An Ecological Assessment of the West Virginia Portions of the Shenandoah River Watershed - 1996

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Summary

Assessment teams visited 15 sites in the Shenandoah River watershed during late August and early September 1996. Although the majority of the watershed is within Virginia, West Virginia does contain two small portions of the watershed. The Jefferson County portion (HUC # 02070007) includes 31 kilometers (19 miles) of the mainstem river nearest its confluence with the Potomac River at Harpers Ferry. Eleven of the 15 sites sampled are on tributaries and two are on the mainstem within this section. The Hardy County portion (HUC # 02070006) contains the two remaining sample sites which are on tributaries of the North Fork of the Shenandoah River. All named streams within West Virginia were sampled, except Rocky Branch (Jefferson Co.) and the headwaters of Spring Run (Hardy Co.), which were deemed inaccessible. Assessments at each site included measurements of physical attributes of the stream and riparian zone, observations of activities and disturbances in the surrounding area, water quality analysis and a benthic macroinvertebrate collection.

The streams in this watershed can be divided into several geological and size categories. Results from the macrobenthic survey are compared within their respective geological and size width classes. One of three streams from the Blue Ridge Area appears to have a moderate level of impairment. The eight streams in the Limestone / Dolomite Valley region ranged from severely impaired to nonimpaired. There were no suitable reference sites within the watershed for the two Hardy County sites. Therefore these two sites were compared to reference sites from the South Branch of the Potomac River watershed, which was also sampled in the late summer of 1996. This comparison indicated moderate impairment at both sites. The benthic collection from the Shenandoah River was evaluated by staff biologists. Based on their best professional judgement there was no major impairment to the benthic community in the Shenandoah

River mainstem.

Cattle and their propensity to damage stream banks and instream habitat, appear to be the largest single problem in the watershed. Agricultural cropland is also abundant in the area and negative effects from fertilizers, herbicides, and pesticides are possible, although any direct effects are difficult to determine with the limited water quality data collected during this study.

Ten sites had fecal coliform bacteria concentrations greater than the criterion for applicable stream uses.

Five priority actions have been suggested based on the findings of this watershed assessment. They are:

- C Cooperate with the U. S. Environmental Protection Agency to develop a program of establishing ecoregional reference sites.

- C Continue the education program and distribution of literature on sediment and eroision control and their benefits to the aquatic community.

- C Determine the sources of impact on the biota of Hog Run and take appropriate restoration actions.

- C Examine North Fork of Bullskin Run and Bullskin Run to determine the cause and sources of the impactment.

- C Continue efforts to reduce fecal coliform bacteria contamination from point and non-point sources.

Acknowledgments

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Janice Smithson, James Moore, Jeffrey Bailey, and Douglas Wood collected the samples and assessed the sites. Marshall University Students, Eric Wilhelm and Andrea Henry, under the supervision of Dr. Donald Tarter and Jeffrey Bailey, processed the benthic macroinvertebrate samples. Janice Smithson, Jeffrey Bailey, Douglas Wood, and Alvan Gale identified the macroinvertebrates. Charles Surbaugh entered the raw data into the database. John Wirts, the primary author of this report, summarized the data and created the tables and figures. Patrick Campbell and Michael Arcuri provided help in reviewing the various drafts of this report and bringing it to completion. James Hudson assisted in editing and laying out this report.

A Relatively Intact Stream Reach

Watersheds and their Assessment

In 1959, the West Virginia Legislature created the State Water Commission, predecessor of the Office of Water Resources (OWR). The OWR has since been charged with balancing the human 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 (the Act) plus its subsequent amendments to restore the quality of our nation's waters. For 25 years, the Act's National Pollutant Discharge Elimination System (NPDES) has caused reductions in pollutants piped to surface waters. There is broad consensus that, because NPDES permits have reduced the amount of contaminants in point sources, the water quality of many of our nation's streams has improved significantly.

Under the federal law, each state was given the option of managing NPDES permits within its borders or leaving the federal government in that role. When West Virginia assumed primacy over NPDES permits in 1982, the state's Water Resources Board [combined with the Air Pollution Control Board in 1994 to become the Environmental Quality Board (EQB)] began developing water quality criteria for each kind of use designated for the state's waters (see box). In addition the WV Division of Environmental Protection's (DEP) water protection activities are guided by the EQB's anti-degradation policy, which charges the OWR with maintaining surface waters at sufficient quality to support existing uses, 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 examining pollutants flushing off the landscape from a broad array of hard to identify and control sources. Recognizing the negative impacts of these Non-Point Sources (NPS) of pollution, which do not originate at clearly identifiable pipes or other outlets, was a conceptual step that served as a catalyst for today's holistic watershed approach to improving water quality.

Water Quality Criteria - The levels of water quality parameters or 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,
- agricultural and wildlife uses, and
- industrial uses.

A variety of watershed projects are currently being implemented by several DEP units, including the Watershed Assessment Program (the Program). Located within the OWR, the Program's scientists are charged with evaluating the health of West Virginia's watersheds. The Program is guided, in part, by the Interagency Watershed Management Steering Committee (see sidebar).

The Program uses the U.S. Geological Survey's (USGS) scheme of hydrologic units to divide the state into 32 watersheds (see map, Figure 2). Some of these watershed units are entire stream basins bounded by natural hydrologic divides (*e.g.*, Upper Guyandotte River watershed). Two 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) and (2) the West Virginia parts of interstate basins (*e.g.*, Tug Fork watershed). A goal of the Program is to assess each watershed unit every 5 years, an interval coinciding with the reissuance of National Pollutant Discharge Elimination System (NPDES) permits.

The Interagency Watershed Management Steering Committee consists of representatives from each agency which signed the Watershed Management Framework. It coordinates 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. This position organizes and facilitates the Steering Committee meetings, maintains the watershed management schedule, assists with public outreach, and is the primary contact for watershed management related issues.

GENERAL WATERSHED ASSESSMENT STRATEGY

A watershed can be envisioned as an aquatic “tree”, a system of upwardly branching, successively smaller streams. An ideal watershed assessment would document changes in the quantity and quality of water flowing down every stream, at all water levels, in all seasons, from headwater reaches to the exit point of the watershed. Land uses throughout the watershed would also be quantified. Obviously this approach requires more time and resources than are available to any agency.

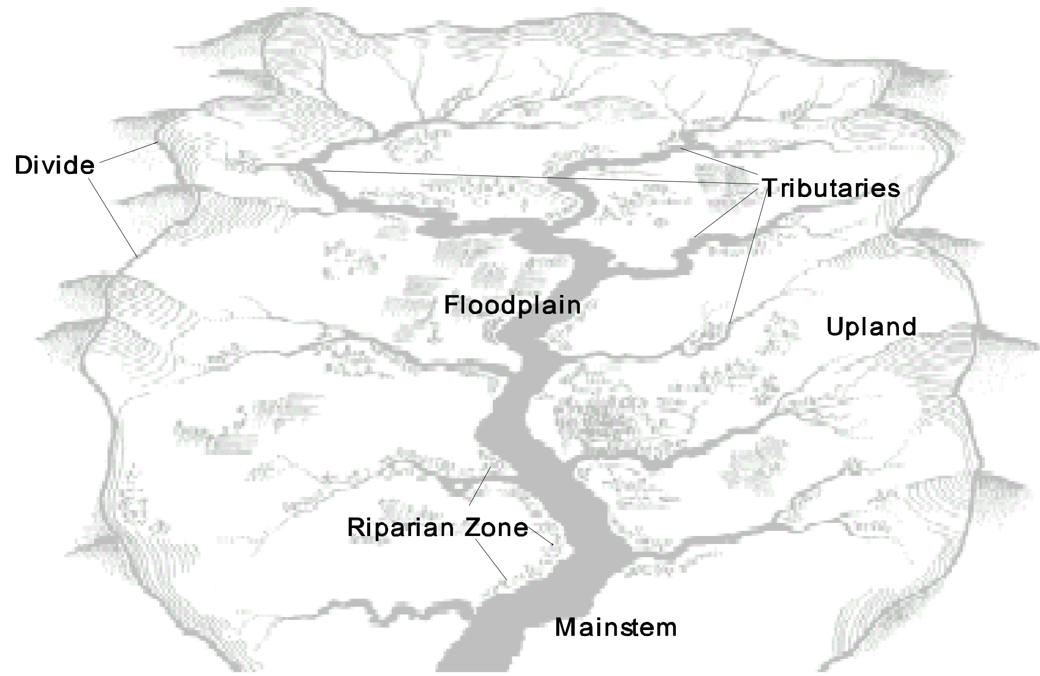
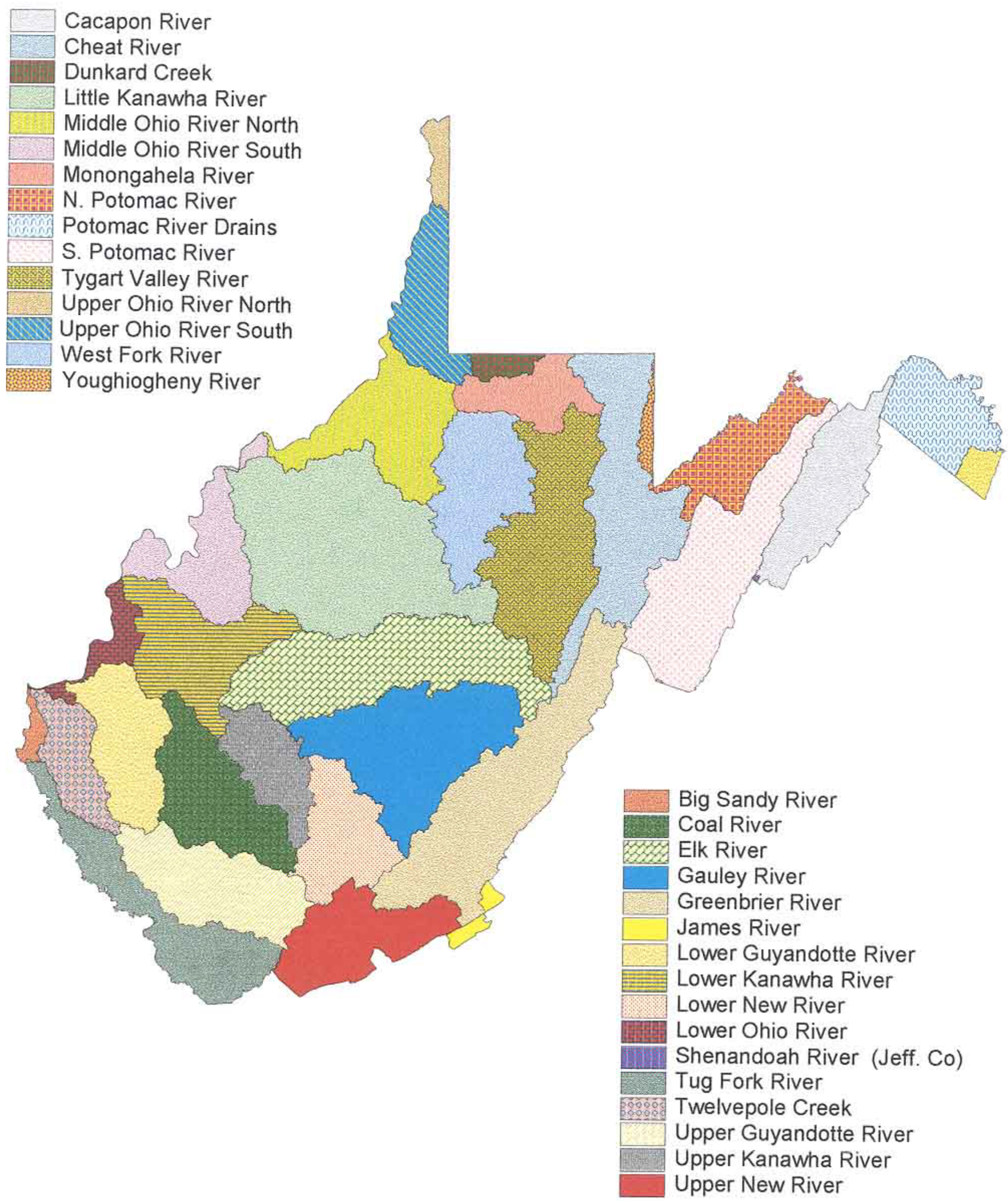


FIGURE 1: A Generalized Watershed

Adapted from Sarah B. Lauterbach

Watershed: In several dictionaries, the first definition of "watershed" is the divide between adjoining water drainage areas. This report, though, uses an alternate definition, namely "all the land surface from which water drains to a specific point". For example, the Shenandoah River watershed, detailed in this report, includes the part of Jefferson and Hardy counties that sheds surface water to Shenandoah River at the point it leaves the state of West Virginia.

Figure 2. Map of West Virginia Watersheds



The Program, therefore, assesses the health of a watershed by evaluating the health of as many of its streams as possible, as close to their mouths as possible. An exception to this general strategy is the strategy developed specifically for comparing watersheds to one another. This special sampling strategy is detailed in the section titled "Special Watershed Assessment Strategy." The general sampling strategy can be broken into several steps:

- The names of streams in the watershed are retrieved from the United States Environmental Protection Agency's (EPA) Water Body System database.

- A list of streams is developed that consists of several sub-lists. These sub-lists include:
  1. Severely impaired streams,
  2. Slightly or Moderately impaired streams,
  3. Unimpaired streams,
  4. Unassessed streams,
  5. High Quality Streams, and
  6. Streams of particular concern to citizens, and permit writers.

- Assessment teams visit as many streams listed as possible and sample as close to the streams' mouths as allowed by road access and sample site suitability. Longer streams may also be sampled at additional sites further upstream. In general if a stream is 15 to 30 miles (25 to 50 km) long, two sites are sampled. If a stream is 30 to 50 miles (50 to 89 km) long, three sites are sampled. If a stream is 50 to 100 miles (80 to 160 km) long, four sites are sampled. If a stream is longer than 100 miles (160 km), five sites are sampled. If inaccessible or unsuitable sites are dropped from the list, they are replaced with previously determined alternate sites.

The Program has scheduled the study of each watershed for a specific year of a 5-year cycle. Advantages of this pre-set timetable include: a) synchronizing study dates with permit cycles, b) facilitating the addition of stakeholders to the information gathering process, c) insuring assessment of all watersheds, d) improving the OWR's ability to plan and e) buffering the assessment process against domination by special interests.

Streambank Erosion in an Agricultural Area

In broad terms, OWR evaluates the streams and the Interagency Watershed Management Steering Committee sets priorities in each watershed in 5 phases:

Phase 1 - For an initial cursory view assessment teams measure or estimate about 50 indicator parameters in as many of each watershed's streams as possible.

Phase 2 - Combining pre-existing information, new Phase 1 data and stakeholders' reports, the Basin Coordinator produces a list of streams of concern.

Phase 3 - From the list of streams of concern, the Interagency Watershed Management Steering Committee (see sidebar) develops a smaller list of priority streams for more detailed study.

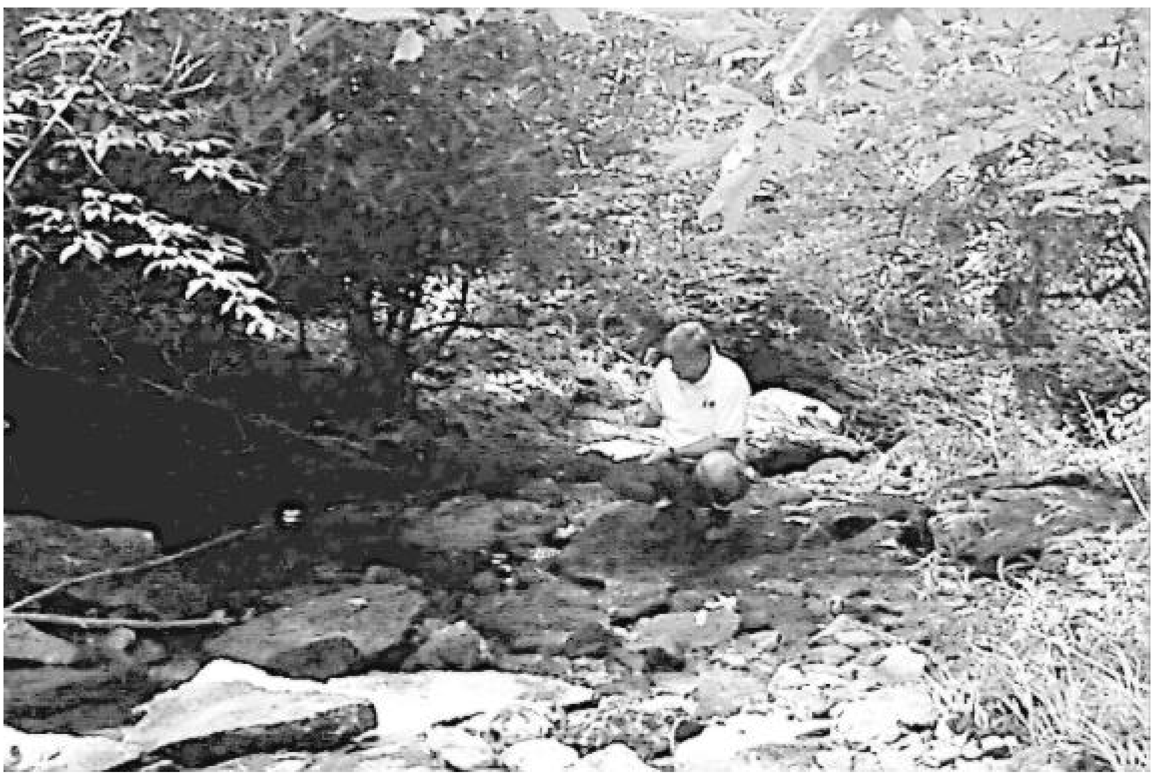
Phase 4 - Depending on the situation, Program teams or outside teams (*e.g.*, USGS or consultants) intensively study the priority streams.

