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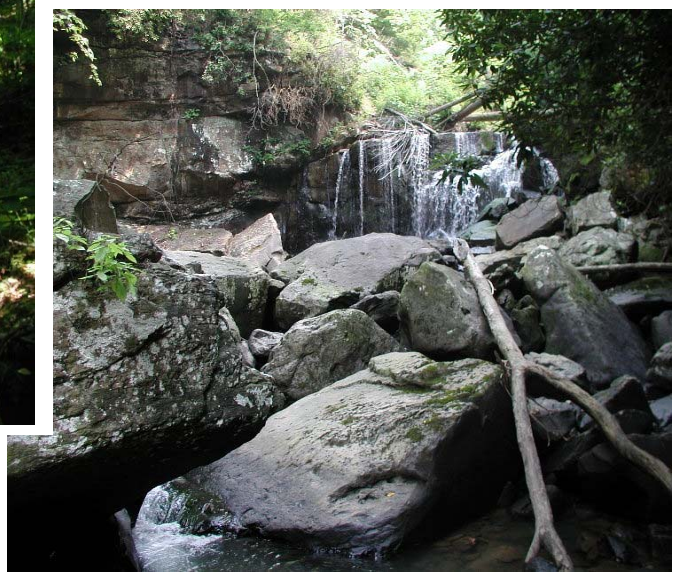
Northeast Region
Philadelphia, Pennsylvania

Condition Assessment of 5 Tributary Watershed Ecosystems At Allegheny Portage Railroad National Historic Site and New River Gorge National River

Technical Report NPS/NER/NRTR-2007/086



ON THE COVER
Top left: Photograph of Blair Gap Run (Station ALPO 25) at Allegheny Portage Railroad NHS.
Bottom right: Photograph of Wolf Creek (Station WC 37), tributary watershed in the New River Gorge NR.
Photographs by: Brian Armstrong.

Condition Assessment of 5 Tributary Watershed Ecosystems At Allegheny Portage Railroad National Historic Site and New River Gorge National River

Technical Report NPS/NER/NRTR-2007/086

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April 2007

U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

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Executive Summary

This report presents the results of a pilot study conducted from June 2004 to August 2004, which used a Watershed Monitoring Matrix (WMM) to characterize the aquatic ecosystem condition of two national parks within the Eastern Rivers and Mountains Network: Allegheny Portage Railroad National Historic Site (ALPO) and New River Gorge National River (NERI). The WMM was applied on a watershed basis, focusing on the contributing watersheds to each park, which provided identification of potential stressors both within and outside park boundaries. These assessments were designed to aid personnel in evaluating watershed condition by first conducting a widespread, large-scale assessment followed by a rapid, site-level assessment to identify potential threats and an intensive assessment to evaluate the biological community's responses to those threats.

The following five watersheds were selected: 1) Blair Gap Run (ALPO), 2) Buffalo Creek (NERI), 3) Fern Creek (NERI), 4) Dunloup Creek (NERI), and 5) Wolf Creek (NERI). Within each watershed, condition assessments were conducted at three levels of effort: Level 1 – landscape assessment; Level 2 –rapid assessment; and Level 3 –intensive assessment.

The Level 1 assessments used Geographic Information System (GIS) software to characterize the landscape patterns within each watershed through the generation of synoptic maps and landscape metrics, producing a Landscape Index score for the entire watershed and for a 1-km radius circle surrounding each sampling site. Although this analysis can be conducted across an entire region at any site, it only provides a coarse assessment of condition. The Level 2 assessment combined the landscape information with site-specific information (including on-site stressor identification) to produce a natural condition score, which ranked sites from least impacted (i.e., closest to natural condition) to most impacted, and a Stream-Wetland-Riparian (SWR) Index score, which provided more diagnostic interpretations regarding the probable causes of impact. This information is most useful for helping to diagnose the causes of observed degradation. Approximately 20 site locations were assessed for large watersheds; fewer were selected for smaller watersheds. The intensive Level 3 assessment was conducted on a subset of the Level 2 sites and focused on two biological assemblages as indicators of condition: aquatic macroinvertebrates and stream-side salamanders. Level 3 assessments are typically used to calibrate Levels 1 and 2 assessments, because they are often labor consuming and expensive to conduct on a large number of sites. Standard Rapid Bioassessment Procedure (RBP) III methods and metrics were used for characterizing the macroinvertebrate community condition, and the Stream Plethodontid Assemblage Response (SPAR) Index was used to assess the condition of the stream salamander assemblage. To facilitate comparisons, final index scores for all levels of assessment were standardized on a 0 – 1 scale and categorized as optimal, suboptimal, marginal, or poor condition. It is these condition categories that form the main basis for comparison. The following results were organized by watershed.

Blair Gap Run Watershed (ALPO)

Although some areas are impacted by acid mine drainage, the Blair Gap Run watershed appears to be largely in suboptimal to optimal condition, when the effects of acid deposition are discounted. This particular stressor is unlikely to be detected in the landscape and rapid

assessments. Such was the case for the ALPO region where site scores tended to decrease from optimal to poor condition as assessments moved from remote to rapid to intensive. This decreasing trend also suggests that impacts are most likely occurring at the site level.

Lower Landscape Index scores were largely due to a combination of insufficient proportions of contiguous forest surrounding the site (reflected by both lower percentages of surrounding forest and lower mean forest patch sizes), higher Landscape Development Index (LDI) scores, and larger areas of impervious surface. Rapid assessment scores decreased largely due to low buffer scores, high incision ratios, presence of invasive plant species, road proximity, poor stream bank condition, and storm water inputs. In several instances, the Level 3 macroinvertebrate community results agreed with the Level 2 results, occasionally even indicating less impact than the SWR Index predicted. These instances occurred in residential areas bordering the park. Sites impacted by acid mine drainage received lower scores in the more intensive biological assessments, usually indicating poor condition. Salamander assemblages are extremely sensitive to acidification; thus, the SPAR Index indicated poor condition at low to moderate levels of acidification, and rated the ALPO sites as poor. The RBP III results revealed impacts at higher levels with only two of the six sites sampled for macroinvertebrates indicating less than optimal condition. At the community level, aquatic macroinvertebrates, with the possible exception of certain mayfly species, appear to be less sensitive to acidification.

Buffalo Creek Watershed (NERI)

Level 1 landscape assessments considered this watershed to be in optimal condition. The rapid and intensive assessments, however, detected the negative results from extreme flood events, such as the July 2001 flood. Rapid assessments identified high incision ratios and poor stream bank condition due to severe erosion during storm events, which dropped the Buffalo Creek sites to suboptimal condition in the Level 2 assessments. Level 3 intensive assessments revealed that both the macroinvertebrate and salamander communities residing in this watershed are adversely affected by an alternating combination of low flow conditions followed by stream bank erosion and washout during storm events and, consequently, rated sites as suboptimal or marginal in condition.

Fern Creek Watershed (NERI)

Like Buffalo Creek, the Fern Creek watershed is mostly forested and rated as optimal in condition by the Level 1 landscape assessment and the majority of the Level 2 rapid assessments, although timber harvesting and railroad activities were identified as potential threats. Level 3 intensive assessments, both macroinvertebrates and salamanders, indicated mostly suboptimal or marginal conditions due largely to the low gradient nature of the streams, which tends to inhibit species diversity and abundance. Overall, Fern Creek represents a low gradient headwater system that, presently, suffers from only minimal human impact. However, results from the rapid assessment suggest that future impacts, especially from development, may occur. Consequently, this watershed does not appear to require active management, but may require protection from future stressors.

Dunloup Creek Watershed (NERI)

This watershed appears to be impacted mainly from sewage contamination, a stressor unlikely to be detected in the coarser assessments. In most cases, site scores decreased as assessments became more intensive, often dropping from optimal condition in the Level 1 landscape assessment to marginal or poor condition in the Level 3 intensive assessments. This trend suggests that much of this watershed is most likely in need of more intensive biological assessments to identify currently intact areas of high ecological integrity that require protection, as well as moderately disturbed sites that show a high potential for restoration.

Wolf Creek Watershed (NERI)

Of the five watersheds included in this pilot study, the WMM identified Wolf Creek as the most impacted from human activities at all levels of assessment and identified a few sites with potential for restoration. Collectively, all assessments revealed moderate to high levels of human disturbance, resulting in poor stream conditions from stormwater inputs and fecal coliform contamination, and a dominance of invasive plant species. Of the Level 3 intensive assessments conducted, all considered sites to be in either marginal or poor condition. Given the high levels of disturbance in this watershed, it is important to identify any locations that may be displaying signs of at least moderate ecological integrity. Thus, more intensive surveys should be directed at locations displaying optimal or suboptimal condition in both the Level 1 landscape and Level 2 rapid assessments to identify additional sites within this watershed that may presently provide good habitat for macroinvertebrates and/or salamanders.

Overall, the Level 2 rapid assessment added information to the Level 1 landscape assessment, resulting in a more accurate approximation of site condition. Results of the Level 3 intensive assessments revealed the condition of the biological communities and detected impacts missed by the rapid assessment. Inclusion of both macroinvertebrates and salamanders as indicators provided more diagnostic evaluations at different levels of impact. Discrepancies between the RBP III and SPAR Index results for these watersheds were due, in part, to differing responses by each assemblage to different stressors, with the salamanders appearing to be more sensitive to acidification and the macroinvertebrate communities responding more to sedimentation and, possibly, organic enrichment. Thus, the choice of assessment level and indicator depends on several factors, including the suite of probable stressors, the number of targeted sites, and the ultimate goals of the project.

These results, combined with the local knowledge and professional expertise of park managers, should produce a powerful tool for evaluating the ecological condition of a watershed and developing appropriate protection, conservation, or restoration strategies. Advice on how to apply the WMM to study watersheds is provided, as well as cautionary statements regarding its limitations.

Introduction

Background

To aid the National Park Service (NPS) in accomplishing the various tasks of interpreting, protecting, and restoring the environmental and cultural resources of its parks, as well as complying with federal and state regulations regarding those resources, a cooperative agreement was established with the Penn State Cooperative Wetlands Center (CWC) of The Pennsylvania State University to develop a tributary watersheds ecosystem monitoring program. The intent of this program is to assess the ecological integrity of selected aquatic ecosystems on a watershed basis (primarily tributary watersheds), allowing identification of both internal and external threats to the aquatic resources within a park.

To aid in this process, the CWC proposed to conduct a pilot study to evaluate the utility of the Watershed Monitoring Matrix (WMM) in conducting assessments of watershed condition at various levels of effort and across a range of human disturbances. The WMM was initially developed by the CWC to assess wetland condition, and has been adapted for watershed application (Brooks et al. 2004).

Project Objectives

The primary objective was to use the WMM's inventorying and assessment techniques, applied at different spatial scales, to determine the aquatic ecosystem condition of the contributing watersheds of two national park units within the Eastern Rivers and Mountains Network: Allegheny Portage Railroad National Historic Site (ALPO) and New River Gorge National River (NERI). Field sampling for this pilot study was conducted between June 2004 and July 2004 at ALPO and July 2004 and August 2004 at NERI.

Study Area

Allegheny Portage Railroad National Historic Site (ALPO)

The major focus for this project was the Blair Gap Run watershed, which drains into the Juniata River and, eventually, the Susquehanna River and the Chesapeake Bay. The main stream, Blair Gap Run, begins near the Cresson Mountain Summit and flows through the park to Duncansville. This fairly large watershed (6,777 ha) drains portions of Blair and Cambria counties, including the towns of Hollidaysburg and Altoona. Urban development, including floodplain development, may be a probable source of stress within the watershed (Blair County Conservation District 2005). Potential impairments to the watershed include sediment pollution from roads and timber harvesting practices (Blair County Conservation District 2005). Approximately 5% of the watershed area is located within the park boundaries (Figure 1).

In addition, an intermittent tributary to Bradley Run, which originates near the park's Main Unit and flows north toward Clearfield and the West Branch of the Susquehanna River, was evaluated at two locations within park boundaries (Figure 1). The tributary's close proximity to the park's Summit Level Visitor Center combined with the probable impacts from adjacent abandoned mines warranted the inclusion of this small headwater stream in this study. However, since only a small portion of this watershed affects the park, we did not conduct a separate watershed assessment. Instead, we included the Bradley Run tributary results in the result tables for each of the assessment levels, but excluded these points when displaying the watershed analyses and multi-level summary table, which were both based on the Blair Gap Run watershed assessment only. Condition assessments were conducted at 18 sites: 16 along Blair Gap Run and its tributaries; two along the unnamed tributary (UNT) to Bradley Run (Figure 1). Appendix A lists information regarding the location and type of assessment conducted for each site.

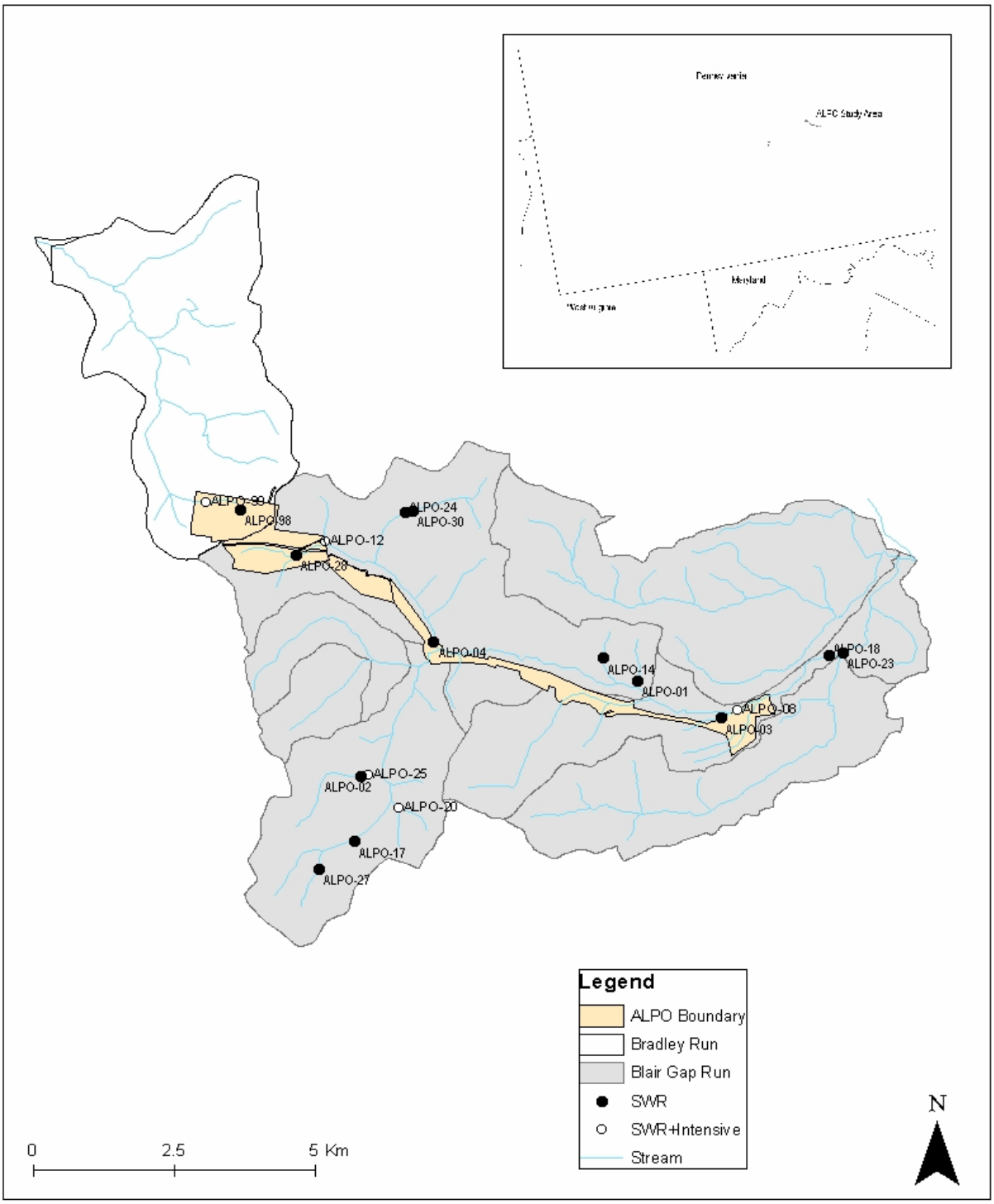

Figure 1. Sampling locations for Allegheny Portage Railroad National Historic Site (ALPO). Black circles denote sites where only landscape and rapid sampling (SWR) occurred. White circles represent sites sampled by landscape, rapid and intensive methods.

New River Gorge National River (NERI)

A total of 51 sites across four tributary watersheds were assessed for New River Gorge National River (Figure 2). The locations and types of assessment conducted at each of these sites are listed in Appendix A. To ensure coverage across a range of human disturbances, an attempt was made to select *a priori* two minimally impacted watersheds (Buffalo Creek, Fern Creek) and two significantly stressed watersheds (Dunloup Creek, Wolf Creek). Due to the difficulty in finding a large watershed with minimal impact throughout, Buffalo Creek and Fern Creek watersheds were chosen despite the fact that they were substantially smaller in size than the more disturbed watersheds of Dunloup Creek and Wolf Creek. A brief description of each watershed follows.

Buffalo Creek Watershed

Buffalo Creek is located between Claremont and Thayer on the east side of the New River, and is a relatively small watershed encompassing 1412 ha. All sampling locations (six total) were located on park property, which represents 26% (373 ha) of the total Buffalo Creek watershed area (Figure 3). The rugged and steep terrain (9% slope along the main channel from the park boundary to the New River confluence; up to 20% slope in tributaries) prohibits most forms of development and agriculture, and can contribute greatly to scouring and widening of the channel during floods. It is important to note the effects of the July 2001 floods, which drastically altered the stream channel and adjacent area through massive downcutting (Purvis et al. 2002). Recovery has commenced and is expected to be a long-going process. In addition, an upstream tributary may be affected by past mining activities.

Fern Creek Watershed

Fern Creek is located between Lansing and Edmond on the east side of the New River, approximately five miles from the National Park Service's Canyon Rim Visitor Center. The park contains the downstream portion of this watershed and covers 10% (98 ha) of the total watershed area (940 ha) and four of the six sites sampled were within park boundaries (Figure 4). The combination of small drainage area and low elevational drop from headwaters to mouth produces insufficient stream energy (i.e., erosive force) to cut to the New River level. This results in a slow-moving, sandy stream with little to no gradient (1.5% slope along much of the mainstem) until it nears the confluence with the New River where a substantial drop in elevation (32% slope) creates a great waterfall. Thus, Fern Creek is different from Buffalo Creek, which has a similar drainage area but much greater decrease in elevation (i.e., more erosive energy). Such differences may account for the lesser impact of the July 2001 flood on the Fern Creek watershed compared to Buffalo Creek. Overall, this small watershed displays only minimal signs of impact (e.g., possible road runoff and a few nearby houses along the upstream portions of the tributaries and main stem), the exception being a clearcut in the area surrounding one of the unnamed tributaries.

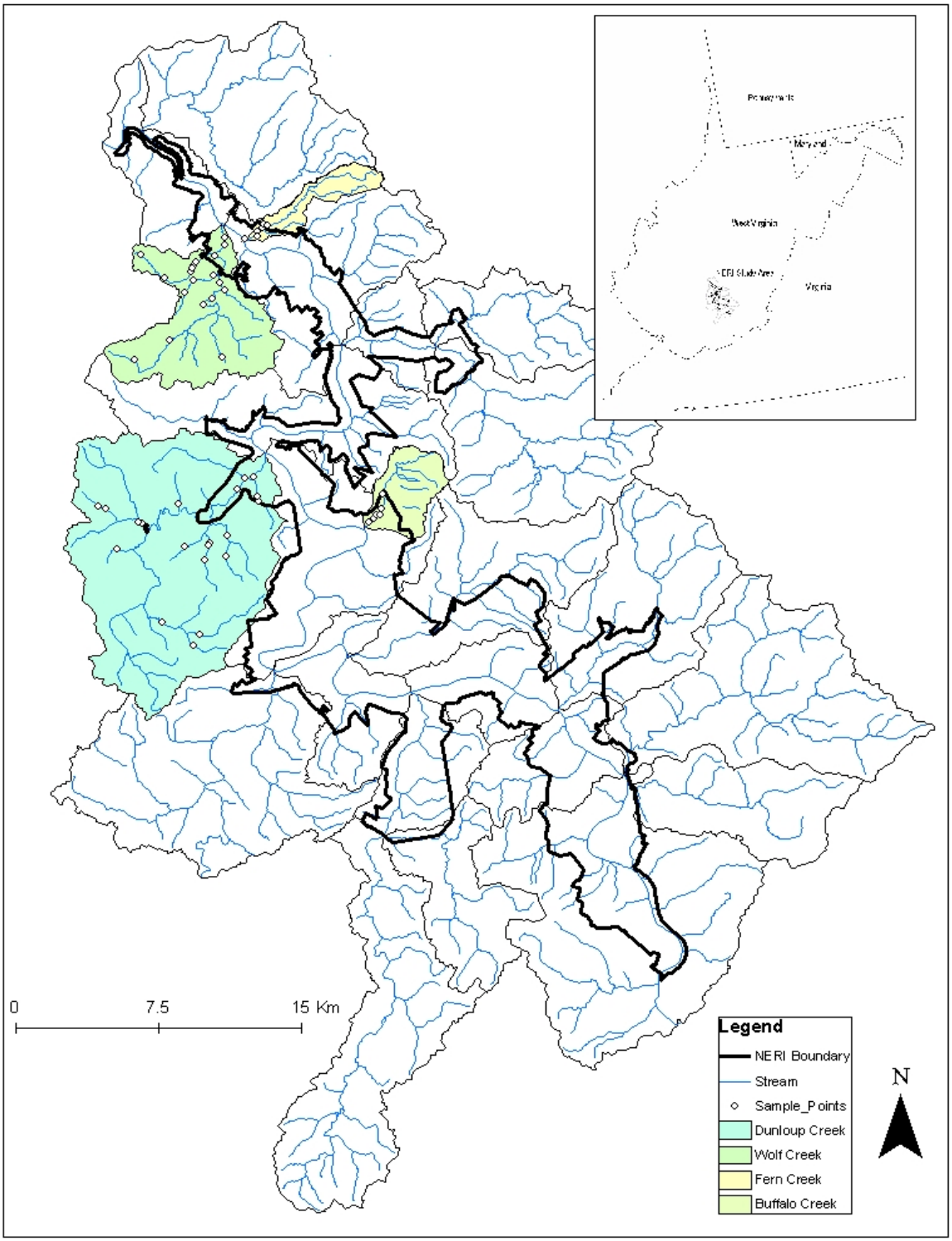

Figure 2. The New River Gorge National River (NERI) area denoting the park boundary and the watersheds sampled for the pilot study.

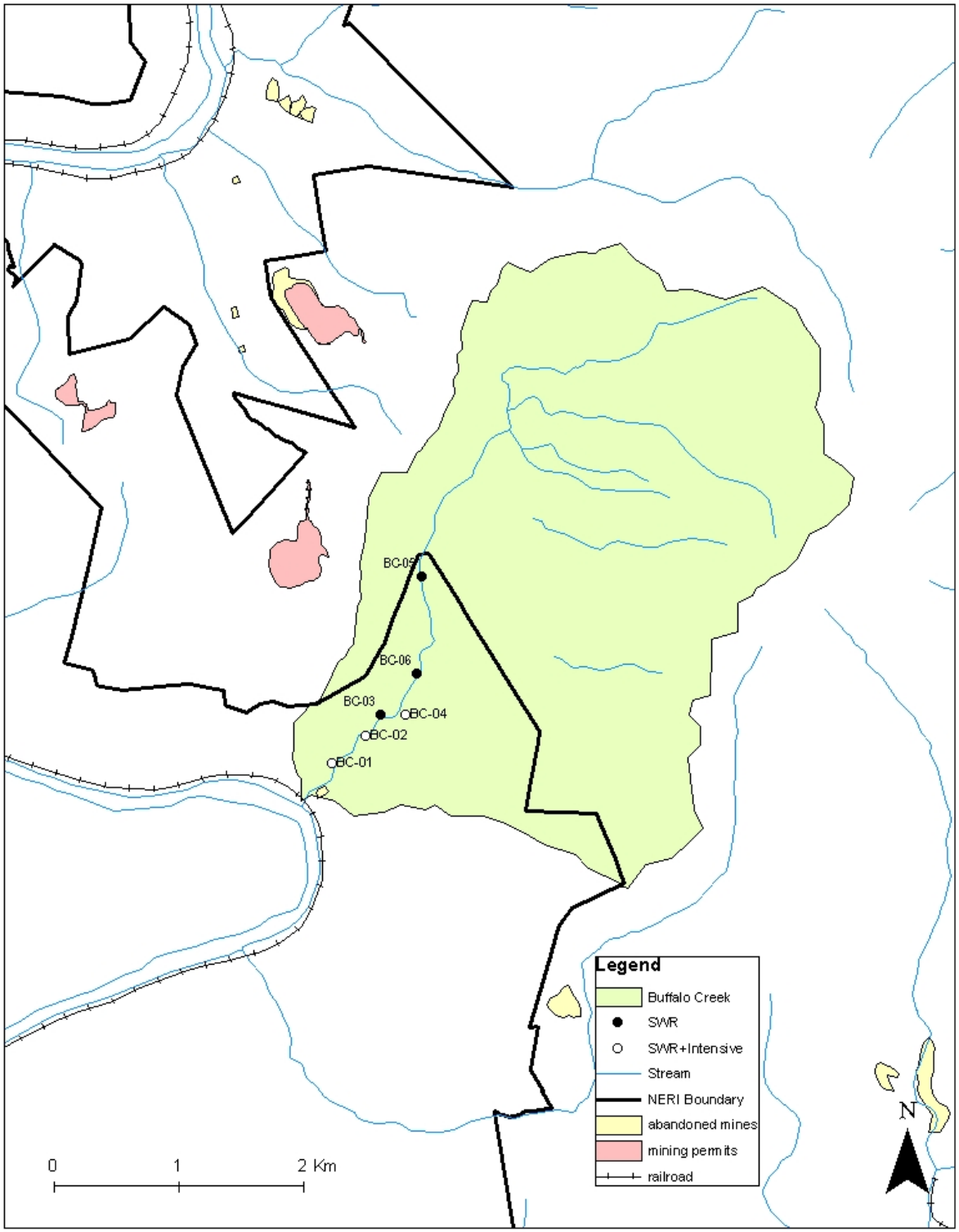

Figure 3. Buffalo Creek watershed, including sampling locations and park boundary. Black circles denote sites where only landscape and rapid (SWR) sampling occurred. White circles represent sites sampled for landscape, rapid and intensive assessments.

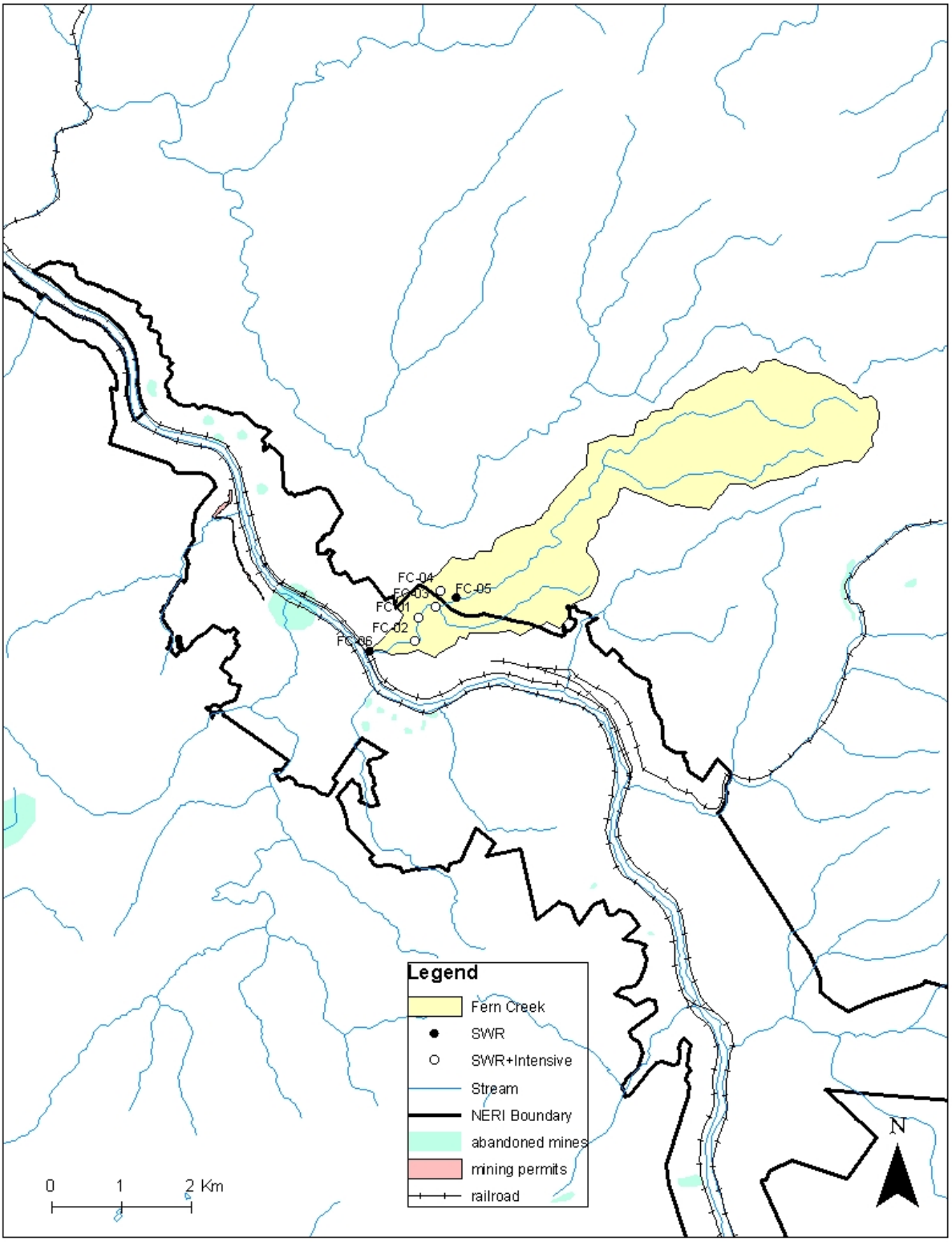

Figure 4. Fern Creek watershed, including sampling locations and park boundary. Black circles denote sites where only landscape and rapid (SWR) sampling occurred. White circles represent sites sampled for landscape, rapid and intensive assessments.

Dunloup Creek Watershed

The Dunloup Creek is a fairly large watershed (12,536 ha) that surrounds the park office in Glen Jean and drains parts of both Fayette and Raleigh counties on the west side of the New River. The downstream portion of Dunloup Creek (725 ha or 6 % of the total watershed area) occurs within the park. Condition assessments were conducted at 20 sampling points, 5 of these points were located inside the park (Figure 5). Although the elevational drop (generally 1-3% slope) is similar to Fern Creek, the larger drainage area of Dunloup Creek creates enough potential stream energy to produce a higher gradient stream network. Impacts to this watershed include urban runoff, improperly treated domestic sewage, and mining (Purvis et al. 2002). Water monitoring along Dunloup Creek frequently reveals high fecal coliform densities (Wilson et al. 2006). This can pose significant risk to aquatic resource condition, as well as human health.

Wolf Creek Watershed

The second largest of the studied watersheds (4,384 ha), Wolf Creek watershed is located south and east of Fayetteville and flows from the west into the New River just south of the Canyon Rim Visitor Center. Condition assessments were conducted at 19 sampling points, three of which were located within the park (Figure 6). Like Dunloup Creek, the lower reaches of the watershed fall within the park (287 ha or 6.5 % or total watershed area), thus, human activities in the headwaters or upper reaches of the watershed could impact the downstream area within the park. Examples of known impacts to the watershed are primarily bacterial and trace metal contamination from various sources, including urban runoff from residential and municipal development, poor septic systems and waste disposal, active and abandoned coal mines, and farming activities (Purvis et al. 2002).

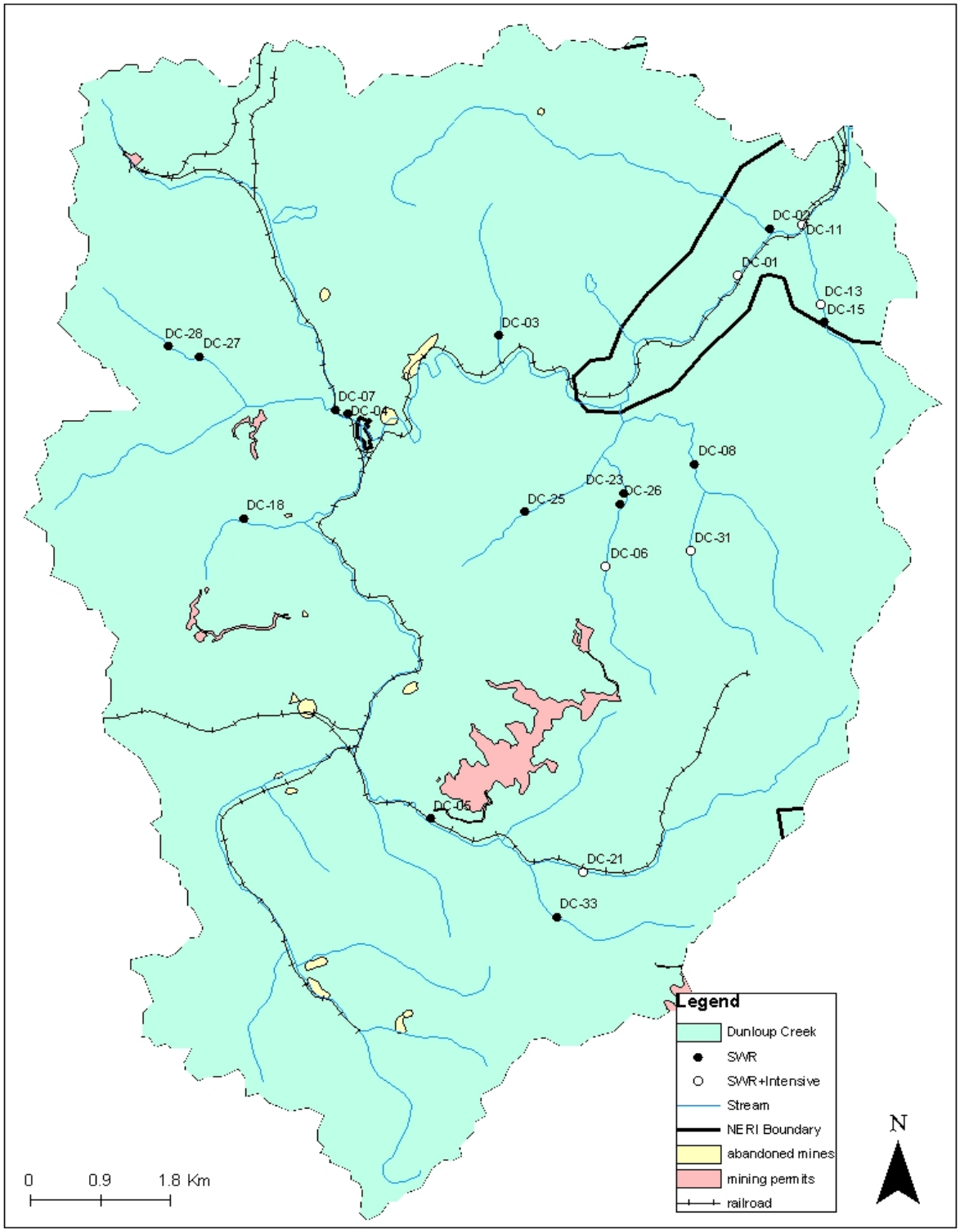

Figure 5. Dunloup Creek watershed, including sampling locations and park boundary. Black circles denote sites where only landscape and rapid (SWR) sampling occurred. White circles represent sites sampled for landscape, rapid and intensive assessments.

