ACID MINE DRAINAGE REMEDIATION IN A SMALL WATERSHED[1]

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Abstract: In 1979, the Maryland Abandoned Mine Inventory (MAMI) estimated that over 450 miles of Maryland streams had been damaged by acid mine drainage (AMD) from abandoned pre-law coal mine sites. Aaron Run, a sub-drainage of the Savage River Watershed, has been severely impacted by acid mine drainage from pre-law mining activities, and is now listed on Maryland's 1998-303 (d) list of Water Quality Limited Segments (WQLSs) for pH impairment. In 2005 the Maryland Department of Environment, Bureau of Mines (MDE-BOM) submitted a proposal, and received funding through the Environmental Protection Agency's (EPA) 319 program to demonstrate de-listing of Aaron Run. Overall, the remediation plan developed and carried out by the MDE-BOM, proposes to mitigate AMD impacts at 3 project locations, to raise the entire stream's average pH from approximately 3.3 to 7.0, and eliminate the majority of all AMD inflow. Treatment technologies will include Aluminator© systems, limestone leach beds and a limestone doser, in 2008. MDE-BOM initiated the formation of the Savage River Watershed Association (SRWA) along with numerous cohesive partnerships. These partnerships have facilitated applying for match funding through OSM Watershed Cooperative Grants, and other sources. The SRWA has provided in-kind services through volunteer effort to help with the monitoring of Aaron Run. The Savage River Watershed Association hired an OSM/VISTA (Office of Surface Mines/Volunteer in Service to America) in June 2007 to assist with monitoring of planned project sites and to build capacity of the organization. The Aaron Run Watershed Restoration initiative is an ideal opportunity to exemplify a holistic approach to watershed restoration through joint efforts. There is potential to de-list a watershed from Maryland's 1998-303(d) list, restore a currently extirpated population of native brook trout, remediate numerous AMD impacts, and protect important economic fisheries resources. Because the Savage River is known for its pristine quality and is frequently used as a reference site to characterize the quality of other streams, it is truly a priority conservation system. Success of the Aaron Run restoration effort may lead the way for future regional watershed restoration efforts.

Additional Key Words: brook trout, OSM/VISTA, water quality monitoring, Maryland

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[1] Paper was presented at the 2008 National Meeting of the American Society of Mining and Reclamation, Richmond, VA, ***New Opportunities to Apply Our Science*** June 14-19, 2008. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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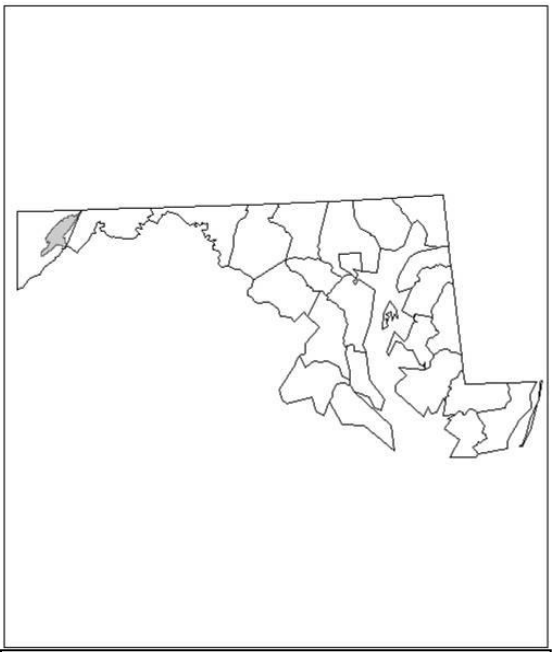
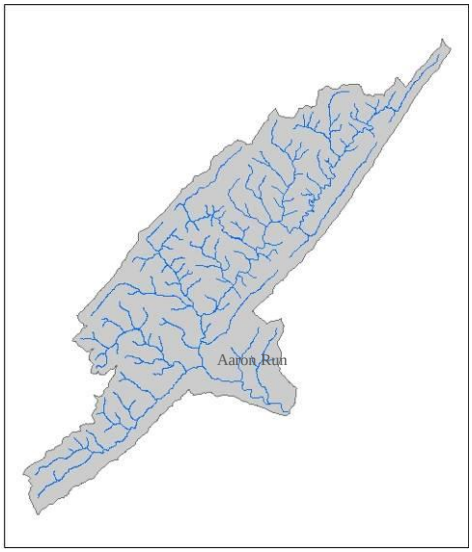
Proceedings America Society of Mining and Reclamation, 2008 pp 600-612
DOI: 10.21000/JASMR08010600
http://dx.doi.org/10.21000/JASMR08010600

