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A Site Specific Impact Study: Valley Fill Construction Impacts on Water Chemistry and Benthic Macroinvertebrate Assemblages

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A Site Specific Impact Study: Valley Fill Construction Impacts on Water Chemistry and Benthic Macroinvertebrate Assemblages

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ABSTRACT

Downstream impacts of contour surface mining and valley fill construction were evaluated utilizing both water chemistry and EPA approved Rapid Bioassessment Protocol III. Wiley Branch was sampled in February of 1999 before mining perturbation. Five downstream stations were established with benthic macroinvertebrates and water samples collected seasonally for a period of sixteen months. Water chemistry parameters, pH, total aluminum, iron, and manganese, total suspended solids, total dissolved solids, sulfates, alkalinity, acidity and specific conductivity fluctuated but generally remained within acceptable governmental limits. Initially, benthic macroinvertebrate communities were well balanced within the stream. There was a high abundance of EPT individuals compared to Chironomidae. No population showed high levels of dominance and the Hilsenhoff Biotic Index (HBI) was 3.3. Shredders were more abundant at the upstream stations while filterer/collectors and grazer/scrapers were more abundant at downstream stations. During mining, taxa richness and the EPT index generally increased; however, the percent EPT decreased while the percent Chironomidae increased. Family dominance and the HBI also increased. The percentage of shredders decreased at the upstream stations but increased slightly at the downstream stations. Percent filterer/collectors increased at the upstream stations but decreased at the downstream stations, while grazer/scrapers populations decreased at all mainstream stations. Utilizing the West Virginia Stream Condition Index, Wiley Branch was considered highly comparable to reference conditions before mining. After mining began, the stream became increasing different from reference conditions.

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CHAPTER I

INTRODUCTION

Biological assessment is an evaluation of the condition of a body of water using biological surveys and other direct measurements of the resident biota in surface waters (Barbour et al. 1999). Biological monitoring is the systematic use of the response of living organisms to determine the changing quality of the aquatic environment (Merritt and Cummins 1996). This study begins with a community level biological assessment of Wiley Branch, a first-order stream in southern West Virginia, and continues with the biological monitoring of Wiley Branch during the initial stages of contour surface mining. An attempt will be made to summarize the magnitude, ecological consequences, and overall impact of contour surface mining on a specific size watershed.

Benthic macroinvertebrate assemblages will be used to assess and monitor water quality. They have long been used as biological indicators of localized environmental conditions and biological integrity. Macroinvertebrates are the group most frequently used in the assessment of water quality for a variety of reasons. Benthic macroinvertebrates are ubiquitous and easy to collect (Cummins 1975). The large numbers of species exhibit a wide spectrum of responses to environmental stress (Rosenberg and Resh 1993). According to Resh and Jackson (1993), macroinvertebrates are suitable organisms for studying site-specific impact because of their generally sedentary nature. According to Southerland and Stribling (1995), benthic macroinvertebrates are used in 90% of the state water quality assessment programs in the United States. There are, however, several difficulties to consider when using benthic macroinvertebrates in water quality assessment. Seasonal variation in distribution and abundance may complicate interpretations of comparisons between samples taken during different seasons (Seuss 1982). “Natural” variability can be a confounding factor in any biological assessment program (Resh and McElravy 1993). In certain situations, macroinvertebrates have the propensity to drift into areas where they do not normally occur (Rosenberg and Resh 1993). Moreover, accurate lower-level taxonomic identification of early instars can be difficult.

The biological integrity of all aquatic systems is not solely dependent on the quality of the water. Karr et al. (1986) identified five major classes of environmental factors that affect aquatic biota: 1) energy source, 2) water quality, 3) habitat quality, 4) flow regime, and 5) biotic interaction. Along with an examination of biotic interactions, this study will employ physical and chemical measurements of quality as well. The amount of allochthonous energy sources can be altered by land use changes or riparian zone perturbation. This will be interpreted with an analysis of changes to functional feeding groups. Erosion and nutrient run-off can affect water quality and will be measured by standardized water chemistry analysis. Potential changes in habitat quality will be defined with a habitat assessment. Stream impoundment and alteration in watershed drainage patterns may alter flow. These factors collectively describe the impact of activities throughout the entire watershed. Physical and chemical measurements are instantaneous and describe conditions that exist when the sample is collected or measurement taken. In contrast, the benthic macroinvertebrate community has been exposed to past conditions as well as current conditions adding a temporal depth to the analysis. By using biological sampling, cumulative effects of successive disturbances in a body of water can be revealed (Gibson et al. 1996). However, the distribution of aquatic benthic macroinvertebrate populations is ultimately set by the physical and chemical tolerances of the individuals within the population to a variety of environmental factors (Merritt and Cummins 1996).

The potential impact to Wiley Branch resulted from a multiple seam contour mining operation in the Wiley Branch watershed. Contour mining involves making a cut along the edge of a hillside to expose a coal seam. Multiple seam contour mining is the removal of more than one coal seam. The overburden or spoil is eventually returned to the bench and the hillside is returned to approximate original contour (AOC). AOC slopes are constructed with terraces which function to provide stability and erosion control. The excavation process creates excess spoil volume or “swell” and this is placed in engineered valley fills in the head of a hollow. Sedimentation control structures are constructed below valley fills to reduce sedimentation downstream (McComas 1992). Surface mining produces a type of point source pollution that has the potential to threaten the quality of surface waters. The effect of these methods on biological communities downstream from the valley fill is uncertain.

The purpose of this study is to document the biological, physical and chemical conditions of Wiley Branch before mining begins and to monitor the changes in these conditions during the initial stages of mining. It is predicted that benthic macroinvertebrate assemblages will show a reduction of non-tolerant species resulting in the reduction of species diversity. It is expected that this will be accompanied by an increase in productivity of tolerant species. Physical alterations of habitat and chemical degradation of water quality will presumably result in changes in dominance of taxa present. Potential impacts from mining are numerous, including, but not limited to, increased sedimentation, nutrient enrichment, acid mine drainage, increased metal loads and disturbance of riparian zones. Impact on the Wiley Branch watershed will be based on estimates of change from reference or least impacted conditions using a regional stream condition index. This study utilizes a multimetric characterization of the aquatic community, habitat evaluation and water chemistry.

This paper will address the following specific questions:

1. How does water quality change during the initial stages of mining?
2. How does the stream macroinvertebrate assemblage change as a result of contour mining activities?
3. How do increased sedimentation, stream impoundment and disturbance of riparian corridors impact functional feeding groups?
4. How far downstream of impact is the benthic macroinvertebrate assemblage affected?

CHAPTER II

STUDY SITE

Watershed

Wiley Branch is a first-order stream draining approximately 1112 acres (450 hectares) of deciduous forest. This perennial stream flows into the East Fork of Twelve Pole Creek, which empties into the Ohio River near Huntington, West Virginia (Fig. 1). Pen Coal's current permitted mining activities will impact approximately 82 acres (33 hectares), or 7% of the Wiley Branch watershed. Wiley Branch is a 2.4-kilometer perennial warm water stream located near Dunlow, West Virginia, in southern Wayne County (Latitude, 38°58'30" / Longitude, 82°16'46" / Twelve Pole Creek Basin). Wayne County is located in the unglaciated Allegheny Plateau Section of the Appalachian Plateau Physiographic Province (Fenneman 1950). The Appalachian Plateau Province is predominantly underlain by shales, sandstones and lesser amounts of limestone of the Upper Devonian, Mississippian and Silurian systems (Mills and Delcourt 1991). Wiley Branch does not receive water from any other flowing water source but is solely spring fed. Because of the difference in elevation of the alluvial floor and that of the proposed mining operation, no interruption of groundwater supply was measured. The area has previously been used for timber, oil and gas exploration and development as well as wildlife habitat. The area is isolated and undeveloped due to existing topographic features that prohibit agriculture or commercial development.

Sampling Stations

Four sampling stations were established on Wiley Branch and one on the East Fork of Twelve Pole Creek (Fig. 1). Since the goal of this study was to determine the health of the entire stream, three sampling stations (WB4, WB3, and WB1) were established in the main channel of Wiley Branch and one station (WB2) in the Left Fork of Wiley Branch. A fifth sampling station was established in the East Fork of Twelve Pole Creek just below the confluence with Wiley Branch (12P). Twelve Pole Creek is a third-order stream located near Dunlow, West Virginia, traveling through the counties of Lincoln, Mingo and Wayne (Fig. 2). The predominant surrounding land use was deciduous forest; however, in the area of WB2 some logging operations had taken place within the last ten years.

Station 4 (WB4) was located upstream below one durable rock valley fill (124,012 cubic yards) and two sedimentation ponds approximately 0.11 km below the lowest pond (262 meters elevation). Within the past seventy-five years this area was used as pasture/farm land and a small log shack still stands in the area; however, no one has lived in the area or farmed the land in a number of years. No local watershed erosion was observed. The riparian vegetation was dominated by trees (*Cornus florida, Acer saccharum, Quercus spp.*, *Oxydendrum arboreum*, *Platanus occidentalis*, *Carpinus caroliniana*, *Tsuga canadensis*, *Hamamelis virginiana*, *Ulmus rubra*), shrubs (*Eupatorium purpureum*, *Polygonum sp.*, *Justicia americana*, *Rosa multiflora*, *Impatiens capensis*) and grasses (*Panicum clandestinum*, *Leersia oryzoides*). The dominant species were *Quercus spp.* and *Carpinus caroliniana*. The canopy cover was shaded. The

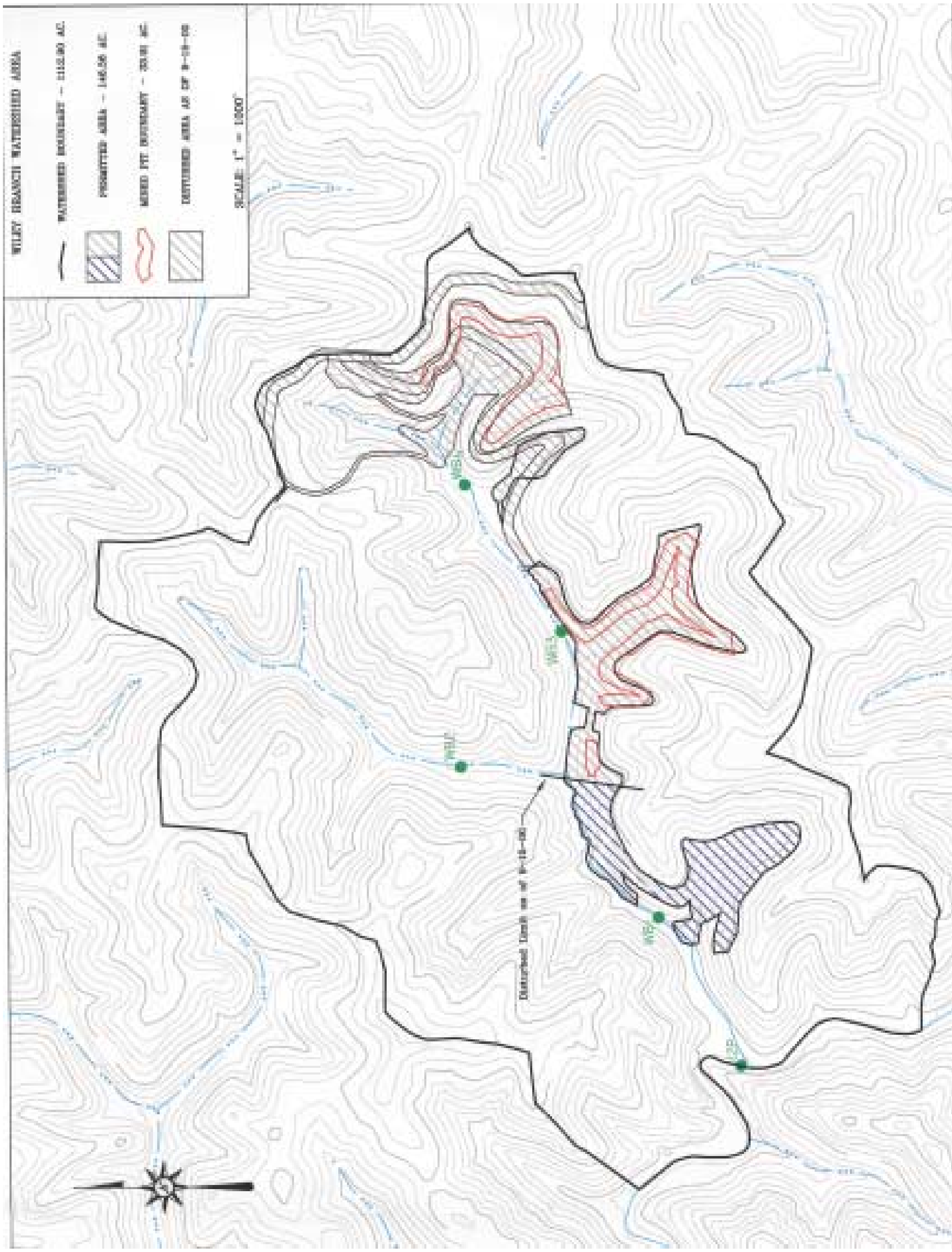

Figure 1. Sampling Stations on Wiley Branch and Twelve Pole Creek.

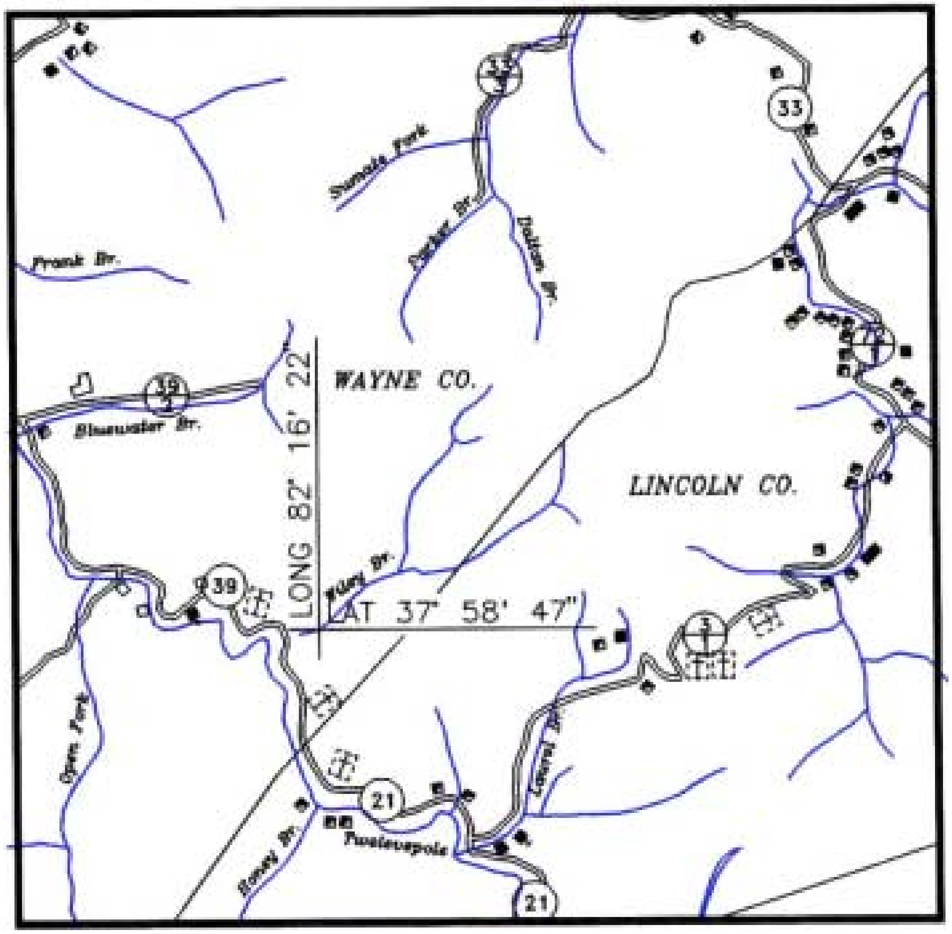

Figure 2. Wilsondale Quadrangle. Harts Creek and Stonewall District of Lincoln and Wayne Counties. Receiving stream: Wiley Branch of Twelve Pole Creek of Ohio River

estimated reach length for the sampling area was 7.6 m, the estimated reach width was 0.6 m for a sampling reach area of 4.56 m^2. The estimated stream depth was less than 3 cm. The morphology of the sampling area indicated that this part of the stream had once been an old road-bed. The stream flowed in two sections resembling the spacing of tire tracks. Both floating and attached algae were present and covered approximately 50% of the sampling reach. Detritus (sticks, wood, and coarse plant material) was the most abundant organic substrate component representing approximately 10% of the sampling area. The description of this sampling site did not change during the fifteen months of monitoring (Fig. 3).

Figure 3. Station 4 on Wiley Branch (WB4)

The valley fills in the Wiley Branch watershed were constructed using mine spoil comprised of eighty percent or greater durable rock. Ground surfaces were cleared of trees, brush, shrubs and other organic materials before excess spoil was deposited. Rock underdrains were installed in each durable rock fill. Downstream slopes of each fill were 2:1 (horizontal:vertical) with 6 meter side benches constructed at 15 meter vertical increments.

Station 3 (WB3) was located 0.80 km downstream from Station 4. Station 3 was below a second valley fill (447,289 cubic years) and two additional sedimentation ponds. Initially, local watershed erosion was not noted; however, one year into the mining process stream bank erosion at this station had increased. The riparian vegetation was dominated by trees (*Platanus occidentalis, Carpinus caroliniana, Hamamelis virginiana*, *Juglans nigra*, *Liriodendron tulipifera*), the dominant species being *Carpinus caroliniana*. The canopy cover was partly shaded within the sampling reach but sunny upstream and downstream. The estimated reach length for the sampling area was 22.9 m, the reach width was 1m for a sampling reach area of 22.9 m^2. The estimated stream depth was less than 5.5 cm. The riparian zone on the east bank was severely impacted by road and sedimentation pond construction. The average width of the riparian zone was reduced to approximately 3 meters. In some areas there was no riparian vegetation on the east bank. Detritus (sticks, wood, coarse plant materials) was the most abundant organic substrate component representing approximately 45% of the sampling area (Fig. 4).

Figure 4. Station 3 on Wiley Branch (WB3)

Station 2 (WB2) was established in the Left Fork of Wiley Branch (253 meters elevation). This station was not directly affected by mining operations but some minor logging did take place in the upper reaches of the hollow during the sampling period. Local watershed erosion was moderate, possibly due to soil and substrate being pushed over the riparian zone during logging. Cut logs up to 30 cm were apparent in the stream channel. The riparian vegetation was dominated by trees (*Cornus florida*, *Acer saccharum*, *Quercus rubra*, *Asimina triloba*, *Platanus occidentalis*, *Liriodendron tulipifera*, *Tsuga canadensis*, *Juglans cinerea*). The canopy cover was shaded. The estimated reach length for the sampling area was 305 m, the estimated reach width was 1 m for a sampling reach area of 305 m^2. The estimated stream depth was less than 3 cm. The sampling reach in this portion of the stream was greater because of low flow during unseasonably dry periods. Detritus (sticks, wood, coarse plant materials) was the most abundant organic substrate component representing approximately 75% of the sampling area. The description of this sampling site did not change during the fifteen months of monitoring (Fig. 5).

Figure 5. Station 2 on the Left Fork of Wiley Branch (WB2)

Station 1 (WB1) was located just above the confluence point with Twelve Pole Creek approximately 1.01 km below station 3 (229 meters elevation). Slight local watershed erosion was observed. The riparian vegetation was dominated by trees (*Acer saccharum, Platanus occidentalis*, *Carpinus caroliniana*, *Asimina triloba*, *Betula nigra*, *Carya spp.*, *Robinia pseudo-acacia, Liriodendron tulipifera*). The dominant species was *Carpinus caroliniana*. The canopy cover was partly shaded. The estimated reach length for the sampling area was 11 m, the estimated reach width was 1.5 m for a sampling reach area of 16.5 m^2. The estimated stream depth was less than 4.5 cm. Detritus (sticks, wood, coarse plant materials) was the most abundant organic substrate component representing approximately 20% of the sampling area. The description of this sampling site did not change during the fifteen months of monitoring.

It should be noted that parts of Wiley Branch were used as an access road to the head of hollow areas. Although none of the sampling stations were directly impacted by vehicular traffic, reaches both above and below were subjected to automobile tire perturbation (Fig. 6).

Figure 6. Station 1 on Wiley Branch (WB1)

A fifth sampling station was established in the East Fork of Twelve Pole Creek just below the confluence of Wiley Branch (750 foot elevation). No local watershed erosion was observed. The riparian vegetation was dominated by trees (*Acer saccharum*, *Platanus occidentalis*, *Tsuga canadensis*, *Asimina triloba*, *Betula nigra*, *Fagus grandifolia*). The dominant tree species was *Platanus occidentalis* and the dominant shrub was *Impatiens capensis.* The canopy cover was partly open. The estimated reach length for the sampling area was 3.1 m, the estimated reach width was 9.1 m for a sampling reach area of 28.21 m^2. The estimated stream depth was 5 cm. Manganese deposits were noted on rocks collected from this sampling site. Detritus (sticks, wood, coarse plant materials) was the most abundant organic substrate component representing approximately 55% of the sampling area. The East Fork of Twelve Pole Creek is a perennial warm water stream that has a mixture of origins. The description of this sampling site did not change during the fifteen months of monitoring (Fig. 7).

Figure 7. Twelve Pole Creek (12P)

Geology

Two coal seams were targeted for the Wiley Branch surface-contour mining operation: Coalburg and Five Block coal seams. Total sulfur content of the Coalburg coal seam ranged from 0.448% to 0.664%. The total sulfur content of the Five Block coal seam ranged from 0.02% to 5.04% across the mining area. Pyritic sulfur content for the two seams showed an overall weighted average ranging from 0.06% to 1.52% in core holes analyzed from the permit area. In general, coal seams with pyritic sulfur concentrations less than 1.0% are not associated with production of acid mine drainage. Appendix A contains geology raw data.

The major rock units in this region consisted largely of sandstones and shales. The alluvial aquifers present were predominately comprised of sand and silt with minor amounts of clay and gravel. Given the potential for hydraulic transport of sediment from the disturbed area, the mining plan provided for the construction of a series of sediment control structures to lessen this impact. The depth of bedrock was approximately fifteen to twenty-eight centimeters from the bottom of the stream channels. A fine layer of silt covered the bedrock in these areas. Table 1 shows a comparison of substrate components for each sampling station.

Substrate Type	**WB4**	**WB3**	**WB2**	**WB1**	**12P**
Bedrock	0	10	0	0	0
Boulder	0	10	0	0	0
Cobble	10	10	45	45	5
Gravel	45	30	45	50	80
Sand	45	30	10	5	15
Silt	0	10	0	0	0
Clay	0	0	0	0	0

Table 1. Substrate Component Percentage Composition at Each Sampling Station

CHAPTER III

METHODS AND MATERIALS

For each station water flow was measured, water samples were collected for chemical analysis, benthic macroinvertebrate samples were collected and a habitat assessment was conducted. Pre-mining data was collected on February 20, 1999. Initial mining operations began in April of the same year. Seasonal sampling was initiated on May 27, 1999 and continued until May 10, 2000. The individual methodologies are described separately.

Flow

This measurement is an indicator of the surface and groundwater discharge in the watershed.

Water Chemistry

Water samples were collected from each station at the time of benthic sampling. Each water grab sample was preserved, and transported to Standard Laboratories, Inc for analysis. Each parameter measured utilized the current EPA-approved analytical methodology. Parameters determined at each station were pH, total alkalinity (mg/L $CaCO_3$), acidity (mg/L $CaCO_3$), sulfate (mg/L), total aluminum (mg/L), total iron (mg/L), total manganese (mg/L) total suspended solids (mg/L), total dissolved solids (mg/L), and specific conductivity (umhos/cm). Raw data are presented in Appendix B.

Benthic Macroinvertebrate Assemblage

EPA's Rapid Bioassessment Protocol methods were utilized in the collection of the benthic macroinvertebrate specimens. At each station, benthic organisms were collected with a Surber Stream Bottom Sampler fitted with a mesh net. This type of sampler is best used in water less than 457 mm (18") deep. The sampler was placed firmly on the stream bottom and substrate was stirred and scrubbed within the frame boundaries. The open base encloses an area of 305mm X 305mm (12" X 12"). One collection was taken from a fast flowing riffle area and a second replicate was taken from a slower run area at each station. Stratified random sampling was used to facilitate comparisons, decrease variability, and increase sensitivity of the study to detect environmental change (Resh and McElravy 1993). Samples at each station were combined and preserved in 70% ethanol and returned to the laboratory for processing (Fig. 8). Composites of sample units from sites can be used when the objective is to determine changes in a stream site before and after a disturbance (Merritt and Cummins 1996).

Figure 8. Collection using a Surber Sampler

In the laboratory, samples were rinsed and strained using a size 35 U.S. standard sieve with a 500-micron screen. Entire samples were picked under a Bausch and Lomb magnifying lens. Detrital material was discarded only after a second check to insure that no macroinvertebrates had been missed. All macroinvertebrates were identified to lowest practical taxonomic level and enumerated using Peckarsky et al. (1990) and Merritt and Cummings (1996). Raw data are presented in Appendix D. Metrics for each station (Appendix E) were calculated using the methods outlined by Plafkin et al. (1989) and Kerans and Karr (1994). Each metric measures a different component of community structure and has a different range of sensitivity to pollution stress. The following is a brief explanation of each of the metrics used in this study:

Community Structure

Metric 1. Taxa or Species Richness – This metric reflects the health of the community by measuring the diversity of the aquatic assemblage (Resh et al., 1995). The total number of taxa in each sample was counted and recorded. An ecologically healthy system is generally expected to support a more diverse community of fauna; therefore, this value decreases in response to increased perturbation and decreased habitat diversity.

Metric 2. EPT Index – This index is the total number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera. These insect orders are generally considered to be pollution sensitive. The EPT Index generally decreases in response to increased perturbation.

Community Balance

Metric 3. Percent EPT – This index is the percent of the composite of Ephemeroptera, Plecoptera and Trichoptera to total organisms. These three orders are considered to be the most sensitive to environmental stressors. The value was obtained by dividing the total number of EPT by the total number of individuals in the sample. This metric should decrease in response to increased perturbation.

Metric 4. Percent Chironomidae – This index is the percent of the composite of Chironomidae to total organisms. This family of Diptera is considered to be more pollution tolerant in the aquatic environment. The value was obtained by dividing the total number of Chironomidae by the total number of individuals in the sample. This metric should increase in response to increased perturbation (Barbour et al., 1994).

Metric 5. Percent Contribution of the Two Dominant Families – Measuring the dominance of the two most abundant families, this metric measures community balance or lack thereof. A community dominated by relatively few families could indicate environmental stress. The metric was determined by dividing the total number of the two most dominant families by the total number of organisms in the sample. Generally, the predicted response to increased perturbation is an increase in the percent dominance.

Taxonomic Composition

Metric 6. Modified Hilsenhoff Biotic Index (MHBI) – Developed by Hilsenhoff (1987), this index summarizes overall pollution tolerance of the benthic community inhabiting rock or gravel riffles. A single value integrates tolerance classification and abundance. It is oriented toward detection of organic and nutrient pollution. The formula for calculating the biotic index is:

$$HBI = \Sigma \frac{xi \cdot ti}{n}$$

where

xi = number of individuals within a family
ti = tolerance value of a family
n = total number of organisms in the sample

Generally, an increase in the MHBI value reflects an increase in perturbation. Where available, tolerance values for genera were used.

Biological Processes

Metric 7. Percent Filterer-Collectors – The relative abundance of filterer/collectors indicates the availability of both suspended fine particulate organic material (FPOM) and attachment sites for filtering. Generalists, such as filterers and collectors, have a broad range of acceptable food materials and are thus more tolerant to pollution that might alter availability of certain foods (Cummins and Klug 1979). This metric value was obtained by dividing the number of filterer/collectors by the total number of organisms in the sample. As perturbation increases, this metric value is expected to increase.

Metric 8. Percent Grazers-Scrapers – The relative abundance of grazers-scrapers indicates the periphyton community composition. Specialized feeders, such as grazers-scrapers, are the more sensitive organisms and are thought to be well represented in healthy stream environments (Cummins and Klug 1979). This metric value was obtained by dividing the number of grazers-scrapers by the total number of organisms in the sample. As perturbation increases this metric value is expected to decrease.

Metric 9. Percent Shredders - The relative abundance of shredders indicates the availability of coarse particulate organic material (CPOM) and reflects riparian zone impacts. Shredders are also considered to be specialized feeders and are thus the more sensitive organisms in the aquatic environment (Cummins and Klug 1979). This metric value was obtained by dividing the number of shredders by the total number of organisms in the sample and is expected to decrease in response to increased perturbation (Barbour et al. 1992).

The proportions of these three functional feeding groups were important because a predominance of a particular feeding type may indicate an unbalanced community responding to an overabundance of a particular food source. These groups also respond to toxicants and are useful to evaluate chemical contamination from nonpoint-source impacts (Plafkin et al. 1989). Functional Feeding Group classifications were assigned using Merritt and Cummins (1996) and are described according to adaptations for food acquisition rather than food eaten.

A Stream Condition Index for West Virginia Wadeable Streams (WV-SCI) (Gerritsen et al. 2000) was utilized for the development of a multimetric index for Wiley Branch. The WV-SCI was calibrated for a long-term biological index period extending from April through October. The index was used as an indicator of ecosystem health and therefore could identify impairment of Wiley Branch with respect to reference conditions in West Virginia. The six metrics utilized in the WV-SCI were total taxa, EPT taxa, percent EPT, percent Chironomidae, percent top two dominant taxa and HBI (Gerritsen et al. 2000). The WV-SCI was developed from a data set of 1268 benthic samples collected in riffle habitats from 1996 to 1998. This data includes 107 reference samples.

