

**TRIBUTARY TO MONOCACY CREEK
STREAM RESTORATION PROJECT**

July 2000

Wildlands Conservancy

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Protection Watershed Restoration and Assistance Program

Rivers Department

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The Borough of Bath donated the use of excavating equipment and dump trucks. The Borough also provided staff who assisted in maintaining and planting trees as well as constructing in-stream devices. The Borough also accepted materials deliveries for the project and provided lunches and drinks throughout the week.

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Hilltop Excavating, Inc. donated a portion of their excavation and hauling services and provided technical assistance during the implementation of the project.

Keystone Cement Company

Keystone Cement Company donated the stone used in constructing the rock weirs, the sawtooth deflector and other devices installed during this project.

Lance Leonhardt

Lance Leonhardt, with the assistance of several Saucon Valley High School students, conducted the macro-invertebrate sampling and analysis for this project.

Monocacy Creek Chapter of Trout Unlimited

The Monocacy Creek Chapter of Trout Unlimited provided volunteers to assist in the construction and planting of the project.

Northampton Area High School

Northampton Area High School provided volunteers to assist in the construction and planting of the project.

Northampton County Conservation District

Northampton County Conservation District reviewed the Erosion and Sedimentation Control Plan that was developed for the project.

Pennsylvania Department of Environmental Protection, Soils and Waterways Section

Pennsylvania Department of Environmental Protection, Soils and Waterways Section reviewed the design plan that was developed for the project and provided permitting assistance.

Pennsylvania Department of Environmental Protection, Watershed Restoration Assistance Program

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Pennsylvania Fish and Boat Commission, Division of Environmental Services reviewed the design plan that was developed for the project and provided permitting assistance.

Pennsylvania Fish and Boat Commission, Habitat Management Section

Pennsylvania Fish and Boat Commission, Habitat Management Section provided technical guidance and on-site assistance during implementation of the project.

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United States Army Corps of Engineers

The United States Army Corps of Engineers reviewed the design plan that was developed for the project and provided permitting and on-site assistance during project implementation.

Additional Wildlands Staff

Rivers Department Interns Gregg Woodruff, Jared Bundra and Vanessa Diegel assisted in implementing the project and developing the project's final report. Tom Gettings, Director of Special Projects, provided the pre- and post-project photographs used in this report. Other Wildlands Conservancy staff also assisted in the implementation of the project.

ABSTRACT

This project addressed the non-point source pollution of a 745-foot section of an unnamed tributary to the Monocacy Creek in Bath Borough. By providing bank stabilization and in-stream habitat improvements, fish and macro-invertebrate habitat has been restored and water quality improvements are expected.

INTRODUCTION

In August 1999, Wildlands Conservancy received a grant through the Pennsylvania Department of Environmental Protection's Watershed Restoration and Assistance Program (WRAP) in the amount of \$17, 959, to implement a stream restoration project on an unnamed tributary to the Monocacy Creek (Refer to Appendix A for a Site Map.) The objectives of the project are to reduce non-point source pollution, provide bank stabilization, improve water quality and restore degraded fish and macro-invertebrate habitat. A riparian buffer has been established, gabion baskets have been removed, grade control devices and sawtooth deflectors have been constructed and biological engineering techniques have been applied to the stream banks. By providing bank stabilization and in-stream habitat enhancement, fish and macro-invertebrate habitat has been restored and water quality improvements are expected.

The Pennsylvania Department of Environmental Protection's Chapter 93, Water Quality Standards designate Monocacy Creek as a "High Quality-Cold Water Fishery". The unnamed tributary accounts for approximately 1 square mile of the total 48.8 square miles of the drainage area of the Monocacy Creek. The unnamed tributary originates in East Allen Township, Northampton County and flows approximately 1.0 mile east into the Borough of Bath where it converges with Monocacy Creek. The predominant surrounding land uses are agricultural, rural and residential. Monocacy Creek is listed on the Section 303 D list of impaired streams. Agriculture, local quarries and urban storm water runoff contribute to heavy siltation, which is the main impairment to the tributary.

The project site is located immediately upstream of the tributary's confluence with Monocacy Creek, within Keystone Park in the Borough of Bath. The *Monocacy Creek Rivers Conservation Management Plan*, which was produced by Wildlands Conservancy in 1998, recommends restoration improvements be implemented along this tributary. Prior to restoration, the tributary suffered from severe stream bank erosion, which had been accelerated by urban storm water flow, stream channelization and absence of riparian vegetation. The steep and unprotected banks had contributed heavy amounts of sediment to the tributary and were a safety hazard.