Introduction

In 1979, the Maryland Abandoned Mine Inventory (MAMI) generally estimated that over 450 miles of Maryland streams had been damaged by acid mine drainage (AMD) from abandoned coal mine sites that existed before enactment of the Surface Mine Control of Reclamation Act of 1977. Across Garrett and western Alleghany counties, in western Maryland, many streams are impacted by AMD from abandoned pre-law coal mine sites. Aaron Run, severely impacted by acid mine drainage from numerous pre-law underground and surface coal mines, is now listed on Maryland's 1998-303 (d) list of Water Quality Limited Segments (WQLSs) for pH impairment. During the 1930s, small deep mining operations began in Aaron Run that peaked in the 1940s, eventually being replaced by surface mining. Hundreds of acres have been disturbed from deep and surface mining activity over the years in the watershed. Historic mining activity in the watershed was concentrated west of Aaron Run where Bakerstown and Sewickley coal seams were mined. Before pre-law mining activities Aaron Run was a healthy trout stream; now it is severely degraded with water quality incapable of supporting most aquatic life.



Map of the state of Maryland, the Savage River watershed is the gray area located in Garrett County, Western MD.



Aaron Run, sub-watershed of the Savage River watershed drains approximately 2,270 acres (3.5 square miles Of Garrett County, Maryland.

Aaron Run is a three mile long tributary that flows into the lower Savage River just above the confluence of the Savage with the North Branch Potomac River. Low pH values in Aaron Run (3.3-4.0) have been documented since 1966 and there is a decrease of pH in the Savage River at sites sampled below the confluence of Aaron Run (PHRA 1989, Morgan et al., 2000). Impacts from AMD are concentrated in the upper portion of the watershed with additional problems of stream bank erosion in the headwaters. Poor water quality in Aaron Run also has a negative impact on the native brook trout fishery in the lower 1-mile portion of Savage River, one of the last remaining areas in Maryland that contains intact populations of brook trout (Hudy et al., 2006). Savage River, known for pristine water quality and fast flowing water, is used as a reference site for other streams in western Maryland. Most of the Savage River watershed is contained within the Savage River State Forest and Aaron Run is the only tributary impacted by AMD in the Savage River watershed. Restoration of Aaron Run will pave the way for future restoration and conservation projects in the Savage River watershed.

In 2005 the Maryland Department of the Environment, Bureau of Mines (MDE-BOM) submitted a proposal that included plans to remediate AMD impacts in Aaron Run that would delist the watershed from the 319 (d) list of impaired watersheds. MDE-BOM had already collected data from previous studies (PHR&A, 1989, Morgan et al., 2000). After reviewing the data, MDE-BOM realized that restoring Aaron Run was an ideal opportunity to demonstrate a

holistic approach to watershed restoration through joint efforts and to restore a population of brook trout that have been impacted by AMD.

A two-year (1985-87) feasibility study conducted by Patton, Harris, Rust & Associates (PHR&A) tested geologic conditions, water chemistry of mine seeps and surface water, and the flow and chemical parameters of groundwater to determine the sources and extent of impact from past mining practices. A second study (Morgan et al., 2000) was conducted to evaluate Aaron Run using biological indicators (fishes and benthic macro-invertebrates), water chemistry parameters, and physical habitat evaluation. Data from both studies consistently indicate that Aaron Run is degraded by AMD from numerous pre-law underground and surface coal mines.