Phase 5 - The Office of Water Resources issues recommendations for improvement; develops total maximum daily loads, if applicable (see box); and makes data available to any interested party such as local watershed associations, educators, consultants and citizen monitoring teams.

This document, which reports Phase 1 findings for the Shenandoah River watershed in West Virginia, has been prepared for a wide variety of users, including elected officials, environmental consultants, educators and natural resources managers.

SPECIAL WATERSHED ASSESSMENT STRATEGY - RANDOM SAMPLING

EPA and other federal agencies have been interested in the relative conditions of the nation's waters since the Clean Water Act of 1972 mandated they prioritize water quality restoration efforts. Within West Virginia, several state agencies have an interest in prioritizing such efforts as well. The general sampling strategy, discussed on page 5, can be used to compare watersheds, but it was designed with other purposes in mind and will not pass the rigors of statistical tests that must be applied in a scientifically-sound, comparative study.



Assessing the Habitat

<u>Total Maximum Daily Load and the 303(d) List</u> - The term "total maximum daily load" (TMDL) originates in the federal Clean Water Act, which requires that degraded streams be restored to their designated uses.

Every two 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. Prior to adding a stream to the list, technology-based pollution controls must have been implemented or the conclusion must have been reached that even after implementing such controls the stream would not support its designated uses. West Virginia's 303(d) list includes streams and lakes affected by a number of stressors including mine drainage, acid rain, 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) stream begins by calculating a TMDL, which involves several steps:

- define when a water quality problem is occurring, the critical condition, (*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,
- distribute 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 implementable.

The Program was designed in part to determine whether a stream belongs on the 303(d) list. In some cases, this determination can be made readily, for example, a stream degraded by acid mine drainage (AMD). However, the determination is more difficult to make for most streams because of a lack of data or data that are conflicting, of questionable quality or too old. Any stream which would not support its designated uses, even after technology based controls were applied, is a candidate for listing.

The Program's Phase 1 screening process provides information for making decisions on listing. A broader interagency process, the West Virginia Watershed Management Approach, enables diverse stakeholders to collectively decide which streams should be studied more intensively.

After the 1996 sampling season the Program developed a special sampling strategy to compare watersheds to themselves and each other. It can be highlighted in a few steps:

C 30-45 stream locations in each watershed are selected randomly from an EPA database.

C Personnel from the Program, Environmental Enforcement and other groups reconnoiter the locations to secure landowner approval for sampling.

C Sampling teams visit the sites and sample in the manner described under the general assessment strategy.

C Analysis of the data allows the Program to make statistically valid statements about the watershed.

The Shenandoah River Watershed

The Shenandoah River watershed makes up the majority of the Great Valley physiographic province which also includes the Opequon, Conococheague and Antietam Creek watersheds. It is the largest tributary of the main stem of the Potomac River and drains approximately 7900 square kilometers (3050 square miles). It drains the eastern slopes of Great North Mountain, the western slopes of the Blue Ridge Mountains, and the broad valleys between. The West Virginia portion of the Shenandoah watershed actually consists of two very small hydrologic units: the Jefferson County unit (HUC # 02070007); and the Hardy County unit (HUC # 02070006). (see sidebar)

Hydrologic Unit Code - The U.S. Geological Survey has developed a Hydrologic Unit Code (HUC) used to identify watersheds throughout the United States. These numbers have replaced the older "map code" system of identifying watersheds.

HUC numbers consist of eight digits. The first two indicate the region the watershed is located in. West Virginia watersheds are located in one of two regions: 02 (Mid-Atlantic) is used to designate those watersheds which drain to the Atlantic Ocean. 05 is used to designate those streams which flow to the Gulf of Mexico via the Ohio River.

The next two digits indicate the subregion. All streams which flow into the Ohio at its beginnings in Pittsburgh are in sub-region 02. Those watersheds flowing into the Ohio between Pittsburgh and the mouth of the Kanawha at Point Pleasant are in sub-region 03. The Kanawha River watershed is sub-region 05. The Mud River and Big Sandy/Tug Fork water sheds are sub-region 07. Twelve Pole Creek and the scattering of creeks between Point Pleasant and the mouth of Mud River are sub-region 09.

For the Mid-Atlantic Region the Potomac River drainage (which contains the Shenadoah River) is sub-region 07. The James River watershed (in Pendleton and Monroe Counties) is sub-region 08. The remaining four digits indicate the accounting and catalog units for the individual watersheds.

The Shenandoah River is formed by the confluence of its North and South Forks at the north end of Massanutten Mountain at Riverton, Virginia. From Riverton it flows 55 kilometers (34 miles) to the southern boundary of Jefferson County, West Virginia. It then flows 31 kilometers (19 miles) near the eastern border of Jefferson County to its confluence with the Potomac River at Harpers Ferry. The drainage within this area includes a number of long tributaries flowing through the relatively flat agricultural land to the west of the river and several shorter streams which drain the more forested western slopes of the Blue Ridge Mountains to the east.

A survey by the WV Division of Natural Resources (DNR) in 1954 indicated that the Shenandoah had recovered from the widespread pollution that occurred during the 1940s in association with logging, the introduction of toxic chemicals and untreated domestic sewage (Ross & Lewis 1969). The Halltown Paper Board plant is located on Flowing Springs Run about 2.4 kilometers (1.5 miles) upstream from the 1996 sample point. There are several large sewage treatment plants in the area. Flowing Springs Run receives the discharges from two plants which serve the two Charles Town racetracks. They discharge more than 100,000 each gallons per day. Willow Springs Public Service District's treatment plant discharges 100,000 gallons per day into Cattail Run. Evitts Run receives discharges from the main Charles Town wastewater treatment plant which range from 600,000 to 700,000 gallons per day. This plant is capable of discharging up to 1,200,000 gallons per day. (Kevin Lilly -DEP Inspector, personal communication). Potomac Light and Power Company has a hydroelectric plant on the Shenandoah River approximately 9 kilometers (5.5 miles) from its confluence with the Potomac.

Leading industries in Jefferson County are cement, road materials, clothing, paper, boxboard, lumber, brass, lime marl, dolomite, and fertilizer. Jefferson's main agricultural products are fruit, livestock, hay, grain, and dairy (WV Bluebook).

The small Hardy County portion of the watershed has no industrial or municipal discharges. The area is primarily forested, with cropland in areas where the topography allows (see Figure 6).

The only stream in the watershed on the 1996 303(d) list is the Shenandoah River mainstem, which is listed for PCB's (Polychlorinated biphenyls) because levels found in fish tissue (carp, catfish and sucker species) exceeded the advisory threshold. The list indicates that the entire 31 kilometers (19 miles) of the mainstem within West Virginia are impaired. Despite the PCB problem, the Shenandoah River is considered an excellent fishery, especially for smallmouth bass, rock bass, sunfish and channel catfish (Gerry Lewis, District II Fisheries Biologist, personal communication). Bullskin Run, Evitts Run, and Long Marsh Run are all stocked with trout by the WV Division of Natural Resources (WVDNR).

The Shenandoah River watershed is predominantly in the Ridge and Valley ecoregion (Ecoregion 67) (Omernik 1997), specifically in the Northern Limestone/ Dolomite Valleys sub-ecoregion (67a). This subregion is a lowland characterized by broad, level to undulating, fertile valleys that are extensively farmed. The growing season is around 160 days. The average annual precipitation at the Kearneysville climatological station is just over 0.9 meters (38 inches) (National Weather Service, personal communication). Sinkholes, underground diffuse flows, (one entrance zone and several exit points) and other karst features have developed on the underlying limestone/dolomite, and as a result, the surface drainage density is low. Where streams do occur, they tend to have gentle gradients and plentiful perennial flow.

Figure 3. Jefferson County sample sites

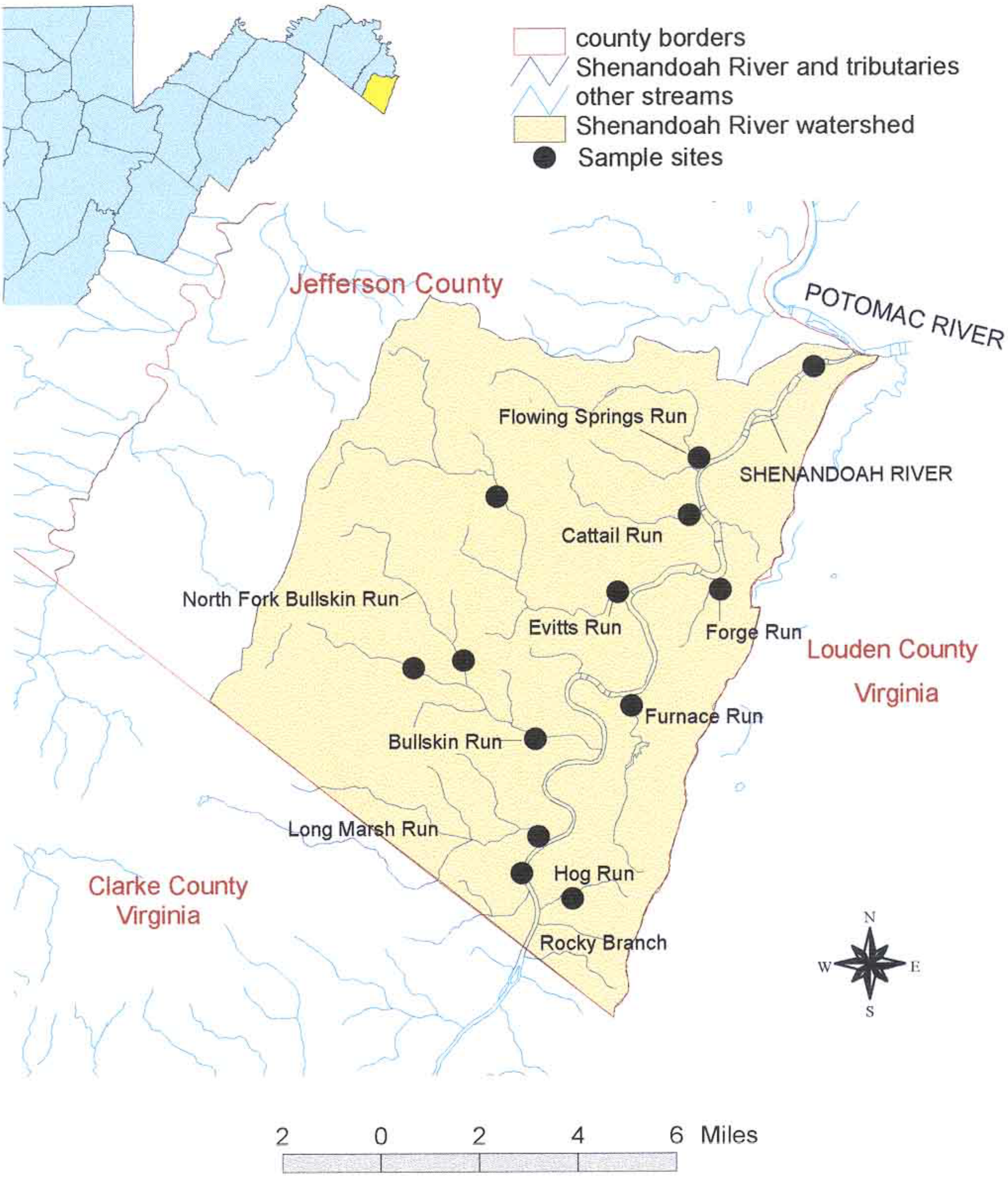
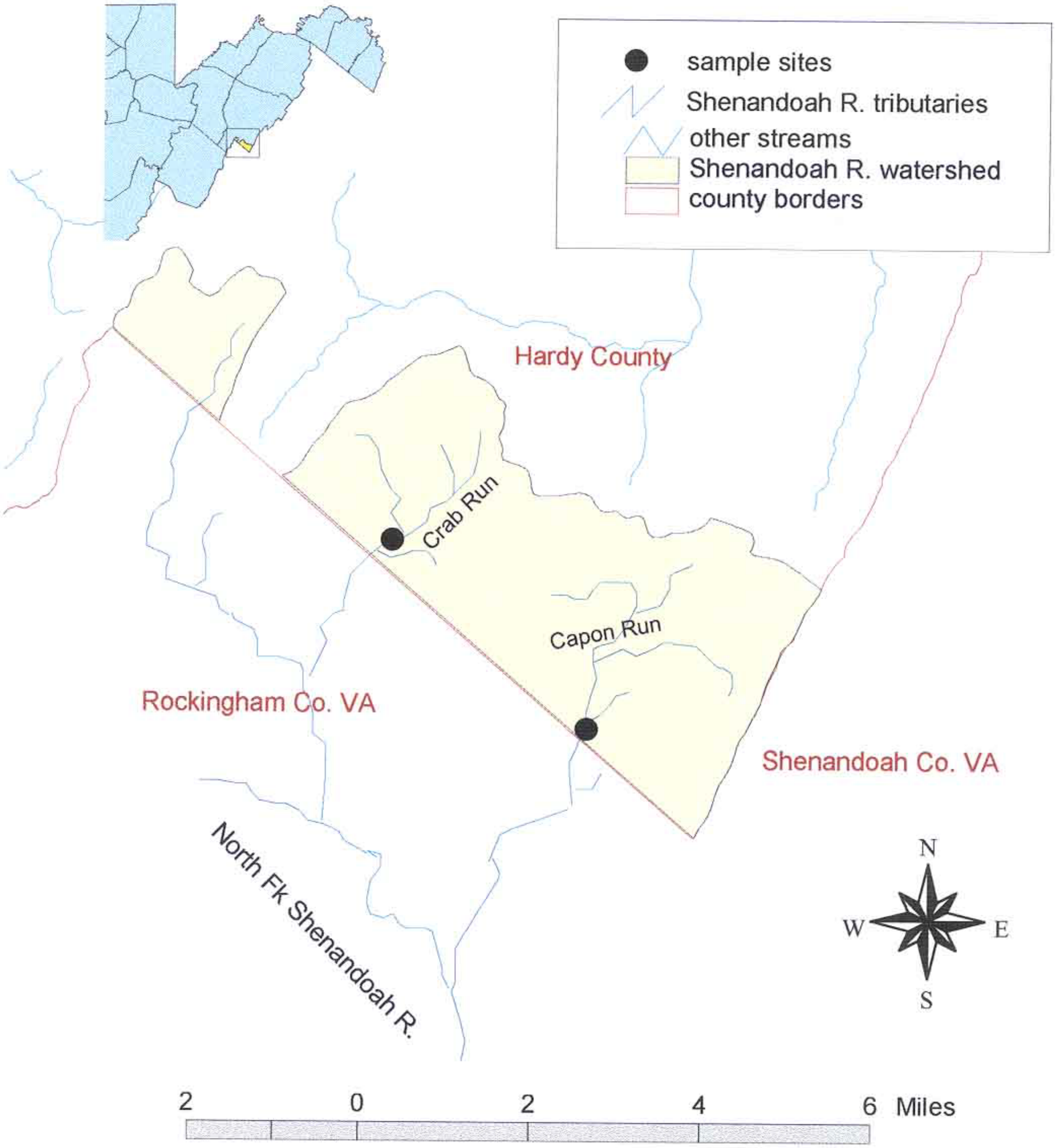