Keystone Park is a 5.9-acre recreational area owned by Bath Borough. The park is located immediately upstream of the tributary's confluence with the Monocacy Creek. The Borough agreed to participate in the project and granted access to the park.

During the stream restoration project, approximately 160 feet of gabion baskets were removed. Two rock weirs were installed to provide grade control and direct the flow of water away from eroded stream banks (for standard drawings of these devices refer to Appendix D). Approximately 475 feet of stream bank was stabilized and re-vegetated using sawtooth deflectors and biological engineering techniques. A total of 40 lbs. of facultative wetland meadow seed, 185 trees, 545 shrubs, and 1600 herbaceous plugs were used to further stabilize the stream banks and establish a riparian buffer. The riparian buffer is approximately 745 feet long and 50 feet wide (37,250 square feet) and functions to reduce non-point source pollution, improve water quality and provide habitat for wildlife, fish and aquatic macro-invertebrates.

PRE-PROJECT DATA COLLECTION AND INTERPRETATION

A pre-project habitat assessment was conducted to aid in the development of an overall management strategy and to provide a comparison for evaluating the overall success of the stream restoration project. A pre-project macro-invertebrate survey was also conducted and used as a biological index. Pre-and post-project photographs were also used as a tool to evaluate the success of the project.

Habitat Assessment

The Wildlands Conservancy Rivers Department staff completed a habitat assessment along 745 feet within the project site using a version of US EPA's Rapid Bioassessment Protocols that had been modified by The Pennsylvania Fish and Boat Commission, Habitat Management Section. A series of physical habitat-related parameters were evaluated and numerically scored to identify specific habitat-related limiting factors existing within the riparian zone and stream channel. This assessment was used to determine which parameters would be addressed through the stream restoration project. Depending upon the final numeric score, the section would be classified as poor, marginal, sub-optimal or optimal regarding the quality of desirable fish and aquatic macro-invertebrate habitat. The area was assessed using a "riffle/run" type assessment form, where areas of high gradient (slope) and high water velocities (greater than 1 meter/second) are most prevalent.

Results of the habitat assessment yielded a total score of 101/200, placing the stream reach in the category of "marginal" regarding fish and aquatic macro-invertebrate habitat. The primary limiting factors impacting the area appeared to be limited stream bank stability and riparian vegetation. Other limiting factors

impacting the reach were channelization, lack of epifaunal substrate and available cover, lack of velocity/depth combinations and riffle/run embeddedness. These parameters are addressed through in-stream habitat restoration and riparian buffer establishment. Completed habitat assessment forms are located in Appendix B.

The Wildlands Conservancy will conduct a post-project habitat assessment within the reach and it is anticipated that the results will yield an increase in total score, reflecting an improvement in the quality of fish and macro-invertebrate habitat and riparian conditions.

Macro-Invertebrate Survey

On April 13, 2000, Lance Leonhardt, a licensed aquatic biologist and biology teacher at Saucon Valley High School, completed a macro-invertebrate survey of the project site with the assistance of Wildlands Conservancy staff. The sample location was within a cobble and gravel dominated riffle section approximately 20 feet upstream from the Route 329 Bridge. This location was chosen because of its downstream relation to the entire project area and its potential to measure the effect of restoration on the entire stretch. An aquatic kick net was used to collect the specimens as they were stirred from a 1-meter square area of the stream. Once the specimens were collected they were counted and identified. The structure and composition of the sample was evaluated to determine the biological condition of the stream.

As a result of the macro-invertebrate survey analysis, many conclusions can be made regarding the stream's biological health prior to restoration. Based on the relatively high percentage of the Order *Plecoptera* found, in conjunction with a favorable ratio of intolerant to tolerant taxa, the stream can be classified as having generally good water quality. The dominant species found within the sample belong to the Family *Chironomidae*. Since *Chironomidae* is classified as a water quality tolerant Family, its dominance in the sample likely indicates elevated levels of nutrients entering into the stream. The low ratio of shredders to collectors may suggest a lack of in-stream organic material such as woody debris and leaf litter.