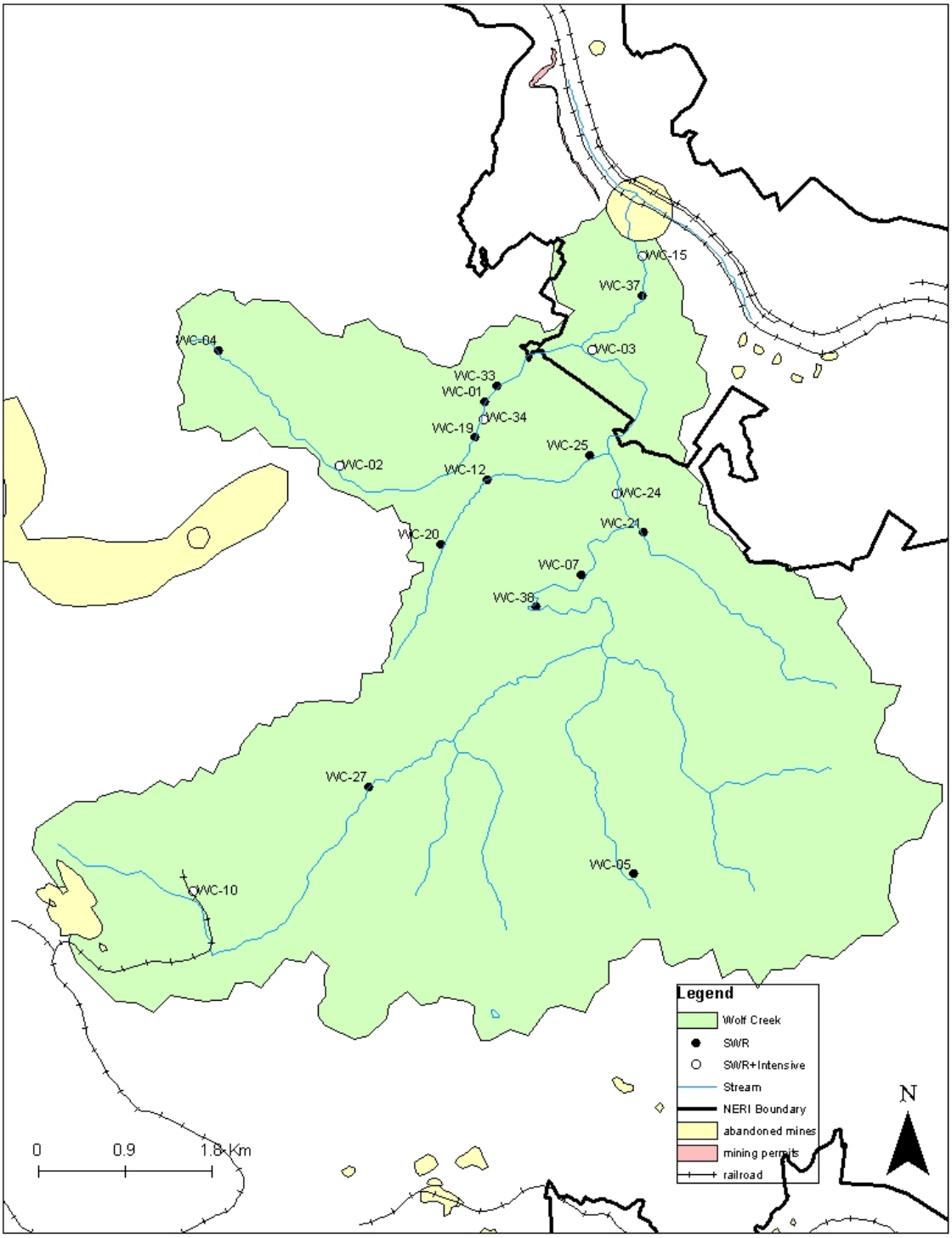

Figure 6. Wolf Creek watershed, including sampling locations and park boundary. Black circles denote sites where only landscape and rapid (SWR) sampling occurred. White circles represent sites sampled for landscape, rapid and intensive assessments.

Methods

We applied a comprehensive approach to the inventory and assessment of watershed ecosystem condition referred to as the Watershed Monitoring Matrix (WMM) (Brooks et al. 2004). The WMM protocol employs three levels of effort, which are applied across each of the following three tasks: (1) inventory, (2) assessment, and (3) restoration. For this 2004 pilot study, the CWC focused on task two, condition assessment, using primarily a reference approach. This approach evaluates a site's condition by comparing it to the regional reference condition. "Reference" is defined as the best obtainable condition with minimal human disturbance (Brooks et al. 2006b). The three levels of effort increase as one moves from the first to the third level and consist of the following: Level 1 – landscape assessment, Level 2 – rapid assessment, and Level 3 – intensive assessment.

Level 1 - Landscape Assessment

Landscape assessments emphasize the interactions among spatial patterns and ecological processes, and can be quite useful in interpreting watershed condition at larger scales (Cardille and Turner 2002). Using publicly available geospatial datasets and Geographic Information System software (GIS), synoptic maps and landscape-level metrics (Table 1) were generated to characterize landscape patterns for each watershed (refer to Appendix B for further information). Sampling points were randomly placed along streams within each watershed and served as sites for all three levels of assessment. This random placement process was stratified by stream order in roughly the same proportion that each order class occurs in the study watersheds (thirteen 1st-2nd order, four 3rd order, two 4th order, and one 5th order stream points). In the case of the smaller watersheds (Buffalo Creek and Fern Creek), this random selection process was not possible, not only because third order or greater streams did not exist, but also because steep gradients made several areas inaccessible, thus intensive sampling locations were limited to areas with flow. As a result, sites were randomly selected from a list of accessible and feasible sampling locations, which typically occurred in the downstream portions of both Fern Creek and Buffalo Creek. For further information, Appendix B contains detailed descriptions of the landscape assessment methods, including National Land Cover Dataset (NLCD) information for both Pennsylvania and West Virginia.

Landscape metrics were computed for two spatial scales; first, for the surface area of each watershed and, second, for a 1-km radius circle surrounding each randomly placed sampling point (Table 1). The Landscape Index for 1-km radius circles consisted of four metrics (forest cover, Landscape Development Index, impervious surface, and mean forest patch size), while the Landscape Index for each watershed included an additional metric of core forest to total forest (Table 1). Each landscape metric score was converted to a 0 – 1 scale, with 0 representing most disturbed condition and 1 representing least disturbed condition. The final Landscape Index score was determined via weighted averaging of the standardized metric scores. Refer to Appendix B for more details.

Table 1. Metrics used in the computation of Landscape Indexes for assessing aquatic condition of small watersheds. All metric calculations were based on the NLCD land cover for Pennsylvania and West Virginia and were computed in ArcView 3.3 with Patch Analyst (FRAGSTATS) and Spatial Analyst extension. See Appendix B for more details.

Metric	Type	Description	Citation	Index for 1-km circles	Index for watershed
Forest Cover (%)	Land Cover	Percent of area that is forest (combined deciduous, coniferous, and mixed forest categories)	FRAGSTATS (McGarigal et al. 2002)	✓	✓
Landscape Development Intensity Index (LDI)	Urbanization	Uses land use data and a development intensity measure derived from energy use per unit area to estimate the potential impacts from human-dominated activities on ecological systems	Brown and Vivas 2005	✓	✓
Impervious Surface (%)	Urbanization	Approximate percentage of total area of impervious surface; considers the % of each NLCD land cover class that is impervious, and the density and width of roads	B. Griscom et al. (unpublished)	✓	✓
Mean Forest Patch Size (ha)	Fragmentation	Average size of forest patches	FRAGSTATS (McGarigal et al. 2002)	✓	✓
Core Forest / Total Forest (%)	Fragmentation	The sum of the area of forest patches that is farther than 100 m from the patch perimeter, divided by the total area of forest	FRAGSTATS (McGarigal et al. 2002)		✓

Level 2 – Rapid Assessment

The Level 2 rapid assessment combines land use information obtained from the Level 1 landscape assessment with site-level information, and is divided into two main parts: (1) a natural condition score, and (2) a Stream, Wetland, Riparian (SWR) Index. The natural condition score and the SWR Index are separated into two components to allow managers the versatility of choosing one or both components in a Level 2 rapid assessment. Both methods and calculations are described in more detail in Appendix C. Examples of the raw data sheets can be found in Appendix E.

Natural Condition Score

The natural condition score serves as a tool for ranking sites along a disturbance gradient from most impacted (human-altered condition) to least impacted (natural condition). In the Mid-Atlantic region, natural condition is associated with a forested landscape, and human-altered condition is associated with a variety of stressors. Thus, the natural condition score is determined by combining the measures of percent forest (surrounding the site), buffer type and width (e.g., 100 m of mature forest), and presence of on-site stressors (e.g., stormwater inputs/culverts) (Brooks et al. 2004). Stressors are classified into 10 categories: enrichment/eutrophication, organic loading and eutrophication, contaminant toxicity, acidification, salinization, sedimentation, turbidity, vegetation removal/alteration, thermal alteration, and hydrologic modification (Adamus and Brandt 1990, Brooks et al. 2004). The presence of these onsite stressor categories is recorded. All of the above information is compiled to produce a natural condition score for each site scaled from 0 to 1, with 0 representing the lowest score and most disturbed condition and 1 representing the highest score and most natural condition. Appendix C provides additional information regarding the natural condition score equation.

SWR Index

The SWR Index entails a more comprehensive site assessment that provides more diagnostic interpretations regarding the probable causes of impact. Like the natural condition score, stressor and buffer information are also considered here. However, rather than consider the site holistically, the SWR Index evaluates the on-site stressors across three separate components (stream, wetland, and riparian zone). In addition, it considers the individual types of stressors, rather than the broader stressor categories. For example, a site that contains a channelized and dammed stream and a drainage ditch in the floodplain would represent one unique stressor category in the natural condition score but two stream stressors plus one floodplain stressor in the SWR Index. Buffer information is expanded, as well, to include a separate scoring of categorical distances across a 0 to 300 m swath perpendicular to both stream banks (Appendix C). In addition to the stressor and buffer information, the SWR Index includes information on wetland presence/classification, instream habitat condition, stream cross-section morphology, and structure and quality of surrounding vegetation (e.g., presence and/or abundance of invasive plant species).

For each sampling site (20 stream-centered points for large watersheds, six for small watersheds), the above information is collected via a rapidly implemented (<2 hr) sampling protocol within a 100 m x 100 m plot. Floodplain-wetland and stream metrics are then calculated from the above measurements and combined to form the SWR Index, an indicator of the overall condition of the watershed (Brooks et al. 2006a). Like the landscape metrics and the natural condition score, the SWR Index values are also on a 0 to 1 scale. Like the natural condition score, 0 represents most disturbed (i.e., poorest) condition and 1 represents least disturbed (i.e., best attainable) condition. Table 2 provides descriptions of the individual floodplain-wetland and stream metrics used in the SWR Index. Refer to Appendix C for more information regarding the SWR Index and Appendix E for SWR raw data sheets.

Table 2. Floodplain-wetland (F-W) and Stream (S) metrics used in compilation of the final Stream Wetland Riparian (SWR) Index. Main plot refers to the 100 m x 100 m plot.

Metric	Location	Description
Buffer Condition (0-300 m from stream)	Floodplain-Wetland	Percentage of total possible buffer score for 300 m (lateral distance from each bank) (e.g., 300 m mature forest on both sides of the stream = 100% of total possible buffer score)
Basal Area (m^2/ha)	Floodplain-Wetland	Cross section area of all tree stems at three points within the main plot, computed by using diameter at breast height (dbh)
Invasives Cover Class	Floodplain-Wetland	Estimated percentage of invasive plant species cover within the main plot using the following guidelines: 0 = no invasives; 1 = <5%; 2 = 5-20%; 3 = 20-50%; 4 = >50%
Number of Floodplain-Wetland Stressors	Floodplain-Wetland	Total number of probable floodplain and wetland stressors present on-site
Stream Habitat Assessment (SHA) (0-200 points)	Stream	Total instream habitat condition score adapted from US EPA Rapid Bioassessment Protocols (Barbour et al. 1999)
Incision Ratio	Stream	Ratio of bank height/bankfull height, which measures the stream's morphological response to erosion
Number of Stream Stressors	Stream	Total number of probable stream stressors present on-site

Level 3 – Intensive Assessment

Macroinvertebrate Community Characterization

Since the Rapid Bioassessment Protocols (RBPs) developed by the U. S. Environmental Protection Agency (US EPA) are widely used, we chose this method for conducting the macroinvertebrate community assessments (Plafkin et al. 1989; Barbour et al. 1999). Macroinvertebrate sampling was conducted at six sites for each large watershed (e.g., Blair Gap Run, Dunloup Creek, and Wolf Creek). Smaller watersheds contained fewer sampling sites (e.g., Buffalo Creek – three sites; Fern Creek – four sites). We used a modified version of the RBP III method (modified by sampling apparatus and sample separation), which measures the physical, chemical, and biological components of each site (Plafkin et al. 1989; Barbour et al. 1999). Aquatic macroinvertebrate community composition is largely a result of the physical and chemical environment in which the community resides. Therefore, water chemistry measurements were taken and in-stream habitat condition was evaluated at each macroinvertebrate sampling location. Macroinvertebrates were collected using the standard kick method in riffle habitat, except for the low-gradient Fern Creek, which was sampled in multiple habitat types. Field and laboratory methods are described in more detail in Appendix D.

From this information, the RBP method determines the water quality, physical habitat, and biological condition of each site based on similarity to reference condition. Reference conditions should represent the natural range of variation in "minimally" disturbed conditions and can be defined by either a site-specific or "paired" watershed approach or by a regional reference approach (Barbour et al. 1996; Gibson et al. 1996). The latter approach is most often used when a suitable reference condition does not exist either upstream or within the watershed, and, thus, reference condition is defined from a suite of relatively unimpaired sites of similar habitat that are located within the same region. Although Fern Creek and Buffalo Creek appear to be relatively undisturbed watersheds, their smaller size and differing morphologies make them difficult to compare to the larger, more disturbed watersheds of Dunloup Creek and Wolf Creek. Consequently, we employed the regional reference approach by including data collected from nearby reference sites in the EMAP Mid-Atlantic Streams Monitoring Project (US EPA 2006). EMAP or Environmental Monitoring and Assessment Project, is a research program implemented by the US EPA, which uses a probability-based sampling design emphasizing biological indicators to monitor the condition of our ecological resources on a regional basis (US EPA 2006).

Following sample processing, the macroinvertebrate data for each site were compiled into metrics. Each metric value was then compared to the metric value for the corresponding EMAP reference average (EMAP riffle data was used for the high gradient streams; EMAP pool data was used for the low gradient Fern Creek sites), and the corresponding scores were based on similarity to the reference average (i.e., 100% similarity represents the highest score). Table 3 provides the names and descriptions of the seven macroinvertebrate metrics used in the RBP III assessment. The Modified HBI indicates excellent to very good water quality at values below 4.5, while values above 6.5 suggest significant to severe degradation. Although taxa richness

Table 3. Macroinvertebrate metrics used in the RBP III intensive assessment. Descriptions and expected response to human disturbance are also included.

Metric	Description	Expected Disturbance Response
Modified Hilsenhoff Biotic Index (HBI)	Measures the sensitivity of the benthic community to organic pollutants. Each taxon is assigned a pollution tolerance value between 0 (least tolerant) and 10 (most tolerant); the HBI value is the mean value of all the organisms in the sample.	Increase
Taxa Richness	Represents the total number of unique taxa [class, order, family, or genus (depending on level of taxonomic resolution achieved for each taxon)]	Decrease
EPT Index	Represents the total number of taxa present from the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Decrease
Ephemeroptera Taxa	Represents the total number of mayfly taxa collected	Decrease
Plecoptera Taxa	Represents the total number of stonefly taxa collected	Decrease
Trichoptera Taxa	Represents the total number of caddisfly taxa collected	Decrease
Dominance of the Top Taxon	Represents the proportion of total individuals in the most abundant (dominant) taxon	Increase

may experience an initial increase at low to moderate levels of human disturbance, the overall response of this metric is to decrease at higher levels of impact or stress. The EPT Index is more sensitive to changes in water quality than taxa richness, since most mayflies, stoneflies, and caddisflies are intolerant and are usually well represented (i.e., diverse) in high quality streams. Exceptions exist however for certain genera within these orders. For example, many Hydropsychidae genera (e.g., *Cheumatopsyche*) increase in abundance in organically enriched streams. Separation of the EPT orders is often useful in diagnosing particular sources of stress. Mayflies tend to be more susceptible to low pH levels and drop out of the community rather quickly when streams become impacted by acidification. Stoneflies, on the other hand, are more sensitive to organic enrichment, while a few genera may become abundant in acidified streams. In general, the order Plecoptera represent a particularly sensitive taxonomic group that is characteristic of cool, clear running water and is the first to respond to changes in temperature or siltation (Stewart and Harper 1996). Dominance by a few taxa suggests environmental stress, although the tolerance value of the top taxon should be considered.

Metrics are scored following the RBP III methods, which are described fully in Appendix D. Final scores are then standardized to fit a 0 to 1 scale, where 0 represents the worst or most disturbed conditions and 1 represents the best attainable or least disturbed conditions. This allows for comparison of the macroinvertebrate results to the landscape and rapid assessment results. Habitat assessments, substrate information, and water quality measurements provided supplemental information and aided in the decision process, especially for borderline sites.

Stream Salamander Assemblage

The Stream Plethodontid Assemblage Response (SPAR) Index was developed to complement other measures of stream condition as well as serving as a coarse, stand-alone headwater assessment tool for Mid-Atlantic Highlands Area (MAHA) headwaters. The development of the SPAR Index is described in detail in Rocco et al. (2004). Its development and how it was used in this study is discussed briefly in Appendix D to aid interpreting the results of this project.

Salamanders of all life stages were captured from terrestrial and aquatic portions of three 4 m^2 rectangular plots (2 m x 2 m) as described in Rocco and Brooks (2000). The method entails the capture of all salamanders (using hand-held dip-nets) in aquatic and terrestrial portions of the plot through a systematic removal of the substrate within the plot (Figure 7). Sampling by this method is assumed to be a complete count (Thompson et al., 1998, Jung et al. 2000). Channel morphology, substrate particle size, and bank habitat were measured by a modified Ohio EPA (2001) methodology. Plots were photographed before searches began and analyzed in the laboratory for percent cover. Only riffle and run areas were sampled. Plots were always located in wetted segments of the stream channel. In the absence of surface water, sampling locations were positioned downstream or upstream to coincide with the nearest wetted, and preferably flowing, section of the stream. Sampling in wetted areas (regardless of how reduced in width) that exhibited at least some flow was deemed crucial to minimize the effects of varying hydrology on the target assemblage.

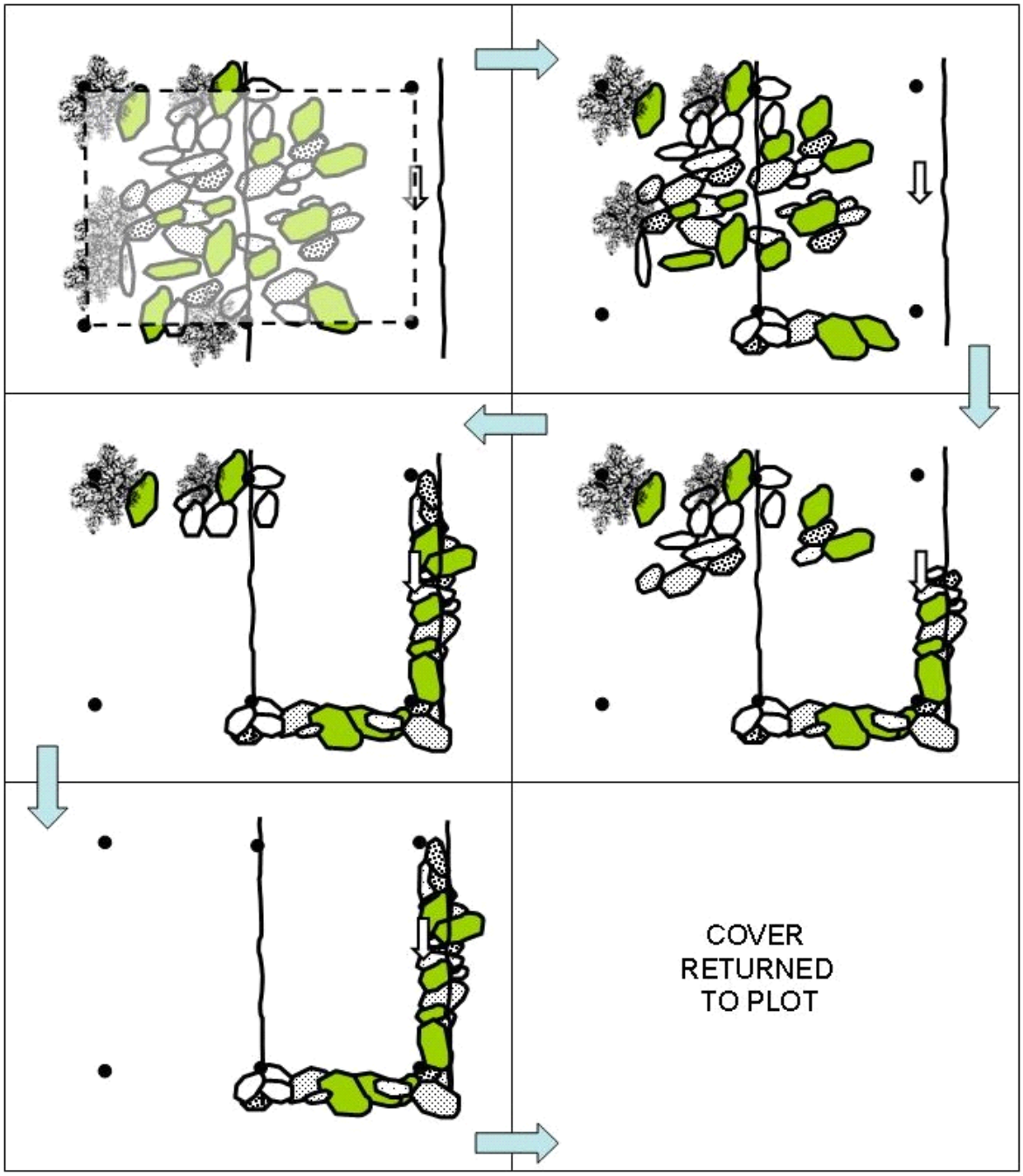

Figure 7. Suggested sampling of stream salamanders from wet and dry portions of the 4 m square plot proceeded by systematic removal of all cover, beginning with downstream edge of plot. White arrows indicate direction of stream flow.

This field information allows one to characterize the stream salamander community at each site and apply the SPAR Index. Like the macroinvertebrate community characterization, the SPAR Index is based on similarity to reference condition, with salamander assemblage attributes observed at references serving as the benchmarks or standards by which test sites are compared. Stream sites serving as SPAR references were minimally degraded headwaters that met water chemistry, stream habitat, and other criteria established by US EPA (Appendix D).

In this study, SPAR Index values were computed by averaging the scores of three or four metrics reflecting salamanders observed at sampled sites (Tables 4 and 5). Metric E, for example, is the total number of salamanders and its raw metric value would be 65 if this number of individuals were captured in the three sampled plots. Averaging scores from multiple metrics required converting raw metric values to a common scale. For this purpose, a raw metric value at or above the 50th percentile (median) of all references was scored a 10; a 5 was awarded to raw metric values below the 50th percentile but above the 25th, and a 0 for raw metric values below the 25th. Thus, in the example above, Metric E would score a 10 if the 50th percentile of the number of salamanders in reference sites was at or above 65. This method to score raw metric values was based on Southerland et. al. (2004). In hindsight, finer scoring criteria may be more desirable e.g. points are assigned at every decile (every 10th percentile) rather than at the intervals presented above. Future efforts to improve the SPAR index will probably require revising current scoring criteria.

SPAR index values were computed by averaging metric scores. Thus, if a SPAR index consisted of 4 metrics, and their scores were 10, 5, 0, and 10, its index score would equal their average or 6.25. As demonstrated above, computation of a SPAR index value is simple enough if scoring criteria are known for each metric. What becomes confusing is why different SPAR indices and scoring criteria are used.

Natural gradients can mask a community's response to stressors. A set of references, even if minimally disturbed, may be a poor representation of what should occur at a test site in a totally different natural environment. Thus, multiple SPAR indices and different scoring criteria were developed for different MAHA regions and stream habitats. Park stream sites corresponding to Northern Mid-Appalachian, high gradient sites, (Group 1) were assessed with a SPAR index composed of Metric A, Metric C and Metric G (Tables 4 and 5). Southern Mid-Appalachian, high gradient (Group 2) park stream sites were assessed by the SPAR index employing metrics A, E, F, and I. The SPAR index consisting of metrics D, E, and F was chosen for Mid-Appalachian low gradient test sites (Group 3). This group-specific (GS) approach was optional. It required prior classification of park sampling locations into one of the aforementioned groups. Discriminant functions developed in Rocco et al. (2004) were used to classify park sampling sites into groups. The functions required stream site measurements for latitude, boulder cover, stream gradient, and water temperature. Scoring criteria were unique to each group because there were 3 sets of references.

The alternative was to apply a SPAR index that was non-group specific (NGS); this approach did not require prior classification of park sampling sites and scoring criteria were based on references from the entire MAHA. The SPAR index employing metrics A, E, F, and I, the same used to assess Group 2 sites, performed satisfactorily. It was also the index originally developed by Southerland et al., (2004) and referred to as the Stream Salamander IBI or SS IBI.

Table 4. Composition of SPAR indexes used to assess park stream sites. Metrics comprising each of the four IBIs are identified with an 'x'. Computation of metric scores for group specific (GS) IBIs required prior classification of park stream sites to a group. Geographic location and stream habitat determined group membership.

SPAR Indexes		No. of References	No. of Metrics in Index	Metric Name and IBI Composition						
				A	C	D	E	F	G	I
Non-group Specific (NGS) Assessment/IBI		*34*	*4*	X			X	X		X
Group Specific IBIs	*Group 1: Northern MAHA High Gradient*	*9*	*3*	X	X				X	
	Group 2: Sourthern MAHA High Gradient	*16*	*4*	X			X	X		X
	Group 3: MAHA Low Gradient	*9*	*3*			X	X	X		

Table 5. Description of the seven stream salamander metrics used in constructing the four SPAR IBIs to assess park stream sites. Metrics were exclusively based on assemblage attributes of lungless stream salamanders (Family Plethodontidae).

Metric Name	Metric Description
A Species Richness	Number of stream salamander species including woodland species (*Plethoodon* spp.)
C No. of Two-lined	Number of salamanders of the two-lined complex (*Eurycea bislineata*, *E. cirrigera*, and possibly larval *E. Longicauda*)
D No. of Northern Spring	Number of salamanders of the northern spring genus *Gyrinophilus*
E No. of Salamanders	Number of individuals of all salamander species – abundance for lungless taxa.
F No. of Intolerants	"No. of Salamanders" minus "No. of Two-lined"
G No. of Nutrient Tolerant	"No. of Two-lined" plus number of northern dusky (*Desmognathus fuscus*)
I No. of Terrestrials	Number of without gills or gill stubs

Group-specific outcomes may provide a more accurate assessment of condition, provided that sites were correctly classified. When comparing the results by the two methods, the reader should realize that the one compares a test site to a large set of references (NGS) from the entire region, whereas the second method relies on a smaller set of references, that are however more similar to the test site (GS). Hence, regional benchmarks are used in the first approach in contrast to local ones in the second. Appendix D provides more information on how the SPAR index was developed and its use to assess NPS park stream sites.

Results

The following results are organized by watershed, with the ALPO (Blair Gap Run watershed) results displayed first, followed by the NERI watersheds (Buffalo Creek, Fern Creek, Dunloup Creek, and Wolf Creek). Within each watershed, the results are broken down by assessment level with the landscape assessment results displayed first, followed by the rapid and finally the intensive assessment results.

When reading the results, keep the following in mind. The landscape assessment represents a coarse screening of condition assessment based entirely on landscape-level measures. The advantages of a wide geographic coverage are offset by the limitations of the data that are intended mainly as a screening tool for additional, more intensive assessments. However, broad conclusions regarding watershed condition can be drawn, while remaining mindful of the limitations. The following hints are designed to aid in the interpretation of the Level 1 landscape assessment results. For more clarification, consult the citations provided.

When comparing the watershed assessment results to the 1-km radius circle assessment results, it is important to remember that the watershed analysis is run on the entire surface area of the watershed, while the 1-km circle analyses center mostly on the stream channel and surrounding riparian zone. Thus, 1-km radius circle assessments may generate higher Landscape Index scores than assessments of the entire watershed, which incorporate more of the agricultural and urban landscape. Typically, a watershed score that is close to or even higher than the mean of the 1-km radius circle scores implies a relatively undisturbed watershed in good condition.

Generally, a higher percentage of surrounding forest represents better ecological condition of a site (Brooks et al. 2004). The CWC found that 85% forest appears to be a general threshold, below which ecological integrity begins to decline (Hychka 2004). The Landscape Development Index (LDI) is best interpreted as a measure of human impact. The more developed the land use, the greater the amount of energy spent to maintain it, which often results in a greater number of stressors and a higher level of impact (Brown and Vivas 2005). Regarding impervious surface, stream water quality begins to decline at 3-4% imperviousness, and the rate and magnitude of degradation increases above 10% imperviousness (Arnold and Gibbons 1996; Brabec et al. 2002). These thresholds must be regarded with caution, however, since the actual impacts of impervious surfaces are dependent on several factors that can change within and between watersheds (Brabec et al. 2002). Mean forest patch size provides information regarding the degree of forest fragmentation, the effects of which increase landscape heterogeneity and, overall, are regarded as detrimental to ecological integrity if patch sizes become too small to support various wildlife species, especially those requiring contiguous forest interior habitat (Scalet et al. 1996; Turner et al. 2001). The proportion of core forest to total forest provides additional information regarding the amount of interior forest habitat available (i.e., habitat that is protected from edge effects, which can increase rates of parasitism, disease, etc.) (Scalet et al. 1996; Turner et al. 2001). In both instances, the larger the size, the better.

The Level 2 rapid assessment results, while still rather coarse, should contain sufficient information to begin diagnosing the presence of different types of environmental stress and their most likely causes. The natural condition score should be used to rank the sites within each

watershed from worst to best condition, to compare conditions between sites, or to identify sites for protection or restoration. The SWR Index (and individual metric results) should be used to identify particular problems within each site.

The Level 3 intensive assessment results reflect the biological response to watershed condition and may, or may not, agree with the landscape and rapid assessment results. Typically, biological assessments reveal more impacts than landscape or physical assessments, resulting in lower condition scores.

Allegheny Portage Railroad National Historic Site (ALPO) – Blair Gap Run Watershed

ALPO Landscape Assessment (Level 1) Results

The Level 1 results for both spatial analyses (the Blair Gap Run watershed analysis and each 1-km radius circle surrounding the individual sampling points) are listed in Table 6, including landscape metric values and final Landscape Index scores. The metric values and scores for the surface area of the Blair Gap Run watershed are listed in the table as bold text. The spatial analysis of the entire watershed listed Blair Gap Run as suboptimal in condition with a Landscape Index Score of 0.73, while the majority of 1-km circle analyses (75%) characterized the Blair Gap Run sites as being in optimal condition, with a mean score of 0.81 (Table 6, Figure 8). Such a close association between watershed and 1-km radius circle Landscape Index scores is typical for small watersheds like Blair Gap Run that are largely characterized by a forested matrix and relatively undisturbed condition.

Although not included in Figure 8, results for sites within the Bradley Run watershed (ALPO-98 and ALPO-99) are listed in Table 6. Both were borderline suboptimal in condition, which is most likely due to a higher proportion of impervious surface (probably from close proximity to the highway). The landscape assessment identified three sampling points (19% of the Blair Gap Run sites) as marginal in condition (ALPO-08, ALPO-18, and ALPO-23) (Table 6, Figure 8). Each of these sites were located near the Duncansville end of the park and were characterized by less than 50% surrounding forest, higher landscape development indexes, higher proportions of impervious surface, and lower mean forest patch sizes (Table 6). ALPO-03, also near Duncansville, was surrounded by 60% forest and moderate levels of land development and impervious surface, giving this location a Landscape Index score in the suboptimal range (Table 6).

Table 6. Landscape metric values and final Landscape Index scores for the Blair Gap Run watershed (in bold) and for each ALPO sampling site.

Site ID	Forest Cover (%)	LDI (unitless)	Impervious Surface (%)	Mean Forest Patch Size(m²)	Core Forest/ Total Forest (%)	LANDSCAPE INDEX SCORE
BLAIR GAP RUN WATERSHED	**80.1**	**1.68**	**4.03**	**30.7**	**0.74**	**0.73**
BLAIR GAP RUN SITE SCORES (1-km radius circle)						
ALPO-01	84.7	1.41	1.33	37.8	0.57	0.80
ALPO-02	99.3	1.02	0.00	310.0	0.98	1.00
ALPO-03	60.3	2.44	8.11	9.4	0.53	0.55
ALPO-04	97.7	1.02	0.44	304.9	0.79	0.96
ALPO-08	48.2	2.87	10.70	7.2	0.38	0.47
ALPO-12	94.2	1.33	0.88	73.5	0.62	0.92
ALPO-14	89.1	1.27	0.77	139.1	0.63	0.91
ALPO-17	97.8	1.06	0.29	305.2	0.78	0.97
ALPO-18	28.3	3.95	22.13	1.8	0.26	0.26
ALPO-20	98.7	1.03	0.28	308.1	0.80	0.98
ALPO-23	29.8	4.11	25.53	2.1	0.25	0.27
ALPO-24	99.1	1.05	0.10	309.5	0.92	1.00
ALPO-25	99.4	1.01	0.00	310.3	0.98	1.00
ALPO-27	98.5	1.04	0.26	307.4	0.80	0.98
ALPO-28	91.6	1.38	0.94	57.2	0.67	0.91
ALPO-30	99.2	1.05	0.08	309.6	0.93	1.00
BRADLEY RUN SITE SCORES (1-km radius circle)						
ALPO-98	84.3	1.94	10.54	65.8	0.50	0.75
ALPO-99	84.2	1.98	10.79	87.6	0.53	0.77

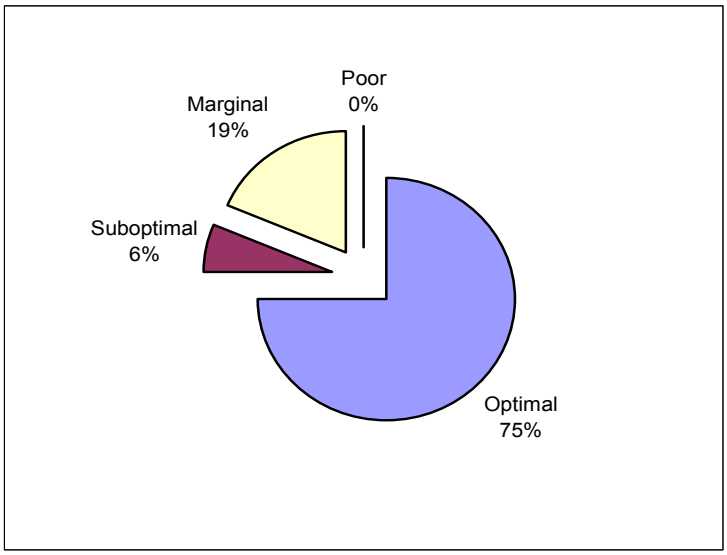

Figure 8. Proportion of Blair Gap Run sites receiving the following Level 1 landscape assessment condition categories (determined from final Landscape Index scores): 0.76 - 1.0 = Optimal; 0.51 - 0.75 = Suboptimal; 0.26 - 0.50 = Marginal; 0.0 - 0.25 = Poor.

