

RESTORING THE BENNETT BRANCH SINNEMAHONING CREEK, CLEARFIELD AND ELK COUNTIES, PENNSYLVANIA¹

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Abstract. Since 2004, the Pennsylvania Department of Environmental Protection (PA-DEP), Bureau of Abandoned Mine Reclamation (BAMR) has been working with multiple partners to restore water quality and reclaim abandoned mines in the Bennett Branch Sinnemahoning Creek. The primary water quality problems in the watershed are the result of uncontrolled and untreated discharges of acid mine drainage (AMD) from abandoned mine lands (AML) that have severely degraded the water quality in the lower 53.1 kilometers (33 miles) of the Bennett Branch and many of its tributaries. The primary objective of the Bennett Branch Restoration Project is to develop and implement a detailed mine drainage abatement and abandoned mine reclamation plan. The goals of the plan are to restore water quality in the main stem of the Bennett Branch, improve water quality in the AMD impacted tributaries, and maximize the reclamation of AML throughout the watershed. The restoration work is being pursued in conjunction with the PA Wilds Initiative which advocates economic development and tourism throughout north-central Pennsylvania. The PA-DEP-BAMR has partnered with a local watershed association, state and federal agencies, and the mining industry to maximize the restoration work and to reduce the overall project cost. A considerable amount of work is currently underway or has been completed while more work still needs to be done. This report will focus on the background of the Bennett Branch Restoration Project, the restoration efforts to date, and the work planned for the future.

Additional Key Words: Watershed Restoration, Acid Mine Drainage, Alkaline Addition, Surface and Groundwater Hydrology, Partnerships, Wildlife Habitat Revitalization

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Background Information

Figure 1 shows the location of the Bennett Branch Watershed in north-central Pennsylvania. In March 2004, PA-DEP completed an assessment of the work required to abate the adverse impacts of mine drainage in the Bennett Branch Sinnemahoning Creek. The analysis was completed using historical data and records of the PA-DEP and a watershed assessment completed by the Bennett Branch Watershed Association (BBWA) in 2003 which was funded by Pennsylvania's Growing Greener Program. The analysis was presented to the Governor's PA Wilds Task Force in May 2004 and, after a favorable review of the assessment, a decision was made to move forward with the continued development and implementation of a detailed mine drainage abatement plan and AML reclamation plan for the Bennett Branch.

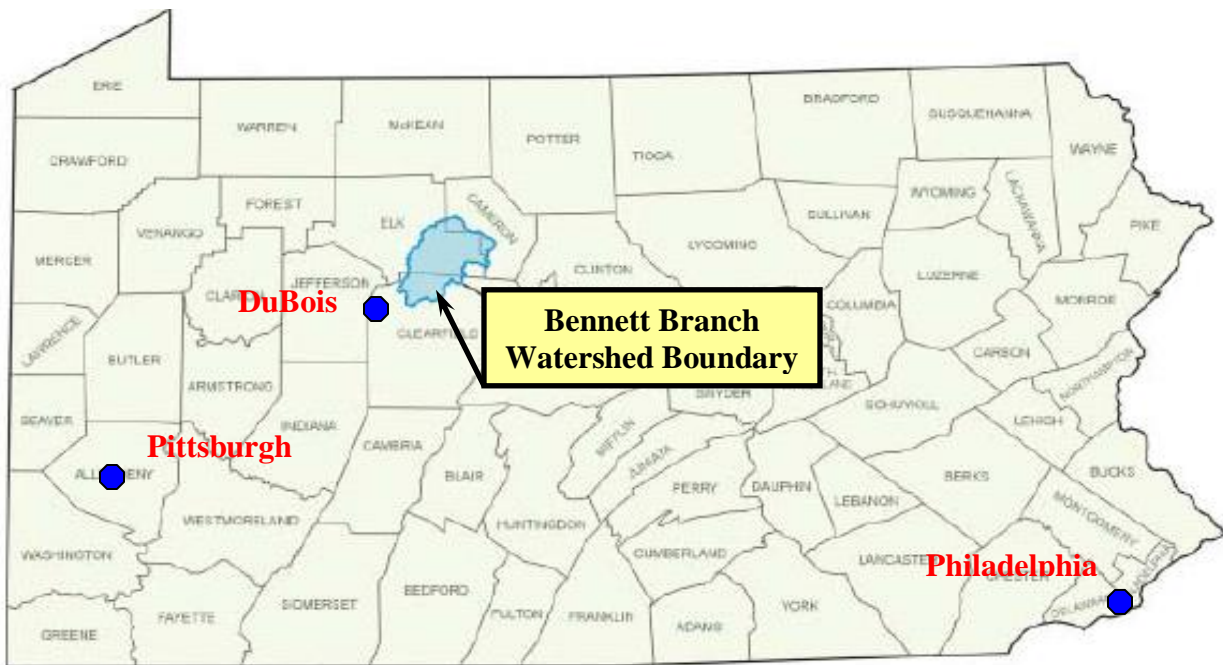


Fig. 1. Location Map of the Bennett Branch Watershed.