A post-project macro-invertebrate survey will be conducted to determine the post-project macro-invertebrate community's structure and composition. It is anticipated that improvements in water quality will be reflected. The establishment of an extensive riparian buffer is expected to reduce non-point source pollution and increase richness and diversity within the water quality sensitive Orders *Ephemeroptera*, *Plecoptera*, and *Tricoptera*. The added riparian buffer will also increase the quantity of leaf litter and woody debris entering into the reach, increasing the richness and diversity of shredders found. A description of the macro-invertebrate communities found in the sample is located in Appendix C.

IN-STREAM RESTORATION

The in-stream restoration phase of this project was designed by Wildlands Conservancy's Rivers Department staff, and was implemented with the cooperation of several other participants. Refer to Appendix D for Standard Drawings of the in-stream devices installed during the project.



Figure 1. Gabion baskets have channelized a portion of the stream reach within Keystone Park. Stream channelization, urban storm water and a lack of riparian vegetation have impacted this reach by accelerating bank erosion and sedimentation.

Gabion Basket Removal

The in-stream restoration phase of the project involved the removal of approximately 160 total feet of existing gabion baskets (cube shaped wire baskets filled with stone) (Figures 1 – 4.) These baskets had been placed along separate sections of the stream to provide bank stability.

Gabions had been placed within one particularly straight section of the stream channel along the right bank (from 487 feet to 600 feet). Gabions placed along this bank caused channelization, which limited the establishment of sinuosity or meander bends in the stream channel. Since the stream was unable to establish meander bends and contained a significant change in gradient, water flowing through this section of the stream had a tendency to gain a significant amount of

energy, especially during storm events. This condition accelerated stream bank erosion immediately downstream of the baskets, where the stream was able to establish meander bends. Severe bank erosion was evident along the outside of these meander bends where a stream typically dissipates its energy. This process accelerated the deposition of fine sediment into the tributary and the Monocacy Creek.

In addition to channelizing the stream, accelerating bank erosion and causing sedimentation, the gabions presented a safety hazard. Throughout the park, the gabion baskets created sharp, unsafe drops into the stream channel.

The existing gabion baskets also showed signs of structural failure. In several areas the stream bottom substrate had begun to scour beneath the baskets causing them to tilt inward toward the stream channel. This most likely occurred because certain sections of baskets had not been adequately trenched below the stream bottom to prevent scour. Under these conditions the baskets would eventually collapse into the stream channel and cause additional problems.



Figure 2. Gabion basket removal. To remove the baskets, a trench was excavated behind the baskets so that they could be pulled away from the channel. This method of removal minimized impacts to the stream. The stone that was contained within the baskets was used to stabilize the toe of this bank after grading was completed.



Figure 3. An approximate 3:1 grade was applied to this length of bank following gabion basket removal. Silt fencing was used to minimize siltation and adhere to erosion and sedimentation control practices.



Figure 4. A graded stream bank allows for the establishment of riparian vegetation that will provide stabilization and habitat within the stream corridor.

Gabion baskets had also been placed along the right stream bank, between 190 feet and 215 feet, directly upstream of a footbridge. Following the removal of the gabion basket the stream banks were graded and stabilized using sawtooth deflectors (Figures 5 - 7). The use of sawtooth deflectors was appropriate along this section of the stream because the eroded banks were in close proximity to the footbridge. Another benefit of replacing gabion baskets with sawtooth deflectors is the ability of the deflectors to allow the establishment of riparian vegetation, which promotes bank stability and is aesthetically desirable.



Figure 5. Gabion baskets within the park were structurally failing and offering little opportunity for the establishment of bank vegetation. Before the project was implemented, grass was mowed to the edge of the stream banks.



Figure 6. The placement of “hard structure” was appropriate along this stream bank due to the proximity of the foot bridge. Sawtooth deflectors are designed to direct the flow of water away from the stream bank and toward the center of the stream channel.



Figure 7. Stream bank vegetation became established quickly after recommendations to establish a no-mow zone were adopted.

Rock Weir Installation

After the gabion baskets were removed, two rock weirs were constructed 510 and 575 feet upstream from the Route 329 Bridge using stone ranging from 24 to 36 inches in diameter. These devices are designed to provide grade control and reduce water velocities by directing the flow of water vertically toward the stream bottom (Figures 8 & 9.) As a result of their installation, a scour pool is developing immediately downstream of the weir and the energy of the water is being dissipated. The scour pools that have been created immediately downstream of the weirs will also provide habitat diversity, since the majority of the tributary is predominantly comprised of shallow riffles. The large stones within the devices were spaced and trenched low relative to the stream bottom to facilitate fish passage and sediment transport.

