.4
WVP-4.5-{0.5}	1.6	0.03	0.05	0.2
WVP-5	6.5	0.15	0.2	0.4
WVP-5-A-{1.4}	8.1	0.1	0.15	0.3
WVP-6-{1.2}	22.3	0.15	0.2	
WVP-6-{9.1}	4.5	0.2	0.8	2
WVP-6-{17.3}	24.8	0.1	0.2	0.3
WVP-6-{18.4}	17.3	0.15	0.4	1.5
WVP-6-{33.8}	25	0.25	0.35	0.5
WVP-6-A-{0.5}	15	0.05	0.2	0.5
WVP-6-A-{1.3}	13.7	0.1	0.25	0.5
WVP-6-A-{9.4}	0.9	0.01	0.1	0.25
WVP-6-A-1-{1.6}	2.1	0.02	0.11	0.28
WVP-6-A.1	0.8	0.05	0.1	0.2
WVP-6-A.2	2.4	0.04	0.15	0.32
WVP-6-A.5-{0.2}	2	0.05	0.15	
WVP-6-C.8-{0.6}	2.5	0.05	0.15	0.2
WVP-6-D	2.7	0.05	0.1	0.5
WVP-6-D	2.8	0.1	0.15	0.6
WVP-6-G-1	4	0.1	0.15	0.4
WVP-8	2.8	0.06	0.14	0.25
WVP-9-{1}	19.7	0.15	0.25	0.4

Table A-2. Physical characteristics of 100 M stream reach (cont.).

Stream Code	Stream Width (m)	Riffle Depth (m)	Run Depth (m)	Pool Depth (m)
WVP-9-{10}	16.8	0.15	0.3	0.4
WVP-9-{12.2}	18.8	0.08	0.2	0.5
WVP-9-{15.2}	13.3	0.12	0.3	0.6
WVP-9-{18.2}	15.3		0.2	0.7
WVP-9-{21.6}	19.9	0.15	0.25	0.7
WVP-9-{23.6}	20.5	0.06	0.25	0.6
WVP-9-{33.2}	15.7	0.1	0.2	0.6
WVP-9-{35.6}	6	0.05	0.25	0.5
WVP-9-{36.8}	9	0.05	0.2	0.5
WVP-9-B-{0}	7.8	0.1	0.15	0.25
WVP-9-B-{12.8}	3.7	0.1	0.2	0.4
WVP-9-B-1-A-{0.1}	2	0.1	0.2	0.7
WVP-9-D.8-{0.5}	3.5	0.05	0.1	0.4
WVP-9-E-{1.5}	4.4	0.05	0.2	0.7
WVP-9-E-{7}	2	0.05	0.1	0.6
WVP-9-E-1	3.9	0.08	0.15	0.3
WVP-9-F	5.7	0.08	0.2	0.35
WVP-9-G-{0.25}	9.1	0.05	0.15	1
WVP-9-G-1	2.4	0.03	0.1	0.3
WVP-9-G-1	2.6	0.05	0.08	0.35
WVP-9-G-2-{0}	3.3	0.1	0.2	0.4
WVP-9-G-3	2.3	0.07	0.15	0.25
WVP-9-I	1.2	0.05	0.1	0.1
WVP-12-{5.2}	4.7	0.08	0.2	0.22

Table A-3. Observed Sediment Characteristics.

Stream Code	Sediment odors	Sediment oils	Sediment deposits
WVP-1-A-{0.8}	normal	absent	sand, silt
WVP-2.2-{0.3}	normal	absent	sand,marl,silt
WVP-4-{1.3}	normal	absent	sand,marl
WVP-4-{9.8}	normal	absent	sand,silt
WVP-4-{17.8}	normal	absent	marl,silt
WVP-4-{18.8}	normal	absent	sand,marl,silt
WVP-4-{29.2}	normal	absent	sand,marl,silt
WVP-4-B	sewage	absent	sludge,sand,silt
WVP-4-C-{0.2}	anaerobic	absent	sludge,marl,silt
WVP-4-C-{1.5}	anaerobic	absent	sand,relic shells,marl
WVP-4-C-{6}	normal	absent	sand,silt
WVP-4-C-1-{0.4}	normal	absent	sand,silt
WVP-4-D	normal	absent	marl,silt, leaf pack in upper area
WVP-4-I	manure	absent	sand,marl,silt
WVP-4-I	normal	absent	sand,marl,silt
WVP-4-J-{0.1}	normal	absent	sand,marl,silt
WVP-4-J-1-{1.2}	fishy	absent	sand,silt
WVP-4-M	normal	absent	sand,marl,silt
WVP-4-M-{7.8}	normal	absent	sand,silt
WVP-4-M-{7.8}	normal	absent	sand,silt
WVP-4-M-1	normal	absent	sand,marl,silt
WVP-4-M-2	none	absent	
WVP-4-M-2	normal	absent	sand,marl,silt
WVP-4-P	normal	absent	sand,silt
WVP-4-P	anaerobic	absent	sand,silt,metal hydroxides
WVP-4.5-{0.5}	normal	absent	sand,silt
WVP-5	normal	absent	sand,marl
WVP-5-A-{1.4}	normal	absent	sand,silt
WVP-6-{1.2}	normal	absent	sand
WVP-6-{9.1}	none	absent	silt
WVP-6-{17.3}	normal	absent	sand,silt
WVP-6-{18.4}	none	absent	sand,silt
WVP-6-{33.8}	normal	absent	sand,silt
WVP-6-A-{0.5}	normal	absent	sand,silt
WVP-6-A-{1.3}	normal	absent	sand,silt
WVP-6-A-{9.4}	normal	absent	sand,silt
WVP-6-A-1-{1.6}	none	absent	sand
WVP-6-A.1	normal	absent	sand,silt
WVP-6-A.2	none	absent	silt
WVP-6-A.5-{0.2}	normal	absent	sand,silt
WVP-6-C.8-{0.6}	none	absent	silt
WVP-6-D	normal	absent	sand,silt
WVP-6-D	none	absent	sand
WVP-6-G-1	normal	absent	sand
WVP-8	none	absent	silt
WVP-9-{1}	normal	absent	sand

Table A-3. Observed Sediment Characteristics (continued).

Stream Code	Sediment odors	Sediment oils	Sediment deposits
WVP-9-{10}	normal	absent	sand,silt
WVP-9-{12.2}	normal	absent	sand,silt
WVP-9-{15.2}	normal	absent	sand,silt
WVP-9-{18.2}	normal	slight	sand,silt
WVP-9-{21.6}	normal	absent	sand,silt
WVP-9-{23.6}	normal	absent	sand,silt
WVP-9-{33.2}	normal	absent	sand,silt
WVP-9-{35.6}	normal	absent	sand,silt
WVP-9-{36.8}	normal	absent	sand,silt,clay
WVP-9-B-{0}	normal	absent	sand
WVP-9-B-{12.8}	normal	absent	sand
WVP-9-B-1-A-{0.1}	slightly sulfuric	absent	sand
WVP-9-D.8-{0.5}	normal	absent	sand,silt
WVP-9-E-{1.5}	normal	absent	sand,silt
WVP-9-E-{7}	normal	absent	sand,silt
WVP-9-E-1	normal	absent	sand,silt
WVP-9-F	normal	absent	sand,silt
WVP-9-G-{0.25}	normal	absent	sand,silt
WVP-9-G-1	normal	absent	sand,silt
WVP-9-G-1	normal	absent	sand,silt
WVP-9-G-2-{0}	normal	absent	sand
WVP-9-G-3	normal	absent	sand,marl,silt
WVP-9-I	normal	absent	sand,silt
WVP-12-{5.2}	normal	absent	sand,silt

Table A-4. Substrate composition in benthic collection area.

Stream Code	% bedrock	% boulder	% cobble	% gravel	% sand	% silt	% clay
WVP-1-A-{0.8}	0	0	10	80	10	0	0
WVP-2.2-{0.3}	0	0	20	50	30	0	0
WVP-4-{1.3}	0	45	50	5	0	0	0
WVP-4-{17.8}	0	0	0	0	70	10	20
WVP-4-{29.2}	0	10	50	35	5	0	0
WVP-4-B	0	0	10	60	30	0	0
WVP-4-C-{0.2}	0	10	25	35	30	0	0
WVP-4-C-{1.5}	0	0	0	40	60	0	0
WVP-4-C-{6}	0	0	10	60	30	0	0
WVP-4-C-1-{0.4}	0	0	80	20	0	0	0
WVP-4-D	0	0	20	45	35	0	0
WVP-4-I	0	0	25	40	35	0	0
WVP-4-I	0	0	25	55	20	0	0
WVP-4-J-{0.1}	0	0	20	45	35	0	0
WVP-4-J-1-{1.2}	15	5	25	45	10	0	0
WVP-4-M	0	5	50	35	10	0	0
WVP-4-M-{7.8}	0	40	40	10	10	0	0
WVP-4-M-{7.8}	0	30	50	10	10	0	0
WVP-4-M-1	0	10	55	34	1	0	0
WVP-4-M-2	0	15	70	15	0	0	0
WVP-4-M-2	0	25	30	30	15	0	0
WVP-4-P	0	0	30	50	20	0	0
WVP-4-P	0	5	40	40	10	5	0
WVP-4.5-{0.5}	2	0	0	60	35	0	3
WVP-5	0	0	35	45	20	0	0
WVP-5-A-{1.4}	5	5	45	35	10	0	0
WVP-6-{1.2}	0	5	60	20	15	0	0
WVP-6-{9.1}	0	0	35	60	5	0	0
WVP-6-{17.3}	0	0	40	30	30	0	0
WVP-6-{18.4}	0	0	60	25	15	0	0
WVP-6-{33.8}	0	0	30	45	20	5	0
WVP-6-A-{0.5}	0	5	50	40	5	0	0
WVP-6-A-{1.3}	0	5	30	35	20	10	0
WVP-6-A-{9.4}	0	20	30	30	15	5	0
WVP-6-A-1-{1.6}	0	0	40	50	10	0	0
WVP-6-A.1	0	0	60	25	15	0	0
WVP-6-A.2	0	5	55	30	10	0	0
WVP-6-A.5-{0.2}	0	5	60	25	10	0	0
WVP-6-C.8-{0.6}	0	0	60	30	10	0	0
WVP-6-D	0	0	70	15	15	0	0
WVP-6-D	0	0	70	15	15	0	0
WVP-6-G-1	0	10	60	10	20	0	0
WVP-8	5	0	50	40	5	0	0
WVP-9-{1}	0	15	60	15	10	0	0
WVP-9-{10}	0	10	60	10	20	0	0

Table A-4. Substrate composition in benthic collection area (cont.).

Stream Code	% bedrock	% boulder	% cobble	% gravel	% sand	% silt	% clay
WVP-9-{12.2}	0	0	30	60	8	2	0
WVP-9-{15.2}	0	15	50	20	10	5	0
WVP-9-{18.2}	0	0	30	55	5	10	0
WVP-9-{21.6}	0	0	40	55	5	0	0
WVP-9-{23.6}	0	0	30	50	16	4	0
WVP-9-{33.2}	0	5	45	30	15	5	0
WVP-9-{35.6}	0	5	30	40	20	5	0
WVP-9-{36.8}	0	0	35	45	15	5	0
WVP-9-B-{0}	0	20	80	0	0	0	0
WVP-9-B-{12.8}	0	30	50	10	10	0	0
WVP-9-B-1-A-{0.1}	0	40	40	10	10	0	0
WVP-9-D.8-{0.5}	5	0	30	50	10	5	0
WVP-9-E-{1.5}	0	0	45	40	10	5	0
WVP-9-E-{7}	0	0	20	60	10	10	0
WVP-9-E-1	0	0	40	45	10	5	0
WVP-9-F	10	5	40	30	15	0	0
WVP-9-G-{0.25}	0	5	40	40	10	0	5
WVP-9-G-1	0	0	40	50	8	2	0
WVP-9-G-1	0	0	45	50	5	0	0
WVP-9-G-2-{0}	0	10	60	20	10	0	0
WVP-9-G-3	0	10	30	50	7	3	0
WVP-12-{5.2}	0	15	35	30	20	0	0

Table A-5. Macrobenthic community metrics and WVSCI scores.