ALPO Rapid Assessment (Level 2) Results

The mean natural condition score for the ALPO sites was 0.70 (0 -1 scale with zero representing most disturbed condition). The majority of sites were surrounded by a buffer of natural forest (e.g., ALPO-02, ALPO-17, ALPO-24, and ALPO-25). Not surprisingly, these sites received the highest natural condition scores (>0.979) (Table 7). Three sites were located in areas with little or no buffer, and two sites were intermediate in nature, surrounded by a mix of natural forest and urban buffer components. Natural condition scores for these latter sites ranged from 0.202 to 0.579 with disturbance levels increasing as the percentage of surrounding forest (and overall natural condition scores) decreased (Table 7). Buffer penetrations were in the form of adjacent construction (ALPO-14) and railroad or industrial sites (ALPO-23).

Table 8 displays the results from the SWR assessment, including individual metric values and final SWR Index scores. In general, SWR Index scores (mean = 0.68) agreed with natural condition scores: sites surrounded by natural forest received the highest scores, ranging from 0.53 to 0.94; while sites in more populated areas with less forest received lower SWR scores ranging from 0.35 to 0.42 (Table 8). The exception was ALPO-08, which received a rather low natural condition score (0.398) but a high SWR Index score (0.70) (Tables 7 and 8). This discrepancy is most likely due to the residential area bordering the left stream bank, which would lower the percentage of surrounding forest, subsequently decreasing the natural condition score. Upon closer inspection, however, stream habitat conditions appeared to be in optimal to suboptimal condition with few apparent stressors, resulting in a high SWR Index score. Since the SWR Index is more indicative of condition at the reach scale, it probably represents the more accurate prediction of condition for this site. The intensive assessment results, which were also conducted at this site, will provide additional information.

Stream and riparian stressors in forested areas were primarily in the form of adjacent roadbeds and stormwater inputs from culverts and/or tile drains, both of which appeared to increase the level of sedimentation. In addition, sites in more urban areas (e.g., ALPO-18 and ALPO-23) were also channelized and possibly subjected to filling, grading, or dredging. These stressors were reflected by low instream habitat scores (e.g., ALPO-03 and ALPO-14) and relatively high incision ratios (e.g., ALPO-23) (Table 8).

Figure 9 illustrates the proportion of Blair Gap Run sampling sites rated as optimal, suboptimal, marginal, or poor in condition by the rapid assessment (SWR Index scores). Only the SWR Index scores were used (rather than combining SWR Index scores with natural condition scores) to summarize the rapid assessment results, since they contain additional information and provide a more accurate assessment of condition. The rapid assessment rated most sites (44%) in optimal condition, 31% in suboptimal condition, and 25% in marginal condition (Figure 9). No sites were considered to be in poor condition.

Table 7. Natural condition score components and final natural condition scores for ALPO sampling sites.

Site ID	% Forest (1 km Circle)	# Unique Stressors	Buffer Score	Buffer Penetrations	Natural Condition Score
ALPO-01	84.66	2	4.5	0	0.68
ALPO-02	99.28	0	6	0	0.99
ALPO-03	60.28	4	3.9	0	0.38
ALPO-04	97.67	2	4.8	0	0.78
ALPO-08	48.17	2	3.6	0	0.40
ALPO-12	94.18	3	3	0	0.65
ALPO-14	89.10	3	0	1	0.58
ALPO-17	97.75	0	6	0	0.98
ALPO-18	28.31	2	0.2	0	0.22
ALPO-20	98.67	0	6	0	0.99
ALPO-23	29.78	3	1.6	1	0.20
ALPO-24	99.14	0	6	0	0.99
ALPO-25	99.39	0	6	0	0.99
ALPO-27	98.47	3	5.4	0	0.70
ALPO-28	91.55	1	5.2	0	0.83
ALPO-30	99.16	1	3.6	0	0.88
ALPO-98	84.32	1	6	0	0.77
ALPO-99	84.17	3	5.4	0	0.61

Table 8. Results from Level 2 rapid assessment: SWR metric values and final SWR Index scores for ALPO sites.

Site ID	Buffer Cond (%)	Incision Ratio	Basal Area[1]	Invasive Cover Class[2]	Stream Habitat Score[3]	# Stream Stressors	# Flood.-Wetl Stressors	SWR Index Score
BLAIR GAP RUN WATERSHED								
ALPO-01	75.00	2.15	11.50	1	155.00	5	2	0.64
ALPO-02	100.00	1.68	27.00	0	185.00	0	0	0.94
ALPO-03	65.00	4.14	8.00	1	51.00	4	3	0.42
ALPO-04	80.00	1.49	16.00	0	143.00	7	5	0.61
ALPO-08	60.00	2.30	8.00	1	171.00	3	2	0.70
ALPO-12	50.00	2.11	20.00	1	148.00	9	6	0.53
ALPO-14	0.00	2.87	8.00	1	110.00	11	10	0.38
ALPO-17	100.00	1.46	14.33	0	179.00	0	0	0.92
ALPO-18	3.33	2.41	2.00	1	118.00	10	7	0.42
ALPO-20	100.00	3.34	19.00	1	186.00	0	0	0.83
ALPO-23	26.67	6.23	13.50	1	150.00	8	7	0.35
ALPO-24	100.00	2.01	19.33	0	177.00	0	0	0.90
ALPO-25	100.00	1.54	13.33	0	186.00	0	0	0.92
ALPO-27	90.00	1.74	15.50	0	160.00	5	5	0.68
ALPO-28	86.67	1.66	17.67	1	178.00	0	1	0.88
ALPO-30	60.00	1.82	19.67	0	164.00	1	1	0.81
BRADLEY RUN WATERSHED								
ALPO-98	100.00	2.10	24.00	0	156.00	2	0	0.80
ALPO-99	90.00	1.99	21.67	0	128.00	4	2	0.69

[1] Units in m^2/ha.
[2] Classes defined as follows: 0 = no invasives; 1 = <5%; 2 = 5-20%; 3 = 20-50%; 4 = >50%.
[3] Scores range from 0 – 200 points, with 200 representing maximum score or optimal condition.

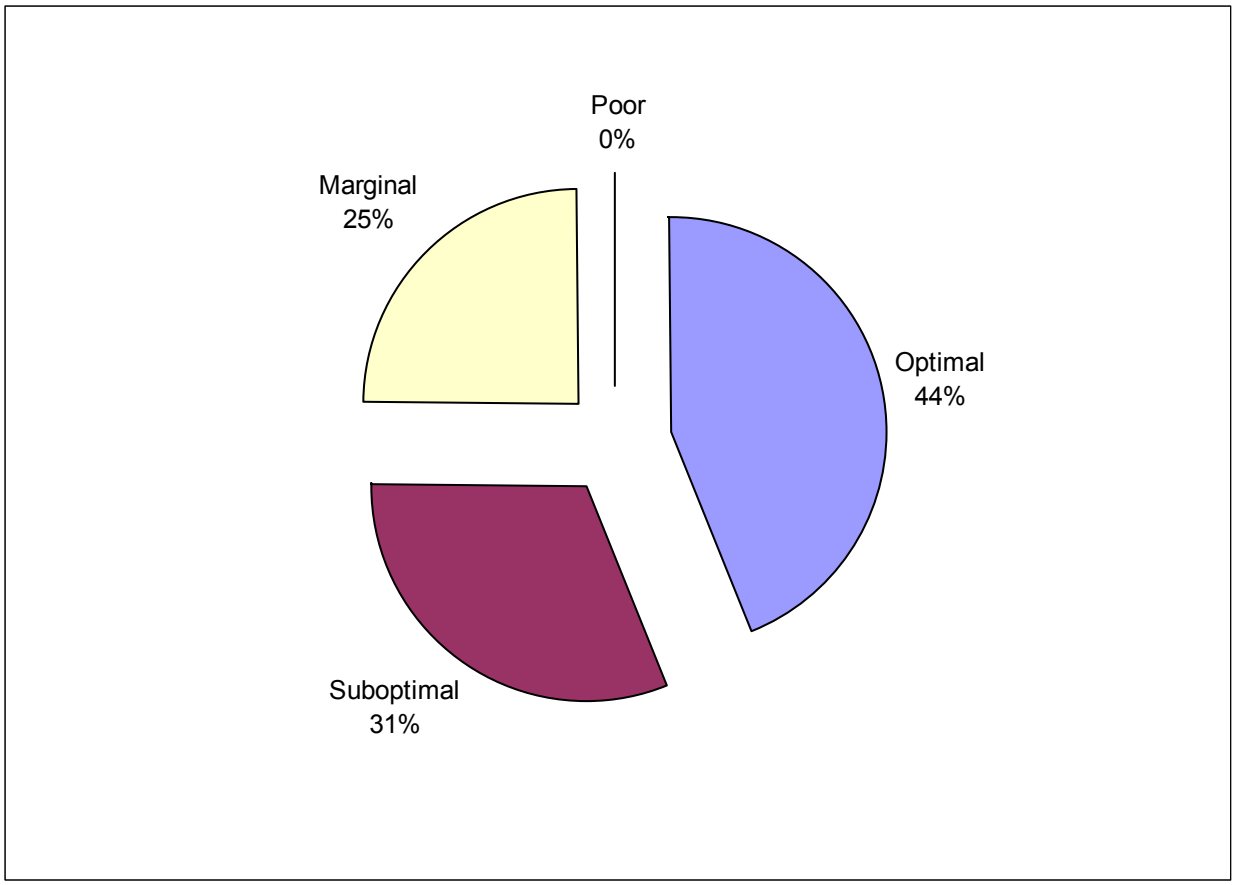

Figure 9. Proportion of Blair Gap Run sites receiving the following Level 2 rapid assessment condition categories (determined from the SWR Index scores): 0.76 - 1.0 = Optimal; 0.51 - 0.75 = Suboptimal; 0.26 - 0.50 = Marginal; 0.0 - 0.25 = Poor.

ALPO Intensive Assessment (Level 3) Results

Macroinvertebrate Community Characterization: Figure 10 compares the relative abundance of the major insect orders collected from the Blair Gap Run intensive sampling sites. Ephemeroptera (24%), Plecoptera (23%), and Trichoptera (31%) (EPT) were the most abundant orders collected, and were represented by the following genera: *Epeorus* and *Baetis* (mayflies); *Leuctra, Acroneuria, Amphinemura,* and *Peltoperla* (stoneflies); and *Ceratopsyche, Dolophilodes, Diplectrona,* and *Rhyacophila* (caddisflies). The high relative abundance of these mostly intolerant genera, as well as relatively equal proportions of individuals from each of the three EPT orders, implies a well-functioning macroinvertebrate community.

Unlike Blair Gap Run, collections from the Bradley Run intensive sampling site (ALPO-99) were dominated by Plecoptera (68%), mostly *Leuctra.* Samples from this site contained only a few Trichoptera (16% of individuals collected) and one Ephemeroptera individual. Such proportions where leuctrid stoneflies proliferate and mayflies are rare or absent often indicate acidic conditions.

Table 9 displays the results for the RBP III assessment of the ALPO intensive sampling sites, including water chemistry parameters, macroinvertebrate metrics, and site condition categories (based on similarity to reference condition). On average, the modified HBI indicated no apparent presence of organic pollution at the Blair Gap Run sites (mean HBI = 3.42). Mean taxa richness and EPT index were 32.2 and 19.5 taxa, respectively. Overall, the biological condition of the Blair Gap Run streams averaged approximately 87% similarity to regional reference condition, characterizing the Blair Gap Run watershed in optimal condition with a mean standardized condition score of 0.85 (refer to Appendix D for RBP III condition score conversion information).

Regarding the condition of the individual sites, stations along Blair Gap Run ranged from suboptimal to optimal condition (Table 9). ALPO-08, which was located directly downstream of the old Rt. 22 crossing near Duncansville, was considered in suboptimal condition due to a possible slight organic enrichment, which was reflected by a higher modified HBI value and a dominance of *Ceratopsyche* (Table 9). All other intensive sampling sites within the Blair Gap Run watershed contained no obvious signs of impairment and were classified as in optimal condition for supporting aquatic macroinvertebrate communities, including ALPO-20 which contained 40 taxa despite extremely low pH levels (Table 9). The Bradley Run site (ALPO-99) was classified as in marginal condition with moderate levels of impairment most likely due to acid mine drainage (pH<5) (Table 9). As expected with such a stressor, total taxa and EPT taxa richness were low, with only one mayfly representative. Percent dominance was moderately high with 49% of the individuals collected represented by the acid-tolerant stonefly genus *Leuctra*.

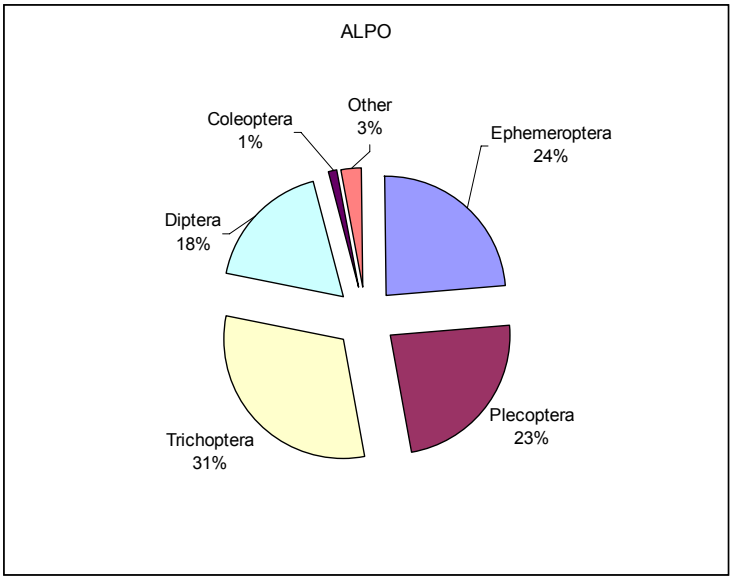

Figure 10. Breakdown by common insect order of the total macroinvertebrate individuals collected in the Blair Gap Run intensive sampling sites.

Table 9. Results of Level 3 intensive assessments (macroinvertebrates) for the ALPO region, including water chemistry parameters, RBP III metric values, percent similarity to reference, and overall condition categories. Asterisk (*) denotes missing data.

	Level 3 Intensive Sampling Site					PA EMAP
	BLAIR GAP RUN				BRADLEY RUN	Reference
	ALPO-08	ALPO-12	ALPO-20	ALPO-25	ALPO-99	Average
Date Collected	7/6/2004	6/14/2004	6/23/2004	6/24/2004	6/14/2004	*
Water Chemistry						
pH	*	5.87	4.79	5.57	4.39	*
Temperature (°C)	*	15.3	12.2	10.95	16.5	*
Conductivity (µS/cm)	*	137.95	33.55	40.5	114.2	*
Dissolved Oxygen (mg/L)	*	8.74	6.83	7.41	7.66	*
Macroinvertebrate Metric						
Modified HBI	4.15	2.88	2.82	3.86	2.55	2.82
Taxa Richness	35	20	40	34	20	28
EPT Index	23	11	23	21	9	20
Ephemeroptera Taxa	9	3	7	8	1	9
Plecoptera Taxa	5	5	7	6	3	6
Trichoptera Taxa	9	3	9	7	5	4
Dominance of Top Taxon	0.36	0.35	0.16	0.22	0.49	0.31
% Similarity to Reference	90	58	100	100	47	100
Standardized Condition Score	0.86	0.54	1.0	1.0	0.45	1.0
Condition Category	Optimal	Suboptimal	Optimal	Optimal	Marginal	*

Stream Salamander Assemblage: Although salamanders were observed at all sites sampled for them, only the mountain dusky (*Desmognathus ochrophaeus*), northern dusky (*D. fuscus fuscus*), and spring (*Gyrinophilus porphyriticus*) salamanders were observed at the ALPO locations. The absence of the northern two-lined (*Eurycea bislineata*) at ALPO was unexpected but not unusual; the mountain dusky and northern spring salamanders are key components of plethodontid assemblages in northern MAHA high gradient streams in reference condition (Rocco and Brooks 2004; refer to Appendix D). These two species combined accounted for 90% of all stream salamanders observed at ALPO. The northern two-lined and northern dusky also inhabit minimally disturbed northern MAHA high gradient streams (Group 1) but are not as ubiquitous in, or as tolerant to acidified environments. The SPAR index used for Group 1 stream sites requires representation by two-lined and northern dusky salamanders. The absence of the former and only a few of the latter prevented ALPO sites from scoring above poor condition. ALPO sites evaluated by a non-group specific (NGS) SPAR index scored similarly, with ALPO-99 (Bradley Run) actually scoring lower than the group specific (GS) value (Table 10).

ALPO Blair Gap Run Watershed Summary

Table 11 provides a summary of the landscape (Level 1), rapid (Level 2), and intensive (Level 3) results for the Blair Gap Run watershed. In general, site scores tended to decrease as assessments moved from remote to rapid to intensive (Table 11). In these instances, impacts (if present) are most likely occurring at the site level. Mean landscape and rapid (both disturbance and SWR Index) scores decreased from optimal to suboptimal condition and declined sharply to poor condition in the intensive assessment (SPAR Index). However, mean scores for macroinvertebrates actually improved for the Blair Gap Run watershed (Table 11). This is probably due to the higher RBP III scores at ALPO-08 and ALPO-20. ALPO-08 was located in a residential area, resulting in marginal landscape and rapid (natural condition score only) assessment scores (Table 11). Nevertheless, the stream contained a high occurrence of riffles and a good mix of boulder, cobble, and gravel substrates. There was no evidence of excessive, or even moderate, levels of sedimentation. Stream banks and bank vegetation were also in good condition. The SWR Index reflected these observations, rating the site as suboptimal in condition (Table 11). Thus, any possible onsite stressors did not appear to be affecting the macroinvertebrate community, which contained a high diversity and abundance of EPT taxa and rated the site as optimal in condition (Tables 9 and 11). ALPO-08 provides a good example of a site that is surrounded by increasing pressure from urbanization, yet appears to maintain a high ecological integrity. Further investigation is recommended to ensure the maintenance of this condition, such as repeated sampling events to evaluate ongoing biological condition and/or more detailed evaluations of existing or needed stream habitat protection. Additional sampling of the salamander assemblage inhabiting this site is also recommended to determine if slight to moderate effects from acidification are present. In each case, especially ALPO-12 and ALPO-20, discrepancies existed between the macroinvertebrate (RBP III) results and the salamander (SPAR Index) results (Table 11). The SPAR Index tends to be more sensitive to acidification than the RBP III metrics, some of which place a high value on many acid-tolerant species (e.g. *Leuctra*). Mayflies are also sensitive to low pH levels, but displayed adequate levels of diversity at ALPO-20 (Table 9). Apparently, the level of impact from acidification at ALPO-20 is low enough to maintain the mayfly community but high enough to significantly impact the salamander assemblages, whereas both macroinvertebrates and salamanders responded to increased acidification at ALPO-12.

Table 10. SPAR Index values and condition categories for ALPO intensive sampling sites.

	Level 3 Intensive Sampling Site		
	Blair Gap Run		Bradley Run
	ALPO-12	ALPO-20	ALPO-99
Date Collected	6/21/2004	6/23/2004	6/24/2004
Non-group Specific (NGS) Assessment			
Metric A	10	10	10
Metric E	0	0	0
Metric F	5	5	0
Metric I	5	5	0
SPAR Index Value	5	5	2.5
SPAR Condition Category	Non-reference	Non-reference	Degraded
Standardized Condition Score	0.25	0.25	0.125
Condition Category	Poor	Poor	Poor
Group Specific (GS) Assessment			
Group Designation*	1	1	1
Metric A	10	10	10
Metric C	0	0	0
Metric G	0	0	5
SPAR Index Value	3.3	3.3	5
SPAR Condition Category	Degraded	Degraded	Non-reference
Standardized Condition Score	0.08	0.08	0.25
Condition Category	Poor	Poor	Poor

* Group 1 are the northern Mid-Atlantic high gradient headwaters

Table 11. Summary of landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessment scores for the ALPO region. All scores have been standardized to a 0 to 1 scale in order to facilitate comparisons of condition.

Site ID	Level One Landscape Index	Level Two Natural Condition Score	SWR Index	Level Three Macroinvertebrates (RBP III)	Salamanders (SPAR Index)
ALPO Mean	0.81	0.71	0.69	0.77	0.14
ALPO-01	0.80	0.68	0.64		
ALPO-02	1.00	0.99	0.94		
ALPO-03	0.55	0.38	0.42		
ALPO-04	0.96	0.78	0.61		
ALPO-08	0.47	0.40	0.70	0.85	
ALPO-12	0.92	0.65	0.53	0.54	0.08
ALPO-14	0.91	0.58	0.38		
ALPO-17	0.97	0.98	0.92		
ALPO-18	0.26	0.22	0.42		
ALPO-20	0.98	0.99	0.83	1.0	0.08
ALPO-23	0.27	0.20	0.35		
ALPO-24	1.00	0.99	0.90		
ALPO-25	1.00	0.99	0.92	1.0	
ALPO-27	0.98	0.70	0.68		
ALPO-28	0.91	0.83	0.88		
ALPO-30	1.00	0.88	0.81		
ALPO-98	0.75	0.77	0.80		
ALPO-99	0.77	0.61	0.69	0.45	0.25

Condition Category		
	0.76 - 1.0	Optimal
	0.51 - 0.75	Suboptimal
	0.26 - 0.50	Marginal
	0.0 - 0.25	Poor

New River Gorge National River (NERI) – Buffalo Creek Watershed; Fern Creek Watershed; Dunloup Creek Watershed; and Wolf Creek Watershed

NERI Buffalo Creek Watershed Landscape Assessment (Level 1) Results

Landscape metric values and final Landscape Index scores for the Buffalo Creek watershed and individual landscape assessment sites are listed in Table 12, and summarized as condition categories in Figure 11. The landscape assessment classified the entire Buffalo Creek watershed as in optimal condition, at both the watershed and site level scales. The Landscape Index score for the entire watershed (0.97) was quite similar to the individual 1-km radius circle Landscape Index scores (0.95 – 1.00), indicating a matrix of large forest patches both surrounding the riparian zones and beyond. This is not surprising, considering the steep terrain, which results in both reduced land development and a high percentage of contiguous forest. The percentage of surrounding forest was 96.3% for the entire watershed and ranged from 90.8% to 99.0% within the 1-km radius circles surrounding each landscape assessment site (Table 12). LDI values were indicative of those found in natural systems (Brown and Vivas 2005) and ranged from 1.02 to 1.07 (Table 12). Imperviousness was less than one percent for the watershed and the sampling sites. Large forest patch sizes and high proportions of core forest/total forest suggest an abundance of continuous interior forest habitat.

NERI Buffalo Creek Watershed Rapid Assessment (Level 2) Results

Table 13 displays the natural condition scores for the Buffalo Creek watershed rapid assessment locations. All sampling sites within this watershed received high natural condition scores implying optimal conditions for these sites (mean = 0.91; range 0.827 to 0.990 [on a 0 to 1 scale where zero represents most disturbed condition]). This is primarily due to the large expanse of forest surrounding Buffalo Creek and its tributaries. As such, these sites had the highest buffer scores and contained no buffer penetrations. The additional stressor and physical habitat information resulted in SWR Index scores being lower than the corresponding natural condition scores, although the overall condition rating from the SWR assessment classified sites as suboptimal or optimal in condition (Table 14; Figure 12). SWR Index scores ranged from 0.56 to 0.82 with a mean of 0.73 (Table 14). Impacts to this watershed may arise from the extremely high gradient nature of the streams which appear to produce extreme fluctuations in flow status ranging from little or no flow to scouring torrents during flood periods, as illustrated by the July 2001 flood events. The result was excessive bank erosion and fairly high sediment deposition, and was reflected by high incision ratios and lower stream habitat scores at two unnamed tributaries to Buffalo Creek: BC-02 and BC-06 (Table 14). Mining in the headwaters of these tributaries should also be considered as a probable stressor.

Table 12. Landscape metric values and final Landscape Index scores for the Buffalo Creek watershed (in bold) and for each Buffalo Creek sampling site.

Site ID	Forest Cover (%)	LDI (unitless)	Impervious Surface (%)	Mean Forest Patch Size(m²)	Core Forest/ Total Forest (%)	LANDSCAPE INDEX SCORE
BUFFALO CREEK WATERSHED	**96.3**	**1.04**	**0.21**	**252.4**	**0.87**	**0.97**
BUFFALO CREEK SITE SCORES (1-km radius circle)						
BC-01	90.8	1.07	0.29	141.7	0.84	0.95
BC-02	95.0	1.06	0.24	148.3	0.84	0.97
BC-03	97.5	1.05	0.18	304.3	0.86	0.99
BC-04	97.7	1.04	0.13	305.0	0.88	0.99
BC-05	99.0	1.02	0.03	309.0	0.96	1.00
BC-06	98.2	1.03	0.04	306.5	0.95	0.99

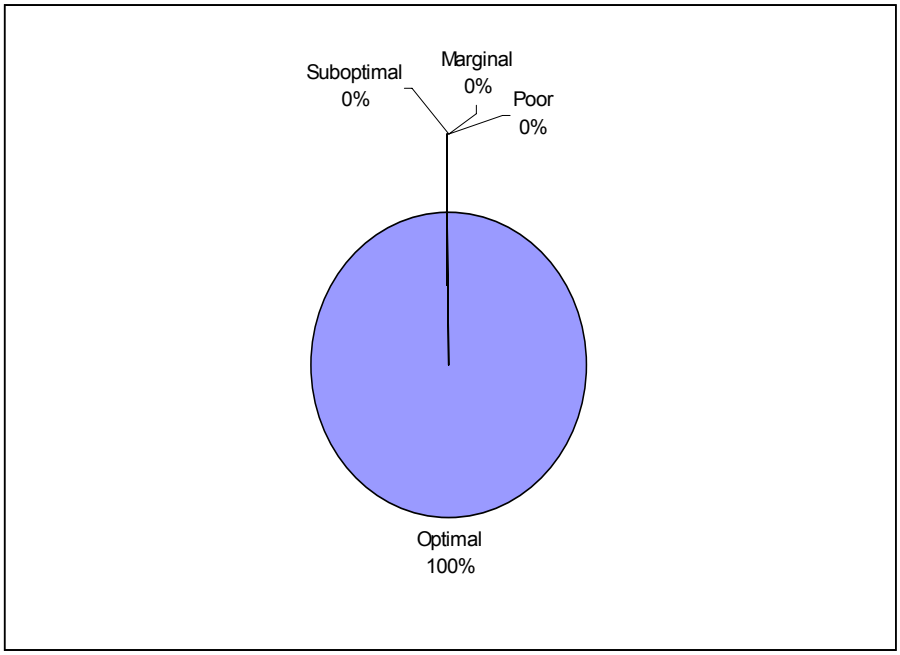

Figure 11. Proportion of Buffalo Creek sites receiving the following Level 1 landscape assessment condition categories (determined from final Landscape Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

Table 13. Natural condition score components and final natural condition scores for Buffalo Creek sampling sites.

Site ID	% Forest (1 km Circle)	# Unique Stressors	Buffer Score	Buffer Penetrations	Natural Condition Score
BC-01	90.75	1	6	0	0.83
BC-02	94.98	1	6	0	0.86
BC-03	97.46	1	6	0	0.88
BC-04	97.69	1	6	0	0.89
BC-05	98.96	0	6	0	0.99
BC-06	98.16	0	6	0	0.98

Table 14. Results from Level 2 rapid assessment: SWR metric values and final SWR Index scores for Buffalo Creek sampling sites.

Site ID	Buffer Cond (%)	Incision Ratio	Basal Area	Invasive Cover Class	Stream Habitat Score	# Stream Stressors	# Flood.-Wetl Stressors	SWR Index Score
BC-01	100.00	2.19	8.00	1	180.00	1	1	0.82
BC-02	100.00	9.93	12.67	1	164.00	3	0	0.56
BC-03	100.00	2.98	11.33	0	167.00	2	0	0.74
BC-04	100.00	2.57	9.67	1	178.00	1	0	0.81
BC-05	100.00	4.74	11.67	0	175.00	0	0	0.74
BC-06	100.00	9.24	17.67	0	157.00	0	0	0.68

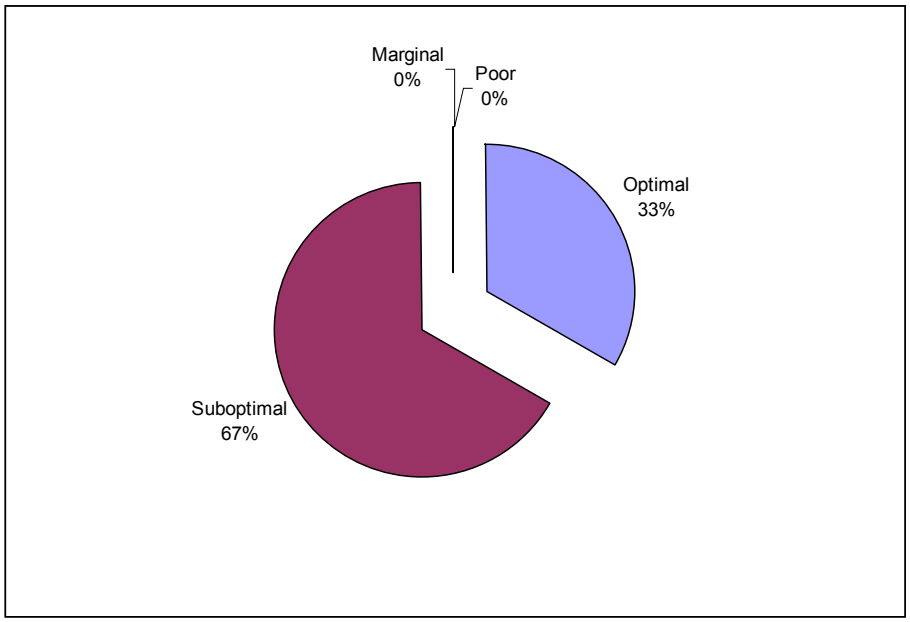

Figure 12. Proportion of Buffalo Creek sites receiving the following Level 2 rapid assessment condition categories (determined from SWR Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

NERI Buffalo Creek Watershed Intensive Assessment (Level 3) Results

Macroinvertebrate Community Characterization: Figure 13 compares the relative abundance of the major insect orders (and other invertebrates) collected from the Buffalo Creek watershed. Trichoptera (30%) and Diptera (28%) were the most abundant orders collected followed by Ephemeroptera (23%) and Plecoptera (13%). *Diplectrona* was the most abundant caddisfly, followed by *Ceratopsyche* and *Glossosoma*. Although an abundance of Hydropsychidae individuals can indicate organic enrichment, it is important to consider the particular genera involved. *Diplectrona,* for example, is actually an intolerant genus (in eastern North America it's represented by the species *Diplectrona modesta*) that occurs primarily in streams indicative of high water quality and is usually absent in organically enriched streams. *Ceratopsyche* contains several species that range in pollution tolerance from intolerant to mostly facultative (0-4 on a scale of 1-10 with 10 being most pollution tolerant) (Barbour et al. 1999). Diptera were dominated mostly by Chironomidae, as well as two fairly intolerant crane fly genera (*Hexatoma* and *Dicranota*). The most abundant mayflies were *Baetis* and *Leucrocuta*, while the stoneflies consisted mostly of the genera *Leuctra, Soyedina,* and *Malirekus*.

Table 15 displays the results for the RBP III assessment of the Buffalo Creek watershed intensive sampling sites, including water chemistry parameters, macroinvertebrate metrics, and site condition categories (based on similarity to reference condition). Although six locations were selected for macroinvertebrate sampling, three were not sampled due to the extremely high gradient nature of the stream reach. Of the remaining three, BC-01 (Buffalo Creek) and BC-02 (unnamed tributary) were considered to be in suboptimal condition, and BC-04 (unnamed tributary) was considered to be in marginal condition (Table 15).

All water chemistry parameters were within normal range (Table 15, Appendix D). The variability in specific conductivity between the sites can most likely be attributed to the effects of evaporation in observed low-flow conditions, since the highest values were recorded in the tributaries (BC-02 and BC-04), both of which had lower flow conditions than the main branch (BC-01) at the time of sampling. Modified HBI values were very good, indicating the possibility of only slight organic pollution. Taxa richness values were high for BC-01 and BC-02. Although Trichoptera represented the most abundant order, caddisfly diversity was low with all individuals collected belonging to a few intolerant genera. BC-04 experienced reductions in total taxa diversity and EPT taxa (especially mayflies), as well as a slight increase in the modified HBI value and was considered marginal in condition. This station was located on an unnamed tributary whose headwaters were surrounded by quarry and mining activities. In addition, the entire site was characterized by low flow conditions. Therefore, a variety of potential stressors, both past and present, may be affecting BC-04, requiring further investigation. BC-01 and BC-02, although located downstream of the confluence of the aforementioned tributary, were most likely slightly impacted by significant bank erosion during flooding of the steep terrain.