These devices have a cumulative effect in reducing water velocities within this section of the tributary and will play an important role in reducing stream bank erosion and the resulting downstream sedimentation.

After the weirs were installed biodegradable erosion control blanket was used to stabilize the graded banks along sections of the stream. A combination of wetland meadow seed mix, native trees, shrubs and herbaceous plants were planted along this bank to establish a riparian buffer. This riparian buffer will

provide habitat benefits for fish, aquatic macro-invertebrates and wildlife and is expected to improve water quality by reducing non-point source pollution.



Figure 8. Rock weirs were installed to provide grade control and habitat diversity within a high gradient stream reach dominated by shallow riffles. These devices should have a cumulative effect in reducing water velocities throughout the tributary.



Figure 9. Grading stream banks allows streams access to their floodplains where they can dissipate their energy. Floodplain access and grade control is important in reducing water velocity and stream bank erosion.

Biological Engineering Techniques

The scope of this project also included grading and stabilizing several eroded stream banks through a variety of biological engineering techniques (Figures 10 - 18.) The degree of stream bank erosion and physical stream features were considered to determine appropriate techniques for stabilizing and vegetating the eroded stream banks.

In areas where stream bank erosion was most severe, banks were graded to an approximately 3:1 slope. Biodegradable coconut coir logs were used to stabilize the toe portion of the eroded stream banks. The logs were trenched approximately five feet into the stream bank on both ends and secured in the trenches using stone and topsoil. Each coir log was secured to the stream bottom using 2 x 2 inch oak stakes on both sides of the log and the logs were secured to one another using coconut fiber twine. Stone was then placed along the toe of the coir logs to prevent scouring. Areas disturbed during construction, were stabilized using biodegradable erosion control blanket and wetland meadow seed mix and a variety of native shrubs and trees were planted in these areas to provide vegetative stabilization.

In areas where erosion was less severe, more passive techniques effectively provide bank stabilization. Grading the banks to an approximate 3:1 slope, securing biodegradable erosion control blanket and using stone along the toe of the stream bank was sufficient in stabilizing these stream banks. All areas stabilized with erosion control blanket were planted with wetland meadow seed mix and a variety of native vegetation.



Figure 10. Bank erosion was most severe along stream banks that were situated along the outside of meander bends. Shallow rooted grasses offer little stabilization value. These banks would require more intensive techniques to stabilize and revegetate.



Figure 11. The availability of multiple excavators allowed for simultaneous bank work, which was necessary for the timely completion of this project.



Figure 12. Communication with equipment operators is essential in assuring that restoration techniques are implemented to design specifications.



Figure 13. Cooperation and ingenuity allowed for the efficient implementation and completion of this project. In this photo, Wildlands Conservancy staff drive oak stakes into biodegradable coconut logs for the insertion of herbaceous plugs.



Figure 14. Natural materials were incorporated into the restoration design where appropriate. The use of coconut coir logs allowed for vegetated toe stabilization that would mimic the natural contours of the stream.



Figure 15. Multiple objectives were considered in developing the final site plan. Access points were incorporated into the site design due to the project's location within Keystone Park.



Figure 16. The use of biodegradable erosion control blanket and straw will provide moisture retention for newly planted vegetation.



Figure 17. Modest quantities of stone were used along certain banks that required less aggressive stabilization techniques.



Figure 18. This picture illustrates the tendency of the stream to meander in time, thus exposing an electric line that was once buried in the stream bank.



Figure 19. Bath Borough workers and Wildands Conservancy staff prepared holes for the planting of a riparian buffer. An auger was used to create approximately 730 holes for native trees and shrubs.

RIPARIAN BUFFER ESTABLISHMENT

The riparian buffer was established to provide bank stabilization, reduce non-point source pollution entering into the stream and improve the water quality and habitat within the tributary and stream corridor for wildlife, fish and aquatic macro-invertebrates. The riparian planting phase of the stream restoration project was designed by the Wildlands Conservancy Rivers Department staff and was implemented with the cooperation of several other participants (refer to Acknowledgements). During this phase of the project, native trees, shrubs, herbaceous plugs and wetland meadow seeds were planted in a semi-random arrangement (Figure 19.) The dimensions of the buffer are approximately 25 feet in width on each bank and 745 feet in total length. Refer to Appendix E for a complete listing of the species planted on the project site.

