United States Environmental Protection Agency

Baltimore County Stream Restoration Improves Quality of Life

Baltimore County, Maryland, faces a challenge common to most areas experiencing urban growth: how to keep its waterways stable and healthy for the sake of its ecosystems and residents. Having completed more than 40 stream restoration projects (with a similar number in budget, design, permitting, or construction phases), the ***Baltimore County Department of Environmental Protection and Resource Management (DEPRM)*** has been successful in meeting its objectives to restore watershed health. This publication highlights DEPRM's watershed approach to stream restoration and is intended for municipalities and technical teams responsible for implementing similar initiatives. Resources regarding associated processes and terminology can be found on the last page.

Background

Baltimore County is centrally located in Maryland and lies entirely within the Chesapeake Bay watershed (Fig. 1a). With approximately 90% of the County's 800,000 residents living within designated urban areas—which account for less than a third of the total land area—the County has actively preserved significant portions of its rural heritage (Fig. 1b, red line). Between 2000 and 2005, Baltimore County experienced a population growth rate of just under 10%, a rate that is expected to continue. The County's extensive system of waterways (Fig. 1b) have been affected by agricultural, industrial and residential development. As a result, many of these streams have been degraded to the point of adversely affecting water quality, infrastructure, and streamside properties. Since 1980, the County has strived to protect its natural resources by implementing environmental regulations.

In 1987, DEPRM initiated a capital environmental restoration program to (1) assess and identify water quality problems and (2) implement design and construction of watershed restoration projects. In addition to stream restoration, DEPRM's efforts to improve and protect waterways include stormwater retrofits, waterway dredging, and shoreline erosion control measures.

DEPRM integrates state-of-the-art techniques with an environmentally sensitive approach to stabilizing streams and reducing sediment loads, in turn enhancing stream morphology, ecological function, water quality, and aquatic habitat. DEPRM addresses these issues in the context of how one impaired stream (or reach) affects the health and function of all waterways, residents, and habitats downstream. This perspective requires a **watershed approach**—an understanding of how waterways are directly linked to one another, the land, and the Chesapeake Bay.