Stream Code	Total Taxa	EPT taxa	% EPT	% 2 dom	% chiros	HBI	WVSCI
WVP-1-A-{0.8}	10	4	9.33	66.38	31.24	5.00	46.33
WVP-2.2-{0.3}	11	4	14.61	62.66	20.45	4.97	50.95
WVP-4-{1.3}	12	2	5.33	74.67	10.22	4.52	46.97
WVP-4-{17.8}	11	5	13.57	88.44	80.90	5.58	33.55
WVP-4-{18.8}	19	10	40.24	54.44	40.24	4.66	69.02
WVP-4-{29.2}	14	7	33.33	56.21	28.81	4.68	61.50
WVP-4-B	5	1	1.03	97.44	94.36	6.10	15.69
WVP-4-C-{0.2}	4	1	3.98	92.61	67.61	5.53	22.59
WVP-4-C-{1.5}	7	1	3.72	88.85	77.32	6.46	22.06
WVP-4-C-{6}	13	5	30.61	69.16	48.13	5.20	49.79
WVP-4-C-1-{0.4}	14	4	8.16	64.63	44.22	5.60	46.05
WVP-4-D	13	6	23.50	72.50	60.50	5.38	46.34
WVP-4-I	11	6	25.07	79.83	66.28	5.46	42.02
WVP-4-I	9	5	28.50	87.50	65.50	5.48	37.91
WVP-4-J-{0.1}	14	6	32.04	61.33	44.20	4.90	55.53
WVP-4-J-1-{1.2}	17	6	20.16	69.17	56.13	5.21	50.76
WVP-4-M	15	8	42.26	72.10	42.58	5.04	57.85
WVP-4-M-{7.8}	9	3	8.85	88.02	60.42	5.84	31.60
WVP-4-M-{7.8}	5	2	7.85	95.29	89.01	5.88	20.22
WVP-4-M-1	16	8	26.84	86.44	66.95	5.49	46.77
WVP-4-M-2	7	2	1.00	79.00	60.50	6.02	29.31
WVP-4-M-2	11	5	5.00	65.50	31.00	6.17	45.18
WVP-4-P	13	3	14.29	79.37	59.26	5.35	39.24
WVP-4-P	13	5	14.29	82.76	71.43	5.62	38.23
WVP-4.5-{0.5}	14	5	38.39	54.98	16.59	3.81	64.26
WVP-5	12	5	34.20	60.10	19.17	5.30	56.80
WVP-5-A-{1.4}	15	6	39.62	52.20	11.32	4.70	66.15
WVP-6-{1.2}	16	9	51.15	40.23	9.20	4.16	77.66
WVP-6-{9.1}	17	9	82.78	63.33	8.33	3.27	80.34
WVP-6-{17.3}	18	9	75.96	56.83	5.46	3.07	82.48
WVP-6-{18.4}	15	9	85.25	65.44	5.07	3.13	79.59
WVP-6-{33.8}	20	11	63.04	43.24	16.18	4.08	83.68
WVP-6-A-{0.5}	17	9	53.07	50.28	30.73	4.55	71.58
WVP-6-A-{1.3}	20	10	54.76	55.71	28.57	4.64	74.17
WVP-6-A-{9.4}	17	10	76.67	37.50	5.00	2.97	88.59
WVP-6-A-1-{1.6}	15	9	80.24	80.84	14.97	2.16	74.05
WVP-6-A.1	15	9	72.28	75.74	22.77	2.75	72.28
WVP-6-A.2	15	8	31.61	48.19	10.36	3.89	70.28
WVP-6-A.5-{0.2}	17	8	63.01	68.79	28.32	3.14	70.81
WVP-6-C.8-{0.6}	18	12	88.52	64.59	4.78	2.60	87.76
WVP-6-D	15	9	52.86	73.84	40.33	3.77	63.90
WVP-6-D	15	9	70.12	84.06	24.30	2.62	69.70
WVP-6-G-1	18	10	60.74	43.56	17.18	3.31	81.92
WVP-8	18	10	50.56	47.78	32.22	4.47	73.74
WVP-9-{1}	20	10	62.95	52.13	27.54	3.88	78.54
WVP-9-{10}	15	8	63.44	51.61	7.53	2.90	78.02
WVP-9-{12.2}	20	10	51.41	44.63	25.42	3.67	79.21

Table A-5. Macrobenthic community metrics and WVSCI scores(cont.)

Stream Code	Total Taxa	EPT taxa	% EPT	% 2 dom	% chiros	HBI	WVSCI
WVP-9-{15.2}	18	10	75.94	50.27	7.49	2.81	85.76
WVP-9-{18.2}	18	9	46.86	48.57	32.57	5.19	69.86
WVP-9-{21.6}	19	10	67.23	48.32	20.17	3.96	80.66
WVP-9-{23.6}	16	10	87.98	44.71	6.25	3.03	87.67
WVP-9-{33.2}	19	11	54.21	50.47	38.32	4.20	75.33
WVP-9-{35.6}	20	12	53.00	46.50	32.50	4.00	79.63
WVP-9-{36.8}	19	12	63.78	56.12	16.84	4.28	80.36
WVP-9-B-{0}	16	11	56.50	53.00	38.00	4.14	72.99
WVP-9-B-{12.8}	18	7	39.51	61.95	30.24	3.61	66.34
WVP-9-B-1-A-{0.1}	16	7	79.46	66.96	9.82	2.39	76.66
WVP-9-D.8-{0.5}	15	9	62.07	42.86	9.36	3.54	79.61
WVP-9-E-{1.5}	15	10	43.20	68.45	5.83	3.24	71.84
WVP-9-E-{7}	12	5	48.29	43.90	22.93	3.83	66.41
WVP-9-E-1	18	10	68.42	29.47	8.95	3.49	86.01
WVP-9-F	19	11	69.83	53.63	7.26	3.99	83.14
WVP-9-G-{0.25}	17	10	86.52	62.17	8.26	3.00	83.23
WVP-9-G-1	18	11	82.63	80.84	12.87	2.05	79.69
WVP-9-G-1	15	9	83.98	84.95	11.65	1.96	74.22
WVP-9-G-2-{0}	18	14	66.06	34.55	16.36	3.41	88.34
WVP-9-G-3	18	10	66.79	72.14	20.99	2.74	76.09
WVP-9-I	22	13	75.00	50.00	15.09	2.68	91.53
WVP-12-{5.2}	15	8	66.30	44.75	13.26	3.91	77.12

Table A-6. Numbers of each taxon found at each sample site

Sample site	Taxa	No. of individuals
WVP-1-A-{0.8}	Hydropsychidae	1
WVP-1-A-{0.8}	Tipulidae	4
WVP-1-A-{0.8}	Leptophlebiidae	1
WVP-1-A-{0.8}	Gammaridae	162
WVP-1-A-{0.8}	Ephemerellidae	16
WVP-1-A-{0.8}	Elmidae	49
WVP-1-A-{0.8}	Chironomidae	144
WVP-1-A-{0.8}	Baetidae	25
WVP-1-A-{0.8}	Asellidae	37
WVP-1-A-{0.8}	Simuliidae	22
WVP-2.2-{0.3}	Simuliidae	41
WVP-2.2-{0.3}	Gammaridae	130
WVP-2.2-{0.3}	Tipulidae	3
WVP-2.2-{0.3}	Oligochaeta	1
WVP-2.2-{0.3}	Leptophlebiidae	2
WVP-2.2-{0.3}	Hydropsychidae	1
WVP-2.2-{0.3}	Curculionidae	1
WVP-2.2-{0.3}	Chironomidae	63
WVP-2.2-{0.3}	Baetidae	35
WVP-2.2-{0.3}	Asellidae	24
WVP-2.2-{0.3}	Ephemerellidae	7
WVP-4-{1.3}	Corbiculidae	3
WVP-4-{1.3}	Psephenidae	4
WVP-4-{1.3}	Simuliidae	2
WVP-4-{1.3}	Oligochaeta	2
WVP-4-{1.3}	Hydropsychidae	11
WVP-4-{1.3}	Asellidae	8
WVP-4-{1.3}	Pleuroceridae	2
WVP-4-{1.3}	Chironomidae	23
WVP-4-{1.3}	Elmidae	24
WVP-4-{1.3}	Gammaridae	144
WVP-4-{1.3}	Ephemerellidae	1
WVP-4-{1.3}	Cambaridae	1
WVP-4-{17.8}	Chironomidae	161
WVP-4-{17.8}	Tricorythidae	3
WVP-4-{17.8}	Athericidae	1
WVP-4-{17.8}	Ephemerellidae	1
WVP-4-{17.8}	Hydropsychidae	15
WVP-4-{17.8}	Perlidae	7
WVP-4-{17.8}	Sialidae	1
WVP-4-{17.8}	Tipulidae	2
WVP-4-{17.8}	Elmidae	6
WVP-4-{17.8}	Asellidae	1
WVP-4-{17.8}	Heptageniidae	1
WVP-4-{18.8}	Perlidae	24
WVP-4-{18.8}	Calopterygidae	1
WVP-4-{18.8}	Cambaridae	2
WVP-4-{18.8}	Chironomidae	68
WVP-4-{18.8}	Elmidae	13
WVP-4-{18.8}	Ephemerellidae	8
WVP-4-{18.8}	Heptageniidae	2
WVP-4-{18.8}	Caenidae	4
WVP-4-{18.8}	Hydroptilidae	2
WVP-4-{18.8}	Sialidae	1
WVP-4-{18.8}	Polycentropodidae	1
WVP-4-{18.8}	Psychomyiidae	2
WVP-4-{18.8}	Simuliidae	1
WVP-4-{18.8}	Tricorythidae	6
WVP-4-{18.8}	Veliidae	13
WVP-4-{18.8}	Hydropsychidae	17
WVP-4-{18.8}	Athericidae	1
WVP-4-{18.8}	Baetidae	2
WVP-4-{18.8}	Tipulidae	1
WVP-4-{29.2}	Isonychiidae	6
WVP-4-{29.2}	Caenidae	3
WVP-4-{29.2}	Chironomidae	102
WVP-4-{29.2}	Elmidae	97
WVP-4-{29.2}	Athericidae	7
WVP-4-{29.2}	Hydropsychidae	91
WVP-4-{29.2}	Corydalidae	1
WVP-4-{29.2}	Perlidae	2
WVP-4-{29.2}	Psephenidae	3
WVP-4-{29.2}	Simuliidae	1
WVP-4-{29.2}	Tipulidae	25
WVP-4-{29.2}	Tricorythidae	1
WVP-4-{29.2}	Heptageniidae	7
WVP-4-{29.2}	Ephemerellidae	8
WVP-4-B	Chironomidae	184
WVP-4-B	Hydropsychidae	2
WVP-4-B	Oligochaeta	6
WVP-4-B	Simuliidae	2
WVP-4-B	Elmidae	1

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-4-C-{0.2}	Chironomidae	119
WVP-4-C-{0.2}	Asellidae	6
WVP-4-C-{0.2}	Gammaridae	44
WVP-4-C-{0.2}	Hydropsychidae	7
WVP-4-C-{1.5}	Cambaridae	1
WVP-4-C-{1.5}	Oligochaeta	31
WVP-4-C-{1.5}	Simuliidae	12
WVP-4-C-{1.5}	Chironomidae	208
WVP-4-C-{1.5}	Hydropsychidae	10
WVP-4-C-{1.5}	Physidae	6
WVP-4-C-{1.5}	Nemertea	1
WVP-4-C-{6}	Psephenidae	2
WVP-4-C-{6}	Simuliidae	21
WVP-4-C-{6}	Philopotamidae	1
WVP-4-C-{6}	Oligochaeta	2
WVP-4-C-{6}	Heptageniidae	1
WVP-4-C-{6}	Gammaridae	2
WVP-4-C-{6}	Ephemerellidae	23
WVP-4-C-{6}	Elmidae	39
WVP-4-C-{6}	Chironomidae	206
WVP-4-C-{6}	Baetidae	90
WVP-4-C-{6}	Asellidae	16
WVP-4-C-{6}	Tipulidae	9
WVP-4-C-{6}	Hydropsychidae	16
WVP-4-C-1-{0.4}	Elmidae	1
WVP-4-C-1-{0.4}	Simuliidae	30
WVP-4-C-1-{0.4}	Physidae	3
WVP-4-C-1-{0.4}	Lymnaeidae	3
WVP-4-C-1-{0.4}	Hydropsychidae	6
WVP-4-C-1-{0.4}	Heptageniidae	1
WVP-4-C-1-{0.4}	Gammaridae	12
WVP-4-C-1-{0.4}	Dytiscidae	9
WVP-4-C-1-{0.4}	Corixidae	9
WVP-4-C-1-{0.4}	Chironomidae	65
WVP-4-C-1-{0.4}	Capniidae/Leuctri	1
WVP-4-C-1-{0.4}	Cambaridae	2
WVP-4-C-1-{0.4}	Baetidae	4
WVP-4-C-1-{0.4}	Haliplidae	1
WVP-4-D	Asellidae	8
WVP-4-D	Tipulidae	9
WVP-4-D	Simuliidae	4
WVP-4-D	Sialidae	1
WVP-4-D	Philopotamidae	1
WVP-4-D	Perlidae	1
WVP-4-D	Nemouridae	1
WVP-4-D	Hydropsychidae	24
WVP-4-D	Gammaridae	2
WVP-4-D	Ephemerellidae	14
WVP-4-D	Elmidae	8
WVP-4-D	Chironomidae	121
WVP-4-D	Baetidae	6
WVP-4-I	Tricorythidae	1
WVP-4-I	Chironomidae	230
WVP-4-I	Baetidae	14
WVP-4-I	Athericidae	3
WVP-4-I	Ephemerellidae	5
WVP-4-I	Hydropsychidae	47
WVP-4-I	Philopotamidae	19
WVP-4-I	Simuliidae	18
WVP-4-I	Tipulidae	6
WVP-4-I	Elmidae	3
WVP-4-I	Heptageniidae	1
WVP-4-I	Hydropsychidae	44
WVP-4-I	Simuliidae	4
WVP-4-I	Philopotamidae	5
WVP-4-I	Baetidae	5
WVP-4-I	Caenidae	1
WVP-4-I	Chironomidae	131
WVP-4-I	Ephemerellidae	2
WVP-4-I	Athericidae	6
WVP-4-I	Tipulidae	2
WVP-4-J-{0.1}	Asellidae	1
WVP-4-J-{0.1}	Simuliidae	4
WVP-4-J-{0.1}	Philopotamidae	1
WVP-4-J-{0.1}	Perlidae	2
WVP-4-J-{0.1}	Isonychiidae	1
WVP-4-J-{0.1}	Hydropsychidae	31
WVP-4-J-{0.1}	Gammaridae	1
WVP-4-J-{0.1}	Ephemerellidae	15
WVP-4-J-{0.1}	Elmidae	21