CONCLUSION

In August 1999, Wildlands Conservancy received a grant through the Pennsylvania Department of Environmental Protection's Watershed Restoration and Assistance Program (WRAP) to implement a stream restoration project along a 750-foot section of an unnamed tributary to the Monocacy Creek at Bath Borough's Keystone Park in Northampton County (Figure 20.)

The Wildlands Conservancy Rivers Department staff planned and implemented the *Tributary to the Monocacy Creek Stream Restoration Project* and received permitting and technical assistance from the Pennsylvania Department of Environmental Protection; the US Army Corps of Engineers; the Northampton County Conservation District; and the Pennsylvania Fish and Boat Commission. Also assisting in the implementation of the project was the Borough of Bath, Hilltop Excavating and 13 volunteers from 4 local organizations and the general public. The objectives of the project are to reduce non-point source pollution, provide bank stabilization, improve water quality and restore degraded habitat for fish and aquatic macro-invertebrates. A riparian buffer has been established, Gabon baskets have been removed, grade control devices and saw tooth deflectors have been constructed and biological engineering techniques have been applied to the stream banks. By providing bank stabilization and in-stream habitat construction, fish and macro-invertebrate habitat has been restored and water quality improvements are expected.

The Tributary to the Monocacy Creek Stream Restoration Project will serve as a demonstration site for future stream restoration projects, educating resource professionals, local and state government and the general public. It is anticipated that the results of the post project habitat assessment and macro-invertebrate survey will show improvements in water quality, an increase in the quality and quantity of desirable fish and macro-invertebrate habitat and an increase in species diversity and abundance. These improvements will have positive impacts not only on the tributary, but also on the Monocacy Creek.



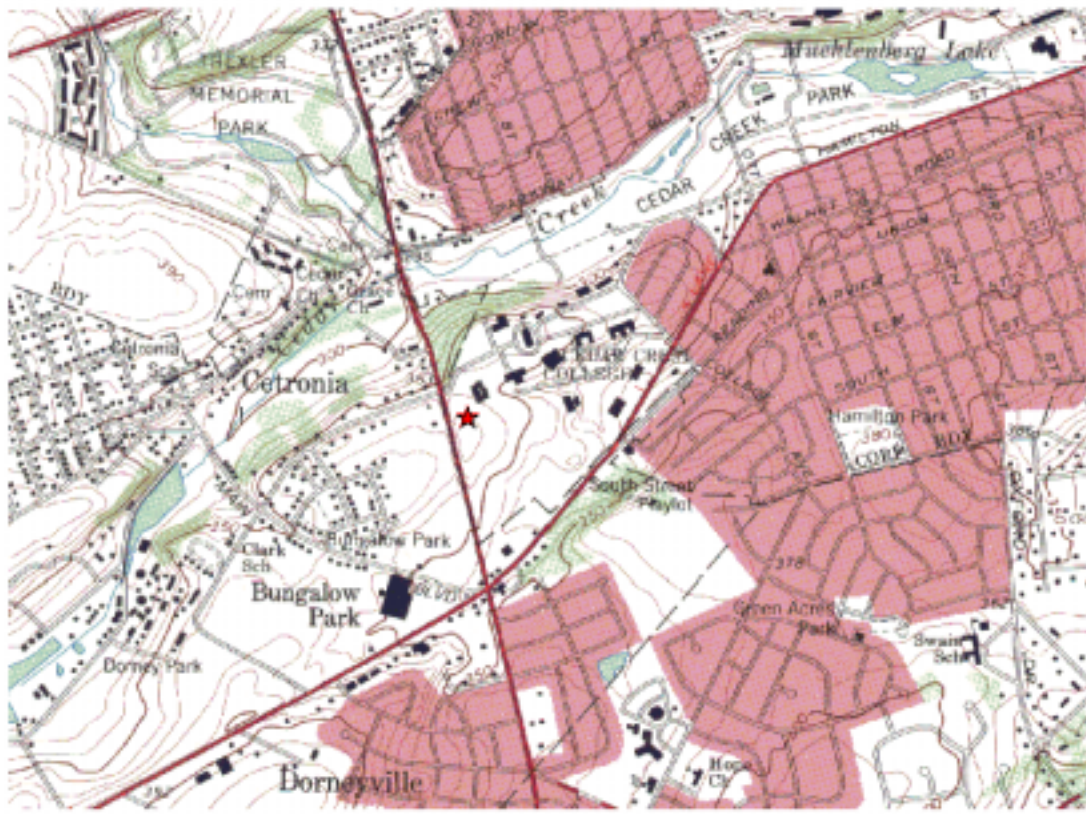
Figure 20. An upstream view of Keystone Park, following project completion. This project should improve the water quality of the Monocacy Creek and will serve as a valuable example to other municipalities facing similar stream corridor management challenges.