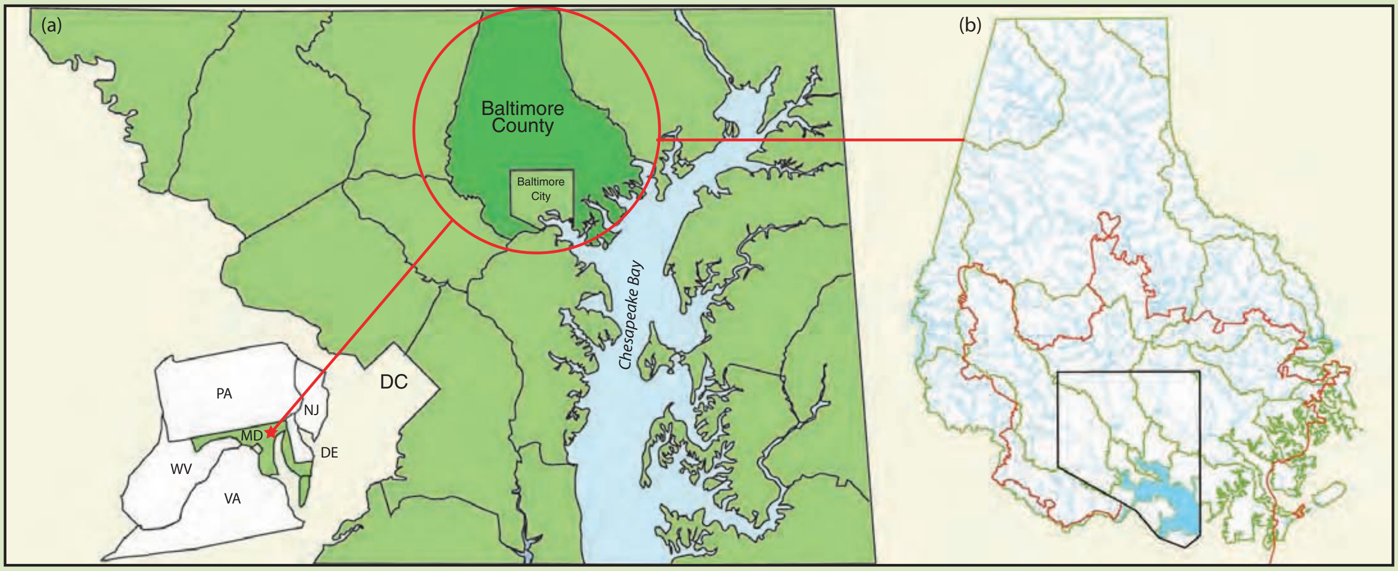

Figure 1. (a) Baltimore County surrounds Baltimore City, and contains a significant portion of the infrastructure associated with this major metropolitan area including a network of interstate highways, marine terminals, and three reservoirs. (b) Fourteen major watershed basins (outlined in green) and over 2,000 miles of streams are located within the County. The red line indicates the urban-rural demarcation line (URDL), the County's urban growth boundary.

Urbanization of Baltimore County Streams

A watershed is affected by **urbanization** when intensive development and land use activities interrupt the natural and beneficial processes of streams and riparian zones. Streams represent a complex system of variables within a watershed. Each component—such as flow velocity and volume, stream channel shape and slope, and channel bed and bank materials—must be in balance in order for streams to function properly. Urbanization often disrupts these interrelated variables, ultimately degrading stream quality. In turn, degraded streams, may become a nuisance or danger to adjacent and downstream communities by causing a host of problems including erosion, flooding, and sediment and nutrient pollution.

Figure 2. Increased imperviousness: an aerial photo of western Baltimore County at the I-695/I-70 interchange.

Table 1. Examples of problems and impacts resulting from the urbanization of watersheds.

Problems		Impacts
Increased impervious area	➔	Increased volume and/or velocity of stream flow during storms; decreased baseflow
Lack of riparian buffer adjacent to the stream	➔	Destabilization of stream banks and/or bed which leads to erosion; increased water temperature
Modifications to waterways such as piping, armoring, and/or rerouting	➔	Loss of environmental functionality such as groundwater recharge, wildlife habitat, sediment transport, and pollutant removal
Infrastructure encroachment such as undersized road crossings, sewer lines within the stream valley, storm drain connections and floodplain development	➔	Flooding and damage to public and private property
Increased pollutant and sediment loads within the stream	➔	Impaired water quality and aquatic habitat

Baltimore County has an aggressive program to implement stormwater retrofit projects in response to water quality and quantity issues. These projects, though not discussed in this document, are elements of Best Management Practices (BMPs) critical to the overall watershed restoration effort.

Prior to the 1980s, many streams in Baltimore County were straightened, channelized, and piped to maximize land for development and to divert stormwater. Sizing of bridges and culverts frequently did not account for flows during large storms, subsequently causing backwater effects and flooding. Sewer lines were often installed in stream valleys for gravity flow and ease of construction. Structures were built close to stream banks without accounting for water level increases during large storms, and storm drains linked impervious surfaces directly to streams. The removal of vegetative buffer areas and development of vast areas of impervious surface compounded adverse effects on impacted streams. At the time, there was little understanding of the influence these practices would have on long-term stream stability and water quality.

Baltimore County began implementing stormwater management regulations in the late 1970s and stream buffer setbacks for development in the late 1980s. These regulations attempt to minimize the effects of development on streams, but on-going development continues to affect natural streams. Interception of runoff by stormwater management facilities decreases peak stream flows; however, because of higher stormwater volume, the duration of release of the storm flow from the facility is longer. Riparian buffers, open space reservations, and forest conservation easements are now part of development regulations aimed at minimizing the impacts urbanization has on streams. Areas of redevelopment must adhere to current regulations as well.