Habitat Assessment

Habitat assessment is defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour et al. 1996). A team of two biologists was used to evaluate habitat assessment for the purpose of consensus on determination of quality. Weather conditions were noted the day of sampling as well as for seven days immediately preceding the sampling date. This information was important to interpret the effects of storm events on the sampled data. Watershed features such as predominant surrounding land use and stream origin were determined from topographic and land use maps and confirmed with a site survey. Dominant type and species of riparian vegetation were recorded. Measurements were taken to monitor the size of the riparian zone buffer strip.

Instream features such as width, depth, canopy cover, and proportion of stream morphology types were also a part of the habitat assessment. Stream width was measured from bank to bank at three points for each station and an average taken to determine the width that was representative for the given area. Stream depth was measured as a vertical distance from water surface to stream bottom at three points for each station and an average taken to determine the depth that was representative for the given area. Canopy cover was the general proportion of open to shaded area which best described the amount of cover at each station. The proportion represented by riffles, runs and pools was noted to describe the morphological heterogeneity of each station. The relative proportion of each of the seven substrate/particle types, bedrock, boulder, cobble, gravel, sand, silt, and clay, was determined for each station. Sediment deposits were noted when present.

CHAPTER IV

RESULTS

Water Chemistry

Pre-mining data was collected on February 20, 1999. Initial mining operations began in April of the same year. Seasonal sampling was initiated on May 27, 1999 and continued until May 10, 2000. Daily high temperature and precipitation for each of the seven days prior to each sampling session were recorded (Appendix B). Mean temperature for the sixteen-month study period was 13.1 °C. Monthly extremes were –4.4 and 29.2°C, February 1999 and July 1999, respectively. Annual precipitation data from the National Weather Service in Charleston, West Virginia, is also recorded in Appendix B.

There were no dramatic changes in pH during the entire sampling period among all of the sampling stations (Fig. 9). The range was from 6.88 to 8.79 while the mean was 7.74 with a 0.4 standard deviation. According to the West Virginia Division of Environmental Protection (1998), sites are considered stressed if the pH drops below 6.0 or rises above 9.0. Acid mine drainage is not a serious problem because sulfur content of the coal and overburden was low. The acidity of 0.00 mg/L $CaCO_3$ was unchanged during the entire sampling period.

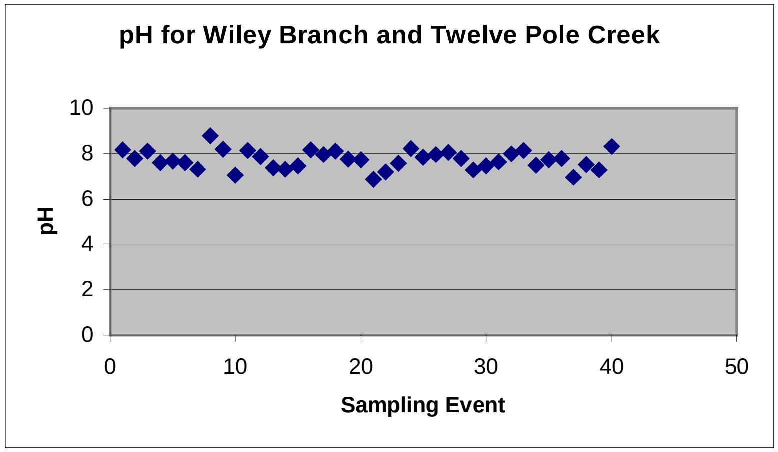

Figure 9. pH data from Feb. 1999 - May 2000.

In Wiley Branch, flow rates generally dropped 67 to 83% after the onset of mining (Fig. 10). In the main channel of Wiley Branch, flow was greatest at the mouth of the stream (WB1) and least at the headwaters (WB4). On the Left Fork of Wiley Branch, (Station WB2), a 70% decrease in flow was recorded after onset of mining operations. Further decreases in flow were recorded at all stations during the summer sampling period with subsequent slight increases in November 1999 and March 2000. Decreases at all stations were again recorded in May 2000.

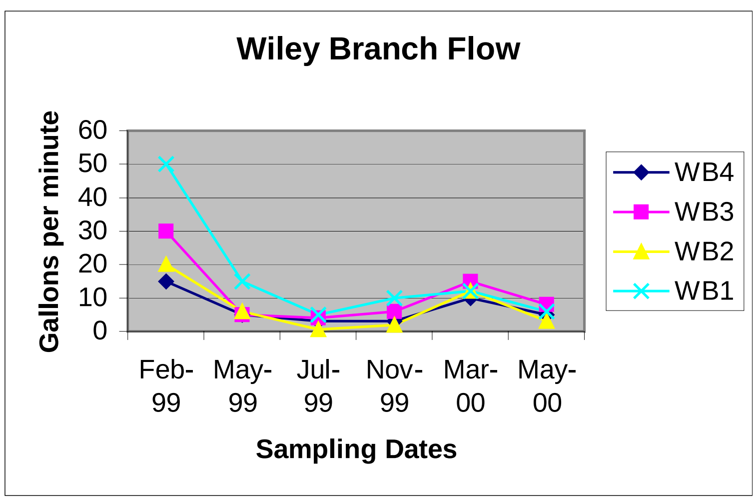

Figure 10. Flow Measurements on Wiley Branch

In Twelve Pole Creek, flow ranged from 3000 gallons per minute (GPM) in February 1999 to 38 GPM in May 2000. Other flow measurements recorded were 200 GPM and 600 GPM, July 1999 and November 1999, respectively.

At all stations, total alkalinity increased during the initial stages of mining and leveled off beginning in July 1999 (Fig. 11). The range of total alkalinity on Wiley Branch was 19 to 98 mg/L $CaCO_3$, February 1999 (WB1) and July 1999 (WB4), respectively. The range on Twelve Pole Creek was 16 to 86 mg/L $CaCO_3$, March 2000 and September 1999, respectively. The mean for Wiley Branch was 65 mg/L $CaCO_3$ while the mean for Twelve Pole Creek was 79 mg/L $CaCO_3$. The total alkalinity at the Twelve Pole Creek Station (12P) mirrored that of the Wiley Branch Stations with an increase during the initial months of mining, a leveling off period between July 1999 and November 1999, and a decrease during the first three months of 2000. As with the other stations on Wiley Branch, Twelve Pole Creek showed an increase in total alkalinity during the May 2000 sampling period with the sharpest increase at Station WB1.

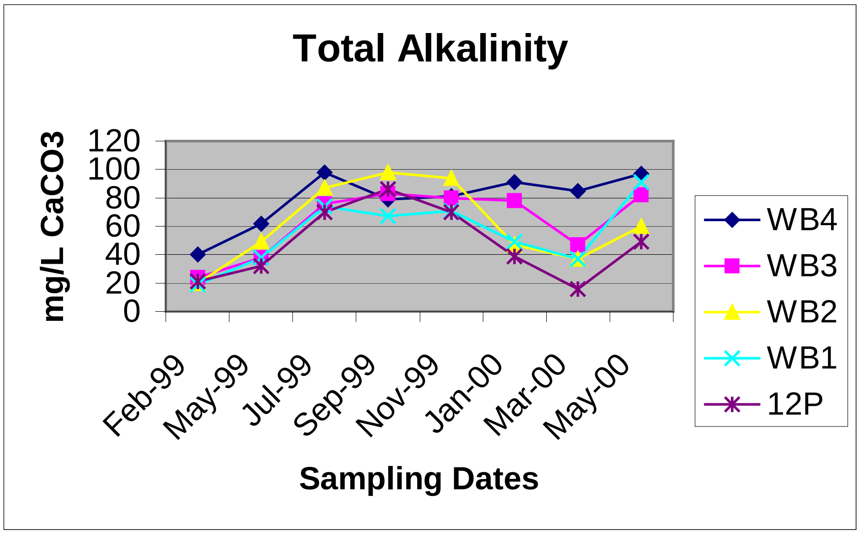

Figure 11. Total Alkalinity for all Stations

Concentrations of sulfate were consistently higher at Station WB4 than any other station (Fig. 12). For all stations, sulfate concentrations decreased from pre-mining sampling data (2/99) to the first seasonal sampling date (5/99). After May 1999, sulfate concentrations on Wiley Branch gradually increased. At the upstream station, WB4, the sulfate concentration increased from 18 mg/L in May of 1999 to a high of 108 mg/L over an eight-month period. The concentration fell to 55.4 mg/L in March 2000 but returned to the higher levels in May 2000 (102 mg/L). Station WB3 also showed increases in sulfate during the initial stages of mining rising from 6 mg/L (5/99) to 82 mg/L (1/00). The first five months of 2000 showed a slight decrease of sulfate at this station. Station WB2 had higher sulfate concentrations during July 1999 but this station had the lowest concentrations on every other sampling date. Station WB1 showed only slight changes in sulfate concentrations during initial stages of mining (17.1 to 34.2 mg/L); however, in May 2000 the concentration increased by 191% from 34 to 99 mg/L. The range for Wiley Branch was from 1 (9/99, WB2) to 108 mg/L sulfate (1/00, WB4); X= 38.5 mg/L. Changes in sulfate concentrations on Twelve Pole Creek did not mirror those of Wiley Branch. The sulfate concentrations in February 1999 were 24.0 mg/L decreasing to 8.1 mg/L in May 1999. A sharp increase was seen in July 1999 (56.2 mg/L) with a gradual decrease over the remainder of the sampling period.

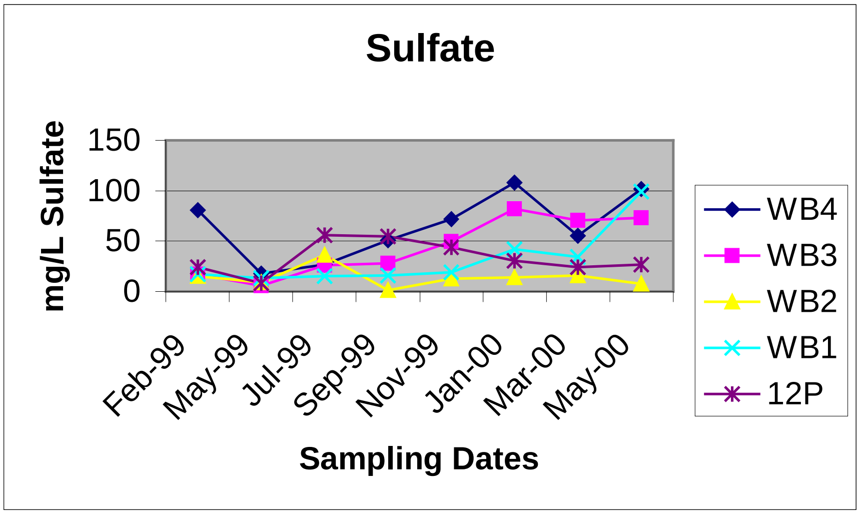

Figure 12. Sulfate Concentrations for all Stations.

Total aluminum (Al) concentrations increased at all stations from February 1999 to May 1999 (Fig. 13) with the highest increase at Station WB3. The range of total aluminum for both streams was less than 0.07 (multiple sampling dates and sites) to 7.7 mg/L aluminum (May 1999, WB3). The Wiley Branch mean for the sampling period was 0.66 mg/L aluminum while the Twelve Pole Creek average was 0.86 mg/L aluminum.

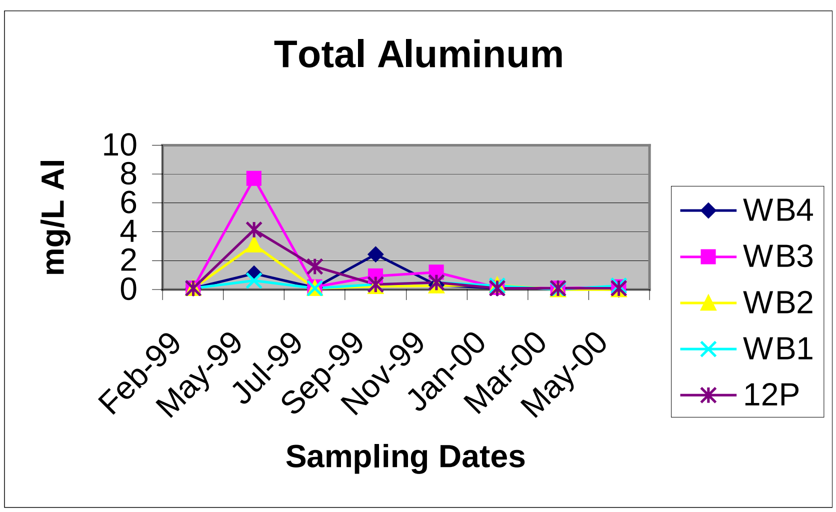

Figure 13. Total Aluminum for all Stations.

Total iron (Fe) concentrations increased at all stations from February 1999 to May 1999 with the highest increase at station WB3 (Fig. 14). The average iron concentration on Wiley Branch during the sampling period was 0.61 mg/L while the range was from less than 0.025 to 9.16 mg/L iron (5/99, WB3). On Twelve Pole Creek the average was 0.96 mg/L iron. The range was from 0.19 to 3.88 mg/L iron, May 2000 and May 1999, respectively.

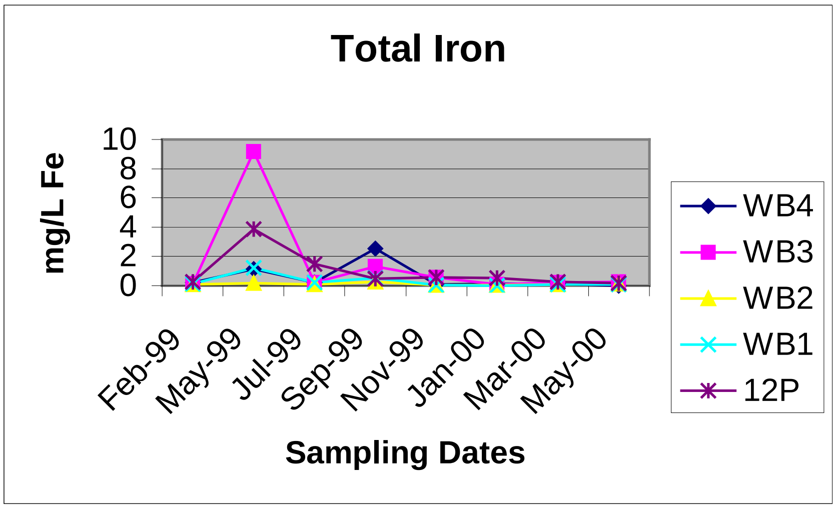

Figure 14. Total Iron for all Stations.

Manganese (Mn) fluctuated during the sampling period more than any other metal (Fig. 15). At Station WB4, manganese concentrations were greatest in September 1999 (0.57 mg/L Mn) and January 2000 (0.43 mg/L Mn). At Station WB3, concentrations were greatest in May 1999 (0.66 mg/L Mn), dropping dramatically in July (0.02 mg/L Mn) and increasing again in September (0.29 mg/L Mn) with a subsequent decrease for the remainder of the sampling period. Stations WB2 and WB1 showed only trace amounts of manganese the entire sampling period. The range was from less than 0.02 to 0.66 mg/L manganese; X = 0.10. Twelve Pole Creek also showed low levels of manganese the entire sampling period. The range was from less than 0.05 to 0.09 mg/L with an average of 0.07 mg/L manganese.

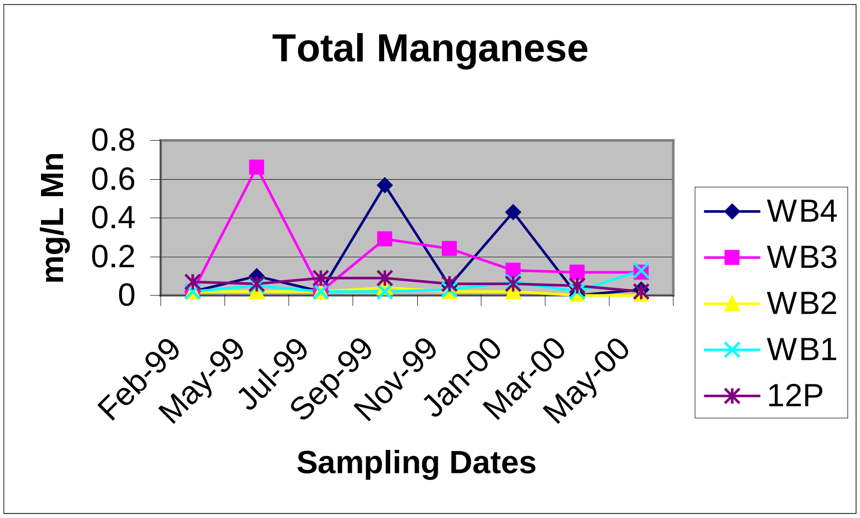

Figure 15. Total Manganese for all Stations.

Total suspended solids (TSS) showed a dramatic increase at Station WB3 in May 1999 with a subsequent drop in July 1999 (Fig. 16). Station WB4 showed a slight increase in TSS on the September 1999 sampling date. All other stations and sampling periods had low levels of TSS. The range on Wiley Branch was less than 5.0 to 263 mg/L suspended solids; X = 15 mg/L TSS. Twelve Pole Creek also showed low levels of TSS. There was a slight increase during the May 1999 sampling period (60 mg/L TSS). The range on Twelve Pole Creek was less than 5.0 to 60 mg/L TSS.

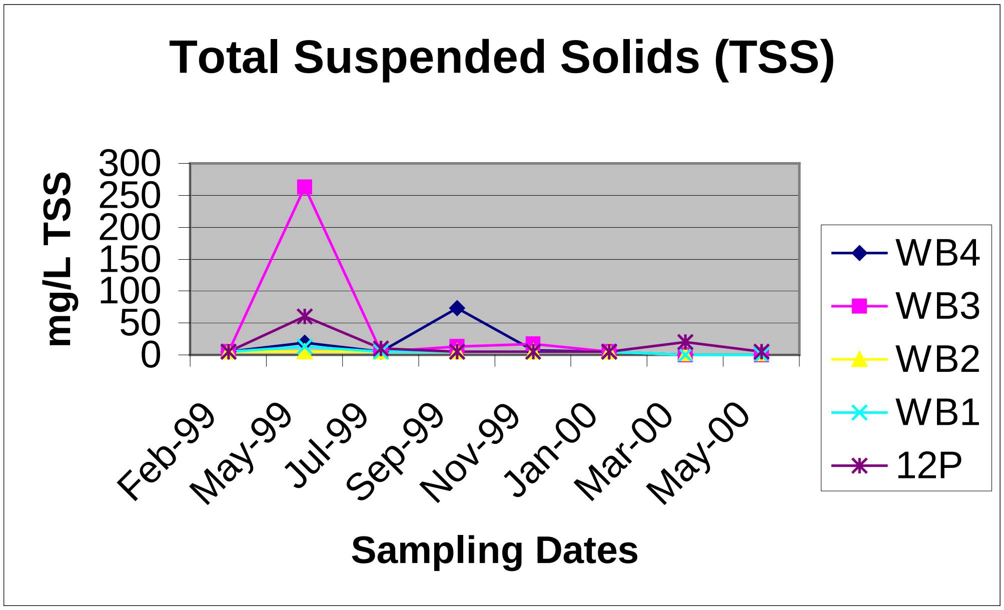

Figure 16. Total Suspended Solids for all Stations.

Total dissolved solids (TDS) fluctuated between 74 and 310 mg/L TDS (Fig. 17). The highest concentration was at Station WB4 and WB1 in May 2000. The average concentration of total dissolved solids over the entire sampling period was 137 mg/L TDS. Increases of TDS were seen in all stations during the May 2000 sampling period, the greatest increase being at Station WB1. Changes on Twelve Pole Creek generally mirrored those on Wiley Branch but were not as extreme. Total dissolved solids fluctuated between 68 and 180 mg/L TDS. The highest concentrations were in the summer of 1999.

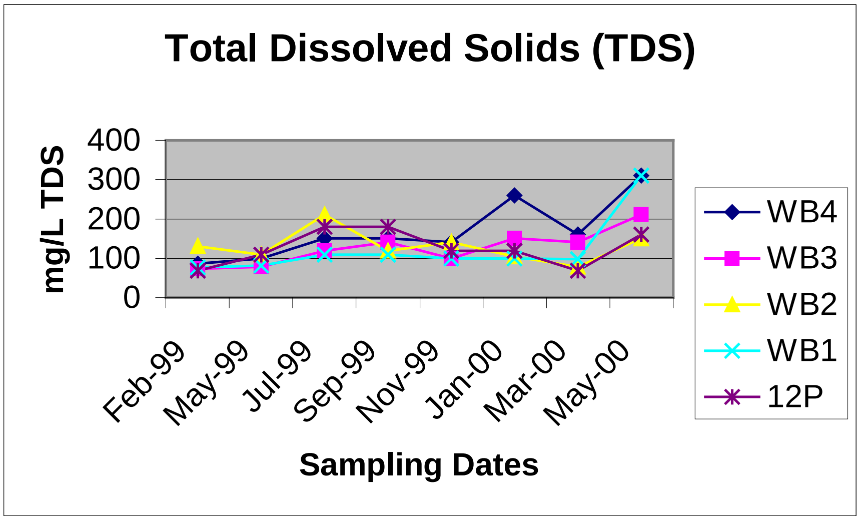

Figure 17. Total Dissolved Solids for all Stations.

Specific conductivity (Fig. 18) steadily increased at Stations WB4 (100 to 353 umhos/cm) and WB3 (80 to 286 umhos/cm). At Station WB2, the specific conductivity ranged between 153 and 260 umhos/cm. Recordings at Station WB1 showed a general increase from 90 to 200 umhos/cm in November 1999 and then a slight drop to 193 umhos/cm in January 2000 with a larger increase in May 2000 to 343 umhos/cm. Main channel Wiley Branch stream averages for each sampling date were 90 (2/99), 147 (5/99), 184 (7/99), 213 (9/99), 243 (11/99), 295 (1/00), 225 (3/00) and 327 umhos/cm (5/00). This represents a 263% increase over the sampling period. By contrast, Station WB2 initially had a recording of 200 umhos/cm dropping to 154 umhos/cm in May 2000. Twelve Pole Creek originally had a recording of 100 umhos/cm, reaching a high of 300 umhos/cm in September 1999, and dropping to 162 umhos/cm in May 2000.

Raw data for all water chemistry parameters is presented in Appendix C.

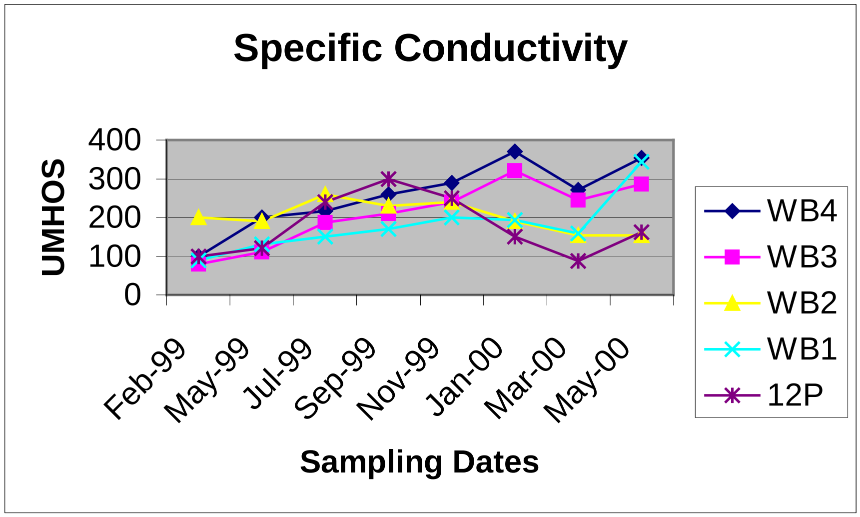

Figure 18. Specific Conductivity for all Stations.

Benthic Macroinvertebrate Assemblages

Appendix D contains raw data for all benthic macroinvertebrate assemblages. Nine metrics were utilized to describe changes to the benthic macroinvertebrate assemblages during this study (Appendix E). Six metrics were employed to determine the West Virginia Stream Condition Index (WV-SCI): Taxa Richness, EPT Taxa, percent EPT, percent Chironomidae, percent two dominant families, and HBI. The remaining three metrics refer to the functional feeding groups percent filterer-collectors, percent grazer-scrapers, and percent shredders. These were used to analyze potential impact upon riparian zones. Using all nine metrics and the WV-SCI, I will first describe the conditions of Wiley Branch and Twelve Pole Creek before mining operations began. I will then describe the changes in both streams that occurred over the twelve-month time period during the beginning stages of mining (May 1999 – May 2000).

Pre-mining Conditions

The February 10, 1999 benthic sample provides a representation of benthic communities before mining operations. The main channel of Wiley Branch was sampled at three locations, upstream (WB4), mid-stream (WB3) and downstream (WB1). Taxa richness ranged from 16 upstream to 14 downstream (Fig. 19). Station WB2 (Left Fork of Wiley Branch) had a taxa richness of 29 while Twelve Pole Creek had 15 different taxa.

Combined number of taxa from the pollution sensitive Ephemeroptera, Plecoptera and Trichoptera groups (EPT) was 15, 14 and 8 at Stations WB4, WB3 and WB1, respectively (Fig. 19). Station WB2 had 18 different EPT taxa while Twelve Pole Creek had 12.

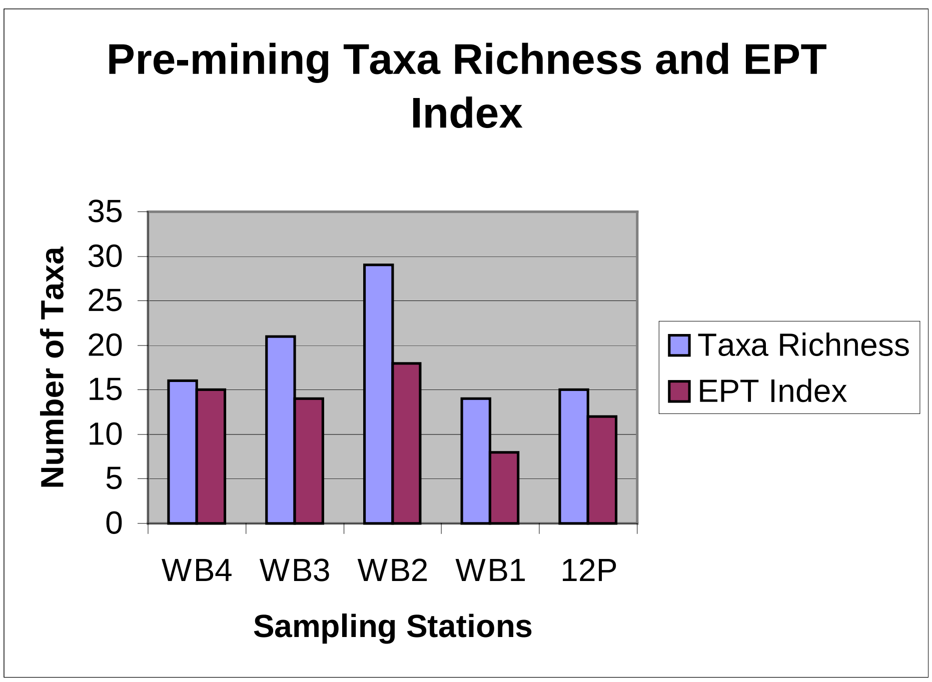

Figure 19. Pre-mining Taxa Richness and EPT Index for Wiley Branch and Twelve Pole Creek.

Figure 20 shows pre-mining percentages of EPT and the pollution tolerant family Chironomidae. Beginning with the upstream station (WB4), the main channel had EPT percentages of 0.69, 0.84 and 0.62. Station WB2 had an EPT percentage of 0.8 with a Chironomidae percentage of 0.06. Twelve Pole Creek EPT percentage was 0.84 while the Chironomidae percentage was 0.12. On the main channel of Wiley Branch, Chironomidae percentages were 0.31 (WB4), 0.08 (WB3), and 0.04 (WB1), respectively.

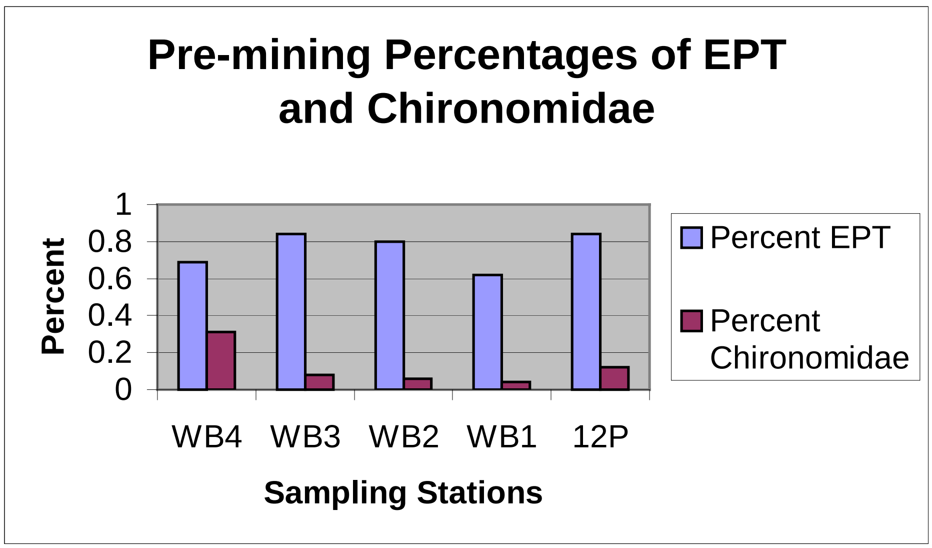

Figure 20. Pre-mining Percentages of EPT and Chironomidae for Wiley Branch and Twelve Pole Creek.