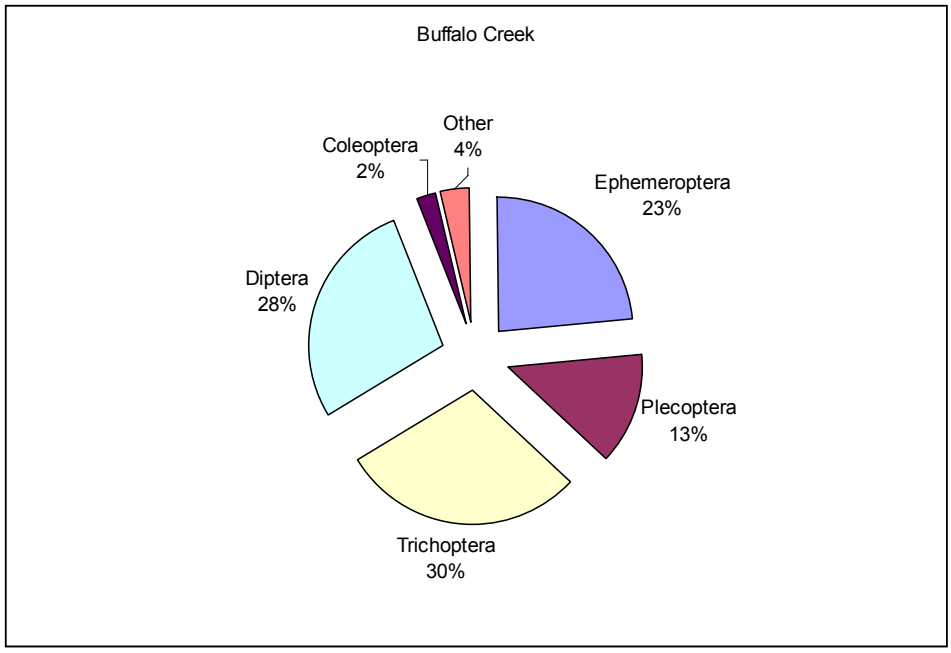

Figure 13. Breakdown by common insect order of the total macroinvertebrate individuals collected in the Buffalo Creek watershed.

Table 15. Results of Level 3 intensive assessments (macroinvertebrates) for the Buffalo Creek watershed, including water chemistry parameters, RBP III metric values, percent similarity to reference, and overall condition categories.

	Level 3 Intensive Sampling Site			WV EMAP
	BC-01	BC-02	BC-04	REF AV
Date Collected	7/29/2004	7/29/2004	7/29/2004	
Water Chemistry				
pH	6.24	7.25	7.27	*
Temperature (°C)	17.5	16.5	17.6	*
Conductivity (µS/cm)	79.45	274	177	*
Dissolved Oxygen (mg/L)	7.41	7.69	7.29	*
Macroinvertebrate Metric				
Modified HBI	4.01	3.38	4.24	2.40
Taxa Richness	34	33	26	33
EPT Index	19	15	14	24
Ephemeroptera Taxa	8	4	5	9
Plecoptera Taxa	6	6	4	7
Trichoptera Taxa	5	5	5	8
Dominance of Top Taxon	0.2	0.36	0.26	0.16
% Similarity to Reference	76	57	43	100
Standardized Condition Score	0.69	0.53	0.42	1.0
Condition Category	Suboptimal	Suboptimal	Marginal	*

Stream Salamander Assemblage: BC- 02 and BC-04 were occupied by 5 species of salamanders, including considerable numbers of the seal salamander (*Desmognathus monticola*), a ubiquitous and wide-ranging taxon in southern MAHA headwaters and numerous larval northern spring salamanders (*Gyrinophilus porphyriticus*). Not surprisingly, assemblages at both sites compared favorably to the MAHA-wide set of references: NGS SPAR index value of 8.8 and 7.5, respectively (Table 16). On the other hand, when compared to Group 2 references, the group to which both sites were assigned based on their location and stream habitat, their condition was judged lower. In fact, their GS SPAR index value was lower (6.3 for both) and resulted in a standardized condition score of 0.48, or marginal (Table 16). Both sites have desirable salamander assemblage attributes from a regional perspective, but it could be better relative to its southern reference counterparts.

NERI Buffalo Creek Watershed Summary

Table 17 provides a summary of the landscape (Level 1), rapid (Level 2), and intensive (Level 3) results for the Buffalo Creek watershed. The landscape assessment rated the Buffalo Creek sites as optimal in condition (mean = 0.98) (Table 17). Rapid assessment scores differed between the natural condition score (mean = 0.91) and the more refined SWR Index (mean = 0.73), which dropped four of the six sampling sites down to the suboptimal condition category due to high incision rates and/or poor stream bank condition, most likely a result of the 2001 flood events. Both of the intensive assessments primarily rated the Buffalo Creek sites as suboptimal in condition, except BC-04, which was rated as marginal in condition by the macroinvertebrate assessment (Table 17). This site had low flow conditions and appeared to dry during portions of the year and, thus, contained lower EPT and overall taxonomic diversity (Table 17). Low flows as well as suboptimal stream bank habitat would adversely affect stream salamanders. These factors combined may explain why less than ideal scores resulted for salamanders in a stream draining a seemingly minimally disturbed landscape.

NERI Fern Creek Watershed Landscape Assessment (Level 1) Results

Landscape metric values and final Landscape Index scores for the Fern Creek watershed and individual landscape assessment sites are listed in Table 18, and summarized as condition categories in Figure 14. The landscape assessment classified the entire Fern Creek watershed as in optimal condition, at both the watershed and site level scales. However, this watershed is under increasing pressure from future land development that may introduce or increase existing environmental stressors. Percent forest cover surrounding each site and the entire watershed was above 90% and LDI values and percent impervious surface were both low (Table 18).

Table 16. SPAR Index results for Buffalo Creek Level 3 intensive sampling sites.

	Level 3 Intensive Sampling Site	
	BC-02	BC-04
Date Collected	7/18/2004	7/29/2004
Non-group Specific (NGS) Assessment		
Metric A	10	10
Metric E	5	5
Metric F	10	5
Metric I	10	10
SPAR Index Value	8.8	7.5
SPAR Condition Category	Reference	Reference
Standardized Condition Score	0.69	0.40
Condition Category	Suboptimal	Marginal
Group Specific (GS) Assessment		
Group Designation*	2	2
Metric A	10	10
Metric E	0	5
Metric F	5	5
Metric I	10	5
SPAR Index Value	6.3	6.3
SPAR Condition Category	Non-reference	Non-reference
Standardized Condition Score	0.48	0.48
Condition Category	Marginal	Marginal

* Group 2 are the southern Mid-Atlantic high gradient headwaters

Table 17. Summary of landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessment scores for the Buffalo Creek watershed. All scores have been standardized to a 0 to 1 scale in order to facilitate comparisons of condition.

Site ID	Level One Landscape Index	Level Two Natural Condition Score	SWR Index	Level Three Macroinvertebrates (RBP III)	Salamanders (SPAR Index)
Buffalo Mean	0.98	0.91	0.73	0.55	0.48
BC-01	0.95	0.83	0.82	0.70	
BC-02	0.97	0.86	0.56	0.53	0.48
BC-03	0.99	0.88	0.74		
BC-04	0.99	0.89	0.81	0.42	0.48
BC-05	1.00	0.99	0.74		
BC-06	0.99	0.98	0.68		

Condition Category		
	0.76 - 1.0	Optimal
	0.51 - 0.75	Suboptimal
	0.26 - 0.50	Marginal
	0.0 - 0.25	Poor

Table 18. Landscape metric values and final Landscape Index scores for the Fern Creek watershed (in bold) and for each Fern Creek sampling site.

Site ID	Forest Cover (%)	LDI (unitless)	Impervious Surface (%)	Mean Forest Patch Size(m²)	Core Forest/ Total Forest (%)	LANDSCAPE INDEX SCORE
FERN CREEK WATERSHED	**94.04**	**1.10**	**0.586**	**109.8**	**0.83**	**0.92**
FERN CREEK SITE SCORES (1-km radius circle)						
FC-01	93.2	1.14	0.65	58.2	0.81	0.93
FC-02	90.4	1.08	0.44	56.5	0.94	0.94
FC-03	95.6	1.12	0.68	99.5	0.77	0.94
FC-04	94.9	1.14	0.73	148.1	0.75	0.94
FC-05	97.5	1.07	0.65	152.2	0.75	0.95
FC-06	92.7	1.04	0.07	144.6	0.98	0.97

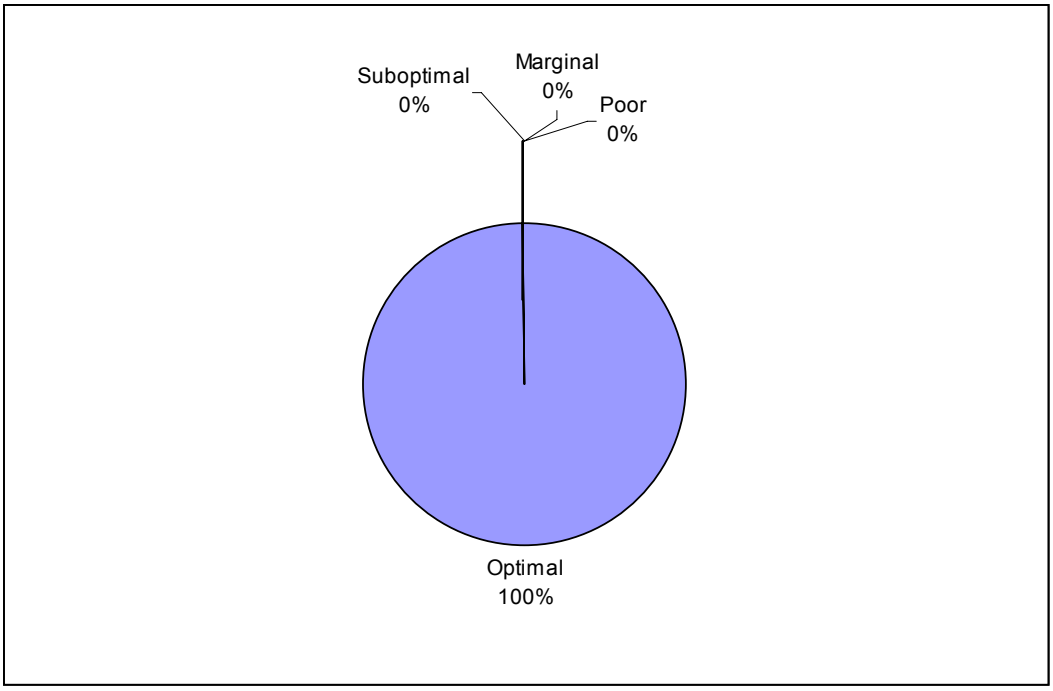

Figure 14. Proportion of Fern Creek sites receiving the following Level 1 landscape assessment condition categories (determined from final Landscape Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

NERI Fern Creek Watershed Rapid Assessment (Level 2) Results

Table 19 displays the natural condition scores for the Fern Creek watershed rapid assessment locations; Table 20 displays the results of the SWR assessment. Natural condition scores ranged from 0.648 to 0.936 (mean = 0.812); site receiving lower natural condition scores (e.g., FC-04 and FC-06) had increased numbers of onsite stressors, lower buffer scores, and buffer penetrations (Table 19). FC-04 lies north of CR 82 and is adjacent to an ongoing clearcut; FC-06 is located just south of an active railroad bed. In general, SWR Index scores were higher at this watershed than the Buffalo Creek watershed, ranging from 0.63 to 0.88, with a mean of 0.76 (Table 20). This is probably due to the increased incision ratio at the Buffalo Creek tributaries. More floodplain and wetland stressors, however, were noted at the Fern Creek sites (Table 20). Overall, the SWR Index scores classified 67% of the sites sampled in the Fern Creek watershed as optimal in condition. The remaining 33% of Fern Creek sites were considered in suboptimal condition (Figure 15).

NERI Fern Creek Watershed Intensive Assessment (Level 3) Results

Macroinvertebrate Community Characterization: Figure 16 compares the relative abundance of the major insect orders and other invertebrates collected from the Fern Creek watershed. Diptera (66%) dominated the collections, consisting primarily of Chironomidae midges. Other taxa were largely Oligochaeta (aquatic worms) and Amphipoda (*Gammarus* and *Crangonyx*). Collectively, EPT taxa made up 19% of the total individuals collected and consisted mainly of Plecoptera (*Leuctra* and *Isoperla*) and Trichoptera (*Diplectrona*) (Figure 16). Community dominance by midge larvae and non-insects (e.g., Oligochaeta) is common in low gradient streams that do not contain a prevalence of the riffle habitats preferred by many EPT taxa.

Table 21 displays the results of the RBP III assessment of the Fern Creek watershed intensive sampling sites, including water chemistry parameters, macroinvertebrate metrics, and site condition categories (based on similarity to reference condition). Macroinvertebrate sampling was conducted at four site locations in the Fern Creek watershed. FC-01 and FC-02 were located along Fern Creek; FC-03 and FC-04 were both located upstream along unnamed tributaries of Fern Creek. Water pH was low at all sites (mean = 5.03); dissolved oxygen was also low (mean = 4.87 mg/L) (Table 21). The RBP III assessment characterized both FC-01 and FC-03 in suboptimal condition. Both stream reaches consisted of scattered pools with sandy substrate and some woody debris. Although a natural condition, fewer invertebrates can survive in this habitat type compared to riffle habitats (which Fern Creek lacked), resulting in low diversity and abundance (especially of common EPT taxa) and dominance of a few taxa (especially Chironomidae). Unlike the other sites, FC-02 contained a mix of cobble, gravel, boulder, and sand, providing more suitable habitat for EPT taxa and resulting in a judgment of optimal condition (Table 21). An adjacent clearcut may have contributed to the marginal condition of FC-04, which contained only five EPT genera.

Table 19. Natural condition score components and final natural condition scores for Fern Creek sampling sites.

Site ID	% Forest (1 km Circle)	# Unique Stressors	Buffer Score	Buffer Penetrations	Natural Condition Score
FC-01	93.20	0	6	0	0.94
FC-02	90.43	0	6	0	0.91
FC-03	95.56	1	5.7	0	0.87
FC-04	94.87	3	3.3	1	0.65
FC-05	97.52	2	6	0	0.79
FC-06	92.65	2	3	1	0.72

Table 20. Results from Level 2 rapid assessment: SWR metric values and final SWR Index scores for Fern Creek sampling site.

Site ID	Buffer Cond (%)	Incision Ratio	Basal Area	Invasive Cover Class	Stream Habitat Score	# Stream Stressors	# Flood.-Wetl Stressors	SWR Index Score
FC-01	100.00	3.29	21.00	0	162.00	0	0	0.81
FC-02	100.00	1.95	10.33	0	177.00	0	0	0.88
FC-03	95.00	2.93	16.00	1	164.00	1	0	0.78
FC-04	55.00	1.90	7.67	1	121.00	1	3	0.71
FC-05	100.00	2.43	13.33	0	162.00	2	1	0.76
FC-06	50.00	3.68	9.67	0	176.00	3	2	0.63

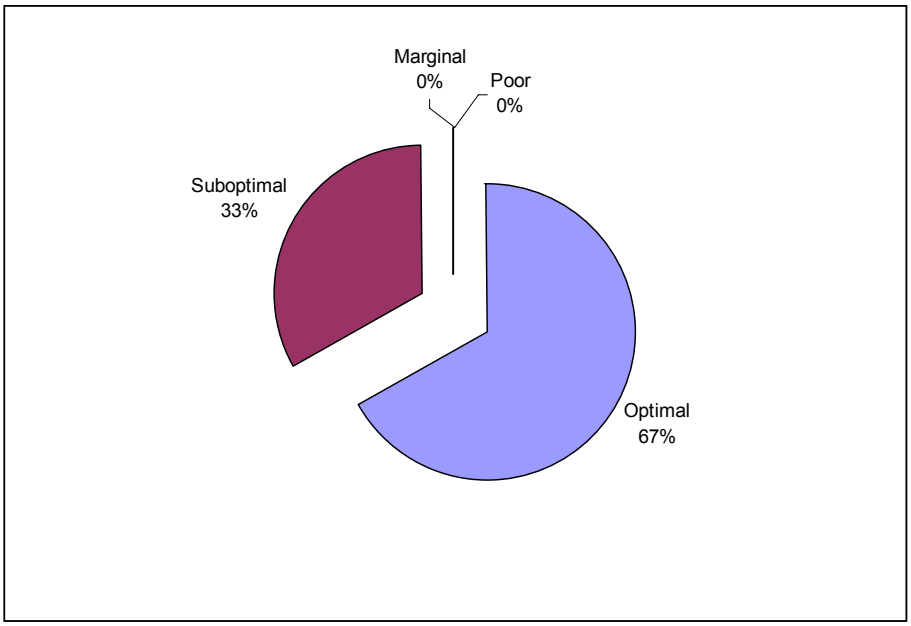

Figure 15. Proportion of Fern Creek sites receiving the following Level 2 rapid assessment condition categories (determined from SWR Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

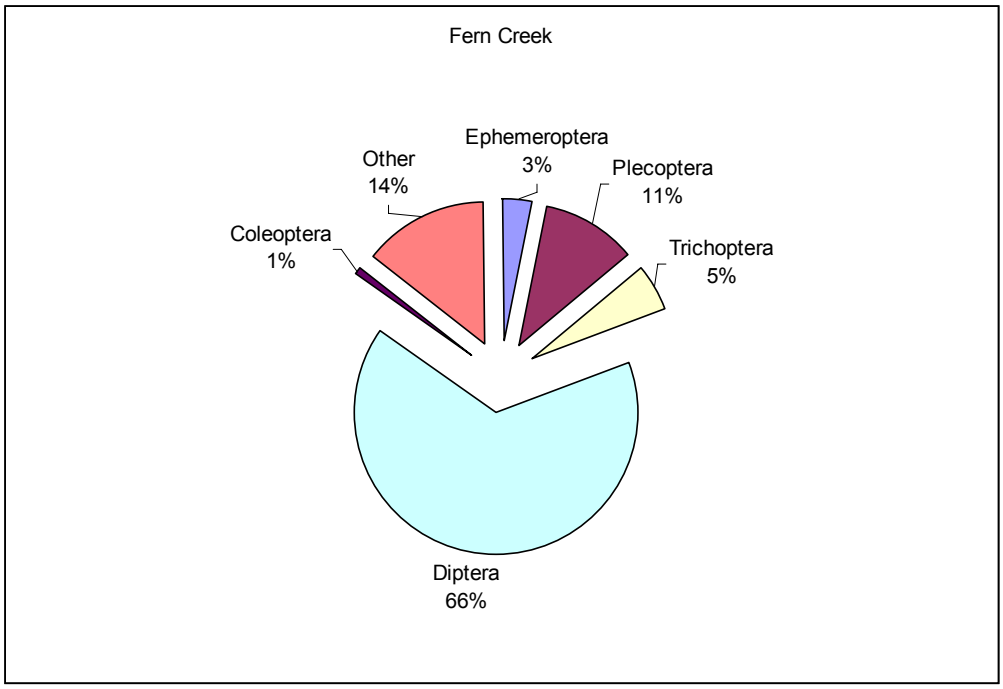

Figure 16. Breakdown by common insect order of the total macroinvertebrate individuals collected in the Fern Creek watershed.

Table 21. Results of Level 3 intensive assessments (macroinvertebrates) for the Fern Creek watershed, including water chemistry parameters, RBP III metric values, percent similarity to reference, and overall condition categories.

	Level 3 Intensive Sampling Site				WV EMAP
	FC-01	FC-02	FC-03	FC-04	REF AV
Date Collected	7/16/2004	7/15/2004	7/30/2004	7/16/2004	
Water Chemistry					*
pH	5.04	5.14	5.21	4.1	*
Temperature (°C)	16.3	18.2	17.5	18.35	*
Conductivity (µS/cm)	59	71.1	100.55	56.55	*
Dissolved Oxygen (mg/L)	4.24	5.13	6.59	4.18	
Macroinvertebrate Metric					
Modified HBI	5.06	5.31	5.89	5.51	4.49
Taxa Richness	27	31	16	31	13
EPT Index	7	14	9	5	7
Ephemeroptera Taxa	3	6	1	1	4
Plecoptera Taxa	2	4	1	2	3
Trichoptera Taxa	2	6	7	2	4
Dominance of Top Taxon	0.56	0.59	0.39	0.6	0.27
% Similarity to Reference	70	90	60	45	100
Standardized Condition Score	0.64	0.86	0.56	0.43	1.0
Condition Category	Suboptimal	Optimal	Suboptimal	Marginal	*

When interpreting these results, it is important to realize the limitations of the RBP III protocol in assessments of low gradient headwater streams, such as Fern Creek. These metrics are based primarily on macroinvertebrate responses to disturbance in high gradient riffle habitats. Although substituting data from reference-standard pool habitats creates a more accurate comparison of reference condition, it cannot fully rectify this discrepancy, because the metrics themselves may not apply. For example, EPT taxa are highly abundant and diverse in riffle habitats of high gradient reference streams and decline sharply as anthropogenic disturbances increase in these habitats. In low gradient streams, however, EPT taxa tend to be poorly represented across the entire human disturbance range, making it difficult to separate streams in optimal condition from those in marginal or poor condition. Although the CWC has developed metrics for low gradient headwater streams, they are based on limited data and require additional testing before they can be applied in condition assessments. Therefore, the recommended course of action is to (1) recognize the possibility that a low condition score at Fern Creek may be a reflection of these limitations, and does not necessarily imply marginal or poor conditions for supporting macroinvertebrate communities; and (2) consider the possibility of future assessments using indexes designed for low gradient streams.

Stream Salamander Assemblage: FC-03 and FC-04, both located on tributaries to Fern Creek, supported 4 species of salamanders; the southern two-lined salamander (*Eurycea cirrigera*) was the most abundant. Both stream sites were assigned to Group 3, low gradient MAHA headwaters and scored relatively high, 8.3 and 5.0, respectively, relative to their counterpart references (Table 22). Their standardized condition score was 0.58 and 0.27, values that match the suboptimal and marginal categories, respectively (Table 22). Not surprising is the outcome of their NGS scores and corresponding condition category: the assemblage observed, while satisfactory by Group 3 standards, compares poorly to the larger regional set of references that includes more diverse, higher scoring assemblages. Thus, a low percent rank (0.25 and 0.125) and condition of "poor" relative to a regional standard is to be expected.

As with macroinvertebrates, sandy substrates and sparse cover may limit salamander assemblage development as well as impair searches. Low scores in these situations should be interpreted with caution. But stream pH at Fern Creek was also low, particularly at FC-04. The low scores for the latter site may be a reflection of lack of cover as well as low pH.

Table 22. SPAR Index scores for Fern Creek Level 3 intensive sampling sites.

	Level 3 Intensive Sampling Site	
	FC-03	FC-04
Date Collected	7/11/2004	7/15/2004
Non-group Specific (NGS) Assessment		
Metric A	10	10
Metric E	5	0
Metric F	0	0
Metric I	5	0
SPAR Index Value	5	2.5
SPAR Condition Category	Non-reference	Degraded
Standardized Condition Score	0.25	0.13
Condition Category	Poor	Poor
Group Specific (GS) Assessment		
Group Designation*	3	3
Metric D	10.0	10.0
Metric E	10.0	0.0
Metric F	5.0	5.0
SPAR Index Value	8.3	5.0
SPAR Condition Category	Reference	Non-reference
Standardized Condition Score	0.58	0.27
Condition Category	Suboptimal	Marginal

* Group 3 are the Mid-Atlantic low gradient headwaters

NERI Fern Creek Watershed Summary

Table 23 provides a summary of the landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessments for the Fern Creek watershed. Results were typical with landscape assessment scores rating all sites as optimal in condition (mean = 0.95), and more intensive assessments producing equal or lower ratings (Table 23). FC-01 and FC-03 were listed in optimal condition by both landscape and rapid assessment levels, but declined to suboptimal condition in the intensive macroinvertebrate assessment due to lower diversity of Plecoptera and Trichoptera taxa and a high dominance of Chironomidae (Table 21). FC-04 dropped to marginal condition in the intensive assessments.

Fern Creek represents a low gradient headwater system that, presently, shows little sign of human impact. Limitations placed on the biological communities probably stem more from the natural characteristics of a small watershed with little elevational drop (resulting in insufficient stream power to create habitats preferred by typical riffle taxa) than from anthropogenic disturbances. However, stressor information gathered from the rapid assessment (e.g., adjacent clearcutting), along with the possibility of future development (according to local landowners) suggests that future human impacts may occur. Therefore, this watershed does not appear to need active management, but instead may require protection from future stressors to ensure the maintenance of its ecological integrity.

NERI Dunloup Creek Watershed Landscape Assessment (Level 1) Results

Landscape metric values and final Landscape Index scores for the Dunloup Creek watershed, as well as the individual sampling sites, are listed in Table 24 and summarized as condition categories in Figure 17. Although Dunloup Creek was chosen to represent the more disturbed NERI watersheds, the landscape assessment rated the entire watershed and the majority of the individual sampling sites (90%) as optimal in condition (Table 24, Figure 17). Fifteen of the 20 1-km radius circles evaluated had mean forest patch sizes larger than 140 m^2. The average mean forest patch size for the 1-km radius circles was 199.3 m^2, which is much larger than the mean forest patch size for the surface area of the watershed (76.7 m^2). This implies that forest cover was more prevalent along the stream sampling sites than throughout the rest of the watershed. Thus, the Landscape Index score for the entire watershed may be a more accurate representation of overall watershed condition. Of the individual sampling locations, only two (DC-04 and DC-07), were surrounded by a mix of small forest patches and urban development and were rated as suboptimal in condition. For both sites, the total percentage of surrounding forest in a 1-km radius circle was much lower (64.7%) than the watershed's site mean of 92.5% (Table 24). In addition, LDI values were lower, impervious surface was much higher, and mean forest patch size and the proportion of core forest to total forest were much lower than the other sampling sites in the Dunloup Creek watershed. Thus, the landscape assessment reveals two locations, DC-04 and DC-07 (both located near park property and Glen Jean) that may be of interest when targeting areas of possible impact to the park's natural resources.

Table 23. Summary of landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessment scores for the Fern Creek watershed. All scores have been standardized to a 0 to 1 scale in order to facilitate comparisons of condition.

Site ID	Level One Landscape Index	Level Two Natural Condition Score	SWR Index	Level Three Macroinvertebrates (RBP III)	Salamanders (SPAR Index)
Fern Mean	0.95	0.81	0.76	0.62	0.42
FC-01	0.93	0.94	0.81	0.64	
FC-02	0.94	0.91	0.88	0.85	
FC-03	0.94	0.87	0.78	0.55	0.58
FC-04	0.94	0.65	0.71	0.44	0.27
FC-05	0.95	0.79	0.76		
FC-06	0.97	0.72	0.63		

Condition Category		
	0.76 - 1.0	Optimal
	0.51 - 0.75	Suboptimal
	0.26 - 0.50	Marginal
	0.0 - 0.25	Poor

Table 24. Landscape metric values and final Landscape Index scores for the Dunloup Creek watershed (in bold) and for each Dunloup Creek sampling site.

Site ID	Forest Cover (%)	LDI (unitless)	Impervious Surface (%)	Mean Forest Patch Size(m²)	Core Forest/ Total Forest (%)	LANDSCAPE INDEX SCORE
DUNLOUP CREEK WATERSHED	**88.1**	**1.51**	**2.79**	**76.7**	**0.68**	**0.79**
DUNLOUP CREEK SITE SCORES (1-km radius circle)						
DC-01	98.7	1.05	0.32	154.1	0.78	0.98
DC-02	98.4	1.03	0.40	307.3	0.79	0.97
DC-03	85.6	1.53	3.71	38.2	0.49	0.77
DC-04	64.7	2.92	18.90	8.8	0.26	0.52
DC-05	91.6	1.42	1.57	143.1	0.69	0.90
DC-06	94.6	1.32	0.28	147.7	0.74	0.96
DC-07	64.7	2.89	18.50	8.4	0.24	0.52
DC-08	99.8	1.00	0.09	311.7	0.93	1.00
DC-11	98.9	1.01	0.43	308.6	0.81	0.97
DC-13	99.6	1.01	0.14	310.9	0.91	1.00
DC-15	99.6	1.01	0.25	310.9	0.85	0.99
DC-18	87.8	1.41	3.69	54.9	0.74	0.80
DC-21	99.8	1.01	0.75	311.5	0.74	0.96
DC-23	98.4	1.08	0.28	307.4	0.79	0.98
DC-25	91.9	1.50	0.14	143.5	0.73	0.96
DC-26	97.9	1.11	0.29	152.8	0.78	0.97
DC-27	86.5	1.24	0.11	54.0	0.89	0.89
DC-28	93.5	1.11	0.29	292.1	0.84	0.96
DC-31	99.6	1.01	0.15	310.9	0.91	1.00

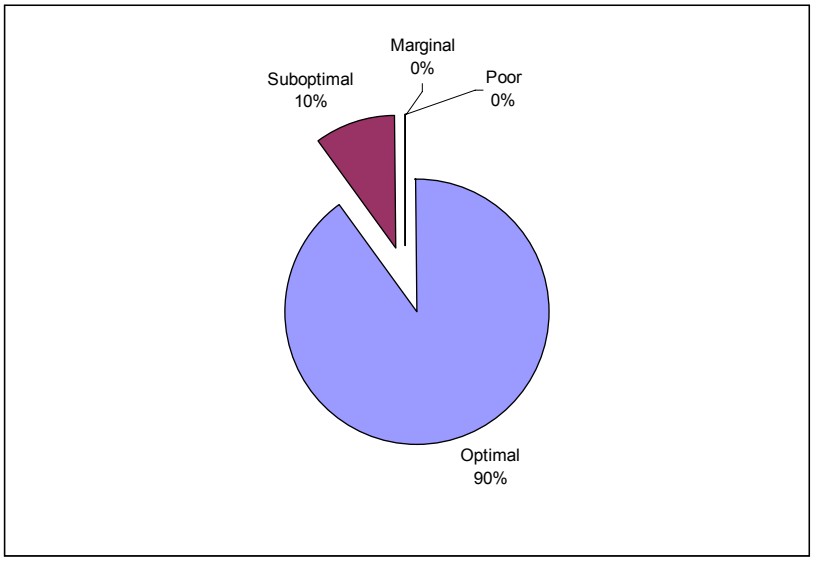

Figure 17. Proportion of Dunloup Creek sites receiving the following Level 1 landscape assessment condition categories (determined from final Landscape Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

NERI Dunloup Creek Watershed Rapid Assessment (Level 2) Results

Natural condition scores for the Dunloup Creek watershed ranged from 0.41 to 1.0, with a mean of 0.724 (Table 25). SWR Index scores ranged from 0.47 to 0.90 with a mean of 0.69 (Table 26). Figure 18 breaks down the 20 Dunloup sampling sites by SWR condition category. Seven sampling sites were located in heavily forested headwaters with little or no apparent stressors (DC-02, DC-06, DC-08, DC-13, DC-15, DC-23, and DC-26). These areas were characterized by both high Natural condition scores (0.86 to 1.0) and high SWR scores (0.79 to 0.90) (Tables 25 and 26). Although DC-25 was influenced by a beaver impoundment, prohibiting the collection of various SWR information (e.g., incision ratio and stream habitat condition), it scored in the suboptimal (Natural condition score = 0.74) and optimal conditions (SWR Index = 0.81). The lower Natural condition score can probably be attributed to a slightly lower percentage of surrounding forest at the impounded site (91% compared to average 98% at other optimal condition sites), resulting from a higher proportion of open water. Unlike the Natural condition score, forest cover does not affect the SWR Index. DC-31 was borderline suboptimal condition; this was reflected by the Natural condition score (0.70) and the SWR score (0.77) (Tables 25 and 26). Reduction in condition at this site is most likely due to strip mining near the headwaters of the DC-31 tributary.

Many sites, however, contained at least some evidence of a variety of stressor types, ranging from road and railroad beds to abundant stands of invasive plant species to stormwater inputs from tile drains and culverts to fecal coliform contamination from poor sewage disposal practices. In addition, mining activities were also present in many of the headwater reaches. Most sites were in suboptimal condition (Figure 18), with Natural condition scores between 0.78 and 0.41 (Table 25) and SWR Index scores between 0.53 and 0.73 (Table 26). DC-07 and DC-18 had low buffer scores and were influenced by old spoil piles, power lines, and an abandoned railroad bed. DC-01 and DC-11 were both located on the mainstem of Dunloup Creek, just downstream of the sewage treatment plant. Both stream reaches were contaminated with fecal coliform (determined from posted warning signs) and contained excessive algal mats and a strong detergent odor. DC-03 and DC-04 had the lowest SWR scores (0.48 and 0.47, respectively) and were considered to be in marginal condition (Table 26). Each contained a high number of stream stressors, including channelization, culverts, stormwater inputs, and road crossings.

NERI Dunloup Creek Watershed Intensive Assessment (Level 3) Results

Macroinvertebrate Community Characterization: Figure 19 compares the relative abundance of the major insect orders and other invertebrates collected from the Dunloup Creek watershed. Ephemeroptera (29%) and Diptera (29%) contained the most abundant taxa, primarily *Baetis, Stenonema,* and *Leucrocuta*, and midge flies (Chironomidae). Certain species within these mayfly genera can tolerate at least moderate levels of organic enrichment. Trichoptera represented 24% of the total individuals collected and consisted mostly of *Ceratopsyche* and *Diplectrona*. Although *Diplectrona* is considered intolerant, several species of *Ceratopsyche* can also tolerate organic enrichment. *Leuctra* was the most abundant stonefly collected from this watershed, but was only abundant in one tributary stream.

Table 25. Natural condition score components and final natural condition scores for Dunloup Creek sampling sites.

Site ID	% Forest (1 km Circle)	# Unique Stressors	Buffer Score	Buffer Penetrations	Natural Condition Score
DC-01	98.73	6	5.1	1	0.41
DC-02	98.41	0	6	0	0.99
DC-03	85.62	3	2.2	0	0.59
DC-04	64.66	3	2.4	0	0.45
DC-05	91.64	3	4.7	0	0.65
DC-06	94.58	1	6	0	0.86
DC-07	64.69	2	3.9	0	0.53
DC-08	99.83	1	6	0	0.90
DC-11	98.85	4	5.4	2	0.59
DC-13	99.57	1	6	0	0.90
DC-15	99.57	0	6	0	1.00
DC-18	87.84	5	4.1	2	0.43
DC-21	99.77	3	5.4	0	0.71
DC-23	98.44	0	6	0	0.99
DC-25	91.9	2	5.2	0	0.74
DC-26	97.87	1	6	0	0.89
DC-27	86.45	1	5.4	0	0.78
DC-28	93.54	3	5.4	0	0.67
DC-31	99.57	3	6	2	0.70
DC-33	99.34	3	5	0	0.70

Table 26. Results from Level 2 rapid assessment: SWR metric values and final SWR Index scores for Dunloup Creek sampling sites.