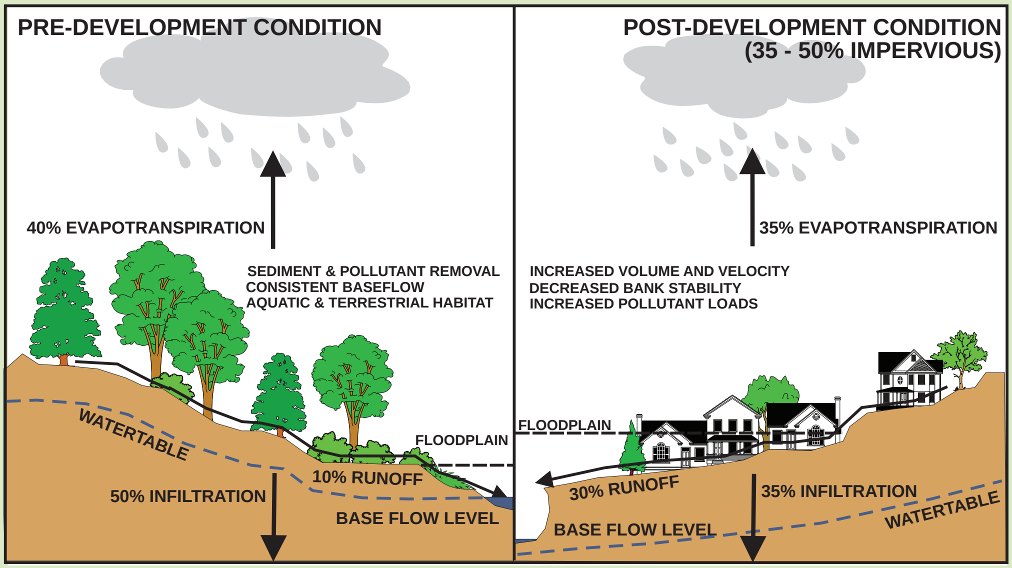

Figure 3. Comparison of a naturally functioning watershed (pre-development) versus a watershed compromised by urbanization (post-development). Less infiltration and greater runoff of precipitation leads to a lower water table and baseflow level, deeply cut banks, and a broadened floodplain.

The benefits of naturally functioning streams and their associated riparian areas include:

- Stable stream bed and planform, which reduces erosion
- Storage and drainage of flood waters
- Balanced conveyance of water and sediment
- Pollutant removal by plant uptake and cohesion to soil
- Recharge of groundwater (or subsurface) aquifers
- Critical habitat for riparian and aquatic species
- Temperature regulation through shading of streams from direct sun
- Good water quality in recreational areas for swimming and fishing

How Do Degraded Streams Affect Individuals?

Urbanized streams can negatively affect human health and property in the following ways:

- Developed floodplains and increased water volume from impervious areas during storms can cause flooding and severe erosion.
- Stream bank erosion can cause damage to yards and structures built too close to a stream. Erosion can undermine trees, causing them to fall and potentially damage property.
- Warmed and polluted urban runoff can render streams unusable for swimming and fishing.
- Decreased ground water recharge can lower well water levels and produce higher concentrations of pollutants.
- Increased water volume and velocity undercut roads, sewer systems, and storm drains increasing the costs of public services.
- Poor aesthetics of nearby waterways can decrease property values.

Figure 4. Streams degraded by development: (a) a failing concrete channel, and (b) a severely undercut stream bank.

DEPRM Stream Restoration Goals:

- To recreate naturally functioning, self-sustaining stream systems.
- To reconnect streams with their floodplains, thereby restoring hydrologic function.

DEPRM's Approach to Stream Restoration

The DEPRM Stream Restoration Program restores natural stream and floodplain function by addressing problems on an individual project basis within the context of benefiting the entire watershed. The program focuses on urban stream problems including bank instability, channel degradation, insufficient streamside buffers, poor water quality, and habitat loss.

Beginning in 1990, DEPRM began developing watershed plans to target specific impairments for twelve of its fourteen watersheds. Each plan identifies specific problems associated with the watershed and prioritizes potential restoration projects. Small Watershed Action Plans are being developed, which allow for more targeted analysis of impaired areas and provide opportunities for community input. DEPRM responds to citizen stream complaints and has maintained a database since 1991 to track problem areas and trends.