Ten abandoned mine portals, previously identified by MDE-BOM, throughout the Aaron Run watershed continue to severely degrade the water quality of Aaron Run. These portals contribute to Aaron Run a total combined average discharge of 135 gallons per minute (GPM), and loadings of Fe (67.32 lbs/day), Al (85.84 lbs/day), alkalinity (0.1 lbs/day) and acidity (422.73lbs/day). The Aaron Run remediation plan developed and carried out by the MDE-BOM proposes to mitigate AMD impacts from all discharges in the watershed at the 3 project locations. The goals of this project are to raise the entire stream's average pH from approximately 3.3 to 7.0, and greatly decrease the impact of AMD inflow by installing the best acid mine drainage treatment technologies to neutralize the acid and reduce metals that flow from the primary sources of acid mine drainage in the main stem of Aaron Run. Acid mine drainage treatment technologies chosen by Damariscotta, the company responsible for the design of the projects, were based on water quality data, available space for systems, discharge flow, as well as State and Federal regulations. After water quality improvement, Maryland Department of Natural Resources Fisheries (DNR) will reintroduce native brook trout from the Savage River to re-establish native brook trout populations in the Aaron Run main stem. The initiative will also promote the recovery of fish populations into the lower 1-mile of Savage River that currently experiences a reduction in numbers of fishes below the confluence of Aaron Run.

Savage River is a highly valued recreational trout stream in Garrett County that contains populations of native brook trout, and has become a conservation priority. Consequently the Aaron Run Watershed Restoration Project has gained attention that has encouraged numerous partnerships. Efforts of MDE-BOM and Maryland Brook Trout Association (MBTA) initiated the establishment of the Savage River Watershed Association (SRWA). The SRWA and

Appalachian Coal Country Watershed Team (ACCWT), was provided an Office of Surface Mining/AmeriCorps*Volunteer in Service to America (OSM/VISTA) to assist with the monitoring of Aaron Run and to help build capacity of Savage River Watershed Association. Since placement of the OSM/VISTA, SRWA has made much progress. As a relatively new watershed organization, SRWA's main capacity building goals are fundraising and membership recruitment/retention. Over thirty new paid members have been recruited since July 2007 and SRWA has held two successful fundraising events. The OSM/VISTA has also helped prepare and submit 4 grant proposals. SRWA obtained Arc GIS 9X in fall 2007 to map water quality monitoring data. SRWA also received funding to send out a membership drive letter to 1500 stakeholders in the watershed. In just a year, SRWA has grown and begun building the foundation for a sustainable organization as a result of the OSM/VISTA program.

Methods

Project Planning

The first year of the Aaron Run Watershed Restoration Project efforts were focused on collecting baseline data needed for project design, and extensive project planning. Efforts included water quality monitoring, planning for survey, drafting and design, meeting with landowners, obtaining right of entry (ROE) documentation, identifying match funding sources, meeting Office of Surface Mining (OSM) requirements, biological monitoring and planning for future monitoring efforts. The primary funding sources for the project are incremental EPA 319 grants. Matching fund sources include: Office of Surface Mining- Watershed Cooperative Grants (applied for and managed by Western Maryland Resource Conservation & Development Council, Inc) and other MDE-BOM fund sources. In-kind contributions have been made by DNR and SRWA. Initial plans for monitoring included placing an OSM/VISTA with SRWA to help with monitoring. The OSM/VISTA was placed in June 2007 and assisted in monitoring towards the end of project planning, and will assist in post construction monitoring efforts. The OSM/VISTA assisted in the development of a volunteer water quality monitoring program to begin assessing the next conservation or restoration effort in the watershed.

Water Quality Monitoring: Chemical and Physical

A watershed survey was conducted to evaluate water quality conditions, quantify AMD impacts, and select monitoring stations for project planning. Water samples, flow data, GPS

points and photos were taken at 15 stations. Ten abandoned deep mine discharges were identified to be contributing to the degradation of Aaron Run, with a total flow of 135 gallons per minute. After review of reconnaissance and initial watershed survey data, potential project areas were identified, and monitoring stations were chosen to conduct continued monitoring. A water quality monitoring schedule was drafted and sampling was conducted monthly at 9-16 stations. Stream flow rates were measured using a Marsh-McBirney, Flo-Mate 2000 portable flow meter.

Sufficient baseline data were collected for design of the 2 projects planned for spring of 2008. Subsequent water quality monitoring focused on project sites planned for construction in 2009, to provide baseline data for design. Stations were monitored monthly by collecting grab samples and using a hand held meter to measure pH, conductivity, temperature and flow. Two grab samples were taken from each location and brought to a lab for analysis. Nitric acid was added to one sample in preparation for analysis of Al, total Fe, Mg, Mn, and Zn. The second sample would be used to analyze acidity, alkalinity, and sulfates. Water quality samples and data analysis were collected by MDE-BOM staff and the OSM/VISTA according to an approved Quality Assurance Project Plan (MDE- BOM, 2000).