Appendix

- I. Site Location Map**
- II. Habitat Assessment**
- III. Microinvertebrate Survey**
- IV. Riparian Species List**

Unnamed Tributary to Monocacy Creek Stream Restoration Project at Keystone Park

CATASAUQUA QUADRANGLE



STREAM HABITAT ASSESSMENT DATA SHEET

Total Score: 88

Unnamed Tributary to the Monocacy Creek / Keystone Park
Stream/Site

3/30/00
Date

1 EPIFAUNAL SUBSTRATE/AVAILABLE COVER

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/Available Cover (high and low gradient)	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potent potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for lo for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE <u> 3 </u>	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

2 EMBEDDEDNESS

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
2.a Embeddedness (high gradient)	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-70% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE <u> 16 </u>	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

3a VELOCITY/DEPTH COMBINATIONS

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
3a. Velocity/Depth Regimes (high gradient)	All 4 velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (slow is <0.3 m/s, deep is > 0.5m)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE <u> 6 </u>	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

4 SEDIMENT DEPOSITION

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
4. Sediment Deposition (high and low gradient)	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constructions and bends; moderate depositions of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE <u> 19 </u>	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

5 CHANNEL FLOW STATUS

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
5. Channel Flow Status (high and low gradient)	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE <u> 18 </u>	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

6 CHANNEL ALTERATION

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration (high and low gradient)	Channelization or dredging absent or minimal; stream with normal pattern	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

7a FREQUENCY OF RIFFLES (OR BENDS)

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
7a. Frequency of Riffles (or bends) (high gradient)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffle infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

8 BANK STABILITY (condition of banks)

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable, infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 2 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

9 BANK VEGETATIVE PROTECTION

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
9. Vegetative Protection (score each bank) Note: Determine left or right side by facing downstream (high and low gradient)	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 cm. or less in average stubble height.
SCORE 3 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 3 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

10 RIPARIAN VEGETATIVE ZONE WIDTH

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
10. Riparian Vegetative Zone Width (score each bank riparian zone) (high and low gradient)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Macroinvertebrate Survey: Keystone Run/April 13, 2000/Keystone Park, Bath, PA / Farthest downstream riffle at site

Taxonomic Classification				Number of Individuals in Sample	Functional Feeding Group	Family Level Pollution Tolerance Value (adapted from Hilsenhoff) for PA. DEP Unassessed Waters Field Form: Wadeable Streams	Tolerance Category (Based on FLPTV) I ≤ 4 T ≥ 5
Class	Order	Family	Genus				
INSECTS/	Plecoptera	Capniidae	<i>Allocapnia</i>	2	SH (shredder)	3	I
		Nemouridae	<i>Amphinemura</i>	9	SH	2	I
		Perlidae	<i>Isoperla</i>	165	PR (predator)	2	I
	/Ephemeroptera	Heptageniidae	<i>Epeorus</i>	1	CG (collector gatherer)	3	I
		Amelitidae	<i>Ameletus</i>	2	SC (scraper)	0	I
		Ephemerellidae	<i>Ephemerella</i>	8	CG	2	I
		Hydropsychidae	<i>Cheumatopsyche</i>	1	CF (collector filterer)	5	T
	/Tricoptera	Rhyacophilidae	<i>Rhyacophila</i>	10	PR	1	I
		/Diptera	Chironomidae		466	CG / 10% PR	6
	Tipulidae		<i>Tipula</i>	5	SH	4	I
Simuliidae			1	CF	6	T	
Emphididae	<i>Clinocera</i>		1	PR	6	T	
/Coleoptera	Psephenidae	<i>Psephenus</i>	3	SC	4	I	
	Elmidae	<i>Optioservus</i>	3 (A+L)	SC	5	T	
	Dystiscidae	<i>Agabus</i>	1	PR	5	T	
ANNELIDA/				10	CG	9	T
TOTAL TAXA = 16							
TOTAL NUMBER of INDIVIDUALS IN SAMPLE				688			
SAMPLE TYPE				m ² kick-screen			
SAMPLE AREA				1 m ²			