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-4-J-{0.1}	Chironomidae	80
WVP-4-J-{0.1}	Ceratopogonidae	1
WVP-4-J-{0.1}	Baetidae	8
WVP-4-J-{0.1}	Athericidae	4
WVP-4-J-{0.1}	Tipulidae	11
WVP-4-J-1-{1.2}	Ceratopogonidae	1
WVP-4-J-1-{1.2}	Gomphidae	3
WVP-4-J-1-{1.2}	Chironomidae	142
WVP-4-J-1-{1.2}	Chloroperlidae	1
WVP-4-J-1-{1.2}	Dytiscidae	3
WVP-4-J-1-{1.2}	Elmidae	28
WVP-4-J-1-{1.2}	Heptageniidae	5
WVP-4-J-1-{1.2}	Hydropsychidae	33
WVP-4-J-1-{1.2}	Perlidae	4
WVP-4-J-1-{1.2}	Philopotamidae	1
WVP-4-J-1-{1.2}	Physidae	4
WVP-4-J-1-{1.2}	Psephenidae	2
WVP-4-J-1-{1.2}	Sialidae	7
WVP-4-J-1-{1.2}	Tipulidae	3
WVP-4-J-1-{1.2}	Baetidae	7
WVP-4-J-1-{1.2}	Hydrophilidae	3
WVP-4-J-1-{1.2}	Athericidae	6
WVP-4-M	Athericidae	2
WVP-4-M	Baetidae	2
WVP-4-M	Caenidae	1
WVP-4-M	Chironomidae	264
WVP-4-M	Asellidae	3
WVP-4-M	Hydropsychidae	183
WVP-4-M	Elmidae	8
WVP-4-M	Isonychiidae	7
WVP-4-M	Perlidae	1
WVP-4-M	Philopotamidae	3
WVP-4-M	Sialidae	1
WVP-4-M	Simuliidae	28
WVP-4-M	Tipulidae	52
WVP-4-M	Ephemerellidae	62
WVP-4-M	Heptageniidae	3
WVP-4-M-{7.8}	Baetidae	1
WVP-4-M-{7.8}	Tipulidae	3
WVP-4-M-{7.8}	Simuliidae	53
WVP-4-M-{7.8}	Nemertea	1
WVP-4-M-{7.8}	Hydropsychidae	14
WVP-4-M-{7.8}	Heptageniidae	2
WVP-4-M-{7.8}	Elmidae	1
WVP-4-M-{7.8}	Chironomidae	116
WVP-4-M-{7.8}	Ceratopogonidae	1
WVP-4-M-{7.8}	Hydropsychidae	12
WVP-4-M-{7.8}	Heptageniidae	3
WVP-4-M-{7.8}	Elmidae	2
WVP-4-M-{7.8}	Simuliidae	4
WVP-4-M-{7.8}	Chironomidae	170
WVP-4-M-1	Corydalidae	2
WVP-4-M-1	Simuliidae	5
WVP-4-M-1	Baetidae	2
WVP-4-M-1	Elmidae	8
WVP-4-M-1	Ephemerellidae	11
WVP-4-M-1	Gammaridae	1
WVP-4-M-1	Tipulidae	4
WVP-4-M-1	Heptageniidae	5
WVP-4-M-1	Hydropsychidae	69
WVP-4-M-1	Ephemeridae	1
WVP-4-M-1	Hydroptilidae	1
WVP-4-M-1	Isonychiidae	2
WVP-4-M-1	Nemouridae	4
WVP-4-M-1	Sialidae	1
WVP-4-M-1	Chironomidae	237
WVP-4-M-1	Gomphidae	1
WVP-4-M-2	Asellidae	37
WVP-4-M-2	Chironomidae	121
WVP-4-M-2	Dytiscidae	1
WVP-4-M-2	Gammaridae	33
WVP-4-M-2	Hydropsychidae	1
WVP-4-M-2	Simuliidae	6
WVP-4-M-2	Baetidae	1
WVP-4-M-2	Brachycentridae	1
WVP-4-M-2	Baetidae	1
WVP-4-M-2	Hydropsychidae	5
WVP-4-M-2	Chironomidae	62
WVP-4-M-2	Dytiscidae	1
WVP-4-M-2	Elmidae	5
WVP-4-M-2	Ephemerellidae	1
WVP-4-M-2	Gammaridae	37
WVP-4-M-2	Hydroptilidae	2
WVP-4-M-2	Asellidae	69
WVP-4-M-2	Simuliidae	16

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-4-P	Elmidae	38
WVP-4-P	Veliidae	1
WVP-4-P	Sialidae	1
WVP-4-P	Physidae	4
WVP-4-P	Perlidae	6
WVP-4-P	Gerridae	1
WVP-4-P	Dytiscidae	1
WVP-4-P	Chironomidae	112
WVP-4-P	Ceratopogonidae	1
WVP-4-P	Cambaridae	2
WVP-4-P	Caenidae	1
WVP-4-P	Aeshnidae	1
WVP-4-P	Hydropsychidae	20
WVP-4-P	Baetidae	1
WVP-4-P	Physidae	2
WVP-4-P	Philopotamidae	2
WVP-4-P	Perlidae	2
WVP-4-P	Oligochaeta	1
WVP-4-P	Hydropsychidae	23
WVP-4-P	Elmidae	16
WVP-4-P	Corydalidae	6
WVP-4-P	Chironomidae	145
WVP-4-P	Ceratopogonidae	1
WVP-4-P	Caenidae	1
WVP-4-P	Tipulidae	2
WVP-4-P	Cambaridae	1
WVP-4.5-{0.5}	Perlidae	65
WVP-4.5-{0.5}	Tipulidae	5
WVP-4.5-{0.5}	Tabanidae	1
WVP-4.5-{0.5}	Simuliidae	1
WVP-4.5-{0.5}	Physidae	19
WVP-4.5-{0.5}	Chironomidae	35
WVP-4.5-{0.5}	Hydropsychidae	11
WVP-4.5-{0.5}	Baetidae	1
WVP-4.5-{0.5}	Glossosomatidae	1
WVP-4.5-{0.5}	Gammaridae	6
WVP-4.5-{0.5}	Elmidae	51
WVP-4.5-{0.5}	Cambaridae	11
WVP-4.5-{0.5}	Capniidae/Leuctri	3
WVP-4.5-{0.5}	Sialidae	1
WVP-5	Tipulidae	6
WVP-5	Hydropsychidae	43
WVP-5	Simuliidae	73
WVP-5	Philopotamidae	3
WVP-5	Oligochaeta	1
WVP-5	Leptophlebiidae	1
WVP-5	Ephemerellidae	12
WVP-5	Elmidae	8
WVP-5	Chironomidae	37
WVP-5	Asellidae	1
WVP-5	Baetidae	7
WVP-5	Gammaridae	1
WVP-5-A-{1.4}	Heptageniidae	2
WVP-5-A-{1.4}	Tipulidae	1
WVP-5-A-{1.4}	Simuliidae	30
WVP-5-A-{1.4}	Physidae	1
WVP-5-A-{1.4}	Philopotamidae	9
WVP-5-A-{1.4}	Leptophlebiidae	2
WVP-5-A-{1.4}	Hydropsychidae	92
WVP-5-A-{1.4}	Baetidae	18
WVP-5-A-{1.4}	Hygrobatidae	1
WVP-5-A-{1.4}	Asellidae	2
WVP-5-A-{1.4}	Gammaridae	74
WVP-5-A-{1.4}	Branchiobdellidae	1
WVP-5-A-{1.4}	Chironomidae	36
WVP-5-A-{1.4}	Elmidae	46
WVP-5-A-{1.4}	Ephemerellidae	3
WVP-6-{1.2}	Isonychiidae	27
WVP-6-{1.2}	Corbiculidae	2
WVP-6-{1.2}	Polycentropodidae	1
WVP-6-{1.2}	Pleuroceridae	22
WVP-6-{1.2}	Philopotamidae	1
WVP-6-{1.2}	Sialidae	5
WVP-6-{1.2}	Perlidae	4
WVP-6-{1.2}	Simuliidae	11
WVP-6-{1.2}	Psephenidae	3
WVP-6-{1.2}	Elmidae	26
WVP-6-{1.2}	Chironomidae	16
WVP-6-{1.2}	Capniidae/Leuctri	5
WVP-6-{1.2}	Caenidae	1
WVP-6-{1.2}	Baetidae	6
WVP-6-{1.2}	Heptageniidae	1
WVP-6-{1.2}	Hydropsychidae	43

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-6-{9.1}	Baetidae	3
WVP-6-{9.1}	Corydalidae	1
WVP-6-{9.1}	Chironomidae	15
WVP-6-{9.1}	Capniidae/Leuctri	9
WVP-6-{9.1}	Elmidae	8
WVP-6-{9.1}	Caenidae	1
WVP-6-{9.1}	Oligochaeta	2
WVP-6-{9.1}	Tipulidae	1
WVP-6-{9.1}	Cambaridae	1
WVP-6-{9.1}	Gyrinidae	2
WVP-6-{9.1}	Heptageniidae	1
WVP-6-{9.1}	Isonychiidae	71
WVP-6-{9.1}	Perlidae	17
WVP-6-{9.1}	Philopotamidae	3
WVP-6-{9.1}	Polycentropodidae	1
WVP-6-{9.1}	Sialidae	1
WVP-6-{9.1}	Hydropsychidae	43
WVP-6-{17.3}	Tipulidae	1
WVP-6-{17.3}	Tricorythidae	1
WVP-6-{17.3}	Sialidae	2
WVP-6-{17.3}	Planorbidae	1
WVP-6-{17.3}	Philopotamidae	5
WVP-6-{17.3}	Perlidae	14
WVP-6-{17.3}	Isonychiidae	83
WVP-6-{17.3}	Hydropsychidae	9
WVP-6-{17.3}	Heptageniidae	4
WVP-6-{17.3}	Ephemerellidae	2
WVP-6-{17.3}	Elmidae	21
WVP-6-{17.3}	Corbiculidae	1
WVP-6-{17.3}	Coenagrionidae	1
WVP-6-{17.3}	Chironomidae	10
WVP-6-{17.3}	Capniidae/Leuctri	2
WVP-6-{17.3}	Aeshnidae	1
WVP-6-{17.3}	Simuliidae	6
WVP-6-{17.3}	Baetidae	19
WVP-6-{18.4}	Isonychiidae	111
WVP-6-{18.4}	Baetidae	15
WVP-6-{18.4}	Capniidae/Leuctri	2
WVP-6-{18.4}	Chironomidae	11
WVP-6-{18.4}	Corydalidae	1
WVP-6-{18.4}	Elmidae	15
WVP-6-{18.4}	Ephemerellidae	3
WVP-6-{18.4}	Hydropsychidae	31
WVP-6-{18.4}	Tricorythidae	1
WVP-6-{18.4}	Perlidae	4
WVP-6-{18.4}	Philopotamidae	5
WVP-6-{18.4}	Pleuroceridae	1
WVP-6-{18.4}	Simuliidae	3
WVP-6-{18.4}	Tipulidae	1
WVP-6-{18.4}	Heptageniidae	13
WVP-6-{33.8}	Tricorythidae	2
WVP-6-{33.8}	Oligochaeta	3
WVP-6-{33.8}	Chironomidae	67
WVP-6-{33.8}	Athericidae	4
WVP-6-{33.8}	Baetidae	17
WVP-6-{33.8}	Caenidae	6
WVP-6-{33.8}	Philopotamidae	31
WVP-6-{33.8}	Capniidae/Leuctri	1
WVP-6-{33.8}	Tipulidae	1
WVP-6-{33.8}	Corbiculidae	1
WVP-6-{33.8}	Elmidae	15
WVP-6-{33.8}	Gyrinidae	1
WVP-6-{33.8}	Heptageniidae	9
WVP-6-{33.8}	Hydropsychidae	61
WVP-6-{33.8}	Isonychiidae	112
WVP-6-{33.8}	Simuliidae	60
WVP-6-{33.8}	Perlidae	19
WVP-6-{33.8}	Polycentropodidae	1
WVP-6-{33.8}	Ephemerellidae	2
WVP-6-{33.8}	Cambaridae	1
WVP-6-A-{0.5}	Veliidae	1
WVP-6-A-{0.5}	Heptageniidae	4
WVP-6-A-{0.5}	Hydropsychidae	35
WVP-6-A-{0.5}	Isonychiidae	14
WVP-6-A-{0.5}	Perlidae	2
WVP-6-A-{0.5}	Philopotamidae	1
WVP-6-A-{0.5}	Tipulidae	12
WVP-6-A-{0.5}	Elmidae	1
WVP-6-A-{0.5}	Sialidae	2
WVP-6-A-{0.5}	Ephemerellidae	5
WVP-6-A-{0.5}	Corydalidae	2
WVP-6-A-{0.5}	Chironomidae	55
WVP-6-A-{0.5}	Capniidae/Leuctri	5
WVP-6-A-{0.5}	Caenidae	12
WVP-6-A-{0.5}	Baetidae	17