Figure 4. Hardy County sample sites

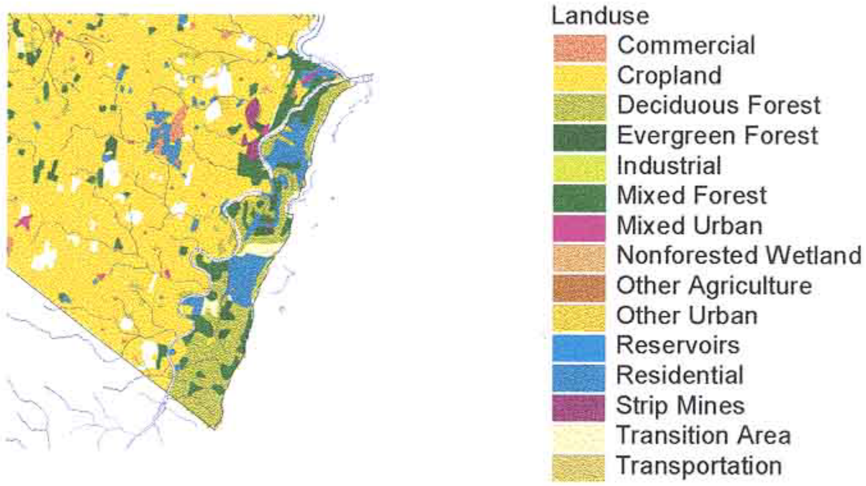


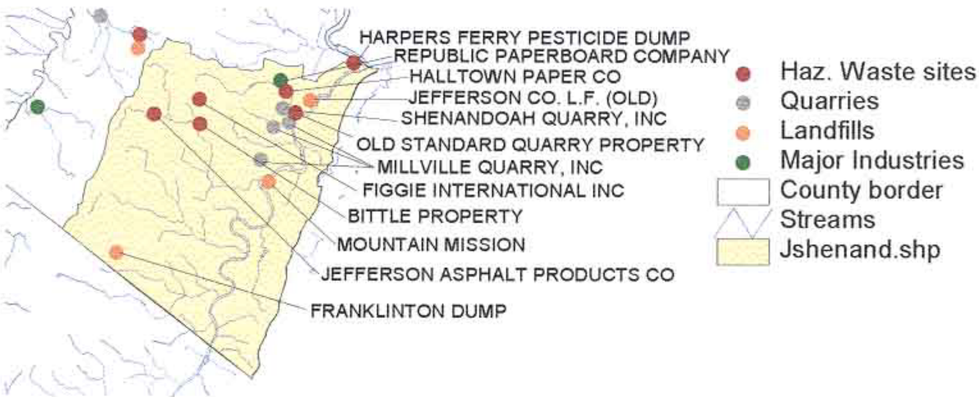
The two Hardy County sample sites are located in the Northern Shale Valleys sub-ecoregion of the Ridge and Valley ecoregion. This sub-ecoregion is primarily rolling valleys and low hills. It is underlain mostly by shale, siltstone and fine-grained sandstone. Since these strata are not as permeable as limestone, surface streams are larger and drainage density is greater than in the adjoining Northern Limestone/Dolomite Valleys.

The Blue Ridge Mountains Ecoregion is east of the Shenandoah Rivers mainstem. This area is within the Northern Sedimentary-Metasedimentary Ridges Sub-ecoregion (66b). It is composed of high, steeply sloping ridges and deep, narrow valleys. The underlying rocks are resistant to erosion and form soils that are stony, relatively infertile and acidic. Streams are typically cool and clear, and have many riffle sections. They have limited buffering capacity and are subject to acidification.

Stream Ford

Figure 5. Landuse Categories, Industrial Sites, and Municipal Discharges - Jefferson County





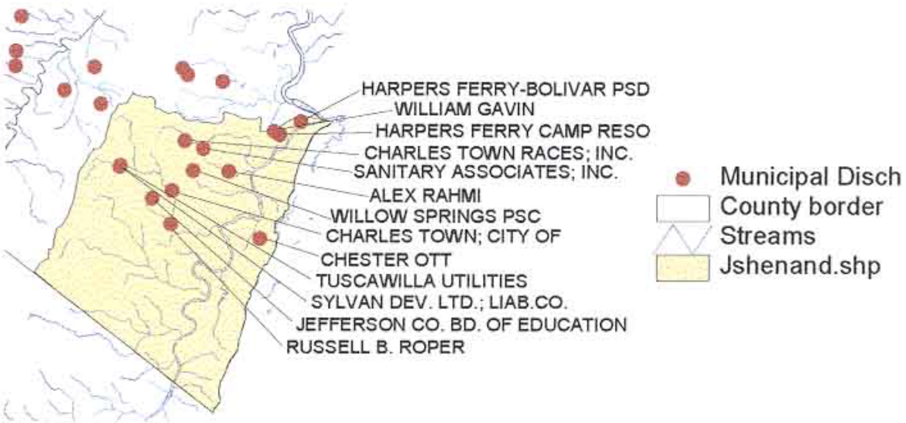
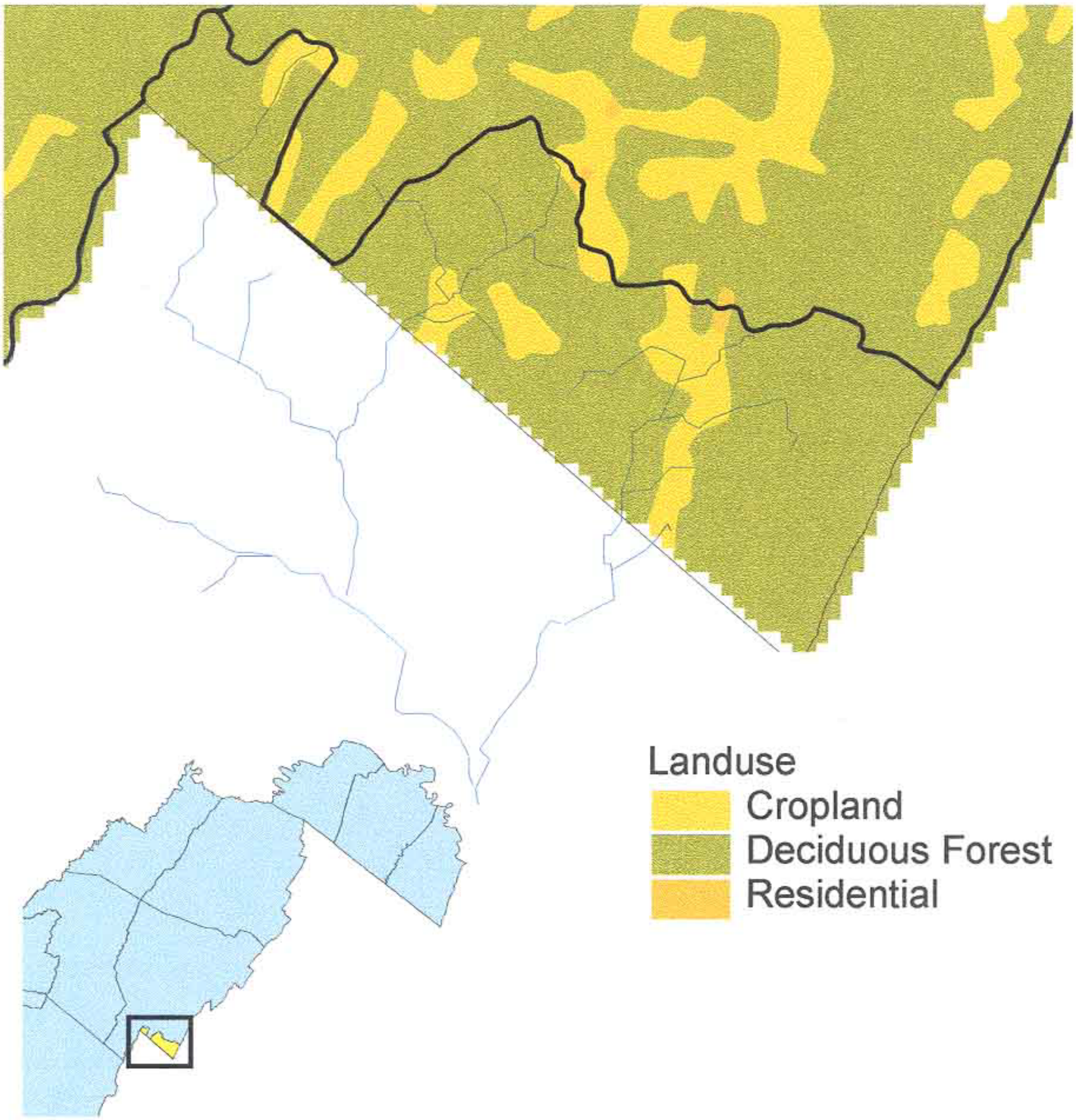


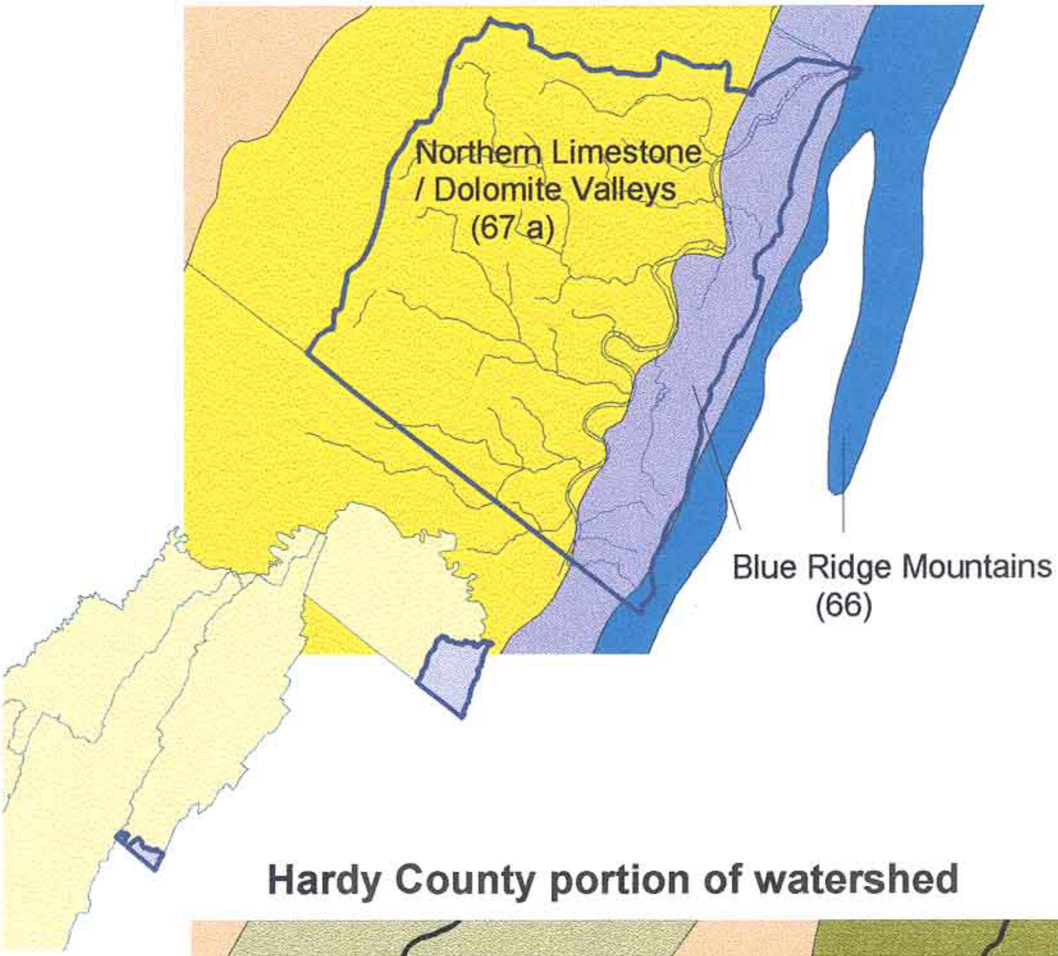
Figure 6. Landuse Categories, Industrial Sites, and Municipal Discharges* - Hardy County



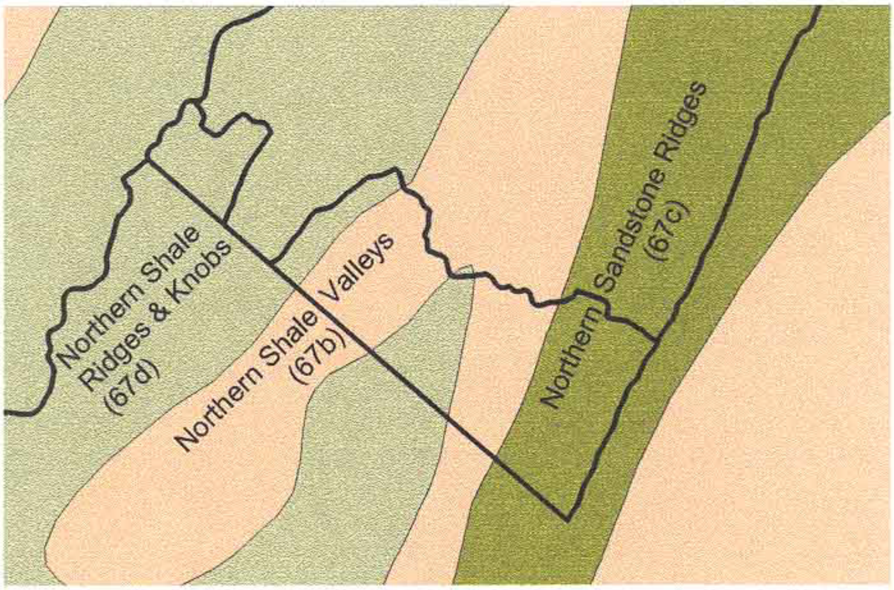
* There are no industrial sites or municipal discharges in this area of the watershed.

Figure 7. Map of Ecoregions in Watershed

Jefferson County portion of watershed



Hardy County portion of watershed



Source - US EPA, Corvallis OR.

Assessment Procedures for the Shenandoah Watershed

The Jefferson County sites were visited August 27, 28, and 29 by a field assessment team and the two Hardy County sites were visited on September 11 by another team (Figures 3 and 4 and Table 3). All named streams of the Shenandoah River watershed that are in West Virginia were sampled, except Rocky Branch (Jefferson Co.) and Spring Run (Hardy Co.) which were deemed inaccessible.

TABLE 1

SHENANDOAH RIVER WATERSHED SAMPLING SITE SUMMARY

Named streams	14
Sites visited	15
Streams visited	12
Named, not visited	2
Habitat assessed	15
Water Quality sampled	15
Benthos sampled	14

The field teams collected benthic macroinvertebrate samples at each site following Rapid Bioassessment Protocol II (RBP II) (Plafkin, et. al. 1989), except the upstream site on Bullskin Run which had insufficient habitat to obtain a complete benthic sample. Samples were collected through the use of a half-meter wide rectangular frame kick net. The sampling technique and the metrics are described in Appendix B.

The benthic samples were delivered to Marshall University where students of Dr. Donald Tarter, Professor of Aquatic Biology, prepared them for identification by Office of Water Resources personnel. The 100-count subsample preparation technique (Plafkin, et. al. 1989) was used. Evaluation of the benthic data consisted of summarizing the results of six community metrics [taxa richness, EPT taxa, Modified HBI (FBI), % dominant taxa, the ratio of EPT taxa to chironomidae, and the ratio of scrapers to filtering collectors].

In order to determine the biological health of a stream, it is necessary to have a reference condition to compare it to. In previous assessments, the Program has used the least impaired single site as the reference condition. This assumes that there is at least one non-impaired stream in an assessment area to compare other sites to, and that this one stream will fairly represent the entire study area. As the watershed assessment movement progressed, it became clear that it is sometimes difficult to identify a single reference site that has both (1) minimal impairment and (2) the type of biological community that would provide defensible conclusions about the impairment of assessed sites. As a result, the Program began using a collection of streams that meet predetermined minimum criteria, to define the reference condition.

The benthic community metric values for this reference set of sites are calculated and the distribution of these values over a percentage continuum determines the scoring criteria for each metric. For each metric there are three possible scores: optimal receives a 2; mid-range receives a 1; and the lowest values receive a 0. The range from 100% to 25% of the reference set is used as the optimal score range for metrics with values that decrease with increasing disturbance to the benthic cummunity. For these metrics, values that fall within this range, receive a score of “2". The range fro 0% to 75% defines the optimal range for metrics with values that increase with increasing disturbance (HBI, percent dominant taxa). For these metrics, values that fall within this range, also receive a score of “2".