Site ID	Buffer Cond (%)	Incision Ratio	Basal Area	Invasive Cover Class	Stream Habitat Score	# Stream Stressors	# Flood.-Wetl Stressors	SWR Index Score
DC-01	85.00	1.91	5.00	3	156.00	8	5	0.53
DC-02	100.00	2.74	11.33	1	178.00	0	0	0.84
DC-03	36.67	2.17	9.50	3	130.00	7	6	0.48
DC-04	40.00	2.43	4.00	3	141.00	7	7	0.47
DC-05	78.33	4.71	9.00	2	160.00	4	1	0.55
DC-06	100.00	1.73	15.33	1	174.00	1	0	0.86
DC-07	65.00	2.68	5.00	3	142.00	4	5	0.57
DC-08	100.00	1.86	14.33	0	139.00	1	1	0.80
DC-11	90.00	1.85	8.33	3	165.00	9	7	0.54
DC-13	100.00	2.15	12.00	0	176.00	1	0	0.84
DC-15	100.00	2.73	16.67	0	176.00	0	0	0.86
DC-18	68.33	2.90	8.00	4	146.00	4	6	0.54
DC-21	90.00	2.15	9.00	1	169.00	5	5	0.65
DC-23	100.00	1.88	15.00	1	183.00	0	0	0.90
DC-25	86.67	*	7.00	1	*	0	2	0.81
DC-26	100.00	2.14	13.00	0	161.00	2	0	0.79
DC-27	90.00	1.94	8.67	1	145.00	3	0	0.73
DC-28	90.00	2.95	12.00	3	147.00	4	2	0.61
DC-31	100.00	1.94	9.67	1	173.00	3	0	0.77
DC-33	83.33	2.47	8.00	1	150.00	2	2	0.71

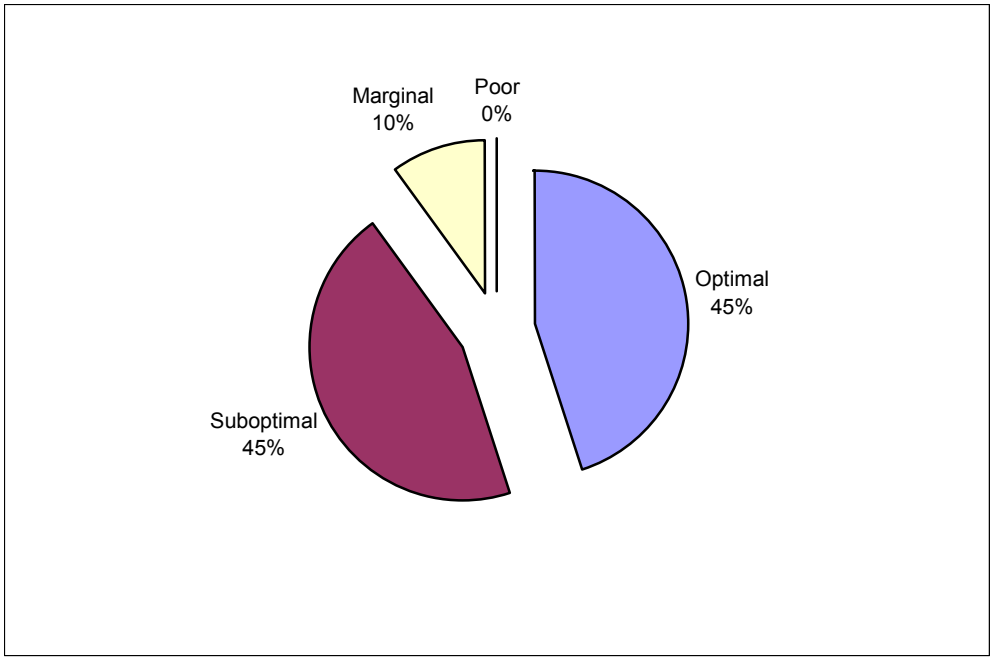

Figure 18. Proportion of Dunloup Creek sites receiving the following Level 2 rapid assessment condition categories (determined from SWR Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

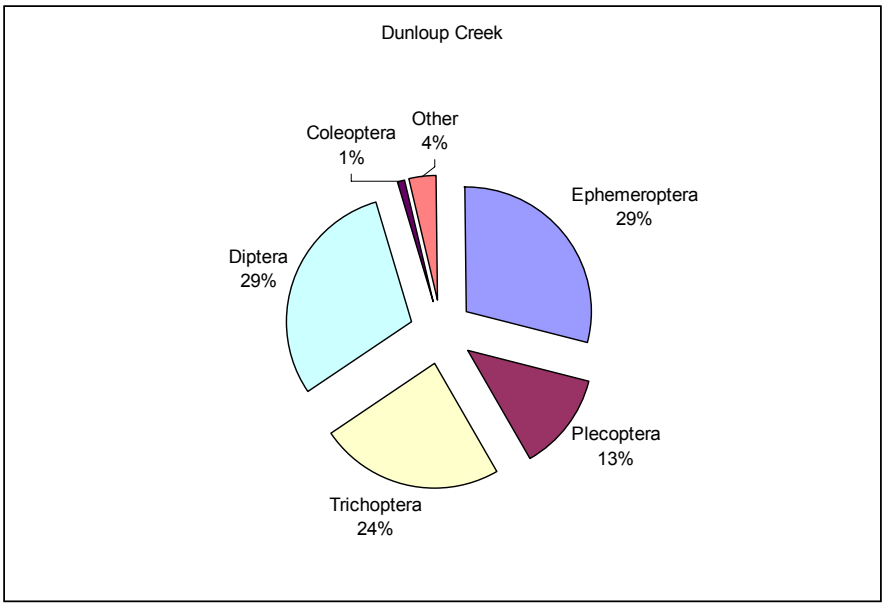

Figure 19. Breakdown by common insect order of the total macroinvertebrate individuals collected in the Dunloup Creek watershed.

Table 27 displays the results from the RBP III assessment of the Dunloup Creek watershed, including water chemistry measurements, macroinvertebrate metrics, and site condition categories (based on similarity to reference condition). Several sources of impairment have been identified for this watershed, including inadequate sewage treatment and metals (iron, aluminum, and manganese) from mine drainage (Purvis et al. 2002). The results of this study support this. Water pH and specific conductivity varied throughout the watershed (most likely due to sewage or mine pollution), while dissolved oxygen and temperature remained relatively constant (Table 22). Macroinvertebrate community results also varied (Table 27). DC-21, the only station sampled along Mill Creek, was surrounded by mature forest. Modified HBI value indicated excellent condition with no apparent organic pollution. Yet, this reach was deemed in poor condition due to extremely low taxa and EPT richness, especially mayflies and stoneflies. Although surrounding mines may be a source of impact, an adjacent trash dump may also serve as a potential source.

DC-01 and DC-11 were located along forested areas of Dunloup Creek and were characterized by higher pH values (7.74 and 7.91, respectively) and high specific conductivities (712.5 and 795 µS/cm, respectively), most likely the result of wastewater inputs from improperly treated sewage (Table 27). The biological results reflected the water chemistry; both sites were characterized as in marginal condition (Table 27). Each showed reduced taxa richness and low diversity of EPT taxa, especially mayflies and stoneflies. Caddisflies were relatively diverse, but consisted mainly of the more tolerant hydropsychid genera. Modified HBI values indicated the presence of some organic pollution. *Baetis, Ceratopsyche,* and Chironomidae dominated these sampling locations and tend to increase in abundance as organic enrichment increases.

DC-06, located along the Turley Branch, was also considered to be moderately impaired resulting in a marginal condition category. The abundance of leuctrid stoneflies and conspicuous absence of most mayfly taxa, coupled with the proximity of several mines in the headwaters and surrounding areas, suggest mining as the primary stressor. However, pH (6.77) and taxa richness (29 taxa) reflect low to moderate levels of impact.

DC-31 lies within the Hamilton Branch, a sub-watershed adjacent to the Turley Branch; this small stream was severely impaired by mine drainage, containing only 11 macroinvertebrate taxa and 3 EPT taxa (Table 27). Water chemistry confirmed this (pH = 2.76; conductivity = 755 µS/cm) (Table 27). The low pH at DC-31 suggests the high conductivity is due to mine drainage. Extremely low pH creates soluble conditions for metals (e.g., sulfate) and results in high concentrations of charged ions, which increases electrical conductance (Gray 1996). In addition, high specific conductivity at low pH values suggests the source of contamination is from deep flooded mines, rather than surface mining. Of the Dunloup Creek sub-watersheds chosen for intensive sampling, the heavily forested Camp Creek (containing DC-13) appears to be in the best biological condition. This site was characterized as suboptimal in condition and contained a mix of macroinvertebrate taxa, including EPT genera. However, pH (5.53) and lower mayfly taxa richness imply at least slightly acidic conditions at this sight.

Table 27. Results of Level 3 intensive assessments (macroinvertebrates) for the Dunloup Creek watershed, including water chemistry parameters, RBP III metric values, percent similarity to reference, and overall condition categories.

	Level 3 Intensive Sampling Site						WV EMAP
	DC-01	DC-06	DC-11	DC-13	DC-21	DC-31	REF AV
Date Collected	7/30/2004	7/31/2004	7/26/2004	7/26/2004	7/31/2004	8/2/2004	
Water Chemistry							
pH	7.74	6.77	7.91	5.53	6.01	2.76	*
Temperature (°C)	18.6	18.8	19.4	18.2	18.2	19.1	*
Conductivity (µS/cm)	712.5	412.5	795	84.75	292.5	755	*
Dissolved Oxygen (mg/L)	7.21	6.76	7.51	6.52	7.17	6.77	*
Macroinvertebrate Metric							
Modified HBI	5.08	3.95	5.14	3.86	3.19	5.64	2.40
Taxa Richness	25	29	28	37	17	11	33
EPT Index	13	11	11	21	6	3	24
Ephemeroptera Taxa	3	2	4	5	1	0	9
Plecoptera Taxa	3	4	1	7	1	1	7
Trichoptera Taxa	7	5	6	9	4	2	8
Dominance of Top Taxon	0.27	0.3	0.43	0.36	0.51	0.56	0.16
% Similarity to Reference	38	38	29	67	19	0	100
Standardized Condition Score	0.38	0.38	0.32	0.62	0.23	0	1.0
Condition Category	Marginal	Marginal	Marginal	Suboptimal	Poor	Poor	*

Stream Salamander Assemblage: Only 5 individuals of 2 species, both dusky salamanders, occupied DC-31. Its score was not surprisingly low (Table 28). DC-6 and DC-13 were occupied by 4 species of salamanders, but the former consisted of only 7 individuals. It too scored poorly regardless of IBI used. DC-13 had the largest number of Appalachian seal salamanders (*D. monticola*) and a fair number of the other taxa. Its NGS SPAR index score of 10 and corresponding standardized score of 1 compared it favorably to regional references (Table 28). All three sites were assigned to Group 2 – a set of references represented by the top performers. Although scores were lower, 7.5 for the SPAR index and 0.66 for the standardized score, it also identified DC-13 as reference or/or suboptimal condition (Table 28).

NERI Dunloup Creek Watershed Summary

Table 29 provides a summary of the landscape (Level 1), rapid (Level 2), and intensive (Level 3) results for the Dunloup Creek watershed. In most cases, site scores (and corresponding condition) decreased as assessments became more intensive, often dropping from the optimal category in the landscape assessment to the marginal and poor categories in the intensive assessments. This sharp drop in condition suggests that much of this watershed is most likely in need of more intensive assessments before decisions regarding ecological condition and potential management strategies can be made. This is typical in watersheds where the stressors are unlikely to be detected in the coarser (e.g., landscape level) assessments. Such may be the case with the Dunloup Creek watershed where sewage contamination and mining activities appear to be some of the major sources of impact. Elevated levels of sewage may in part explain the paucity of salamanders at two stream sites. High concentrations of nitrate and other by-products (boron) of treated wastewater have been shown to affect vernal pool-breeding amphibians (Laposata and Dunson, 1998, Laposata and Dunson, 2000). However, the presence of other stressors (e.g., mining and urbanization) suggests that salamander paucity may result from a combination of these stressors, rather than sewage contamination alone.

DC-04 and DC-07 are both located in urbanized areas and were the only sites identified by the Landscape Index as being in less than optimal condition. These areas would represent locations with a high degree of stress and low restoration potential. DC-13, however, received the highest scores in the intensive assessments and was rated suboptimal in condition (Table 29). This location may be suitable for protection and/or restoration activities, since it indicates a high potential for success. DC-08, DC-15, and DC-23 maintained the highest scores throughout the Level 1 and Level 2 assessments, and may be good candidates for conducting more intensive assessments to confirm if they also represent ideal areas for protection.

Table 28. SPAR Index results for Dunloup Creek watershed Level 3 intensive sampling sites.

	Level 3 Intensive Sampling Site		
	DC-06	DC-13	DC-31
Date Collected	7/31/2004	7/30/2004	8/2/2004
Non-group Specific (NGS) Assessment			
Metric A	10	10	0
Metric E	0	10	0
Metric F	0	10	0
Metric I	0	10	0
SPAR Index Value	2.5	10	0
SPAR Condition Category	Degraded	Reference	Degraded
Standardized Condition Score	0.13	1.00	0.000
Condition Category	Poor	Optimal	Poor
Group Specific (GS) Assessment			
Group Designation*	2	2	2
Metric A	10	10	0
Metric E	0	5	0
Metric F	0	5	0
Metric I	0	10	0
SPAR Index Value	2.5	7.5	0
SPAR Condition Category	Degraded	Reference	Degraded
Standardized Condition Score	0	0.66	0
Condition Category	Poor	Suboptimal	Poor

* Group 2 are the southern Mid-Atlantic high gradient headwaters

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Table 29. Summary of landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessment scores for the Dunloup Creek watershed. All scores have been standardized to a 0 to 1 scale in order to facilitate comparisons of condition.

	Level One	Level Two		Level Three	
Site ID	Landscape Index	Natural Condition Score	SWR Index	Macroinvertebrates (RBP III)	Salamanders (SPAR Index)
Dunloup Mean	0.90	0.72	0.68	0.32	0.22
DC-01	0.98	0.41	0.53	0.38	
DC-02	0.97	0.99	0.84		
DC-03	0.77	0.59	0.48		
DC-04	0.52	0.45	0.47		
DC-05	0.90	0.65	0.55		
DC-06	0.96	0.86	0.86	0.38	0.0
DC-07	0.52	0.53	0.57		
DC-08	1.00	0.90	0.80		
DC-11	0.97	0.59	0.54	0.31	
DC-13	1.00	0.90	0.84	0.62	0.66
DC-15	0.99	1.00	0.86		
DC-18	0.80	0.43	0.54		
DC-21	0.96	0.71	0.65	0.23	
DC-23	0.98	0.99	0.90		
DC-25	0.96	0.74	0.54		
DC-26	0.97	0.89	0.79		
DC-27	0.89	0.78	0.73		
DC-28	0.96	0.67	0.61		
DC-31	1.00	0.70	0.77	0.0	0.0
DC-33	0.96	0.70	0.71		

Condition Category		
	0.76 - 1.0	Optimal
	0.51 - 0.75	Suboptimal
	0.26 - 0.50	Marginal
	0.0 - 0.25	Poor

NERI Wolf Creek Watershed Landscape Assessment (Level 1) Results

Landscape metric values and final Landscape Index scores for the Wolf Creek watershed and individual sampling sites are listed in Table 30 and summarized as condition categories in Figure 20. This assessment revealed a watershed Landscape Index score of 0.62 (suboptimal condition) with the majority of sites (68%) estimated as suboptimal condition and, thus, subjected to at least low to moderate levels of stress (Table 30; Figure 20). The watershed is characterized by 71% forest cover, and LDI value of 2.02, with 5% impervious surface, and small mean forest patch sizes (17.4 m^2) and only moderate proportion of core forest to total forest (0.46) (Table 30). For the most part, the individual sampling sites reflected the watershed values, and the mean Landscape Index score for the 1-km radius circles (0.69) was similar to the Landscape Index score for the entire watershed (0.62), implying that, unlike Dunloup Creek, the land use surrounding the streams and riparian zones is similar to that throughout the rest of the Wolf Creek watershed. Results from individual landscape metrics suggest that the Wolf Creek watershed may suffer water quality impacts from increased amounts of impervious surface and fragmented forest cover.

NERI Wolf Creek Watershed Rapid Assessment (Level 2) Results

Table 31 contains the natural condition scores from the rapid assessment of Wolf Creek; Table 32 displays the SWR metrics and Index scores from the rapid assessment. Although natural condition scores ranged from 0.35 to 0.92 (Table 31), this watershed appeared to be the most impacted by urbanization, consequently containing the greatest levels of disturbance of the four NERI watersheds (mean = 0.55). It also had the lowest SWR Index scores, which ranged from 0.28 to 0.86 and averaged 0.56 (Table 32). Stressors were similar to those found in the Dunloup Creek watershed, including stormwater and sewage inputs from drains and ditches, adjacent roads and railroads, and mining activities. Excessive sedimentation resulting from stream channelization and subsequent channel incision was quite prevalent.

Only two sites were listed in optimal condition: WC-03 and WC-37 (Table 32; Figure 21). Both sites were located along Wolf Creek in forested areas and received low natural condition scores and high SWR scores (Tables 31 and 32). Most sites within this watershed were in suboptimal condition (Table 32; Figure 21). WC-15, located farther downstream near the New River confluence, contained excessive algal mats and stormwater inputs from culverts and tile drains, resulting in a lower SWR score (0.56) (Table 32). WC-12 and WC-21 received suboptimal SWR scores of 0.70 and 0.60, respectively (Table 32). Other sites within this watershed (32%) were rated as marginal in condition with natural condition scores between 0.35 and 0.57 (Table 31) and SWR Index scores between 0.28 and 0.68 (Table 32; Figure 11). Several sites received low buffer scores due to urban development (e.g., WC-20, WC-33) or agriculture (e.g., WC-05). Urban sprawl within the watershed also contributed to a high number of in-stream stressors (e.g., WC-10, WC-25, WC-33).

Table 30. Landscape metric values and final Landscape Index scores for the Wolf Creek watershed (in bold) and for each Wolf Creek sampling site.

Site ID	Forest Cover (%)	LDI (unitless)	Impervious Surface (%)	Mean Forest Patch Size(m²)	Core Forest/ Total Forest (%)	LANDSCAPE INDEX SCORE
WOLF CREEK WATERSHED	**71.0**	**2.02**	**5.13**	**17.4**	**0.46**	**0.62**
WOLF CREEK SITE SCORES (1-km radius circle)						
WC-01	72.8	2.29	11.93	20.7	0.27	0.63
WC-02	59.9	2.43	10.82	7.2	0.16	0.52
WC-03	91.9	1.32	2.75	47.8	0.72	0.88
WC-04	87.3	1.29	1.45	90.8	0.66	0.86
WC-05	78.0	1.60	0.68	40.6	0.49	0.79
WC-07	59.7	2.02	0.96	31.1	0.16	0.69
WC-10	65.6	2.92	18.64	13.6	0.26	0.55
WC-12	67.7	1.89	3.26	19.2	0.20	0.66
WC-15	92.0	1.16	2.31	47.9	0.72	0.89
WC-19	71.4	2.17	9.48	13.1	0.22	0.61
WC-20	52.6	2.33	4.30	6.3	0.18	0.52
WC-21	74.0	1.72	2.56	28.9	0.22	0.72
WC-24	77.8	1.59	2.24	34.7	0.27	0.75
WC-25	82.9	1.41	1.50	43.1	0.35	0.80
WC-27	66.5	2.71	16.53	10.4	0.46	0.55
WC-33	70.5	2.43	13.32	12.2	0.29	0.58
WC-34	73.6	2.17	10.14	14.4	0.26	0.62
WC-37	95.2	1.06	0.55	59.4	0.87	0.95
WC-38	51.9	2.22	1.06	12.5	0.14	0.60

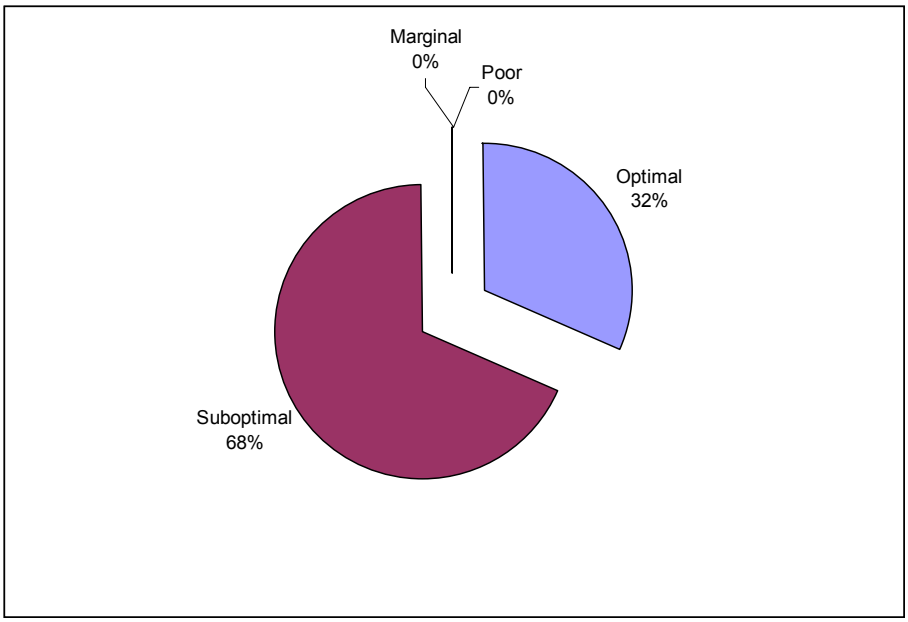

Figure 20. Proportion of Wolf Creek sites receiving the following Level 1 landscape assessment condition categories (determined from final Landscape Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

Table 31. Natural condition score components and final natural condition scores for Wolf Creek sampling sites.

Site ID	% Forest (1 km Circle)	# Unique Stressors	Buffer Score	Buffer Penetrations	Natural Condition Score
WC-01	72.79	3	2.6	0	0.51
WC-02	59.93	2	4.5	0	0.49
WC-03	91.9	0	6	0	0.92
WC-04	87.29	4	3	0	0.52
WC-05	77.95	3	0	1	0.51
WC-07	59.67	2	3	0	0.48
WC-10	65.55	3	1.8	0	0.45
WC-12	67.69	1	5.4	0	0.63
WC-15	92.01	1	5.4	0	0.83
WC-19	71.4	3	5.7	0	0.53
WC-20	52.55	3	0	0	0.35
WC-21	74.03	2	5.7	0	0.61
WC-24	77.77	4	4.4	0	0.48
WC-25	82.88	3	2	0	0.57
WC-27	66.47	3	2	0	0.46
WC-33	70.45	3	0	0	0.47
WC-34	73.57	4	5.1	0	0.46
WC-37	95.16	1	6	0	0.86
WC-38	51.89	2	4.8	0	0.44

Table 32. Results from Level 2 rapid assessment: SWR metric values and final SWR Index scores for Wolf Creek sampling sites.

Site ID	Buffer Cond (%)	Incision Ratio	Basal Area	Invasive Cover Class	Stream Habitat Score	# Stream Stressors	# Flood.-Wetl Stressors	SWR Index Score
WC-01	43.33	2.05	6.00	3	111.00	4	8	0.53
WC-02	75.00	2.18	9.33	2	139.00	3	1	0.67
WC-03	100.00	1.99	12.00	1	164.00	0	0	0.86
WC-04	50.00	1.62	2.33	3	117.00	5	8	0.53
WC-05	0.00	4.33	9.50	1	91.00	5	5	0.39
WC-07	50.00	2.08	10.33	0	132.00	2	3	0.68
WC-10	30.00	1.53	14.00	3	131.00	9	8	0.48
WC-12	90.00	1.82	16.00	1	124.00	3	2	0.70
WC-15	90.00	44.77	9.67	0	173.00	3	0	0.56
WC-19	95.00	2.35	11.00	1	110.00	6	0	0.59
WC-20	0.00	4.34	2.00	3	112.00	8	7	0.28
WC-21	95.00	2.79	16.67	2	120.00	4	5	0.60
WC-24	73.33	2.29	9.50	2	138.00	6	6	0.55
WC-25	33.33	2.09	1.00	3	101.00	9	7	0.40
WC-27	33.33	1.53	1.00	1	86.00	7	5	0.47
WC-33	0.00	2.40	2.00	2	90.00	9	8	0.37
WC-34	85.00	2.04	13.67	2	147.00	6	6	0.58
WC-37	100.00	*	1.00	0	181.00	1	0	0.84
WC-38	80.00	3.55	12.00	1	123.00	3	3	0.58

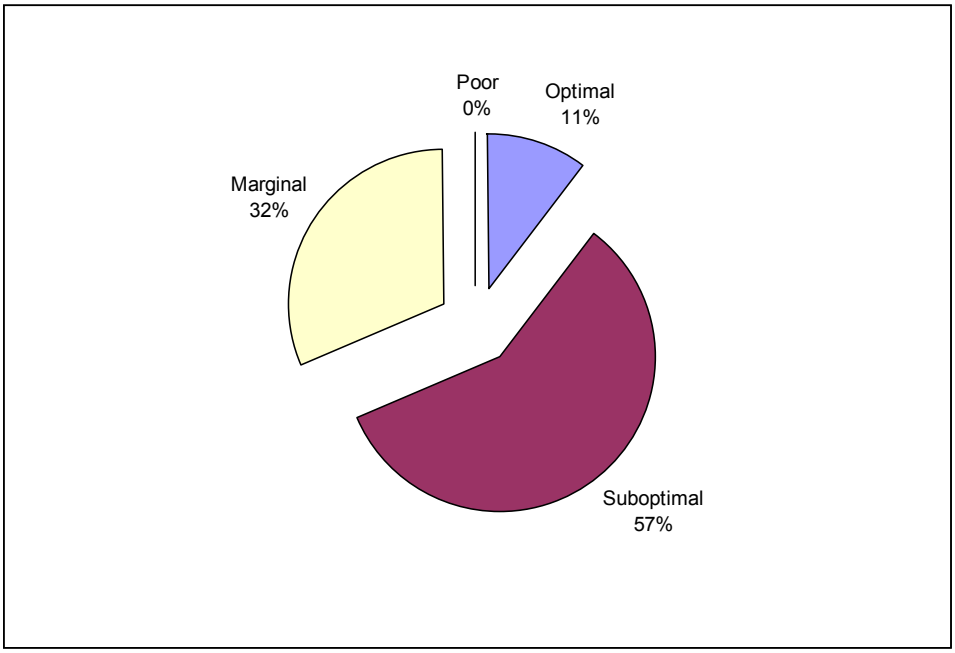

Figure 21. Proportion of Wolf Creek sites receiving the following Level 2 rapid assessment condition categories (determined from SWR Index scores): 0.76 – 1.0 = Optimal; 0.51 – 0.75 = Suboptimal; 0.26 – 0.50 = Marginal; 0.0 – 0.25 = Poor.

NERI Wolf Creek Watershed Intensive Assessment (Level 3) Results

Macroinvertebrate Community Characterization: Figure 22 compares the relative abundances of the major insect orders and other invertebrates collected from the Wolf Creek watershed. Diptera (28%), mostly midge larvae (Chironomidae) and black flies (*Simulium*), and Amphipoda (*Gammarus*) (26%) were the most abundant macroinvertebrates collected in this watershed. Such an assemblage often indicates decreased water quality. Of the mayfly genera, only *Baetis* was abundant, while stoneflies were quite rare, again suggesting lower water quality in the streams sampled. Trichoptera (30% of individuals collected) was dominated by Hydropsychidae, especially *Cheumatopsyche*, suggesting organic enrichment.

Table 33 displays the results from the RBP III assessment of the Wolf Creek watershed, including water chemistry measurements, macroinvertebrate metrics, and site condition scores (based on similarity to reference condition). Water chemistry was characterized by neutral to alkaline pH (range of 6.08 to 8.32), warmer temperatures (mean = 19.7° C) than the other study watersheds, high specific conductivity (mean = 540 mg $CaCO_3$ mg/L), and generally low but variable dissolved oxygen (range of 2.26 to 6.45 mg/L).

Biologically, all intensively sampled sites within this watershed were characterized by either marginal or poor conditions. WC-03, WC-24, and WC-15 were all located along the mainstem of Wolf Creek, which is listed in the West Virginia 2004 303(d) list as impaired by fecal coliform. The 303 (d) list is a requirement of the Clean Water Act that all states must assemble and submit to the US EPA a list of impaired waters (stream segments and lakes) every two years. WC-24 and WC-15 were considered severely impaired. These sites contained the lowest macroinvertebrate diversity of the Wolf Creek watershed samples. Stoneflies and mayflies were either absent or extremely rare. The amphipod genus *Gammarus* represented more than half the individuals collected at WC-15. Modified HBI values suggested some fairly significant amounts of organic pollution. WC-03 appears to be moderately impaired with very few mayflies and stoneflies present. Hydropsychidae and Chironomidae were the most abundant taxa at this site. Their abundance, combined with the HBI value, suggested the presence of organic pollution.

WC-34 and WC-02 were both located along the House Branch tributary. Both sites were buffered by forest, but assessments revealed marginal and poor conditions respectively. Mayflies and stoneflies were completely absent from WC-02 samples, and rarely encountered in the WC-34 samples. Modified HBI values suggested slight to fair levels of organic pollution. Improperly treated sewage is, again, the most likely cause. WC-10 was located on an unnamed tributary. This site had the lowest dissolved oxygen (2.26 mg/L) (Table 33), which was reflected by a low taxonomic diversity (Table 33). Mayflies and stoneflies were rare or absent. Modified HBI suggested the possibility of slight organic pollution. Although mines surround the headwaters near the source, the adjacent residential area may be a significant source of stress. The upstream portion of the sampling area at WC-10 was located at a bridge abutment, which deepened the channel, resulting in lost riffle habitat and most likely contributed to the cause of the low dissolved oxygen and loss of EPT taxa. A nearby church parking lot may also have an effect on the water quality at WC-10.

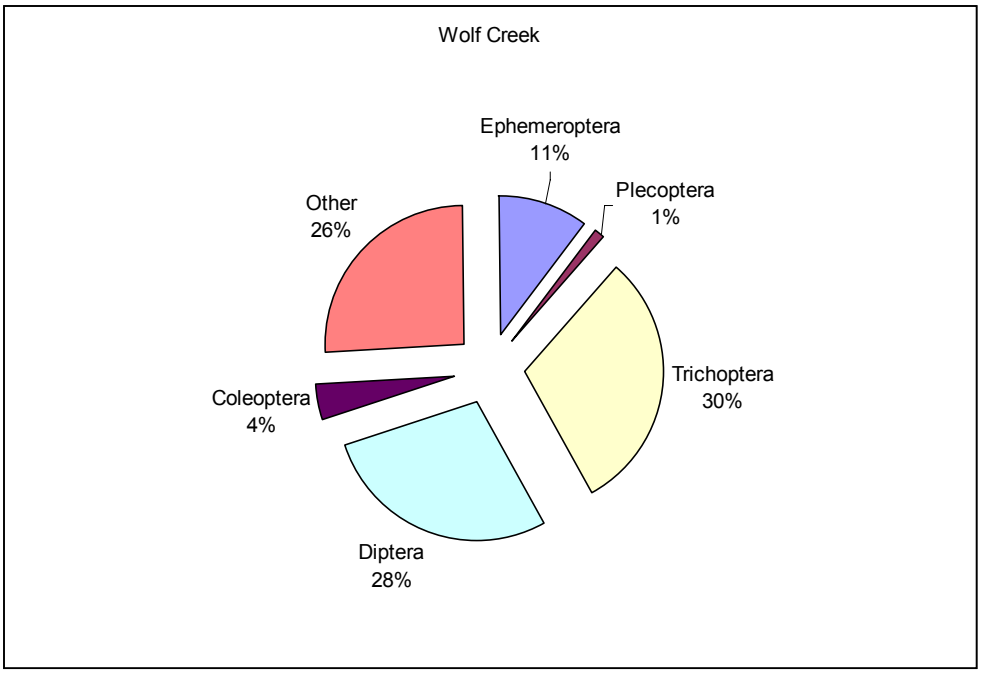

Figure 22. Breakdown by common insect order of the total macroinvertebrate individuals collected in the Wolf Creek watershed.

Table 33. Results of Level 3 intensive assessments (macroinvertebrates) for the Wolf Creek watershed, including water chemistry parameters, RBP III metric values, percent similarity to reference, and overall condition categories. Asterisk denotes missing data.

	Level 3 Intensive Sampling Site						WV EMAP
	WC-02	WC-03	WC-10	WC-15	WC-24	WC-34	REF AV
Date Collected	7/14/2004	7/13/2004	7/4/2004	7/14/2004	7/14/2004	7/13/2004	
Water Chemistry							*
pH	6.7	7.18	6.27	8.32	6.08	6.46	*
Temperature (°C)	20.7	20.9	19.5	17.1	20.9	19	*
Conductivity (µS/cm)	398	631.5	408	891.5	611	302.5	*
Dissolved Oxygen (mg/L)	4.89	5.48	2.26	6.45	4.08	5.48	
Macroinvertebrate Metric							
Modified HBI	4.8	5.33	5.57	5.00	6.32	3.9	2.40
Taxa Richness	23	16	22	21	17	20	33
EPT Index	11	9	5	7	7	9	24
Ephemeroptera Taxa	2	2	0	2	1	2	9
Plecoptera Taxa	1	1	0	1	0	1	7
Trichoptera Taxa	8	6	5	4	6	6	8
Dominance of Top Taxon	0.36	0.44	0.57	0.32	0.55	0.49	0.16
% Similarity to Reference	33	14	19	19	14	29	100
Standardized Condition Score	0.35	0.17	0.23	0.23	0.17	0.32	1.0
Condition Category	Marginal	Poor	Poor	Poor	Poor	Marginal	*

Stream Salamander Assemblage: All three Wolf Creek stream sites, assigned to the low gradient group (Group 3), compared poorly to their corresponding references regardless of approach (GS or NGS) (Table 34). A single taxon was observed at two sites (WC-02 and WC-10) and 7 individuals of 3 taxa were found at WC-34. Stressors stemming from increasing urbanization and associated contaminants may be the likely cause for the poor quality of salamander assemblages observed.

NERI Wolf Creek Watershed Summary

Table 35 provides a summary of the landscape (Level 1), rapid (Level 2), and intensive (Level 3) results for the Wolf Creek watershed. Few sites received optimal condition categories from any assessment level. The majority was rated as suboptimal in condition by the landscape assessment, marginal in condition by the rapid assessment and poor in condition by the intensive assessment. Collectively, the Wolf Creek watershed demonstrates moderate to high levels of human disturbance. Thus, this watershed would most likely benefit from restoration activities targeted at sites demonstrating the highest possibilities for success. Sites of this nature would be located on park property (or be owned by cooperative landowners) and would be subjected to only moderate levels of human disturbance (i.e., trashed sites would require more effort to restore). Of the Wolf Creek sites sampled at all three levels, WC-03 appears to be the best candidate for restoration; WC-34 should also be considered. Both were considered to be in marginal condition based on the biological assessments and should require the least effort to restore. Local knowledge of the areas surrounding these sites should be checked to confirm or refute this suggestion.

Table 34. SPAR Index scores for Wolf Creek watershed Level 3 intensive sampling sites.

	Level 3 Intensive Sampling Site		
	WC-02	WC-10	WC-34
Date Collected	7/14/2004	7/4/2004	7/13/2004
Non-group Specific (NGS) Assessment			
Metric A	0	0	10
Metric E	0	0	0
Metric F	0	5	0
Metric I	0	0	0
SPAR Index Value	0	1.3	2.5
SPAR Condition Category	Degraded	Degraded	Degraded
Standardized Condition Score	0.00	0.10	0.125
Condition Category	Poor	Poor	Poor
Group Specific (GS) Assessment			
Group Designation*	3	3	3
Metric D	0.0	0.0	10
Metric E	5.0	0.0	0
Metric F	0.0	10.0	5
SPAR Index Value	1.7	3.3	5
SPAR Condition Category	Degraded	Degraded	Non-reference
Standardized Condition Score	0.08	0.12	0.27
Condition Category	Poor	Poor	Marginal

* Group 3 are the Mid-Atlantic low gradient headwaters

Table 35. Summary of landscape (Level 1), rapid (Level 2), and intensive (Level 3) assessment scores for the Wolf Creek watershed. All scores have been standardized to a 0 to 1 scale in order to facilitate comparisons of condition.