The Stream Restoration Program prioritizes projects, in part, by evaluating opportunities identified in the watershed plans. Sites are selected based on a watershed approach and systematic assessment that address the severity of the problem and the goals that can be achieved. Restoration priority is further determined by several factors, including (1) benefit of the project to overall watershed health, (2) restoration sustainability and availability of easements, (3) stakeholder input and concerns, (4) protection of existing infrastructure (roads, bridges, utilities), and (5) estimated restoration cost.

Once a degraded stream has been identified as a restoration project, DEPRM solicits the services of one of its on-call stream design consultants. Consultants are selected by committee based on a combination of personnel qualifications, past project experience, and demonstrated understanding of Baltimore County's approach to stream restoration. Staff for both Baltimore County and its consultants includes representatives from various disciplines such as engineering, fluvial geomorphology, environmental science, biology, resource planning, and ecology.

Fluvial Geomorphology: *The study of the effects of river and stream processes on landform.*

DEPRM's approach to stream restoration is rooted in principles of fluvial geomorphology.

NATURAL RIPARIAN ECOSYSTEM

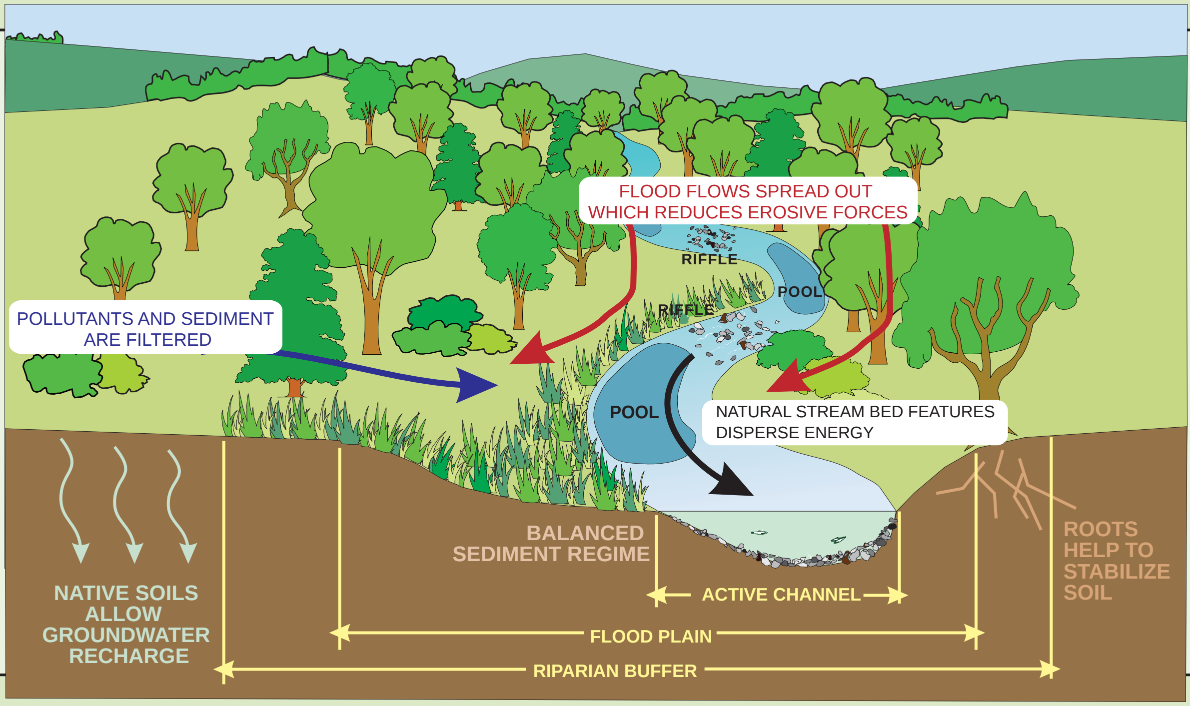

Figure 5. Features of a healthy stream. Natural streambed features, such as pools, riffles and sinuosity, disperse flow energy. Undeveloped floodplains allow expanded flow volumes to diffuse over a wider area, thus reducing erosive forces. Intact riparian buffers stabilize soils, filter pollutants and sediments, and allow for groundwater recharge.