The division between the mid-range and lowest score is the value which is equidistant between the lower optimal score percentile and the lowest possible score for those values that decrease with increasing disturbance. For values that increase with increasing disturbance the division between the mid-range and the lowest score is the value which is equidistant between the higher optimal score percentile and the highest possible score. **The sum of the scores of the 6 metrics used by the Program provide a single index value for each site. This value is adjusted to a scale of 100 (a score of 12, which is the highest possible, becomes 100). This value is referred to as the "biological condition".** The biological condition number is the value used in the biological and habitat data summary figures.

Also collected from each site was a fecal coliform bacteria sample. EPA sampling guidelines limit the field holding time for such samples to 6 hours. However, due to the distance to laboratories, personnel limitations and time constraints, 24 hours was the holding time utilized during this sampling effort. All bacteria samples were packed in wet ice until delivered to the laboratory. Hydrochem Laboratories in Shenandoah Junction (Jefferson County sites) and CT&E Environmental Services (Hardy County sites) performed the analyses via the membrane filter method.

The physico-chemical parameters of temperature, pH, dissolved oxygen, and conductivity were determined on site using a Hydrolab™ instrument. If the assessment team suspected a stream to have elevated levels of nutrients, (e.g., an agricultural area, raw sewage, etc) they collected water samples for the analysis of nitrite + nitrate nitrogen, total phosphorus, and ammonia. CT&E Environmental Services performed these analyses.

An eight page Stream Assessment Form was filled out 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. The assessment team recorded the location of each site, utilizing a Global Positioning System (GPS) receiver when possible, and provided detailed directions so that future researchers can return to the same site. A map was also sketched to aid in locating each site. The team recorded stream measurements, erosion potential, possible sources of non-point source pollution, and any anthropogenic (caused by humans) activities and disturbances. It also recorded observations about the substrate, water and the land within the first 18 meters on each side of the 100 meter reach sampled. Part of the eight-page form is a two-page Rapid Habitat Assessment (adapted from Klemm and Lazorchak, 1994) which provides a numerical score of the habitat conditions most likely to affect aquatic life.

All the sampling and evaluation methods, as well as materials used in sampling, are described in greater detail in Appendix B.

Findings

Benthological Sampling

Benthic data are difficult, if not impossible, to interpret without comparing them to data from a reference site (i. e. one that is from a similar region, time and sample size, and that has a minimum of human or other negative impacts) or, preferably, a collection of reference sites. The fifteen sites sampled are located in three different sub-ecoregions: three are in the Blue Ridge Ecoregion, eight are in the Limestone/ Dolomite Valley sub-ecoregion of the Ridge and Valley Eco-region, and the two Hardy County sites are in the Shale Valleys sub-ecoregion of the Ridge and Valley Eco-region. (Omernik) In addition the two sites on the mainstem Shenandoah River have much larger flows than the others. These differences in sub-ecoregions and size classes made comparisons among all the sites inappropriate. Because of the small number of sites within each sub-ecoregion, comparisons within them were difficult to interpret.

The Watershed Assessment Program is presently debating the proper use of size classes in making stream comparisons. Typically, aquatic communities at stream sites of vastly different sizes are not considered comparable to one another. The reasons for this fact are myriad, but collectively they can be identified as differences in number and character of ecological niches among various sizes of streams. However, recently, several authors have published data that support the grouping of wadeable streams [stream orders 1-3 (Stribling et. al. 1993) and streams with drainages of less than 1300 square kilometers (500 square miles) (PA DEP 1997)] with similar habitats. Due to these findings and the fact that the number of sample sites on this watershed was low, the program elected to group what had previously been interpreted separately as SWC I (Stream Width Class I -average widths greater than 0 meters, but equal to or less than 3 meters) and SWC II (widths greater than 3 meters, but equal to or less than 10 meters).

We will continue to consider streams with widths greater than 10 meters as a separate group.

Example of a Typical Riffle and Pool

The three sites which drain from the Blue Ridge Mountain are not biologically comparable to the other sites because of geologically influenced differences in the water chemistry of these streams. Forge Run, Furnace Run, and Hog Run all drain relatively undisturbed forested hillsides. All three met the Program's minimum criteria for reference sites due to the undisturbed nature of their riparian zones and other factors.

The method by which the Program scored streams for biological impairment in 1996 required calculating percentiles of metric scores for all reference sites in the ecoregion. The value at the 25th percentile is the lower cutoff for the non-impaired status. As a result, one or more sites in this watershed designated as a reference will be scored as impaired for each metric.

Because only three streams were used to establish the percentiles in the Blue Ridge Mountains Ecoregion, one of these always receive an impaired score for each metric. In this case *Hog Run's* metric scores were lower in four out of six metrics (Table 18) and thus received a relatively low biological score of 58.3 (out of 100) compared to 91.6 for both *Forge and Furnace Runs* (Figures 8 & 9 show selected metric scores and Figures 10 & 11 have biological and habitat comparisons). The assessment team did not notice anything in the area of Hog Run which would indicate a potential problem, in fact they had recommended it for possible use as a reference site. The conductivity was the lowest recorded for this survey (69 µmhos). This low electrical conductance could indicate natural oligotrophic conditions (lacking nutrients), but an examination of the taxa collected (Table 19) suggests otherwise. Typically stoneflies would be present in an oligotrophic stream, yet none were found. The dominance of Hydropschidae, Simuliidae, and Chironomidae indicates that there may have been an organic enrichment problem. This conclusion is supported by the fact that this stream had the worst score for FBI (modified HBI), a metric designed to measure organic pollution.

Fig 8. Selected Macroinvertebrate Community Metrics

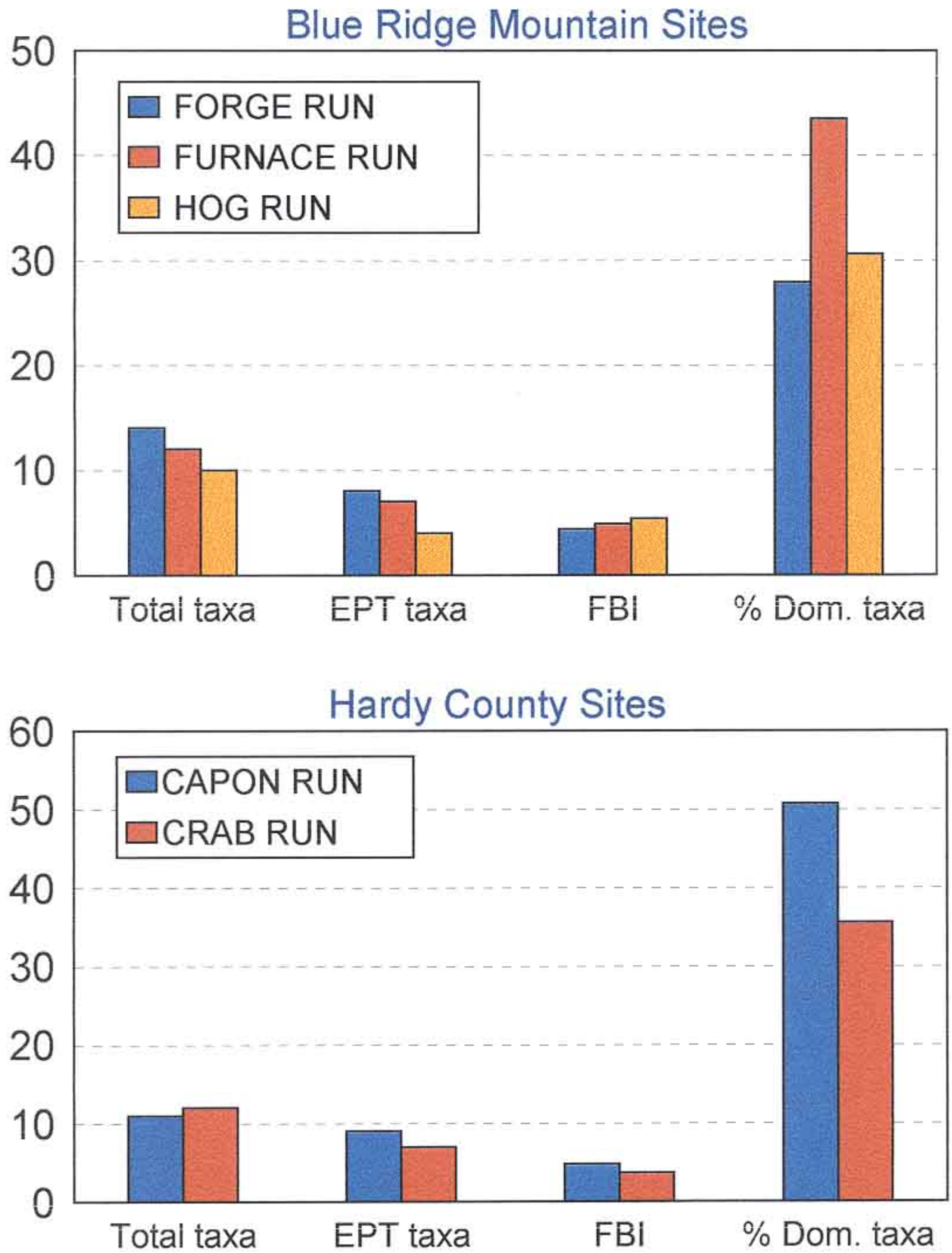


Fig 9. Selected Macroinvertebrate Community Metrics

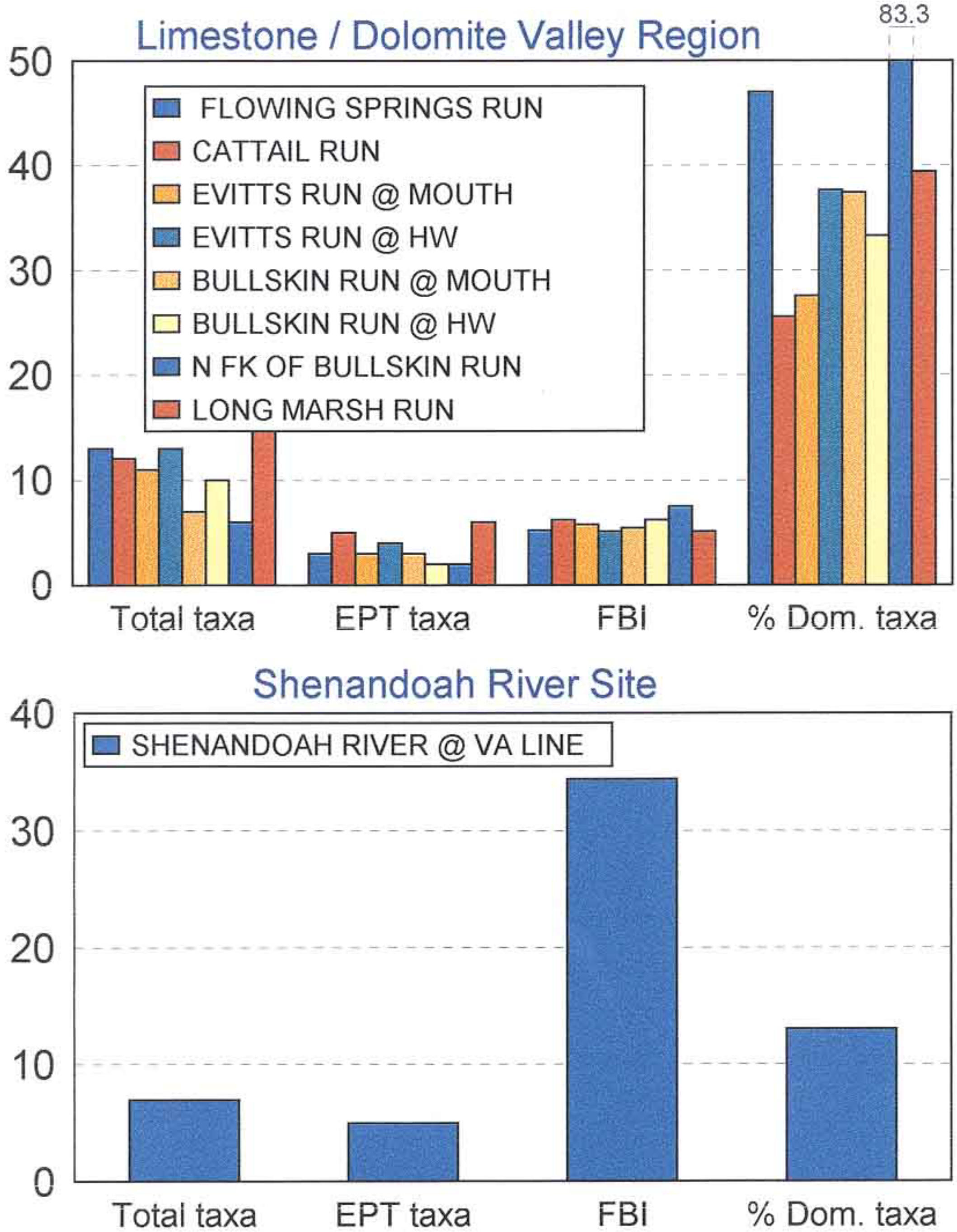
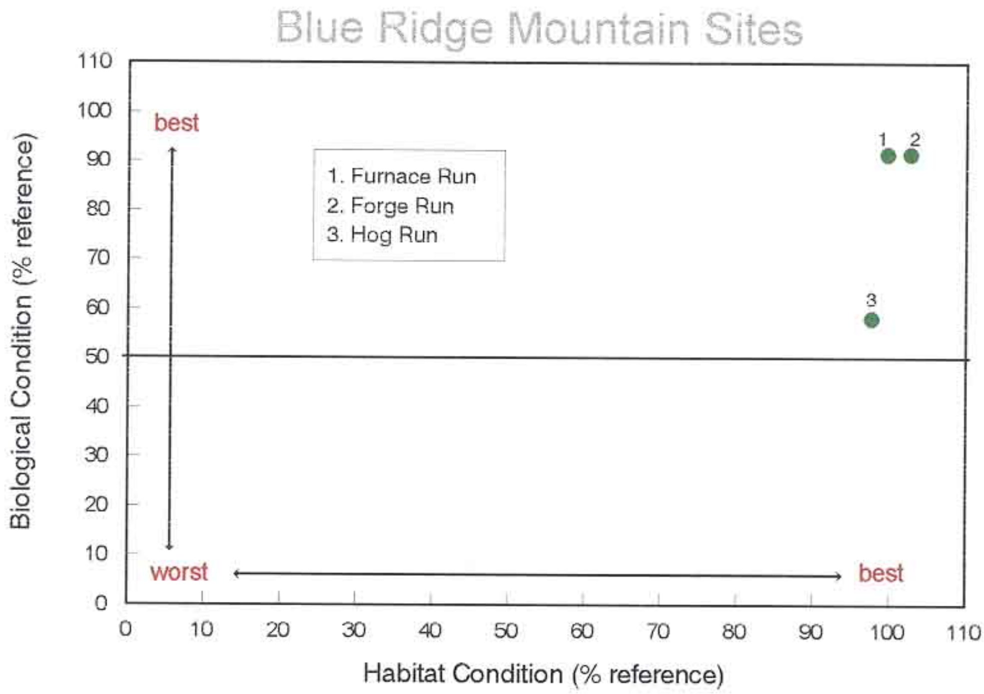