Bennett Branch Watershed Facts

The Bennett Branch Watershed is roughly 1002 square kilometers (387 square miles) in size, and roughly 5 percent, or 49 square kilometers (19 square miles), contain abandoned underground mine workings. Another 41 square kilometers (16 square miles) or approximately 3,885 hectares (9,600 acres) of the watershed have been surface mined or used for coal refuse disposal. The majority of the watershed is forested and mountainous with deeply cut valleys. The stream drops approximately 274 meters (900 feet) in elevation from the headwaters near the

village of Sabula to the mouth at Driftwood. Figure 2 shows the major villages and tributaries in the Bennett Branch Watershed. Relief within the watershed is 411 meters (1,348 feet). The highest elevation is 703 meters (2,308 feet) above mean sea level at Red Hill Summit. The Eastern Continental Divide coincides with the northern boundary of the Bennett Branch Watershed. This ridge top separates runoff draining directly to the Atlantic Ocean from that draining to the Gulf of Mexico.

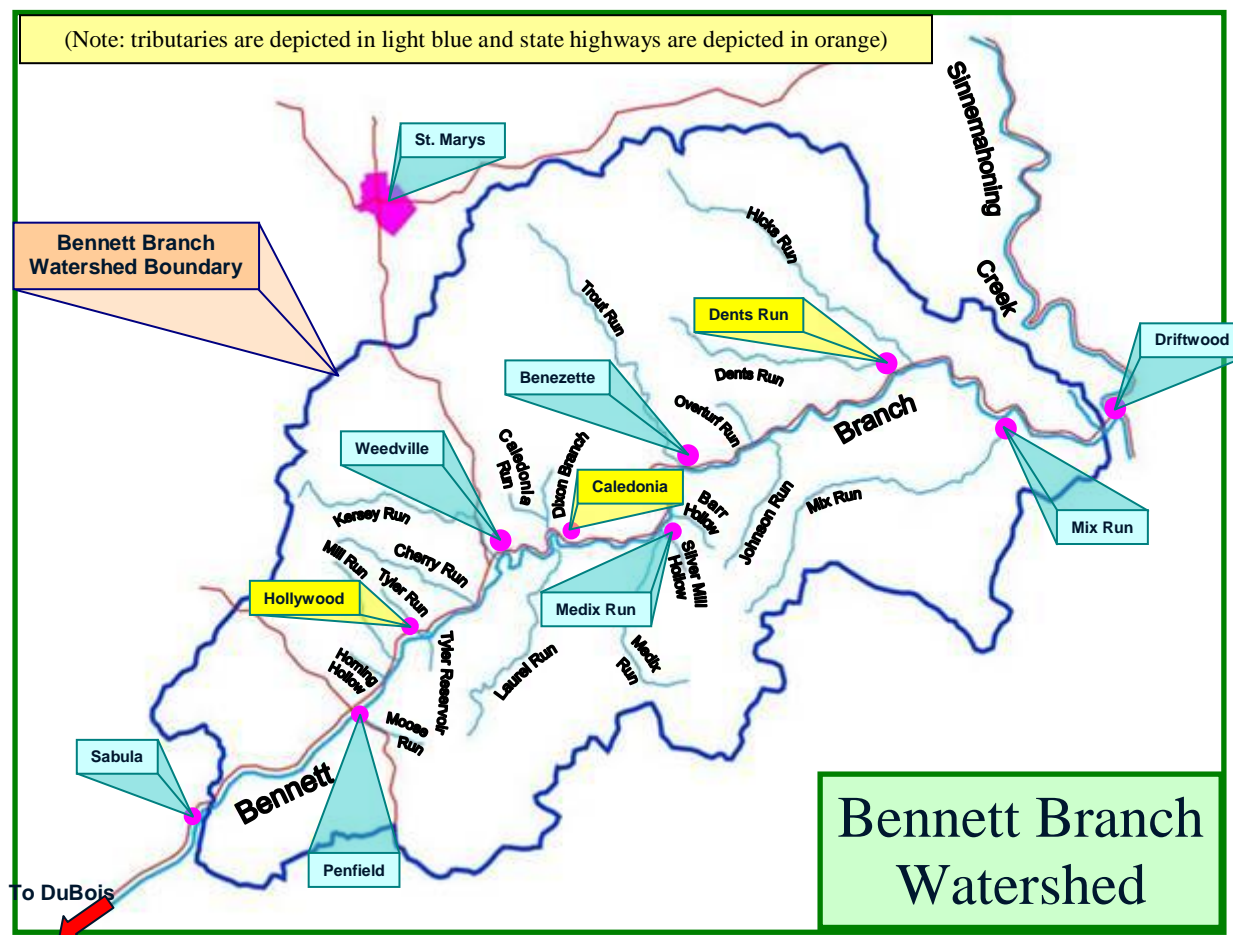


Fig. 2. Villages and major tributaries within the Bennett Branch Watershed. Villages highlighted in yellow are located near tributaries that contribute the majority of the AMD pollution to the Bennett Branch.

The average daily flow at the mouth of the stream near Driftwood is 1,718 million liters per day (454 million gallons per day) or approximately 1,192,405 liters per minute (315,000 gallons per minute). The total length of the main stem of the stream is approximately 61 kilometers (38 miles), and the lower 53 kilometers (33 miles) are severely impacted by acid mine drainage. No

other significant sources of pollution or other impairments to the stream morphology, habitat or hydrology exist within the watershed.

Approximately 70 percent of the land within the watershed is state-owned as either State Forest Lands including portions of Elk, Moshannon and Sproul State Forests or State Game Lands including all or portions of State Game Lands 14, 34, 93, and 311. The Bennett Branch is a tributary to the Susquehanna River and the Chesapeake Bay. Much of Pennsylvania's growing elk herd is also located within the watershed. Finally, the watershed has enormous potential for growth in tourism and outdoor recreation. Every fall, tourists flock to Elk County to view elk and listen to the bulls bugle while enjoying the magnificent fall foliage. Figure 3 shows a large bull elk in the Bennett Branch Watershed, and Figure 4 shows the geographical extents of the PA Wilds recreation area including the public land holdings within the area and the location of the Bennett Branch Watershed.



Fig.3. Large bull elk on Winslow Hill in Benezette Township, Elk County.