The two most dominant families varied among all five stations. Station WB4 had 53% Chironomidae and Nemouridae, Station WB3 showed 58% Nemouridae and Heptageniidae while Station WB1 had 57% Elmidae and Philopotamidae (Fig. 21). The mayfly family Heptageniidae and stonefly family Nemouridae were the largest groups at Station WB2 with 47% of the sample population. The most abundant families in the Twelve Pole Creek sample were Nemouridae and Ameletidae at 55%.

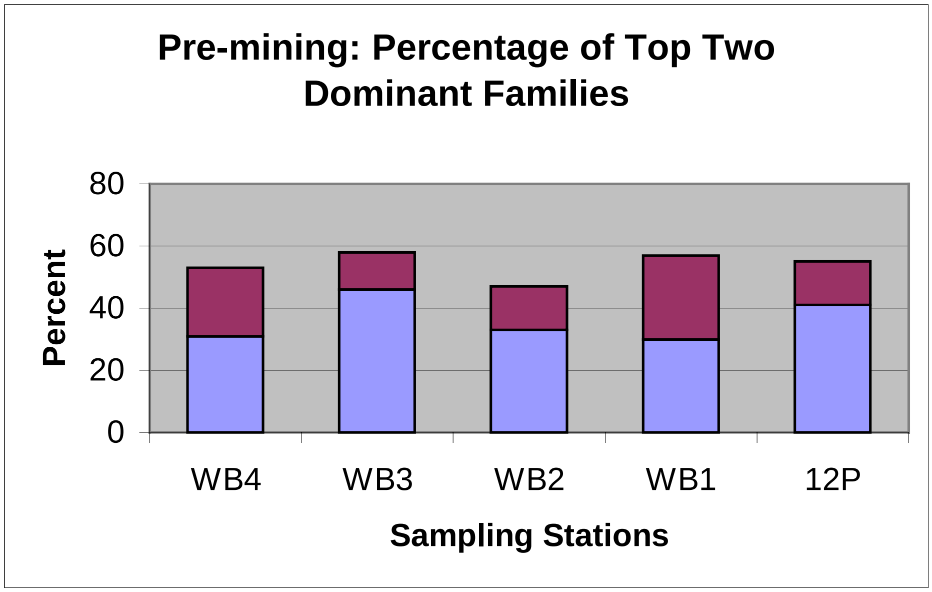

Figure 21. Pre-mining Percent Contribution of Top Two Dominant Families for Wiley Branch and Twelve Pole Creek.

The modified Hilsenhoff Biotic Index (mHBI) for all stations ranged between 3.00 and 4.00 (Fig. 22). The average for the main channel of Wiley Branch was 3.33. Station WB2 was 3.23 and Twelve Pole Creek was 3.21.

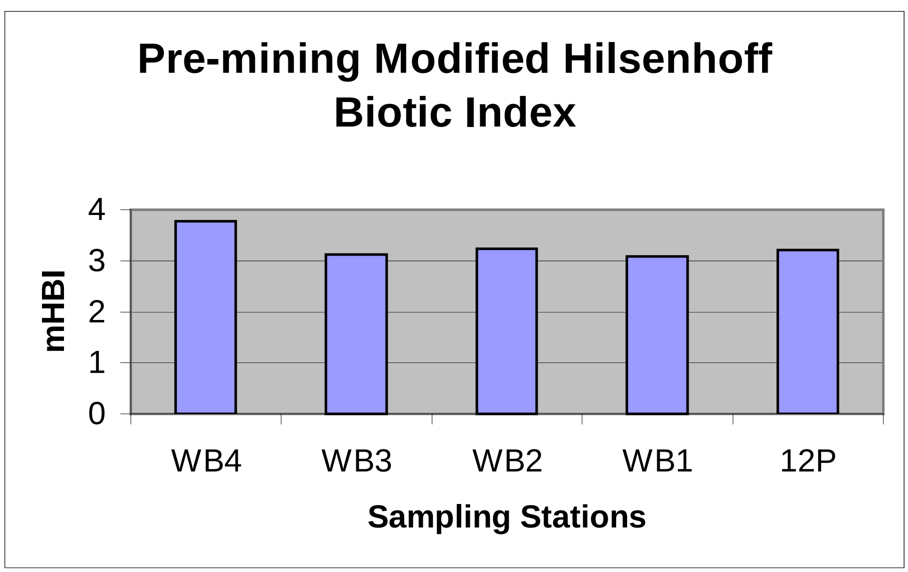

Figure 22. Pre-mining modified Hilsenhoff Biotic Index for Wiley Branch and Twelve Pole Creek.

Figure 23 depicts the relationships among the three most common functional feeding groups: filterer-collectors, grazer-scrapers and shredders. At the upstream stations, WB4 and WB3, shredders were the most abundant feeding group (30% and 60%, respectively) followed by grazer-scrapers (6% and 16%, respectively) and then filterer-collectors (3% and 4%, respectively). At the mouth of Wiley Branch, Station WB1, grazer-scrapers were the most abundant feeding group (46%) followed closely by filterer-collectors (41%). Shredders were the least abundant group at this site (4%). The Left Fork of Wiley Branch (WB2) showed a higher percentage of grazer-scrapers (35%) followed closely by shredders (30%) and a minimal number of filterer-collectors (5%). The Twelve Pole Creek sample had 50% shredders, 8% grazer-scrapers and 6% filterer-collectors.

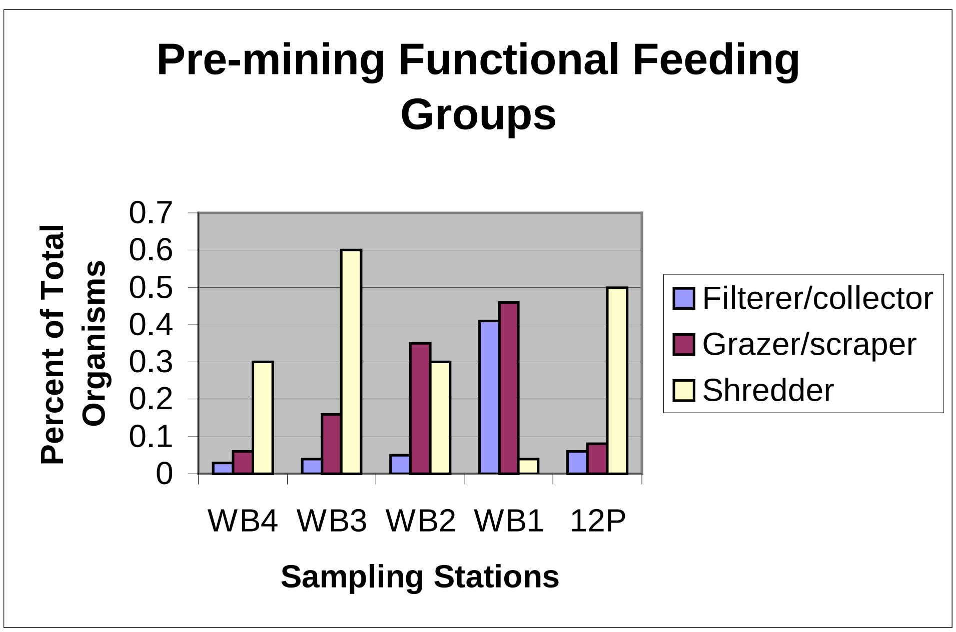

Figure 23. Pre-mining Functional Feeding Groups for Wiley Branch and Twelve Pole Creek.

The West Virginia Stream Condition Index (WV-SCI) was used to rate the biological condition of Wiley Branch and Twelve Pole Creek against metric values that had been calibrated with local reference conditions in the state (Appendix F). With the exception of Station WB1, all other stations were highly comparable to reference sites. According to *A Stream Condition Index for West Virginia Wadeable Streams* (Gerritsen et al. 2000), the range of scores 78 to 100 indicate highly comparable conditions (above the 25th percentile) to least impacted reference sites. The Left Fork of Wiley Branch, Station WB2, had the highest value of 93. In the main channel of Wiley Branch the upstream station, WB4, had a value of 80, the mid-stream station, WB3, had a value of 91 and the downstream station, WB1, had the lowest value of 76. Twelve Pole Creek had a value of 85.

Conditions During Mining Operations

Seven seasonal sampling events occurred after the initiation of mining in April 1999. These samples were taken in May, July, September, and November of 1999 and January, March and May of 2000. The following is a description of how each metric changed over the course of the study period.

Taxa Richness

Taxa richness trends for all five stations during the entire sampling period are displayed in Figure 24. On the Left Fork of Wiley Branch (Station WB2), initial taxa richness was 29 distinct taxa. The highest taxa richness for this station was recorded in May 1999 (34 taxa) and the lowest was in September 1999 (16 taxa). Twelve Pole Creek had a maximum taxa richness of 21 distinct taxa in both July 1999 and January 2000. The lowest measurement for this station was 13 distinct taxa in May 1999.

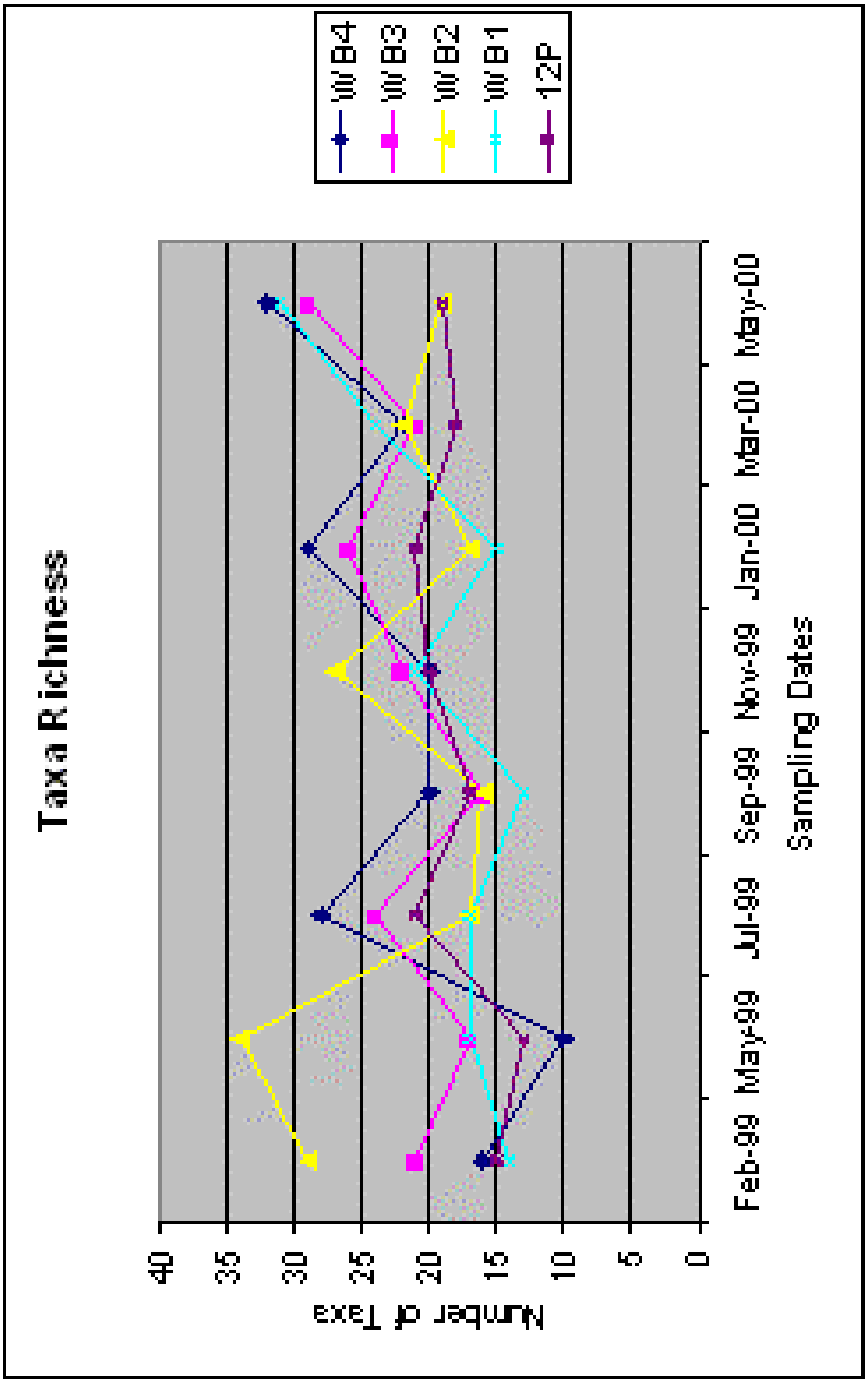

Figure 24. Taxa Richness for Wiley Branch and Twelve Pole Creek.

In the main channel of Wiley Branch, all stations generally showed increases in taxa richness between February 1999 and May 2000. The upstream station, WB4, initially had a taxa richness of 16 (2/99) which dropped to 10 taxa after mining operations began in April, rose to 28 taxa in July, and leveled at 20 taxa during September and November 1999. Taxa richness values continued in 2000 at 29, 22 and 32, January, March and May, respectively. The midstream station, WB3, began with 21 distinct taxa and dropped to 17 after initial mining operations. The trends at this station followed Station WB4, with an increase to 24 taxa in July, and a decrease to 16 and then 22 taxa in September and November 1999. The year 2000 began with 26 distinct taxa with a drop to 21 in March and rise to 29 taxa in May. With the exception of May 1999 and January 2000, the downstream station, WB1, followed the same patterns as the other two mainstream stations (WB4 and WB3). Initial values in February 1999 were 14 taxa with an increase to 17 taxa in May 1999. The number of taxa remained the same through the summer with a drop to 13 taxa in September 1999. An increase to 21 taxa was seen in November with a drop to 15 taxa in January 2000. During March, taxa richness at Station WB1 increased to 24 taxa with a further increase to 31 taxa in May 2000.

One of the greatest challenges when assessing perturbation in the field is separating natural variation in community structure from variation due to anthropogenic disturbance. A comparison is therefore offered between the annual winter and spring collection periods (Fig. 25). For the upstream station, WB4, a 38% increase in taxa richness was recorded from winter 1999 to winter 2000 while a 120% increase was recorded from spring 1999 to spring 2000. The midstream station, WB3, showed no increase during the winter periods but did show an increase of 71% from spring 1999 to spring 2000. The last main stream station, WB1, showed increases of 71% and 82%, winter and spring, respectively. The Left Fork of Wiley Branch, Station WB2, was the only station to show decreases in taxa richness. From winter 1999 to winter 2000 there was a decrease in taxa richness of 24% and from spring 1999 to spring 2000 there was a decrease of 44%. In Twelve Pole Creek there was a 20% increase in taxa richness for winter and a 46% increase for spring.

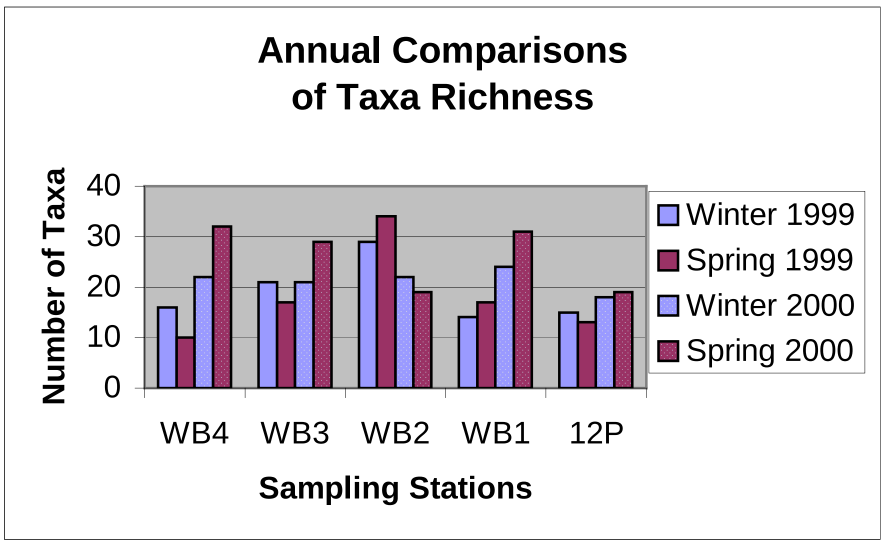

Figure 25. Annual Comparisons of Taxa Richness for all stations.

EPT Index

The number of taxa from the pollution sensitive orders Ephemeroptera, Plecoptera and Trichoptera (EPT) varied for all five stations over the entire fifteen-month sampling period (Fig. 26). The greatest change was recorded at Station WB2. Pre-mining data showed 18 EPT taxa, rising to 20 in May 1999 dropping to 5 during July and September, and then rising to 13 in November 1999. During 2000, the EPT taxa count began at 11

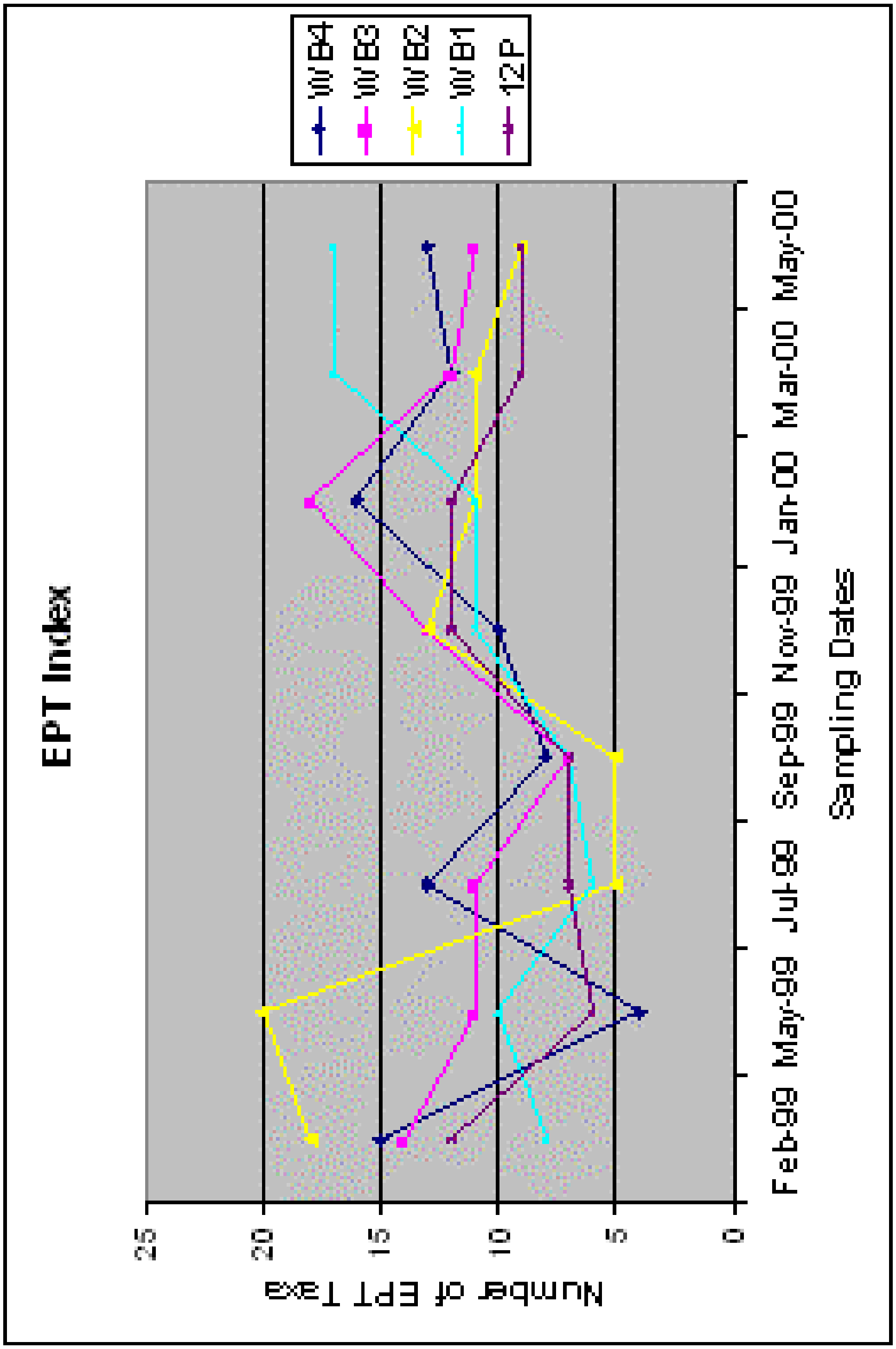

Figure 26. EPT Index for Wiley Branch and Twelve Pole Creek.

(Jan.), remained at 11 in March and dropped to 9 EPT taxa in May. In Twelve Pole Creek the EPT taxa numbers began at 12 (2/99), dropped to 6 (5/99), 7 (7/99 and 9/99), and increased to 12 (11/99 and Jan 00). In March and May 2000 there were 9 EPT taxa for each sampling date.

In the main channel of Wiley Branch Stations WB4 (upstream) and WB3 (midstream) were generally very similar, 15 and 14 EPT taxa, respectively (2/99). Station WB4 showed a decrease to 4 EPT taxa after initial mining operations, increasing to 13 in July, dropping to 8 in September, increasing to 10 and then 16 in November and January 2000. Initially, Station WB3 registered 14 EPT taxa dropping to 11 (5/99 and 7/99) and 7 taxa in September 1999. An increase to 13 EPT was seen in November 1999 with another increase to 18 taxa in January 2000. A decrease to 12 EPT taxa was recorded in March 2000 with a further decrease to 11 taxa in May 2000. Station WB1 began the study with the lowest number of EPT taxa, 8. With the exception of the two summer sampling periods, the EPT taxa numbers progressively increased, 10 (5/99), 11 (11/99 and 1/00) and 17 (3/00 and 5/00).

Annual comparisons show that during the 2000 winter sampling dates the number of EPT taxa decreased at every station except station WB1 (20% Station WB4, 14% Station WB3, 39% Station WB2, 25% Station 12P). Station WB1 showed a 113% increase of EPT taxa from winter 1999 to winter 2000 (Fig. 27). More increases in EPT taxa were recorded in the annual spring sampling comparisons than in the winter. Station WB4 had increased EPT taxa numbers of 225%, Station WB3 stayed the same, and Station WB1 increased 70% while the Twelve Pole Creek EPT taxa numbers increased 50%. Station WB2 was the only spring station to show a decrease in EPT taxa of 55%.

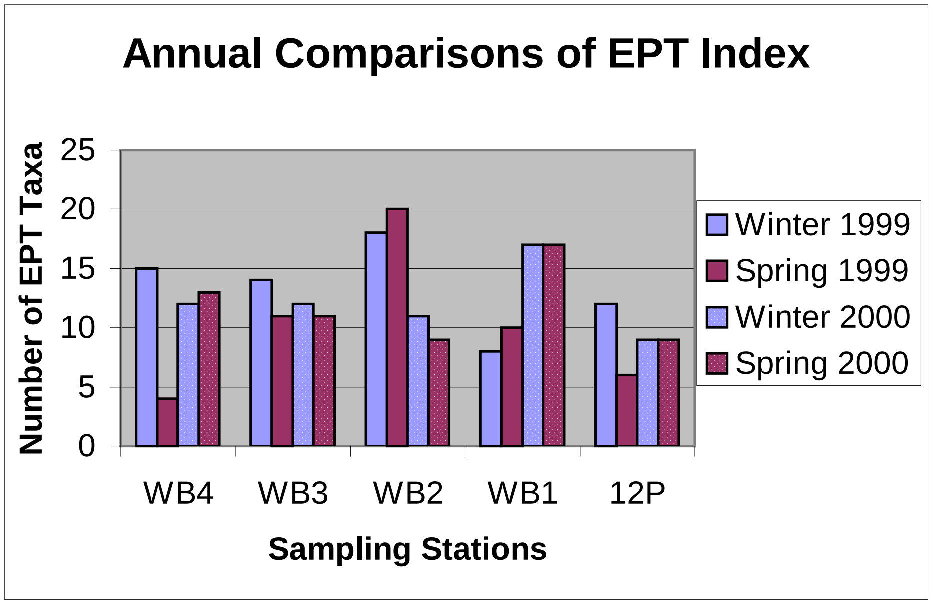

Figure 27. Annual Comparisons of EPT Index Values for Wiley Branch and Twelve Pole Creek.

<u>Percent EPT</u>

Percent EPT was calculated by dividing the total number of organisms in the pollution sensitive orders Ephemeroptera, Plecoptera, and Trichoptera by the total number of organisms in the sample (Fig. 28). From February 1999 to September 1999 the percent EPT values for Station WB2 decreased: 0.8, 0.38, 0.23 and 0.12. There was a sharp increase to 0.9 in November 1999, dropping to 0.57 in January 2000, increasing to 0.78 in March 2000 and dropping to 0.59 in May 2000. The percent EPT in Twelve Pole Creek ranged from 0.84 (2/99) to 0.22 (5/00). In between these extremes the values fluctuated as follows: 0.27 (5/99), 0.78 (7/99), 0.57 (9/99), 0.61 (11/99), 0.63 (1/00), and 0.44 (3/00).

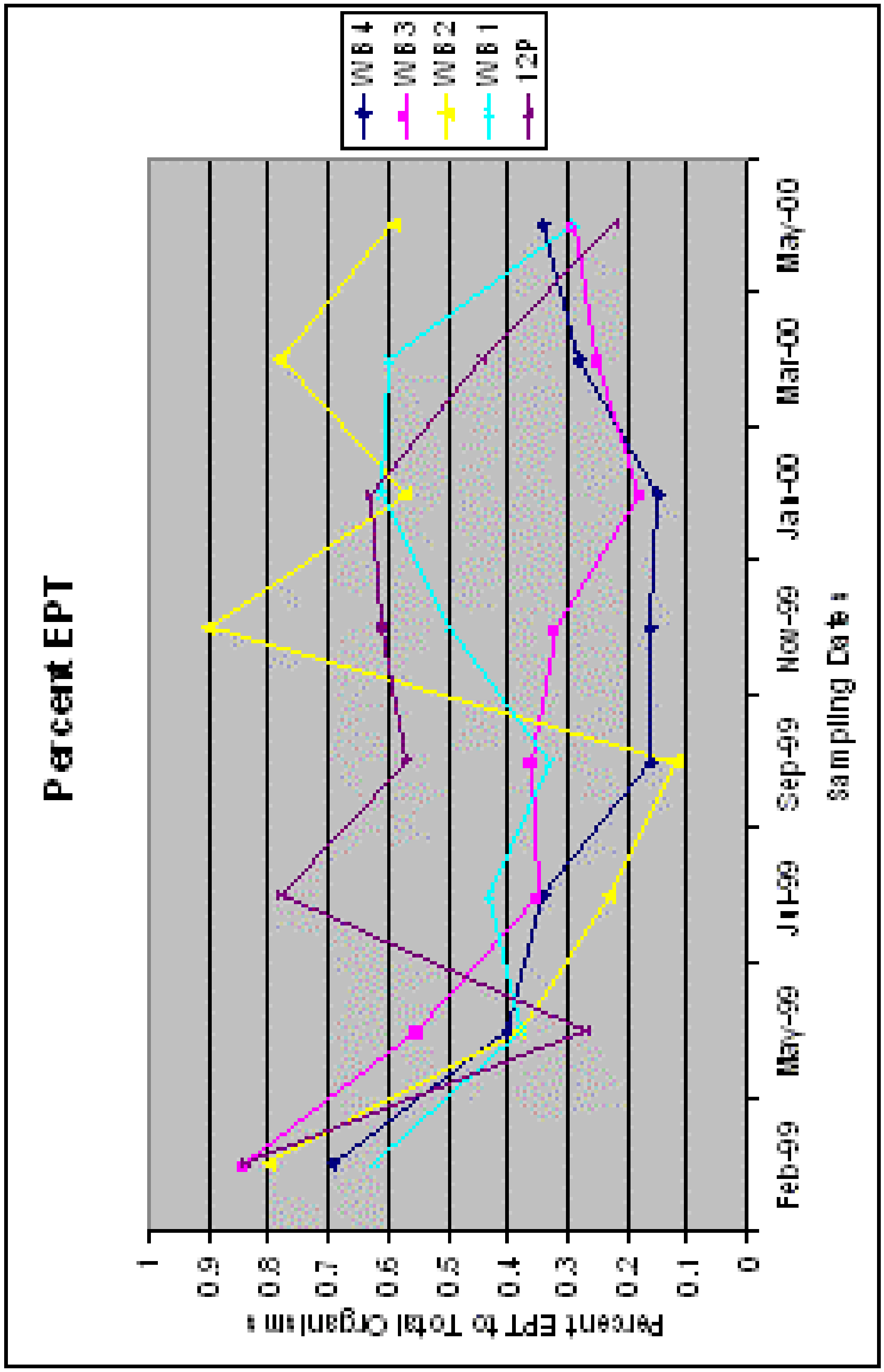

Figure 28. Percent EPT for Wiley Branch and Twelve Pole Creek.