Figure 10. Biological and Habitat Data Summary



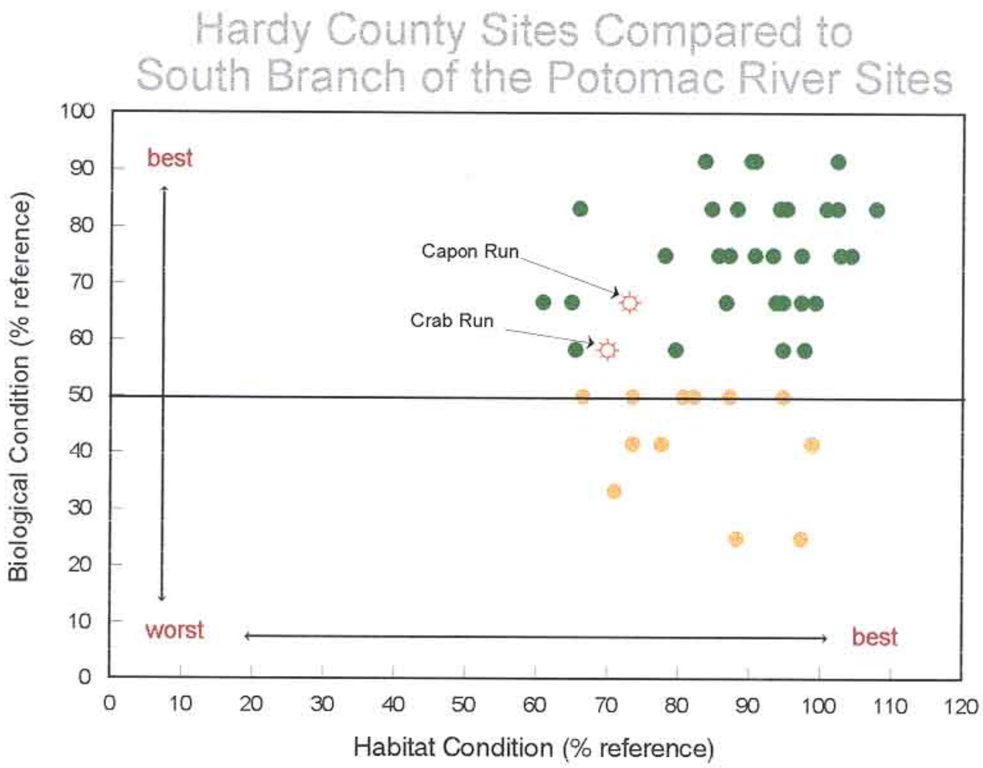
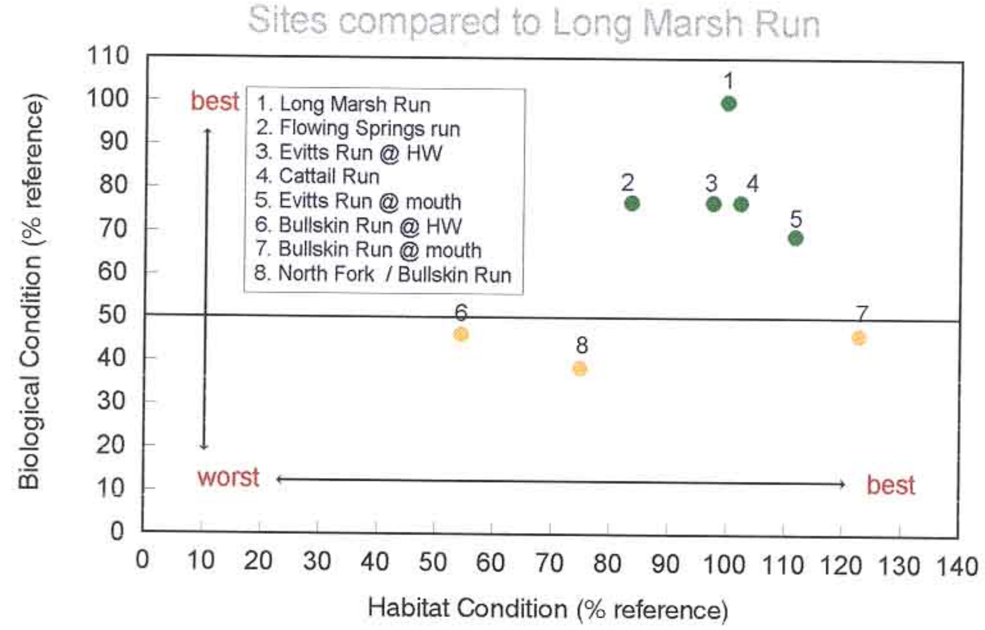
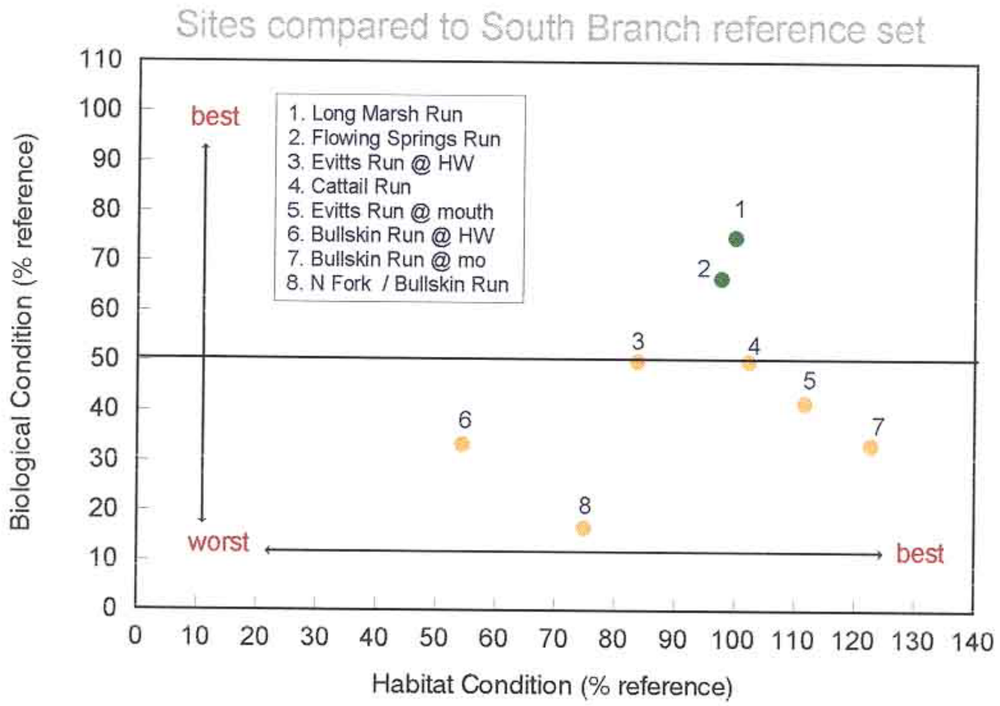


Figure 11. Biological & Habitat Data Summary

Limestone Valleys Region





The two Hardy County sites are not comparable to sites in either the Limestone/ Dolomite Valley Sub-ecoregion or the Blue Ridge Ecoregion. They are, however, comparable to sites in the South Branch of the Potomac River watershed, which was also sampled in late summer of 1996. Therefore, we were able to 'borrow' the reference set from the South Branch for comparison purposes (EPA 822-B-96-001). The comparison indicates that the biological community was moderately impaired (Figure 8). *Crab Run* received a score of 58.3 and *Capon Run* scored 66.7, neither being low enough to be placed on the list of biologically impaired streams.

The sampling team reported that both sites drained hay fields (Table 8). They collected water samples to check nutrient levels (as they were instructed to do if they suspected a problem). *Crab Run* had a nitrogen level (nitrate + nitrite) of 2.0 mg/l and total phosphorus was 0.03 mg/l. *Capon Run*'s nitrogen level was 0.60 mg/l and phosphorus was not detected at a detection limit of 0.02 mg/l (Table 10). Since these levels are not extremely high, nutrients are not suspected of contributing to the degradation of the benthic community.

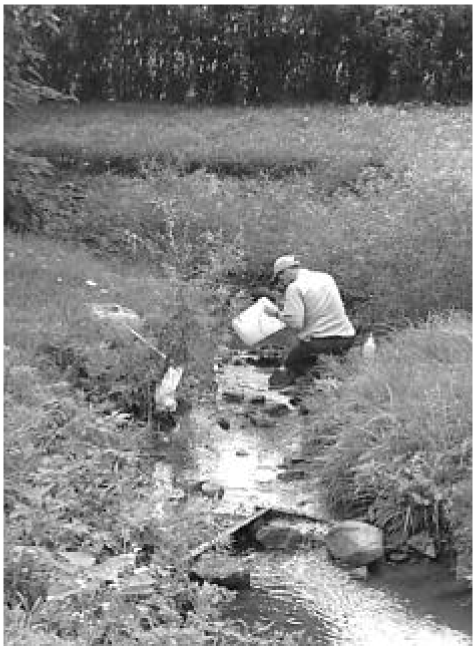
Confounding the results, is the fact that there were three heavy rain events associated with hurricanes prior to sampling. It was apparent at the time of sampling (5 days after the last rain event) that the stream beds had been recently scoured.

The eight streams in the Limestone/ Dolomite Valley Sub-ecoregion drain areas which are much more developed (residences, industries and agriculture) than those in the Blue Ridge Ecoregion. As a result of this development, none met the criteria for reference sites. Despite the lack of true reference sites, the staff chose Long Marsh Run, which appeared to have the least impacted benthic community, for comparison purposes. In addition to the water quality, habitat data, and the comparison to Long Marsh Run, the reference set for the South Branch of the Potomac River (Figure 10) were used for interpretation. Although the geologies of these areas are somewhat different, the use of this comparison provided the staff another tool for analysis.

In order to determine the level of impairment, the Program staff examined the results from these comparisons and used their best judgement to place these streams into the correct impairment category. The streams in this region all had very similar water quality for the parameters tested in the field. The conductivity and pH results were consistent with what would be expected in a limestone dominated area. Conductivities were relatively high, ranging from 535 to 613 µmhos, as was pH, which ranged from 7.72 to 8.31. Temperature and dissolved oxygen levels were all similar and at levels which would not be expected to impair biological health.

Of the six benthic community metrics used in the study, **taxa richness (total number of taxa) and EPT taxa [number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa] are the most useful in determining biological health**. The stream with the worst values for these metrics was the *North Fork of Bullskin Run* . It also scored very poorly for FBI [Modified (Family level) Hilsenhoff Biotic Index] and percent contribution of dominant taxa (Figure 9). The site was in the middle of a pasture that allowed cattle access to the stream, the nitrogen level was elevated, and moss and algae were observed growing on the rocks. The data collected for this study indicate that the benthic community in this stream was severely impaired.

Both sites on *Bullskin Run* were impaired. The upstream site had severely degraded habitat, receiving the lowest score on the Rapid Habitat Assessment (Table 17). The site near the mouth of Bullskin Run received the highest habitat score in this assessment. A high habitat score (i.e., good habitat) combined with an impairment in the benthic community typically indicates a water quality problem. Unfortunately the field collected water data for this stream was lost. USGS report nitrogen levels as 6.7 mg/l during a 1993 survey (NAWQA Fact Sheet 161-95). The most common organisms collected at this site during the Programs 1996 assessmemt were Hydropsychid (caddisflies) and Chironomid (midges) - totalling almost 69 % of the sample. The dominance of these pollution tolerant taxa suggests that there was a water quality problem at this site. The two Bullskin Run sites scored below 50 percent on both comparisons and will be placed on the list of biologically impaired streams.



Sampling Benthos

The *Evitts Run* sites exhibited the same pattern as Bullskin Run. The upstream site had the more degraded habitat but the benthos were not as impaired there as they were downstream. Both sites were probably at least moderately impaired by agriculture and the urban effects of Charles Town. The results from these two streams demonstrate that disruptions upstream may have a negative impact on benthic communities downstream. Although these sites received biological scores at or below 50 percent when compared to the South Branch of the Potomac River reference set, they scored 70 percent or better when compared to Long Marsh Run. The Program staff decided not to list these sites as biologically impaired because of the inconsistencies between the comparisions to the two different reference conditions.

Flowing Springs Run and *Cattail Run* drain areas around Charles Town. Like other watersheds in this area, they contain a large percentage of agricultural land. They both have benthic communities which appear to have some impairment (Figure 11). The fact that the total percentage of sand and silt in the substrate at these sites was high (55 and 45, Table 16) could account for some of the impairment. Employees from the WV DNR conducted a benthic survey along Flowing Springs Run in 1979 to determine the effects of Halltown Paperboard Company on Flowing Springs Run. Results from that survey indicated severe impairment downstream of the Halltown facility. Subsequent visits by DNR personnel found the treatment system working much better and indicated that the degraded condition on Flowing Springs Run should improve. It should be noted that there are substantial differences in sampling and interpretation techniques used in an upstream-downstream comparision such as that

Typical Low Gradient Stream in Summer

conducted by the WV DNR and the regional reference site comparisions used by the Program. Flowing Springs Run scored above 50 percent in both comparisons, Cattail Run scored 50% on one comparision and above 50% on the other. Neither stream will be listed as biologically impaired.

Long Marsh Run had the highest number of total taxa (15) and EPT taxa (6) and appeared to be the least impaired of the sites in this sub-ecoregion. Because this site was chosen as the reference for this group of streams, it scored a perfect 100 in that analysis. In the comparison to the South Branch of the Potomac river watershed, Long Marsh Run had the highest biological score of all the Limestone Valley sites in this study.

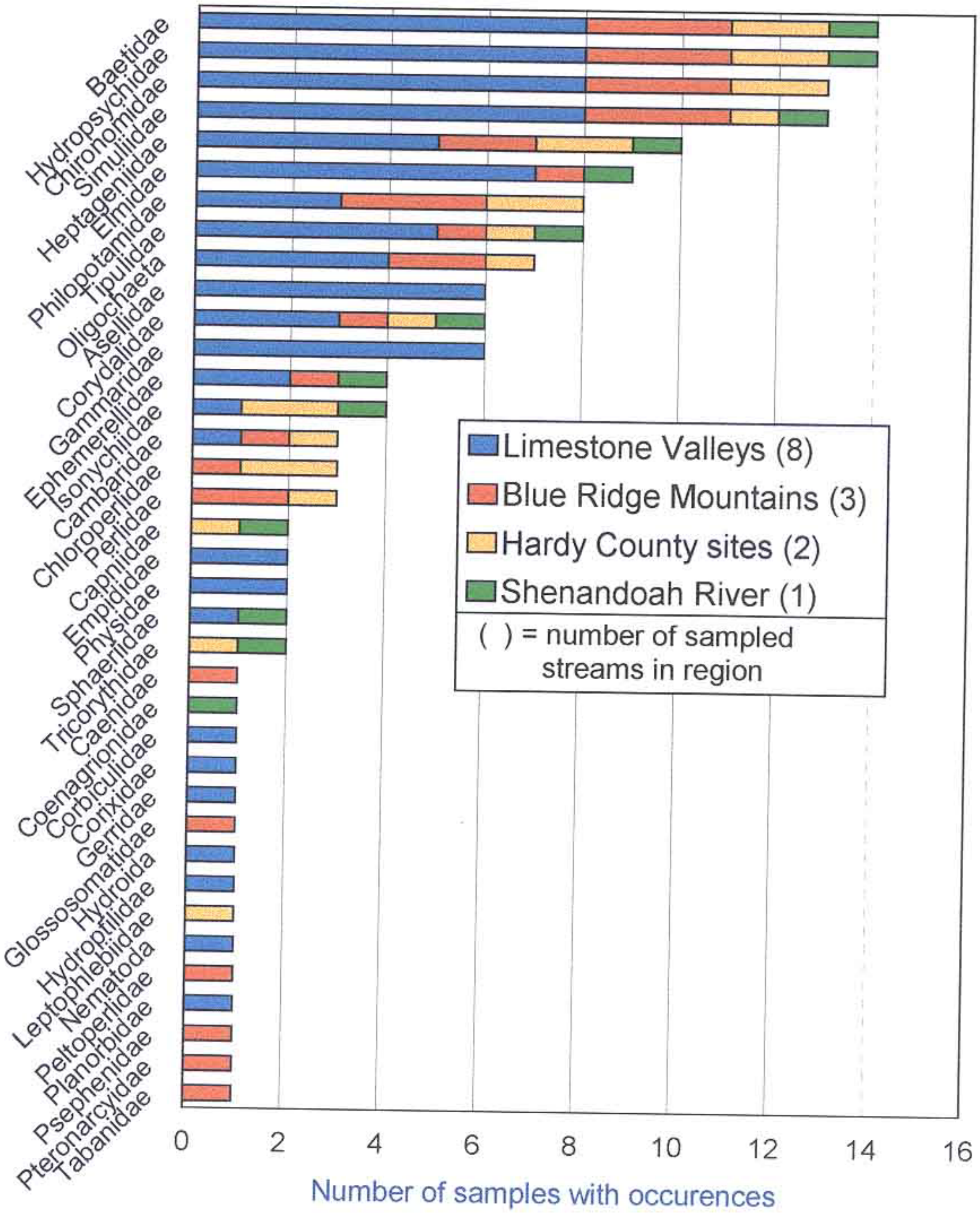
The benthic sample from the *Shenandoah River* site near the mouth was lost after collection. The sample from the site near the Virginia state line had 13 total taxa and 7 EPT taxa. The benthic community was rated as fair based on the FBI and percent contribution from the dominant taxa. The benthic sample indicated that this stream was not greatly impacted despite the intense agricultural activity and a rapidly growing urban area upstream. However, it must be noted that this determination is based on best professional judgement because of the absence of a good reference site for comparison. Although PCB's (polychlorinated biphenyl compounds) are in the river (as made evident from their persistent presence in fish tissue anaysis) apparently they are not affecting the benthic community to any great extent.