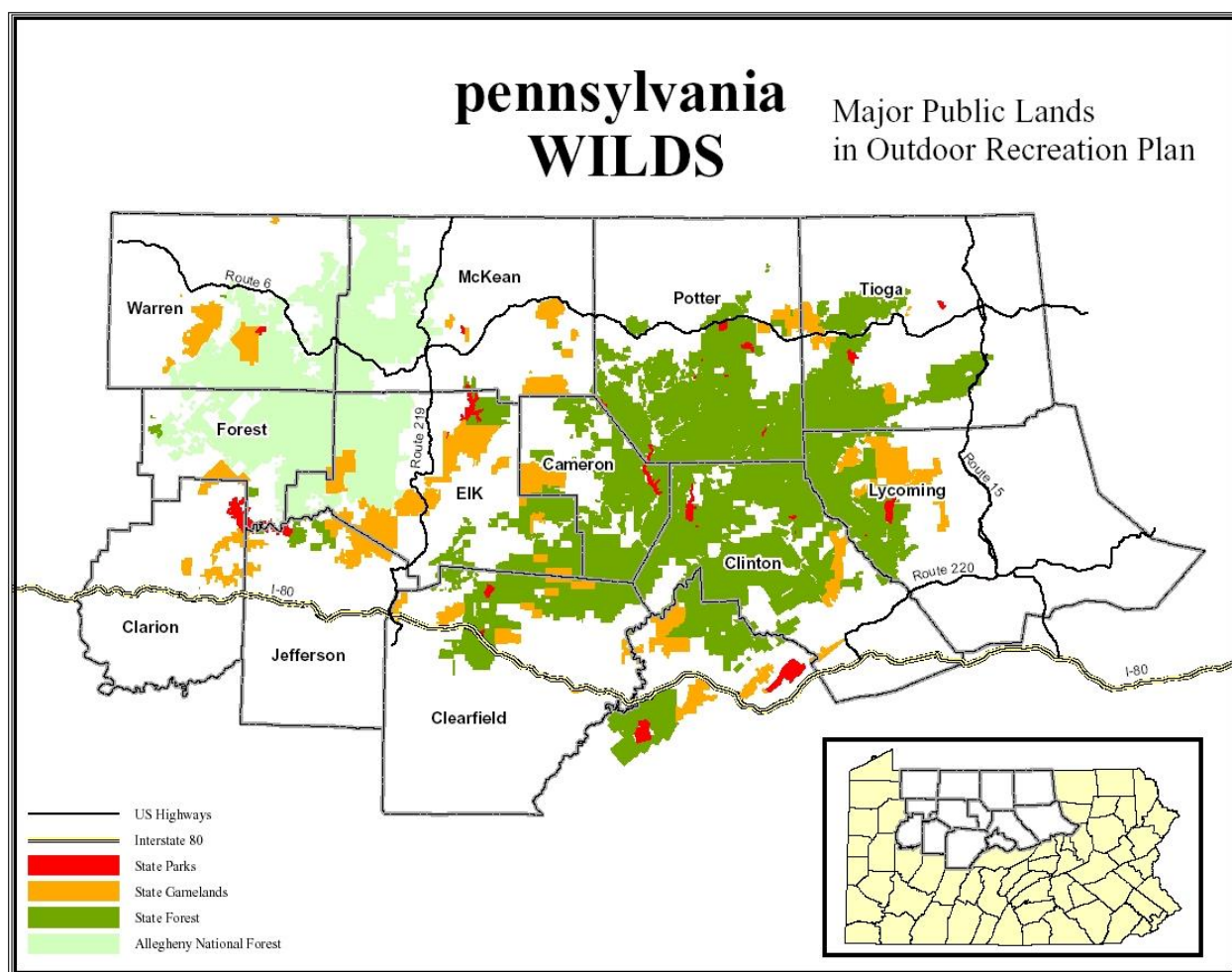


Fig. 4. Map of the PA Wilds recreation area showing the public land holdings and the approximate location of the Bennett Branch Watershed.

Mining History and Geology

Coal mining began in the Bennett Branch Watershed in the middle to late 1800s. By the early 1900s extensive underground mining began and continued into the 1960s. Some limited underground mining continues within the watershed today. Surface or strip-mining began in the 1940s, and also continues to a limited extent today. Most of the underground mining was conducted on the Lower Kittanning Coal Seam, while surface mining has primarily been conducted on the Upper, Middle, and Lower Kittanning as well as the Clarion Coal Seams. All of the aforementioned coal seams are Pennsylvanian in age and belong to the Allegheny Formation. Most of the underground mines were driven up-dip to allow for gravity draining of

any mine water. Many mines, both surface and underground, were abandoned and left unreclaimed.

The main structural geologic feature within the watershed is the Caledonia Syncline. The Bennett Branch flows in a direction more or less parallel to the axis of this syncline, but in an opposite direction to the plunge (NE to SW) of the synclinal axis. Figure 5 is a cross section of the Bennett Branch stream valley near the village of Hollywood. Figure 6 is a profile along the axis of the Caledonia Syncline showing the plunge in the opposite direction of the stream flow. Surface and subsurface drainage is primarily controlled by the geologic structure underlying the watershed. Most of the underground mines operated in the watershed were driven up-dip from the axis of the syncline. The dip of the coal seams averages 5 to 6 percent, but reaches as high as 10 percent.