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-6-A-{0.5}	Athericidae	10
WVP-6-A-{0.5}	Gyrinidae	1
WVP-6-A-{1.3}	Hydropsychidae	57
WVP-6-A-{1.3}	Isonychiidae	18
WVP-6-A-{1.3}	Oligochaeta	1
WVP-6-A-{1.3}	Perlidae	2
WVP-6-A-{1.3}	Philopotamidae	8
WVP-6-A-{1.3}	Polycentropodidae	1
WVP-6-A-{1.3}	Gyrinidae	1
WVP-6-A-{1.3}	Simuliidae	1
WVP-6-A-{1.3}	Gomphidae	1
WVP-6-A-{1.3}	Psephenidae	2
WVP-6-A-{1.3}	Baetidae	2
WVP-6-A-{1.3}	Heptageniidae	5
WVP-6-A-{1.3}	Athericidae	10
WVP-6-A-{1.3}	Tipulidae	10
WVP-6-A-{1.3}	Caenidae	15
WVP-6-A-{1.3}	Capniidae/Leuctri	6
WVP-6-A-{1.3}	Ceratopogonidae	1
WVP-6-A-{1.3}	Chironomidae	60
WVP-6-A-{1.3}	Elmidae	8
WVP-6-A-{1.3}	Ephemerellidae	1
WVP-6-A-{9.4}	Elmidae	2
WVP-6-A-{9.4}	Perlidae	9
WVP-6-A-{9.4}	Tipulidae	4
WVP-6-A-{9.4}	Nemouridae	1
WVP-6-A-{9.4}	Leptophlebiidae	32
WVP-6-A-{9.4}	Hydropsychidae	3
WVP-6-A-{9.4}	Heptageniidae	8
WVP-6-A-{9.4}	Ephemerellidae	12
WVP-6-A-{9.4}	Perlodidae	13
WVP-6-A-{9.4}	Dryopidae	4
WVP-6-A-{9.4}	Chironomidae	6
WVP-6-A-{9.4}	Capniidae/Leuctri	3
WVP-6-A-{9.4}	Cambaridae	8
WVP-6-A-{9.4}	Baetidae	9
WVP-6-A-{9.4}	Ameletidae	2
WVP-6-A-{9.4}	Dytiscidae	3
WVP-6-A-{9.4}	Athericidae	1
WVP-6-A-1-{1.6}	Chironomidae	25
WVP-6-A-1-{1.6}	Tipulidae	3
WVP-6-A-1-{1.6}	Rhyacophilidae	1
WVP-6-A-1-{1.6}	Psephenidae	1
WVP-6-A-1-{1.6}	Philopotamidae	6
WVP-6-A-1-{1.6}	Nemouridae	2
WVP-6-A-1-{1.6}	Leptophlebiidae	5
WVP-6-A-1-{1.6}	Hydropsychidae	4
WVP-6-A-1-{1.6}	Gomphidae	2
WVP-6-A-1-{1.6}	Chloroperlidae	2
WVP-6-A-1-{1.6}	Capniidae/Leuctri	110
WVP-6-A-1-{1.6}	Ceratopogonidae	1
WVP-6-A-1-{1.6}	Veliidae	1
WVP-6-A-1-{1.6}	Ephemerellidae	1
WVP-6-A-1-{1.6}	Baetidae	3
WVP-6-A.1	Perlidae	14
WVP-6-A.1	Baetidae	6
WVP-6-A.1	Capniidae/Leuctri	214
WVP-6-A.1	Ceratopogonidae	2
WVP-6-A.1	Chironomidae	92
WVP-6-A.1	Elmidae	6
WVP-6-A.1	Glossosomatidae	1
WVP-6-A.1	Hydropsychidae	35
WVP-6-A.1	Nemouridae	8
WVP-6-A.1	Philopotamidae	11
WVP-6-A.1	Psephenidae	8
WVP-6-A.1	Rhyacophilidae	1
WVP-6-A.1	Staphylinidae	1
WVP-6-A.1	Tipulidae	3
WVP-6-A.1	Leptophlebiidae	2
WVP-6-A.2	Cambaridae	3
WVP-6-A.2	Tipulidae	5
WVP-6-A.2	Baetidae	3
WVP-6-A.2	Chironomidae	20
WVP-6-A.2	Elmidae	25
WVP-6-A.2	Gammaridae	68
WVP-6-A.2	Hydropsychidae	13
WVP-6-A.2	Leptophlebiidae	13
WVP-6-A.2	Nemouridae	1
WVP-6-A.2	Perlidae	4
WVP-6-A.2	Psephenidae	10
WVP-6-A.2	Perlodidae	4
WVP-6-A.2	Philopotamidae	20
WVP-6-A.2	Lepidostomatidae	3
WVP-6-A.2	Asellidae	1

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-6-A.5-{0.2}	Simuliidae	1
WVP-6-A.5-{0.2}	Gomphidae	3
WVP-6-A.5-{0.2}	Gammaridae	1
WVP-6-A.5-{0.2}	Corydalidae	1
WVP-6-A.5-{0.2}	Chironomidae	49
WVP-6-A.5-{0.2}	Ceratopogonidae	1
WVP-6-A.5-{0.2}	Baetidae	13
WVP-6-A.5-{0.2}	Aeshnidae	1
WVP-6-A.5-{0.2}	Leptophlebiidae	7
WVP-6-A.5-{0.2}	Capniidae/Leuctri	70
WVP-6-A.5-{0.2}	Psephenidae	6
WVP-6-A.5-{0.2}	Nemouridae	5
WVP-6-A.5-{0.2}	Perlidae	7
WVP-6-A.5-{0.2}	Polycentropodidae	3
WVP-6-A.5-{0.2}	Philopotamidae	2
WVP-6-A.5-{0.2}	Hygrobatidae	1
WVP-6-A.5-{0.2}	Hydropsychidae	2
WVP-6-C.8-{0.6}	Heptageniidae	19
WVP-6-C.8-{0.6}	Veliidae	1
WVP-6-C.8-{0.6}	Tipulidae	8
WVP-6-C.8-{0.6}	Rhyacophilidae	1
WVP-6-C.8-{0.6}	Philopotamidae	1
WVP-6-C.8-{0.6}	Perlodidae	3
WVP-6-C.8-{0.6}	Perlidae	3
WVP-6-C.8-{0.6}	Nemouridae	1
WVP-6-C.8-{0.6}	Hydropsychidae	3
WVP-6-C.8-{0.6}	Gerridae	1
WVP-6-C.8-{0.6}	Ephemerellidae	9
WVP-6-C.8-{0.6}	Elmidae	1
WVP-6-C.8-{0.6}	Chloroperlidae	15
WVP-6-C.8-{0.6}	Chironomidae	10
WVP-6-C.8-{0.6}	Cambaridae	3
WVP-6-C.8-{0.6}	Baetidae	12
WVP-6-C.8-{0.6}	Ameletidae	2
WVP-6-C.8-{0.6}	Leptophlebiidae	116
WVP-6-D	Nemouridae	14
WVP-6-D	Simuliidae	19
WVP-6-D	Chironomidae	148
WVP-6-D	Capniidae/Leuctri	123
WVP-6-D	Baetidae	15
WVP-6-D	Hydropsychidae	23
WVP-6-D	Tipulidae	1
WVP-6-D	Elmidae	3
WVP-6-D	Rhyacophilidae	1
WVP-6-D	Philopotamidae	4
WVP-6-D	Perlodidae	1
WVP-6-D	Perlidae	12
WVP-6-D	Veliidae	1
WVP-6-D	Leptophlebiidae	1
WVP-6-D	Corydalidae	1
WVP-6-D	Aeshnidae	1
WVP-6-D	Chironomidae	61
WVP-6-D	Capniidae/Leuctri	150
WVP-6-D	Baetidae	7
WVP-6-D	Corydalidae	3
WVP-6-D	Tipulidae	4
WVP-6-D	Chloroperlidae	1
WVP-6-D	Simuliidae	2
WVP-6-D	Philopotamidae	1
WVP-6-D	Perlodidae	1
WVP-6-D	Perlidae	3
WVP-6-D	Nemouridae	5
WVP-6-D	Hydropsychidae	5
WVP-6-D	Heptageniidae	3
WVP-6-D	Elmidae	4
WVP-6-G-1	Ephemerellidae	5
WVP-6-G-1	Psephenidae	6
WVP-6-G-1	Polycentropodidae	1
WVP-6-G-1	Philopotamidae	15
WVP-6-G-1	Perlodidae	1
WVP-6-G-1	Perlidae	3
WVP-6-G-1	Heptageniidae	5
WVP-6-G-1	Rhyacophilidae	1
WVP-6-G-1	Elmidae	15
WVP-6-G-1	Corydalidae	3
WVP-6-G-1	Chironomidae	28
WVP-6-G-1	Capniidae/Leuctri	43
WVP-6-G-1	Tipulidae	9
WVP-6-G-1	Baetidae	24
WVP-6-G-1	Hydropsychidae	1
WVP-6-G-1	Aeshnidae	1
WVP-6-G-1	Cambaridae	1
WVP-6-G-1	Gomphidae	1
WVP-8	Oligochaeta	2
WVP-8	Ephemerellidae	22
WVP-8	Tipulidae	9

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-8	Simuliidae	10
WVP-8	Perlidae	2
WVP-8	Leptophlebiidae	7
WVP-8	Hydropsychidae	28
WVP-8	Hirudinidae	1
WVP-8	Chloroperlidae	12
WVP-8	Baetidae	11
WVP-8	Caenidae	1
WVP-8	Cambaridae	1
WVP-8	Capniidae/Leuctri	4
WVP-8	Elmidae	5
WVP-8	Chironomidae	58
WVP-8	Heptageniidae	2
WVP-8	Perlodidae	2
WVP-8	Dryopidae	3
WVP-9-{1}	Dryopidae	1
WVP-9-{1}	Chloroperlidae	1
WVP-9-{1}	Chironomidae	84
WVP-9-{1}	Ceratopogonidae	1
WVP-9-{1}	Capniidae/Leuctri	3
WVP-9-{1}	Athericidae	6
WVP-9-{1}	Elmidae	12
WVP-9-{1}	Corydalidae	1
WVP-9-{1}	Baetidae	18
WVP-9-{1}	Sialidae	1
WVP-9-{1}	Ephemerellidae	1
WVP-9-{1}	Tricorythidae	2
WVP-9-{1}	Simuliidae	2
WVP-9-{1}	Philopotamidae	1
WVP-9-{1}	Perlidae	35
WVP-9-{1}	Oligochaeta	4
WVP-9-{1}	Isonychiidae	75
WVP-9-{1}	Hydropsychidae	43
WVP-9-{1}	Heptageniidae	13
WVP-9-{1}	Gammaridae	1
WVP-9-{10}	Elmidae	41
WVP-9-{10}	Hydropsychidae	19
WVP-9-{10}	Psephenidae	3
WVP-9-{10}	Pleuroceridae	2
WVP-9-{10}	Perlodidae	1
WVP-9-{10}	Perlidae	55
WVP-9-{10}	Isonychiidae	33
WVP-9-{10}	Simuliidae	1
WVP-9-{10}	Ephemerellidae	5
WVP-9-{10}	Chironomidae	14
WVP-9-{10}	Capniidae/Leuctri	2
WVP-9-{10}	Caenidae	1
WVP-9-{10}	Baetidae	2
WVP-9-{10}	Athericidae	6
WVP-9-{10}	Gomphidae	1
WVP-9-{12.2}	Heptageniidae	3
WVP-9-{12.2}	Hydropsychidae	12
WVP-9-{12.2}	Isonychiidae	34
WVP-9-{12.2}	Leptophlebiidae	1
WVP-9-{12.2}	Perlidae	25
WVP-9-{12.2}	Psephenidae	2
WVP-9-{12.2}	Sialidae	1
WVP-9-{12.2}	Tipulidae	1
WVP-9-{12.2}	Tricorythidae	5
WVP-9-{12.2}	Simuliidae	1
WVP-9-{12.2}	Aeshnidae	1
WVP-9-{12.2}	Gomphidae	1
WVP-9-{12.2}	Athericidae	8
WVP-9-{12.2}	Baetidae	4
WVP-9-{12.2}	Caenidae	2
WVP-9-{12.2}	Capniidae/Leuctri	2
WVP-9-{12.2}	Chironomidae	45
WVP-9-{12.2}	Elmidae	24
WVP-9-{12.2}	Ephemerellidae	3
WVP-9-{12.2}	Veliidae	2
WVP-9-{15.2}	Sialidae	2
WVP-9-{15.2}	Heptageniidae	2
WVP-9-{15.2}	Simuliidae	3
WVP-9-{15.2}	Philopotamidae	1
WVP-9-{15.2}	Perlodidae	1
WVP-9-{15.2}	Perlidae	47
WVP-9-{15.2}	Oligochaeta	1
WVP-9-{15.2}	Isonychiidae	47
WVP-9-{15.2}	Hydropsychidae	30
WVP-9-{15.2}	Athericidae	19
WVP-9-{15.2}	Ephemerellidae	6
WVP-9-{15.2}	Elmidae	2
WVP-9-{15.2}	Dryopidae	1
WVP-9-{15.2}	Chironomidae	14
WVP-9-{15.2}	Capniidae/Leuctri	4
WVP-9-{15.2}	Caenidae	1