	Level One	Level Two		Level Three	
Site ID	Landscape Index	Natural Condition Score	SWR Index	Macroinvertebrates (RBP III)	Salamanders (SPAR Index)
Wolf Mean	0.69	0.56	0.56	0.24	0.16
WC-01	0.63	0.51	0.53		
WC-02	0.52	0.49	0.67	0.23	0.08
WC-03	0.88	0.92	0.86	0.34	
WC-04	0.86	0.52	0.53		
WC-05	0.79	0.51	0.39		
WC-07	0.69	0.48	0.68		
WC-10	0.55	0.45	0.48	0.23	0.12
WC-12	0.66	0.63	0.70		
WC-15	0.89	0.83	0.56	0.17	
WC-19	0.61	0.53	0.59		
WC-20	0.52	0.35	0.28		
WC-21	0.72	0.61	0.60		
WC-24	0.75	0.48	0.55	0.17	
WC-25	0.80	0.57	0.40		
WC-27	0.55	0.46	0.47		
WC-33	0.58	0.47	0.37		
WC-34	0.62	0.46	0.58	0.31	0.27
WC-37	0.95	0.86	0.84		
WC-38	0.60	0.44	0.58		

Condition Category		
	0.76 - 1.0	Optimal
	0.51 - 0.75	Suboptimal
	0.26 - 0.50	Marginal
	0.0 - 0.25	Poor

Discussion

Summary

In this study, condition assessment proceeded in an hierarchical manner: coarse, large area, landscape-based condition assessments were replaced and supplemented by progressively finer-scaled assessments, dependent on site and assemblage-specific measurements. The landscape assessment represents the first step and provides the framework from which the finer level assessments are conducted. Thus, interpretation of the rapid and intensive assessment results should be made within the context of the landscape assessment. However, as a stand-alone assessment, the landscape assessment is limited to providing a coarse screening of condition based entirely on landscape-level measures. As such, this level would be unlikely to detect site-specific stressors and impacts unrelated to landscape cover. The addition of site visits and physical habitat evaluations in the rapid assessments should pick up many of the stressors that were missed at the previous assessment level. However, identifying subtler, yet possibly significant, sources of impact may require more intensive biological surveys. This appears to be the case with this study, with site scores decreasing as assessments moved from remote to rapid to intensive.

Mean landscape and rapid (both disturbance and SWR Index) scores remained similar between the ALPO and NERI regions, ranging between suboptimal and optimal conditions. However, mean scores declined sharply in the intensive assessment (ALPO – salamanders; NERI – macroinvertebrates and salamanders). Mean scores for macroinvertebrates actually improved for the ALPO region. This is probably due to the abundance of leuctrid and nemourid stoneflies at many of the ALPO sites. The SPAR Index tends to be more sensitive to acidification than the standard RBP metrics, which place high values on many acid-tolerant species (e.g., stoneflies).

Of the NERI watersheds, both Buffalo Creek and Fern Creek scored well in the landscape assessment and relatively well in the rapid assessment. Both watersheds represent systems with natural characteristics that place limitations on their existing biological communities, resulting in lower condition scores in the intensive assessments (both the RBP III and SPAR Index were developed primarily for riffle habitats). In the Buffalo Creek watershed, extremely high gradients produce dry conditions between storms and high flows during storm events that are capable of moving large boulders. The result is extremely large substrates and low flow conditions, both of which limit the types of organisms capable of surviving there. Due to logistical constraints, sampling in Buffalo Creek was conducted slightly outside of the index period for the EMAP reference samples. Given the nature of the streams in this small watershed, this could have affected the results to some extent. In the case of Fern Creek, fine sandy substrates and low flow conditions also limited the macroinvertebrate and salamander communities. It is important to note that we did not distinguish the source of low flows-intermittence or interruption. In the case of the former, lower intensive scores may be due to seasonality, which would lead to the recommendation that the condition of this watershed should be evaluated during seasons when flow is most optimal (e.g., spring and/or fall). We sampled in midsummer when base flows tend to be low. Dunloup Creek is a well-forested watershed and, thus, scored well in the landscape assessments. According to the rapid assessment, impacts are primarily from a dominance of invasive plant species, poor instream habitat, and a plethora of

stream and wetland stressors, including stormwater inputs, road and railroad crossings, and channelization. Mining activities in the headwaters and sewage contamination caused site conditions to plummet to marginal or poor status in the intensive assessments, although at least one site rated as suboptimal in condition and may be a good candidate for restoration. This consistent trend suggests that this watershed may require more intensive biological assessments to distinguish between high ecological integrity areas needing protection and moderately disturbed sites more suitable for restoration activities. The Wolf Creek watershed was rated largely as suboptimal in condition by the landscape assessment, marginal in condition by the rapid assessments, and poor in condition by the intensive assessments. Collectively, this watershed demonstrated moderate to high levels of human disturbance and would most likely benefit from restoration activities targeted at sites with a high potential for success.

Overall, the rapid SWR assessment added information to the landscape assessment, resulting in more accurate approximations of site condition. Results of the intensive assessments revealed the condition of the biological communities and detected impacts missed by the SWR assessment. Inclusion of both macroinvertebrates and salamanders as indicators provided more diagnostic evaluations at different levels of impact, with the SPAR Index responding more to acidification and the macroinvertebrates responding more to other stressors (e.g., organic enrichment and sedimentation). Thus, the choice of assessment level depends on several factors, including the suite of probable stressors, the number of targeted sites, and the ultimate goals of the project.

Application

The use of multiple indicators is a desirable approach to identifying ecological health and management needs. Individual indicators are differentially responsive to various stressors. Indicator A may be better suited than indicator B to detect a particular stressor. Thus in some situations, different indicators may appear in conflict. Multiple indicators also reflect different references.

Similarity to reference is the cornerstone to most if not all IBIs. When conflicting results appear, among other factors, consider how references used to compare a park site for one IBI might have differed from the references used to compare the test site by another IBI that used a totally different set of references. Basically the question comes down to, how similar are the references used to create these different IBIs? Case in point follows: macroinvertebrate fauna at test sites were compared to between 1 – 3 reference sites. By contrast, salamander assemblages at park stream sites were compared to anywhere between 9 – 34 reference sites.

The mechanics of this process is the same in both IBIs: test sites are judged based on how similar they are to references but different sets of references are being used. If two instruments are calibrated to different starting points, why should a manager be surprised to see the same site producing different readings? Further loss of information is possible when original index scores are converted to a second scale intended to facilitate the computation of a single composite score. Original scores are based on similarity to reference. In many IBIs, sites ranking in the 10th percentile of references are judged degraded. This statement means that if a reference set consisted of 100 sites, 90 reference sites would score above the test site. When a second arbitrary scale is introduced, and the averaging process further modifies its value, the

relationship that exists between references is further removed. A single value may be appealing to a manager but if it cannot be linked back to a set of references the value produced from such an arithmetic exercise needs to be interpreted with considerable caution.

We urge viewing the standardized value as merely a starting point and that assessment methods be applied in a "top down" manner beginning with the coarse landscape assessment on a large number of sites, and followed by selected applications of rapid and intensive sampling methods. For example, if an optimal landscape assessment condition + an optimal/suboptimal rapid assessment condition + a poor intensive assessment score implies that offsite (e.g. upstream) sources are affecting the biological communities, then managers should be looking elsewhere for possible causes of impact to that site. Parks downstream of impacts to water resources would most likely encounter this scenario, requiring park personnel to work with groups outside the park to achieve desired conditions. Conversely, if an optimal landscape assessment condition + a poor rapid assessment condition + a poor intensive assessment condition implies that the sources of impact are most likely present on site, then managers should look more closely at the site to determine the source, which may be entirely within park boundaries. In rare instances, the landscape assessment condition is lower than the rapid and intensive assessment conditions, suggesting a situation where the surrounding landscape is impacted by varying land uses (e.g., urban development), but the site (and its residing biological community) is either protected from those human impacts or is on the verge of becoming impacted, in which case preventative steps should be taken.

By listing the various indicator scores and conditions in one matrix, one can compare the relative conditions for biological, physical, chemical, landscape, and maybe even cultural measures, and then use professional judgment to derive the best overall management approach given the geographic and political setting of the park, and the socioeconomic and technical constraints that might influence the choice of solutions for any observed problems. The summary tables provided for each watershed began this step, but additional information should be included (e.g., land ownership, socioeconomic and/or political concerns, local watershed groups, etc.). At this stage, no models or tools exist that can surpass the ability of the park manager's professional judgment. Park managers can decide which areas are the best targets for protection, restoration, or other activity.

We suggest the triage approach, which considers both ecological condition/disturbance level and protection/restoration potential. When applied to a park unit or larger region, the intent is to place watersheds into general categories of condition quickly based on analysis of remotely sensed data. A "triage" or adaptive management approach is used in this prioritization phase (Brooks et al 2006). This process assumes that each site, once assessed, can be placed into one of at least three categories; ecologically intact (optimal condition, usually functioning at high ecological integrity), moderately disturbed (suboptimal or marginal condition, usually functioning at a moderate level of ecological integrity), or severely disturbed (poor condition or functioning at low ecological integrity).

Once a site is ranked, a level of action needed to protect or restore a site or to correct a problem is chosen. We suggest four levels of action: high, moderate, low, and none. High is where the probability of success is good given a moderate to low investment of resources. Low is where the probability of success is poor, and the likely investment of resources is substantial. Moderate

is intermediate between high and low. None is where no action is needed, which could mean maintaining an existing protective status (Brooks et al. 2006).

For the no-action alternative, either the ecological integrity of the site is relatively high and there are no immediate threats identified, or the level of disturbance is so high, resulting in low ecological integrity and a poor likelihood of being reversed. In this case, any attempt at protection or restoration will require a major commitment of resources and technological expertise (e.g., sites in highly urbanized areas, channelized streams). Sites receiving "high" rankings should be given a high priority and probably afforded a high level of protection. Sites receiving "suboptimal or moderate" rankings are often good candidates for restoration or remediation in the near future. Those with a "low or poor" ranking have either technological or economic limitations for a successful conclusion, and are given lower priority.

The results of this pilot study suggest that assessing the tributary watersheds of park units and adjacent private lands using the Watershed Monitoring Matrix (WMM) approach is both useful and practical. Watersheds and individual sites were ranked according to their ecological condition. Stressors causing the degradation of sites were identified, and can be tied back to specific human activities that are causing them. This in turn allows managers to focus on rectifying a specific problem, or at the very least, making the public aware of what stressors and associated human activities are affecting a park. The WMM approach offers a means to assess the aquatic resources of parks providing managers with a phased, but integrated system of condition assessment that can be translated into protective and restorative actions.

Literature Cited

Adamus, P. R., and K. Brandt. 1990. Impacts on quality of inland wetlands of the United States: a survey of indicators, techniques, and application of community-level biomonitoring data. U. S. Environmental Protection Agency, Environ. Res. Lab., Corvallis, OR. EPA/600/3-90/073.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U. S. Geological Survey Professional Paper 964, 28p.

Arnold, C. L., Jr., and C. J. Gibbons. 1996. Impervious surface coverage: emergence of a key environmental factor. Journal of the American Planning Association 62(2):243-58.

Barbour, M. T., J. M. Diamond, and C. O. Yoder. 1996. Biological assessment strategies: applications and limitations. Pages 245-270 in D. R. Grothe, K. L. Dickson, and D. K. Reed-Judkins, editors. Whole effluent toxicity testing: an evaluation of methods and prediction of receiving system impacts. SETAC Press, Pensacola, Florida.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office Office of Water, Washington D.C.

Blair County Conservation District. 2005. Blair County Conservation District Bay tributary strategy. Hollidaysburg, PA. www.pacd.org/districts/CIP/Blair.pdf.

Brabec, E., S. Schultz, and P. L. Richards. 2002. Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. Journal of Planning Literature Vol. 16, No. 4.

Brigham, A. R., W. U. Brigham, and A. Gnilka (editors). 1982. Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, Illinois.

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. U. S. Army Corps of Engineers, Waterways Experiment Station, Technical Report WRP-DE-4, Washington, DC. 79pp.

Brooks, R. P., D. H. Wardrop, and J. A. Bishop. 2004. Assessing wetland condition on a watershed basis in the Mid-Atlantic Region using synoptic land-cover maps. Environmental Monitoring and Assessment 94:9-22.

Brooks, R. P., D. H. Wardrop, K. W. Thornton, D. Whigham, C. Hershner, M. M. Brinson, and J. S. Shortle, editors. 2006a. Integration of ecological and soicioeconomic indicators for estuaries and watersheds of the Atlantic Slope. Final Report to U.S. Environmental Protection Agency STAR Program, Agreement R-82868401, Washington, DC. Prepared by the Atlantic Slope Consortium, University Park, PA. 96pp. + attachments (CD).

Brooks, R. P., M. McKenney-Easterling, M. Brinson, R. Rheinhardt, K. Havens, D. O'Brien, J. Bishop, J. Rubbo, B. Armstrong, and J. Hite. 2006b. A Stream-Wetland-Riparian (SWR) Index for assessing condition of aquatic ecosystems in small watersheds along the Atlantic Slope of the Eastern U.S. Final Report to U.S. Environmental Protection Agency STAR Program, Agreement R-82868401, Washington, DC. Prepared by the Atlantic Slope Consortium, University Park, PA. 96pp. + attachments (CD).

Brooks, R. P., D. H. Wardrop, and C. A. Cole. 2006c. Inventorying and monitoring wetland condition and restoration potential on a watershed basis with examples from Spring Creek watershed, Pennsylvania, USA. Environmental Management 38:673-687.

Brown, M. T. and M. B. Vivas. 2005. Landscape development intensity index. EnvironmentalMonitoring and Assessment, 101:289-309.

Cardille, J. A. and M. G. Turner. 2002. Understanding landscape metrics I. Pages 85-100 in S. E. Gergel and M. G. Turner, editors. Learning landscape ecology: a practical guide to concepts and techniques. Springer-Verlag, New York, NY.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-79/31, Washington, DC. 131pp.

Dougherty, M., R. L. Dymond, S. J. Goetz, C. A. Janitz, and N. Goulet. 2004. Evaluation of impervious surface estimates in a rapidly urbanizing watershed. Photogrammetric Engineering and Remote Sensing, 70(11):1275-1284.

Earle, J. 2002. A guide to Pennsylvania stonefly genera: identification, habitat, life history, tolerance and distribution. Bureau of Watershed Management, PA Department of Environmental Protection, Harrisburg, PA.

ESRI 2005. Environmental Systems Research Institute (ESRI) webpage (http://www.esri.com). ESRI ArcScripts (http://support.esri.com/index.cfm?fa=downloads.gateway). Redlands, California.

Gibson, G. R., M. T. Barbour, J. B. Stribling, J. Gerritsen, and J. R. Karr. 1996. Biological criteria: technical guidance for streams and small rivers (revised edition). U.S. Environmental Protection Agency, Office of Water, Washington, D. C. EPA 822-B-96-001.

Gray, N. F. 1996. Field assessment of acid mine drainage contamination in surface and ground water. Environmental Geology. 27(4):358-361.

Griscom, B., A. McQueen, A. Bayard. 2004. Personal Communication. Preliminary results on impervious surface estimations in the Mid-Atlantic Highlands. Canaan Valley Institute, Davis, West Virginia.

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist 20:31-39.

Hychka, Kristen. 2004. Evaluation of landscape metrics for use in mapping riparian wetland condition: a case study in the Upper Juniata watershed in south-central Pennsylvania. M.S. Thesis. Wildlife and Fisheries Science. Pennsylvania State University, University Park, PA. 93pp.

Johannsen, O.A. 1969. Aquatic Diptera. Entomological Reprint Specialists, Los Angeles, CA.

Jung,. R. E., S. Droege, J. R. Sauer, and R. B. Landy. 2000. Evaluation of terrestrial and streamside salamander monitoring techniques at Shenandoah National Park. Environmental Monitoring and Assessment 63:65-79

Laposata, M. M. and W. A. Dunson. 1998. Effects of Boron and Nitrate on hatching success of amphibian eggs. Environmental Contamination and Toxicology. 35:615-619.

Laposata, M. M. and W. A. Dunson. 2000. Effects of treated wastewater effluent irrigation on terrestrial salamanders. Water, Air, and Soil Pollution 119:45-57.

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial pattern analysis program for categorical maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: www.umass.edu/landeco/research/fragstats/fragstats.html

Merritt, R.W. and K.W. Cummins, (editors). 1996. An Introduction to the Aquatic Insects of North America (3rd edition). Kendall/Hunt Publishing Co., Dubuque, IA.

NHD 2005. National Hydrography Dataset. Webpage: http://nhd.usgs.gov/index.html.

NLCD 1992. National Land Cover Dataset. Webpage: http://www.epa.gov/mrlc/nlcd.html.

Ohio EPA. 2001. Field evaluation manual for Ohio's primary headwater habitat streams. Ohio EPA, Division of Surface Water, Columbus, Ohio, USA

Peckarsky, B. L., P. R. Fraissinet, M. A. Penton, and D. J. Conklin, Jr. 1990. Freshwater macroinvertebrates of Northeastern North America. Cornell U.P., Ithaca, NY.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrate and fish. EPA 440-4-89-001. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Purvis, J. M., M. Mathes, T. Messinger, J. Wiley, K. Paybins and D. Vana-Miller. 2002. Water resources management plan: New River Gorge National River, Gauley River National Recreation Area, Bluestone National Scenic River, West Virginia. Report. New River Gorge National River. Glen Jean, WV.

Rocco, G. L., R. P. Brooks, and J. T. Hite. 2004. Stream plethodontid assemblage response (SPAR) Index: development, application, and verification in the MAHA. Report No. 2004-1 Penn State Cooperative Wetlands Center, University Park, PA, and Final Report to U.S. Environmental Protection Agency, STAR Grant Program, Washington, DC.

Rocco, G. L., and Brooks, R. P. 2000. Abundance and distribution of a stream Plethodontid salamander assemblage in 14 ecologically dissimilar watersheds in the Pennsylvania Central Appalachians. Final Technical Report No. 2000-4 of the Penn State Cooperative Wetlands Center, PSU, University Park, PA. 70 pp.

Scalet, C. G., L. D. Flake, and D. W. Willis. 1996. Introduction to wildlife and fisheries: an integrated approach. W. H. Freeman and Company, New York, NY.

Southerland, M. T., R. E. Jung, D. P. Baxter, I. C. Chellman, G. Mercurio, and J. H. Volstad. 2004. Streamside salamanders as indicators of stream quality in Maryland. Applied Herpetology 2:23-46

Stewart, K. W., and B. P. Stark. 1993. Nymphs of North American Stonefly Genera (Plecoptera). University of North Texas Press, Denton, TX.

Stewart, K. W. and P. P. Harper. 1996. Plecoptera. Pages 217 – 266 *in* Merritt, R. W. and K. W. Cummins (editors). An introduction to the aquatic insects of North America, third edition. Kendall/Hunt Publishing, Dubuque, IA.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, inc. San Diego pp. 233-260.

Tiger 2003. 108th CD Census 2000, Tiger/Line Files. [machine-readable data files] & Technical Documentation, prepared by the U.S. Census Bureau, 2003.

Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape ecology in theory and practice: pattern and process. Springer-Verlag New York, Inc., New York, NY.

U. S. Environmental Protection Agency (US EPA). 2006. Environmental Monitoring and Assessment Program (EMAP). Washington, DC. www.epa.gov/emap.

Waite, I. R., A. T. Herlihy, D. P. Larsen, and D. J. Klemm. 2000. Comparing the strengths of geographic and nongeographic classifications of stream benthic macroinvertebrates in the mid-Atlantic Highlands, USA. Journal of the North American Benthological Society 19:429-441.

Wardrop, D. H., J. A. Bishop, M. Easterling, K. Hychka, W. L. Myers, G. P. Patil, and C. Taille. 2005. Use of landscape and land use parameters for classification and characterization of watersheds in the Mid-Atlantic across five physiographic provinces. Environmental and Ecological Statistics 12(2):209-223.

Wiggins, G. B. 1996. Larvae of the North American Caddisfly Genera (Trichoptera) (2nd edition). University of Toronto Press, Toronto.

Wilson, L., K. Vandersall, and J. M. Purvis. 2002. Water quality monitoring program 2001-2003: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area, West Virginia. Report. New River Gorge National River. Glen Jean, WV.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Appendix A. Supplemental site information for sampling points in the Allegheny Portage Railroad National Historic Site (ALPO) and New River Gorge National River (NERI) watersheds.

Watershed[a]	Site	Lattitude	Longitude	Sampling[b]	Land Owner[c]	Permission	Wetland[d]
ALPO							
BGR	ALPO-01	40.42213	78.47975	L, R	P	Yes	Slope
BGR	ALPO-02	40.41471	78.54065	L, R	SGL	Yes	No
BGR	ALPO-03	40.41364	78.46382	L, R	P	Yes	Slope
BGR	ALPO-04	40.43425	78.52028	L, R	U-NP	Yes	Slope
BGR	ALPO-08	40.41437	78.46001	L, R, l-m	P	Yes	No
BGR	ALPO-12	40.45352	78.53871	L, R, l-m+s	ALPO	Yes	Slope
BGR	ALPO-14	40.42672	78.48589	L, R	P	Yes	Headwater Floodplain
BGR	ALPO-17	40.40428	78.54478	L, R	SGL	Yes	Slope
BGR	ALPO-18	40.42066	78.43900	L, R	P	Yes	No
BGR	ALPO-20	40.40838	78.53403	L, R, l-m+s	SGL	Yes	Slope
BGR	ALPO-23	40.42060	78.43593	L, R	P	Yes	No
BGR	ALPO-24	40.45594	78.52102	L, R	SGL	Yes	Slope
BGR	ALPO-25	40.41471	78.53917	L, R, l-m	SGL	Yes	No
BGR	ALPO-27	40.40090	78.55327	L, R	SGL	Yes	No
BGR	ALPO-28	40.45235	78.54539	L, R	ALPO	Yes	Depression
BGR	ALPO-30	40.45598	78.51936	L, R	SGL	Yes	Depression/Slope
BGR	ALPO-98	40.46116	78.55506	L, R	ALPO	Yes	No
BGR	ALPO-99	40.46324	78.56189	L, R, l-m+s	ALPO	Yes	No
NERI							
DC	DC-01	37.93907	81.09719	L, R, l-m	NPS	Yes	No
DC	DC-02	37.94402	81.09135	L, R	NPS	Yes	No
DC	DC-11	37.94385	81.08648	L, R, l-m	NPS	Yes	No
DC	DC-15	37.93216	81.08562	L, R	NPS	Yes	No
DC	DC-13	37.93423	81.08575	L, R, l-m+s	NPS	Yes	Slope
DC	DC-04	37.93004	81.15734	L, R	U-NP	No	No
DC	DC-07	37.93075	81.15906	L, R	U-NP	No	No
DC	DC-21	37.87265	81.13380	L, R, l-m	U-NP	No	No
DC	DC-18	37.91975	81.17500	L, R	U-NP	No	No

Appendix A. Supplemental site information for sampling points in the Allegheny Portage Railroad National Historic Site (ALPO) and New River Gorge National River (NERI) watersheds (continued).

Watershed[a]	Site	Lattitude	Longitude	Sampling[b]	Land Owner[c]	Permission	Wetland[d]
NERI (continued)							
DC	DC-05	37.88162	81.15475	L, R	P	Yes	No
DC	DC-03	37.93647	81.13343	L, R	P	Yes	Headwater Floodplain
DC	DC-25	37.91551	81.13377	L, R	U-NP	No	Beaver Impoundment
DC	DC-08	37.91802	81.10786	L, R	U-NP	No	Mainstream Floodplain
DC	DC-23	37.91592	81.11880	L, R	U-NP	No	No
DC	DC-26	37.91470	81.11961	L, R	U-NP	No	No
DC	DC-06	37.90770	81.12332	L, R, l-m+s	U-NP	No	No
DC	DC-28	37.94108	81.18191	L, R	P	Yes	Slope
DC	DC-27	37.93935	81.17758	L, R	P	Yes	Depression
DC	DC-31	37.90792	81.11057	L, R, l-m+s	U-NP	Yes	Headwater Floodplain
DC	DC-33	37.86792	81.13869	L, R	U-NP	No	Depression
WC	WC-12	38.04179	81.10299	L, R	P	Yes	No
WC	WC-01	38.04901	81.10178	L, R	P	Yes	Headwater Floodplain
WC	WC-19	38.04586	81.10368	L, R	U-NP	No	No
WC	WC-02	38.04513	81.12036	L, R, l-m+s	P	Yes	No
WC	WC-03	38.05212	81.08816	L, R, l-m	NPS	Yes	No
WC	WC-24	38.03849	81.08788	L, R, l-m	P	Yes	No
WC	WC-07	38.03164	81.09358	L, R	P	Yes	No
WC	WC-15	38.06011	81.08038	L, R, l-m	NPS	Yes	No
WC	WC-04	38.05760	81.13245	L, R	P	Yes	Depression
WC	WC-20	38.03649	81.10967	L, R	P	Yes	Depression
WC	WC-10	38.00804	81.14566	L, R, l-m+s	P	Yes	No
WC	WC-21	38.03464	81.08549	L, R	P	Yes	No
WC	WC-38	38.02930	81.09954	L, R	P	Yes	No
WC	WC-37	38.05649	81.08118	L, R	NPS	Yes	No
WC	WC-34	38.04738	81.10237	L, R, l-m+s	U-NP	No	No
WC	WC-33	38.05032	81.10005	L, R	P	Yes	Depression

Appendix A. Supplemental site information for sampling points in the Allegheny Portage Railroad National Historic Site (ALPO) and New River Gorge National River (NERI) watersheds (continued).

Watershed[a]	Site	Lattitude	Longitude	Sampling[b]	Land Owner[c]	Permission	Wetland[d]
NERI (continued)							
WC	WC-27	38.01518	81.12275	L, R	P	Yes	Headwater Floodplain
WC	WC-25	38.04254	81.09036	L, R	P	Yes	No
WC	WC-05	38.00328	81.09309	L, R	P	Yes	No
BC	BC-01	37.91391	81.02180	L, R, l-m	NPS	Yes	No
BC	BC-02	37.91549	81.01833	L, R, l-m+s	NPS	Yes	No
BC	BC-03	37.91681	81.01666	L, R	NPS	Yes	No
BC	BC-04	37.91650	81.01435	L, R, l-m+s	NPS	Yes	No
BC	BC-05	37.92616	81.01093	L, R	NPS	Yes	No
BC	BC-06	37.91928	81.01273	L, R	NPS	Yes	No
FC	BC-01	38.06059	81.05993	L, R, l-m	NPS	Yes	Depression
FC	BC-02	38.05784	81.06100	L, R, l-m	NPS	Yes	No
FC	BC-03	38.06172	81.05669	L, R, l-m+s	NPS	Yes	Headwater Floodplain
FC	BC-04	38.06350	81.05553	L, R, l-m+s	P	Yes	Headwater Floodplain
FC	BC-05	38.06244	81.05319	L, R	P	Yes	No
FC	BC-06	38.05751	81.06868	L, R	NPS	Yes	No

[a] Watersheds are defined as BGR = Blair Gap Run, DC = Dunloup Creek, WC = Wolf Creek, BC = Buffalo Creek, and FC = Fern Creek.

[b] Sampling is defined as L = Landscape Assessment, R = Rapid Assessment, l-m = Intensive Assessment-macroinvertebrates, and l-m+s = Intensive Assessment-macroinvertebrates + salamanders.

[c] Land Owners are defined as P = Private, SGL = State Game Lands, U-NP = Unknown-Not Posted, ALPO = Allegheny Portage Railroad National Historic Site, and NPS = National Park Service.

[d] Refer to Brinson 1993 for wetland definitions.

Appendix B. Level 1 landscape assessment supplemental information.

Landscape Assessment Methods

Using Geographic Information System (GIS) data, we created synoptic maps displaying various landscape information (e.g., land use, land cover classes, roadways, stream networks) and generated landscape-level metrics (described below) to characterize landscape patterns for each watershed. Landscape assessment was completed using a GIS software program ArcView 3.3, with Spatial Analyst, and Patch Analyst extensions. Three publicly available geospatial datasets were used for landscape characterization. The 1992 vintage National Land Cover Dataset (NLCD) available from the Multi-Resolution Land Characteristics (MRLC) Consortium was used to calculate all the landscape metrics. The NLCD layer was reclassified to help focus analyses on disturbed versus undisturbed areas. For example, all forest classes (deciduous, mixed, and coniferous) were combined into one forest class. Also, Tiger Roads layers, available from the US Census Bureau, were used to calculate impervious surface areas and the National Hydrography Dataset (NHD) streams layers were used for stream metrics and random point placement. Sampling points were randomly placed along streams within each watershed that would be sites for all three levels of assessment. Randomization was accomplished using a GIS spatial algorithm, [available from the Environmental Systems Research Institute (ESRI) webpage (http://www.esri.com), that randomly places points along line features (e.g., USGS-NHD streams) (J. Bishop, personal communication, 2004; Brooks et al. 2004; ESRI 2005).

The following landscape metrics were computed for two spatial scales; first, for the total surface area of each watershed and, second, for a 1-km radius circle surrounding each randomly placed sampling point (Table 1) (McGarigal et al. 2002, Dougherty et al. 2004, Brown and Vivas 2005; Griscom et al. 2006):

- % Forest – percentage of total area as forest, combined all three NLCD forest classes into one percentage;

- Impervious Surface (IMP) – approximate percentage of total area of impervious surface, combines estimates of imperviousness for each NLCD class with estimated road widths for each Tiger line road type;

- Landscape Development Index (LDI) – quantitative measure of the intensity of human land use within a landscape, estimates the intensity of activity based on nonrenewable energy used to create and maintain a given NLCD land cover category and represented by the following equation: $LDI_{Total} = \sum \% LU_i * LDI_i$

  Where LDI_{Total} = LDI ranking for landscape unit
  $\% LU_i$ = % of total area of influence in land use i
  LDI_i = landscape development intensity coefficient for land use (listed as LDI Values in the following table, which are based on Florida values [Brown and Vivas 2005]):

NLCD Land Cover	LDI Value
Open Water	1.00
Woody Wetlands	1.00
Emergent Herbaceous Wetlands	1.00
Deciduous Forest	1.00
Mixed Forest	1.00
Evergreen Forest	1.00
Shrubland	1.00
Transitional	2.02
Pasture/Hay	3.31
Row Crops	5.77
Urban/Recreational Grasses	7.18
Low Intensity Residential	7.18
Bare Rock/Sand/Clay	7.81
Quarries/Strip Mines/Gravel Pits	8.32
High Intensity Residential	8.97
Commercial/Industrial/Transportation	8.97

- Mean Forest Patch Size (MFORPAT) – average forested patch area, where forest patch area is defined as the forest area (m^2) of patch divided by 10,000 (to convert to hectares), this serves as a measure of forest fragmentation as the average decreases fragmentation is increasing;

- % Core Forest/Total % Forest – ratio of percent core forest to percent total forest, where core area is defined as the area of forest patch (m^2) that is farther than 100m depth-of-edge distance from the patch perimeter, divided by 10,000 (to convert to hectares). This variable was not used for the 1-km circle data, because its computation is affected by the proximal boundaries of the circle's perimeter.

The distribution of values from the full suite of Atlantic Slope Consortium watersheds (n = > 3000), another CWC project (refer to Appendix C for details) was used as reference to convert the raw landscape metrics to a 0-1 scale. The following formula was used in the conversion: (value – low) / (high – low), where value refers to the landscape metric value obtained from the NPS project, and high and low refer to the 99.5th and 0.5th percentile distributions of the reference data set, respectively. The final landscape score represented a weighted average of the standardized metric scores and was obtained through the following formula:

$$\frac{(\text{\% Forest score} + [\text{Average of LDI score and IMP score}] + \text{MFORPAT score})}{3}$$

Land Cover Data

This section provides the U.S. Geological Survey descriptions (including references) of the National Land Cover Data for Pennsylvania and West Virginia.

National Land Cover Data: Pennsylvania

Version 05-27-99 (Updated: January, 1996; February, 1997; July 1998; January, 1999; May, 1999; March, 2000)

Introduction

This land cover data set was produced as part of a cooperative project between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (USEPA) to produce a consistent, land cover data layer for the conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. National Land Cover Data (NLCD) was developed from TM data acquired by the Multi-resolution Land Characterization (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), USEPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration.

Pennsylvania

The Pennsylvania NLCD set was produced as part of a project area encompassing portions of Federal Region III, including the states of Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia. This data set was produced under the direction of the MRLC Regional Land Cover Characterization Project of the USGS EROS Data Center (EDC), Sioux Falls, SD. Questions about the data set can be directed to the MRLC Regional Team at (605) 594-6114 or mrlc@edcmail.cr.usgs.gov.

Version/Revisions

1st Draft - Completed 96-01

<u>Version 97-02 Edits</u>

-- The hay/pasture/grass class (initial version) was split into hay/pasture and "other grasses" (parks/golf courses, etc).

-- The high intensity developed class (initial version) was split into high intensity commercial/industrial and high intensity residential.

-- The data set was edge-matched with a Region 2 land cover data set.

Version 98-07 Edits

-- Initial masking and distribution of the state of Pennsylvania. The mask boundaries are the minimum-bounding rectangle for the state of Pennsylvania.

-- Adjustments were made to the agricultural classes, specifically to fine-tune the hay/pasture and row crop classes.

Version 99-01 Edits

-- More refinements made to agricultural classes (in southern part of state), specifically to fine-tune the hay/pasture and row crop classes.

Version 05-27-99

-- Additional 300 meters of data (10 pixels) added beyond the Pennsylvania border to facilitate creation of multi-state mosaics.

Version 2000-03 Edits

--The following processing steps were taken to eliminate about 10 pixels of zero data values found sprinkled through the state. The origin of the zero data is not known but one theory is that they are a result of the modeling process to split confused classes. If a possible model combination was not taken into account, the model returned a value of zero. The zero data values were eliminated using a 3x3 majority filter. It was constrained to only work on zero values and to ignore zeros when determining the majority value.

Projection Information

The initial Landsat TM mosaics, all ancillary data sets, and the land cover product are all map-registered to an Albers Conical Equal Area projection. The following represents projection information for the final land cover product for the state of Pennsylvania.