In the main channel of Wiley Branch a decreasing trend was recorded at all three stations until September 1999 when the percentage EPT at the downstream station started to rise. Station WB4 began at 0.69 (2/99) decreasing over the next five sampling periods: 0.4 (5/99), 0.34 (7/99), 0.16 (9/99), 0.16 (9/99) and 0.15 (1/00). In March 2000 there was a slight increase to 0.28 and in May 2000 another increase to 0.34 percent EPT. Station WB3 mirrored this pattern beginning in February 1999 with a value of 0.84 percent EPT dropping over the next five sampling periods: 0.55 (5/99), 0.35 (7/99), 0.36 (9/99), 0.32 (11/99), and 0.18 (1/00). Small increases were seen in March and May 2000, 0.25 and 0.29 percent EPT, respectively. Station WB1 (downstream) showed the lowest percentage of EPT in February 1999 at 0.62. A very close percentage of 0.60 was reached one year later in March 2000. Between these periods the following recordings were made: 0.38 (5/99), 0.43 (7/99), 0.33 (9/99), 0.5 (11/99), and 0.61 (1/00). In May of 2000 the percent EPT at Station WB1 was 0.29.

Comparing annual data, percent EPT decreased at all stations and dates except one. From spring 1999 to spring 2000 there was an increase of percent EPT at station WB2 (Fig. 29).

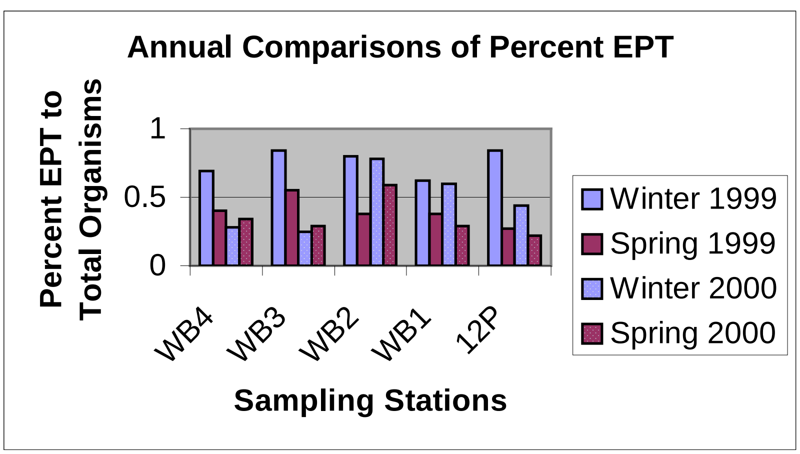

Figure 29. Annual Comparisons of Percent EPT for Wiley Branch and Twelve Pole Creek.

Percent Chironomidae

As mining progressed, the percentage of organisms from the family Chironomidae increased dramatically in the main channel of Wiley Branch (Fig. 30). Generally, the upstream station, WB4, exhibited the greatest increases. The February 1999 data indicated a 31% Chironomidae ratio dropping to 13% in May and then increasing over the remainder of the year: 42% (7/99), 74% (9/99), 74% (11/99) and 81% (1/00). In March of 2000, the numbers of Chironomidae dropped to 67% and then to 60% in May. The midstream station, WB3, reflected this same trend. Initially, there were only 8% Chironomidae in the February 1999 sample, rising to 22% (5/99), 19% (7/99), 48% (9/99), 53% (11/99) and 79% (1/00). The last two sampling periods, March and May 2000, again showed decreases to 67% and 53%, respectively. The final main channel station, WB1, initially had the lowest percent Chironomidae. This station showed increases in percent Chironomidae like the others but decreases were noticed earlier than at the other two sites. In February 1999, the ratio of Chironomidae to total organisms was only 4%, rising to 54% (5/99), 41% (7/99) and 61% (9/99). In November 1999, the ratio decreased to 36% further decreasing to 32% in January 2000. A slight increase was seen in March 2000 to 35% with a larger increase in May 2000 to 63%. The Left Fork of Wiley Branch, Station WB2, showed the smallest changes in percent Chironomidae ranging between 6% and 29% (2/99 and 9/99). The fluctuating pattern began in February 1999 with 6% Chironomidae and continued with 2% (5/99), 11% (7/99), 29% (9/99), 6% (11/99), 28% (1/00), 6% (3/00) and 23% (5/00). February 1999 data reflected 12% Chironomidae in Twelve Pole Creek increasing to 42% (5/99) and then decreasing to 6%. Beginning in September 1999 the ratio of Chironomidae to total

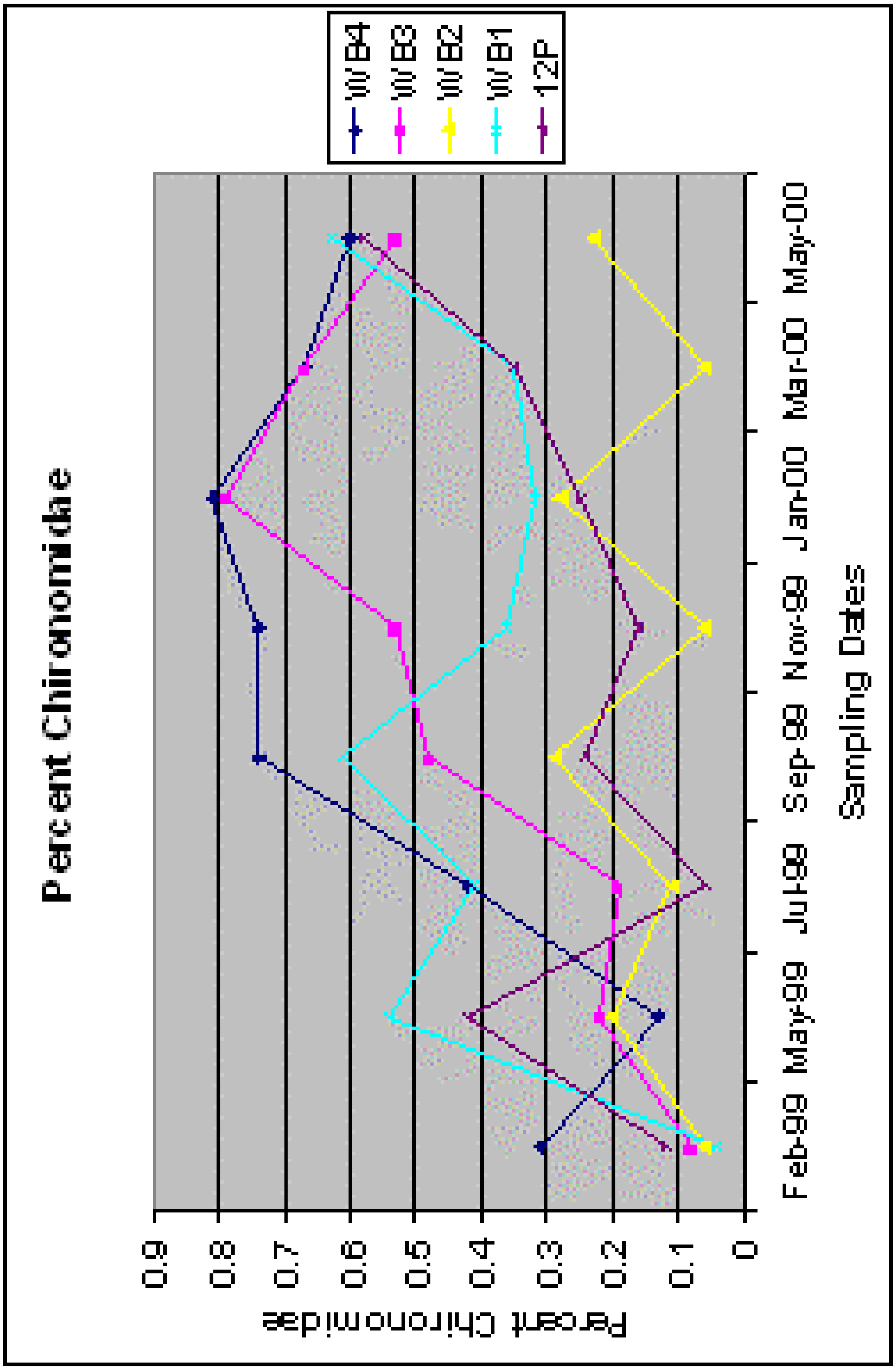

Figure 30. Percent Chironomidae for Wiley Branch and Twelve Pole Creek.

organisms gradually increased: 24% (9/99), 16% (11/99), 25% (1/00), 35% (3/00), and 58% (5/00).

Comparing annual percent Chironomidae data, reveals an increase at all stations between each season with the exception of Station WB2. At Station WB2 there was no increase in the winter data and only a slight increase in the spring data (Fig. 31).

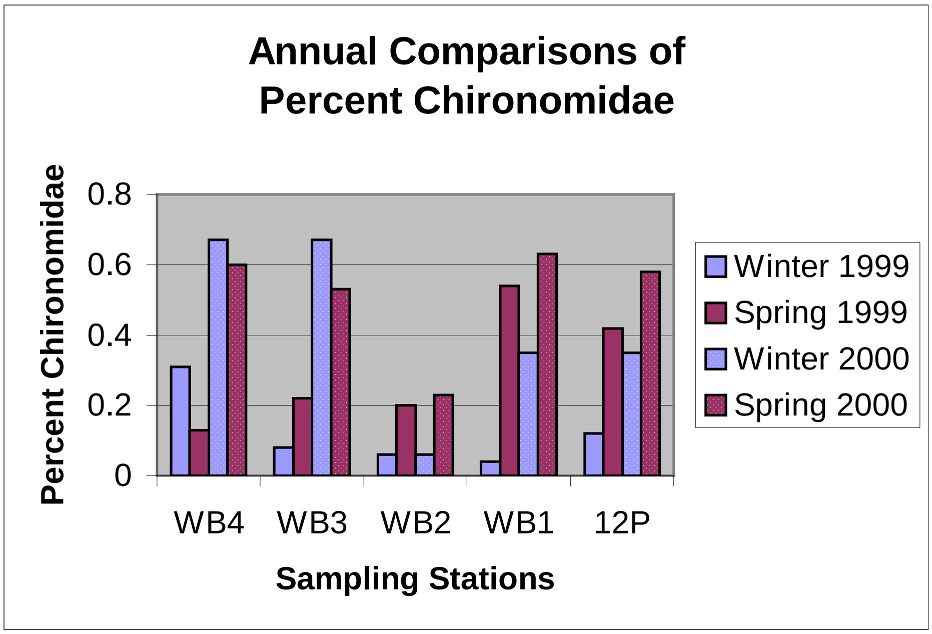

Figure 31. Annual Comparisons of Percent Chironomidae for Wiley Branch and Twelve Pole Creek.

<u>Percent Two Dominant Families</u>

The top two dominant families for each sampling station and sampling date are listed in Table 2. At Station WB4 values ranged from 53% (2/99) to 90% (5/00) with Chironomidae and Hydropsychidae being the most dominant families for six of the eight sampling periods. The values at Station WB3 ranged from 32% (7/99) to 84% (1/00) with the family Chironomidae being the most dominant family for all sampling periods except February 1999. The last station in the main channel of Wiley Branch, Station WB1, had dominance values ranging from 55% (1/00 and 3/00) to 86% (9/99). Again,

	Feb-99	May-99	Jul-99	Sep-99	Nov-99	Jan-00	Mar-00	May-00
WB4	Chironomidae Nemouridae 53%	Annelida Heptageniidae 58%	Chironomidae Hydropsychidae 55%	Chironomidae Hydropsychidae 80%	Chironomidae Hydropsychidae 90%	Chironomidae Hydropsychidae 88%	Chironomidae Hydropsychidae 88%	Chironomidae Hydropsychidae 90%
WB3	Nemouridae Heptageniidae 58%	Chironomidae Ephemerellidae 35%	Chironomidae Gerridae 32%	Chironomidae Hydropsychidae 77%	Chironomidae Hydropsychidae 73%	Chironomidae Nemouridae 84%	Chironomidae Uenoidae 78%	Chironomidae Hydropsychidae 65%
WB2	Heptageniidae Nemouridae 47%	Tipulidae Leutridae 58%	Leutridae Psephenidae 30%	Chironomidae Cambaridae 41%	Capniidae Leutridae 77%	Chironomidae Uenoidae 48%	Uenoidae Nemouridae 40%	Chironomidae Ephemerellidae 43%
WB1	Elmidae Philopotamidae 57%	Chironomidae Hydropsychidae 62%	Chironomidae Hydropsychidae 70%	Chironomidae Hydropsychidae 86%	Chironomidae Capniidae 57%	Chironomidae Uenoidae 55%	Chironomidae Nemouridae 55%	Chironomidae Ameletidae 83%
12P	Nemouridae Ameletidae 55%	Chironomidae Elmidae 64%	Hydropsychidae Isonychidae 53%	Hydropsychidae Chironomidae 56%	Hydropsychidae Chironomidae 37%	Nemouridae Chironomidae 56%	Chironomidae Nemouridae 52%	Chironomidae Annelida 66%

Table 2. Percentage of the Top Two Dominant Families on Wiley Branch and Twelve Pole Creek.

Chironomidae was the most dominant family for all sampling periods except February 1999. Data from the Left Fork of Wiley Branch, Station WB2, reflected a range of dominance values from 30% (7/99) to 77% (11/99). No single family blatantly dominated these samples. In Twelve Pole Creek (Station 12P), the percentage of the top two dominant families ranged from 37% (11/99) to 66% (5/00).

Annual comparisons of the percent top two dominant families reflect increases across both seasons at Stations WB4 and WB3 (Fig. 32). For Station WB2, decreases were recorded across both seasons. The downstream station, WB1, displayed a slight decrease from winter 1999 to winter 2000 but an increase from spring 1999 to spring 2000. Twelve Pole Creek showed a slight decrease across the winter season and a slight increase across the spring season.

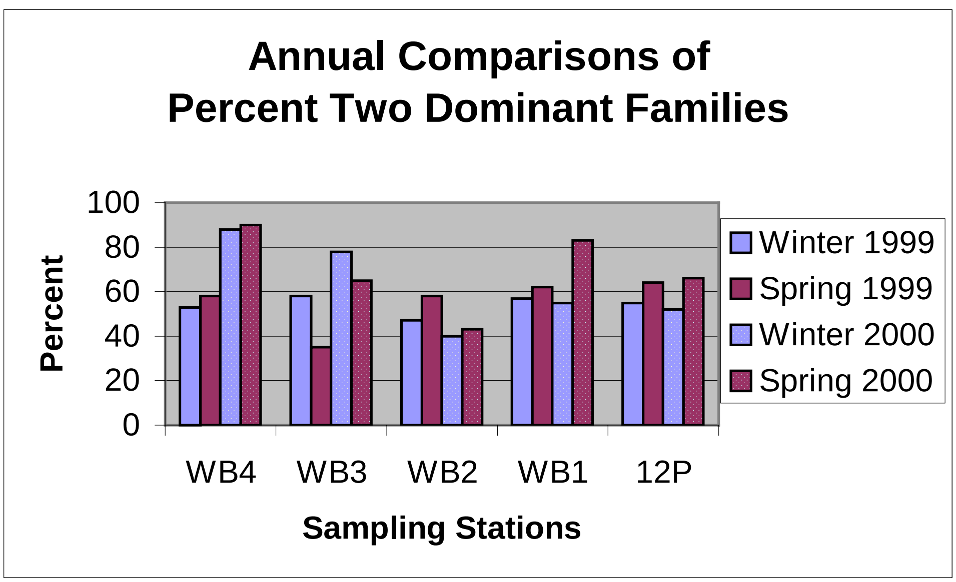

Figure 32. Annual Comparisons of Percent Two Dominant Families for Wiley Branch and Twelve Pole Creek.

Modified Hilsenhoff Biotic Index

The modified Hilsenhoff Biotic Index (mHBI) generally increased across all stations over the course of the sampling period (Fig. 33). On Twelve Pole Creek, the mHBI values ranged from 3.2 (7/99) to 5.39 (5/00). The trend is generally increasing (Table 3). Station WB2, Left Fork of Wiley Branch, fluctuated between 1.25 (11/99) and 4.44 (9/99). The trend was also generally increasing except for the drastic drop in September 1999. After the onset of mining (April 1999), all stations in the main channel of Wiley Branch showed increases in mHBI values. During the next sampling period (7/99), Station WB1 continued to increase to 4.7 while Stations WB4 and WB3 showed decreases, 3.8 and 3.7, respectively. Over the remainder of the sampling period Stations WB4 and WB3 had gradually increasing mHBI values until January 2000 when the values began to drop. Station WB1 continued to increase during the September 1999 sampling period, decreasing in November 1999 and increasing over the remainder of the sampling period.

	Feb-99	**May-99**	**Jul-99**	**Sep-99**	**Nov-99**	**Jan-00**	**Mar-00**	**May-00**
WB4	3.78	5.89	3.8	5.10	5.24	5.54	5.00	4.89
WB3	3.12	4.04	3.7	4.57	4.43	5.34	5.01	4.71
WB2	3.23	2.92	3.13	4.44	1.25	4.15	3.98	4.26
WB1	3.09	4.36	4.7	4.90	3.64	4.05	3.93	5.63
12P	3.21	4.85	3.20	4.01	4.10	3.71	4.46	5.39

Table 3. Modified Hilsenhoff Biotic Index Values for Wiley Branch and Twelve Pole Creek.

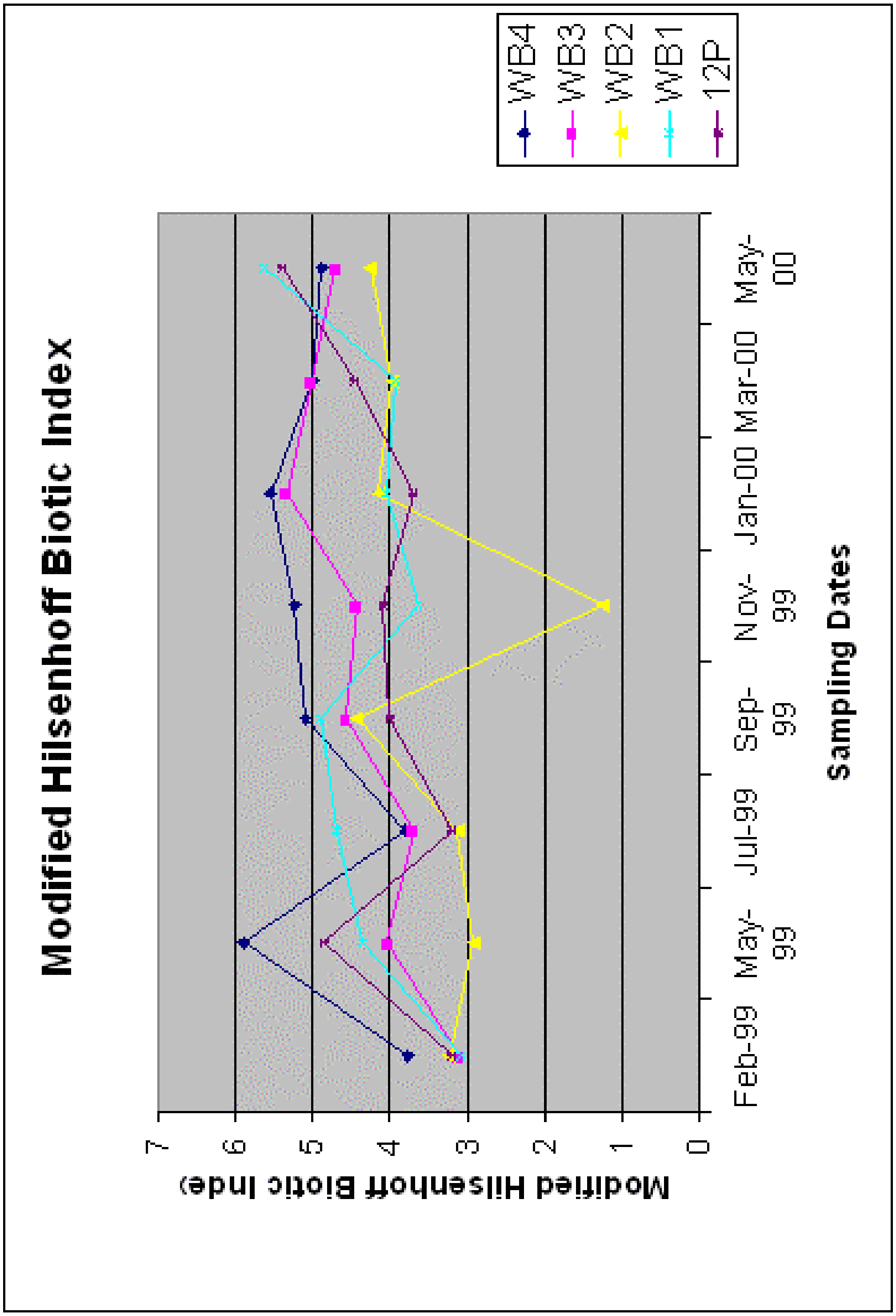

Figure 33. Modified Hilsenhoff Biotic Index for Wiley Branch and Twelve Pole Creek.

The winter comparisons of mHBI values show increases at all stations with the greatest increase at Station WB3 (61%) and the smallest at Station WB2 (23%) (Fig. 34). The spring comparisons show increases at all stations except Station WB4. The greatest increase was at Station WB2 (46%) and the smallest at Station 12P (11%). Station WB4 showed a 17% decrease in mHBI during the spring of 2000 compared to the spring of 1999.

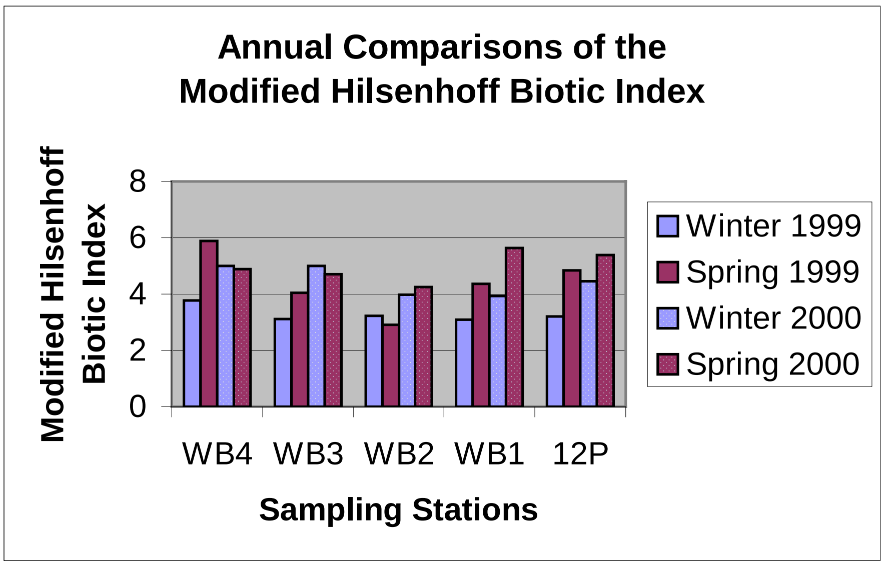

Figure 34. Annual Comparisons of the Modified Hilsenhoff Biotic Index for Wiley Branch and Twelve Pole Creek.

West Virginia Stream Condition Index

The West Virginia Stream Condition Index (WV-SCI) was calculated for each station during each sampling period (Table 4). Before mining, Station WB4 was highly comparable to least impacted reference sites (above the 25th percentile). After mining operations began, this same station was rated as being increasingly different from reference conditions except in July when it was comparable to below-average reference sites (between 5th and 25th percentiles). Station WB3 remained highly comparable to least impacted reference sites until the September 1999 sampling period at which time it fell to increasingly different from reference conditions for the remainder of the sampling period. Station WB1 (main channel downstream) was comparable to below-average reference sites at the beginning of the study (2/99). After mining operations began, the ratings at Station WB1 dropped to increasingly different from reference conditions. In November of 1999 and January 2000 the ratings returned to comparable to below-average reference sites while in March 2000 the rating had risen to distinguish this section of the stream as highly comparable to least impacted reference sites. In May 2000, the ratings again dropped to characterize Station WB1 as increasingly different from reference conditions.

The Left Fork of Wiley Branch, Station WB2, began the study with the highest index rating. This station was highly comparable to least impacted reference sites during the entire study period except during July (below-average) and September 1999 (increasingly different). Twelve Pole Creek (12P) showed the greatest fluctuations in index ratings. Before mining, the station was rated as highly comparable to least impacted reference sites. In May 1999, the site was increasingly different, returning to highly comparable in July 1999. In September 1999, the station was comparable to below-average reference sites rising to highly comparable again in November 1999 and January 2000. In March 2000, the rating fell to below-average and in May 2000 the rating fell further to increasingly different from reference conditions.

	Feb-99	May-99	Jul-99	Sep-99	Nov-99	Jan-00	Mar-00	May-00
WB4	**80**	**56**	**76**	**50**	**50**	**53**	**58**	**60**
WB3	**91**	**82**	**82**	**56**	**67**	**55**	**59**	**66**
WB2	**93**	**82**	**72**	**62**	**88**	**78**	**91**	**79**
WB1	**76**	**64**	**59**	**48**	**77**	**74**	**81**	**60**
12P	**85**	**54**	**84**	**71**	**87**	**83**	**70**	**57**

Table 4. Summary of West Virginia Stream Index Values for Wiley Branch and Twelve Pole Creek. Blue numbers represent those stations that were highly comparable to reference conditions, green numbers represent those stations that were below-average when compared to reference conditions, and red numbers represent those stations that were increasingly different from reference conditions.

Comparisons were made between two different annual sampling events, winter and spring (Fig. 35). If the station was ranked "highly comparable to least impacted reference sites," a value of 3 was assigned. If the station was ranked "comparable to below-average reference sites," a value of 2 was assigned. If the station was ranked "increasingly different from reference condition," a value of 1 was assigned.

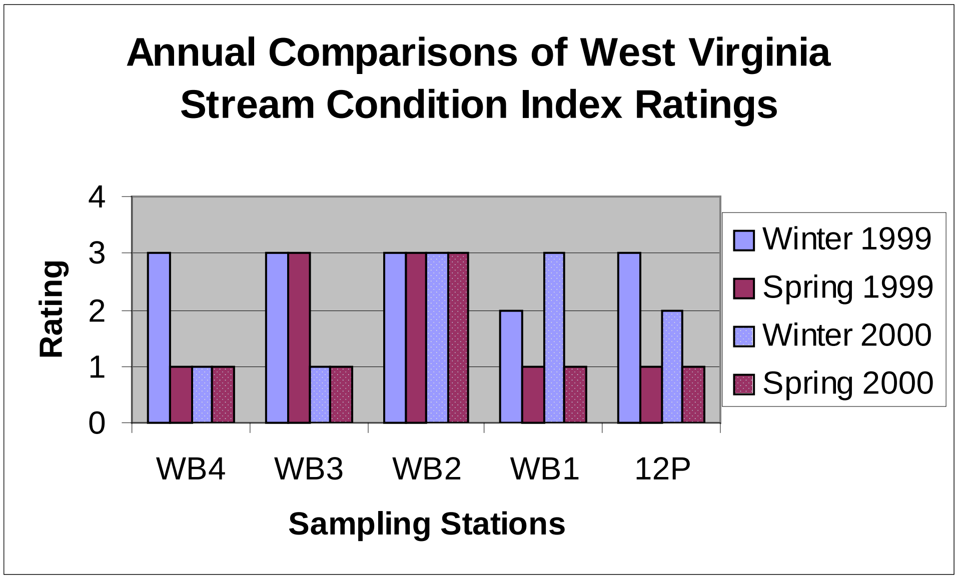

Figure 35. Annual Comparisons of West Virginia Stream Condition Index for Wiley Branch and Twelve Pole Creek.

Station WB 4 was highly comparable to least impacted reference sites before mining operations began. One year later the station was increasingly different from reference conditions. Both spring ratings for this station were also increasingly different from reference conditions. Station WB3 was highly comparable to least impacted reference sites both before mining began and also during the first sampling period after mining operations were initiated. One year later, during both seasons, the station was rated as increasingly different from reference conditions. Comparing winter data, Station WB1 improved from being compared to below-average reference sites to being highly comparable to least impacted reference sites; however, during both spring sampling events this station was rated as increasingly different from reference conditions.

Station WB2, located in the Left Fork of Wiley Branch, was rated as highly comparable to least impacted reference sites during both sampling seasons in both years. In the winter of 1999, Twelve Pole Creek (12P) was rated as highly comparable to least impacted reference sites. During the same season the following year, this station was rated as comparable to below-average reference sites. During both spring sampling events, Twelve Pole Creek was classified as increasingly different from reference conditions.

Percent Filterer-collectors

Percent filterer-collectors to total organisms in the Left Fork of Wiley Branch, Station WB2, was less than 10% except in September of 1999 when the value increased to 25% (Fig. 36). Maximum percentage of filterer-collectors at Station WB1, 41%, was in February 1999. This dropped dramatically in May of 1999 to 12%, increasing to 35% in July 1999 and generally dropping the remainder of the sampling period [12% (9/99), 10% (11/99), 7% (1/00), 8% (3/00) and 2% (5/00)]. Station WB3 showed increases from February (4%) to September 1999 (30%) and then decreased to 3% in March 2000. May 2000 data showed a subsequent increase to 13%. Station WB4 had recordings of 3% filterer-collectors in February 1999 dropping to 0 in May 1999. An increase was noted in July 1999 (16%), decreasing to 12% in September and November 1999. One further drop was recorded in January 2000 (7%) with two subsequent increases in March and May 2000, 23% and 29%, respectively. Twelve Pole Creek percentage of filterer-collectors started at 6% increasing to 58% in July 1999 and 57% in September 1999. Sharp decreases to 27% in November and 8% in January 2000 were subsequently recorded. The last measurements in March and May 2000 were 7% and 11%, respectively.