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-9-{15.2}	Baetidae	3
WVP-9-{15.2}	Gomphidae	3
WVP-9-{18.2}	Heptageniidae	3
WVP-9-{18.2}	Hydropsychidae	4
WVP-9-{18.2}	Leptoceridae	5
WVP-9-{18.2}	Perlidae	4
WVP-9-{18.2}	Planorbidae	1
WVP-9-{18.2}	Psephenidae	1
WVP-9-{18.2}	Baetidae	12
WVP-9-{18.2}	Tricorythidae	20
WVP-9-{18.2}	Ephemerellidae	5
WVP-9-{18.2}	Sialidae	14
WVP-9-{18.2}	Elmidae	5
WVP-9-{18.2}	Dytiscidae	9
WVP-9-{18.2}	Chironomidae	57
WVP-9-{18.2}	Ceratopogonidae	3
WVP-9-{18.2}	Capniidae/Leuctri	1
WVP-9-{18.2}	Caenidae	28
WVP-9-{18.2}	Gerridae	2
WVP-9-{18.2}	Haliplidae	1
WVP-9-{21.6}	Gyrinidae	1
WVP-9-{21.6}	Tricorythidae	1
WVP-9-{21.6}	Isonychiidae	40
WVP-9-{21.6}	Perlidae	12
WVP-9-{21.6}	Perlodidae	2
WVP-9-{21.6}	Philopotamidae	5
WVP-9-{21.6}	Psephenidae	3
WVP-9-{21.6}	Simuliidae	3
WVP-9-{21.6}	Tipulidae	1
WVP-9-{21.6}	Pteronarcyidae	1
WVP-9-{21.6}	Athericidae	1
WVP-9-{21.6}	Hydropsychidae	67
WVP-9-{21.6}	Capniidae/Leuctri	11
WVP-9-{21.6}	Ceratopogonidae	1
WVP-9-{21.6}	Chironomidae	48
WVP-9-{21.6}	Corydalidae	1
WVP-9-{21.6}	Elmidae	19
WVP-9-{21.6}	Ephemerellidae	17
WVP-9-{21.6}	Heptageniidae	4
WVP-9-{23.6}	Elmidae	7
WVP-9-{23.6}	Hydropsychidae	49
WVP-9-{23.6}	Tipulidae	2
WVP-9-{23.6}	Simuliidae	1
WVP-9-{23.6}	Sialidae	1
WVP-9-{23.6}	Philopotamidae	10
WVP-9-{23.6}	Perlidae	38
WVP-9-{23.6}	Isonychiidae	44
WVP-9-{23.6}	Athericidae	1
WVP-9-{23.6}	Chironomidae	13
WVP-9-{23.6}	Capniidae/Leuctri	15
WVP-9-{23.6}	Caenidae	2
WVP-9-{23.6}	Brachycentridae	1
WVP-9-{23.6}	Baetidae	1
WVP-9-{23.6}	Ephemerellidae	20
WVP-9-{23.6}	Heptageniidae	3
WVP-9-{33.2}	Nemouridae	1
WVP-9-{33.2}	Perlidae	18
WVP-9-{33.2}	Philopotamidae	13
WVP-9-{33.2}	Pleuroceridae	1
WVP-9-{33.2}	Psephenidae	5
WVP-9-{33.2}	Tipulidae	2
WVP-9-{33.2}	Simuliidae	1
WVP-9-{33.2}	Baetidae	2
WVP-9-{33.2}	Isonychiidae	20
WVP-9-{33.2}	Pteronarcyidae	1
WVP-9-{33.2}	Heptageniidae	4
WVP-9-{33.2}	Gomphidae	2
WVP-9-{33.2}	Ephemerellidae	5
WVP-9-{33.2}	Elmidae	3
WVP-9-{33.2}	Corydalidae	2
WVP-9-{33.2}	Chironomidae	82
WVP-9-{33.2}	Caenidae	8
WVP-9-{33.2}	Hydropsychidae	26
WVP-9-{33.2}	Capniidae/Leuctri	18
WVP-9-{35.6}	Elmidae	10
WVP-9-{35.6}	Nemouridae	4
WVP-9-{35.6}	Tipulidae	5
WVP-9-{35.6}	Perlidae	11
WVP-9-{35.6}	Tricorythidae	1
WVP-9-{35.6}	Philopotamidae	10
WVP-9-{35.6}	Polycentropodidae	1
WVP-9-{35.6}	Psephenidae	7
WVP-9-{35.6}	Tabanidae	1
WVP-9-{35.6}	Isonychiidae	9
WVP-9-{35.6}	Simuliidae	2

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-9-{35.6}	Glossosomatidae	3
WVP-9-{35.6}	Hydropsychidae	27
WVP-9-{35.6}	Baetidae	5
WVP-9-{35.6}	Caenidae	3
WVP-9-{35.6}	Capniidae/Leuctri	28
WVP-9-{35.6}	Chironomidae	65
WVP-9-{35.6}	Corydalidae	2
WVP-9-{35.6}	Ephemerellidae	4
WVP-9-{35.6}	Gomphidae	2
WVP-9-{36.8}	Glossosomatidae	6
WVP-9-{36.8}	Hydropsychidae	77
WVP-9-{36.8}	Simuliidae	3
WVP-9-{36.8}	Polycentropodidae	1
WVP-9-{36.8}	Pleuroceridae	1
WVP-9-{36.8}	Philopotamidae	13
WVP-9-{36.8}	Perlidae	6
WVP-9-{36.8}	Nemouridae	2
WVP-9-{36.8}	Isonychiidae	2
WVP-9-{36.8}	Tipulidae	1
WVP-9-{36.8}	Capniidae/Leuctri	11
WVP-9-{36.8}	Heptageniidae	2
WVP-9-{36.8}	Baetidae	3
WVP-9-{36.8}	Chironomidae	33
WVP-9-{36.8}	Chloroperlidae	1
WVP-9-{36.8}	Corydalidae	5
WVP-9-{36.8}	Elmidae	27
WVP-9-{36.8}	Ephemerellidae	1
WVP-9-{36.8}	Gomphidae	1
WVP-9-B-{0}	Hydropsychidae	30
WVP-9-B-{0}	Elmidae	4
WVP-9-B-{0}	Rhyacophilidae	3
WVP-9-B-{0}	Philopotamidae	23
WVP-9-B-{0}	Perlodidae	1
WVP-9-B-{0}	Perlidae	18
WVP-9-B-{0}	Nemouridae	1
WVP-9-B-{0}	Leptophlebiidae	3
WVP-9-B-{0}	Simuliidae	4
WVP-9-B-{0}	Baetidae	10
WVP-9-B-{0}	Empididae	1
WVP-9-B-{0}	Chloroperlidae	2
WVP-9-B-{0}	Chironomidae	76
WVP-9-B-{0}	Ceratopogonidae	2
WVP-9-B-{0}	Capniidae/Leuctri	21
WVP-9-B-{0}	Heptageniidae	1
WVP-9-B-{12.8}	Heptageniidae	2
WVP-9-B-{12.8}	Hydropsychidae	8
WVP-9-B-{12.8}	Leptophlebiidae	1
WVP-9-B-{12.8}	Perlidae	2
WVP-9-B-{12.8}	Polycentropodidae	2
WVP-9-B-{12.8}	Simuliidae	2
WVP-9-B-{12.8}	Glossosomatidae	1
WVP-9-B-{12.8}	Tipulidae	17
WVP-9-B-{12.8}	Sialidae	5
WVP-9-B-{12.8}	Cambaridae	1
WVP-9-B-{12.8}	Haliplidae	1
WVP-9-B-{12.8}	Aeshnidae	2
WVP-9-B-{12.8}	Gomphidae	1
WVP-9-B-{12.8}	Capniidae/Leuctri	65
WVP-9-B-{12.8}	Chironomidae	62
WVP-9-B-{12.8}	Corydalidae	4
WVP-9-B-{12.8}	Dryopidae	1
WVP-9-B-{12.8}	Elmidae	28
WVP-9-B-1-A-{0.1}	Hydropsychidae	7
WVP-9-B-1-A-{0.1}	Veliidae	2
WVP-9-B-1-A-{0.1}	Tipulidae	4
WVP-9-B-1-A-{0.1}	Simuliidae	1
WVP-9-B-1-A-{0.1}	Philopotamidae	11
WVP-9-B-1-A-{0.1}	Nemouridae	3
WVP-9-B-1-A-{0.1}	Lepidostomatidae	1
WVP-9-B-1-A-{0.1}	Perlidae	2
WVP-9-B-1-A-{0.1}	Corydalidae	1
WVP-9-B-1-A-{0.1}	Chironomidae	11
WVP-9-B-1-A-{0.1}	Polycentropodidae	1
WVP-9-B-1-A-{0.1}	Capniidae/Leuctri	64
WVP-9-B-1-A-{0.1}	Elmidae	1
WVP-9-B-1-A-{0.1}	Cambaridae	1
WVP-9-B-1-A-{0.1}	Asellidae	1
WVP-9-B-1-A-{0.1}	Aeshnidae	1
WVP-9-D.8-{0.5}	Philopotamidae	2
WVP-9-D.8-{0.5}	Psephenidae	1
WVP-9-D.8-{0.5}	Perlidae	14
WVP-9-D.8-{0.5}	Nemouridae	1
WVP-9-D.8-{0.5}	Leptophlebiidae	17
WVP-9-D.8-{0.5}	Lepidostomatidae	1
WVP-9-D.8-{0.5}	Hydropsychidae	51

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-9-D.8-{0.5}	Baetidae	18
WVP-9-D.8-{0.5}	Corydalidae	1
WVP-9-D.8-{0.5}	Chloroperlidae	1
WVP-9-D.8-{0.5}	Chironomidae	19
WVP-9-D.8-{0.5}	Ceratopogonidae	1
WVP-9-D.8-{0.5}	Capniidae/Leuctri	21
WVP-9-D.8-{0.5}	Elmidae	19
WVP-9-D.8-{0.5}	Tipulidae	36
WVP-9-E-{1.5}	Ephemerellidae	5
WVP-9-E-{1.5}	Hydropsychidae	18
WVP-9-E-{1.5}	Isonychiidae	5
WVP-9-E-{1.5}	Perlidae	52
WVP-9-E-{1.5}	Polycentropodidae	1
WVP-9-E-{1.5}	Chloroperlidae	1
WVP-9-E-{1.5}	Pteronarcyidae	1
WVP-9-E-{1.5}	Philopotamidae	1
WVP-9-E-{1.5}	Corydalidae	1
WVP-9-E-{1.5}	Chironomidae	12
WVP-9-E-{1.5}	Capniidae/Leuctri	3
WVP-9-E-{1.5}	Cambaridae	1
WVP-9-E-{1.5}	Baetidae	2
WVP-9-E-{1.5}	Tipulidae	14
WVP-9-E-{1.5}	Elmidae	89
WVP-9-E-{7}	Hydropsychidae	14
WVP-9-E-{7}	Simuliidae	7
WVP-9-E-{7}	Physidae	1
WVP-9-E-{7}	Tipulidae	15
WVP-9-E-{7}	Perlidae	43
WVP-9-E-{7}	Isonychiidae	3
WVP-9-E-{7}	Elmidae	33
WVP-9-E-{7}	Corydalidae	2
WVP-9-E-{7}	Chironomidae	47
WVP-9-E-{7}	Baetidae	34
WVP-9-E-{7}	Capniidae/Leuctri	5
WVP-9-E-{7}	Empididae	1
WVP-9-E-1	Gomphidae	1
WVP-9-E-1	Tipulidae	15
WVP-9-E-1	Simuliidae	2
WVP-9-E-1	Perlodidae	1
WVP-9-E-1	Perlidae	24
WVP-9-E-1	Leptophlebiidae	4
WVP-9-E-1	Isonychiidae	12
WVP-9-E-1	Heptageniidae	7
WVP-9-E-1	Ephemerellidae	20
WVP-9-E-1	Corydalidae	1
WVP-9-E-1	Chloroperlidae	2
WVP-9-E-1	Chironomidae	17
WVP-9-E-1	Capniidae/Leuctri	4
WVP-9-E-1	Cambaridae	1
WVP-9-E-1	Baetidae	31
WVP-9-E-1	Athericidae	1
WVP-9-E-1	Elmidae	22
WVP-9-E-1	Hydropsychidae	25
WVP-9-F	Baetidae	2
WVP-9-F	Perlidae	5
WVP-9-F	Perlodidae	1
WVP-9-F	Philopotamidae	8
WVP-9-F	Polycentropodidae	2
WVP-9-F	Psephenidae	9
WVP-9-F	Tipulidae	2
WVP-9-F	Ptilodactylidae	1
WVP-9-F	Oligochaeta	1
WVP-9-F	Simuliidae	1
WVP-9-F	Chironomidae	13
WVP-9-F	Nemouridae	4
WVP-9-F	Capniidae/Leuctri	24
WVP-9-F	Chloroperlidae	2
WVP-9-F	Corydalidae	3
WVP-9-F	Elmidae	24
WVP-9-F	Ephemerellidae	3
WVP-9-F	Heptageniidae	2
WVP-9-F	Hydropsychidae	72
WVP-9-G-{0.25}	Gomphidae	5
WVP-9-G-{0.25}	Heptageniidae	17
WVP-9-G-{0.25}	Tipulidae	1
WVP-9-G-{0.25}	Psephenidae	1
WVP-9-G-{0.25}	Philopotamidae	12
WVP-9-G-{0.25}	Perlidae	18
WVP-9-G-{0.25}	Nemouridae	1
WVP-9-G-{0.25}	Isonychiidae	4
WVP-9-G-{0.25}	Veliidae	2
WVP-9-G-{0.25}	Athericidae	2
WVP-9-G-{0.25}	Glossosomatidae	1
WVP-9-G-{0.25}	Corydalidae	1
WVP-9-G-{0.25}	Chironomidae	19