Water Quality Monitoring: Biological

Biological monitoring of fishes and benthic macro-invertebrates was conducted at 3 stations throughout the watershed to establish pre-construction baseline conditions. A survey of fishes was conducted by DNR, and macro-invertebrate surveying was incorporated into SRWA's monitoring plan. Fish were sampled using Electro-fishing techniques and will be monitored annually post construction. The Izaak Walton League of America Save Our Streams (SOS) benthic macro-invertebrates sampling protocols are used by SRWA in their biological monitoring plan which is being carried out through volunteer efforts organized by the OSM/VISTA. Invertebrates will be collected twice a year at 3 sites in Aaron Run as part of a continuous monitoring plan for the Savage River watershed.

Data Management:

Microsoft EXCEL was used to compile and analyze data. Data were used to calculate mass loadings of select parameters to Aaron Run. Arc GIS 9.1 was used to map data from previous studies as a guide to begin monitoring efforts. After one year of data collection, a second map

was constructed to show proposed project sites, sampling points, and to display the degree of impact.

Results

Water Quality: Chemical and Physical

Data from the initial watershed survey showed low pH, high acidity and high metal loadings entering Aaron Run from abandoned mine discharges (Table 1). Comparison of water quality data from above and below the abandoned mine discharges, clearly show severe impacts from AMD discharges (Table 2). Monitoring data from year 1 show that mine discharges have consistently low pH with high loadings of Fe and Al (Table 3). Aaron Run has adequate habitat and maintains temperatures (summer temperatures < 18°C) suitable for native brook trout (Table 4). Data indicate that remediation of AMD impacts in Aaron Run would provide an ideal opportunity to reestablish native brook trout populations.

Table 1. Data from initial watershed survey shown as loadings in lbs/day based on median concentrations and average stream flow rate

Parameter	**Loading (lbs/day)**
Fe	81.61
Mn	3.22
Acidity	458.36
Al	23.25
Ca	389.37
Mg	112.27
SO_4^{2-}	2374.33

Table 2. Average flow, pH, and loading of select parameters in Aaron Run, at stations above, midway, and below AMD impacts.

Station	Flow (gpm)	pH	Acidity (lbs/day)	Alkalinity (lbs/day)	Fe lbs/day)	Al (lbs/day)
Headwaters, above AMD impacts (AH-2)	397	6.7	46.4	21.2	0.88	0.48
Mid-section, below headwater AMD impacts (AA-1)	530	4.1	195.0	44.9	7.11	15.84
Below all AMD impacts (AA-6)	496	3.8	432.0	5.5	39.77	30.15