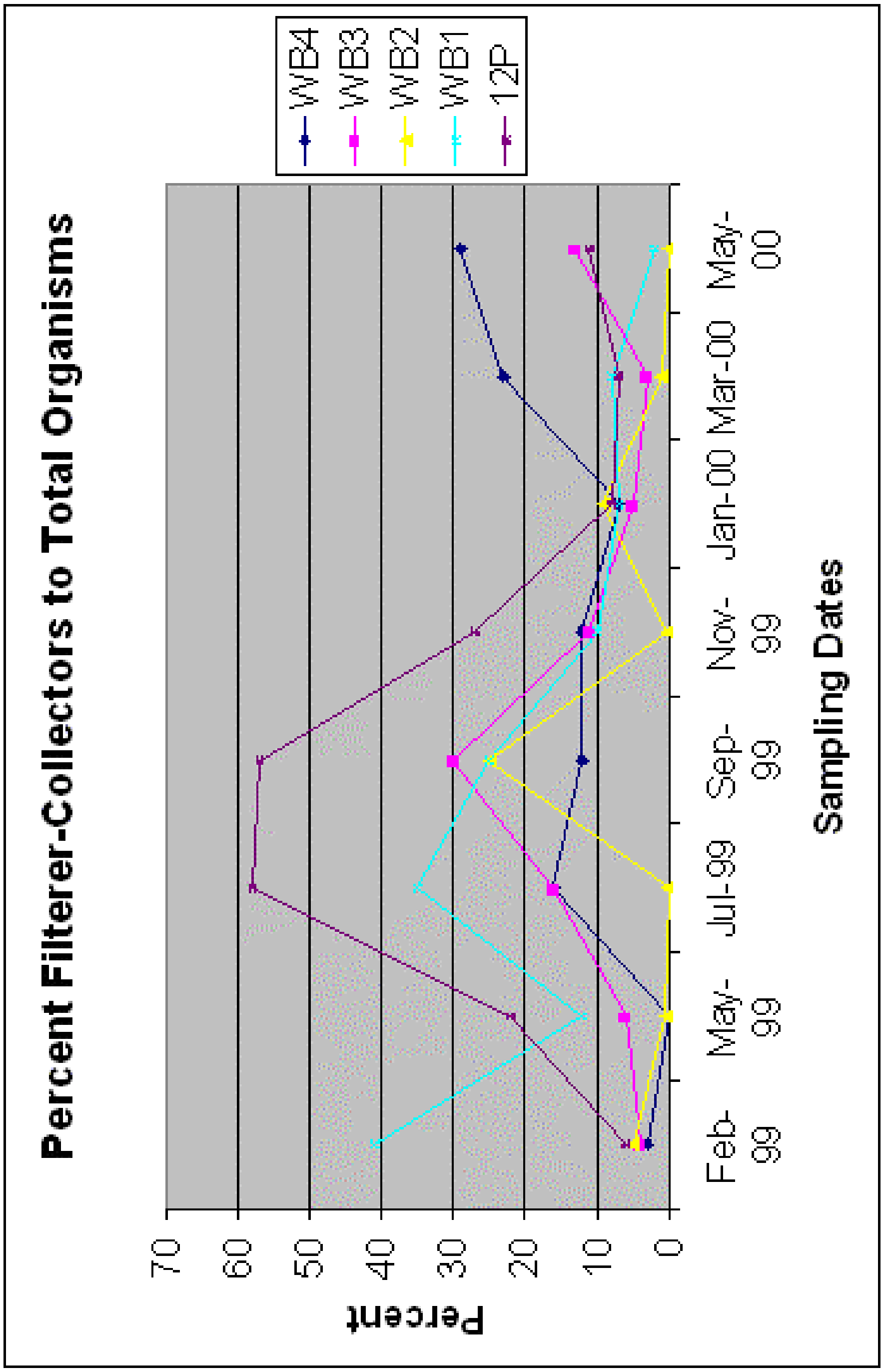

Figure 36. Percent Filterer-Collectors to Total Organisms for Wiley Branch and Twelve Pole Creek.

Changes over annual sampling periods emphasize the previously mentioned trends (Fig. 37). At Station WB4, increases were seen across both winter and spring sampling periods. Station WB1 showed the opposite trend, decreases across both winter and spring sampling period. A slight decrease was seen in the winter comparison for Station WB3 while an increase was seen in the spring comparison. Station WB2 showed only small decreases. Twelve Pole Creek percentages of filterer-collectors remained relatively stable between winter data and decreased between spring data.

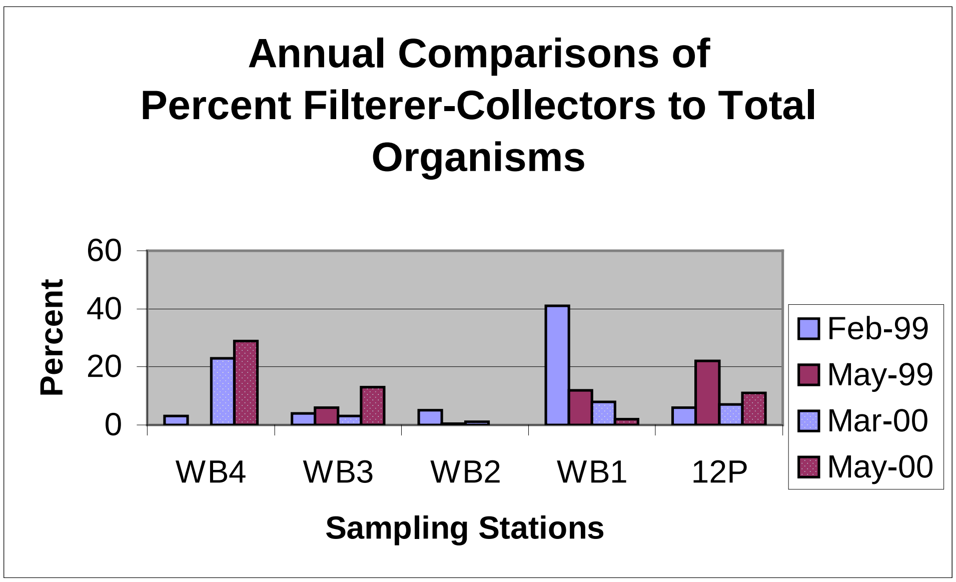

Figure 37. Annual Comparisons of Percent Filterer-Collectors to Total Organisms for Wiley Branch and Twelve Pole Creek.

<u>Percent Grazer-scrapers</u>

The percent grazer-scrapers fluctuated dramatically during the fifteen-month sampling period (Fig. 38). Station WB4 had 6% grazer-scrapers in February 1999 increasing to 22% in May 1999. A general decrease was recorded the remainder of the study period (8% (7/00), 5% (9/99), 2% (11/99), 6% (1/00), 1% (3/00) and 2% (5/00). Station WB3 had 16% grazer-scrapers in both February 1999 and May 1999, increasing

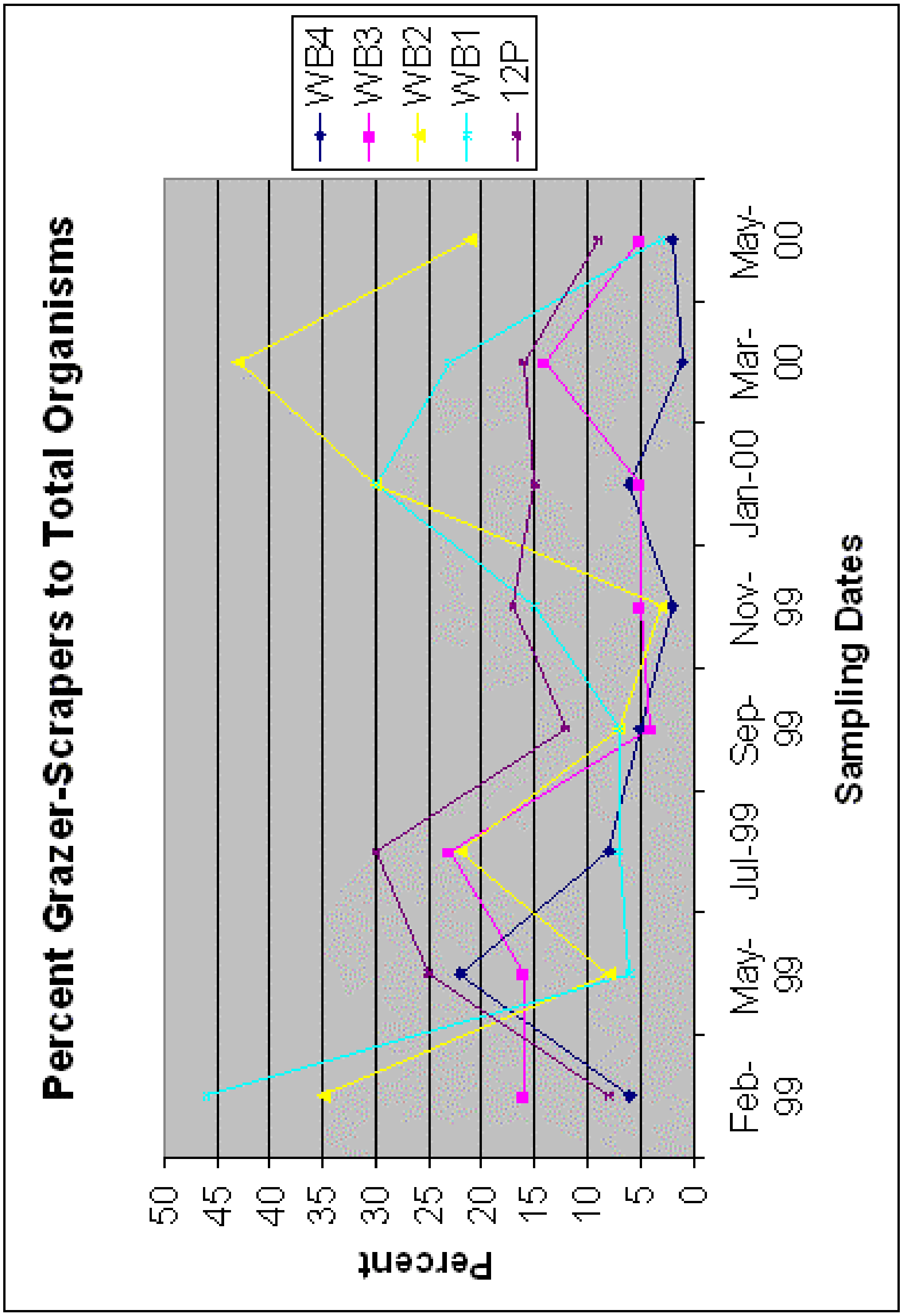

Figure 38. Percent Grazer-Scrapers to Total Organisms for Wiley Branch and Twelve Pole Creek.

to 23% in July 1999 and decreasing to 4% in September 1999. A slight increase to 5% was seen in November 1999 and January 2000 with a larger increase to 14% in March 2000. For May 2000, the percentage grazer-scrapers dropped to 5%. Station WB2 showed dramatic increases. Beginning in February 1999, the metric value was 35%, dropping to 8% in May, increasing to 22% in July, dropping to 7% and 3% in September and November, respectively. A large increase was recorded in January 2000 (30%) and May 2000 (43%) with another dramatic drop in May to 21%. Station WB1 had the highest percent of grazer-scrapers of any station with 46% in February 1999. This value dropped to 6% in May 1999. Subsequent increases were seen over the next four sampling periods: 7% (7/99 and 9/99), 15% (11/99), and 30% (1/00). Another dramatic decrease was recorded through May 2000: 23% (3/00) and 3% (5/00). Twelve Pole Creek had a minimum percent grazer-scrapers of 8% in February 1999 and a maximum of 30% in July 1999. A decrease to 12% was recorded in September 1999 with an increase in November 1999 to 17%. The last three recordings were 15% (1/00), 16% (3/00) and 9% (5/00).

Annual comparisons of percent grazer-scrapers to total organisms reveals a decreasing trend in the main channel Wiley Branch Stations (WB4, WB3 and WB1) between both winter and spring sampling events (Fig. 39). Conversely, Station WB2 showed increases between both winter and spring sampling events. Twelve Pole Creek samples show an increase in percent grazer-scrapers between winter sampling events and a decrease between spring sampling events.

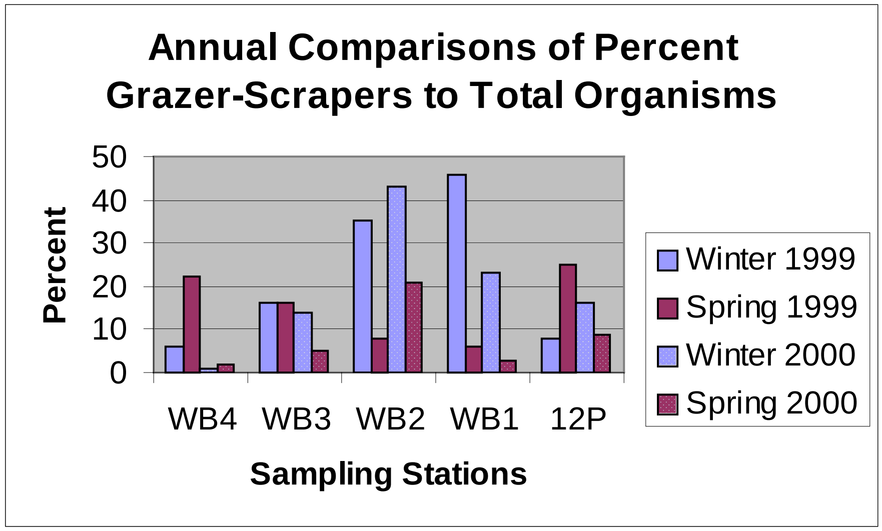

Figure 39. Annual Comparisons of Percent Grazer-Scrapers to Total Organisms for Wiley Branch and Twelve Pole Creek.

Percent Shredders

The greatest fluctuation in percent shredders to total organisms was at Station WB2 (Fig. 40). Initially, there were 30% shredders, increasing to 55% in May 1999 and dropping to a low of 2% in September 1999. During November 1999, the highest percentage was recorded (86%). Another dramatic decrease to 14% in January 2000 was followed by a slight increase to 17% in March and then 15% in May. Station WB4 had a recording of 30% shredders at the beginning of the study. Over the next fifteen months this value decreased [9% (5/99 and 7/99), 2% (9/99), 5% (11/99), 1% (1/00), 2% (3/00) and 1% (5/00)]. In February 1999, the percentage of shredders at Station WB3 was 60%, the highest for this sampling date. In May of 1999, the value dropped to 12%, then 9% (7/99) and 1% (9/99). In November 1999, the percentage rebounded to 17 then subsequently dropped to 9% (1/00), 6% (3/00) and 8% (5/00). Station WB1 had the smallest percentage of shredders during the pre-mining sampling period (4%, 2/99). An increase in May to 14% was recorded before the numbers dropped in July and September,

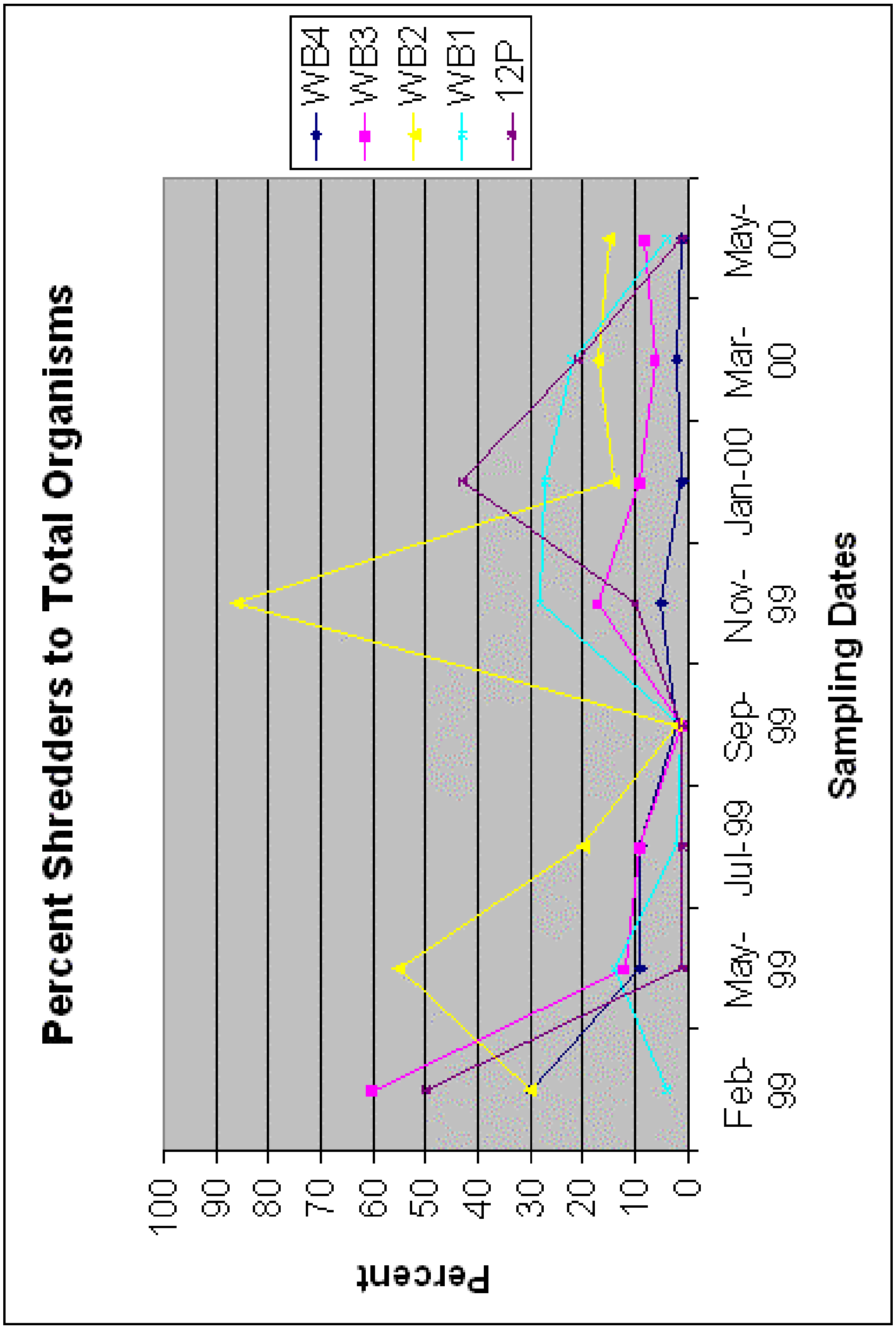

Figure 40. Percent Shredders to Total Organisms for Wiley Branch and Twelve Pole Creek.

2% and 1%, respectively. An increase to 28% was seen in November 1999 with subsequent decreases the remainder of the sampling period [27% (1/00), 22% (3/00), 4% (5/00)]. In Twelve Pole Creek, percentage of shredders fell from 50% in February 1999 to 1% in May, July, and September 1999. The percentage increased to 43 in January 2000 before dropping again to 21% in March and 1% in May.

Annual comparisons of percent shredders to total organisms reveals decreases at all stations between winter sampling periods except at Station WB1 where an increase was observed (Fig. 41). Between spring sampling periods, decreases were also seen at all stations except Twelve Pole Creek which remained the same.

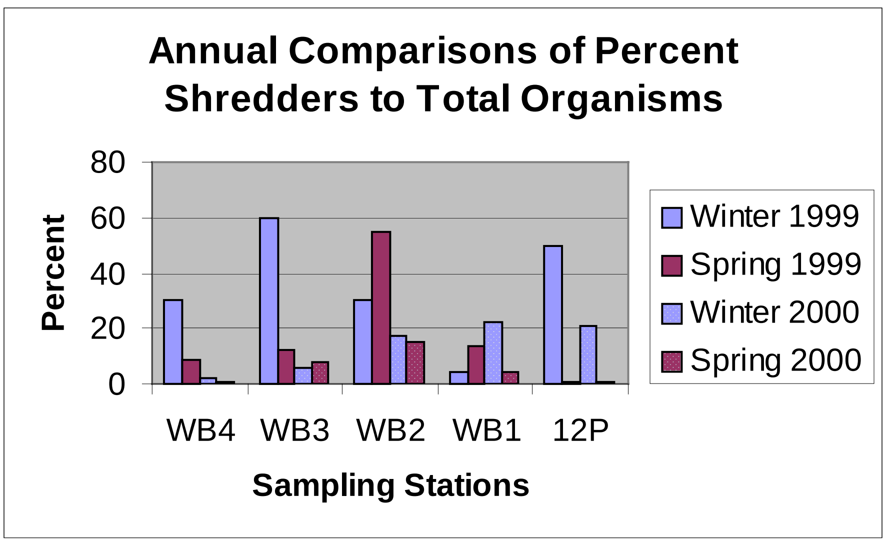

Figure 41. Annual Comparisons of Percent Shredders to Total Organisms for Wiley Branch and Twelve Pole Creek.

CHAPTER V

DISCUSSION

Several forms of point source pollution are associated with surface mining. Sedimentation, changes in pH level, alteration of the aquatic biota and introduction of metals are but a few. Initial stages of mining involve clear-cutting the area where sedimentation control structures are to be placed. The area where spoil is to be placed is also scraped of trees and brush. The topsoil is removed and stock piled for later use. Organic debris is burned or hauled off leaving the ground exposed. A drainage channel is cut in the area of the valley fill and then filled with rocks. As overburden is placed over this, a rock-lined trench serves as a drainage channel for the fill area. These types of surface mining activities accelerate the natural processes of erosion and sedimentation (Sengupta 1993).

<u>How does water quality change during the initial stages of mining?</u>

The exposure of rock surfaces to weathering accelerates the dilution of minerals into the stream altering water chemistry. The mining process uncovers coal and adjacent rock strata composed of sulfur- and iron- containing compounds (Cole 1975). Sulfate is released during weathering of rocks and soils. Iron disulfides are oxidized in the presence air and water to sulfuric acid (Zobell 1973). This reaction tends to lower pH levels which in turn affects the oxidative weathering reactions of numerous other minerals. In the case of Wiley Branch, sulfur content of the two exposed coal seams was low (0.448 – 1.2%). Given the overall low concentrations of pyritic sulfur in this watershed, acid mine drainage was not a problem. In fact, pH never dropped below 6.88.

Even though low pH values were not recorded on Wiley Branch, there were still slight increases in sulfate concentrations. The major source of sulfate is the oxidation of sulfides, mainly pyrite contained in coal, shale, and sandstone throughout the watershed. Generally, the greatest sulfate concentrations were found at the main channel stations WB4, WB3, and WB1. The sampling station on Twelve Pole Creek also showed slight increases initially. During the entire sampling period, the concentration of sulfate did not rise above 110 mg/L sulfate. The recommended limit in drinking water is 250 mg/L (U.S. E.P.A. 1979).

Sulfate and other dissolved minerals such as dissolved calcium and magnesium enhances the ability of stream water to conduct electric current (James and McCulloch 1990). The water quality parameter, specific conductance, is a measure of the ability of the stream water to conduct electrical flow. With increasing ion content in the water (decreasing water quality), specific conductance will increase. Generally, specific conductance increased at all stations during the first year of mining; however, no station ever reached above 400 umhos. According to the West Virginia Division of Environmental Protection (1998), sites are considered stressed if conductivity exceeds 500 umhos/cm. In a study conducted by USEPA Region 3 (Green et al. 2000), streams with valley fills had substantially higher median conductivity than unmined sites. These same authors found the strongest and most significant associations to be between biological conditions and conductivity.

Total dissolved solids (TDS) is a measure of the amount of dissolved materials in the water and is directly related to conductivity. The trend of TDS mirrored that of specific conductance showing only slight increases during the first year of mining.
TDS concentrations are affected by variations in stream flow (Borchers et al. 1991). An inverse relationship between stream flow and dissolved solid concentrations existed on Wiley Branch. Initially, when flow decreased, TDS increased and conversely when flow slightly increased in March 2000 TDS decreased slightly. During the entire sampling period, TDS never approached or exceeded 5000 mg/L, the maximum recommended concentration in drinking water (U.S.E.P.A. 1979). Borchers et al. (1991) suggested that stream flow is decreased because runoff is reduced as a result of fracture systems in the bedrock in the mined area. Water that would normally run-off into the stream infiltrates down through cracks and fractures into ground water. Stream water is also reduced because of sedimentation pond construction, a form of stream impoundment.

The U.S. Geological Survey water-stage recorder in the East Fork of Twelve Pole Creek (#03206600) recorded the same general patterns of decreased flow as Wiley Branch (Appendix C). Figure 42 shows a comparison of the flow trends in each stream.

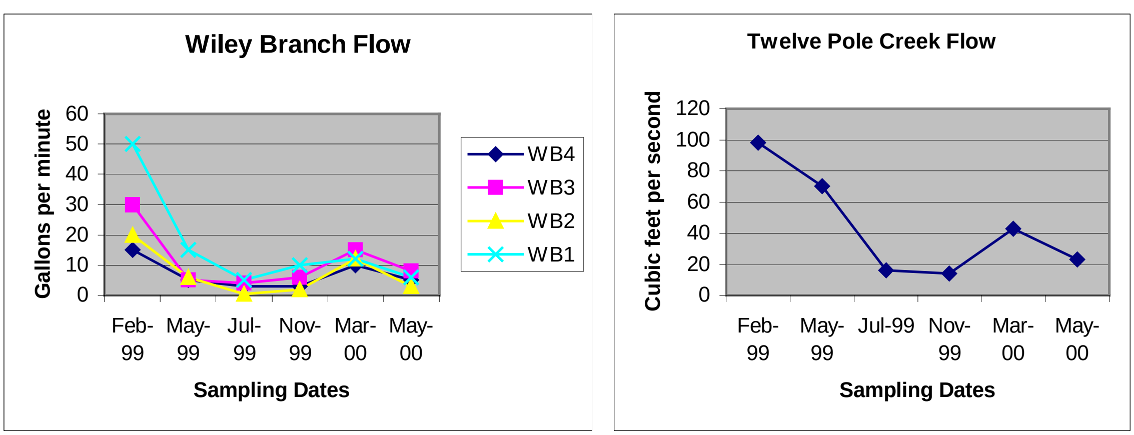

Figure 42. Flow comparisons between Wiley Branch and Twelve Pole Creek

Appendix B2 documents the monthly precipitation amount from the National Weather Service in Charleston, West Virginia. During 1999 and 2000, there were record low annual precipitation levels as compared with the standard 30-year period, 1961 – 1990. This would indicate that low flows recorded in Wiley Branch were probably attributed to decreased precipitation.

Sedimentation is frequently considered to be the most common form of point source pollution in surface water resources (Sengupta 1993). Silt may stay in suspension blocking sunlight to photosynthetic organisms or may drop out of the water column blanketing the stream bottom. This may cause smothering of benthic biota by inhibiting the proper function of delicate gills. The silt may also cover substrate making it unavailable for habitation by aquatic flora and fauna (Sizemore 1973, Minshall 1984).

With the exception of Station WB3 in May of 1999, Total Suspended Solids (TSS) at all stations measured less than 100 mg/L. The same general changes in TSS were seen in total aluminum (Al) and total iron (Fe) concentrations. The first sampling period after mining began (May 1999) showed increases in Al and Fe with the largest increase being at Station WB3. After this initial increase, the only concentrations of Fe to exceed 1 mg/L were in September 1999 at Station WB4 (2.54 mg/L) and WB3 (1.30 mg/L). The concentration of Al only exceeded 1 mg/L once, at Station WB4 (2.46 mg/L) in September 1999. The low concentrations of Al and Fe are attributed to the general low levels of these metals in the mined area. As stated earlier, since pH levels were not low there was not a problem of metal precipitates. West Virginia water quality standards allow a maximum of 1.5 mg/L total iron (WV Water Resources Board 1993).

Alkalinity of waters refers to the quantity and types of compounds present that collectively shift the pH to the alkaline side of neutrality (Wetzel 1983). Alkalinity usually indicates the presence of bicarbonates, carbonates or hydroxides and represents the major buffering capacity of water. Total alkalinity at all stations increased proportionally during the initial stages of mining. These values stabilized through the summer months (1999). With the exception of Station WB4, the total alkalinity began to drop in the winter of 2000 rising slightly during the last sampling period (May 2000). The maximum alkalinity at any station during the sampling period never exceeded 100 mg/L $CaCO_3$. During the surface mining process, soil is exposed and rocks are broken into smaller pieces increasing the exposed surface area. As carbon dioxide and water interact with these exposed surfaces of sedimentary carbonate rocks some of the carbonate is dissolved out to form bicarbonate solutions that could lead to the recorded slight increases in alkalinity.

The presence of manganese results from leaching of rocks and soil in the mining area. Manganese (Mn) exists in the divalent and trivalent state as manganous and manganic ions, respectively. Manganese hydroxides and carbonates are only sparingly soluble in water so the smothering of eggs and benthic organisms, as well as the degradation of bottom substrates for benthos colonization, results from the precipitation of such hydroxides (Sizemore 1973). Upper main channel stations WB4 and WB3 were the only sites to display dramatic changes in manganese; however, changes at these two stations only ranged between 0 and 0.8 mg/L manganese. Manganese concentrations at Stations WB2, WB1 and 12P never exceeded 0.2 mg/L manganese. The West Virginia water quality limit of manganese is 1.0 mg/L (West Virginia Water Resources Board

1993). Low concentrations of manganese in the stream are attributed to low levels of manganese deposits in the mined area and to preventative mining practices that involve reducing the exposure of manganese materials by covering them as soon as possible and isolating them from the stream area.