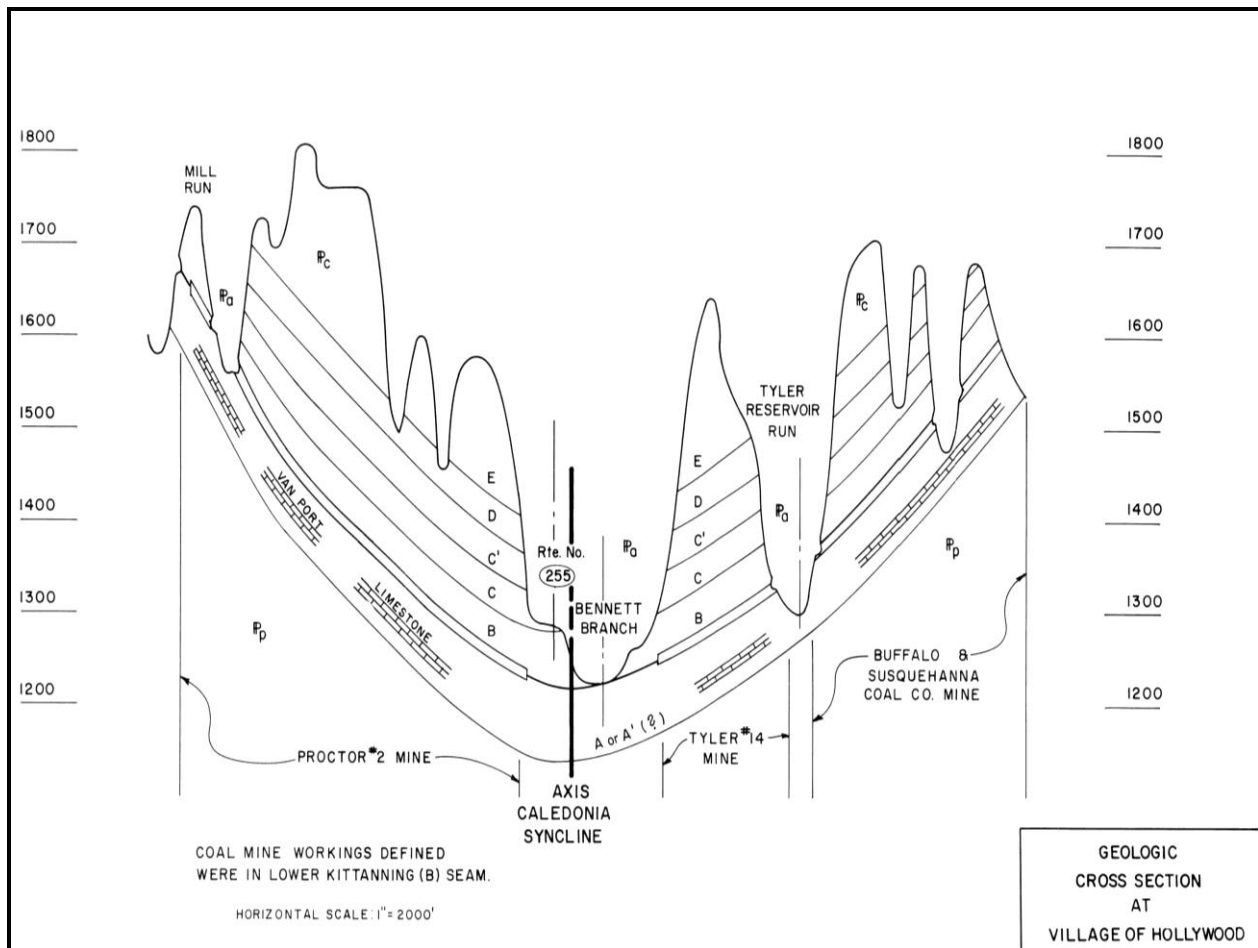


Fig. 5. Cross section across the Bennett Branch stream valley near the village of Hollywood (Source: Berger 1976).