Key Components of Natural Channel Design

Successfully implementing natural channel design requires several fundamental components, including:

Figure 6. Natural stream/floodplain interactions restored along with the creation of adjacent stormwater wetlands.

- Understanding fluvial geomorphological processes
- Understanding the topography and geology of the project area
- Knowledge of ecological and aquatic systems
- Accurate field data
- Hydrologic and hydraulic data for the project area, collected from the region for a significant period of time, adapted from a similar physiographic region or based on accepted analytical models
- Use of reference reach data and/or empirical relationships to calculate flow regime and stream channel dimensions, planform, and profile
- Sediment transport analysis
- Vegetation viability analysis
- Appropriate implementation of innovative techniques to emulate a natural appearance while providing bank stability, grade control, and/or habitat enhancement. Such techniques include bioengineering (e.g., live stakes, fascines, sod matting), rock structures (e.g., cross vanes, step-pools, boulder toe protection, riffle grade controls), and wood (e.g., log vanes, root wads)
- Recognition of project constraints such as utilities, property ownership, space limitations, floodplain impacts
- Progressive design teams and specialty construction contractors
- Long-term monitoring to ensure that the goals have been achieved, to implement remedial measures if necessary, and/or to provide guidance for future projects

Natural Channel Design

Baltimore County responds to degraded urban streams with an adaptive natural channel design (NCD) approach to evaluate, design, and implement projects that rehabilitate essential stream system processes. The NCD approach relies on the principles of fluvial geomorphology to evaluate stream flow, channel dimension, and bed and bank materials in order to optimize water and sediment movement and minimize erosive forces. Effective NCD involves gathering critical data, making scientifically defensible predictions, and having a thorough understanding of the project goals and constraints. The end result is a naturally functioning, self-sustaining stream system that provides valuable ecological processes.

The NCD approach recreates the natural features of a stream such as pools, runs, riffles and floodplain with appropriate channel substrate and bank materials, all within the context of urbanized watershed hydrology. By utilizing natural and urban reference reach data or empirical relationships to recreate these sequences, a stream is able to dissipate energy with minimal erosion. Stream banks and beds are stabilized at key locations using natural materials such as rock, wood and vegetation (Fig. 5).

Reference Reach: *A stable river segment with similar physical parameters used as a template for restoration design.*

Permitting and Construction

Baltimore County stream restoration projects must adhere to the same permitting process as all other waterway construction projects in the region. Projects are reviewed by and permits obtained from regulatory agencies representing federal, state, and local jurisdictions. Typically the permitting process takes from nine to eighteen months and is initiated early in the design process after approval of the technical approach.

Construction is performed by contractors specializing in stream restoration. Baltimore County pre-qualifies contractors based on construction expertise and past project experience. Projects are awarded to the qualified contractor with the lowest competitive bid. Specially sized and appointed equipment is often specified—such as small-scale track vehicles and a backhoe with an articulated thumb—to minimize disturbance and place materials with precision.

Case Studies

The following projects represent DEPRM's various uses of Natural Channel Design. The County's watershed approach to individual restoration efforts demands a unique set of goals for each project, dependent on site constraints. Once thoroughly evaluated against their individual goals, these projects were deemed exemplary successes in creating stable streams with enhanced environmental functionality.

1. North Fork of White Marsh Run

Length of project: 7,000 linear feet   Cost: $1,110,000   Year Constructed: 2003

Background:
Because of its location in a designated growth area, the North Fork of White Marsh Run had become a heavily developed headwater stream exhibiting a severely down-cut channel that was no longer connected to the floodplain during normal storm flows. This stream system is located on the divide between the Piedmont Plateau and Coastal Plain physiographic provinces, and as such has a low slope and highly erodible soils.