Generally, water quality measurements were within the boundaries of aquatic life criteria; however, in many cases, criteria for biological life were not available. Because of this, there is difficulty in determining if water quality is the limiting factor in the stream. The grab samples also may not be representative of long-term water quality conditions.

Water quality parameters often do not indicate all human effects to streams; however, the resident biota is thought to respond to an integration of all human impacts (Karr 1991). Unlike chemical water quality measures, benthic assemblages are directly exposed to varying water quality conditions over extended periods of time, providing a continuous monitor of water quality (Voshell et al. 1989). In Ohio, Yoder (1991) found that almost fifty percent of the time, assessments using biota, correctly identified the presence of human influence when it was not identified by water quality variables. Nine core metrics were selected to represent the diverse aspects of community structure, community balance, taxonomic composition and biological processes of the aquatic biota. These metrics change in predictable ways with increased human influence (Barbour et al. 1996). Since natural environmental variables cannot be controlled, trends and extremes will be utilized to define impact to the benthic community.

How does the stream macroinvertebrate assemblage change as a result of contour mining activities?

Variation in environmental systems has long been recognized as a confounding factor in interpreting field surveys reliably and making assessments of the condition of water resources (LaPoint et al. 1996). Seasonal changes, or temporal variation, in the structure and function of the aquatic community is one aspect of natural variation. During the remainder of this discussion, emphasis will be placed on comparisons during successive seasons. Spatial variance will depend on the type of habitat, type of sampling method used and daily range of organismal movement (LaPoint et al. 1996). Sampling was always conducted in riffle habitats with a Surber sampler and during the morning hours to limit these spatial variances. Given these attempts to limit variability, species abundance and distributions are attributed to other spatial factors such as changes in substrate composition, flow and energy input. In other words, changes to benthic macroinvertebrate assemblages are a function of perturbation.

Utilizing the West Virginia Stream Condition Index (WV-SCI), the main channel of Wiley Branch, before mining, was generally highly comparable to least impacted reference sites. The benthic community had a high proportion of taxa from the pollution-sensitive orders Ephemeroptera, Plecoptera and Trichoptera (EPT) with a low proportion of the pollution-tolerant family Chironomidae. Five of the six dominant families within the main channel were from pollution-sensitive families.

During the initial twelve months of multiple seam contour surface mining, definite changes to the benthic macroinvertebrate community were observed. Biological impairment of the benthic community may be indicted by the loss of generally pollution-sensitive macroinvertebrate taxa (EPT), dominance by any particular taxon combined with lowered taxa richness, or appreciable shifts in community composition relative to the reference condition (Plafkin et al. 1989). The expected impacts from mining were decreases in the number of total taxa, number of EPT taxa, and percent EPT. Increases were expected in percent Chironomidae, percent top two dominant families and modified Hilsenhoff Biotic Index (mHBI). The results of this study do not completely substantiate these expected outcomes.

Taxa richness is the most commonly used measure to describe macroinvertebrate communities. This measure is based on the premise that the number of taxa will decrease as water quality also decreases (Merritt and Cummins 1996). There was a general trend of increasing taxa richness over the initial one-year mining period in the main channel of Wiley Branch. This trend was reflected also in Twelve Pole Creek. The only site where taxa richness decreased was in the non-impacted Left Fork of Wiley Branch (Station WB2).

These finding directly contradict the predicted patterns. If water quality decreased during the initial stages of mining, then taxa richness should have also decreased; but in actuality, taxa richness increased. According to Clements and Kiffney (1994), richness is relatively ineffective as a metric in some systems due to replacement of sensitive taxa by more tolerant taxa. This analysis is brought into sharper focus when combined with the second metric analyzed, number of EPT taxa. Most taxa in these three orders are pollution sensitive. Past research has shown that the EPT Index was reduced in streams impacted by sedimentation and nutrient enrichment (Lenat 1988). Reviewing winter comparisons shows that the number of EPT decreased at all stations with the exception of the downstream main channel site, WB1 (Fig. 27). In other words, while the number of total taxa was increasing, the number of EPT taxa was decreasing. An increased number of taxa is usually associated with increased diversity (Kerans and Karr 1994). In this case, the increased diversity was not of pollution-sensitive organisms but of pollution-tolerant organisms. As stated earlier, an increase in the number of pollution-tolerant organisms is an indication of disturbances to the stream environment (Plafkin et al. 1989).

Gray (1989) describes "best-documented" responses to environmental stressors as reduction in species richness and change in species composition to dominance by opportunistic species. In this study, taxa richness increased thereby alluding to the conclusion of no environmental stress; however, change in taxonomic composition of dominance suggests otherwise. Percent contribution of the top two dominant families measures community balance or lack there of. A community dominated by relatively few families could indicate environmental stress. Generally, the predicted response to increased perturbation is an increase in the percent dominant family value (Plafkin et al. 1989, Barbour et al. 1999). With the exception of Station WB1/Winter 2000, increases in percent top two dominant families were recorded at all main channel Wiley Branch stations. The upstream stations showed a shift from dominance by sensitive organisms to dominance by more opportunistic taxa from the order Trichoptera and family Chironomidae. In contrast, over both seasons (winter and spring), decreases in percent top two dominant families were recorded on the left Fork of Wiley Branch (Station WB2). This data supports the predicted outcome of increased dominance as a result of increased perturbation.

This evidence is echoed with the percent EPT metric. Winter comparisons showed decreases in percent EPT across all stations (Fig. 29). The final evidence for this trend is found with the metric, percent Chironomidae. At all main channel sites the percent Chironomidae increased (Fig. 31). Kerans and Karr (1994) suggest that high yearly variation in relative abundance of chironomids may be the result of a variable environment. However, Barbour et al. (1992) found high variability in abundance of chironomids in a study of reference sites. Winter comparisons on the Left Fork of Wiley Branch (Station WB2) showed no changes in percent Chironomidae. With a range of changes from 31 to 59 percentage points in the main channel, there does appear to be a dramatic difference between the impacted portion of the stream and non-impacted portion of the stream.

Biotic indices are popular because they provide an easily understood numerical expression of biological responses (Merritt and Cummins 1996). The pre-mining average modified Hilsenhoff Biotic Index (mHBI) for the main channel of Wiley Branch was 3, excellent water quality/no apparent organic pollution (Hilsenhoff 1987). One year later the average was 5, good water quality/some organic pollution (Hilsenhoff 1987). This increase indicates a slight decrease in water quality. An increase in the mHBI value from 3 to 4 was calculated at Station WB2 showing a smaller decrease in water quality.

Three problems exist in using the modified HBI: 1) difficulties with lower level taxonomic classification, 2) limitations of geographic tolerance families, and 3) generalizations in type of pollution indicated. The family Chironomidae is diverse including species with different pollution sensitivities (Berg and Hellenthal 1990). It is suggested that chironomids must be identified to taxonomic units whose pollution tolerances are known (i.e. genus or species level). Because chironomid taxonomy is difficult, Kerans and Karr (1994) suggest that chironomids may not be the most effective for use in an Index of Biotic Integrity. For this study, chironomids were identified only to the family level; therefore, using family level HBI tolerance values may cause a loss of biotic index accuracy. The family level HBI usually indicates greater pollution than the HBI in unpolluted or slightly polluted streams and less pollution in unpolluted streams (Hilsenhoff 1988). A second major problem with biotic indices is their geographic limitations for developed lists of organisms and their tolerance factors (Krueger et al. 1988). Where possible, generic tolerance values were utilized in this study as well as values from the southeast portion of the United States. Lastly, biotic indices are usually specific to a type of pollution (Merritt and Cummins 1996). The Hilsenhoff Biotic Index is specific to organic pollution (Hilsenhoff 1987). Mining in the Wiley Branch watershed resulted in increased sedimentation, inorganic pollution, and nutrient enrichment.

Secondary production is defined as the living organic matter, or biomass, that is created or produced by an animal population during an interval of time (Benke 1984). Production of aquatic macroinvertebrates represents a large part of the food available for fish species. It has been suggested that a side effect of some types of mining are increases in secondary production. Secondary production is normally measured in biomass, which was not a component of this study. However, from winter 1999 (before mining) to winter 2000 there was a 186% increase in productivity in the main channel of Wiley Branch based on total organisms counts. Total organisms decreased at Station WB2 by 44%. Given the previous analysis of taxa richness, percent EPT, percent dominance and percent Chironomidae, this increased productivity was due to the increased number of individuals in the pollution-tolerant family Chironomidae.

The influences of human society on the environment are as diverse as biological systems are complex. Each of the biological metrics used in this study measures the effect of a certain type of perturbation on a particular group of organisms. This “indicator species concept” has dominated biological evaluations (Kremen 1992). However, this method lacks environmental realism (LaPoint et al. 1996). When an attempt is made to interpret these metrics separately, system-level responses can be lost (Buikema and Voshell 1993). Individual metrics may not truly represent the complex cumulative impacts found in the aquatic system (Karr 1991). Since the purpose of this paper is to examine the overall ecological health of a single watershed, Wiley Branch, a better method would be to establish biological condition before and after mining with a broadly based multimetric approach (Karr 1991). The comprehensive multimetric approach is also more appropriate in reflecting the broad range of human impacts (Barbour et al. 1995). The value of the multimetric approach is that various metrics will differ in their sensitivity to impairment (Resh et al. 1995). Currently, some type of multimetric approach is being used for water resource monitoring in more than 85% of the state water quality programs in the United States (Southerland and Stribling 1995).

The multimetric approach first involves defining an array of metrics that will clearly and accurately document relationships between human disturbances and biological conditions (Kerans and Karr 1994). When integrated, these metrics will provide for a single index value describing the environmental condition. The difference between observed values and those expected from reference conditions are a measure of the degree of environmental impact (Resh and Jackson 1993). The strength of the multimetric approach is its ability to integrate information from the population, community and ecosystem levels (Karr et al. 1986; Plafkin et al. 1989; Karr 1991). It is also able to respond to the effects of human society in detectable ways (Kerans and Karr 1994).

To accurately evaluate the extent to which study sites are influenced by human actions, comparisons to reference conditions are essential (Omernik 1995). The newly released Stream Condition Index for West Virginia Wadeable Streams (Gerritsen et al. 2000) (WV-SCI) provides a multimetric index to be used as an indicator of ecosystem health with respect to the regional reference condition. All metric values were weighted equally in the composite bioassessment score. Metrics with redundancies and high correlations were not used. The WV-SCI was calibrated against local reference conditions and is used only to compare relative standings among sites. Since samples were collected only in Wiley Branch and Twelve Pole Creek, there is the potential for "pseudoreplication" as described by Hurlbert (1984). The paired site comparison methodology makes it difficult to determine if differences at downstream sites are caused by some factor other than the one being tested. As a solution, Wiley Branch trends were compared with the local reference conditions described in the WV-SCI. Thirteen physical and chemical parameters were used as reference criteria for the WV-SCI (Appendix F). According to Gibson et al. (1996) reference conditions are best established through systematic monitoring of actual sites that represent the natural range of variation in minimally disturbed water chemistry, habitat, and biological conditions. This approach accounts for natural variation expected for the region (LaPoint et al. 1996).

It is not possible to account for natural variation with a single reference site or with a single off-stream site; therefore, use of the regional reference conditions index allows for a more discriminating and accurate assessment of biological impairment (Barbour et al. 1996).

A statewide region was determined to be sufficient for assessment because the partitioning of streams and watersheds into Level 3 Ecoregions did not appear to improve biological assessment (Gerritsen et al. 2000). The regional reference sites were considered to be relatively unimpaired within a fairly homogeneous ecological region and habitat type. According to LaPoint et al. (1996), in states where regional reference conditions have been established, the assessment of biological impact will be more accurate with respect to regional expectations.

Generally, the two upstream stations (WB4 and WB3) were reduced from highly comparable to reference conditions to increasingly different from reference conditions. This reflects the same patterns described earlier with individual biotic metrics. With the exception of summer sampling times, the Left Fork of Wiley Branch, Station WB2, remained highly comparable to least impacted reference sites. This supports the argument for making comparisons between this station (non-impacted) and the main channel stations (impacted). Green et al. (2000) reported that biological conditions in streams with valley fills were substantially different from conditions in unmined streams and therefore were impaired.

The WV-SCI designations are based on percentiles as follows: highly comparable to least impacted reference sites (above 25th percentile), comparable to below-average reference sites (between 5th and 25th percentiles) and increasingly different from reference conditions (below the 5th percentile). In a field survey such as this one, there is always the difficulty of distinguishing between natural variability and perturbation-induced changes. Shackleford (1988) suggests that changes in a measure caused by perturbation may be considered important when they are as low as 20 – 30%. It is possible then that the percentage quartiles used in the WV-SCI may incorrectly indicate that some impairment has occurred. However, in a review of rapid assessment programs around the country, Resh et al. (1995) concluded that regional reference site approaches had the highest rankings for environmental accuracy and discriminatory power.

<u>How do increased sedimentation, stream impoundment and disturbance of riparian corridors impact functional feeding groups?</u>

The functional feeding group analysis was advantageous because it enables a numerical assessment of the degree to which the invertebrate biota was dependent upon a particular food source (Merritt and Cummins 1996). The aquatic invertebrate community is highly dependent on detritus (Coffman et al. 1971). Organisms are placed into three functional feeding groups based on their morphological-behavioral food-gathering mechanisms (Merritt and Cummins 1996): filterer-collectors, grazer-scrapers and shredders. Each group is expected to occur in proportionally higher abundances associated with particular habitat types or in accumulations of particular food sources (Merritt and Cummins 1996).

Recent evidence suggests that changes in trophic functional feeding levels may be due to sedimentation (Kerans and Karr 1994), stream impoundment (Gore 1996), or disturbance of riparian corridors (Cummins et al. 1989, Kerans and Karr 1994). All of these disturbances were demonstrated in the Wiley Branch watershed. Sedimentation generally leads to decreases in the periphyton community subsequently leading to changes in the grazer-scraper population (Kerans and Karr 1994). Stream impoundments alter flow thus impacting populations downstream (Gore 1996). Merritt and Cummins (1996) suggest there is a linkage between riparian-dominated headwater streams and the amount of coarse particulate organic matter (CPOM) available for the shredder population.

The percent grazer-scrapers during pre-mining conditions was highest at Station WB1 (46%) followed by Station WB2 (35%), Station WB3 (16%), and Station WB4 (6%). The higher percentages of grazer-scrapers at Stations WB1 and WB2 reflect a higher level of periphyton or substrate on which periphyton can attach. Periphyton is usually dominated by algae but may also include bacteria, microinvertebrates, and associated organic materials (Rosen 1995). Grazer-scrapers are those macroinvertebrates that have morphological features that allow them to "scrape" the periphyton from the substrate as a food source. Several studies have illustrated the response of periphyton to a variety of disturbances: nutrient disturbance (Stevenson et al. 1991), turbidity (Chessman 1986), and reduction in riparian cover (DeNicola et al. 1992).

Assuming only natural variation at Station WB2, the percentage of grazer-scrapers changed from 35% (winter 1999) to 43% (winter 2000) of the total population. In the main channel of Wiley Branch, the population of grazer-scrapers decreased at all three stations, WB4 (6% - 1%), WB3 (16% - 14%), and WB1 (46% - 23%) during the same time period (Fig. 42). Grazers may track decreases in periphyton abundance as a result of sedimentation (Kerans and Karr 1994). Sedimentation covers stream bottoms, smothering the aquatic biota or clogging interstitial spaces used by a variety of benthic macroinvertebrate organisms (Sengupta 1993). Stream flow is effective in carrying sediment when the stream water is at the bankfull elevation, where flow is at its highest velocity (Verry 2000). Reduction in stream flow either from stream impoundment, diverted run-off, alteration of subsurface flow, or decreased precipitation leads to increased sedimentation. However, data analyzed by Green et al. (2000), indicates that valley fills and associated mining activity did not cause excessive sediment deposition in the upper reaches of watersheds studied.

Hydrological changes in rivers or streams particularly coincide with stream impoundments. The construction of sedimentation ponds to control sediment movement downstream also impacts condition of riparian zones and influences discharge or flow regimes. The physical-chemical nature of release water influences the structure and function of downstream communities. Alterations in flow pattern influence distributions of substrate particles (Gore 1996). These bring about changes in the microhabitat downstream thus causing changes in benthic macroinvertebrate communities. According to Ward and Stanford (1983), these discontinuities can have the effect of 'resetting' community structure to mimic those of areas farther upstream. Prior to mining operations, shredders were more abundant than filterer-collectors at the upstream stations while filterer-collectors were more abundant than shredders downstream. After the initiation of mining, the downstream station WB1 had a shredder/filterer-collector ratio more like an upstream station.

Filterer-collectors are generalists that feed on suspended fine particulate organic material (FPOM). These organisms have a broad range of acceptable food materials and are thus more tolerant to changes in the environment that might alter availability of certain foods (Cummins and Klug 1979). Because of this method of feeding, filterer-collectors are dependent on the shredder population to convert CPOM to FPOM. Shredders are those organisms that process detrital leaf litter in the aquatic system. About 30% of the conversion of CPOM leaf to FPOM has been attributed to shredder feeding (Cuffney et al. 1990). The FPOM that shredders generate consist of plant fragments and feces (Cummins and Klug 1979).

Figure 43 pictorially describes the functional feeding group relationships on Wiley Branch during the winter of 1999 (pre-mining) and during the winter of 2000. Almost a third of the populations at the headwater stations WB4 and WB2 were shredders indicating the high availability of CPOM. The population at Station WB3 was almost two-thirds shredders. These three sections of the stream were the narrowest part of the stream and had partly shaded to heavily shaded canopy cover. Given the appropriate substrate, the shredder community will be in balance with the riparian plant community (Cummins et al. 1989). One year later, after eight months of mining, the shredder populations at these three stations changed dramatically. Only 2% of the remaining populations of macroinvertebrates at Station WB4 were shredders. This represents a drop of 28 percentage points. The shredder population at Station WB3 dropped 54 percentage points to 6%. However, at Station WB2, the population of shredders dropped only 13 percentage points to 17%. Assuming only natural variation at Station WB2, the greater decreases in the shredder population at the other two stations were probably due to mining impacts. Kerans and Karr (1994) found that sharp decreases in percent shredders might reflect impacts to the riparian zone. Sedimentation structures above the most impacted sites (WB4 and WB3) had to be located within the headwaters of the stream. To do so, the riparian zone at the headwater area was removed allowing for the construction of two ponds that covered one acre. The riparian zone on the east side of Wiley Branch, Station WB3, was greatly reduced, and at some points completely eliminated. Removal of riparian vegetation could have also altered the thermal regime of the stream further affecting insect composition (Merritt and Cummins 1996). It is proposed that reduced amounts of CPOM at stations WB4 and WB3 were unable to support the shredder community in these areas. As a result, a lower rate of leaf litter processing resulted in reductions in FPOM export and subsequently reductions in filterer-collector populations farther downstream.

There were dramatically more shredders at the upstream stations than at the downstream station (WB4, 30%; WB3, 60%; WB1, 4%). Station WB1 was near the mouth of Wiley Branch where the stream was widest. Functional feeding group proportions were quite different at this site. According to the river continuum concept (Vannote et al. 1980), shredders process upstream leaf litter subsequently exporting FPOM to downstream areas for the filterer-collector feeding populations; therefore, the dominance of shredders will decrease as stream size increases. In a least impacted site, it would be expected that shredders would be more dominant upstream and filterer-collector more dominant downstream.

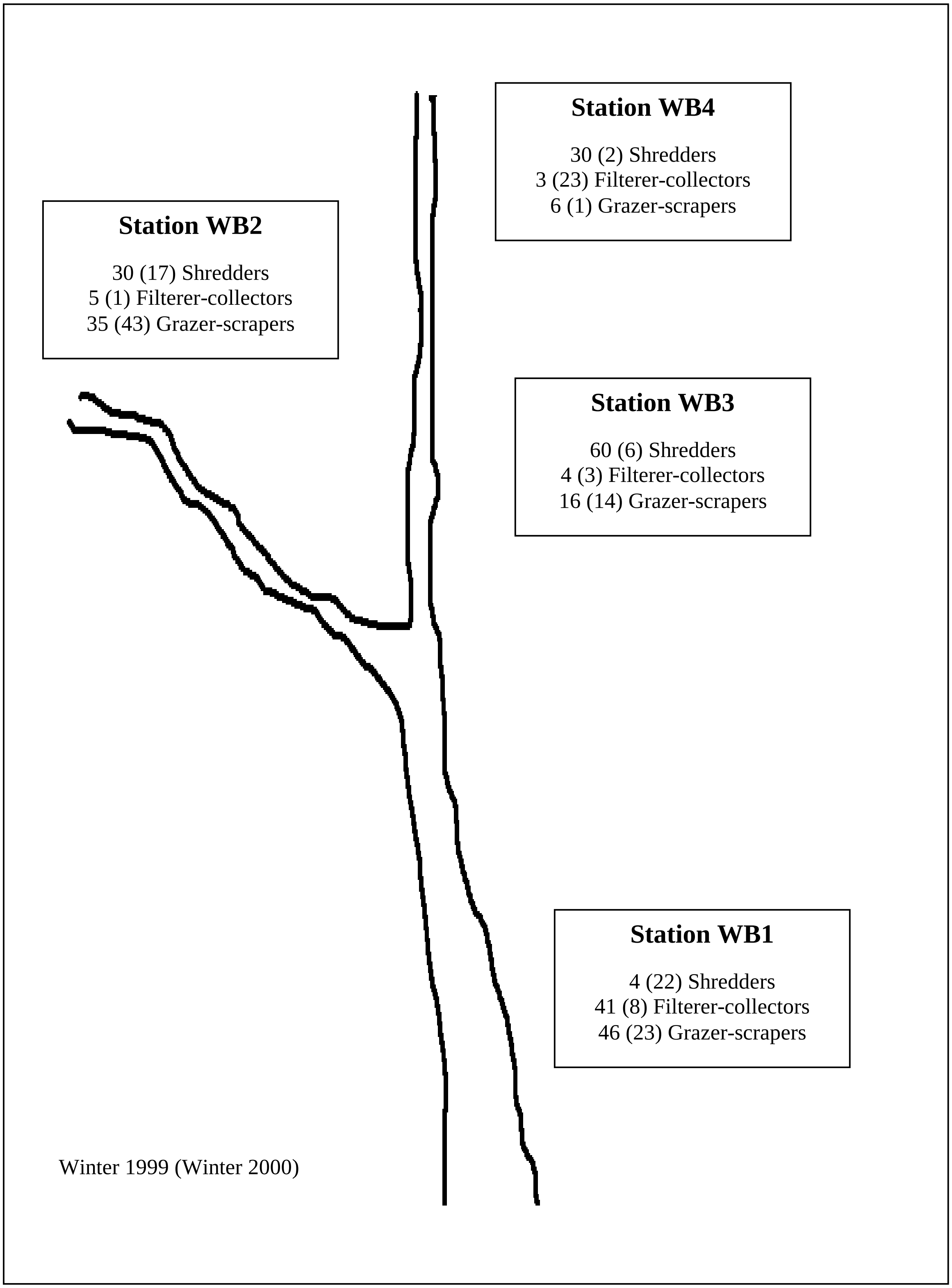

Figure 43. Pictorial representation of functional feeding groups on Wiley Branch during winter 1999 and winter 2000 sampling periods.

Initial populations of filterer-collectors at the upstream stations, WB4, WB3 and WB2, were less than six percent reflecting low levels of FPOM. The initial population of filterer-collectors at the downstream station (WB1) was 41%. During the winter of 2000, the filterer-collector population at the upstream station WB4 increased dramatically from 3% to 23% of the total population. Plafkin et al. (1989) suggests an increase in filterer-collectors results from organic enrichment. During watershed disturbance the input of FPOM is altered from seasonal to continuous, leading to the nutritional resource base for filterer-collectors to be abundant and continuous causing increases in populations (Cummins 1996). With sedimentation pond construction, increased sunlight on the pond could lead to increased plankton production thus changing the energy source of the stream. This would assume that water quality was not a limiting factor to plankton growth. The percentage of filterer-collectors was almost unchanged at Station WB3 while the population of filterer-collectors at Station WB1 dropped from 41% to 8%. The decreased number of shredders at the upstream stations would result in a decrease in the amount of FPOM flowing downstream for use by the filterer-collector communities.

Filter-feeding collectors are strongly influenced by local flow conditions because they exploit the current for gathering food with minimal energy expenditure (Merritt and Cummins 1996). Flow conditions then have important consequences for allochontonous energy or nutrient dispersal. The flow rate at Station WB1 dropped from 50 GPM during the pre-mining sampling period to below 15 GPM the remainder of the study period. A decreased flow in the stream could be a result of decreased runoff resulting from increased infiltration rates by more permeable rock strata that were exposed by the mining operation (Sengupta 1993), from sedimentation pond construction upstream or from decreased rainfall. The annual precipitation amount for 1998 was above average while the amounts for 1999 and 2000 were dramatically below average (Appendix B). In this study, decreased flow could be a result of natural variation from decreased precipitation. However, Cuffney et al. (1990) found that shredder densities in two reference streams did not differ significantly between two years despite a drought during the second year.

<u>How far downstream of impact is the benthic macroinvertebrate assemblage affected?</u>

Impacts to benthic macroinvertebrate assemblages have been shown from sedimentation, stream impoundment and disturbance to riparian corridors. Cumulative impacts are often predicted downstream, but how far downstream? What constitutes a significant spatial extent is not well defined (LaPoint et al. 1996). Wiley Branch is approximately a 2.4 km stream. Station WB1 was located near the mouth of Wiley Branch approximately 2 km below the uppermost sedimentation pond. Five metrics were selected to analyze trends between Wiley Branch main channel stations, WB4, WB3, and WB1, and Twelve Pole Creek, 12P. Between winter 1999 and winter 2000, the downstream station, WB1, had the highest increase in total taxa (71%) as well as the highest increase in number of EPT taxa (113%). Percent EPT decreased at all stations but the lowest percent change was at Station WB1 (2%). Percent Chronomidae increased at all stations; the smallest increase was at Station 12P (23%) and the next smallest increase was at Station WB1 (31%). The mHBI value increased at all sites but, again, the smallest increase was at Station WB1 (3.09-3.93). Further studies in this area would be needed before a general statement could be made about stream length and the distance of cumulative impacts. However, I propose that perturbation, in a watershed less than 486 hectares where mining impacts are less than 10% of the watershed with no AMD, impacts the benthic macroinvertebrate assemblage downstream to a lesser degree than those upstream. Utilization of the WV-SCI adds confirmation this concept. The overall WV-SCI value for Station WB1 increased 5 points between the winter sampling periods. All of the other stations had index values that decreased between 2 and 32 points.

CHAPTER VI

CONCLUSIONS

As is the case with most fieldwork, there is difficulty in determining ecological significance with particular results. Natural variation is the foremost confounding factor. LaPoint et al. (1996) suggest that endpoint changes having a high magnitude, relative to natural variation, long duration and/or large spatial extent affected, represent significant ecological change. Before this definition can be used, however, the natural variability accepted in biological assessment needs to be defined and agreed upon by governmental agencies, citizen groups, environmental groups and those causing environmental changes. The West Virginia Stream Condition Index (Gerritsen et al. 2000) may be the starting point for this concurrence. If the multiple reference sites indeed are representative of all streams in West Virginia, then, the Index should serve its function: to characterize the existence and severity of point and nonpoint source impairment.

Magnitude is another aspect of the definition for significant ecological change. With a multimetric approach, the effect on multiple taxonomic groups is considered more ecologically significant than the effect on a single taxon; therefore, a large change in a multimetric score will generally reflect ecological significance. According to LaPoint et al. (1996), a decrease in the bioassessment score from an ecoregional reference value represents an adverse ecological response in terms of magnitude.

The third part of this definition for ecological change involves duration. Systems must be sampled for many years to establish patterns of annual variability to act as an adequate baseline for comparisons of conditions before and after an impact (Cooper and

Barmuta 1993). After mining is completed, as well as during the reclamation process and bond release time period, this initial data can be used as baseline information in measuring the long-term effects of surface mining at this particular location. According to Gore and Milner (1990), continued low flows do not provide habitat criteria favorable to recolonization; therefore, efforts should be made to remove sedimentation ponds so that full flow can be restored to the stream.

A narrower sampling window of late spring to early summer would also improve the assessments by reducing variability. Biological index periods are useful for controlling seasonal fluctuation in community structure (LaPoint et al. 1996). This index period should be the period of time when emergence and mortality of young are not confounding factors in sampling (LaPoint et al. 1996). Continued monitoring of Wiley Branch, then, should occur during the spring months April and May and during the fall months September and October. Sampling should not be conducted in the summer months because of reduced sensitivity of the HBI.

Kerans and Karr (1994) suggest that impacts on streams from sedimentation may be more clearly demonstrated in pools rather than riffles. Possible influences of drought conditions may also be reflected better in pool communities. In this study the confinement of sampling to riffles was in an effort to reduce variability. Sampling benthic populations from pools, however, should be considered for future testing.

Low pH, high concentrations of heavy metals and ferric hydroxide precipitation are often associated with surface coal mining. These environmental conditions traditionally eliminate aquatic insects from affected areas for many years following cessation of mining. Several current mining practices are addressing these adverse environmental conditions. Construction of sedimentation ponds below mining areas prior to the commencement of mining operations is reducing the amount of sediment and silt moving downstream. The negative side of these sedimentation ponds is the amount of riparian vegetation that must be eliminated in the construction of the ponds.