BIOASSESSMENT: KEYSTONE RUN APRIL 13, 2000 SAMPLE

CATEGORY	METRIC	EXPECTED RESPONSE TO INCREASING PERTERBATION	KEYSTONE RUN 4/13/00 SAMPLE
Richness Measures:	Total N. taxa	Decrease	16
	No. EPT taxa	Decrease	8
Composition Measures:	Ratio EPT/Chiron. Abundance (more robust when > 1)	Decrease	0.425
	%EPT	Decrease	29.0%
	%Ephemeroptera	Decrease	1.6%
	%Plecoptera	Decrease	26.0%
	%Tricoptera	Decrease	1.6%
	% Chironomidae	Increase	67.7%
	% Dominant Taxa	Increase	67.7%
	FBI Index: Excellent 0.00-3.75 V.Good 3.76-4.25 Good 4.26-5.00 Fair 5.01-5.75 Fairly Poor 5.76-6.50 Poor 6.51-7.25 V.Poor. 7.26-10.00	Increase	4.85 Good
# Intolerant Taxa (FLPTV ≤ 2)	Decrease	5	
% Individuals tolerant taxa (more robust when < 50%)	Increase	70.2	
Density (Individuals/ m²)	Variable	688.0/m²	
Feeding Measures:	Scrapers/Shredders + Total collectors	Autotrophic >0.75	0.0175
	Shredders/ Total Collectors	Normal Shredder association linked to functioning riparian system >0.25	0.036
	Filtering Collectors/Gathering Collectors	FPOM Transport (in suspension) greater than normal particulate load in suspension >0.50	0.0046
	Scrapers + Filtering Collectors/Shredders + Gathering Collectors	Stable Substate (e.g. bedrock, boulders, cobbles. Large woody debris) plentiful >0.50	0.022
	Predators/ Total of all other groups	Normal predator prey balance < 0.15	0.483

EVALUATION:

Keystone Run: Scores for %P, FBI and Ratio Intolerant/ Tolerant taxa indicate generally good water quality. Yet, % Chironomidae/Dominant Taxa may indicate the presence of elevated nutrient inputs from external sources. The higher than normal Predators/ Total of all other groups seems to indicate the dominance of prey (chironomids) having short life cycles (rapid turnover) and a lack of balance between prey species with long and short life cycles. A low Shredders/ Total Collectors score may indicate a lack of adequate riparian vegetation. A low Scrapers + Filtering Collectors/Shredders + Gathering Collectors score may indicate the need for increased stabilization of substrates.

BENTHIC INDEX OF BIOTIC INTEGRITY

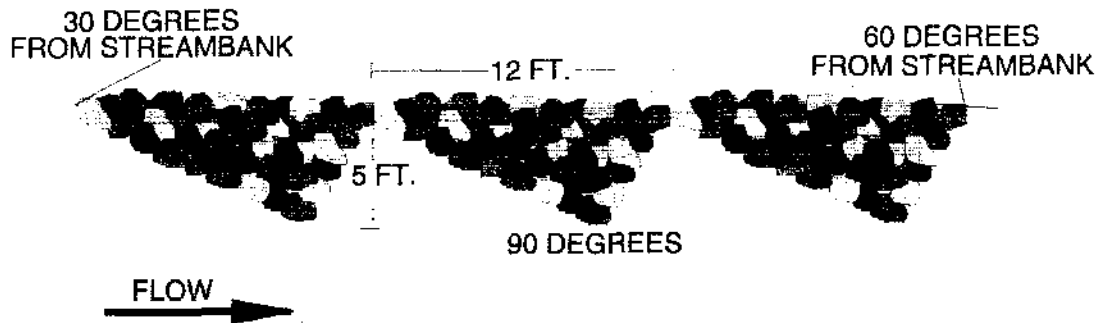
(adapted by Leonhardt for use in 1-3 order streams of Lehigh Valley, PA, from Karr et. al.)