Design Objectives:
Baltimore County's ultimate goal for the North Fork was to **re-establish the stream's baseflow to improve the aquatic ecosystem**. The County used a nested channel approach to maintain sediment transport during low flow conditions and to convey storm flow events. Raising the channel bed reconnected the stream with the adjacent floodplain. A deformable channel was created to allow the stream to adjust to changes in the hydrologic regime while armoring key locations to protect adjacent infrastructure.

Results:
By reconnecting the stream to floodplain features and planting a riparian buffer, the stream ceased to be an incised channel and once again became part of the interactive floodplain ecosystem. The stream is stable and ecologically functional (Fig. 7).

Before

After

Figure 7. Severely down-cut banks compromised riparian vegetation before restoration ensued. Now restored, the North Fork is a stable, functioning system, reconnected to its floodplains.

A Baltimore County inspector provides daily construction oversight. In addition, the design consultant and Baltimore County project manager frequently inspect the project to ensure that structures are installed correctly and the project is built according to design intent. Following completion, Baltimore County and the design consultant review an "as-built" survey of all structures, grading, and landscaping within the project area.

Sediment and erosion control is an important part of the restoration process. Generally construction is conducted in a dewatered channel using a pump-around method. If feasible, construction begins at the upstream project limit and continues downstream. Disturbance is limited to the area that can be stabilized at the end of each day. Any variance to these guidelines must be approved by the appropriate regulatory agency.

2. Goodwin Run at Padonia Road

Length of project: 1,000 linear feet   Cost: $350,000   Year Constructed: 2001

Background:

What was once a well-populated trout stream was converted to a steep concrete channel in the 1960s to allow construction of a four-lane highway in a narrow valley. A driveway crossing with an undersized culvert impeded fish passage in Goodwin Run. A steep valley wall on one side and a four-lane highway on the other further constricted the stream.

Design Objectives:

DEPRM's main objective at Goodwin Run was to **revert the concrete channel back to a natural channel**, which involved the creation of a step-pool sequence. The pools and steps were sized to **allow fish passage and to re-establish ecological connectivity** along the length of the project area. The driveway-culvert combination was replaced with a bottomless arch bridge to allow fish passage.

Results:

The resulting stream is a stable system that allows fish passage while still conveying adequate stormwater flow. Monitoring has indicated an increase in diversity and abundance of aquatic species. While trout have not yet returned to this area, the food web that would support their resurgence is being re-established (Fig. 8).

Before

After

Figure 8. A steep concrete channel was replaced with a series of step-pool structures. This sequence of small pools (visible in the photo on the right) slows stream flow, disperses energy during storms, and provides a stable, naturally functioning channel with improved habitat. (Note the outflow pipe on the right-hand side of both photographs.)

3. Minebank Run

	Length of project	Cost	Year Constructed
Phase I	7,900 linear feet	$1,200,000	1999
Phase II	9,500 linear feet	$4,420,000 (includes $1,635,000 for infrastructure)	2005

Background:

Phase I

The first Minebank project was implemented in a heavily developed headwater area. The typical problems of stream buffer removal, flashy flow regime, and floodplain encroachment were evident. A failed concrete channel and an eight-foot concrete in-stream drop structure disrupted ecological connectivity. The system had severely eroding banks due to structural failures and the clear water discharge from the high percentage of imperviousness in the watershed.

Phase II

The second phase is located in a less developed area downstream from Phase I, including the County-owned Cromwell Valley Park (Fig. 9) and a small tributary on Loch Raven High School grounds (Fig. 10). Due to agricultural and recreational use, the riparian buffer area had been diminished to allow more land for fields and pasture. The banks were highly erodible, which contributed to unbalanced sediment loading and a frequently migrating planform. The poor condition of the stream was undermining infrastructure such as sewer lines, park roads, and access bridges. Two undersized bridge openings restricted stream flow, and exposed sewer lines were causing additional instabilities.

Before

After

Figure 9. A severely eroded bank caused in part by agricultural activities was restored by regrading the streambank, installing rock grade-control structures (to prevent bed degradation), and establishing riparian buffer.