If high sulfur content coal seams and overburden are avoided, severe acid mine drainage can be avoided. Coal companies are also taking steps to reduce the oxidation of pyritic materials in waste piles by burying iron-sulfide overburden in the deepest part of the valley fill as well as utilizing back stack and special encapsulation cells. They are also employing timely revegetation practices and landscaping sculpturing techniques to limit erosion in the watershed. Ward (1984) describes a coal mining operation that caused no detrimental effects on the extant aquatic community. Community composition was generally similar above, adjacent to, and below mine spoils. Abundance and biomass even increased in the downstream direction. Ward (1984) attributes the lack of discernible detrimental effects to the following: (1) the absence of acid-mine drainage; (2) the low solubility of most heavy metals; (3) the buffer zone between the mine spoils and the stream; and (4) the large, relatively undisturbed watershed above the mine spoils.

Given the brief period of time during which this study was conducted and the fact that it is a site specific approach, care should be taken with making generalizations about impact of contour surface mining to watersheds of different sizes and geological composition.

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APPENDIX A

Geology Data

APPENDIX A

Appendix A is geology data derived from core samples taken from the Coalburg and Five Block Coal Seams during the summer of 1996. Central Testing Inc., Summersville, West Virginia, analyzed each core sample as part of the West Virginia Division of Environmental Protection's mining permit requirements.

Sulfur Content and pH for Mined Areas from the Coalburg Seam

Coalburg Seam	pH	Thickness (feet)	Sulfur forms (%)			
			Organic	Pyritic	Sulfate	Total
Drill Hole 96-1						
J	8.29	4.20	0.68	0.20	0.02	0.90
K	9.26	6.48				0.00
L	6.95	25.80	0.60	0.10	0.00	0.70
Weighted Average		**36.48**	**0.503**	**0.094**	**0.002**	**0.599**
Drill Hole 96-3						
I & J	7.71	4.32	0.17	0.05	0.00	0.22
K	5.63	16.32	0.44	0.12	0.01	0.57
Weighted Average		**20.64**	**0.383**	**0.105**	**0.008**	**0.497**
Drill Hole 96-4						
B	7.04	12.60	0.40	0.10	0.01	0.51
C	7.55	6.24				0.10
D	6.77	12.24	0.49	0.08	0.00	0.57
E	7.47	14.40	0.2	0.06	0.00	0.26
F,G & H	7.31	21.12	0.48	0.08	0.01	0.57
Weighted Average		**66.60**	**0.361**	**0.072**	**0.005**	**0.448**
Drill Hole 96-6						
N	5.48	3.12	0.29	0.72	0.00	1.01
O	8.07	4.20	0.13	0.06	0.00	0.10
P	6.65	19.56	0.58	0.15	0.00	0.73
Weighted Average		**26.88**	**0.476**	**0.202**	**0.000**	**0.664**
Drill Hole 96-7						
K & L	7.35	5.76	0.44	0.06	0.00	0.50
M	7.28	17.64	0.49	0.06	0.00	0.55
Weighted Average		**23.40**	**0.478**	**0.060**	**0.000**	**0.538**

Sulfur Content and pH for Mined Areas from the Five Block Seam

Five Block Seam	pH	Thickness (feet)	Sulfur forms (%)			
			Organic	Pyritic	Sulfate	Total
Drill Hole 96-36						
1-10	8.4	40.0				
11	7.8	1.35	0.16	0.04	0.06	0.26
12	4.5	0.45	1.47	1.04	1.16	3.67
13	5.0	0.70	0.44	0.43	0.24	1.11
14	3.1	0.95	2.27	1.52	1.25	5.04
15	4.2	0.35	0.49	0.20	0.50	1.19
16	5.8	3.10	0.13	0.10	0.06	0.29
17-33	8.6	37.65				
34	7.0	0.55	0.40	0.30	0.20	0.90
35-51	8.7	38.3				
52	8.7	4.45	0.09	<0.01	0.03	0.12
53	8.5	1.95	0.13	0.06	0.03	0.22
54	8.5	1.10				
55	8.2	5.10	0.02	0.01	<0.01	0.03
56	8.2	5.00	0.03	<0.01	<0.01	0.02
57	8.4	5.00	0.02	<0.01	<0.01	0.02
58	8.4	5.90	0.02	<0.01	<0.01	0.02
59-66	8.3	21.30				
67	8.3	1.50	0.28	0.01	0.31	0.60
68	8.3	2.60	0.07	0.02	0.05	0.14
69-76	8.3	25.2				
77	8.0	0.24	0.08	0.05	0.03	0.16
78	8.2	0.99	0.02	0.01	<0.01	0.03
79	8.0	1.20	0.02	0.01	<0.01	0.03
80	8.1	2.75	0.02	0.02	<0.01	0.04
81-83	8.3	4.11				
84	8.3	2.00	0.02	<0.01	<0.01	0.02
85	6.7	4.00	0.02	0.01	<0.01	0.03

APPENDIX B

Climatic Conditions

APPENDIX B

Appendix B1 is a record of the climatic conditions three to seven days prior to each sampling period. Measurements were obtained from the Charleston, West Virginia Yeager Airport. Data with bold font represent sampling dates.

Appendix B2 is a record of monthly and annual precipitation amounts provided by the National Weather Service in Charleston, West Virginia. An average based on the 30-year period, 1961 – 1990 is compared to precipitation amounts for 1991 – 2000.

Appendix B1. Climatic Conditions Seven Days Prior to Each Sampling Event

Date	Average Temperature (°C)	Precipitation (cm)	Events	Snow Depth (cm)
2/13/99	-4.4	0	Snow	2.5
2/14/99	-2.7	0	Snow	
2/15/99	3.1	0		
2/16/99	7.9	0		
2/17/99	7.2	0.05	Rain	
2/18/99	2.1	0		
2/19/99	0.3	0		
2/20/99	**-1.6**	**0**		
5/21/99	20.3	0		
5/22/99	17.9	2.8	Rain	
5/23/99	18.4	0.5	Rain	
5/24/99	15.0	0.9	Rain	
5/25/99	14.6	0.1	Rain	
5/26/99	16.5	0		
5/27/99	**15.8**	**0**		
7/6/99	29.2	0		
7/7/99	26.9	0		
7/8/99	23.6	0		
7/9/99	26.3	0.2	Rain	
7/10/99	23.8	0.8	Rain	
7/11/99	21.3	0		
7/12/99	18.6	0		
7/13/99	**20.9**	**0**		
9/9/99	22.3	0		
9/10/99	15.7	0		
9/11/99	16.4	0		
9/12/99	20.8	0		
9/13/99	**19.7**	**0**		
10/25/99	3.5	0		
10/26/99	8.5	0		
10/27/99	7.6	0		
10/28/99	9.1	0		
10/29/99	13.7	0		
10/30/99	14.1	0		
10/31/99	17.6	0		
11/1/99	**17.2**	**0**		
12/29/99	-1.9	0		
12/30/99	8.8	0		
12/31/99	5.0	0		
1/1/00	11.3	0		
1/2/00	12.9	0		
1/3/00	16.8	NA	Rain	
1/4/00	8.8	2.86	Rain, Snow	
1/5/00	**-1.0**	**NA**	**Snow**	
3/3/00	2.3	0		
3/4/00	7.9	0		
3/5/00	11.1	0		
3/6/00	14.4	0		

3/7/00	19.1	0		
3/8/00	17.6	0		
3/9/00	21.5	0		
3/10/00	**14.2**	**0**		
5/3/00	16.7	0		
5/4/00	19.0	0		
5/10/00	**20.6**	**0**		

Appendix B2. Monthly and Annual Precipitation for Charleston, West Virginia.

	Monthly Precipitation (inches)												Annual Precipitation (inches)
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	
Standard 30-year period 1961-1990	2.91	3.04	3.63	3.31	3.91	3.59	4.99	4.01	3.24	2.39	3.59	3.39	42.53
1991	2.68	2.98	6.07	3.49	1.47	2.49	2.84	2.95	5.51	1.10	5.00	5.89	42.47
1992	1.94	2.72	4.79	2.93	4.66	3.21	6.41	4.41	1.38	0.94	3.15	3.50	40.04
1993	1.87	2.98	6.68	1.78	1.98	5.01	1.98	2.71	5.99	3.50	3.95	3.23	41.66
1994	6.42	5.56	7.73	3.78	3.98	4.43	3.71	6.20	1.95	1.13	1.95	2.52	49.36
1995	6.02	2.98	2.73	2.59	6.15	4.93	2.91	5.81	2.70	2.61	3.31	2.79	45.53
1996	5.18	2.82	4.32	3.77	7.40	3.59	9.60	2.82	7.37	2.49	4.36	2.04	54.66
1997	1.76	1.76	8.35	2.77	3.60	5.24	5.83	4.14	1.94	0.84	2.96	1.57	40.76
1998	3.43	4.23	3.41	4.77	5.27	10.56	3.65	3.70	2.50	1.67	1.89	3.18	48.26
1999	4.81	2.67	3.70	2.20	1.90	1.30	5.37	2.97	1.81	3.43	4.53	2.55	37.24
2000	1.41	4.25	2.26	4.67	4.75	3.38	6.06	4.35	2.87	0.87	1.27	2.10	38.24

APPENDIX C

Water Chemistry

APPENDIX C

Appendix C is water chemistry data derived from water samples collected at each station on each sampling visit. Pen Coal Company personnel measured flow and pH in the field. All other chemistry parameters were determined according to United States Environmental Protection Agency standards by Standard Laboratories, Inc., South Charleston, West Virginia.

Wiley Branch – Station #4

	2/11/99	5/27/99	7/13/99	9/13/99	11/1/99	1/6/00	3/10/00	5/10/00
pH	8.17	7.79	8.10	7.62	7.68	7.61	7.32	8.79
Flow (GPM)	15	5	3	-	3	-	10	5
Total Alkalinity (mg/l $CaCO_3$)	40	62.0	98.0	79	81	91	85	97
Acidity (mg/l $CaCO_3$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (mg/l SO_4)	80.6	18.0	26.9	50.8	72.0	108	55.4	102
Total Aluminum (mg/l Al)	<0.07	1.12	0.15	2.46	0.30	<0.07	0.09	BDL
Total Iron (mg/l Fe)	0.22	1.14	0.22	2.54	0.10	0.12	0.13	BDL
Total Manganese (mg/l Mn)	0.02	0.10	0.02	0.57	0.05	0.43	BDL	0.03
Total Suspended Solids (mg/l TSS)	<5.0	19	<5.0	73	7.0	<5.0	BDL	BDL
Total Dissolved Solids (mg/l TDS)	86	100	150	150	140	260	160	310
Specific Conductivity (umhos/cm)	100	200	217	260	290	371	271	353

Wiley Branch – Station #3

	2/11/99	5/27/99	7/13/99	9/13/99	11/1/99	1/6/00	3/10/00	5/10/00
pH	8.21	7.04	8.13	7.89	7.36	7.32	7.47	8.18
Flow (GPM)	30	5	4	-	6	-	15	8
Total Alkalinity (mg/l $CaCO_3$)	24	38.0	76.0	83	80	78	47	82
Acidity (mg/l $CaCO_3$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (mg/l SO_4)	17.0	6.0	26.1	28.0	49.6	82.0	70.6	72.8
Total Aluminum (mg/l Al)	<0.07	7.70	0.18	0.94	1.21	0.13	0.11	0.20
Total Iron (mg/l Fe)	0.15	9.16	0.24	1.30	0.57	0.07	0.24	0.27
Total Manganese (mg/l Mn)	0.02	0.66	<0.02	0.29	0.24	0.13	0.12	0.12
Total Suspended Solids (mg/l TSS)	<5.0	263	<5	13	17	<5.0	BDL	BDL
Total Dissolved Solids (mg/l TDS)	74	78	120	140	100	150	140	210
Specific Conductivity (umhos/cm)	80	110	186	210	240	321	244	286

Wiley Branch – Station #2

	2/11/99	5/27/99	7/13/99	9/13/99	11/1/99	1/6/00	3/10/00	5/10/00
pH	7.96	8.11	7.75	7.73	6.88	7.20	7.57	8.23
Flow (GPM)	20	6	<0.5	-	2	-	12	3
Total Alkalinity (mg/l $CaCO_3$)	20	49.0	87.0	98	94	47	37	60
Acidity (mg/l $CaCO_3$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (mg/l SO_4)	15.1	8.6	36.0	1.0	13.0	14.0	16	7.6
Total Aluminum (mg/l Al)	0.10	3.12	0.08	0.23	0.28	0.31	BDL	BDL
Total Iron (mg/l Fe)	0.07	0.16	0.07	0.27	<0.025	<0.025	0.07	0.13
Total Manganese (mg/l Mn)	0.02	<0.02	<0.02	0.04	0.02	<0.02	BDL	BDL
Total Suspended Solids (mg/l TSS)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	BDL	BDL
Total Dissolved Solids (mg/l TDS)	130	110	210	120	140	105	78	150
Specific Conductivity (umhos/cm)	200	190	260	230	240	190	153	154

Wiley Branch – Station #1

	2/11/99	5/27/99	7/13/99	9/13/99	11/1/99	1/6/00	3/10/00	5/10/00
pH	7.85	7.96	8.06	7.80	7.28	7.45	7.63	8.00
Flow (GPM)	50	15	5	-	10	-	120	6
Total Alkalinity (mg/l $CaCO_3$)	19	38.0	74.0	67	71	49	37	91
Acidity (mg/l $CaCO_3$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (mg/l SO_4)	17.1	13.2	15.0	16.0	19.0	42.1	34.2	99.2
Total Aluminum (mg/l Al)	<0.07	0.61	0.07	0.34	0.47	0.25	BDL	0.26
Total Iron (mg/l Fe)	0.11	1.25	0.20	0.54	0.03	0.14	0.08	0.09
Total Manganese (mg/l Mn)	<0.02	0.05	<0.02	0.02	0.03	0.07	0.02	0.13
Total Suspended Solids (mg/l TSS)	<5.0	13	<5	<5.0	<5.0	5.0	BDL	BDL
Total Dissolved Solids (mg/l TDS)	76	82	110	110	100	100	98	310
Specific Conductivity (umhos/cm)	90	130	150	170	200	193	159	343

Twelve Pole – Station #12P

	2/11/99	5/19/99	7/13/99	9/13/99	11/1/99	1/6/00	3/23/00	5/10/00
pH	8.15	7.50	7.73	7.79	6.96	7.51	7.3	8.31
Flow (GPM)	3000	-	200	-	600	-	-	38
Total Alkalinity (mg/l $CaCO_3$)	21	32	70	86	70	39	16	49
Acidity (mg/l $CaCO_3$)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (mg/l SO_4)	24.0	8.1	56.2	54.6	43.9	30.3	24.4	26.9
Total Aluminum (mg/l Al)	<0.07	4.15	1.59	0.36	0.47	0.09	0.09	BDL
Total Iron (mg/l Fe)	0.26	3.88	1.48	0.49	0.58	0.51	0.26	0.19
Total Manganese (mg/l Mn)	0.07	0.06	0.09	0.09	0.06	0.06	0.05	BDL
Total Suspended Solids (mg/l TSS)	<5.0	60	10	5.0	<5.0	<5.0	20	BDL
Total Dissolved Solids (mg/l TDS)	68	110	180	180	120	120	68	160
Specific Conductivity (umhos/cm)	100	120	240	300	250	150	87.6	162

U. S. Geological Survey monitoring station #03206600 on the East Fork of Twelve Pole Creek near Dunlow, West Virginia (Lat. 38° 01’ 02”, Long. 82° 17’ 46”)

	Feb-99	May-99	Jul-99	Sep-99	Nov-99	Jan-00	Mar-00	May-00	1965-2000 average
Average Monthly Flow (ft^3/sec)	98.2	69.7	15.8	9.11	13.9	8.75	43.4	22.6	52

APPENDIX D

Benthic Macroinvertebrate

Assemblage Data

APPENDIX D

Appendix D is the benthic macroinvertebrate assemblage data for each collection date. Included are family or regional genera level tolerance values described by Hilsenhoff (1987) or Barbour et al. (1999) as well as primary functional feeding group classifications and habit or behavior designations described by Merritt and Cummings (1996). Tolerance values are on a 0 to 10 scale, with 0 representing the tolerance value of an extremely sensitive organism and 10 the tolerance value of an extremely tolerant organism. Functional feeding group classifications and habit/behavior designations generally pertain to insect larval forms and are mostly at the genus level. The following is a list of the abbreviations used in this appendix.

Functional Feeding Designations

PR = predator
OM = omnivore
GC = gatherer/collector
FC – filter/collector
SC = scraper
SH = shredder

Habit/Behavior Designations

cn = clinger
cb = climber
sp = sprawler
bu = burrower
sw = swimmer
dv = diver
sk = skater

Benthic Macroinvertebrate Assemblage Data
February 10, 1999

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera								
Ameletidae								
Ameletus	7	GC	sw,cb	12	6	2		7
Heptageniidae								
Epeorus	4	GC	cn	4	13	61		
Stenonema	4	SC	cn				3	
Ephemerellidae								
Ephemerella	2.9	GC	cn,sw		6	9		1
Eurylophella	2.1	SC	cn,sp	1		1		3
Serratella	0.6	GC	cn	6		2		
Leptophlebiidae								
Habrophleboides	2	GC	sw,cn			1		
Paraleptophlebia	2.8	GC	sw,cn		1	3		
Ephemeridae								
Ephemera	3.1	GC	bu		1			1
Caenidae								
Caenis	3.1	GC	sp,cb				1	
Isonychiidae								
Isonychia	1.9	FC	sw,cn				1	
Baetiscidae								
Baetisca	3	GC	sp					1
Plecoptera								
Perlidae								
Acroneuria	1	PR	cn	1	1	1		
Eccoptura	1	PR	cn			2		
Perlodidae								
Clioperla	2	PR	cn	3				
Malirekus	2	PR	cn	4		1		
Cultus	2	PR	cn	1				
Isoperla	2	PR	cn, sp		1	3		2
Capniidae								
Allocapnia	1	SH	sp,cn	3		1		1
Nemouridae								
Nemoura	2	SH	sp,cn	21	50	27	5	21
Chloroperlidae								
Haploperla	1	PR	cn	5		13		
Leuctridae								
Leuctra	0	SH	sp,cn	3	2	8		2
Taeniopterygidae								
Oemopteryx	2	SC	sp,cn				17	
Strophopteryx	2	SC	sp, cn		1			

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Trichoptera								
Hydropsychidae								
Hydropsyche	4	FC	cn	1		8		
Diplectrona	4	FC	cn	2	2			
Cheumatopsyche	2.9	FC	cn				17	2
Uenoidae								
Neophylax	4	SC	cn	1				
Limnephilidae								1
Pycnopsyche	3.3	SH	sp, cb, cn		7			
Philopotamidae								
Chimarra	3	FC	cn		1	1	34	
Dolophilodes	3	GC	cn			5		
Psychomyiidae								
Neureclipsis	2.7	FC	cn		1			
Nyctiophylax	2.5	FC	cn					1
Hydroptilidae								
Hydroptila	3.2	SC,PR	cn				1	
Diptera								
Chironomidae	6	GC	bu	31	9	11	5	6
Tipulidae	3	SH	bu			8		
Tipula	7.2	SH	bu		1	2		
Hexatoma	2.3	PR	bu,sp			2		
Pseudolimnophila	3	PR	bu			1		
Dicranota	3	PR	sp, bu		2			
Ceratopogonidae								
Bezzia	6	PR,GC	bu			5		
Megaloptera								
Corydalidae								
Nigronia	0	PR	cn,cb,bu		1	1	2	
Corydalus	0	PR	cn,cb,sw				1	
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn		1	1	2	1
Optioservus	3.6	SC	cn		2	2	36	
Psephenidae								
Ectopria	4	SC	cn			2		
Hydrophilidae								
Hydrochus	5	SH	sw,dv			1		
Odonata - Anisoptera								
Gomphidae								
Gomphus	1	PR	bu		1			1
Lepidoptera								
Cossidae								
Prionoxystus	5	SH	bu			1		

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Annelida	8	GC	bu				2	
Total Organisms				**99**	**109**	**186**	**127**	**51**
Total EPT				**68**	**92**	**149**	**79**	**43**
Total Taxa				**16**	**21**	**29**	**14**	**15**
Total EPT Taxa				**15**	**14**	**18**	**8**	**12**

Benthic Macroinvertebrate Assemblage Data
May 27, 1999

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera								
Ameletidae								
Ameletus	7	GC	sw, cb	6	6	2	2	3
Heptageniidae								
Heptagenia	4	SC	cn	9	1	4		
Stenonema	4	SC	cn				1	1
Stenacron	3.1	SC	cn		1			
Nixe	4	SC/GC	cn		1			
Epeorus	4	SC	cn			1		
Cinygmula	4	SC	cn			1		
Leucrocuta	2.4	SC/GC	cn			3		
Ephemerellidae								
Drunella	1	PR	cn,sp		7	5		1
Ephemerella	2.9	GC	cn,sw			4		
Eurylophella	2.1	SC	cn,sp					1
Leptophlebiidae								
Habrophlebiodes	2	GC	sw,cn			8		
Paraleptophlebia	2.8	GC	sw,cn		1			
Isonychiidae								
Isonychia	1.9	FC	sw,cn				3	
Baetidae								
Baetis	3.1	GC	sw,cb		1	18	6	
Plecoptera								
Perlidae								
Acroneuria	1	PR	cn	2			1	
Eccoptura	1	PR	cn		1	2		
Perlesta	4.5	PR	cn				1	
Capniidae								
Allocapnia	1	SH	sp,cn				3	
Nemouridae								
Amphinemura	2	SH	sp, cn		1	2	3	
Prostoia	2	SH	sp,cn			9		
Leuctridae								
Leuctra	0	SH	sp,cn	1		125	6	
Zealeuctra	0	SH	sp, cn		5			
Perlodidae								
Remenus	2	PR	cn			3		
Trichoptera						3 pupa		
Hydropsychidae								
Cheumatopsyche	2.9	FC	cn		3		7	21
Diplectrona	4	FC	cn			2		1
Uenoidae								
Neophylax	4	SC	cn			2		
Glossosomatidae								
Agapetus	0	SC	cn			4		

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Philopotamidae								
Dolophilodes	3	GC	cn			1		
Polycentropodidae								
Cernotina	6	PR	cn			4		
Rhyacophilidae								
Rhyacophila	0	PR	cn			1		
Diptera								
Chironomidae	6	GC	bu	6	11	99	42	43
Procladius	6.5	PR,GC	sp				2	1
Orthocladius	3.9	GC	sp, bu			9	2	
Unknown pupa	6	GC					1	
Ceratopogonidae	6	PR	bu			4		
Tipulidae	3	SH		3		158		
Tipula	7.2	SH	bu			3		
Hexatoma	2.3	PR	bu,sp			29	2	
Dicranota	3	PR	sp, bu			2		
Empididae								
Hemerodromia	6	PR	sp, bu			1		
Dixidae								
Dixa	2.8	GC	sw, cb			2		
Culicidae	9	FC	sw					1
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn		4	3	1	
Optioservus	3.6	SC	cn	1		16	3	23
Psephenidae								
Ectopria	4	SC	cn		1	9		1
Dryopidae								
Helichus	3.2	SH	cn			1		1
Hemiptera								
Gerridae		PR	sk	1				
Odonata - Anisoptera								
Gomphidae								
Gomphus	1	PR	bu	1	1	1		
Annelida	8	GC	bu	17	5			6
Decapoda								
Cambaridae								
Cambarus	8.1	OM	bu		1	3	1	
Total Organisms				**45**	**51**	**544**	**87**	**104**
Total EPT				**18**	**28**	**204**	**33**	**28**
Total Taxa				**10**	**17**	**34**	**17**	**13**
Total EPT Taxa				**4**	**11**	**20**	**10**	**6**

Benthic Macroinvertebrate Assemblage Data
July 13, 1999

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn				1	
Ameletidae								
Ameletus	7	GC	sw, cb				3	
Heptageniidae				1				
Stenonema	4	SC	cn		3	1	7	208
Stenacron	3.1	SC	cn		3			
Ephemerellidae								
Ephemerella	3.1	GC	bu	5	2			
Caenidae								
Caenis	3.1	GC	sp,cb				1	2
Baetidae								
Baetis	3.1	GC	sw,cb	2				
Isonychiidae								
Isonychia	1.9	FC	sw, cn					271
Plecoptera								
Perlidae								
Eccoptura	1	PR	cn	17	5		1	
Perlodidae								
Malirekus	2	PR	cn	1				
Capniidae								
Capnia	1	SH	cn			1		
Chloroperlidae								
Haploperla	1	PR	cn	6				5
Alloperla	1	PR	cn		1			
Leuctridae								
Leuctra	0	SH	sp,cn	21	2	13		4
Trichoptera								
Hydropsychidae								
Hydropsyche	4	FC	cn	10				
Diplectrona	4	FC	cn	9	2			
Cheumatopsyche	2.9	FC	cn	20	5		49	306
Uenoidae								
Neophylax	4	SC	cn	2	2			
Limnephilidae								
Pycnopsyche	3.3	SH	sp,cb,cn			1		
Philopotamidae								
Chimarra	3	FC	cn	8	2		11	51
Dolophilodes	3	GC	cn	1				
Hydroptilidae								
Hydroptila	3.2	SC, PR	cn			2		
Diptera	4.5	PR	bu					1
Chironomidae	6	GC	bu	126	14	9	69	68
Procladius	6.5	PR/GC	sp		1		1	

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Tipulidae	3	SH	bu	3	4	1	2	
Tipula	7.2	SH	bu	1				4
Hexatoma	2.3	PR	bu,sp	2	2	6	1	
Pseudolimnophela	3	PR	bu	4		3		
Dicranota	3	PR	sp, bu		2			
Antocha	2.2	GC	cn	3				
Ceratopogonidae								
Bezzia	6	GC/PR	bu	3	1	4		2
Empididae								
Hemerodromia	6	PR	sp, bu	3				13
Megaloptera								
Corydalidae								
Corydalus	0	PR	cn,cb,sw					1
Nigronia	0	PR	cn,cb,sw	17	1			14
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	3	1	2	3	4
Optioservus	3.6	SC	cn	13	5	1	2	113
Psephenidae								
Ectopria	4	SC	cn	5	4	11		
Hydrophilidae	5	SH	sw			1		
Hydrochus	5	SH	sw			1		
Dryopidae								
Helichus	3.2	SH	cn		1		1	
Hemiptera								
Gerridae					9	8		
Trepobates		PR	sk		1			
Veliidae								
Microvelia		PR	sk	12			1	1
Rhagovelia		PR	sk		1		2	2
Odonata - Anisoptera								
Gomphidae								
Gomphus	1	PR	bu		1	10	3	
Lanthus	1	PR	bu					1
Aeshnidae								
Boyeria	2	PR	bu	1				
Lepidoptera								
Cossidae								
Prionoxystus	5	SH	bu	1				
Decapoda								
Cambaridae								
Cambarus	8.1	OM	bu		3	1	1	
Orconectes	6	OM	bu					2

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Annelida	8	GC	bu			3	12	9
Gastropoda								
Physidae								
Physa	8	SC	bu					4
Total Organisms				**300**	**78**	**79**	**171**	**1086**
Total EPT				**103**	**27**	**18**	**73**	**847**
Total Taxa				**28**	**24**	**17**	**17**	**21**
Total EPT Taxa				**13**	**11**	**5**	**6**	**7**

Benthic Macroinvertebrate Assemblage Data
September 13, 1999

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn					1
Ameletidae								
Ameletus	7	GC	sw,cb				1	
Heptageniidae	4	SC	cn	1	1	1		
Epeorus	4	SC	cn				1	
Stenonema	4	SC	cn				1	32
Heptagenia	4	SC	cn					7
Ephemerellidae	2.1	SC	cn, sp	1				
Eurylophella	2.1	SC	cn,sp			1	1	
Leptophlebiidae	2	GC	sw, cn			2		
Ephemeridae								
Ephemera	3.1	GC	bu		2	1		
Baetidae								
Baetis	3.1	GC	sw,cb				1	
Isonychiidae								
Isonychia	1.9	FC	sw, cn					116
Caenidae								
Caenis	3.1	GC	sp, cb					1
Plecoptera								
Perlidae								
Eccoptura	1	PR	cn	1	2			
Capniidae								
Capnia	1	SH	cn	1				
Leuctridae								
Leuctra	0	SH	sp,cn	1				1
Trichoptera	4	FC	cn		2			
Hydropsychidae								
Hydropsyche	4	FC	cn		2			
Diplectrona	4	FC	cn	6				
Cheumatopsyche	2.9	FC	cn	29	27		19	225
Uenoidae								
Neophylax	4	SC	cn				1	
Limnephilidae								
Platycentropus	4	SH	cb		1			
Psychomyiidae								
Neureclipsis	2.7	FC	cn		1			
Phryganeidae								
Ptilostomis	5	SH	cb			1		
Philopotamidae								
Chimarra	3	FC	cn					20
Diptera	4.5	PR	bu	2				3
Chironomidae	6	GC	bu	202	51	9	46	170
Ablabesmyia	5.2	GC	sp			6		
Orthocladius	3.9	GC	sp, bu	17				
Chironomus	8.1	GC	bu					2