Cattle Path Allowing Access to Stream

Bacteriological and Physico-chemical Sampling

Overall, 66.7% (10 of 15) of the samples analyzed for fecal coliform bacteria had concentrations exceeding the water quality criterion of no more than 400 colonies per 100ml in more than 10% of all samples collected within a month. One stream, Long Marsh Run had a concentration greater than 1000 (1030). Results are summarized in Table 10, and Figure 13.

Figure 12. Frequency of Occurrence of Macrobenthic Taxa in Collections



Habitat Assessments

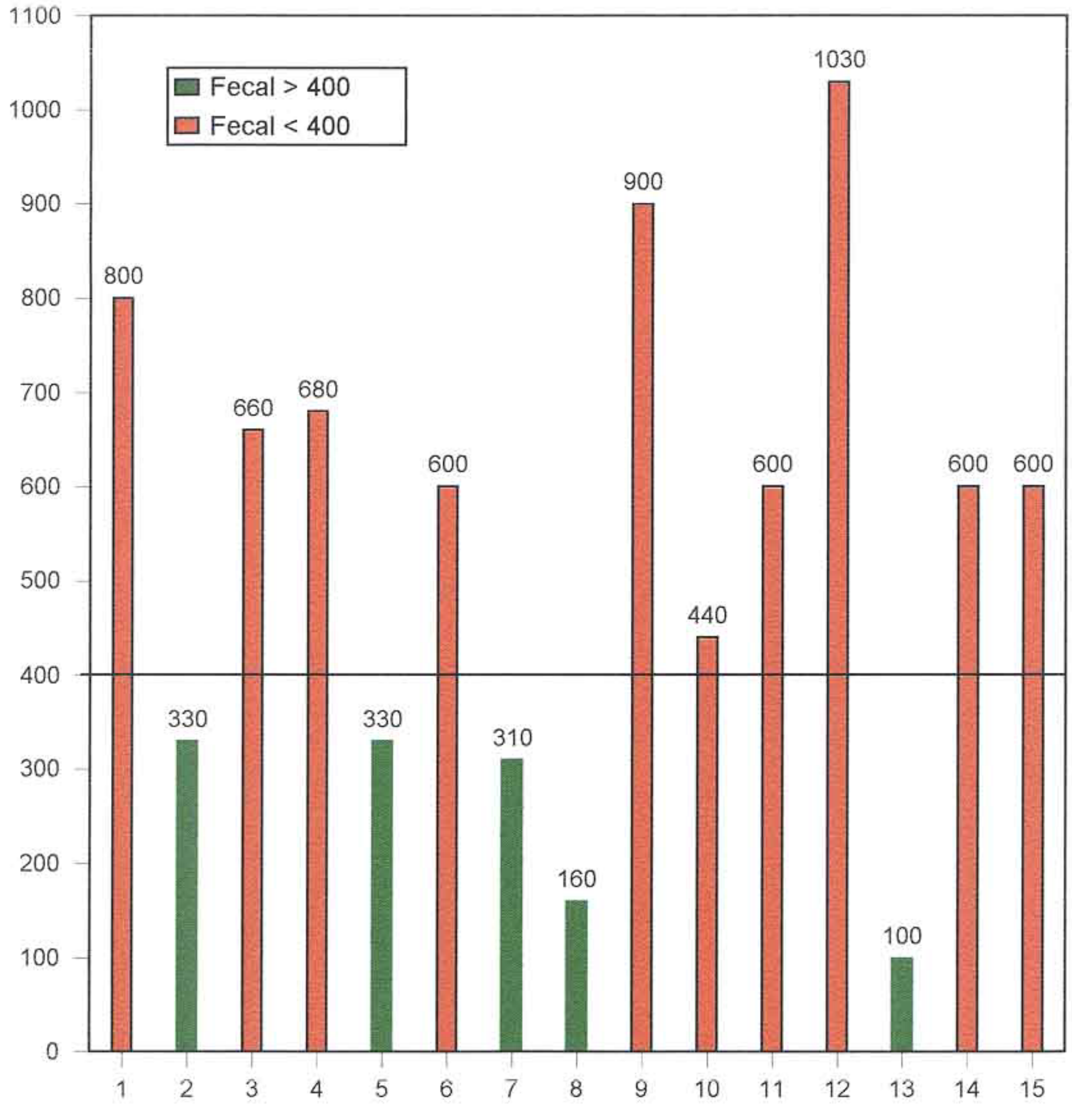
All habitat data are summarized in the tables in Appendix A. All sites contained adequate amounts of riffle habitat to allow the use of the preferred kick-net method for sampling macrobenthos. The substrates of the sampled streams were mostly cobble, gravel and sand (Table 16).

Erosion potential at the sites ranged from slight to heavy, and non-point source pollution was obvious or potential at all sites. Activities and disturbances were mostly residential, recreational and agricultural in nature (Tables 5 through 9). Industries are fairly common in the Jefferson County portion of the watershed (Figure 6), but the sample sites were not in the immediate vicinity of any.

All streams had normal water and sediment odor and no surface or sediment oils were detected (Tables 11A, 15A and 15B). Turbidity ranged from clear to moderately turbid (Table 11B). Another category that reflects sediment load is embeddedness (Table 17). The average embeddedness value was approximately 14, with 20 representing the least amount of embeddedness (Figure 14).

The streamside zone (Tables 12, 13 and 14) along the sample reaches had few large trees (greater than 1 meter diameter at breast height). Smaller diameter trees were more common in the canopy and understory than large trees. Ground cover consisted primarily of non-woody herbs, grasses and ferns.

Fig 13. Fecal Coliform Bacteria (colonies per 100 ml)



1. SHENANDOAH RIVER @ MOUTH
2. SHENANDOAH RIVER @ VA LINE
3. FLOWING SPRINGS RUN
4. CATTAIL RUN
5. FORGE RUN
6. EVITTS RUN @ MOUTH
7. EVITTS RUN @ HW
8. FURNACE RUN
9. BULLSKIN RUN @ MOUTH
10. BULLSKIN RUN @ HW
11. NORTH FORK OF BULLSKIN RUN
12. LONG MARSH RUN
13. HOG RUN
14. CAPON RUN
15. CRAB RUN

Implications

The streams in the Limestone Valleys sub-ecoregion need to be studied further to properly determine the cause and degree of benthologic impairment. Because of the dominance of agriculture in the area, it would be logical to obtain nutrient and suspended sediment data for these streams. Analyses for pesticides would also yield useful information for watersheds with a large percentage of agricultural land. These analyses are expensive and require monetary resources beyond those currently available in the Program. The small number of streams in this sub-ecoregion and the lack of a suitable reference site made it difficult to determine the levels of impairment. This watershed is a prime example of why it may be necessary to go outside of a watershed under study to find suitable reference sites. The vast majority of streams suitable for reference sites in this ecoregion are within Virginia. Therefore, it is advisable to contact the appropriate agencies of that commonwealth to assist with establishing ecoregion reference sites. This would be advisable for all watersheds that cross West Virginia's borders.

In order to improve the benthic habitat of the streams in this area, the landowners should be presented with the data from this and similar studies and shown ways of reducing the amount of erosion on their properties. To make this more appealing, it should be made clear that improving the habitat for macrobenthos also helps the entire aquatic community. For example improving the habitat for macrobenthos yields food for fish and improves the chances for stocked trout and native fishes to survive and reproduce.

Forge Run and Furnace Run in the Blue Ridge area appear to be healthy and need no further study except revisiting them in five years as scheduled. The relatively poor benthic sample from Hog Run cannot be attributed to any known disturbance, and needs to be looked at more closely to determine if the problem is organic pollution as suspected. Collection of nutrient data and a closer inspection of the watershed upstream of the sample site should answer these questions. Rocky Branch, one of the sites deemed inaccessible, should be sampled, possibly by wading or canoeing across the Shenandoah River.

North Fork of Bullskin Run and Bullskin Run at both its headwaters and its mouth, scored less than 50% when compared to the Long Marsh Run reference site. These two streams should be further examined to determine the cause and source of impactment.

TABLE 2
SUGGESTED ACTION LIST

1. Cooperate with U.S. EPA to develop a program to establish ecoregion reference sites.

2. Continue the education program and literature for landowners (residential, commercial, industrial and agricultural) on sediment-eroision control and its benefits to the aquatic community.

3. Determine sources of organic pollution impacting the biota of Hog Run and take appropriate restoration actions.

4. Further examine North Fork of Bullskin Run and Bullskin Run at both its headwaters and its mouth to determine the cause and source of impactment.

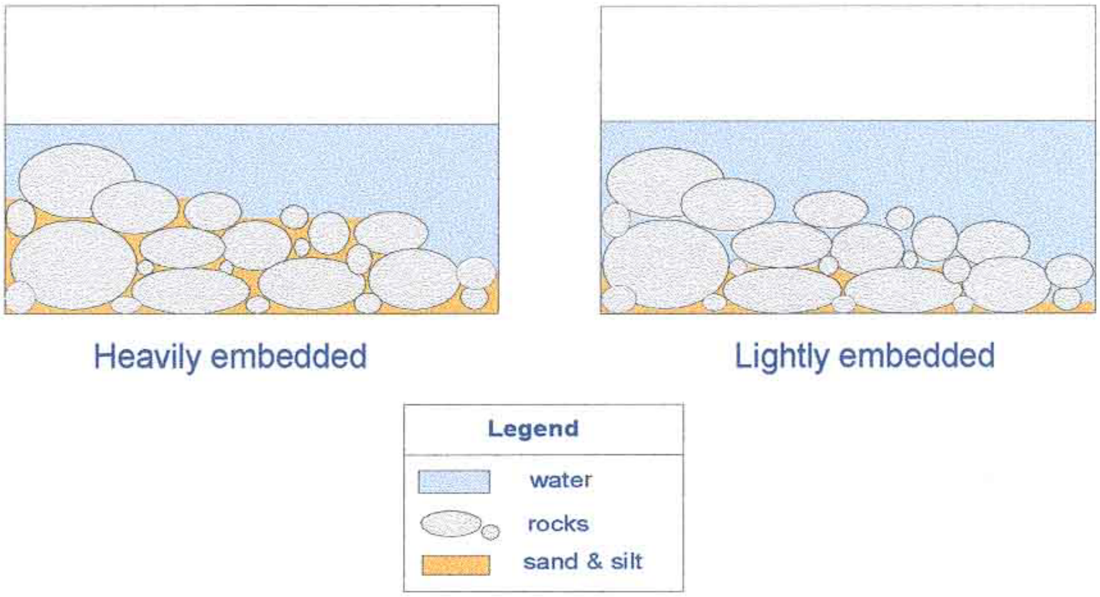
5. Continue efforts to reduce fecal coliform bacteria contamination from point and non-point sources.

The sites within Hardy County, Capon Run and Crab Run, revealed some biological impairment, but, due to the flooding just prior to sampling, it cannot be determined if the problem was chronic or a result of the scouring of the substrate associated with very high flows.

The Shenandoah River mainstem sites should be compared to sites upstream in Virginia and to other large streams in the region. The data collected for this survey are not useful in determining if the river should be removed from the state's 303(d) list, since its reason for being on the list, PCB levels, was not analyzed.

The macrobenthos subsampling methods currently used do not allow quantitative data to be summarized. To determine the number of the macrobenthos at our sample points, the program needs to know what portion the subsample is of the whole sample (i.e. what number of squares were picked to get the 100 specimen subsample). This would require little additional effort and provide useful data, especially in areas where eutrophication is suspected.

Figure 14. 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 rocks and gravel)



ADDITIONAL RESOURCES

The watershed movement in West Virginia includes a wide variety of federal, state and non-governmental organizations that are available to help improve the health of the streams in this watershed. Several agencies have established the West Virginia Watershed Management Framework. A Basin Coordinator has been employed to coordinate the activities of these agencies. The Basin Coordinator may be contacted at 1-304-558-2108. In addition, the DEP's Stream Partners Program coordinator, available at 1-800-556-8181, serves as a clearinghouse for these and other resources.

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APPENDIX A: TABLES AND DATA

Table 3. Sample Sites

name	ancode	date	latitude			longitude			county
SHENANDOAH RIVER @ MOUTH	WVS-00-{00.5}	8/28/96	39E	19'	19.26"	-77E	43'	55.41"	JEFFERSON
SHENANDOAH RIVER @ VA LINE	WVS-00-{17.0}	8/28/96	39E	10'	35.54"	-77E	51'	36.43"	JEFFERSON
FLOWING SPRINGS RUN	WVS-1	8/29/96	39E	17'	34.04"	-77E	41'	11.27"	JEFFERSON
CATTAIL RUN	WVS-2	8/29/96	39E	16'	37.12"	-77E	47'	17.97"	JEFFERSON
FORGE RUN	WVS-3	8/28/96	39E	15'	25.00"	-77E	47'	5.00"	JEFFERSON
EVITTS RUN @ MOUTH	WVS-4-{00.1}	8/28/96	39E	15'	19.99"	-77E	49'	14.06"	JEFFERSON
EVITTS RUN @ HW	WVS-4-{06.0}	8/28/96	39E	17'	16.47"	-77E	51'	55.42"	JEFFERSON
FURNACE RUN	WVS-5	8/28/96	39E	13'	13.58"	-77E	48'	56.36"	JEFFERSON
BULLSKIN RUN @ MOUTH	WVS-6-{00.1}	8/28/96	39E	12'	41.91"	-77E	50'	5.04"	JEFFERSON
BULLSKIN RUN @ HW	WVS-6-{06.0}	8/27/96	39E	14'	33.76"	-77E	55'	30.20"	JEFFERSON
NORTH FORK OF BULLSKIN RUN	WVS-6-A	8/28/96	39E	14'	44.89"	-77E	53'	15.29"	JEFFERSON
LONG MARSH RUN	WVS-7	8/28/96	39E	11'	4.88"	-77E	51'	15.97"	JEFFERSON
HOG RUN	WVS-8	8/28/96	39E	9'	55.68"	-77E	51'	12.63"	JEFFERSON
CAPON RUN	WVS-9-A	9/11/96	38E	47'	4.98"	-78E	53'	45.70"	HARDY
CRAB RUN	WVS-10	9/11/96	38E	48'	47.86"	-78E	56'	29.12"	HARDY

Table 4. Stream Reach Characteristics and Observations on Potential Pollution

name	stream width (m)	riffle depth (m)	run depth (m)	pool depth (m)	watershed erosion	N.P.S. pollution
SHENANDOAH RIVER @ MOUTH	50	1.75		>5.00	M	POT
SHENANDOAH RIVER @ VA LINE	50	0.5		>5.00	M	POT
FLOWING SPRINGS RUN	3	0.25	0.3	0.5	S	OBV
CATTAIL RUN	3.5	0.3	0.4	1	M	POT
FORGE RUN	3.5	0.6		1.5	S	POT
EVITTS RUN @ MOUTH	4.5	0.3	0.5	0.6	S	POT
EVITTS RUN @ HW	3	0.25	0.5	0	N	POT
FURNACE RUN	9	0.13		1.3	S	POT
BULLSKIN RUN @ MOUTH	9	0.1		1	S	POT
BULLSKIN RUN @ HW	2.25		0.15	1	S	OBV
NORTH FORK OF BULLSKIN RUN	1	0.08		0.5	S	OBV
LONG MARSH RUN	3.5		0.3	>1.00	M	OBV
HOG RUN	2.5	0.03		1	S	POT
CAPON RUN	6	0.2	0.5		H	OBV
CRAB RUN	5	0.1	0.3	0.7	H	OBV

Blanks indicate habitat type not present

Key: Watershed erosion: N=none, S=slight, M=moderate, H=heavy;
N.P.S.(Non-Point Source) Pollution: OBV=obvious, POT=potential sources, NOE=no evidence.