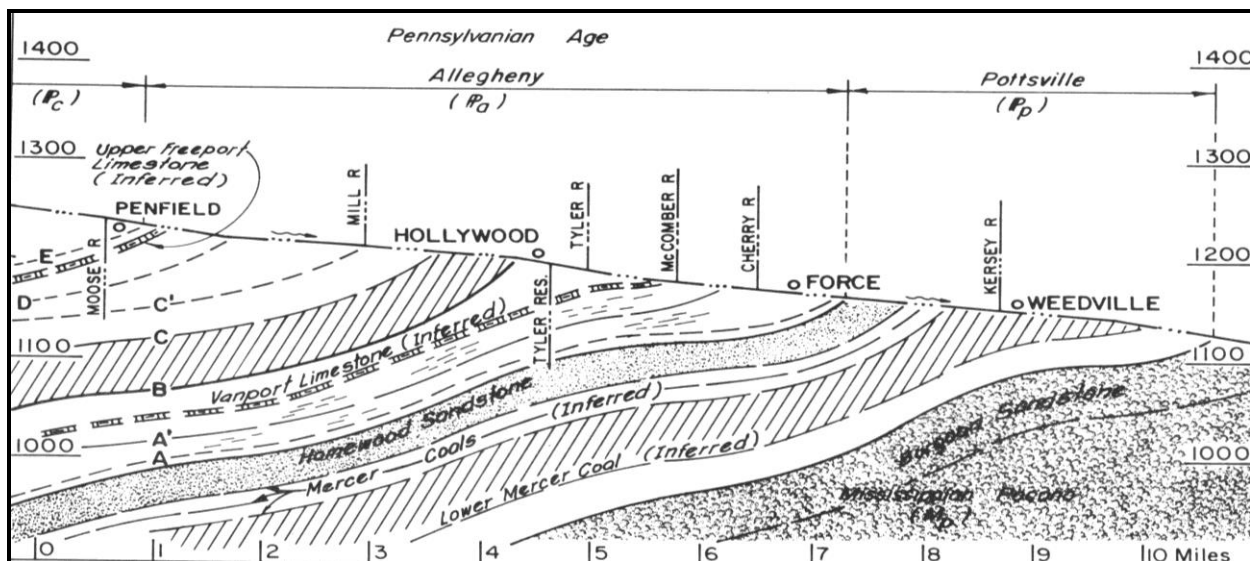


Fig. 6. Profile along the axis of the Caledonia Syncline showing the plunge in the opposite direction of the stream flow (Source: Berger 1976).