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Tipulidae	3	SH	bu		4			
Tipula	7.2	SH	bu				1	4
Hexatoma	2.3	PR	bu,sp	1	4	4		
Pseudolimnophila	3	PR	bu			1		
Ceratopogonidae								
Bezzia	6	PR,GC	bu		1		1	
Simuliidae								
Simulium	6	FC	cn					39
Empididae								
Hemerodromia	6	PR	sp, bu	1				
Megaloptera								
Corydalidae								
Corydalus	0	PR	cn,cb,sw					5
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	8	1	4		
Optioservus	3.6	SC	cn		1		1	45
Psephenidae								
Ectopria	4	SC	cn	5	1	3		
Hydrophilidae	5	GC	dv, sw	1				
Helochares	5	GC	dv, sw	1		1		
Dryopidae								
Helichus	3.2	SH	cn					2
Hemiptera								
Veliidae		PR	sk			4		
Microvelia		PR	sk	2	3		1	
Hydrometridae								
Hydrometra		PR	sk					1
Odonata -Anisoptera								
Gomphidae								
Gomphus	1	PR	bu			4		
Lanthus	1	PR	bu					1
Ophiogomphus	1	PR	bu				1	
Odonata - Zygoptera								
Calopterygidae								
Calopteryx	3.7	PR	cb	1				
Decapoda								
Cambaridae								
Cambarus	8.1	OM	bu	1	1	6		
Annelida	8	GC	bu		1	3		31
Naididae	8	GC	bu	2				
Tubificidae	8	GC	bu	1				

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Total Organisms				**296**	**106**	**51**	**76**	**706**
Total EPT				**48**	**38**	**6**	**25**	**403**
Total Taxa				**20**	**16**	**16**	**13**	**17**
Total EPT Taxa				**8**	**7**	**5**	**7**	**7**

Benthic Macroinvertebrate Assemblage Data
November 1, 1999

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn					1
Ameletidae								
Ameletus	7	GC	sw,cb	3	3	4		
Heptageniidae	4	SC	cn			1		
Stenonema	4	SC	cn	8	3		10	37
Ephemerellidae								
Ephemerella	2.9	GC	cn,sw	4				
Eurylophella	2.1	SC	cn, sp		10	27	32	4
Serratella	0.6	GC	cn					1
Leptophlebiidae								
Leptophlebia	2	GC	sw,cn,sp			1		
Ephemeridae								
Ephemera	3.1	GC	bu		6	2	3	
Caenidae								
Caenis	3.1	GC	sp, cb		1			1
Isonychiidae								
Isonychia	1.9	FC	sw, cn				1	12
Baetiscidae								
Baetisca	3	GC	sp					68
Baetidae								
Baetis	3.1	GC	sw, cb				1	
Plecoptera	1	PR	cn		1	7		
Perlidae								
Eccoptura	1	PR	cn	1		1		
Perlodidae	2	PR	cn			1		
Diploperla	2	PR	cn				1	
Capniidae								
Allocapnia	1	SH	sp, cn		39	653	46	15
Nemouridae								
Nemoura	2	SH	sp,cn	5	5	138	27	
Prostoia	2	SH	sp, cn		7			
Chloroperlidae								
Haploperla	1	PR	cn	2				
Leuctridae								
Leuctra	0	SH	sp,cn	19	19	440	23	12
Taeniopterygidae								
Taeniopteryx	2	SH	sp, cn					6
Trichoptera								
Hydropsychidae								
Hydropsyche	4	FC	cn	3	10		2	
Diplectrona	4	FC	cn	13				
Cheumatopsyche	2.9	FC	cn	96	38	1	31	91
Uenoidae								
Neophylax	4	SC	cn			1		

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Limnephilidae								
Pycnopsyche	3.3	SH	sp,cb,cn					2
Philopotamidae								
Chimarra	3	FC	cn		1			11
Psychomyiidae								
Nyctiophylax	2.5	FC	cn		1			
Rhyacophilidae								
Rhyacophila	0	PR	cn			4		
Diptera	4.5	PR	bu			1		
Chironomidae	6	GC	bu	718	241	80	127	67
Orthocladius	3.9	GC	sp, bu	37	43		27	2
Tipulidae	3	SH	bu	28	6	1	1	5
Tipula	7.2	SH	bu			2		2
Hexatoma	2.3	PR	bu,sp	7		9	2	
Pseudolimnophila	3	PR	bu	4	3	3	1	
Antocha	2.2	GC	cn	2				
Dicranota	3	PR	sp, bu			3		
Ceratopogonidae								
Bezzia	6	GC/PR	bu	3	3	9	3	
Empididae								
Hemerodromia	6	PR	sp, bu	6				
Athericidae								
Atherix	2	PR	sp, bu	1				
Simuliidae								
Simulium	6	FC	cn					1
Megaloptera								
Corydalidae								
Nigronia	0	PR	cn,cb,sw			1		
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	2				1
Optioservus	3.6	SC	cn	7	9	9	7	30
Psephenidae								
Ectopria	4	SC	cn		1	6		
Psephenus	4	SC	cn				2	
Dryopidae								
Helichus	5	SC	cn			2		
Hydrophilidae								
Helochares	5	GC	dv, sw				1	
Hemiptera					1			
Veliidae								
Microvelia		PR	sk		1			
Odonata - Anisoptera								
Gomphidae								
Gomphus	1	PR	bu		1			

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Lanthus	1	PR	bu			9		1
Aeshnidae								
Boyeria	3	PR	cb, sp			1		
Cordulegastridae								
Cordulegaster	3	PR	bu			1		
Odonata - Zygoptera								
Calopterygidae								
Calopteryx	5	PR	cb				1	
Annelida	8	GC	bu		2	8	2	61
Total Organisms				**969**	**455**	**1428**	**351**	**431**
Total EPT				**154**	**144**	**1283**	**177**	**261**
Total Taxa				**20**	**22**	**27**	**21**	**20**
Total EPT Taxa				**10**	**13**	**13**	**11**	**12**

Benthic Macroinvertebrate Assemblage Data
January 5, 2000

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn			1		2
Ameletidae								
Ameletus	7	GC	sw,cb	13	3	7	1	3
Heptageniidae								
Epeorus	4	SC	cn		2		1	
Stenonema	4	SC	cn	1			2	15
Stenacron	3.1	SC	cn		1			
Ephemerellidae								
Ephemerella	2.9	GC	cn,sw	2				
Eurylophella	2.1	SC	cn,sp		1		1	2
Serratella	0.6	GC	cn		2			
Ephemeridae								
Ephemera	3.1	GC	bu	1				
Isonychiidae								
Isonychia	1.9	FC	sw, cn					5
Caenidae								
Caenis	3.1	GC	sp, cb					1
Plecoptera								
Perlidae								
Eccoptura	1	PR	cn	1				
Perlodidae								
Clioperla	2	PR	cn	1			1	
Malirekus	2	PR	cn	1		1		1
Cultus	2	PR	cn	1				
Isoperla	2	PR	cn, sp	2	1			
Diploperla	2	PR	cn		1		2	1
Capniidae								
Capnia	1	SH	cn		1	4		
Nemouridae								
Nemoura	2	SH	sp,cn	1	26	2	20	3
Prostoia	2	SH	sp, cn					54
Chloroperlidae								
Haploperla	1	PR	cn		1			
Leuctridae								
Leuctra	0	SH	sp,cn		3	2		
Paraleuctra	0	SH	sp,cn	1				
Taeniopterygidae								
Taeniopteryx	2	SH	sp, cn		7		6	16
Trichoptera								
Hydropsychidae								
Hydropsyche	4	FC	cn	2	1	1		
Diplectrona	4	FC	cn	12	1	2		
Cheumatopsyche	2.9	FC	cn	47	18	3	7	8
Uenoidae								
Neophylax	4	SC	cn	47	12	14	24	

	Tolerance Value	**Functional Feeding Group**	Habit/ **Behavior**	**WB 4**	**WB 3**	**WB 2**	**WB 1**	**12 Pole**
Philopotamidae								
Chimarra	3	FC	cn	4			1	
Dolophilodes	3	GC	cn		1			
Psychomyiidae								
Neureclipsis	2.7	FC	cn		1			
Rhyacophilidae								
Rhyacophila	0	PR	cn			2		4
Diptera								
Chironomidae	6	GC	bu	724	365	17	34	45
Orthocladius/pupa	3.9	GC	sp, bu	5		2		
Unknown pupa	6				6		1	
Tipulidae	3	SH	bu	2	4	2		
Tipula	7.2	SH	bu	1	1		3	6
Hexatoma	2.3	PR	bu,sp	6	1	2		
Pseudolimnophila	3	PR	bu	1				
Pedicia	3	PR	bu		2			
Ceratopogonidae								
Bezzia	6	PR,GC	bu		2			1
Empididae								
Hemerodromia	6	PR	sp, bu	10	1			
Chaoboridae								
Chaoborus	8	PR	sp	4				
Tabanidae								
Chrysops	4.6	GC,PR	sp, bu	1				
Megaloptera								
Corydalidae								
Nigronia	0	PR	cn,cb,bu				1	
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	1				1
Optioservus	3.6	SC	cn	1	4	3	3	7
Psephenidae								
Ectopria	4	SC	cn	3	2	4		
Annelida	8	GC	bu	1				4
Nematoda	8	PA	bu	1				
Mollusca								
Gastropoda								
Physidae								
Physella	7.6	SC	bu					1
Planorbidae	6.5	SC	bu					1
Bivalvia								
Sphaeriidae								
Pisidium	4.6	FC	bu					1

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Total Organisms				**898**	**471**	**69**	**108**	**182**
Total EPT				**137**	**83**	**39**	**66**	**115**
Total Taxa				**29**	**26**	**17**	**15**	**21**
Total EPT Taxa				**16**	**18**	**11**	**11**	**12**

Benthic Macroinvertebrate Assemblage Data
March 10, 2000

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn	1		1		
Ameletidae								
Ameletus	7	GC	sw, cb	10		11	3	1
Heptageniidae	4	SC	cn		1		1	
Epeorus	4	GC	cn			3		
Stenonema	4	SC	cn			10	3	4
Stenacron	4	GC	cn				1	
Leucrocuta	4	SC	cn		4			
Ephemerellidae								
Ephemerella	2.9	GC	cn, sw			6		
Eurylophella	2.1	SC	cn, sp		1		8	
Serratella	0.6	GC	cn	7	5		11	
Ephemeridae								
Ephemera	3.1	GC	bu	1	1			
Caenidae								
Caenis	3.1	GC	sp, cb			1		3
Baetiscidae								
Baetisca	3	GC	sp					3
Plecoptera	2	PR	cn		2			
Perlodidae								
Clioperla	2	PR	cn		3	1	1	
Malirekus	2	PR	cn	1				
Cultus	2	PR	cn			2		1
Diploperla	2	PR	cn		1			
Capniidae								
Capnia	1	SH	cn		1			
Nemouridae	2	SH					1	
Nemoura	2	SH	sp, cn				1	11
Amphinemura	2	SH	sp, cn			16	16	
Prostoia	2	SH	sp, cn		10		12	
Chloroperlidae								
Haploperla	1	PR	cn	2			2	
Alloperla	1	PR	cn			4		
Leuctridae								
Leuctra	0	SH	sp,cn	3			2	
Taeniopterygidae								
Strophopteryx	2	SC	sp, cn				1	
Trichoptera								
Hydropsychidae	4	FC	cn	2				
Hydropsyche	4	FC	cn	5	1		4	
Diplectrona	4	FC	cn	2			1	
Cheumatopsyche	2.9	FC	cn	101	7		3	3
Uenoidae								
Neophylax	4	SC	cn	5	29	26	21	2

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Limnephilidae								
Pycnopsyche	3.3	SH	sp,cb,cn			1		
Philopotamidae	3	FC	cn	1				
Chimarra	3	FC	cn	8				2
Dolophilodes	3	FC	cn	1	1		1	
Diptera								
Chironomidae	6	GC	bu	336	164	5	50	23
Orthocladius	3.9	GC	sp	23	19	1	2	1
Procladius	6.5	PR,GC	sp				2	
Tipulidae	3	SH	bu	4	3	1	1	
Tipula	7.2	SH	bu	3	3		1	3
Hexatoma	2.3	PR	bu,sp		7	1		
Pseudolimnophela	3	PR	bu	10				
Ceratopogonidae								
Bezzia	6	GC/PR	bu	1	2	5		
Empididae								
Hemerodromia	6	PR	sp, bu	1				1
Tabanidae	6	PR	sp, bu			2		
Simuliidae								
Simulium	6	FC	cn			1	3	
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	2		1		2
Optioservus	3.6	SC	cn		1		1	2
Psephenidae								
Ectopria	4	SC	cn		2	5		
Dryopidae								
Helichus	3.2	SH	cn		1			
Hemiptera								
Viliidae								
Microvelia		PR	sk	1				
Odonata-Anisoptera								
Gomphidae								
Gomphus	1	PR	bu					2
Annelida	8	GC	bu	1	3			3
Decapoda								
Cambaridae								
Cambarus	8.1	OM	bu	1		1	1	
Mollusca								
Gastropoda								
Planorbidae	6.5	SC	bu					1

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Total Organisms				**533**	**272**	**105**	**154**	**68**
Total EPT				**150**	**67**	**82**	**93**	**30**
Total Taxa				**22**	**21**	**22**	**24**	**18**
Total EPT Taxa				**12**	**12**	**11**	**17**	**9**

Benthic Macroinvertebrate Assemblage Data
May 10, 2000

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Ephemeroptera	3	GC	cn			3		5
Ameletidae								
Ameletus	7	GC	sw,cb	6	6	23	88	5
Heptageniidae								
Heptagenia	4	SC	cn			5		
Epeorus	4	SC	cn		1		1	4
Stenonema	5	SC	cn	9			1	8
Ephemerellidae								
Ephemerella	2.9	GC	cn,sw		2	16	10	
Drunella	1	PR	cn,sp		2	10	12	
Eurylophella	2.1	SC	cn,sp			2	1	
Isonychiidae								
Isonychia	1.9	FC	sw,cn				2	8
Baetidae								
Baetis	3.1	GC	sw, cb	17	20			12
Baetiscidae								
Baetisca	3	GC	sp					3
Plecoptera	2	PR	cn	6				1
Perlidae								
Eccoptura	1	PR	cn	4			3	
Perlesta	4.5	PR	cn	14	4			
Perlodidae								
Clioperla	2	PR	cn					3
Malirekus	2	PR	cn	1				
Cultus	2	PR	cn	1	1			
Remenus	2	PR	cn		2			
Nemouridae								
Nemoura	2	SH	sp,cn			1	3	
Amphinemura	2	SH	sp, cn	3	10	7	11	2
Chloroperlidae								
Alloperla	1	PR	cn				1	
Leuctridae								
Leuctra	0	SH	sp,cn	9	3	10	5	
Trichoptera	4	FC	cn		1			
Hydropsychidae	4	FC	cn		3			
Hydropsyche	4	FC	cn				1	
Diplectrona	4	FC	cn	16			4	
Cheumatopsyche	2.9	FC	cn	477	33		3	7
Uenoidae								
Neophylax	4	SC	cn	2		11	10	
Philopotamidae								
Chimarra	3	FC	cn	2				
Dolophilodes	3	GC	cn				1	
Diptera	4.5	PR	bu	14		1		
Chironomidae	6	GC	bu	1005	146	34	342	147

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Orthocladius	3.9	GC	sp, bu		7	2	8	6
Procladius	6.5	PR,GC	sp	17	2		16	
Ablabesmyia	8	PR	sp		2			
Chironomus	10	GC	bu		1			
Tipulidae	3	SH	bu		10			
Tipula	7.2	SH	bu	2	1	5	4	
Hexatoma	2.3	PR	bu,sp	6	3	2	1	
Dicranota	3	PR	sp, bu	5	8	1		
Ceratopogonidae								
Bezzia	6	GC/PR	bu	17	6	1	5	6
Culicoides	6	PR/GC	bu				3	
Athericidae								
Atherix	2	PR	sp, bu	1			2	
Simulidae								
Simulium	6	FC	cn	2	2			3
Empididae								
Hemerodromia	6	PR	sp, bu	8	2			
Clinocera	6	PR	cn	2				
Dixidae								
Dixella	2.8	GC	sw, cb	20				
Megaloptera								
Corydalidae								
Nigronia	0	PR	cn,cb,bu		1			
Coleoptera								
Elmidae								
Stenelmis	3	SC	cn	12	10	7	1	5
Optioservus	3.6	SC	cn	8	3	7	3	5
Psephenidae								
Ectopria	4	SC	cn		1		1	
Isopoda								
Asellus (Caecidotea)	8	GC				1		
Odonata - Anisoptera								
Gomphidae								
Gomphus	1	PR	bu		5		2	
Lanthus	1	PR	bu	1				
Lepidoptera								
Cossidae								
Prionoxystus	5	SH	sw, dv	1				
Hemiptera		PR	sk		1			
Gyrinidae								
Dineutus		PR	sk	1				
Notonectidae		PR	sk	1				
Annelida	8	GC	bu	4		1	1	21

	Tolerance Value	Functional Feeding Group	Habit/ Behavior	WB 4	WB 3	WB 2	WB 1	12 Pole
Decapoda								
Cambaridae								
Cambarus	8.1	OM	bu	1	1			
Mollusca								
Bivalvia								
Sphaeracea								
Corbiculidae								
Corbicula fluminea	3.2	FC	bu					1
Sphaeriidae								
Pisidium	4.6	FC	bu					9
Gastropoda								
Physidae								
Physella	7.6	SC	bu					1
Total Organisms				**1695**	**300**	**150**	**547**	**262**
Total EPT				**567**	**88**	**88**	**157**	**58**
Total Taxa				**32**	**29**	**19**	**31**	**19**
Total EPT Taxa				**13**	**11**	**9**	**17**	**9**

APPENDIX E

Benthic Macroinvertebrate Metrics

APPENDIX E

Appendix E contains nine different metric evaluations for each sampling date and station. A description of each metric can be found in the Materials and Methods section of this paper. The first six metrics are used to determine the West Virginia Stream Condition Index (Appendix F). The last three metrics are used to evaluate potential impacts to the riparian zone.

February 10, 1999

Metric	WB4	WB3	WB2	WB1	12 Pole
Taxa Richness	16	21	29	14	15
EPT Index	15	14	18	8	12
Percent EPT	0.69	0.84	0.80	0.62	0.84
Percent Chironomidae	0.31	0.08	0.06	0.04	0.12
Percent Top Two Dominant Families	0.31 Chironomidae Nemouridae	0.46 Nemouridae Heptageniidae	0.33 Heptageniidae Nemouridae	0.30 Elmidae Philopotamidae	0.41 Nemouridae Ameletidae
Modified Hilsenhoff Biotic Index	3.78	3.12	3.23	3.09	3.21
Percent filterer-collectors to total organisms	0.03	0.04	0.05	0.41	0.06
Percent grazer-scrapers to total organisms	0.06	0.16	0.35	0.46	0.08
Percent shredders to total organisms	0.3	0.6	0.3	0.04	0.5

May 27, 1999

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	10	17	34	17	13
EPT Index	4	11	20	10	6
Percent EPT	0.40	0.55	0.38	0.38	0.27
Percent Chironomidae	0.13	0.22	0.20	0.54	0.42
Percent Top Two Dominant Families	0.38 Annelida Heptageniidae	0.22 Chironomidae Ephemerellidae	0.35 Tipulidae Leutridae	0.54 Chironomidae Hydropsychidae	0.42 Chironomidae Elmidae
Modified Hilsenhoff Biotic Index	5.89	4.04	2.92	4.36	4.85
Percent filterer-collectors to total organisms	0	0.06	0.004	0.12	0.22
Percent grazer-scrapers to total organisms	0.22	0.16	0.08	0.06	0.25
Percent shredders to total organisms	0.09	0.12	0.55	0.14	0.01

July 13, 1999

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	28	24	17	17	21
EPT Index	13	11	5	6	7
Percent EPT	0.34	0.35	0.23	0.43	0.78
Percent Chironomidae	0.42	0.19	0.11	0.41	0.06
Percent Top Two Dominant Families	0.42 Chironomidae Hydropsychidae	0.19 Chironomidae Gerridae	0.16 Leutridae Psephenidae	0.41 Chironomidae Hydropsychidae	0.28 Hydropsychidae Isonychidae
Modified Hilsenhoff Biotic Index	3.8	3.7		4.7	3.20
Percent filterer-collectors to total organisms	0.16	0.16	0	0.35	0.58
Percent grazer-scrapers to total organisms	0.08	0.23	0.22	0.07	0.30
Percent shredders to total organisms	0.09	0.09	0.20	0.02	0.01

September 13, 1999

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	20	16	16	13	17
EPT Index	8	7	5	7	7
Percent EPT	0.16	0.36	0.12	0.33	0.57
Percent Chironomidae	0.74	0.48	0.29	0.61	0.24
Percent Top Two Dominant Families	0.74 Chironomidae Hydropsychidae	0.48 Chironomidae Hydropsychidae	0.29 Chironomidae Cambaridae	0.61 Chironomidae Hydropsychidae	0.32 Hydropsychidae Chironomidae
Modified Hilsenhoff Biotic Index	5.10	4.57	4.44	4.90	4.01
Percent filterer-collectors to total organisms	0.12	0.30	0.25	0.25	0.57
Percent grazer-scrapers to total organisms	0.05	0.04	0.07	0.07	0.12
Percent shredders to total organisms	0.02	0.01	0.02	0.01	0.01

November 1, 1999

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	20	22	27	21	20
EPT Index	10	13	13	11	12
Percent EPT	0.16	0.32	0.90	0.50	0.61
Percent Chironomidae	0.74	0.53	0.06	0.36	0.16
Percent Top Two Dominant Families	0.78 Chironomidae Hydropsychidae	0.62 Chironomidae Hydropsychidae	0.46 Capnidae Leutridae	0.44 Chironomidae Capniidae	0.21 Hydropsychidae Chironomidae
Modified Hilsenhoff Biotic Index	5.24	4.43	1.25	3.64	4.10
Percent filterer-collectors to total organisms	0.12	0.11	0.001	0.10	0.27
Percent grazer-scrapers to total organisms	0.02	0.05	0.03	0.15	0.17
Percent shredders to total organisms	0.05	0.17	0.86	0.28	0.10

January 5, 2000

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	29	26	17	15	21
EPT Index	16	18	11	11	12
Percent EPT	0.15	0.18	0.57	0.61	0.63
Percent Chironomidae	0.81	0.79	0.28	0.32	0.25
Percent Top Two Dominant Families	0.81 Chironomidae Hydropsychidae	0.79 Chironomidae Nemouridae	0.27 Chironomidae Uenoidae	0.32 Chironomidae Uenoidae	0.31 Nemouridae Chironomidae
Modified Hilsenhoff Biotic Index	5.54	5.34	4.15	4.05	3.71
Percent filterer-collectors to total organisms	0.07	0.05	0.09	0.07	0.08
Percent grazer-scrapers to total organisms	0.06	0.05	0.30	0.30	0.15
Percent shredders to total organisms	0.01	0.09	0.14	0.27	0.43

March 10, 2000

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	22	21	22	24	18
EPT Index	12	12	11	17	9
Percent EPT	0.28	0.25	0.78	0.60	0.44
Percent Chironomidae	0.67	0.67	0.06	0.35	0.35
Percent Top Two Dominant Families	0.67 Chironomidae Hydropsychidae	0.67 Chironomidae Uenoide	0.25 Uenoidae Nemouridae	0.35 Chironomidae Nemouridae	0.35 Chironomidae Nemouridae
Modified Hilsenhoff Biotic Index	5.00	5.01	3.98	3.93	4.46
Percent filterer-collectors to total organisms	0.23	0.03	0.01	0.08	0.07
Percent grazer-scrapers to total organisms	0.01	0.14	0.43	0.23	0.16
Percent shredders to total organisms	0.02	0.06	0.17	0.22	0.21

May 10, 2000

Metric	WB 4	WB 3	WB 2	WB 1	12 Pole
Taxa Richness	32	29	19	31	19
EPT Index	13	11	9	17	9
Percent EPT	0.34	0.29	0.59	0.29	0.22
Percent Chironomidae	0.60	0.53	0.23	0.63	0.58
Percent Top Two Dominant Families	0.60 Chironomidae Hydropsychidae	0.53 Chironomidae Hydropsychidae	0.23 Chironomidae Ephemerellidae	0.63 Chironomidae Ameletidae	0.58 Chironomidae Annelida
Modified Hilsenhoff Biotic Index	4.89	4.71	4.26	5.63	5.39
Percent filterer-collectors to total organisms	0.29	0.13	0	0.02	0.11
Percent grazer-scrapers to total organisms	0.02	0.05	0.21	0.03	0.09
Percent shredders to total organisms	0.01	0.08	0.15	0.04	0.01

APPENDIX F

West Virginia Stream Condition Index

APPENDIX F

Appendix F is the West Virginia Stream Condition Index (WV-SCI) evaluation for six metrics on all sampling dates and sites. There is also a table summarizing the index values for each site and date. The rating system for WV-SCI scores is given as well. Procedures for this evaluation were found in *A Stream Condition Index for West Virginia Wadeable Streams* (Gerritsen et al. 2000).

Standardization formulas were as follows: (X = metric value)

Total taxa	score = $100 \times (X/21)$
EPT taxa	score = $100 \times (X/13)$
% EPT	score = $100 \times (X/91.9)$
% Chironomidae	score = $100 \times [(100-X)/(100-0.98)]$
% 2 dominant	score = $100 \times [(100-X)/(100-36.0)]$
HBI	score = $100 \times [(10-X)/(10-2.9)]$

Reference Criteria

Parameter	Criterion
Dissolved oxygen	$\geq$ 6.0 mg/l
pH	$\geq$ 6.0 and $\leq$ 9.0
Conductivity	< 500 umhos/cm
Fecal coliform	< 800 colonies/100ml
No obvious sources of non-point source pollution	
Epifaunal substrate score	$\geq$ 11
Channel alteration score	$\geq$ 11
Sediment deposition score	$\geq$ 11
Bank disruptive pressure score	$\geq$ 11
Riparian vegetation zone width score	$\geq$ 6 (variable depending on watershed)
Total habitat score	65% of maximum 240 (% is variable depending on watershed)
Evaluation of anthropogenic activities/disturbances	Best professional judgment
No known point source discharges upstream of assessment site	

February 10, 1999

	WB4	WB3	WB2	WB1	12P
Total Taxa	76	100	138(100)	67	71
EPT Taxa	115(100)	115(100)	133(100)	62	92
%EPT	75	91	87	68	91
%Chironomidae	70	93	95	97	89
% 2 dominant	73	66	83	67	70
HBI	88	97	95	97	96
Final Index Score	**80**	**91**	**93**	**76**	**85**

May 27, 1999

	WB4	WB3	WB2	WB1	12P
Total Taxa	48	81	162(100)	81	62
EPT Taxa	31	85	154(100)	77	46
%EPT	44	60	41	41	29
%Chironomidae	88	79	81	47	59
% 2 dominant	66	102(100)	66	59	56
HBI	58	84	100	79	73
Final Index Score	**56**	**82**	**81**	**64**	**54**

July 13, 1999

	WB4	WB3	WB2	WB1	12P
Total Taxa	133(100)	114(100)	81	81	100
EPT Taxa	100	85	39	46	54
%EPT	37	38	25	47	85
%Chironomidae	59	82	90	60	95
% 2 dominant	70	106(100)	109(100)	47	73
HBI	87	89	97	75	96
Final Index Score	**76**	**82**	**72**	**59**	**84**

September 13, 1999

	WB4	WB3	WB2	WB1	12P
Total Taxa	95	76	76	62	81
EPT Taxa	62	54	39	54	54
%EPT	17	39	13	36	62
%Chironomidae	26	53	72	39	77
% 2 dominant	31	36	92	22	69
HBI	69	77	78	72	84
Final Index Score	**50**	**56**	**62**	**48**	**71**

November 1, 1999

	WB4	WB3	WB2	WB1	12P
Total Taxa	95	105(100)	129(100)	100	95
EPT Taxa	77	100	100	85	92
%EPT	17	35	98	54	66
%Chironomidae	26	48	95	65	85
% 2 dominant	16	42	36	67	98
HBI	67	79	123(100)	90	83
Final Index Score	**50**	**67**	**88**	**77**	**87**

January 5, 2000

	WB4	WB3	WB2	WB1	12P
Total Taxa	138(100)	124(100)	81	71	100
EPT Taxa	123(100)	139(100)	85	85	92
%EPT	16	20	62	66	69
%Chironomidae	19	21	73	69	76
% 2 dominant	19	25	81	70	69
HBI	63	66	83	84	89
Final Index Score	**53**	**55**	**78**	**74**	**83**

March 10, 2000

	WB4	WB3	WB2	WB1	12P
Total Taxa	105(100)	100	105(100)	114(100)	86
EPT Taxa	92	92	85	131(100)	69
%EPT	31	27	85	65	48
%Chironomidae	33	33	95	66	66
% 2 dominant	19	34	94	70	75
HBI	70	70	85	86	78
Final Index Score	**58**	**59**	**91**	**81**	**70**

May 10, 2000

	WB4	WB3	WB2	WB1	12P
Total Taxa	152(100)	138(100)	91	148(100)	91
EPT Taxa	100	85	69	131(100)	69
%EPT	34	32	64	32	24
%Chironomidae	40	48	78	37	42
% 2 dominant	16	55	89	27	53
HBI	72	75	81	62	65
Final Index Score	**60**	**66**	**79**	**60**	**57**

Summary of West Virginia Stream Index Values

	Feb-99	May-99	Jul-99	Sep-99	Nov-99	Jan-00	Mar-00	May-00
WB4	80	56	76	50	50	53	58	60
WB3	91	82	82	56	67	55	59	66
WB2	93	82	72	62	88	78	91	79
WB1	76	64	59	48	77	74	81	60
12P	85	54	84	71	87	83	70	57

Rating system for West Virginia SCI scores.

SCI score	Rating
> 78 – 100	Highly comparable to reference sites (above 25th percentile)
> 68 – 77	Comparable to below-average reference sites (between 5th and 25th percentiles)
> 46 – 68 > 23 – 45 0 – 22	Increasingly different from reference condition