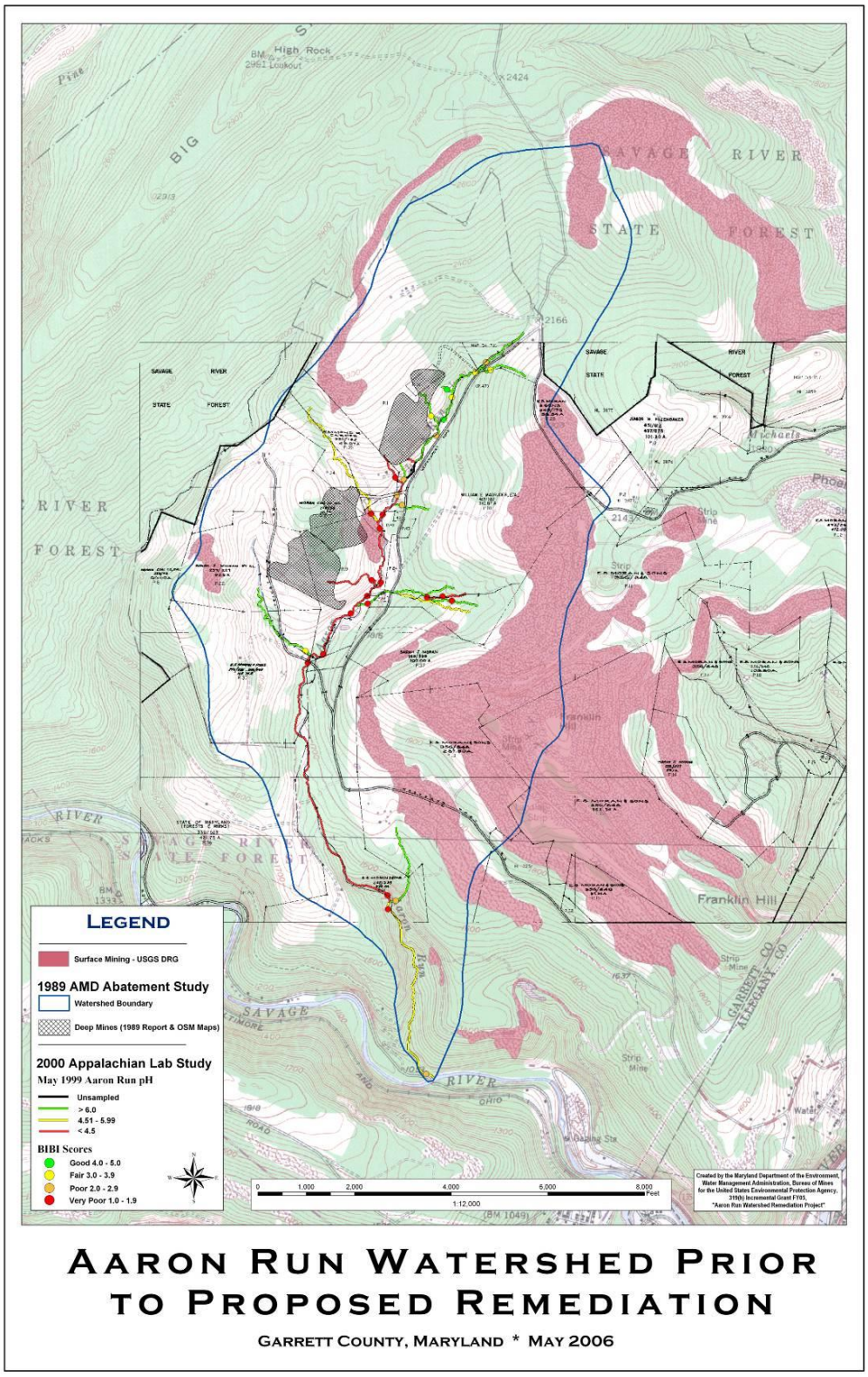
Table 3. Average values for flow, pH, and loadings of select metals contributed by AMD discharges in the Aaron Run watershed. Stations are AMD discharge sites listed in order from the headwater to the discharge lowest in the watershed.

Station	Flow(gpm)	pH	Acidity (lbs/day)	Alkalinity (lbs/day)	Fe (lbs/day)	Al (lbs/day)
AH-1	4	4.7	1	0.1	0.05	0.06
AH-4*	46	3.0	5.73	0.0	2.15	57
AC-1	4	3.1	17	0.0	0.05	1.75
AC-2	32	2.9	59	0.0	5.26	5.27
AA-2	7	3.1	63	0.0	13.72	4.42
AA-3a	39	2.6	259	0.0	43.00	15.93
AA-3b	3	2.8	18	0.0	3.09	1.41
Totals	**135**	**NA**	**422.73**	**0.1**	**67.32**	**85.84**

*AH-4 has 4 portal discharges contributing

Table 4. Annual variation of Aaron Run water temperature above and below AMD impacted areas.

Date	Above AMD (AH-2)	Below AMD (AA-6)
28Mar06	4.8	5.4
11Apr06	7.9	5.1
27Apr06	9.3	6.9
9May06	9.4	9.8
23May06	8.7	8.2
28Jun06	16.3	16.1
25July06	17.1	16.8
22Aug06	17.9	15.8
26Sep06	13.3	11.5
24Oct06	4.7	5.0
9Jan07	NM	3.8
1Mar07	2.2	NM



Map of Aaron Run showing surface mining and deep mine sites, and stream sampling locations (Map Prepared by MDE-BOM for Aaron Run Watershed Remediation Project, 2007)

Water Quality: Biological

During the biological survey of fishes in Aaron Run, only one blacknose dase, a pollutant tolerant species (Jenkins and Burkhead, 1993), was found above the impacted areas. No fish species were present at the stations located midway and below impacted areas. Macro-invertebrates were collected by SRWA volunteers using the SOS technique. The midway and lower most stations had ratings of poor while the upstream station rated fair.