Restoration Plan Development

Extensive water sampling and monitoring of mine drainage discharges and of sampling stations along the Bennett Branch and its tributaries have been conducted since 2004. Approximately 150 sample stations were established that have been sampled and monitored at various frequencies since the restoration effort began. In addition, all inventoried AML sites located within the watershed have been catalogued. Figures 7 through 14 show a few of the major mine drainage discharges within the watershed and a few of the gauging stations on the main stem of Bennett Branch.

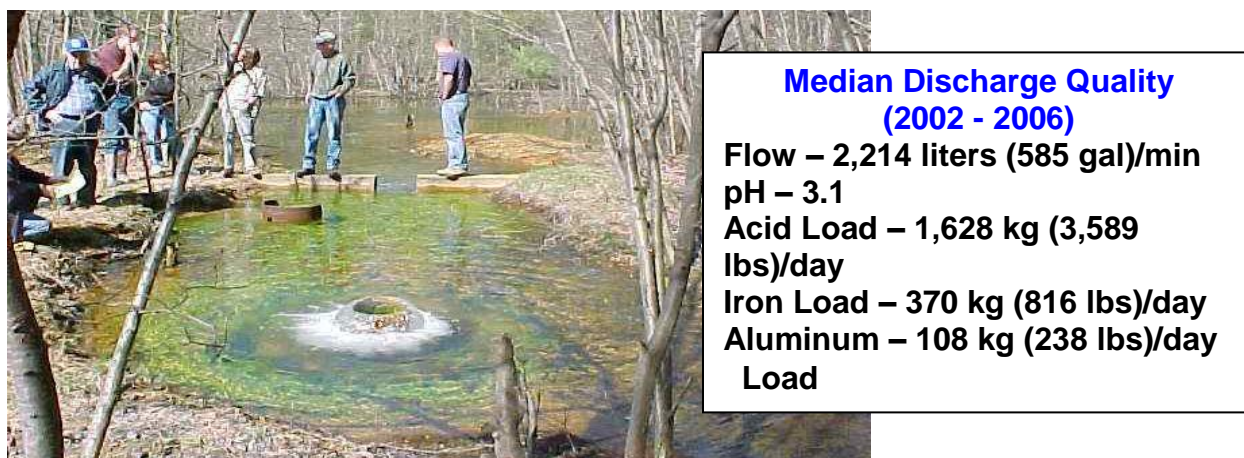


Fig. 7. Mill Run Borehole discharges draining the Proctor No. 2 deep mine in Huston Township, Clearfield County.