Table 5. Stream Reach Disturbances - Residential Landuses

name	residences	lawns	boatdock	construction	pipe/ drain	road	bridge/ culvert
SHENANDOAH RIVER @ MOUTH							
SHENANDOAH RIVER @ VA LINE	T	T				T	
FLOWING SPRINGS RUN	T	T				T	T
CATTAIL RUN							
FORGE RUN							
EVITTS RUN @ MOUTH	T	T				T	T
EVITTS RUN @ HW	T	T				T	T
FURNACE RUN						T	T
BULLSKIN RUN @ MOUTH	T	T				T	T
BULLSKIN RUN @ HW	T					T	T
NORTH FORK OF BULLSKIN RUN	T					T	
LONG MARSH RUN	T	T				T	T
HOG RUN							
CAPON RUN							
CRAB RUN		T				T	

T = present

Table 6. Stream Reach Activities and Disturbances - Recreational Landuses

name	parks / camp	parkin g lot	boat dock	swim-ming	fis h-ing	pipe/ drain	foot trails	atv/horse / bike trail	roads	bridge/ culvert
SHENANDOAH RIVER @ MOUTH	**T**	**T**		**T**	**T**		**T**		**T**	**T**
SHENANDOAH RIVER @ VA LINE				**T**	**T**					
FLOWING SPRINGS RUN										
CATTAIL RUN			**T**							**T**
FORGE RUN	**T**		**T**		**T**		**T**			
EVITTS RUN @ MOUTH										
EVITTS RUN @ HW	**T**	**T**								
FURNACE RUN										
BULLSKIN RUN @ MOUTH					**T**					
BULLSKIN RUN @ HW										
NORTH FORK OF BULLSKIN RUN										
LONG MARSH RUN				**T**	**T**		**T**			
HOG RUN										
CAPON RUN										
CRAB RUN										

T = present

Table 7A - Stream Reach activities and Disturbances - Industrial (Part 1)

name	industrial plant	surface mine	deep mine	coal prep	quarries	oil / gas well	power plant	logging
SHENANDOAH RIVER @ MOUTH								
SHENANDOAH RIVER @ VA LINE								
FLOWING SPRINGS RUN								
CATTAIL RUN								
FORGE RUN								
EVITTS RUN @ MOUTH								
EVITTS RUN @ HW								
FURNACE RUN								
BULLSKIN RUN @ MOUTH								
BULLSKIN RUN @ HW								
NORTH FORK OF BULLSKIN RUN								
LONG MARSH RUN								
HOG RUN								
CAPON RUN								
CRAB RUN								

Table 7B. Stream Reach Activities and Disturbances - Industrial (Part 2).

name	sawmill	sanitary landfill	wastewater treatment	public water treatment	pipe/ drain	parking lot	road	bridge/ culvert
SHENANDOAH RIVER @ MOUTH								
SHENANDOAH RIVER @ VA LINE								
FLOWING SPRINGS RUN						**T**		
CATTAIL RUN								
FORGE RUN								
EVITTS RUN @ MOUTH								
EVITTS RUN @ HW								
FURNACE RUN								
BULLSKIN RUN @ MOUTH								
BULLSKIN RUN @ HW								
NORTH FORK OF BULLSKIN RUN								
LONG MARSH RUN								
HOG RUN								
CAPON RUN								
CRAB RUN								

T = present

Table 8. Stream Reach Activities and Disturbances -Agricultural Landuses

name	row crops	pasture	hay	orchard	poultry	cattle acces s	irriga-tion	pipe/ drain	road	bridge/ culvert
SHENANDOAH RIVER @ MOUTH										
SHENANDOAH RIVER @ VA LINE										
FLOWING SPRINGS RUN										
CATTAIL RUN										
FORGE RUN										
EVITTS RUN @ MOUTH										
EVITTS RUN @ HW										
FURNACE RUN										
BULLSKIN RUN @ MOUTH										
BULLSKIN RUN @ HW		**T**								
NORTH FORK OF BULLSKIN RUN	**T**	**T**				**T**			**T**	**T**
LONG MARSH RUN		**T**	**T**			**T**				
HOG RUN			**T**							**T**
CAPON RUN			**T**						**T**	**T**
CRAB RUN			**T**							

T **= present**

Table 9. Stream Reach Activities and Disturbances - Management

name	liming	riprap stabilization	dredging	channelized	fill	dams
SHENANDOAH RIVER @ MOUTH						
SHENANDOAH RIVER @ VA LINE						
FLOWING SPRINGS RUN						
CATTAIL RUN						
FORGE RUN						
EVITTS RUN @ MOUTH						
EVITTS RUN @ HW						
FURNACE RUN						
BULLSKIN RUN @ MOUTH						
BULLSKIN RUN @ HW						
NORTH FORK OF BULLSKIN RUN						
LONG MARSH RUN						
HOG RUN						
CAPON RUN		**T**				
CRAB RUN		**T**	**T**			

T = present

Table 10 - Water Quality Data

name	temp EC	pH	oxygen mg/l	conductivity FS/cm	total phosphorus mg/l	ammonia N mg/l	nitrite/ nitrate N mg/l	fecal colonies / 100 ml
SHENANDOAH RIVER @ MOUTH	23.56	8.13	7.11	371				800
SHENANDOAH RIVER @ VA LINE	23.65	8.4	8.48	362				330
FLOWING SPRINGS RUN	18.21	8.31	8.2	594				660
CATTAIL RUN	14.39	8.31	9.72	613				680
FORGE RUN	20.52	7.82	8.26	133				330
EVITTS RUN @ MOUTH	17.8	8.18	9	589				600
EVITTS RUN @ HW	15.78	7.85	7.68	578				310
FURNACE RUN	22.71	7.54	7.75	89				160
BULLSKIN RUN @ MOUTH	data lost							900
BULLSKIN RUN @ HW	17.43	7.72	8.41	535				440
NORTH FORK OF BULLSKIN RUN	15.9	8.06	9.48	600	0.06		4.2	600
LONG MARSH RUN	16.2	8.18	9.45	568				1030
HOG RUN	21.64	7.54	7.92	69				100
CAPON RUN	18.3	7.1	7.8	81	<0.02	<0.50	0.6	600
CRAB RUN	18.2	7	7.4	107	0.03		2	600

blank lines indicate parameter not tested.

Table 11A. Water Quality Observations - Water Odors and Surface Oils

name	water odors						surface oils				
	normal	sewage	petroleum	chemical	anaerobic	none	slick	sheen	glob	flecks	none
SHENANDOAH RIVER @ MOUTH	T										T
SHENANDOAH RIVER @ VA LINE	T										T
FLOWING SPRINGS RUN	T										T
CATTAIL RUN	T										T
FORGE RUN	T										T
EVITTS RUN @ MOUTH	T										T
EVITTS RUN @ HW	T										T
FURNACE RUN	T										T
BULLSKIN RUN @ MOUTH	T										T
BULLSKIN RUN @ HW	T										T
NORTH FORK OF BULLSKIN RUN	T										T
LONG MARSH RUN	T										T
HOG RUN	T										T
CAPON RUN	T										T
CRAB RUN	T										T

Table 11B. Water Quality Observations - Turbidity

name	turbidity				
	clear	slight	moderate	turbid	opaque
SHENANDOAH RIVER @ MOUTH		T			
SHENANDOAH RIVER @ VA LINE		T			
FLOWING SPRINGS RUN		T			
CATTAIL RUN		T			
FORGE RUN	T				
EVITTS RUN @ MOUTH			T		
EVITTS RUN @ HW			T		
FURNACE RUN	T				
BULLSKIN RUN @ MOUTH			T		
BULLSKIN RUN @ HW	T				
NORTH FORK OF BULLSKIN RUN		T			
LONG MARSH RUN			T		
HOG RUN	T				
CAPON RUN	T				
CRAB RUN	T				

Table 12. Riparian Measurements - Canopy (>5m high).

name	left				right			
	zone width	veg type	big trees	small trees	zone width	veg type	big trees	small trees
SHENANDOAH R. @ MOUTH	20.0	D	2	2	25.0	D	2	4
SHENANDOAH R. @ VA LINE	20.0	D	2	3	20.0	D	2	4
FLOWING SPRINGS RUN	0.0	D	0	1	0.0	D	0	1
CATTAIL RUN	50.0	D	1	4	50.0		0	4
FORGE RUN	20.0	D	1	2	20.0	D	1	2
EVITTS RUN @ MOUTH	7.0	D	1	3	2.0	D	1	2
EVITTS RUN @ HW	0.0	D	1	1	0.0	D	1	1
FURNACE RUN	30.0	D	1	3	30.0	D	1	3
BULLSKIN RUN @ MOUTH	30.0	D	1	4	30.0	D	1	4
BULLSKIN RUN @ HW	3.0	D	1	1	3.0	D	0	2
N. FK. OF BULLSKIN RUN	0.0	D	0	1	0.0	D	0	1
LONG MARSH RUN	7.0	D	1	3	2.0	D	0	3
HOG RUN	30.0	D	1	4	30.0	D	1	4
CAPON RUN	1.0	D	0	1	3.0	D	1	1
CRAB RUN	4.0	D	1	1	4.0	D	0	1

veg type: D = deciduous
C = coniferous
M = mixed (at least 10 % of each type)

Tree values: 0 = absent
1 = sparse (0-10% of canopy)
2 = moderate (10-40%)
3 = heavy (40-75%)
4 = very heavy (>75%)

Table 13. Riparian Measurements - Understory (0.5 - 5m)

name	left			right		
	veg type	shrubs saplings	non-woody herbs	veg type	shrubs saplings	non-woody herbs
SHENANDOAH RIVER @ MOUTH	D	2	1	D	2	2
SHENANDOAH RIVER @ VA LINE	D	2	4	D	3	2
FLOWING SPRINGS RUN	D	1	1	D	1	1
CATTAIL RUN	D	3	1	D	2	1
FORGE RUN	D	3	1	D	3	1
EVITTS RUN @ MOUTH	D	2	3	D	3	3
EVITTS RUN @ HW	N	0	0	N	0	0
FURNACE RUN	D	4	3	D	4	3
BULLSKIN RUN @ MOUTH	D	3	3	D	3	3
BULLSKIN RUN @ HW	D	1	4	D	2	4
NORTH FORK OF BULLSKIN RUN	D	0	1	D	1	1
LONG MARSH RUN	D	2	1	D	2	2
HOG RUN	D	2	1	D	3	2
CAPON RUN	D	1	1	D	2	1
CRAB RUN	D	1	2	D	1	3

veg type: D = deciduous
C = coniferous
M = mixed (at least 10 % of each type)

Tree values:0 = absent
1 = sparse (0-10% of canopy)
2 = moderate (10-40%)
3 = heavy (40-75%)
4 = very heavy (>75%)

Table 14. Riparian Measurements - Ground Cover (0 - 0.5 m) and Stream Shade

name	left				right				stream shade
	shrubs seedlings	non-woody herbs, grasses, ferns	leaf litter	bare soil	shrubs seedlings	non-woody herbs, grasses, ferns	leaf litter	bare soil	
SHENANDOAH R. @ MOUTH	1	1	0	4	2	2	0	1	1
SHENANDOAH R. @ VA LINE	2	4	0	1	0	0	2	2	1
FLOWING SPRINGS RUN	1	4	0	0	1	4	0	0	1
CATTAIL RUN	3	3	0	0	2	2	0	0	4
FORGE RUN	1	4	0	1	1	2	0	2	3
EVITTS RUN @ MOUTH	1	3	0	0	1	4	0	0	4
EVITTS RUN @ HW	0	4	0	0	0	4	0	0	2
FURNACE RUN	1	2	0	0	3	2	0	0	3
BULLSKIN RUN @ MOUTH	2	4	0	0	2	4	0	0	2
BULLSKIN RUN @ HW	1	4	0	0	1	4	0	0	3
N. FK. OF BULLSKIN RUN	0	4	0	0	0	4	0	0	0
LONG MARSH RUN	1	4	0	0	1	4	0	0	4
HOG RUN	1	2	0	2	1	3	0	1	4
CAPON RUN	1	1	0	3	1	1	0	4	0
CRAB RUN	1	2	1	1	1	3	1	1	0

veg values: 0 = absent;
1 = sparse (0-10% of ground area);
2 = moderate (10-40%);
3 = heavy (40-75%);
4 = very heavy (>75%)

stream shade: 1 = fully exposed (0-25% shade);
2 = partially exposed (25-50 %);
3 = partially shaded (50-75%);
4 = fully shaded (75-100%)

Table 15A . Sediment Odors and Oils

name	sediment odors							sediment oils			
	normal	sewage	petro-leum	chem-ical	an-aerobic	none	other	absent	slight	moderate	profuse
SHENANDOAH RIVER @ MOUTH	**T**							**T**			
SHENANDOAH RIVER @ VA LINE	**T**							**T**			
FLOWING SPRINGS RUN	**T**							**T**			
CATTAIL RUN	**T**							**T**			
FORGE RUN	**T**							**T**			
EVITTS RUN @ MOUTH	**T**							**T**			
EVITTS RUN @ HW	**T**							**T**			
FURNACE RUN	**T**							**T**			
BULLSKIN RUN @ MOUTH	**T**							**T**			
BULLSKIN RUN @ HW	**T**							**T**			
NORTH FORK OF BULLSKIN RUN	**T**							**T**			
LONG MARSH RUN	**T**							**T**			
HOG RUN	**T**							**T**			
CAPON RUN	**T**							**T**			
CRAB RUN	**T**							**T**			

T = present

Table 15B. Sediment Deposits

name	sediment deposits									
	sludge	saw dust	paper fiber	sand	relic shell	marl	silt	lime fines	metal hydroxides	other
SHENANDOAH RIVER @ MOUTH				**T**			**T**			
SHENANDOAH RIVER @ VA LINE				**T**			**T**			
FLOWING SPRINGS RUN				**T**			**T**			
CATTAIL RUN				**T**			**T**			
FORGE RUN				**T**			**T**			
EVITTS RUN @ MOUTH				**T**			**T**			
EVITTS RUN @ HW				**T**			**T**			
FURNACE RUN				**T**			**T**			
BULLSKIN RUN @ MOUTH				**T**			**T**			
BULLSKIN RUN @ HW				**T**			**T**			
NORTH FORK OF BULLSKIN RUN				**T**			**T**			
LONG MARSH RUN				**T**			**T**			
HOG RUN				**T**			**T**			
CAPON RUN				**T**						
CRAB RUN				**T**						

T = present

Table 16. Substrate Composition

name	% bedrock	% boulder	% cobble	% gravel	% sand	% silt	% clay
SHENANDOAH RIVER @ MOUTH	20	15	20	20	20	5	0
SHENANDOAH RIVER @ VA LINE	10	40	20	10	10	10	0
FLOWING SPRINGS RUN	0	5	20	20	45	10	0
CATTAIL RUN	0	5	25	25	35	10	0
FORGE RUN	10	20	30	20	15	5	0
EVITTS RUN @ MOUTH	0	20	30	30	10	10	0
EVITTS RUN @ HW	0	5	25	40	20	10	0
FURNACE RUN	0	0	40	30	20	10	0
BULLSKIN RUN @ MOUTH	0	5	40	25	20	10	0
BULLSKIN RUN @ HW	0	0	0	5	20	75	0
NORTH FORK OF BULLSKIN RUN	0	5	40	35	10	10	0
LONG MARSH RUN	0	0	10	20	45	15	0
HOG RUN	0	5	40	30	15	10	0
CAPON RUN	0	20	35	30	15	0	0
CRAB RUN	50	4	20	15	10	0	1

Table 17. Rapid Habitat Assessment Scores

name	cov	subs	ebed	velo	alter	sedi	riffs	flow	banks	bankveg	graze	ripveg	**total**
SHENANDOAH RIVER @ MOUTH	19	15	15	20	19	18	19	20	11	13	17	20	206
SHENANDOAH RIVER @ VA LINE	19	13	17	19	20	17	20	20	15	17	19	20	206
FLOWING SPRINGS RUN	5	17	10	11	15	15	17	19	17	17	0	0	143
CATTAIL RUN	7	19	11	14	15	12	16	19	8	14	20	20	175
FORGE RUN	18	19	16	20	20	18	18	15	17	17	20	20	208
EVITTS RUN @ MOUTH	13	19	17	16	15	16	19	20	16	17	11	2	191
EVITTS RUN @ HW	10	18	16	14	15	10	19	19	18	19	2	7	167
FURNACE RUN	17	19	15	19	15	15	18	17	13	16	18	20	202
BULLSKIN RUN @ MOUTH	19	19	17	20	15	15	16	20	12	18	19	20	210
BULLSKIN RUN @ HW	1	2	0	6	15	0	2	19	19	19	15	5	93
NORTH FK OF BULLSKIN RUN	3	12	15	19	15	16	13	19	6	8	1	1	128
LONG MARSH RUN	18	13	15	14	17	17	12	19	19	18	6	3	171
HOG RUN	16	19	18	20	15	16	18	15	11	16	17	17	198
CAPON RUN	16	17	13	15	15	14	19	6	8	7	10	5	145
CRAB RUN	8	15	14	15	14	11	16	10	11	11	11	3	139

Key: Categories scored 0-20, total score possible = 240
cov = instream cover
subs = epifaunal substrate
ebed = embeddedness
velo = # of velocity/depth regimes present (ie. fast/shallow)
alter = channel alteration
sedi = sediment deposition
riff = frequency of,
flow = channel flow status
banks = erosional condition of banks (ex. 20 = no signs of erosion)
bankveg = vegetative protection
graze = grazing or other disruptive pressure

ripveg = riparian vegetation zone width (least buffered side)