Projection: Albers Conical Equal Area
Datum: NAD83
Spheroid: GRS80
Standard Parallels: 29.5 degrees North Latitude
45.5 degrees North Latitude
Central Meridian: 96.0 degrees West Longitude
Origin of Projection: 23.0 degrees North Latitude
False Easting: 0 meters
False Northing: 0 meters

Number of Lines (rows): 11105
Number of Samples (columns): 17370
Number of Bands: 1
Pixel size: 30 X 30 meters
Projection Coordinates (center of pixel, projection meters)
Upper Left Corner: 1261380 meters (X),
2295150 meters (Y)
Lower Right Corner: 1782450 meters (X),
1962030 meters (Y)

NOTE: Each state data set was extracted from the larger regional data set. State boundaries from the USGS 1:100,000 Digital Line Graph (DLG) series were used as the basis for extracting the state data. In many instances, the precision of the boundaries in the 1:100,000 DLG data does not match the spatial precision of the Landsat TM data. This is most apparent where state boundaries follow small rivers. To overcome the possibility of data being lost in the extraction process, a 300-meter (10 pixel) buffer was added to the state boundary used to extract the state data.

Data Sources

The base data set for this project was leaves-on Landsat TM data, nominal-1992 acquisitions. Other ancillary data layers included leaves-off TM, USGS 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief, Bureau of the Census population and housing density data, USGS land use and land cover (LUDA), and National Wetlands Inventory (NWI) data if available.

Landsat thematic mapper (TM) scenes:

Path	Row	Date
LEAF OFF:		
014	031	09-May-93
014	032	25-Mar-89
014	033	15-Mar-91
015	031	31-Mar-91
015	032	14-Nov-90
015	032	08-May-90
015	033	16-Mar-89
016	031	29-Mar-90
016	032	29-Mar-91
016	033	01-Mar-92
017	031	29-Mar-88
017	032	24-Mar-86
017	033	24-Mar-86
018	031	22-Apr-94
018	032	22-Apr-94
LEAF ON:		
014	032	20-May-91
014	033	10-Jun-93
015	031	14-Mar-92
015	032	17-Jun-93
015	033	08-May-90
016	031	24-Jun-93
016	032	24-Jun-93
016	033	28-Sep-93
017	031	02-Oct-92
017	032	02-Oct-92
017	033	02-Oct-92
018	032	06-Aug-92

Caveats and Concerns

While we believe that the approach taken has yielded a very good general land cover classification product for a very large region, it is important to indicate to the user where there might be some potential problems. The biggest concerns are listed below:

1) Quantitative accuracy checks have yet to be conducted. We plan to make comparisons with existing data sets in order to develop a general overview regarding the quality of the land cover data set developed. Feedback from users of the data will be greatly appreciated.

2) Accurate definition of the transitional barren class was extremely difficult.

The majority of pixels in this class correspond to clear-cut forests in various stages of re-growth. Spectrally, fresh clear-cuts are very similar to row-crops in the leaves-off data. Manual correction of coding errors was performed to improve differentiation between row-crops and clear-cuts, but some errors may still be found. As re-growth occurs in a clear-cut region, the definition of transitional barren verses a forested class becomes problematic. An attempt was made to classify only fresh clear-cuts or those in the earliest stages of re-growth, but there are likely forested regions classed as transitional barren and vice versa.

3) Due to the confusion between clear-cuts, re-growth in clear-cuts, forested areas, and shrublands, no attempts were made to populate the shrubland classes. Any shrubland areas that exist in this area are classed in their like forest class, i.e., deciduous shrubland is classed as deciduous forest, etc

Accuracy Assessment

Accuracy assessment is pending.

23-Class National Land Cover Data Key

NOTE - All Classes May NOT Be Represented in a specific state data set. The class number represents the digital value of the class in the data set.

NLCD Land Cover Classification System Key - Rev. July 20, 1999:

Water
- 11 Open Water
- 12 Perennial Ice/Snow

Developed
- 21 Low Intensity Residential
- 22 High Intensity Residential
- 23 Commercial/Industrial/Transportation

Barren
- 31 Bare Rock/Sand/Clay
- 32 Quarries/Strip Mines/Gravel Pits
- 33 Transitional

Forested Upland
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest

Shrubland
- 51 Shrubland

Non-natural Woody
- 61 Orchards/Vineyards/Other

Herbaceous Upland
- 71 Grasslands/Herbaceous

Herbaceous Planted/Cultivated
- 81 Pasture/Hay
- 82 Row Crops
- 83 Small Grains
- 84 Fallow
- 85 Urban/Recreational Grasses

Wetlands
- 91 Woody Wetlands
- 92 Emergent Herbaceous Wetlands

NLCD Land Cover Classification System Land Cover Class Definitions

Water - All areas of open water or permanent ice/snow cover.

11. Open Water - All areas of open water, typically 25 percent or greater cover of water (per pixel).

12. Perennial Ice/Snow - All areas characterized by yearlong cover of ice and/or snow.

Developed - Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).

21. Low Intensity Residential - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to100 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clear-cuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Non-natural Woody - Areas dominated by non-natural woody vegetation. Non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al. (1979).

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

General Procedures

Land Cover Characterization: The project is being carried out on the basis of 10 Federal Regions that make up the conterminous United States; each region is comprised of multiple states; each region is processed in sub-regional units that are limited to the area covered by no more than 18 Landsat TM scenes. The general NLCD procedure is to: (1) mosaic sub-regional TM scenes and classify them using an unsupervised clustering algorithm, (2) interpret and label the clusters/classes using aerial photographs as reference data, (3) resolve the labeling of confused clusters/classes using the appropriate ancillary data source(s), and (4) incorporate land cover information from other data sets and perform manual edits to augment and refine the "basic" classification developed above.

Two seasonally distinct TM mosaics are produced, a leaves-on version (summer) and a leaves-off (spring/fall) version. TM bands 3, 4, 5, and 7 are mosaicked for both the leaves-on and leaves-off versions. For mosaicking purposes, a base scene is selected for each mosaic and the other scenes are adjusted to mimic spectral properties of the base scene using histogram matching in regions of spatial overlap.

Following mosaicking, either the leaves-off version or leaves-on version is selected to be the "base" for the land cover mapping process. The 4 TM bands of the "base" mosaic are clustered to produce a single 100-class image using an unsupervised clustering algorithm. Each of the spectrally distinct clusters/classes is then assigned to one or more Anderson et al (1976) level 1 and 2 land cover classes using National High Altitude Photography program (NHAP) and National Aerial Photography program (NAPP) aerial photographs as a reference. Almost invariably, individual spectral clusters/classes are confused between two or more land cover classes.

Separation of the confused spectral clusters/classes into appropriate NLCD class is accomplished using ancillary data layers. Standard ancillary data layers include: the "non-base" mosaic TM bands and 100-class cluster image; derived TM normalized vegetation index (NDVI), various TM band ratios, TM date bands; 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; population and housing density data; USGS land use and land cover (LUDA); and National Wetlands Inventory (NWI) data if available. Other ancillary data sources may include soils data, unique state or regional land cover data sets, or data from other federal programs such as the National Gap Analysis Program (GAP) of the USGS Biological Resources Division (BRD). For a given confused spectral cluster/class, digital values of the various ancillary data layers are compared to determine: (1) which data layers are the most effective for splitting the confused cluster/class into the appropriate NLCD class, and (2) the appropriate layer thresholds for making the split(s). Models are then developed using one to several ancillary data layers to split the confused cluster/class into the NLCD class. For example, a population density threshold is used to separate high-intensity residential areas from commercial/industrial/transportation. Or a cluster/class might be confused between row crop and grasslands. To split this particular cluster/class, a TM NDVI threshold might be identified and used with an elevation threshold in a class-splitting model to make the appropriate NLCD class assignments. A purely spectral example is using the temporally opposite TM layers to discriminate confused cluster/classes such as hay pasture vs. row crops and deciduous forests vs. evergreen forests; simple thresholds that contrast the seasonal differences in vegetation between leaves-on vs. leaves-off.

Not all cluster/class confusion can be successfully modeled out. Certain classes such as urban/recreational grasses or quarries/strip mines/gravel pits that are not spectrally unique require manual editing. These class features are typically visually identified and then reclassified using on-screen digitizing and recoding. Other classes such as wetlands require the use of specific data sets such as NWI to provide the most accurate classification. Areas lacking NWI data are typically subset out and modeling is used to estimate wetlands in these localized areas. The final NLCD product results from the classification (interpretation and labeling) of the 100-class "base" cluster mosaic using both automated and manual processes, incorporating both spectral and conditional data layers. For a more detailed explanation please see Vogelmann et al. (1998a) and Vogelmann et al. (1998b).

Accuracy Assessment: An accuracy assessment is done on all NLCD on a Federal Region basis following a revision cycle that incorporates feedback from MRLC Consortium partners and affiliated users. The accuracy assessments are conducted by private sector vendors under contract by the USEPA. A protocol has been established by the USGS and USEPA that incorporates a two-stage, geographically stratified cluster sampling plan (Zhu et al., 1999) utilizing National Aerial Photography Program (NAPP) photographs as the sampling frame and the basic sampling unit. In this design a NAPP photograph is defined as a 1st stage or primary sampling unit (PSU), and a sampled pixel within each PSU is treated as a 2nd stage or secondary sampling unit (SSU).

PSUs are selected from a sampling grid based on NAPP flight-lines and photo centers, each grid cell measures 15' X 15' (minutes of latitude/longitude) and consists of 32 NHAP photographs. A geographically stratified random sampling is performed with 1 NAPP photo being randomly selected from each cell (geographic strata), if a sampled photo falls outside of the regional boundary it is not used. Second stage sampling is accomplished by selecting SSUs (pixels) within each PSU (NAPP photo) to provide the actual locations for the reference land cover classification.

The SSUs are manually interpreted and misclassification errors are estimated and described using a traditional error matrix as well as a number of other important measures including the overall proportion of pixels correctly classified, user's and producer's accuracies, and omission and commission error probabilities.

Discussion: While we believe that the approach taken has yielded a very good general land cover classification product for a large region, it is important to indicate to the user where there might be some potential problems. The biggest concerns are listed below:

1) Some of the TM data sets are not temporally ideal. Leaves-off data sets are heavily relied upon for discriminating between hay/pasture and row crop, and also for discriminating between forest classes. The success of discriminating between these classes using leaves-off data sets hinges on the time of data acquisition. When hay/pasture areas are non-green, they are not easily distinguishable from other agricultural areas using remotely sensed data. However, there is a temporal window during which hay and pasture areas green up before most other vegetation (excluding evergreens, which have different spectral properties); during this window these areas are easily distinguishable from other crop areas. The discrimination between hay/pasture and deciduous forest is likewise optimized by selecting data in a temporal window when deciduous vegetation has yet to leaf out. It is difficult to acquire a single-date of imagery (leaves-on or leaves-off) that adequately differentiates between both deciduous/hay and pasture and hay-pasture/row crop.

2) The data sets used cover a range of years (see data sources), and changes that have taken place across the landscape over the time period may not have been captured. While this is not viewed as a major problem for most classes, it is possible that some land cover features change more rapidly than might be expected (e.g. hay one year, row crop the next).

3) Wetlands classes are extremely difficult to extract from Landsat TM spectral information alone. The use of ancillary information such as National Wetlands Inventory (NWI) data is

highly desirable. We relied on GAP, LUDA, or proximity to streams and rivers as well as spectral data to delineate wetlands in areas without NWI data.

4) Separation of natural grass and shrub is problematic. Areas observed on the ground to be shrub or grass are not always distinguishable spectrally. Likewise, there was often disagreement between LUDA and GAP on these classes.

Acknowledgments

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References

More detailed information on the methodologies and techniques employed in this work can be found in the following:

Kelly, P.M., and White, J.M., 1993. Preprocessing remotely sensed data for efficient analysis and classification, Applications of Artificial Intelligence 1993: Knowledge-Based Systems in Aerospace and Industry, Proceeding of SPIE, 1993, 24-30.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.

Vogelmann, J.E., Sohl, T., and Howard, S.M., 1998a. "Regional Characterization of Land Cover Using Multiple Sources of Data." Photogrammetric Engineering & Remote Sensing, Vol. 64, No. 1, pp. 45-47.

Vogelmann, J.E., Sohl, T., Campbell, P.V., and Shaw, D.M., 1998b. "Regional Land Cover Characterization Using Landsat Thematic Mapper Data and Ancillary Data Sources." Environmental Monitoring and Assessment, Vol. 51, pp. 415-428.

Zhu, Z., Yang, L., Stehman, S., and Czaplewski, R., 1999. "Designing an Accuracy Assessment for USGS Regional Land Cover Mapping Program." (In review) Photogrametric Engineering & Remote Sensing.

National Land Cover Data: West Virginia

Version 05-27-99 (Updated: January, 1996; February, 1997; July, 1998, May, 1999; March, 2000)

Introduction

This land cover data set was produced as part of a cooperative project between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (USEPA) to produce a consistent, land cover data layer for the conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. National Land Cover Data (NLCD) was developed from TM data acquired by the Multi-resoultion Land Characterization (MRLC) Consortium.

The MRLC Consortium is a partnership of federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), USEPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration.

West Virginia

The West Virginia NLCD set was produced as part of a project area encompassing portions of Federal Region III, including the states of Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia. This data set was produced under the direction of the MRLC Regional Land Cover Characterization Project of the USGS EROS Data Center (EDC), Sioux Falls, SD. Questions about the data set can be directed to the MRLC Regional Team at (605) 594-6114 or mrlc@edcmail.cr.usgs.gov.

Version/Revisions

1st Draft - Completed 96-01

<u>Version 97-02 Edits</u>

-- The hay/pasture/grass class (initial version) was split into hay/pasture and "other grasses" (parks/golf courses, etc).

-- The high intensity developed class (initial version) was split into high intensity commercial/industrial and high intensity residential.

-- The data set was edge-matched with a Region 2 land cover data set.

<u>Version 98-07 Edits</u>

-- Initial masking and distribution of the state of West Virginia. The mask boundaries are the minimum bounding rectangle for the state of West Virginia.

-- Adjustments were made to the agricultural classes, specifically to fine-tune the hay/pasture and row crop classes.

Version 99-05 Edits

-- Additional 300 meters of data (10 pixels) added beyond the West Virginia border to facilitate creation of multi-state mosaics.

Version 2000-03 Edits

The following processing steps were taken to eliminate about 20 pixels of zero data values found sprinkled through the state. The origin of the zero data is not known but one theory is that they are a result of the modeling process to split confused classes. If a possible model combination was not taken into account, the model returned a value of zero. The zero data values were eliminated using a 3x3 majority filter. It was constrained to only work on zero values and to ignore zeros when determining the majority value.

Projection Information

The initial Landsat TM mosaics, all ancillary data sets, and the land cover product are all map-registered to an Albers Conical Equal Area projection. The following represents projection information for the final land cover product for the state of West Virginia.

Projection: Albers Conical Equal Area
Datum: NAD83
Spheroid: GRS80
Standard Parallels: 29.5 degrees North Latitude
45.5 degrees North Latitude
Central Meridian: 96 degrees West Longitude
Origin of the Projection: 23 degrees North Latitude
False Easting: 0 meters
False Northing: 0 meters

Number of Lines (rows): 13240
Number of Samples (columns): 13265
Number of Bands: 1 Pixel size: 30 X 30 meters
Projection Coordinates (center of pixel, projection meters)
Upper Left Corner: 1154670 meters (X),
2064600 meters (Y)
Lower Right Corner: 1552590 meters (X),
1667430 meters(Y)

NOTE: Each state data set was extracted from the larger regional data set. State boundaries from the USGS 1:100,000 Digital Line Graph (DLG) series were used as the basis for extracting the state data. In many instances, the precision of the boundaries in the 1:100,000 DLG data does not match the spatial precision of the Landsat TM data. This is most apparent where state boundaries follow small rivers. To overcome the possibility of data being lost in the extraction

process, a 300-meter (10 pixel) buffer was added to the state boundary used to extract the state data.

Data Sources: The base data set for this project was leaves-on Landsat TM data, nominal-1992 acquisitions. Other ancillary data layers included leaves-off TM, USGS 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief, Bureau of the Census population and housing density data, USGS land use and land cover (LUDA), and National Wetlands Inventory (NWI) data if available.

Landsat thematic mapper (TM) scenes:

Path	Row	Date
016	032	29-Mar-91
016	033	01-Mar-92
017	032	24-Mar-86
017	033	24-Mar-86
017	034	24-Mar-86
018	032	22-Apr-94
018	033	19-Apr-97
018	034	29-Nov-93

LEAF ON:

016	032	24-Jun-93
016	033	28-Sep-93
017	032	02-Oct-92
017	033	02-Oct-92
017	034	02-Oct-92
018	032	06-Aug-92
018	033	06-Aug-92
018	034	29-Sept-94

Caveats and Concerns

While we believe that the approach taken has yielded a very good general land cover classification product for a very large region, it is important to indicate to the user where there might be some potential problems. The biggest concerns are listed below:

1) Quantitative accuracy checks have yet to be conducted. We plan to make comparisons with existing data sets in order to develop a general overview regarding the quality of the land cover data set developed. Feedback from users of the data will be greatly appreciated.

2) Accurate definition of the transitional barren class was extremely difficult. The majority of pixels in this class correspond to clear-cut forests in various stages of regrowth. Spectrally, fresh clear-cuts are very similar to row-crops in the leaves-off data. Manual correction of coding errors was performed to improve differentiation between row-crops and clear-cuts, but some errors may still be found. As regrowth occurs in a clear-cut region, the definition of transitional barren verses a forested class becomes problematic. An attempt was made to classify only fresh

clear-cuts or those in the earliest stages of regrowth, but there are likely forested regions classed as transitional barren and vice versa.

3) Due to the confusion between clear-cuts, regrowth in clear-cuts, forested areas, and shrublands, no attempts were made to populate the shrubland classes. Any shrubland areas that exist in this area are classed in their like forest class, i.e., deciduous shrubland is classed as deciduous forest, etc

Accuracy Assessment

Accuracy assessment is pending.

23-Class National Land Cover Data Key

NOTE - All Classes May NOT Be Represented in a specific state data set. The class number represents the digital value of the class in the data set.

NLCD Land Cover Classification System Key - Rev. July 20, 1999

- Water
  - 11 Open Water
  - 12 Perennial Ice/Snow
- Developed
  - 21 Low Intensity Residential
  - 22 High Intensity Residential
  - 23 Commercial/Industrial/Transportation
- Barren
  - 31 Bare Rock/Sand/Clay
  - 32 Quarries/Strip Mines/Gravel Pits
  - 33 Transitional
- Forested Upland
  - 41 Deciduous Forest
  - 42 Evergreen Forest
  - 43 Mixed Forest
- Shrubland
  - 51 Shrubland
- Non-natural Woody
  - 61 Orchards/Vineyards/Other
- Herbaceous Upland
  - 71 Grasslands/Herbaceous
- Herbaceous Planted/Cultivated
  - 81 Pasture/Hay
  - 82 Row Crops
  - 83 Small Grains
  - 84 Fallow
  - 85 Urban/Recreational Grasses

Wetlands
91 Woody Wetlands
92 Emergent Herbaceous Wetlands

NLCD Land Cover Classification System Land Cover Class Definitions

Water - All areas of open water or permanent ice/snow cover.

11. Open Water - All areas of open water, typically 25 percent or greater cover of water (per pixel).

12. Perennial Ice/Snow - All areas characterized by yearlong cover of ice and/or snow.

Developed - Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).

21. Low Intensity Residential - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to100 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Non-natural Woody - Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al. 1979.

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

General Procedures

Land Cover Characterization: The project is being carried out on the basis of 10 Federal Regions that make up the conterminous United States; each region is comprised of multiple states; each region is processed in subregional units that are limited to the area covered by no more than 18 Landsat TM scenes. The general NLCD procedure is to: (1) mosaic subregional TM scenes and classify them using an unsupervised clustering algorithm, (2) interpret and label the clusters/classes using aerial photographs as reference data, (3) resolve the labeling of confused clusters/classes using the appropriate ancillary data source(s), and (4) incorporate land cover information from other data sets and perform manual edits to augment and refine the "basic" classification developed above.

Two seasonally distinct TM mosaics are produced, a leaves-on version (summer) and a leaves-off (spring/fall) version. TM bands 3 4 5 and 7 are mosaicked for both the leaves-on and leaves-off versions. For mosaicking purposes, a base scene is selected for each mosaic and the other scenes are adjusted to mimic spectral properties of the base scene using histogram matching in regions of spatial overlap.

Following mosaicking, either the leaves-off version or leaves-on version is selected to be the "base" for the land cover mapping process. The 4 TM bands of the "base" mosaic are clustered to produce a single 100-class image using an unsupervised clustering algorithm. Each of the spectrally distinct clusters/classes is then assigned to one or more Anderson level 1 and 2 land cover classes using National High Altitude Photography program (NHAP) and National Aerial Photography program (NAPP) aerial photographs as a reference. Almost invariably, individual spectral clusters/classes are confused between two or more land cover classes.

Separation of the confused spectral clusters/classes into appropriate NLCD class is accomplished using ancillary data layers. Standard ancillary data layers include: the "non-base" mosaic TM bands and 100-class cluster image; derived TM normalized vegetation index (NDVI), various TM band ratios, TM date bands; 3-arc second Digital Terrain Elevation Data (DTED) and

derived slope, aspect and shaded relief; population and housing density data; USGS land use and land cover (LUDA); and National Wetlands Inventory (NWI) data if available. Other ancillary data sources may include soils data, unique state or regional land cover data sets, or data from other federal programs such as the National Gap Analysis Program (GAP) of the USGS Biological Resources Division (BRD). For a given confused spectral cluster/class, digital values of the various ancillary data layers are compared to determine: (1) which data layers are the most effective for splitting the confused cluster/class into the appropriate NLCD class, and (2) the appropriate layer thresholds for making the split(s). Models are then developed using one to several ancillary data layers to split the confused cluster/class into the NLCD class. For example, a population density threshold is used to separate high-intensity residential areas from commercial/industrial/transportation. Or a cluster/class might be confused between row crop and grasslands. To split this particular cluster/class, a TM NDVI threshold might be identified and used with an elevation threshold in a class-splitting model to make the appropriate NLCD class assignments. A purely spectral example is using the temporally opposite TM layers to discriminate confused cluster/classes such as hay pasture vs. row crops and deciduous forests vs. evergreen forests; simple thresholds that contrast the seasonal differences in vegetation between leaves-on vs. leaves-off.

Not all cluster/class confusion can be successfully modeled out. Certain classes such as urban/recreational grasses or quarries/strip mines/gravel pits that are not spectrally unique require manual editing. These class features are typically visually identified and then reclassified using on-screen digitizing and recoding. Other classes such as wetlands require the use of specific data sets such as NWI to provide the most accurate classification. Areas lacking NWI data are typically subset out and modeling is used to estimate wetlands in these localized areas. The final NLCD product results from the classification (interpretation and labeling) of the 100-class "base" cluster mosaic using both automated and manual processes, incorporating both spectral and conditional data layers. For a more detailed explanation please see Vogelmann et al. 1998 and Vogelmann et al. 1998.

Accuracy Assessment: An accuracy assessment is done on all NLCD on a Federal Region basis following a revision cycle that incorporates feedback from MRLC Consortium partners and affiliated users. The accuracy assessments are conducted by private sector vendors under contract by the USEPA. A protocol has been established by the USGS and USEPA that incorporates a two-stage, geographically stratified cluster-sampling plan (Zhu et al., 1999) using National Aerial Photography Program (NAPP) photographs as the sampling frame and the basic sampling unit. In this design a NAPP photograph is defined as a 1st stage or primary sampling unit (PSU), and a sampled pixel within each PSU is treated as a 2nd stage or secondary sampling unit (SSU).

PSU's are selected from a sampling grid based on NAPP flight-lines and photo centers, each grid cell measures 15' X 15' (minutes of latitude/longitude) and consists of 32 NHAP photographs. A geographically stratified random sampling is performed with 1 NAPP photo being randomly selected from each cell (geographic strata), if a sampled photo falls outside of the regional boundary it is not used. Second stage sampling is accomplished by selecting SSU's (pixels) within each PSU (NAPP photo) to provide the actual locations for the reference land cover classification.

The SSU's are manually interpreted and misclassification errors are estimated and described using a traditional error matrix as well as a number of other important measures including the overall proportion of pixels correctly classified, user's and producer's accuracies, and omission and commission error probabilities.

Discussion: While we believe that the approach taken has yielded a very good general land cover classification product for a large region, it is important to indicate to the user where there might be some potential problems. The biggest concerns are listed below:

1) Some of the TM data sets are not temporally ideal. Leaves-off data sets are heavily relied upon for discriminating between hay/pasture and row crop, and also for discriminating between forest classes. The success of discriminating between these classes using leaves-off data sets hinges on the time of data acquisition. When hay/pasture areas are non-green, they are not easily distinguishable from other agricultural areas using remotely sensed data. However, there is a temporal window during which hay and pasture areas green up before most other vegetation (excluding evergreens, which have different spectral properties); during this window these areas are easily distinguishable from other crop areas. The discrimination between hay/pasture and deciduous forest is likewise optimized by selecting data in a temporal window when deciduous vegetation has yet to leaf out. It is difficult to acquire a single-date of imagery (leaves-on or leaves-off) that adequately differentiates between both deciduous/hay and pasture and hay-pasture/row crop.

2) The data sets used cover a range of years (see data sources), and changes that have taken place across the landscape over the time period may not have been captured. While this is not viewed as a major problem for most classes, it is possible that some land cover features change more rapidly than might be expected (e.g. hay one year, row crop the next).

3) Wetlands classes are extremely difficult to extract from Landsat TM spectral information alone. The use of ancillary information such as National Wetlands Inventory (NWI) data is highly desirable. We relied on GAP, LUDA, or proximity to streams and rivers as well as spectral data to delineate wetlands in areas without NWI data.

4) Separation of natural grass and shrub is problematic. Areas observed on the ground to be shrub or grass are not always distinguishable spectrally. Likewise, there was often disagreement between LUDA and GAP on these classes.

Acknowledgments

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References

More detailed information on the methodologies and techniques employed in this work can be found in the following:

Kelly, P.M., and White, J.M., 1993. Preprocessing remotely sensed data for efficient analysis and classification, Applications of Artificial Intelligence 1993: Knowledge-Based Systems in Aerospace and Industry, Proceeding of SPIE, 1993, 24-30.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe, 1979. Classification of Wetlands and Deepwater Habitats of the United States, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.

Vogelmann, J.E., Sohl, T., and Howard, S.M., 1998. "Regional Characterization of Land Cover Using Multiple Sources of Data." Photogrammetric Engineering & Remote Sensing, Vol. 64, No. 1, pp. 45-47.

Vogelmann, J.E., Sohl, T., Campbell, P.V., and Shaw, D.M., 1998. "Regional Land Cover Characterization Using Landsat Thematic Mapper Data and Ancillary Data Sources." Environmental Monitoring and Assessment, Vol. 51, pp. 415-428.

Zhu, Z., Yang, L., Stehman, S., and Czaplewski, R., 1999. "Designing an Accuracy Assessment for USGS Regional Land Cover Mapping Program." (In review) Photogrametric Engineering & Remote Sensing.

Appendix C. Level 2 rapid assessment supplemental information.

The randomly selected points from the landscape assessment are used for the rapid assessment. Note that, if one is planning to conduct both a landscape and a rapid assessment, the landscape information (1-km circle data) is not computed until after the rapid assessment sites have been identified. Field crews are given a list of GPS coordinates for 40 randomly selected points (method described above for Level 1). Moving down the list, points are either selected or omitted based on accessibility (e.g., landowner permission to access the site) until a total of 20 points is acquired. Exceptions may be necessary for small watersheds to avoid spatial overlap. Reconnaissance of each of the selected points is then accomplished by a field visit. If one is only interested in computing a natural condition score, only buffer and stressor information needs to be collected. For SWR assessments, a brief (one to two hour) site visit is required and described below.

Natural Condition Score Equation

$$\text{Natural condition score} = \frac{([\%\ \text{forest} \times \text{weighting factor}] + \text{buffer score} - \text{buffer penetrations})}{106^{*}}$$

where: % forest = % forest in a 1-km radius landscape circle surrounding the site

weighting factor = (10 - # unique stressor categories**) / 10

buffer score = numeric value associated with adjacent buffer type and width (determined from buffer section SWR data sheets); maximum buffer score = 6

buffer penetrations = five possible stressors which can directly break a continuous buffer (highlighted on the stressor checklist and include):
- active plowing, etc.
- direct discharges of organic waste, etc.
- adjacent to industrial sites, etc.
- direct discharges from agricultural feedlots
- adjacent spoil piles

Notes: *Dividing by 106 standardizes the score on a 0-1 scale; 106 is the highest possible total (e.g., a site with 100% forest, maximum buffer score of 6, and no stressors or buffer penetrations would equal a numerator of 106; dividing by 106 replaces this maximum value with a value of one).

**Unique stressor category is determined by counting only the number of stressor categories checked, regardless of the location (i.e., whether the stressor was noted in the floodplain, wetland, or stream). This avoids double- or triple-counting of a stressor category that may occur in all locations. Refer to Appendix E, SWR Data Sheet 9 for a complete list of stressors.

SWR Index

The SWR Index was developed as part of a larger project designed to integrate ecological and socioeconomic indicators for estuaries and watersheds of the Atlantic Slope (Brooks et al. 2006a). In this project, SWR rapid assessments were conducted on a total of 521 sites on 24 small (HUC-14) watersheds in the Mid-Atlantic portion of the Atlantic Slope (Wardrop et al. 2005, Brooks et al. 2006b). Existing Level 3 data (e.g., stream Indexes of Biotic Integrity) was used to cross-validate the SWR data (Brooks et al. 2006b). The resulting SWR metrics were selected based on their ability to reflect site condition (both in-stream and in the floodplain-wetland area) and lack of redundancy (Brooks et al. 2006b).

Field Protocol

A 9-page field data form was developed to guide data collection (Appendix E). At each site, aspects of hydrology, soils, vegetation, and topography were measured in a 100 m x 100 m plot. For small to mid-size streams with widths < 10 m, the plot was centered on the stream. For larger streams, the plot was shifted so that only one side of the associated floodplain and riparian zone was sampled. During this process the following information was collected:

- Adjacent Land Use (i.e., record buffer information)
- Riparian Classification (i.e., identify major patch types [e.g., floodplain, wetland, or levee] and record dominant land cover type of each patch)
- On-site Stressors (i.e., complete checklist of stressors organized by stressor category, including their location and distance from the stream)
- Wetland Classification (i.e., classify each wetland by hydrogeomorphic (HGM) subclass and National Wetlands Inventory (NWI) classification)
- Hydrology, Wetland and Soils Assessment (i.e., record information regarding indicators of wetland hydrology)
- Vegetation Assessment (i.e., conduct 3 Bitterlich tree points combined with DBH measurements for each tree)
- Invasive Species (i.e., classify invasive species by cover class and by species)
- Stream Habitat Assessment (i.e., characterize instream habitat condition using EPA's Rapid Bioassessment Protocol)
- Bankfull Parameters (i.e., obtain bankfull width and depth measurements).

SWR Metrics and Scoring Criteria

The SWR Index consists of the following metrics: Buffer Condition 0-300 m from stream, Number of Floodplain-Wetland Stressors, Basal Area, Invasives Cover Class, Number of Stream Stressors, Stream Habitat Assessment Score, and Incision Ratio (Brooks et al. 2006). The first 4 metrics are related to the floodplain-wetland component (FL-WL) of the aquatic system; the last three metrics comprise the instream component (Brooks et al. 2006b). These metrics were computed in the following manner:

- Buffer Condition (0-300 m): 5 distance categories (0 – 3 m, 3 – 10 m, etc.) are considered for each stream bank and scored separately (natural forest = 6, shrubs/saplings = 4, perennial herbaceous = 2, other = 0). These scores are then summed and divided by ten to produce an average buffer score, the maximum of which is six. The actual metric value is the percentage of the maximum score (i.e., the average buffer score normalized on a 0 to 100 scale).

- Number of Floodplain-Wetland Stressors: number of unique floodplain-wetland stressors (if same stressor occurs in both FP and WL it is counted only once)

- Basal Area (BA):

  BA (m^2/ha) = (total # plants at all sample points / # sample points) * BAF
  where BAF = Basal Area Factor (number of units of basal area per acre [or per hectare] represented by each tree; BAF is determined by the ratio of dbh to distance from the plot center and is different in different circumstances. We used a BAF = 2 to calculate basal area.

- Invasives Cover Class: (0=no invasives, 1=<5%, 2=5-20%, 3=20-50%, 4=>50%)

- Number of Stream Stressors: number of stream stressors

- Stream Habitat Assessment Score: total Stream Habitat Assessment score normalized to 0 to 100 scale (expressed as a percentage of the maximum possible score of 200).

- Incision Ratio: ratio between height of bank and bankfull height.

Following computation, all metrics were scored by converting raw measurements to a 0-1 scale where: 0.76 – 1.0 = optimal condition; 0.51 – 0.75 = suboptimal condition; 0.26 – 0.50 = marginal condition; and 0.0 – 0.25 = poor condition.

Categorical breakpoints for each tier were determined separately for each metric based on frequency distributions and/or histograms from the original Atlantic Slope data (Brooks et al. 2006b). For example, 83% represented the 75th percentile in the distribution of buffer condition (0 – 300m) data. Thus, buffer scores of 83 – 100% corresponded to the optimal condition category. Final stream habitat scores were determined by computing the percentage of total possible score obtained (a.k.a. total score/200) and using the existing EPA scoring system, which

corresponds to the four tiers described above (Barbour et al. 1999). Individual metric scores were determined as follows:

Metric	Raw Values	Converted Score Value
Buffer Condition (0-300m)	83 - 100%	0.76 - 1.0
	60 - 82.99%	0.51 - 0.75
	35 - 59.99%	0.26 - 0.50
	0 - 34.99%	0.0 - 0.25
Number of Floodplain-Wetland Stressors	0	1.0
	1	0.75
	2	0.66
	3	0.58
	4	0.50
	5	0.38
	6	0.25
	7	0.15
	8	0.10
	9 to 15	0.05
Basal Area (m^2/ha)	>51	1.0
	29 - 51	0.76 - 1.0
	20 - 28.99	0.51 - 0.75
	12 - 19.99	0.26 - 0.50
	0.5 - 11.99	0.0 - 0.25
Invasives Cover Class	0%	1.0
	<5%	0.90
	5 - 20%	0.75
	20 - 50%	0.45
	>50%	0.15
Number of Stream Stressors	0	1.0
	1	0.85
	2	0.70
	3	0.60
	4	0.50
	5	0.38
	6	0.25
	7	0.15
	8 to 18	0.05
Incision Ratio	1.14 - 2.499	0.76 - 1.0
	2.5 - 3.499	0.51 - 0.75
	3.5 - 4.99	0.26 - 0.50
	5 to 11	0.0 - 0.25
	>11	0
Stream Habitat Assessment Score = (Actual Score / Maximum Possible Score)		

After all metrics were scored on a 0 – 1 scale, the SWR Index was computed. Because the floodplain-wetland (FP-WL) component was considered to be related to, but distinct from, the instream component, the FP-WL Index was first computed separately, but then integrated with the stream metrics to form the Stream-Wetland-Riparian (SWR) Index. The equations were as follows:

FP-WL Index = Average of Buffer Score + Basal Area Score + % Invasive Score + FP-WL Stressor Score

SWR Index = Average of FP-WL Index + Incision Ratio Score + Stream Stressor Score + Stream Habitat Score.