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals
WVP-9-G-{0.25}	Capniidae/Leuctri	82
WVP-9-G-{0.25}	Caenidae	1
WVP-9-G-{0.25}	Baetidae	2
WVP-9-G-{0.25}	Hydropsychidae	61
WVP-9-G-1	Perlidae	10
WVP-9-G-1	Perlodidae	1
WVP-9-G-1	Philopotamidae	9
WVP-9-G-1	Polycentropodidae	1
WVP-9-G-1	Ptilodactylidae	8
WVP-9-G-1	Rhyacophilidae	1
WVP-9-G-1	Tipulidae	2
WVP-9-G-1	Heptageniidae	3
WVP-9-G-1	Nemouridae	6
WVP-9-G-1	Tabanidae	1
WVP-9-G-1	Chironomidae	43
WVP-9-G-1	Leptophlebiidae	8
WVP-9-G-1	Capniidae/Leuctri	227
WVP-9-G-1	Chloroperlidae	1
WVP-9-G-1	Corydalidae	2
WVP-9-G-1	Curculionidae	1
WVP-9-G-1	Gomphidae	1
WVP-9-G-1	Hydropsychidae	9
WVP-9-G-1	Nemouridae	5
WVP-9-G-1	Tipulidae	1
WVP-9-G-1	Perlidae	1
WVP-9-G-1	Simuliidae	1
WVP-9-G-1	Rhyacophilidae	1
WVP-9-G-1	Ptilodactylidae	5
WVP-9-G-1	Polycentropodidae	2
WVP-9-G-1	Tabanidae	1
WVP-9-G-1	Leptophlebiidae	4
WVP-9-G-1	Hydropsychidae	1
WVP-9-G-1	Empididae	1
WVP-9-G-1	Chironomidae	24
WVP-9-G-1	Capniidae/Leuctri	151
WVP-9-G-1	Baetidae	2
WVP-9-G-1	Philopotamidae	6
WVP-9-G-2-{0}	Ephemerellidae	12
WVP-9-G-2-{0}	Tipulidae	10
WVP-9-G-2-{0}	Leptophlebiidae	3
WVP-9-G-2-{0}	Simuliidae	16
WVP-9-G-2-{0}	Perlidae	11
WVP-9-G-2-{0}	Philopotamidae	30
WVP-9-G-2-{0}	Polycentropodidae	1
WVP-9-G-2-{0}	Rhyacophilidae	1
WVP-9-G-2-{0}	Lepidostomatidae	1
WVP-9-G-2-{0}	Pteronarcyidae	2
WVP-9-G-2-{0}	Heptageniidae	2
WVP-9-G-2-{0}	Hydropsychidae	5
WVP-9-G-2-{0}	Baetidae	14
WVP-9-G-2-{0}	Capniidae/Leuctri	22
WVP-9-G-2-{0}	Chironomidae	27
WVP-9-G-2-{0}	Chloroperlidae	2
WVP-9-G-2-{0}	Elmidae	3
WVP-9-G-2-{0}	Glossosomatidae	3
WVP-9-G-3	Hydropsychidae	3
WVP-9-G-3	Leptophlebiidae	1
WVP-9-G-3	Simuliidae	6
WVP-9-G-3	Rhyacophilidae	1
WVP-9-G-3	Psephenidae	1
WVP-9-G-3	Philopotamidae	11
WVP-9-G-3	Perlidae	5
WVP-9-G-3	Oligochaeta	1
WVP-9-G-3	Tipulidae	1
WVP-9-G-3	Baetidae	9
WVP-9-G-3	Glossosomatidae	2
WVP-9-G-3	Gammaridae	16
WVP-9-G-3	Empididae	1
WVP-9-G-3	Elmidae	6
WVP-9-G-3	Chloroperlidae	1
WVP-9-G-3	Chironomidae	55
WVP-9-G-3	Capniidae/Leuctri	134
WVP-9-G-3	Nemouridae	8
WVP-9-I	Helophoridae	1
WVP-9-I	Heptageniidae	1
WVP-9-I	Hydrophilidae	2
WVP-9-I	Philopotamidae	2
WVP-9-I	Hydropsychidae	3
WVP-9-I	Perlodidae	74
WVP-9-I	Leptophlebiidae	16
WVP-9-I	Perlidae	7
WVP-9-I	Capniidae/Leuctri	11
WVP-9-I	Glossosomatidae	1
WVP-9-I	Nemouridae	3
WVP-9-I	Ameletidae	1

Table A-6. Numbers of each taxon found at each sample site (cont.)

Sample site	Taxa	No. of individuals	Sample site	Taxa	No. of individuals
WVP-9-I	Chloroperlidae	32			
WVP-9-I	Ephemerellidae	2			
WVP-9-I	Tipulidae	4			
WVP-9-I	Baetidae	6			
WVP-9-I	Cambaridae	1			
WVP-9-I	Chironomidae	32			
WVP-9-I	Dixidae	1			
WVP-9-I	Dryopidae	3			
WVP-9-I	Dytiscidae	1			
WVP-9-I	Elmidae	8			
WVP-12-{5.2}	Philopotamidae	5			
WVP-12-{5.2}	Gomphidae	1			
WVP-12-{5.2}	Chironomidae	24			
WVP-12-{5.2}	Corydalidae	10			
WVP-12-{5.2}	Elmidae	21			
WVP-12-{5.2}	Gammaridae	1			
WVP-12-{5.2}	Capniidae/Leuctri	14			
WVP-12-{5.2}	Heptageniidae	9			
WVP-12-{5.2}	Hydropsychidae	57			
WVP-12-{5.2}	Isonychiidae	17			
WVP-12-{5.2}	Leptophlebiidae	3			
WVP-12-{5.2}	Perlidae	14			
WVP-12-{5.2}	Psephenidae	3			
WVP-12-{5.2}	Cambaridae	1			
WVP-12-{5.2}	Nemouridae	1			

Table A-7. Water quality parameters measured in the field, and fecal coliform bacteria.

Stream Code	Temp (°C)	pH	DO (mg/L)	Conductivity umhos	Fecal Coliform Bacteria colonies/ 100 mL
WVP-1-A-{0.8}	17.7	7.9	9.2	543	774
WVP-2.2-{0.3}	14.1	8	9.6	573	880
WVP-4-{1.3}	18.8	8.1	7.2	593	420
WVP-4-{9.8}	21	8.2	11	581	106
WVP-4-{17.8}	15.6	8.2	9.4	591	167
WVP-4-{18.8}	19.8	8.3	9.4	586	300
WVP-4-{29.2}	14.2	7.8	8.9	606	172
WVP-4-B	16.2	7.3	5.6	876	210000
WVP-4-C-{0.2}	13.5	7.8	8.8	685	2750
WVP-4-C-{1.5}	14.9	7.8	8.5	713	1660
WVP-4-C-{6}	17	7.7	8.6	564	1850
WVP-4-C-1-{0.4}	17.7	7.7	5	620	1200
WVP-4-D					100
WVP-4-I	15.9	7.9	9.1	543	2550
WVP-4-I					3200
WVP-4-J-{0.1}	14.1	7.9	9.8	569	680
WVP-4-J-1-{1.2}	16.7	7.5	8.4	268	135
WVP-4-M	13.5	8	10.4	577	350
WVP-4-M-{7.8}	17.7	7.8	9.6	571	870
WVP-4-M-{7.8}					290
WVP-4-M-1	16.1	7.9	9.7	523	105
WVP-4-M-2	15.9	7.4	9.6	588	600
WVP-4-M-2					410
WVP-4-P	18.5	7.4	6.1	218	250
WVP-4-P					62
WVP-4.5-{0.5}					1200
WVP-5					840
WVP-5-A-{1.4}					11000
WVP-6-{1.2}	24.1	8	9.2	222	41
WVP-6-{9.1}	21.8	7.6	8.2	235	161
WVP-6-{17.3}	22.4	7.7	8.6	242	100
WVP-6-{18.4}	22	7.6	7.4	239	106
WVP-6-{33.8}	19.2	8.2	8.8	251	13
WVP-6-A-{0.5}	14.7	7.8	10.4	310	71
WVP-6-A-{1.3}	14.6	8	9.9	311	65
WVP-6-A-{9.4}	14	8	7.1	60	50
WVP-6-A-1-{1.6}	15.3	7.6	8	109	270
WVP-6-A.1	19.8	7.8	8.8	280	240
WVP-6-A.2	19.3	7.5	6.8	81	217
WVP-6-A.5-{0.2}	15.5	7.7	9.6	154	360
WVP-6-C.8-{0.6}	19	7.4	8.2	93	156
WVP-6-D	19.5	7.7	8.5	202	300
WVP-6-D					250

Table A-7. Water quality parameters measured in the field, and fecal coliform bacteria (continued).

Stream Code	Temp (°C)	pH	DO (mg/L)	Conductivity umhos	Fecal Coliform Bacteria colonies/ 100 mL
WVP-6-G-1	19.6	6.9	7.5	23	30
WVP-8	16.2	7.6	9	79	160
WVP-9-{1}	25.4	7.5	8	108	80
WVP-9-{10}	24.8	7.5	9	135	71
WVP-9-{12.2}	24.9	7.7	7.4	135	7
WVP-9-{15.2}	23.3	7.6	7.9	142	150
WVP-9-{18.2}	22.6	7.4	7.8	156	124
WVP-9-{21.6}	20	7.3	7.6	158	160
WVP-9-{23.6}	21.6	7.6	7.5	160	167
WVP-9-{33.2}	14.4	8	8.9	183	75
WVP-9-{35.6}	13.6	8	9.4	199	290
WVP-9-{36.8}	13.2	8.1	9.3	197	560
WVP-9-B-{0}	20.6	7	8.6	27	66
WVP-9-B-{12.8}	17.3	6.9	8	22	420
WVP-9-B-1-A-{0.1}	16	5.3	8.8	22	10
WVP-9-D.8-{0.5}	19	7.5	6.5	196	18
WVP-9-E-{1.5}	21.2	7.1	7.5	95	44
WVP-9-E-{7}	14.8	8.2	7.9	101	230
WVP-9-E-1	16.6	7.4	7.6	98	280
WVP-9-F	14.7	7.9	8.7	254	28
WVP-9-G-{0.25}	15.3	7.9	8.9	157	80
WVP-9-G-1	17.9	7.7	6.7	112	40
WVP-9-G-1					66
WVP-9-G-2-{0}	17.3	7.3	8.5	42	10
WVP-9-G-3	14	7.5	7.7	232	66
WVP-9-I	13.6	8.1	9	60	1100
WVP-12-{5.2}	22.4	8.3	7.1	250	100

Table A-8. Additional water quality parameters taken from a subset of all streams sampled.