In conjunction with the Minebank projects, EPA, U.S. Geological Survey, University of Maryland, and Institute for Ecosystem Studies are currently conducting a study of the effects of stream restoration on reducing nitrogen pollution. A series of shallow and deep monitoring wells were installed at intervals along the project reach prior to construction. Analysis has been performed on samples collected from wells on restored reaches prior to construction and following construction, and along unrestored reaches. Preliminary results from the data are indicating notable increases in nitrogen removal rates following stream restoration activities.

Design Objectives:
Both phases of Minebank Run's restoration addressed impacts of urbanization, including a flashy flow regime, rapid erosion, declining ecological function, failing infrastructure, poor water quality and property damage. Restoration required **the establishment of a stable planform by adjusting sinuosity and armoring stream banks at key locations, water quality improvement, reconnection of the stream to the floodplain, and re-establishment of the riparian/ wetland ecosystem.** In addition to these objectives, Phase II included infrastructure improvements within the park, including bridge replacements to allow passage for flood flows, an inner-park connector road, concrete channel removal, and sanitary sewer stabilization.

Results:
The restoration of Minebank Run has re-established stable stream alignment, dimension and channel bed elevation to a system that was highly unstable and erratic. Storm flows were reconnected to the floodplain and enhanced riparian system. Structural bank protection in key locations provides long term protection for sanitary sewer lines, roads and bridges.

Before

During

One Year After

Figure 10. Phase II of the Minebank Run Stream Restoration Project along the Loch Raven High School tributary. A concrete channel was replaced with step-pools, and the sinuosity of the channel was increased.

Post-Restoration Monitoring

To ensure the long-term success of DEPRM's projects, physical stream monitoring is performed at each site following restoration. Permanent cross-sections are established and surveyed annually for a minimum of three years following construction. Depending on individual project goals, biological and chemical monitoring may also occur. Staff often observe project sites during and/or after major storms to see how structures are functioning.

Key factors that indicate a successful restoration include cross sectional stability of the streambed and banks, a balanced sediment and flow regime through the project reach, the return of beneficial aquatic species, and re-establishment of native vegetation. The design may be modified or remedial measures may be implemented if the project is not performing as anticipated.

Figure 11. DEPRM staff conduct post-restoration monitoring at Roland Run.

How Much Does Restoration Cost?

Costs and resource needs vary depending on the project scale and components to be implemented. DEPRM's costs (for projects completed between 1997 and 2005) have ranged from under $70,000 to over $2,000,000. The current cost averages approximately $300 per linear foot.

Baltimore County recognizes that improving overall watershed quality requires a solid on-going commitment of money and resources. The DEPRM Stream Restoration Program receives funding primarily through County bonds approved by County residents. Baltimore County actively seeks additional funding from Federal and State assistance programs, the Chesapeake Bay Program (allocated regionally), the Maryland Tributaries Strategy and a variety of conservation programs and groups.

Stakeholder Involvement & Fostering Partnerships

Baltimore County works to identify and develop rapport among individuals and organizations directly and indirectly affected by restoration efforts. The Stream Restoration Program has benefited from fostering partnerships with a wide array of stakeholders, including: residential, commercial, and industrial property owners; local and regional non-profit organizations, research institutions, and conservation groups; and government agencies with vested interest as regulatory bodies or policy-makers. State and federal agencies, community associations, and environmental advocacy groups have proven instrumental in efforts to inform, guide and support DEPRM's restoration goals.

Community meetings are held and on-going communication occurs throughout each stream restoration project to ensure stakeholder understanding and support. Permanent easements are secured along project sites to permit construction activities and to allow monitoring and maintenance. Often the biggest challenge is educating property owners about the importance of maintaining vegetative buffers along streams. Since many people prefer the neat appearance of a well-manicured lawn, it is sometimes difficult to convince property owners that riparian vegetation is necessary for the stability and health of the stream. DEPRM works with property owners to establish native plantings that require minimum maintenance and provide aesthetic benefits.