Conclusion

Through planning of the Aaron Run Restoration Project, MDE-BOM formed cohesive partnerships and a volunteer effort was initiated. Project partners include: IWLA, Trout Unlimited, MBTA, DNR, other watershed groups, Chesapeake Bay Trust, Chesapeake Bay Funders Network and Appalachian Coal Country Watershed Team, OSM/VISTA. MDE-BOM staff participated in coordinating conservation efforts focused in the Savage River watershed and assisted in building capacity of the SRWA. As project match, the SRWA hosted a stakeholder meeting for which advertisement was provided as an in-kind contribution. Once the SRWA was created, recruiting began to place an OSM/VISTA to help with the AMD monitoring and assist in building capacity of the organization. A total of $5500 in match funding is needed each year that an OSM/VISTA is placed with a watershed organization. SRWA received match funding for the OSM/VISTA from Trout Unlimited and has been fundraising to raise the match funding needed for placement of the next OSM/VISTA. The current OSM/VISTA has served as the group coordinator for SRWA and has been able to work full time to assist the group in capacity building, project planning, grant writing, and building organizational structure necessary for the group's growth and sustainability, helping the SRWA in many ways. The OSM/VISTA has also initiated partnerships with local organizations in the area.

As part of an assessment of the Savage River watershed, SRWA members will be providing continued biological monitoring (using benthic macro-invertebrates) in addition to efforts by the DNR, who will continue to monitor fishes. Since it will take several years of post-construction monitoring to fully demonstrate reestablishment of biological communities, SRWA will continue to monitor these sites. Through volunteer monitoring of Aaron Run, the OSM/VISTA facilitated a water quality monitoring program that extends throughout the Savage River watershed. Consequently SRWA members and volunteers have been trained and certified to conduct macro-

invertebrate surveying using SOS protocols approved by the Environmental Protection Agency (EPA). IWLA wrote and received a grant to supply SRWA with training and needed biological monitoring equipment. During the summer of 2007, SRWA hosted 2 trainings resulting in members being trained and certified in SOS protocols. The SRWA has begun collecting data throughout the rest of the Savage River watershed to identify other impacts. These data will be used to determine priority restoration and conservation areas in the Savage River watershed, and as a first step towards a comprehensive watershed plan.

Restoration of brook trout habitat in Aaron Run will necessarily result in available habitat and water quality conditions suitable to increased diversity of other fish species as well as benthic macro-invertebrates, and will also improve the fishery in the lower 1-mile of Savage River. The lower portion of Aaron Run, and some of the headwaters are all within the Savage River State Forest, thus restoration of this resource also will create an additional public brook trout angling resource.

The Aaron Run Watershed Restoration Initiative is an ideal opportunity to demonstrate a holistic approach to watershed restoration through joint efforts. There is potential to de-list a watershed from Maryland's 1998-303(d) list, restore a currently extirpated population of native brook trout, remediate numerous AMD impacts, and protect important economic fisheries resources. Because Savage River is known for its pristine quality and is frequently used as a reference site to characterize the quality of other streams, it is truly a priority conservation system. Success of the Aaron Run restoration effort may lead the way for future regional watershed restoration efforts as a model for small watershed restoration.

The suggested treatment technologies will include Aluminator© type successive alkalinity producing system, limestone leach beds and a limestone doser, with construction projected for 2008. An Aluminator© is a patented process by Damariscotta that allows for the precipitated Al to be flushed from pipes (Skousen, 1998). Headwater restoration is being planned to add alkalinity to the system and increase stream buffering capacity. The headwater project will ensure success of projects planned downstream and will increase the chances of maintaining a stream pH of 6.5 or higher, which is a limiting factor for brook trout. The doser will be placed to enhance and protect the function of the other systems. These systems will all work together to raise pH and restore water quality.

Acknowledgements

I would like to thank the Maryland Department of Environment, Bureau of Mines (MDE-BOM) for providing resource materials used to summarize the project. I would like to acknowledge the Western Maryland Resource Conservation & Development Council as a significant partner who secured multiple sources of match funding and hired a Project Coordinator to coordinate the planning efforts of Aaron Run Watershed Remediation Project. I would also like to thank my OSM/VISTA supervisor, Laura M. Haynes, who worked as the Aaron Run Project Coordinator until October 2007 and assisted in the writing of this paper.

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