Biometric	Predicted Response To Pollution	Score 1	Score 3	Score 5	Score:
		Biometric Range	Biometric Range	Biometric Range	Keystone Run (4/13/00)
Total # of Taxa	decrease indicates degradation	<10	10-20	>20	3 (16 taxa)
# of ephemeroptera taxa	decrease indicates degradation	<3	3-5	>5	3 (3 taxa)
# of plecoptera taxa	decrease indicates degradation	<3	3-5	>5	3 (3 taxa)
# of trichoptera taxa	decrease indicates degradation	<3	3-5	>5	1 (2 taxa)
# of Long-lived taxa (semi/merovoltine taxa)	decrease indicates degradation	0-1	2-4	>4	3 (2 taxa)
# Intolerant taxa (FLPTV <2)	decrease indicates degradation	0-1	2-5	>5	3 (5 taxa)
% of individuals in tolerant taxa	increase indicates degradation	>50	20-50	<20	1 (70.2)
% of predator individuals	decrease indicates degradation	<5	5-10	>10	5 (48.0)
% dominant taxon	decrease indicates degradation	>50	20-50	<20	1 (67.7)
					Score = 23 FAIR

B-IBI Result Interpretation	
33-45	Good Natural biological conditions indicated
21-33	Fair Slight impairment of biological conditions indicated
0-21	Poor Obvious impairment of biological conditions

SAW-TOOTH DEFLECTOR STANDARD DRAWING

PLAN

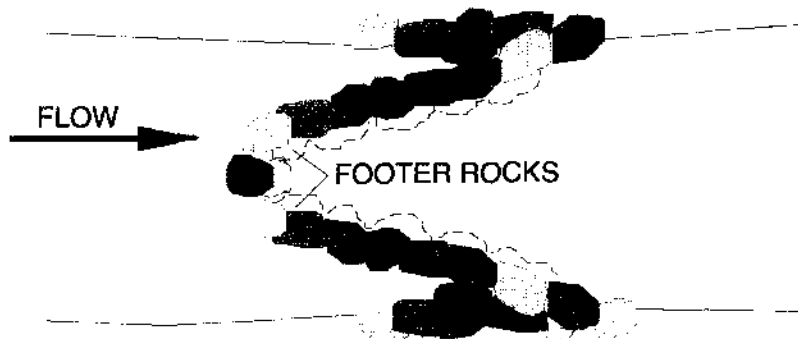


SECTION



CROSS STREAM VANE STANDARD DRAWING

PLAN



SECTION

(LOOKING DOWNSTREAM)



**List of Riparian Plantings
Tributary to Monocacy Creek
Stream Restoration Project**

	Scientific Name	Common Name	Quantity
Trees	<i>Acer rubrum</i>	Red Maple	30
	<i>Acer saccharinum</i>	Silver Maple	30
	<i>Amelanchier canadensis</i>	Shadbush Serviceberry	25
	<i>Betula nigra</i>	River Birch	25
	<i>Cercis canadensis</i>	Eastern Redbud	25
	<i>Fraxinus pennsylvanica</i>	Green Ash	25
	<i>Quercus palustris</i>	Pin Oak	25
Shrubs	<i>Alnus serrulata</i>	Smooth Alder	25
	<i>Aronia arbutifolia</i>	Red Chokeberry	30
	<i>Cornus amomum</i>	Silky Dogwood	95
	<i>Cornus sericea</i>	Red-osier Dogwood	95
	<i>Ilex verticillata</i>	Winterberry	30
	<i>Lindera benzoin</i>	Spicebush	30
	<i>Salix nigra</i>	Black Willow	180
	<i>Viburnum dentatum</i>	Arrowwood	30
	<i>Viburnum lentago</i>	Nannyberry	30
Herbaceous	<i>Asclepias incarnata</i>	Swamp Milkweed	200
	<i>Aster puniceus</i>	Purple Stemmed Aster	200
	<i>Carex stricta</i>	Tussock Sedge	200
	<i>Hibiscus moscheutos</i>	Swamp Mallow Rose	200
	<i>Lobelia cardinalis</i>	Cardinal Flower	200
	<i>Lobelia siphilitica</i>	Blue Lobelia	200
	<i>Scirpus cyperinus</i>	Woolgrass	200
	<i>Scirpus tabermontanii</i>	Soft Stemmed Fulrush	200