Appendix D. Level 3 intensive assessment supplemental information.

Macroinvertebrate Community Characterization

Following are the field and laboratory methods, data analysis, and RBP III metric evaluations used in the macroinvertebrate community characterization. Ideally, field sampling should occur within a single index period of approximately 10 weeks (usually ranging from April to July). This applies to both the study streams and the reference streams. In this study, EMAP reference streams were sampled in June for the ALPO region and late May for the NERI region. With the exception of Buffalo Creek and some Dunloup sites, all samples were collected within this index period. As for precipitation events, the general rule followed was to sample as close to normal summer flows as possible. So, if it had recently rained or was raining, only streams that did not appear to be unduly influenced by the storm event were sampled. Streams running at bankfull discharge or with unusually turbid water were not sampled that day.

Field Sampling

- 4 riffle samples were collected per site (or representative habitat if riffles not present). Each sample consisted of a composite of 2 kicks with a D-frame kick net (500 micron mesh), totaling 8 kicks per site. Although samples were processed separately, the data were compiled for each site prior to computing the metrics. This is modified from the standard RBP III method, which uses a 1-m^2 kick net and 2 kicks per site.

- Prior to macroinvertebrate sampling at each plot, temperature (ºC, YSI 55 DO Portable meter), dissolved oxygen (mg/L or percent saturation, YSI 55 DO Portable meter), water pH (Oakton pH/Conductivity 10 meter), and specific conductivity (µS/cm, Oakton pH/Conductivity 10 meter) were measured at mid-water column. All equipment was calibrated with standard buffers and solutions prior to use.

Laboratory Processing

- Most samples were sorted entirely; a 300-count subsampling procedure was used for samples containing more than 300 individuals (Hilsenhoff 1987).

- Most specimens were identified to genus level whenever possible. Hirudinea, Turbellaria, Hydracarina, and Oligochaeta remained at class level; Chironomidae were left at family level. The following taxonomic sources were used: Johannsen (1969); Brigham et al. (1982); Peckarsky et al. (1990); Merritt and Cummins (1996); Stewart and Stark (1993); Wiggins (1996); and Earle (2002).

Quality Assurance/Quality Control

- Standardized, documented field collections and subsampling procedures were performed at each sampling location.

- 10% of samples were re-sorted to ensure at least 90% recovery of sample organisms.

- 10% of specimen identifications were re-checked to ensure at least 90% accuracy of taxonomic identifications.

- A voucher specimen was retained for each unique taxon collected (Appendix C?).

RBP III Metrics and Scoring Criteria

The following metrics were obtained from each site's compiled macroinvertebrate data: Modified HBI, Taxa Richness, EPT Taxa, Ephemeroptera Taxa, Plecoptera Taxa, Trichoptera Taxa, Dominance of the Top Taxon. To obtain scoring criteria for each metric, each site's metric value was compared to the average value for that metric among the EMAP reference site data and a percent similarity to reference was obtained. Because Fern Creek was a low gradient stream, EMAP reference streams with only pool data were used to calculate the reference average for sites in this watershed. Streams in the remaining watersheds were primarily riffle-dominated and were compared to EMAP data taken from riffle samples in regional reference streams. Each metric's percent similarity to reference condition was then used to determine the corresponding biological condition score based on the following criteria (adapted from Plafkin et al. 1989):

	Biological Condition Scoring Criteria			
Metric	6	4	2	0
Taxa Richness [(a)]	> 80%	60-80%	40-60%	< 40%
Hilsenhoff Biotic Index (modified) [(b)]	> 85%	70-85%	50-70%	< 50%
EPT Index [(a)]	> 90%	80-90%	70-80%	< 70%
Dominance of Top Taxon [(c)]	< 20%	20-30%	30-40%	> 40%
Ephemeroptera Genera [(a)]	> 80%	60-80%	40-60%	< 40%
Plecoptera Genera [(a)]	> 80%	60-80%	40-60%	< 40%
Trichoptera Genera [(a)]	> 80%	60-80%	40-60%	< 40%

(a) Score is a ratio of study site to reference site x 100.
(b) Score is a ratio of reference site to study site x 100.
(c) Scoring criteria evaluate actual percent contribution, not percent comparability to the reference station.
(d) Range of values obtained. A comparison to the reference station is incorporated in these indices.

The aforementioned metric condition scores are then summed for each site and compared to the sum of the reference average (in this case, 7 metrics x maximum score of 6 for each metric = 42 is the typical reference score, so a site with a total biological condition score of 42 would be 100% similar to reference). This final percent comparability to the reference score produces the following biological condition categories (adapted from Plafkin et al. 1989):

% Comparison To Reference Score	Biological Condition Category	Attributes
> 83%	Nonimpaired (NI)	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54 - 79%	Slightly Impaired (SI)	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
21 - 50%	Moderately Impaired (MI)	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
< 17%	Severely Impaired (SEI)	Few species present. If high densities of organisms, then dominated by one or two taxa.

*Although the RBP designates specific terminology for biological condition categories (nonimpaired, slightly impaired, moderately impaired, or severely impaired), for consistency in this report, we converted these terms to optimal, suboptimal, marginal, and poor.

Ideally, percentage values that are intermediate to the above ranges (e.g., 80%) require subjective judgment aided by habitat assessments, substrate information, and water quality measurements. However, because we have an additional step of standardizing these percentages on a 0 to 1 scale, intermediate values were dropped to the lower range. Site condition scores were then standardized in the following manner:

% Comparison to Reference	Standardized Value Range	Condition Category
83 – 100%	0.76 – 1.0	Optimal
54 – 82.99%	0.51 – 0.75	Suboptimal
21 – 53.99%	0.26 – 0.50	Marginal
0 – 20.99%	0.0 – 0.25	Poor

Stream Salamander Assemblage

Development of the Stream Plethodontid Assemblage Response (SPAR) Index in the Mid-Atlantic Highlands

Introduction

The similarity of a test site to a set of references is the basis for the SPAR Index, as it is for many other indices of biological integrity (IBI). In the SPAR index, the units determining similarity are the attributes of the stream salamander "community" occupying test and reference sites. Thus, with respect to these organisms, test sites exhibiting great similarity to references are judged non-degraded, while highly dissimilar test sites are considered degraded.

Establishing references is a key step in constructing IBIs. In this study, non-salamander attributes determined if a site met reference conditions. Reference sites were required to be in good standing in terms of water quality, riparian habitat, and macroinvertebrates, regardless of salamander attributes. This is an important aspect of how SPAR references were established. The goal was to create a biological index that could measure stream health rather than how close test sites were to an ideal salamander community.

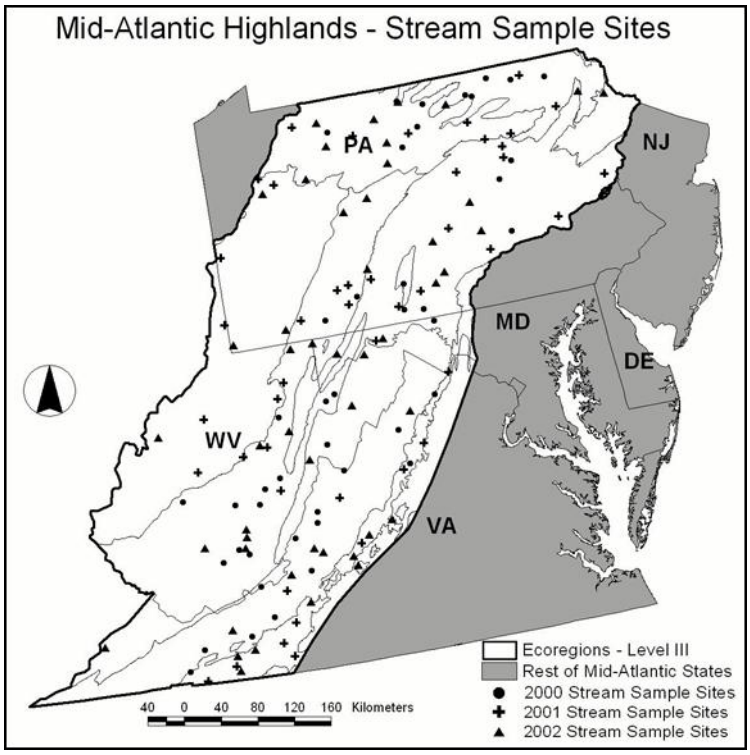
Once reference sites were identified, salamander assemblage attributes at these sites subsequently became the standards for comparison with test sites. All other aspects of the SPAR IBI development process described below were aimed at developing effective currency for comparisons (identification of metrics and construction of IBIs) and how to compensate for natural gradients. The objective was to create a measure of stream health that was simple, inexpensive, and effective.

Step 1: Sampling of stream salamanders from small headwaters (< 3 km drainage basin) located throughout the Mid-Atlantic Highlands region (MAHA)

A subset of Environmental Monitoring Assessment Program (EMAP) streams sites were chosen for this purpose. EMAP stream sites were selected through a random, probabilistic process to represent the region's headwaters.

Why/Objective: Characterization of salamander assemblages and their attributes across the range of natural (cold water vs. warm water) and human-derived degradation gradients (agricultural vs. non-agricultural, etc.) encountered in the study region.

Outcome/example: The 138 EMAP stream sites sampled in 2000 – 2002 were located in 6 different ecoregions and 4 different states. Study watersheds ranged from 0.1 – 3.05 km^2 in size and from 0-100% in forest cover, among many other gradients and are illustrated below.



Location of the 138 SPAR stream sites sampled in 2000-2002.

Step 2: Identification of reference (minimally degraded) sites

EPA's reference criteria (Waite et. al. 2000) were used to distinguish reference from non-reference. The following criteria are based on 6 water chemistry attributes, the mean of several stream habitat scores, and a single benthic macroinvertebrate metric:

Variable	Reference Criteria	Degraded Criteria
Acid Neutralizing Capacity (ueq L-1)	>50	Level not set
Chloride(ueq L-1)	<100	>1000
Sulfate (ueq L-1)	<400	>1000
Total phosphorus (ueq L-1)	<20	>100
Total Nitrogen (ueq L-1)	<750	> 5000
Mean RBP Habitat Score	>15 (optional)	<10 (marginal)
pH	Level not set	< 5
Total No. of Individuals Counted	>99	Level not set

Why/Objective: Assemblage attributes from references are the standards used to judge sites of unknown condition. In order to link stream salamanders to stream/environmental health, other measures must be used to confirm reference condition. Several other regional IBIs (fishes, macroinvertebrates) used EPA's reference criteria to identify reference sites.

Outcome/example: Of the 138 sites sampled in 2000 – 2002, only 18 were true "references", met reference criteria. An additional 16 "near-reference" sites were added to the initial reference pool to produce a total of 34 SPAR "reference/near-reference" sites, a larger, more useful sample size. In Step 2, SPAR sites failing to meet reference/near reference condition were identified as non-reference or degraded. Waite et. al. (2000) also established criteria to flag degraded sites.

Step 3: Examination of stream salamander assemblages in the 34 reference/near-reference sites

Multivariate methods were used to classify assemblages and to investigate their environmental associations.

Why/Objective: To describe and examine how stream salamanders assemble in reference sites. Equally important was to understand the impact of natural gradients on assemblages. Both steps offered the opportunity to detect and if necessary, account for the effect of natural gradients.

Outcome/example: Stream salamanders were classified into 3 broad groups; latitude and stream habitat were important environmental correlates. The classification reveled that some species were more likely to co-occur with others and occupy one environment/geographic region over another.

These assemblages and associated environments were named as follows:

1. Northern Mid-Appalachian, high gradient,

2. Southern Mid-Appalachian, high gradient, and

3. Mid-Appalachian low gradient

Appendix D. Level 3 intensive assessment supplemental information (continued).

GROUP	KEY ASSEMBLAGE ELEMENT(S)	GEOGRAPHIC/ENVIRONMENTAL ATTRIBUTES
1	*Gyrinophilus p. porphyriticus*, *Desmognathus ochrophaeus*	Cool, steep gradient, high boulder cover headwaters in **northern** portion of Mid-Atlantic Highlands
2	*D. monticola*	Cool, steep gradient, high boulder cover headwaters in **southern** portion of Mid-Atlantic Highlands
3	*Eurycea spp.*, *D. fuscus*	**Warmer**, **lower gradient**, **lower boulder cover** headwaters **throughout** Mid-Atlantic Highlands

STEP 4: Classification of non-reference sites into one of the 3 above groups

Developing group specific (GS) metrics and IBIs required prior classification of non-reference sites. Non-references were assigned to 1 of the 3 groups by a series of predictive equations that emerged from the classification of references. Step 4 accomplished what step 3 did for references.

Why/Objective: An apple must be identified as an apple if it is to be compared to other apples, rather than oranges. In this step, geographic location (latitude) and stream habitat determined group membership for non-references.

Outcome/example: Of the 101 non-reference sites, 44, 15, and 42 were assigned to group 1, 2 and 3, respectively. Figure 2 shows the geographic location of references (closed circles) and non-references (open circles) by group in the Mid-Atlantic Highlands. Group 1 sites cluster to the north, whereas Group 2 sites cluster to the south. Geographic affinities in Group 3 are not as evident.

STEP 5: Developing and testing biological measures (metrics) that distinguished reference from degraded sites

Metric effectiveness was evaluated for all 3 groups (Group Specific) and independently of grouping (Non-group Specific). In the latter, metric scores for degraded sites were compared to references/near references (n = 34) from the entire Mid-Atlantic Highlands. This approach did not consider differences in geographic location or stream habitat between references and sites to be evaluated.

Why/Objective: A metric is the building block of an index of biological condition (IBI). It is an assemblage response to one or more stressors. The performance of a metric was gauged by how well it separated references from degraded sites. Ideally, an individual metric is not easily masked by natural gradients or sampling routines.

Outcome/example: Species Richness was among several useful metrics in distinguishing reference from degraded sites for 2 of the 3 stream groups; it was an effective metric in the absence of grouping as well.

STEP 6: IBIs were developed and tested to distinguish reference from degraded sites

Earlier trials using individual metrics guided construction of indices. SPAR IBIs consisted of 2 or more metrics; metric scores were averaged when computing IBI scores. IBIs were developed and tested for each of the 3 groups (GS) and independent of group (NGS).

Why/Objective: Most IBIs consist of 2 or more metrics; effective IBIs are typically constructed from metrics that are poorly correlated to each other and are responsive to different stressors.

Outcome/example: An IBI consisting of 3 metrics achieved 80% correct classification of Northern Mid-Appalachian, high gradient sites (Group 1), but performed poorly with Group 2 and 3 sites. Overall, correct classification by any IBI was the most difficult for sites assigned to Southern Mid-Appalachian, high gradient (Group 2). NGS assessments were satisfactory relative to the group specific approach.

Applying the SPAR Index to NPS Sites

NPS sites were assessed by both group-specific (GS) and non-group specific (NGS) IBI scores. Completing the GS assessment began by assigning each NPS site to one of the 3 groups. As with other study sites, group membership was determined by equations that required site-specific environmental variables to be known (latitude and stream habitat). GS IBI scores were computed only after group membership was established.

Prior classification of test sites to one of the 3 groups was not necessary to compute NGS scores. Furthermore, test sites were compared to references from throughout the Mid-Atlantic Highlands (n = 34), rather than to a smaller set of references of the same group (n = 9 – 16). Results of streams assessments derived from the SPAR index using both GS and NGS methods are presented in the report.

In the original SPAR index study, three (3) levels of environmental condition were established: reference, non-reference, and degraded. Regardless of how scores were computed (GS or NGS) test sites were required to score at or above the 50th percentile of references to be considered in reference condition. A score at or above the 25th percentile was required for a non-reference designation. Scores below the 25th percentile classified sites as degraded.

In this study, environmental condition was determined by several methods, with each employing different thresholds and scales to describe environmental condition. In fact, while all other methods made use of 4 condition categories, the SPAR index utilized only 3. The standardized value range was developed to convert scores from different methods to a common scale ranging from 0 – 1. Since the SPAR index was based on 3 levels rather than 4, conversion of a SPAR index score to a standardized value was achieved by computing the percent rank of a raw score based on its corresponding set of references e.g. a raw index score corresponding to the 70th percentile of references would be given a standardized value of 0.70, which according to this scale, identifies the site as “Suboptimal”. The conversion is simple and merely introduces a fourth arbitrarily assigned category. By this approach, “optimal” and “suboptimal” categories correspond to the SPAR *reference* category, and the “marginal” to *non-reference* and the “poor” to the *degraded*.

Appendix E. Field Data Sheets.

SWR Data Sheet 1: General Site Information and Buffer Score

General Site Info	
Date	
Investigators	
Plot Identification (#)	
State	
County	
Municipality	
River Basin	
Watershed Name	
Stream Name	
GPS Coordinates (N)	
(E)	
Strahler Order of stream	
Photographs (number taken;mark on map)	
Is the site considered a reference standard site?	
Dominant Stream Class (rapid, run, pool, backwater)	
Is the site a beaver impoundment? [1]	

Describe condition of land-use adjacent to stream within each width class

Land use (RIGHT side of stream)

Cover Type:	**Land-use Width (meters)**				
	100-300m	30-100	10-30	3-10	0-3
Natural Forest	6	6	6	6	6
Shrubs/ Sapling	4	4	4	4	4
Perennial Herb	2	2	2	2	2
Other	0	0	0	0	0

Land use (LEFT side of stream)

Cover Type:	**Land-use Width (meters)**				
	100-300m	30-100	10-30	3-10	0-3
Natural Forest	6	6	6	6	6
Shrubs/ Sapling	4	4	4	4	4
Perennial Herb	2	2	2	2	2
Other	0	0	0	0	0

[1] Use Beaver impoundment habitat assessment sheet

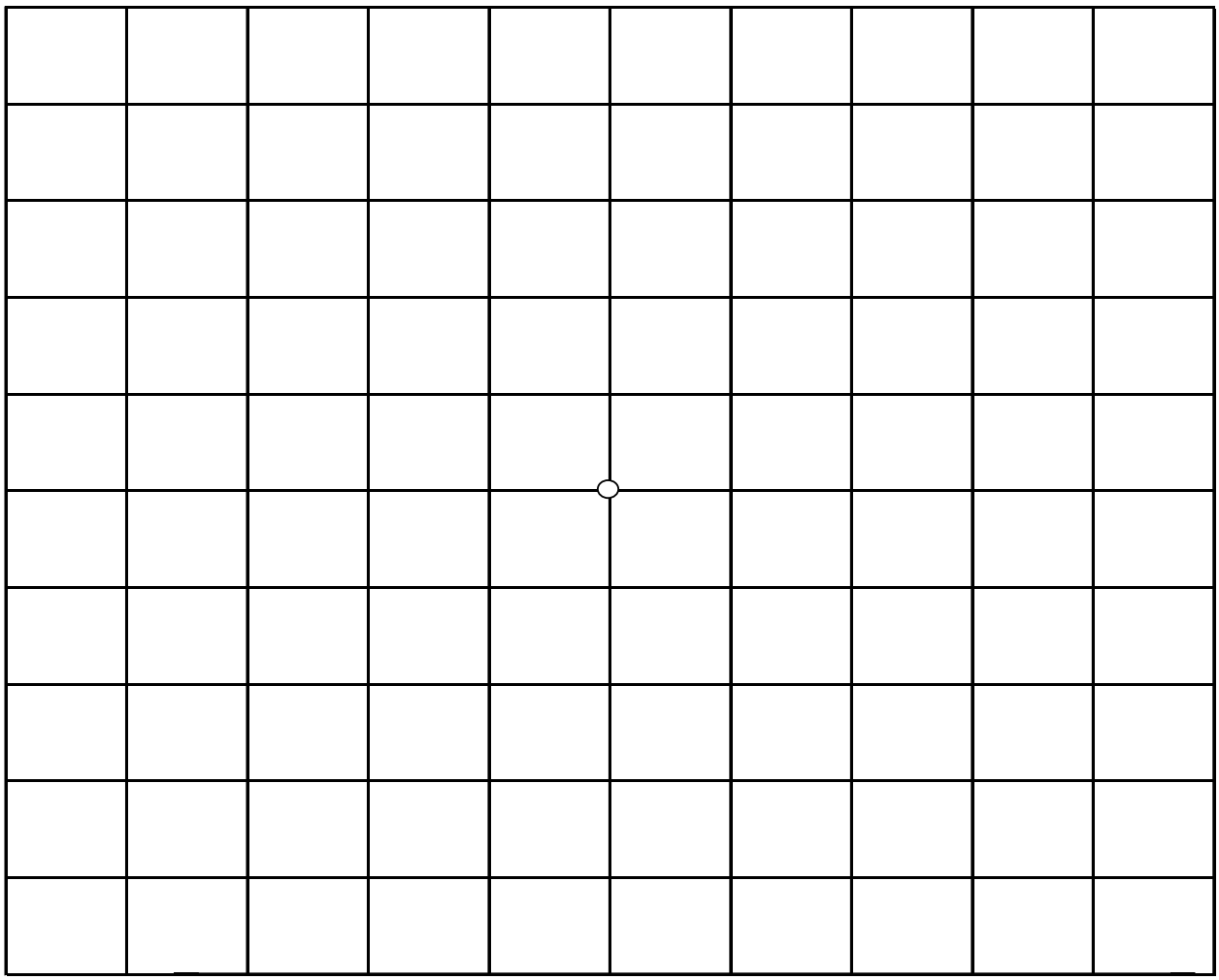
SWR Data Sheet 2: Site Map

Sketch Map (10 m squares)

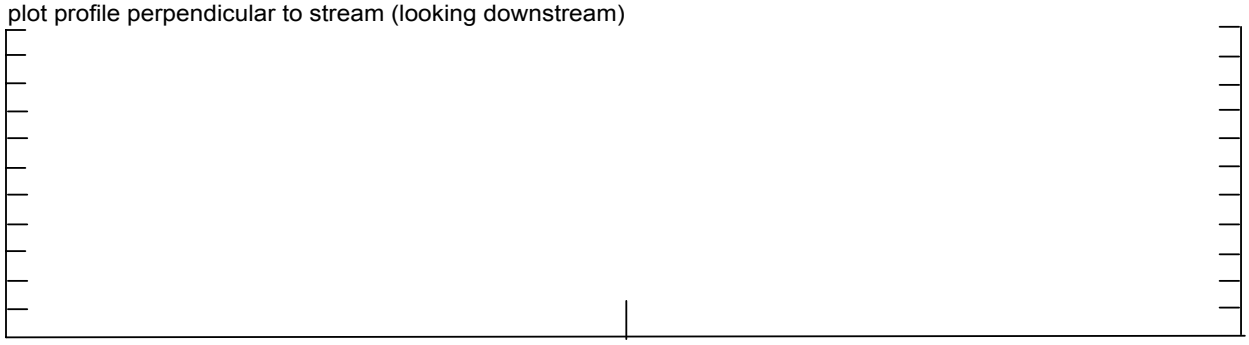
State___ Watershed_____ Plot # ___ Initials ____

ADD STREAM FLOW ARROW, MARK PHOTO POINTS, CODE HABITAT POLYGONS, DRAW NORTH ARROW

downstream



plot profile perpendicular to stream (looking downstream)



SWR Data Sheet 3: Riparian Classification

Riparian Classification
Record the dominant land cover type of each patch in Table 1, using codes defined in table 2. Identify polygons on sketch map using map codes provided in Tables 1 and 2. Additional patch types may be added in blank boxes if necessary.

Riparian Area classification - Levee (if present), Floodplain, Upland Buffer, Wetland (if present)	
Is there a levee present?	**YES / NO**
Is there a wetland present?	**YES / NO**

Table 1.

Patch Type	Map Code	Left	Right
Levee	**A**		
Floodplain Wetland	**B**		
Non-wetland Floodplain	**C**		
Upland non-floodplain	**D**		
Wetland #1	**E**		
Wetland #2	**F**		
	G		
	H		

Table 2. Map Codes.

Deciduous (d, >70%), Mixed (m, 30-70%), Coniferous (c, >70%), Non-forest (x, <30%)

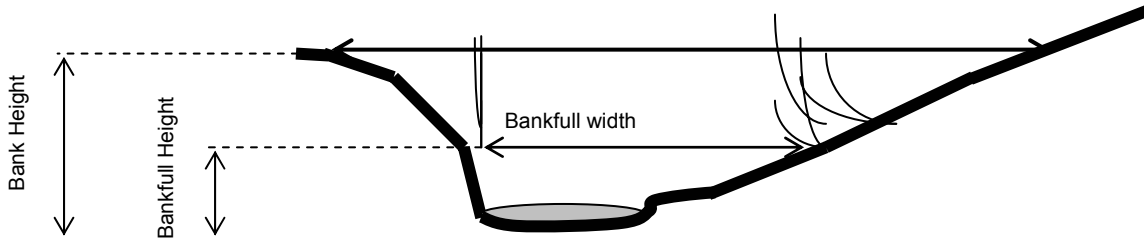
Cover type	Cover Type	Forest Type
Mature forest (>50yr, >30cm dbh trees dominate)	**1**	**d, m, or c**
Pole stage forest (25-50 yr, 10-30 cm dbh trees dominate	**2**	**d, m, or c**
Successional forest (5-25 yr, <10 cm dbh trees dominate)	**3**	**d, m, or c**
Conifer plantation	**4**	**c**
Recently harvested forest (e.g., clear cut, regeneration harvest)	**5**	**d, m, or c**
Dead and dying trees dominate	**6**	**d, m, or c**
Brush/ shrub (< 30% tree canopy cover)	**7**	**x**
Perennial herbaceous: (1) lawn, (2) pasture, (3) recreational fields, (4) meadows, (5) emergents (6) other	**8**	**x(#)**
Annual crop (e.g., corn, soybeans,…)	**9**	**x**
Low-density residential (i.e. abundant gardens, lawns, bushes, woods)	**10**	**x**
High-density residential (I.e. sidewalks, small 1/4 acre lots, dominated by impervious surface)	**11**	**x**
Urban (i.e., combinations of dense residential, commercial, industrial)	**12**	**x**

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 4: Bankfull Parameters

Bankfull Parameters (see diagram)
Take measurements (in cm) at center point, upper 50m and lower 50m of stream reach. Not applicable for beaver impoundments.

Is there a defined channel?	**YES / NO**				
Is the channel backed-up by a downstream dam?	**YES / NO**				
Is the channel incised?	**YES / NO**				
		1(cm)	**2(cm)**	**3(cm)**	**Avg.**
Bankfull Height (thalweg to top of point bar or other indicator of near-annual flow)					
Bankfull Width (width of channel from bank to bank using bankfull indicators used above for bankfull depth)					
Floodprone Height (twice bankfull depth)					(derived)
Bank Height (distance from thalweg to top of bank)					
Incision Ratio (Bank Height/Bankfull Height)					(derived)
Bankfull Width/Depth ratio					(derived)



Appendix E. Field Data Sheets (continued).

SWR Data Sheet 5: Wetland Classification

Wetland Classification (HGM/NWI)
For the floodplain (if it is a wetland) and each additional wetland patch in the sketch map record the wetland classification. If wetland is riverine designate Headwater Floodplain (HF) or Mainstem Floodplain (MF).
Enter in the appropriate box the map codes (from Table 2) identifying each wetland present.

Left side (facing downstream)							
	Depression	Slope	Fringe	Mineral Flat	Organic Flat	Riverine (HF, MF)	Other (write in)
Forested							
Scrub/shrub							
Emergent							
Aquatic Bed							
Open Water							

Right side (facing downstream)							
	Depression	Slope	Fringe	Mineral Flat	Organic Flat	Riverine (HF, MF)	Other (write in)
Forested							
Scrub/shrub							
Emergent							
Aquatic Bed							
Open Water							

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 6: Soils

Hydrology, Wetland, and Soils Assessment
Indicators of hydrologic conditions are arranged in hierarchical ranking from wettest to dryest. Assess floodplain wetlands and any other wetlands present in the plot. Not applicable for beaver impoundments.

Indicators of EXTREMELY wet conditions (one primary indicator (in bold) or two secondary indicators):

Wetland ID:						
Hydrology	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Dominated by obligate hydrophytes						
Visual observation of soil saturation near surface						
Visual observation of inundation not due to recent precip. or flooding						
Sulfidic material (detection of rotten egg smell)						
Soil						
Gleyed conditions in top 10 cm						
Histosol (organic soil, peat, muck) - organic matter dominant to a depth of ___cm below litter layer						
Presence of redox concentrations						

Indicators of MODERATELY wet conditions (one primary indicator (in bold) or two secondary indicators):

Hydrology	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Water-borne sediment deposits						
Surface drainage patterns						
Dominated by obligate and FACW						
Inundated surface due to recent precipitation or flooding						
Oxidized root channels						
Water-stained leaves						
Morphological plant adaptations						
Soil						
Chroma of 2 or less (mottles present - YES / NO)						
Listed hydric mineral soil. peat, or muck (NRCS soil survey)						
Presence of redox concentrations						

Indicators of SOMEWHAT wet conditions (one primary indicator (in bold) or two secondary indicators):

Hydrology	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Water marks						
Drift lines						

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 7: Vegetation Assessment (Trees)

Vegetation Assessment (Trees)										
Use Bitterlich plotless method (BAF=2) for trees, measuring the diameter and recording the species of each tree that "counts." Mark locations of Bitterlich points on map.										
Bitterlich Point #	**Tree species**									

SWR Data Sheet 8: Vegetation Assessment (Understory and Invasives)

Vegetation Assessment (Understory)				
Count all woody stems > 1-m tall and < 7.5 cm dbh in nine 1.9 m radius plots, with centers located at 5 m from Bitterlich point and 120 deg from one another (3 plots at each Bitterlich point). In extremely dense vegetation, use fewer plots (randomize choice).				
Bitterlich point #	**Species**	**Plot 1**	**Plot 2**	**Plot 3**

Additional Vegetation Assessment - Invasives
Are invasive species (from list) present at the site in any layer? YES NO

% cover of all invasives, collectively in 100 m x 100m plot (circle one): < 5%, ≥ 5-20%, ≥ 20-50%, ≥ 50%

If invasives herbaceaous species collectively total >20% areal cover, list below:				
Scientific Name	**<5%**	**≥ 5-20%**	**≥ 20 - 50%**	**≥ 50%**

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 9: Stressor Checklist

ASC - Stressor Checklist Date_____ Watershed name _____ Site ID_____	Total # of stressor categories/items: ____/____	Total # of stressor categories/items: ____/____	<30m	>30-100 m	Total # of stressor categories/items: ____/____	<30m	>30-100 m	**Comments:**
enter 1 if present 0 if not present. If present check distance category.								
Category: Hydrologic Modification	**STREAM**	**FLOODPLAIN**			**OTHER WETLANDS**			
channelized								
tile drain (outfalls)								
ditch (outfalls)								
ditching in riparian corridors								Land use at ditch origin:
artificial levee - flood control, spoil berms								
impounded (by weir/dam)								Type (0=beaver, 1=human):
filling,grading, dredging								Distance upstream/downstream (m):
dominance of dead/dying trees (if beaver=0)								Pool area (ha):
water withdrawal (off-take)								Length of channel impounded (m):
stormwater inputs/culverts								
point source (non-stormwater)								
excavation (sand, gravel, topsoil removal)								
road bed/crossings (bridges, fill with culverts, road, railroad)								Type (write in): Footprint area (ha):
other:								
TOTAL ITEMS:								

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 9: Stressor Checklist (continued)

Category: Sedimentation/Erosion	**STREAM**	**FLOODPLAIN**	**<30m**	**>30-100 m**	**OTHER WETLANDS**	**<30m**	**>30-100 m**	
sediment deposits/plumes (bottom accretion; EPA SHA #4. ≤15 high gradient, ≤10 low gradient. Coastal Plain (CP) SHA #2 ≤ 15								
channel incision								refer to bankfull width measurements:
excessively eroding bank slopes (EPA SHA #8 ≤5 either bank. CP SHA #4 ≤ 8)	L:							
	R:							
urban/road stormwater inputs/culverts								
channel flow status (EPA SHA#5 ≤15 high gradient, ≤10 low gradient, N/A intermittent. CP SHA #3 ≤ 10)								
active/recently active adjacent construction, plowing, heavy grazing, or forest harvesting.								
siltlines on ground, vegetation, or stream bottom								
Other:								
TOTAL ITEMS:								

Category: Dissolved Oxygen	**STREAM**	**FLOODPLAIN**			**OTHER WETLANDS**			
excessive density of aquatic plants or algal mats								
excessive deposition or dumping of organic waste (e.g. leaves, grass clippings)								
direct discharges of organic wastewater or material (e.g. milkhouse waste, food-processing waste, other wastewater								
other:								
TOTAL ITEMS:								

Category: Contaminant Toxicity	**STREAM**	**FLOODPLAIN**			**OTHER WETLANDS**			
obvious spills, discharges,plumes,odors								
fish and wildlife impacts (e.g. tumors, fungi, abnormalities)								
adjacent industrial sites, proximity of railroad								
severe vegetation stress								
other:								
TOTAL ITEMS:								

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 9: Stressor Checklist (continued)

Category: Vegetation Alteration	**STREAM**	**FLOODPLAIN**	**<30m**	**>30-100 m**	**OTHER WETLANDS**	**<30m**	**>30-100 m**	
mowing								
grazing (livestock)								
tree harvesting/cutting (>50% canopy, woody vegetation within past 5 yrs)								
brush cutting, mechanized removal of shrubs/saplings								
excessive herbivory (wildlife)								
chemical defoliation (utility lines, road side, right of way)								
crops (annual row crops)								
forest plantations								
aquatic weed control (mechanical or herbicide)								
dominant presence of exotic or aggressive plant species (e.g. uniform stands of exotic or aggressive species).								% Cover (circle one): 5-20%, >20-50%, >50%
removal of dead and down woody vegetation/debris								
other:								
TOTAL ITEMS:								

Category: Eutrophication	**STREAM**	**FLOODPLAIN**			**OTHER WETLANDS**			
direct discharges from agricultural feedlots, manure pits, aquaculture etc.								
direct discharges from septic or sewage treatment systems								
Heavy or moderately heavy formation of algal mats								
other:								
TOTAL ITEMS:								

Appendix E. Field Data Sheets (continued).

SWR Data Sheet 9: Stressor Checklist (continued)

Category: Acidification	STREAM	FLOODPLAIN	<30m	>30-100 m	OTHER WETLANDS	<30m	>30-100 m	
acid mine drainage discharges								
adjacent mined land/spoil piles								
ancillary information (yes or no)								known acid deposition region
								excessively clear water
								absence of expected biota
other:								
TOTAL ITEMS:								

Category: Turbidity (if high concentration, check both boxes)	STREAM	FLOODPLAIN			OTHER WETLANDS			
moderate concentration of suspended soilds in water column, obvious sediment plumes								
other:								
TOTAL ITEMS:								

Category: Thermal Alteration (e.g., power plant or industrial heated discharges, if high temperature, check both boxes)	STREAM	FLOODPLAIN			OTHER WETLANDS			
significant increase in water temperature								
recent human-induced canopy removal								
other:								
TOTAL ITEMS:								

Category: Salinity	STREAM	FLOODPLAIN			OTHER WETLANDS			
obvious increase in concentration of dissolved salts								
other:								
TOTAL ITEMS:								

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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