Table 18. Benthic Macroinvertebrate Community Metrics

Stream Name	Taxa Richness	EPT	HBI	% Dom. Taxon	EPT/ Chir.	Scrapers/ Fil-Coll
SHENANDOAH RIVER @ MOUTH	SAMPLE LOST					
SHENANDOAH RIVER @ VA LINE	13	7	5	34.4	1	0.12
FLOWING SPRINGS RUN	13	3	5.2	47	0.375	0.611
CATTAIL RUN	12	5	6.2	25.6	0.139	0.231
FORGE RUN	14	8	4.4	27.9	0.31	0
EVITTS RUN @ MOUTH	11	3	5.77	27.6	0.107	0.421
EVITTS RUN @ HW	13	4	5.1	37.6	0.308	0.284
FURNACE RUN	12	7	4.9	43.5	0.7	0.1
BULLSKIN RUN @ MOUTH	7	3	5.4	37.4	0.167	0.019
BULLSKIN RUN @ HW	10	2	6.2	33.3	0.071	0.417
NORTH FORK OF BULLSKIN RUN	6	2	7.5	83.3	0.5	0
LONG MARSH RUN	15	6	5.1	39.4	0.5	0.282
HOG RUN	10	4	5.4	30.6	0.29	0.14
CAPON RUN	11	9	4.8	50.8	0.69	0.03
CRAB RUN	12	7	3.7	35.6	0.41	0.03

Taxa Richness = total number of different macroinverebrate taxa collected
EPT = number of Ephemeropteran (mayfly), Plecopteran (stonefly), and Tricopteran (caddisfly) families collected
HBI = Hilsenhoff Biotic Integrity - an index indicating relative pollution tolerance of macrobenthos collected
% Dom. Fam. = percent of total number of organisms which are of the numerically dominant family
EPT/Chir = ratio of number of EPT taxa to number of Chironomidae
Scraper/Fil-Coll = ratio of scrapers to filtering collectors

Table 19. Benthic Macroinvertebrate Taxa Collected

Stream name	taxa	count
SHENANDOAH RIVER @ MOUTH	Sphaeriidae	1
	Baetidae	41
	Ephemerellidae	1
	Heptageniidae	3
	Tricorythidae	8
	Isonychiidae	2
	Hydropsychidae	52
	Capniidae	1
	Coenagrionidae	1
	Elmidae	8
	Corydalidae	1
	Tipulidae	3
	Simuliidae	29
FLOWING SPRINGS RUN	Oligochaeta	1
	Hydroida	3
	Cambaridae	3
	Asellidae	1
	Gammaridae	1
	Baetidae	47
	Hydropsychidae	1
	Hydroptilidae	3
	Elmidae	2
	Corydalidae	1
	Tipulidae	2
	Simuliidae	1
	Chironomidae	5
CATTAIL RUN	Oligochaeta	5
	Asellidae	13
	Baetidae	20
	Ephemerellidae	2
	Heptageniidae	1
	Hydropsychidae	6

Stream name	taxa	count
CATTAIL RUN (continued)	Philopotamidae	2
	Elmidae	11
	Corydalidae	1
	Empididae	1
	Simuliidae	32
	Chironomidae	31
FORGE RUN	Oligochaeta	3
	Cambaridae	1
	Baetidae	14
	Caenidae	1
	Hydropsychidae	20
	Philopotamidae	31
	Pteronarcyidae	4
	Chloroperlidae	1
	Perlidae	8
	Peltoperlidae	1
	Corydalidae	2
	Chironomidae	18
	Simuliidae	4
	Tipulidae	3
EVITTS RUN @ MOUTH	Oligochaeta	1
	Corbiculidae	1
	Asellidae	5
	Gammaridae	4
	Baetidae	9
	Heptageniidae	2
	Hydropsychidae	9
	Elmidae	30
	Tipulidae	3
	Simuliidae	34
	Chironomidae	25

Stream name	taxa	count
EVITTS RUN @ HW	Physidae	1
	Planorbidae	3
	Asellidae	5
	Gammaridae	4
	Baetidae	29
	Heptageniidae	2
	Hydropsychidae	62
	Philopotamidae	3
	Elmidae	277
	Tipulidae	10
	Empididae	2
	Simuliidae	8
	Chironomidae	9
FURNACE RUN	Baetidae	28
	Ephemerellidae	1
	Heptageniidae	4
	Glossosomatidae	1
	Hydropsychidae	37
	Philopotamidae	2
	Perlidae	2
	Simuliidae	6
	Tabanidae	1
	Chironomidae	3
BULLSKIN RUN @ MOUTH	Baetidae	14
	Heptageniidae	1
	Hydropsychidae	46
	Elmidae	1
	Tipulidae	15
	Simuliidae	55
	Chironomidae	15
BULLSKIN RUN @ HW	Sphaeriidae	2
	Physidae	10
	Gammaridae	2

Stream name	taxa	count
BULLSKIN RUN @ HW (continued)	Baetidae	2
	Hydropsychidae	14
	Elmidae	15
	Corixidae	1
	Gerridae	1
	Simuliidae	5
	Chironomidae	26
NORTH FORK OF BULLSKIN RUN	Asellidae	195
	Gammaridae	8
	Baetidae	14
	Hydropsychidae	2
	Simuliidae	13
	Chironomidae	2
LONG MARSH RUN	Nematoda	2
	Oligochaeta	4
	Asellidae	2
	Gammaridae	2
	Baetidae	2
	Ephemerellidae	5
	Heptageniidae	12
	Isonychiidae	1
	Hydropsychidae	41
	Philopotamidae	1
	Elmidae	10
	Corydalidae	1
	Tipulidae	1
	Simuliidae	14
	Chironomidae	6
HOG RUN	Oligochaeta	1
	Baetidae	10
	Heptageniidae	4
	Hydropsychidae	15

Stream name	taxa	count
HOG RUN (continued)	Philopotamidae	5
	Elmidae	2
	Psephenidae	1
	Simuliidae	22
	Chironomidae	10
CAPON RUN	Oligochaeta	3
	Baetidae	10
	Heptageniidae	1
	Leptophlebiidae	2
	Tricorythidae	1
	Isonychiidae	1
	Hydropsychidae	31
	Philopotamidae	2
	Chloroperlidae	2
	Perlidae	4
	Chironomidae	4
CRAB RUN	Cambaridae	1
	Baetidae	8
	Heptageniidae	1
	Isonychiidae	3
	Hydropsychidae	31
	Philopotamidae	2
	Capniidae	5
	Chloroperlidae	19
	Corydalidae	2
	Tipulidae	2
	Simuliidae	3
	Chironomidae	10

APPENDIX B: ASSESSMENT METHODS

Given its charge and resources, the Program has chosen a specific combination of physical, chemical and biological indicators to evaluate stream health.

The streamside and instream habitats, and the benthic macroinvertebrates are the foci of the site's ecological assessment. (Benthic macroinvertebrates are bottom-dwelling animals, visible to the naked eye, that do not have backbones. This excludes fishes, salamanders, tadpoles, etc.) Habitat evaluations are important to the assessment because they reflect the physical conditions that support the benthic community. The benthic community is crucial to the assessment because it reflects environmental conditions for an extended period prior to the site visit. Other parameters, like dissolved oxygen concentration, are complementary, but may reflect only recent fluctuations in environmental conditions. A release of a contaminant which flowed through the reach a week ago, for example, would be reflected by the impaired benthos, but might not be revealed in a water sample.

A site's fecal coliform bacteria concentration indicates the likelihood of a public health threat; higher concentrations are associated with greater concerns for public health through direct contact with the water. Fecal coliform bacteria are important indicators of contamination due to fecal material found in sewage, livestock waste and wildlife excrement.

Physico-chemical constituents are selected to help determine what types of stressors may be operating on the benthic community. They may also give clues about the sources of those stressors. A list of physico-chemical constituents typically analyzed for is found in Table 20.

ASSESSMENT PROTOCOLS

The assessment protocols described below are detailed to a greater degree in the Program's Standard Operating Procedures (DEP, 1997) manual. This manual is available to interested persons.

Physico-chemical sampling:

Water quality sample collection, handling and analysis methods generally follow procedures approved by the U.S. EPA and detailed in the documents noted in Table 20. The only frequent exception is the holding time for Fecal Coliform Bacteria, which is explained in note 2 of Table 20. Field blanks for metals and nutrients are prepared weekly by each sampling team if metals and nutrients are being analyzed from the sampling sites visited during the week. The primary purpose of this procedure is to check for contamination of preservatives, containers and sample water during sampling and transporting. A secondary purpose is to check the accuracy of analytical procedures.

Field analyses for pH, temperature, dissolved oxygen and conductivity are performed utilizing a Hydrolab™ Scout™ and Multiprobe™ assembly. The manufacturer's calibration guidelines are followed with minimal variation except that the instruments are generally not calibrated at the end of each sampling run.

In some instances, stream flow is measured. Usually this is done only in streams negatively impacted by mine drainage. A current meter is used across a stream transect and the discharge is calculated with the sum-of-partial-discharges method.

TABLE 20
WATER QUALITY CONSTITUENT TABLE

All numbered references to analytical methods are from either 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	5 mg/l	305.1	14 days
Alkalinity	5 mg/l	310.1	14 days
Sulfate	5 mg/l	375.4	28 days
Iron	200 Fg/l	200.7	6 months
Aluminum	100 Fg/l	200.7	6 months
Manganese	10 Fg/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 EC[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		353.3	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.

Physico-chemical data analyses:

Since the sites are sampled only once, potential uses of statistical analyses per site are quite limited. Generally, only simple statistics (*e.g.*, mean, median and percentage) are generated from each watershed's data set. Although limited in application, these simple statistics may give insight into potential causes and sources of impairment.

Evaluation of habitat and the sampling site environment:

Following a specific protocol, summarized in the Program's Stream Assessment Form assessment teams, usually composed of 2 people each, visit sites within the watershed and assess conditions at the sites. Each assessment consists of a 100-meter reach of stream and its streamside environment. The latitude and longitude of each site is recorded by either a Global Positioning System (GPS) instrument or obtained from a topographic map should the GPS unit fail. The total habitat score from the two-page Rapid Habitat Assessment portion of the form is utilized in the data analysis step described under "Integration of biological and habitat data."

Benthic macroinvertebrate sampling:

Macroinvertebrate samples are collected via several techniques, depending upon the stream type and the water level. In streams having plenty of sampleable riffle/run habitat, a modified version of Rapid Bioassessment Protocol II (Plafkin, et. al. 1989) is used for sampling the benthos. In such streams of appropriate size, a modified kick-net (Surber-on-a-stick) is used to catch organisms dislodged through kicking of the substrate and rubbing of the larger rocks by the sampler. In very small riffle/run streams that will not accomodate the Surber-on-a-stick, a D-frame net is used to collect dislodged organisms.

In streams that are too small to accomodate a D-frame net, rocks are picked clean of organisms by hand. This last technique provides only qualitative data that cannot be compared to the data generated from the other, net-assisted sampling procedures.

In streams dominated by glide/pool habitats, a D-frame net is used in a slightly modified version of a procedure developed for Mid-Atlantic Coastal Streams (Maxted 1993). Referred to as the MACS technique, this procedure consists mostly of sampling a variety of habitats (aquatic plants, woody debris, overhanging streambanks, etc) through sweeping motions of the net.

After collection, the organisms are preserved and the sample is sent to the Marshall University Biology Department for subsampling. The 100-organism subsample technique was used in 1996 and 1997. (Plafkin, et. al. 1989). The 200-organism subsample technique has been used since 1998. The subsampled organisms are returned to Program biologists who identify them to the family taxon and count them. The completed samples are kept preserved for future reference and for identification to lower taxa if necessary. In 1996, the initial year of the Program, Safe-fix™ and formalin were used as preservatives. During the 1997 sampling season, the switch was made from formalin to ethanol. Safe-fix™ is no longer used. Since 1997, ethanol has been the standard fixative.

Appropriate biological collection permits are obtained before each sampling season from the WV Division of Natural Resources (DNR). Fishes inadvertently collected are preserved and donated to the DNR fish laboratory. Salamanders collected are preserved and donated to the Marshall University Biological Museum.

Biological data analyses:

Widely accepted biological metrics and indices are calculated to aid in interpreting the benthological data. These tools are described in detail in Plafkin, et. al. 1989 and briefly described below:

Taxa richness - Total number of families. Generally decreases with decreasing water quality, habitat diversity and habitat suitability.

Modified family biotic index (FBI) - Based on organic pollution tolerance of families. Tolerance values range from 0 to 10, increasing with decreasing water quality. Developed by William L. Hilsenhoff for benthic arthropods in Wisconsin (Hilsenhoff 1988).

Ratio of scraper and filtering collectors - Reflects the riffle/run community food base. Based on Functional Feeding Group designations for insect families (Merritt and Cummins 1984). Decreasing ratios generally indicate increasing organic enrichment (decreasing water quality).

Ratio of Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae abundance - Measures community balance. Decreasing ratios indicate increasing organic enrichment or heavy metals concentration (decreasing water quality).

Percent contribution of dominant family - Number of individuals belonging to the dominant family divided by the total number of organisms found. Measures community balance. Increasing percentages indicate increasing environmental stressors (decreasing water quality).

EPT index - Summarizes taxa richness within the insect orders generally considered pollution sensitive. Decreases with decreasing water quality.

Community loss index - Measures the loss of taxa between a reference station and the station of comparison. Range is from 0 to infinity. Increasing values indicate increasing dissimilarity between the two stations.

Integration of biological, habitat and water quality data:

Each site's biological metrics and indices, and rapid habitat assessment score (see "Evaluation of habitat and the sampling site environment") are compared with those of a reference site. The reference site has optimal habitat and no obvious impairments in water quality. The biological condition and habitat condition are expressed as percentages of the reference site, which is assigned values of 100%. These percentages are graphically plotted to indicate the degree of impairment relative to the reference site (see Figures 10 and 12).

The physico-chemical data and field notes are referred to when interpreting the results of the plot. These data and observations are useful in determining causes and sources of impairment.

Biological metrics and indices have been selected to ensure usefulness in discriminating between reference sites and sites with human-induced stressors. The metric and index tools used include those listed under the section titled "Biological data analyses," except for Community Loss Index.

The biometrics and indices are computed from the data for each of the reference sites and descriptive statistics are performed for each of the metrics/indices. From these descriptive statistics (*e.g.*, central tendency, distribution and range), a range of reference index values (i.e., 1, 3, 5) is developed for each metric/index. For metrics/indices that have a positive correlation between benthic community condition and metric/index value, the 25th percentile marks the upper limit of the range of the middle reference index value, 3. Any value above the 25th percentile receives a reference index value of 5. Any value between zero and halfway below the 25th percentile receives a reference index value of 1 (see figures 10 and 11).

For metrics with a negative correlation between benthic condition and metric value (i.e., Modified Family Biotic Index and Percent Contribution of Dominant Family), the 75th percentile marks the upper limit of the highest reference index value range, 5. Above the 75th percentile, the reference index value ranges of 1 and 3 are equidistant to the upper limit of the total range.

The range of possible sums of all the reference index values is determined. Non-reference sites that score below the 50th percentile of this range are considered candidates for the 303(d) list.

APPENDIX C. 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 def.) 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 forms a white precipitate called "white boy".

benthic macroinvertebrates - small animals without backbones yet still visible to the naked eye, that live on the bottom (the substrate) of a water body, that are large enough to be collected with a 595 µm 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.*, 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.

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.

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 / 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 - the amount of molecular oxygen dissolved in water.

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

ecoregion - a land area with relative homogeneity in ecosystems that, under nonimpaired 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 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.

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

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

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

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.

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

impaired - (1) according to the water quality standards, a stream that does not fully support 1 or more of its designated uses; (2) as used in this assessment report, a benthic macroinvertebrate community with metric scores substantially worse than those of an appropriate reference site.

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.

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 Program’s preferred procedure (see Appendix B).

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 (see Appendix B).

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 Office of Water Resources.

nonimpaired - (1) according to the water quality standard, a stream that fully supports all of its designated uses: (2) as used in this assessment report, a benthic community with metric scores comparable to those of an appropriate reference site.

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.

Office of Water Resources (OWR) - 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.

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

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.

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 (Appedix D).

SCA - Soil Conservation Agency

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

STORET - STOrage and RETrieval of U.S. waterways parametric data -a system maintained by EPA and used by OWR to store and analyze water quality data.

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).

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 Environemental Protection, Soil Conservation Agency) officers that recommends streams for intense, detailed study.

Watershed Assessment Program (the Program) - a group of scientists within the OWR 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 coaliton of federal, state, multi-state, and non-governmental groups cooperating to support local watershed associations.