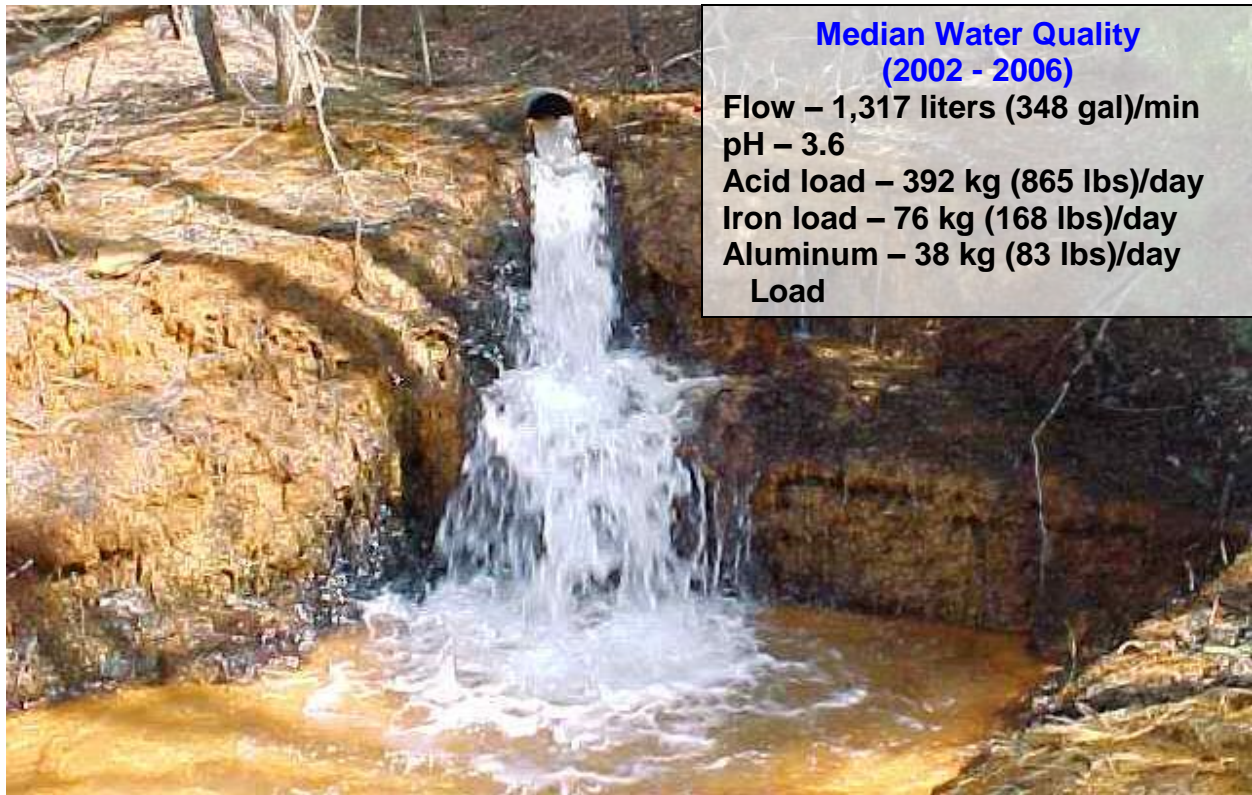


Fig. 8. Deep mine discharge into Fridays Run in the Tyler Run Watershed near the village of Hollywood in Clearfield County.



Fig. 9. Bennett Branch downstream of the confluence with the Mill Run Borehole discharge in Huston Township, Clearfield County.



Fig. 10. Deep mine discharge in the Caledonia Hollow Tributary impacting the mid-Bennett Branch stream valley, Jay Township, Elk County.



Fig. 11. Bennett Branch stream valley near Caledonia in Jay Township, Elk County.



Fig. 12. Deep mine discharge in the Porcupine Hollow Tributary of Dents Run impacting the lower Bennett Branch, Benezette Township, Elk County.



Figure 13. Confluence of Porcupine Run and Dents Run, Benezette Township, Elk County.



Fig. 14. Confluence of the Bennett Branch with the Driftwood Branch to form Sinnemahoning Creek near the village of Driftwood, Gibson Township, Cameron County.

The sampling and monitoring program revealed that the majority of the mine drainage pollution in the watershed was originating from three separate and distinct areas. The headwaters area adjacent to the villages of Hollywood and Tyler contributes 41 percent of the acid load to Bennett Branch on average. Near the middle of the watershed, the Caledonia Run Subbasin contributes 24 percent of the acid load, and in the lower end of the watershed, Dents Run Subbasin contributes 27 percent of the acid load. Table 1 summarizes the percent acid load to the Bennett Branch by tributary. The location of the majority of these tributaries within the watershed is shown on Figure 2.

There are 47 AML problem areas (PAs) located within the watershed. Twenty-two of those PAs contained high-priority (OSM Priority 1 or 2) features with human health and safety hazards that had a total inventoried cost of nearly \$25 million to reclaim. Additional field reconnaissance was completed on those 47 PAs to determine if reclamation could benefit water quality, and based upon those evaluations, 36 project sites in 25 of the 47 PAs were targeted for reclamation.

Table 1. Summary of the Percent Acid Load to Bennett Branch by Tributary.