Keys to Success & Lessons Learned

The DEPRM Stream Restoration Program has been successful on several key levels: in garnering support from a wide array of stakeholders and funding sources, in approaching each project in a scientifically comprehensive manner, and ultimately in turning degraded streams into naturally functioning systems. DEPRM gauges its success by whether or not specified goals set forth in the selection and planning of each project were adequately met. Since its inception, the Stream Restoration Program has identified the following elements as critical to its on-going accomplishments:

Scientific Foundation & Project Planning

- Understanding interactions among stream system components, specifically in the context of the watershed
- Individualized (vs. generalized) approach to each project, emphasizing hydrologic function
- Evaluating existing restoration projects to identify suitable structures for various stream types and goals
- Prioritizing projects to maximize restoration benefits at the local and watershed levels
- Knowledge of long-term land use within the project watershed
- Establishing sustainable native vegetation

Communication & Support

- Fostering and maintaining strong partnerships with local and regional organizations (i.e., citizen groups, watershed associations) and regulatory agencies (i.e., EPA, Army Corps of Engineers, Maryland Department of the Environment)
- Communicating effectively with stakeholders
- Pursuing several funding sources as protection against fluctuations from individual sources
- Harnessing political and fiscal support in the County and region (in large part, a result of Chesapeake Bay watershed improvement policies and campaigns)

Post-Restoration Follow-up

- Effective long-term monitoring and implementation of modifications and repairs, if needed
- Understanding that resurgence of aquatic species is not immediate (it takes time to re-establish necessary food and habitat conditions)

The culmination of these keys to success is DEPRM's acknowledgement that stream restoration is an evolving science that deals with a very complex system of variables. While some adjustments are anticipated following construction, ultimately the final product needs to be a self-sustaining system with greatly improved environmental function.

Figure 12. Minebank Run (Phase I) stream restoration three years after construction.

U.S. Environmental Protection Agency
Mid-Atlantic Integrated Assessment
701 Mapes Road
Fort Meade, MD 20755-5350

EPA/903/F-06/008
August 2006

The Mid-Atlantic Integrated Assessment (MAIA) is an interagency, multidisciplinary research, monitoring, and assessment program to develop high-quality scientific information on the region's natural resources: current conditions, stressors, trends, and vulnerabilities. MAIA results and information must satisfy a broad group of stakeholders' needs, convey important information relevant to their assessment questions and issues, and be understandable and useful in making management decisions.

Resources

EPA: River Corridor and Wetland Restoration Web site
www.epa.gov/owow/wetlands/restore
This site provides a brief discussion of wetland restoration and additional resources. In particular, the Stream Corridor Restoration: Principles, Processes, and Practices manual is a valuable and comprehensive tool.

Stream restoration terminology resources:

Nevada Division of Water Resources: Water Words Dictionary
water.nv.gov/Water%20planning/dict-1/ww-index.htm

U.S. Geological Survey: Water Science Glossary of Terms
ga.water.usgs.gov/edu/dictionary.html

EPA: Polluted Runoff (Nonpoint Source Pollution) Glossary
www.epa.gov/OWOW/NPS/Ecology/chap8.html

MAIA has identified unique solutions to environmental concerns developed by organizations throughout the mid-Atlantic regtion. Local universitites are working with MAIA to document successful solutions. This publication is one of a series designed to communitcate these solutions as a service to state and lcoal governments, regional offices, and non-governmental organizations that make a variety of environmental decisions.

Contacts

U.S. EPA
Mid-Atlantic Integrated Assessment
Patricia Bradley
bradley.patricia@epa.gov
410-305-2744
www.epa.gov/maia

Baltimore County Department of Environmental Protection and Resource Management
Capital Program and Operations
deprm@co.ba.md.us
410-887-2904
www.co.ba.md.us/Agencies/environment

Towson University Environmental Science and Studies Program
Dr. Jane Wolfson
jwolfson@towson.edu
410-704-4920
Joel Knauff
Research Practicum 2006
MS, Environmental Science
www.towson.edu/ess

Illustrations and photographs (except Fig. 1a map) provided courtesy of DEPRM; modified by graphic artist for this publication.

Recycled /Recyclable
Printed with Vegetable Oil Based Inks on 100%
Post-consumer Process Chlorine Free Recycled Paper