Stream Code	Hot acidity (mg/L)	Alkalinity (mg/L)	Sulfate (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Cu (mg/L)	Total Zn (mg/L)
WVP-1-A-{0.8}	< 1	244	20	0.192	0.345	0.026	0.006	< 0.02
WVP-2.2-{0.3}	< 1	227	20	< 0.05	0.147	0.022	0.006	< 0.02
WVP-4-{1.3}	< 1	250	29	0.097	0.232	0.013	0.006	< 0.2
WVP-4-{9.8}	< 1	249	25	0.059	0.135	0.010	0.006	< 0.2
WVP-4-{17.8}	< 1	261	27	0.109	0.129	< 0.01	< 0.005	0.027
WVP-4-{18.8}	< 1	254	24	0.176	0.263	0.018	0.007	0.038
WVP-4-{29.2}	< 1	255	29	0.090	0.075	0.022	< 0.005	< 0.02
WVP-4-C-{1.5}	< 1	282	40	0.158	0.207	0.014	0.008	0.027
WVP-4-C-{6}	< 1	264	23	0.522	0.261	0.017	0.007	< 0.02
WVP-4-J-1-{1.2}	< 1	76.1	45	< 0.5	0.05	< 0.01	< 0.005	0.068
WVP-4-M-{7.8}	< 1	267	19	0.092	0.16	0.026	< 0.005	< 0.02
WVP-4-M-{7.8}	< 1	280	25	0.095	0.215	0.011	< 0.005	0.050
WVP-5-A-{1.4}	< 1	166	20	2.09	2.56	0.060	< 0.005	0.040
WVP-6-{1.2}	< 1	91.9	9	< 0.05	0.135	0.016	< 0.005	< 0.02
WVP-6-{9.1}	< 1	96.1	9	0.066	0.178	0.023	< 0.005	< 0.02
WVP-6-{17.3}	< 1	104	12	< 0.05	0.128	0.020	< 0.005	< 0.02
WVP-6-{18.4}	< 1	100	10	0.051	0.178	0.025	< 0.005	< 0.02
WVP-6-{33.8}	< 1	121	10	< 0.05	0.106	0.015	< 0.005	< 0.02
WVP-6-A-{0.5}	< 1	160	8	< 0.05	0.0689	0.010	< 0.005	< 0.02
WVP-6-A-{1.3}	< 1	166	8	0.119	0.178	0.022	0.005	0.030
WVP-6-A-{9.4}	< 1	11.3	< 5	< 0.05	0.0561	< 0.01	0.005	< 0.02
WVP-6-A-1-{1.6}	< 1	38.1	< 5	0.063	0.145	0.021	< 0.005	< 0.02
WVP-6-A.2	< 1	31.6	6	0.315	0.134	0.027		< 0.02
WVP-6-A.5-{0.2}	< 1	65.6	5	< 0.05	0.05	< 0.01	< 0.005	< 0.02
WVP-6-C.8-{0.6}	< 1	28.1	10	< 0.05	0.05	< 0.01	< 0.005	< 0.02
WVP-6-G-1	5.02	6.7	< 5	< 0.05	0.0673	< 0.01	< 0.005	< 0.02
WVP-9-{1}	< 1	42.6	7	< 0.05	0.0808	0.015	< 0.005	< 0.02
WVP-9-{10}	< 1	55.6	7	< 0.05	3.59	0.012	< 0.005	< 0.02
WVP-9-{12.2}	< 1	58.4	7	< 0.05	0.136	< 0.01	0.005	< 0.02
WVP-9-{15.2}	< 1	62	7	0.054	0.18	0.013	0.006	< 0.02
WVP-9-{18.2}	< 1	67.2	7	< 0.05	0.409	0.023	0.005	< 0.02
WVP-9-{21.6}	< 1	67.9	6	< 0.05	0.224	0.012	0.006	0.021
WVP-9-{23.6}	< 1	70.4	7	< 0.05	0.327	0.018	0.006	< 0.02
WVP-9-{33.2}	< 1	91.2	7	< 0.05	0.0824	< 0.01	< 0.005	< 0.02
WVP-9-{35.6}	< 1	98.3	6	< 0.05	0.108	0.018	< 0.005	0.065
WVP-9-{36.8}	< 1	99.2	7	0.061	0.113	0.015	< 0.005	< 0.02
WVP-9-B-{12.8}	3.52	8.6	< 5	0.123	1.55	0.053	0.005	0.026
WVP-9-B-1-A-{0.1}	8.25	3.6	< 5	0.096	0.25	0.074	< 0.005	0.025
WVP-9-D.8-{0.5}	< 1	72.1	10	< 0.05	0.438	< 0.01	0.007	0.047
WVP-9-E-{1.5}	< 1	31.8	7	0.092	0.207	0.018	0.005	< 0.02
WVP-9-E-{7}	< 1	33.9	7	< 0.05	0.18	0.045	0.005	< 0.02
WVP-9-G-{0.25}	< 1	69.9	7	0.224	0.408	0.038	< 0.005	< 0.02
WVP-9-G-2-{0}	< 1	14.4	5	0.119	0.156	0.020	< 0.005	< 0.02
WVP-12-{5.2}	< 1	120	9.9	< 0.05	0.258	0.034	0.006	< 0.02

Table A-9. Additional water quality parameters taken from a subset of all streams sampled.

Stream Code	Total Phos (mg/L)	NH3-N (mg/L)	NO2-NO3-N (mg/L)	Chloride (mg/L)	Ca-Tot (mg/L)	Mg (mg/L)
WVP-1-A-{0.8}	0.0402	< 0.5	3.22	11.3	80.9	19.1
WVP-2.2-{0.3}	0.0222	< 0.5	6.6	12.9	95	14.4
WVP-4-{1.3}	0.123	< 0.5	2.15	18.8	86.8	16.7
WVP-4-{9.8}	0.0919	< 0.5	2.02	19.4	82.2	16
WVP-4-{17.8}	0.162	< 0.5	2.8	20.2	87.7	18
WVP-4-{18.8}	0.101	< 0.5	2.15	19.5	87	17.5
WVP-4-{29.2}	0.175	< 0.5	2.81	22.1	86.1	24
WVP-4-B	1.55		21			
WVP-4-C-{0.2}	0.305		3.94			
WVP-4-C-{1.5}	0.366	< 0.5	3.91	29	93.3	20.5
WVP-4-C-{6}	0.0312	< 0.5	3	6.95	80.7	22.4
WVP-4-J-1-{1.2}	0.0244	< 0.5	0.077	7.28	27.5	8.82
WVP-4-M-{7.8}	< 0.02	< 0.5	2.49	5.82	80.3	22
WVP-4-M-{7.8}	0.0357	< 0.5	2.69	5.51	86.3	18.4
WVP-4-M-2	< 0.02		1.25			
WVP-5-A-{1.4}	0.099	< 0.5	1.82	7	47.7	15
WVP-6-{1.2}	< 0.02	< 0.5	0.214	4.26	30.7	4.75
WVP-6-{9.1}	< 0.02	< 0.5	0.259	5.38	34.4	5.46
WVP-6-{17.3}	< 0.02	< 0.5	0.246	4.67	33.8	5.56
WVP-6-{18.4}	< 0.02	< 0.5	0.258	6.1	31.2	5.22
WVP-6-{33.8}	< 0.02	< 0.5	0.338	5.23	40.3	6.79
WVP-6-A-{0.5}	< 0.02	< 0.5	0.402	1.02	57.7	5.19
WVP-6-A-{1.3}	< 0.02	< 0.5	0.417	3.4	60.9	5.32
WVP-6-A-{9.4}	< 0.02	< 0.5	0.114	1.03	2.35	1.51
WVP-6-A-1-{1.6}	< 0.02	< 0.5	0.152	6.01	9.28	3
WVP-6-A.2	< 0.02	< 0.5	< 0.05	1.3	7.58	2.67
WVP-6-A.5-{0.2}	0.029	< 0.5	0.129	3.42	20.8	3.56
WVP-6-C.8-{0.6}	< 0.02	< 0.5	0.18	3.55	8.28	3.28
WVP-6-G-1	< 0.02	< 0.5	< 0.05	1.12	1.38	0.995
WVP-9-{1}	< 0.02	< 0.5	0.1	1.71	12.1	2.81
WVP-9-{10}	< 0.02	< 0.5	< 0.05	2.32	17.1	3.59
WVP-9-{12.2}	< 0.02	< 0.5	< 0.05	2.19	19.2	
WVP-9-{15.2}	< 0.02	< 0.5	0.051	2.45	19.8	3.8
WVP-9-{18.2}	< 0.02	< 0.5	0.066	2.5	22.2	4.1
WVP-9-{21.6}	0.0334	< 0.5	0.132	2.26	21.6	4.03
WVP-9-{23.6}	< 0.02	< 0.5	0.133	2.35	24.6	4.33
WVP-9-{33.2}	< 0.02	< 0.5	0.206	1.79	30.2	4.86
WVP-9-{35.6}	< 0.02	< 0.5	0.235	1.78	30.8	4.71
WVP-9-{36.8}	< 0.02	< 0.5	0.244	1.89	31.7	4.85
WVP-9-B-{12.8}	< 0.02	< 0.5	0.075	1.45	1.98	0.924
WVP-9-B-1-A-{0.1}	< 0.02	< 0.5	0.147	1.05	0.979	0.689
WVP-9-D.8-{0.5}	< 0.02	< 0.5	0.225	9.95	25.5	4.28
WVP-9-E-{1.5}	< 0.02	< 0.5	0.159	3.29	8.16	2.84
WVP-9-E-{7}	< 0.02	< 0.5	0.209	3.28	8.42	3.3

Table A-9. Additional water quality parameters taken from a subset of all streams sampled (continued).

Stream Code	Total Phos (mg/L)	NH3-N (mg/L)	NO2-NO3-N (mg/L)	Chloride (mg/L)	Ca-Tot (mg/L)	Mg (mg/L)
WVP-9-G-{0.25}	< 0.02	< 0.5	0.163	2.15	21.8	3.75
WVP-9-G-2-{0}	< 0.02	< 0.5	0.091	1.82	4.75	1.64
WVP-12-{5.2}	< 0.02	< 0.5	0.07	3.8	42.5	7

Table A-10. Rapid Habitat Assessment Scores.

Stream Code	cover	embed	velocity	alteration	sediment	riffle freq.	flow	bank stab.	bank veg	rip veg	**Total**
WVP-1-A-{0.8}	9	8	15	3	11	17	16	13	8	3	**103**
WVP-2.2-{0.3}	16	14	10	20	12	18	17	15	16	4	**142**
WVP-4-{1.3}	14	7	13	19	10	6	13	12	16	10	**120**
WVP-4-{9.8}	10	7	3	20	11	8	14	9	16	16	**114**
WVP-4-{17.8}	10	7	5	20	9	8	13	7	11	12	**102**
WVP-4-{18.8}	5	12	2	20	3	6	19	11	14	16	**108**
WVP-4-{29.2}	17	12	18	17	14	17	17	14	14	11	**151**
WVP-4-B	6	9	15	19	6	17	10	11	17	19	**129**
WVP-4-C-{0.2}	12	9	16	17	8	15	18	15	14	3	**127**
WVP-4-C-{1.5}	7	9	5	18	5	7	20	17	17	17	**122**
WVP-4-C-{6}	15	9	16	15	9	16	16	8	12	4	**120**
WVP-4-C-1-{0.4}	7	10	9	11	6	5	14	18	13	9	**102**
WVP-4-D	8	11	16	15	8	17	12	13	11	13	**124**
WVP-4-I	12	7	17	20	6	18	12	11	12	8	**123**
WVP-4-I	18	11	17	19	8	17	15	10	12	10	**137**
WVP-4-J-{0.1}	11	9	14	19	6	18	15	9	14	18	**133**
WVP-4-J-1-{1.2}	12	13	10	19	14	16	11	16	14	16	**141**
WVP-4-M	16	10	18	17	10	16	16	5	4	2	**114**
WVP-4-M-{7.8}	17	16	14	15	16	17	17	18	18	8	**148**
WVP-4-M-{7.8}	18	14	9	19	15	17	18	17	15	6	**148**
WVP-4-M-1	11	6	14	18	9	17	18	13	16	14	**136**
WVP-4-M-2	11	11	18	12	18	16	18	15	18	0	**137**
WVP-4-M-2	14	9	15	14	10	16	18	16	11	3	**126**
WVP-4-P	14	14	10	14	15	17	9	14	12	10	**129**
WVP-4-P	16	12	14	13	12	16	11	16	10	10	**130**
WVP-4.5-{0.5}	10	11	10	19	7	16	12	12	14	8	**119**
WVP-5	16	7	14	18	12	18	16	9	15	16	**141**
WVP-5-A-{1.4}	6	8	16	7	9	12	18	20	5	5	**106**
WVP-6-{1.2}	16	16	14	18	17	15	18	14	11	19	**158**
WVP-6-{9.1}	10	15	18	15	7	2	11	4	17	19	**118**
WVP-6-{17.3}	11	12	13	17	12	13	16	14	13	18	**139**
WVP-6-{18.4}	15	13	18	17	8	10	15	12	13	9	**130**
WVP-6-{33.8}	14	13	17	16	15	16	17	14	15	12	**149**
WVP-6-A-{0.5}	18	16	17	19	15	16	15	17	13	20	**166**
WVP-6-A-{1.3}	18	14	17	19	14	16	15	17	14	19	**163**
WVP-6-A-{9.4}	12	13	8	18	11	16	8	15	13	18	**132**
WVP-6-A-1-{1.6}	17	16	15	20	12	17	14	9	15	20	**155**
WVP-6-A.1	15	14	10	16	16	18	16	18	18	4	**145**
WVP-6-A.2	18	13	13	20	12	18	15	13	17	20	**159**
WVP-6-A.5-{0.2}	16	16	10	16	14	18	12	18	16	16	**152**
WVP-6-C.8-{0.6}	17	16	11	18	13	17	12	18	18	17	**157**
WVP-6-D	15	16	15	18	15	18	14	17	16	15	**159**
WVP-6-D	16	16	17	19	15	16	14	16	17	10	**156**
WVP-6-G-1	19	15	10	20	15	18	16	19	18	18	**168**

Table A-10. Rapid Habitat Assessment Scores (continued).

Stream Code	cover	substrate	embed	veloc	alteration	sediment	riffle freq.	flow	bank stab.	bank veg	grazing	rip veg	**Total**
WVP-8	14	18	15	16	17	13	15		16	18	14		**156**
WVP-9-{1}	16	16	13	18	17	11	18		18	18	19		**164**
WVP-9-{10}	18	16	18	19	16	16	16		18	12	19		**168**
WVP-9-{12.2}	15	14	14	19	18	10	18		14	16	15		**153**
WVP-9-{15.2}	16	14	17	19	14	16	15		16	15	18		**160**
WVP-9-{18.2}	12	9	16	18	11	4	17		14	11	14		**126**
WVP-9-{21.6}	16	11	15	18	13	11	14		14	16	14		**143**
WVP-9-{23.6}	17	15	19	15	15	15	15		12	15	11		**149**
WVP-9-{33.2}	17	16	18	18	15	16	16		16	18	11		**161**
WVP-9-{35.6}	17	16	12	19	18	16	17		14	14	19		**162**
WVP-9-{36.8}	16	13	17	15	16	15	16		17	17	13		**155**
WVP-9-B-{0}	17	16	13	15	16	18	16		18	13	19		**161**
WVP-9-B-{12.8}	16	12	10	20	15	16	18		17	18	20		**162**
WVP-9-B-1-A-{0.1}	18	17	16	20	17	18	18		20	18	20		**182**
WVP-9-D.8-{0.5}	12	11	14	18	13	17	13		15	16	14		**143**
WVP-9-E-{1.5}	16	15	17	18	13	18	13		7	9	17		**143**
WVP-9-E-{7}	14	14	15	16	12	15	15		7	3	2		**113**
WVP-9-E-1	15	13	10	17	15	17	14		15	15	9		**140**
WVP-9-F	13	12	10	18	14	18	14		14	14	17		**144**
WVP-9-G-{0.25}	17	16	15	17	14	14	14		17	16	11		**151**
WVP-9-G-1	15	14	10	15	15	17	15		13	12	4		**130**
WVP-9-G-1	16	11	12	17	11	16	11		10	12	8		**124**
WVP-9-G-2-{0}	18	16	10	18	16	18	16		16	16	19		**163**
WVP-9-G-3	16	10	9	15	15	16	15		13	16	11		**136**
WVP-9-I	13	11	8	16	12	18	17		18	18	6		**137**
WVP-12-{5.2}	18	13	14	18	14	17	15		14	13	19		**155**

Each category scored 0-20; total possible score = 200.

cover = epifaunal substrate cover/available fish cover.
embed = embeddedness.
velocity = # of velocity/depth regimes.
alteration = channel alteration
sediment = sediment

riffle freq. = riffle frequency.
flow = channel flow status.
bank stab. = bank stability.
bank veg = bank vegetative protection.
rip veg = width of undisturbed vegetative zone.

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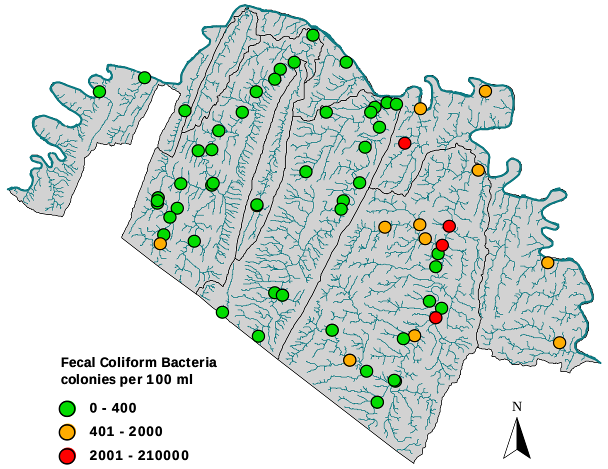
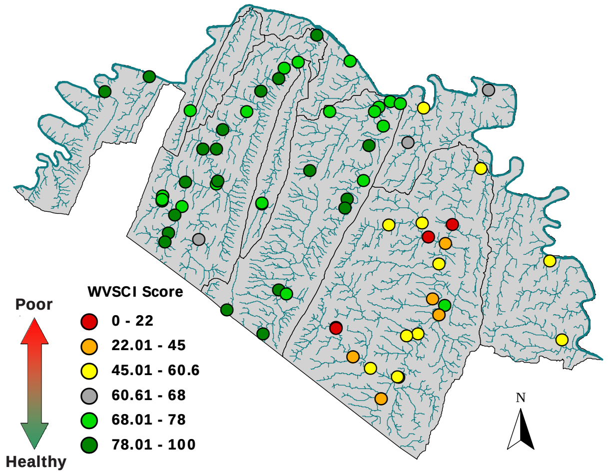
This report summarizes data collected in the Potomac Direct Drains Watershed by the Watershed Assessment Section in 1998. It includes:

Water quality information from 67 sites,



Biological health information (benthic macroinvertebrates) from 67 samples,



And physical habitat and landuse pattern information that helps identify and explain impairments affecting the streams of West Virginia's Potomac River Direct Drains Watershed.

Watershed Assessment Section

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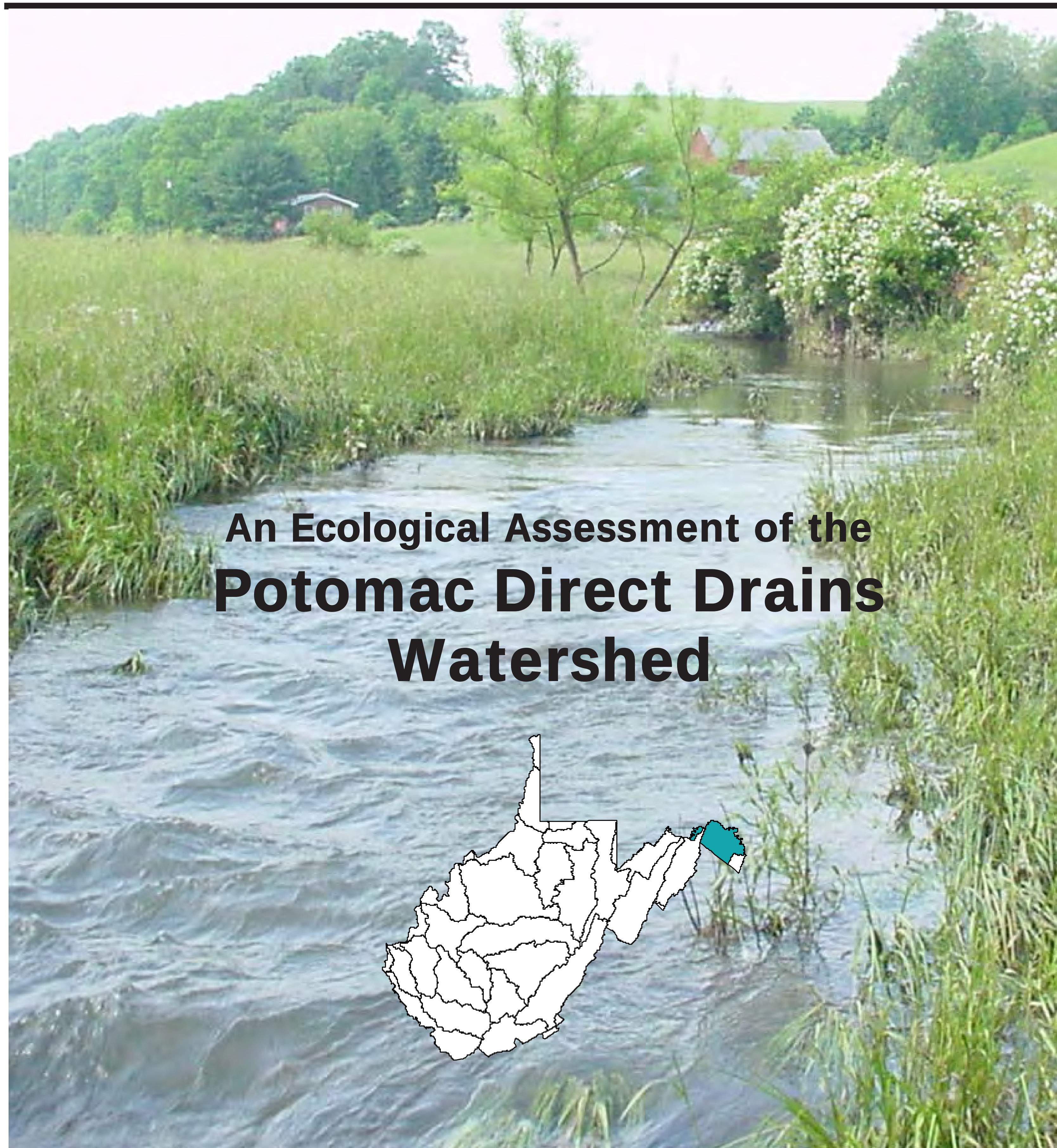
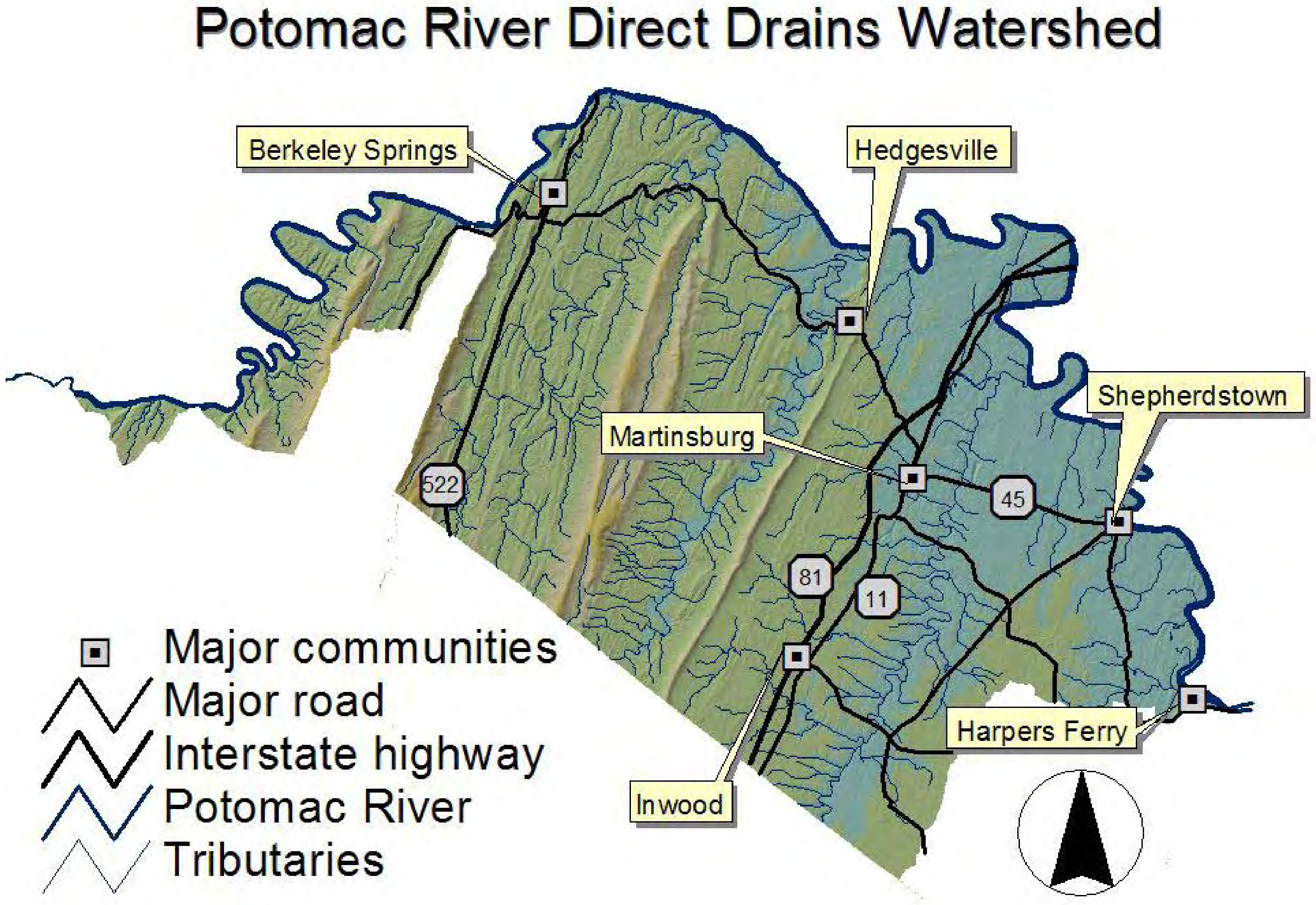
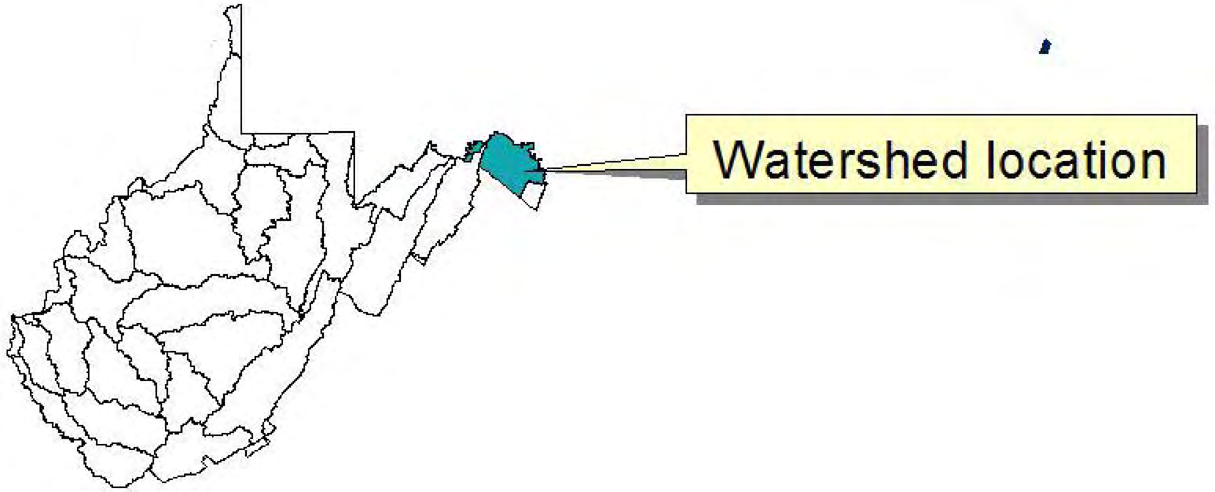


An Ecological Assessment of the
Potomac Direct Drains Watershed





The cover photo of the Middle Fork of Sleepy Creek was taken by Kevin Seagle.
The cover design is by Doug Wood & John Wirts.

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