Bennett Branch Monitoring Summary of the Percent of Acid Load to Bennett Branch by Tributary					
Tributary	Operation Scarlift, 1972- 1976 ^{1,2}	Gannett Fleming, 2003 ³	PA-DEP, July 2004 (High Flow Conditions)	PA-DEP, Oct. 2004 (Low Flow Conditions)	Average of Previous Studies
Dents Run	30.8	34.4	10.4	30.7	26.6
Mill Run	3.9	23.5	29.0	34.0	22.6
Caledonia Run	21.6	16.2	41.5	15.4	23.7
Fridays Run		9.6			2.4
Tyler Reservoir Run	9.3	7.6	8.9	6.1	8.0
Moose Run	4.6			5.7	2.6
Tyler Run	22.9	2.3	1.3	2.2	7.2
Cherry Run	2.8	5.2		2.0	2.5
Tributary across from Force			3.2	1.8	1.2
Baumertown Run	0.2		3.4	1.3	1.6
Wasko Run	0.2	0.9	1.4	0.8	0.8
Browns Run	1.1			0.1	0.3
Tributary near Medix Run				0.1	0.0
Overturf Run	0.1	0.3			0.1
Direct Discharge1 @ Tyler			0.8		0.2
Direct Discharge2 @ Tyler			0.1		0.0
Kersey Run	2.4				0.6
Hollywood Tributaries (Depicted above in pink)	36.3	43.9	40.6	43.1	41.0
Total (Hollywood + Caledonia + Dents)	88.7	94.5	92.5	89.2	91.3

(Sources: ^{1,2} - Berger 1976 and Conable 1971; ³ - Gannett Fleming 2003)

The potential for remining, and/or refuse pile reprocessing was also evaluated. Several exploratory drilling projects were completed in cooperation with various coal companies to assess overburden quality, remaining coal resources, and groundwater conditions. Landowner contacts were made, and the potential for remining is actively being explored and pursued. The overburden analysis was used to determine alkaline addition application rates in accordance with both Pennsylvania and OSM guidelines (Brady et al. 1998). Alkaline addition is necessary to improve water quality for many of the AML sites due to the amount of acid forming materials present in the old spoil piles. Figure 15 shows example of one of the unreclaimed dangerous highwalls located in the Bennett Branch Watershed. Figure 16 shows sulfate salts crystallized on the rocks as a result of the weathering of the acid forming materials within the highwall at an unreclaimed surface mine located in the Bennett Branch Watershed.



Fig. 15. High-priority unreclaimed dangerous highwall located on State Game Lands in the Bennett Branch Watershed.



Fig. 16. Sulfate salts crystallized on the rocks of an unreclaimed dangerous highwall located on State Game Lands No. 311 in the Bennett Branch Watershed.

Restoration Plan Implementation – Current Status

Based on all of the data analysis, the PA-DEP, in cooperation with the other project partners, developed a detailed restoration plan for the Bennett Branch. Thirty-seven projects had been identified in the restoration plan. The headwaters area near Hollywood included a mix of reclamation, remining and the construction of a large centralized treatment plant. The Caledonia Run Subbasin included a mix of reclamation with alkaline addition, remining, and several lime dosers. The Dents Run Subbasin included a mix of reclamation with alkaline addition, remining, passive treatment and the installation of two lime dosers. Beginning in early 2005, the PA-DEP and all of the project partners began implementing the plan. As of the beginning of January 2010, 20 projects had been completed at a total cost in excess of \$19 million. Figures 17 and 18 show an aerial view of an abandoned surface mine project before and after reclamation. Figure 19 shows a completed passive mine drainage treatment system in the Dents Run Tributary. Figures 20 and 21 show a tipping bucket lime doser treating a highly acidic discharge also within the Dents Run Tributary of Bennett Branch. Also as of the beginning of January 2010, an additional five projects were under construction at a cost of just under \$5 million, and four projects were under design at a cost of just under \$18 million. The seven remaining projects were still in planning or under project development. Tables 2 through 5 summarize the status of all of the projects. Once completed, the total cost of restoration for the Bennett Branch Watershed will exceed \$40 million.



Fig. 17. Aerial view of an abandoned surface mine on State Game Lands No. 311 in Benezette Township, Elk County prior to reclamation.



Fig. 18. Aerial view of the same abandoned surface mine on State Game Lands No. 311 in Benezette Township, Elk County, following reclamation.



Fig. 19. Completed passive mine drainage treatment system in the Porcupine Hollow Tributary of Dents Run.



Fig. 20. Lime silos for a tipping bucket lime doser treating another mine discharge in the Porcupine Hollow Tributary of Dents Run.



Figure 21. Tipping bucket mechanism dispensing lime to neutralize the highly acidic discharge.

Table 2. Summary of the completed projects in the Bennett Branch Restoration Project.

Completed Projects - (As of January 1, 2010)				
Problem Area	Watershed Area	Project Cost	Project Description	Funding Agency
0512	Hollywood	\$ 62,196	Water Supply Replacement	DEP/BAMR
0523	Hollywood	\$ 214,188	15.4 ha (38.1 ac) of AML Reclamation	DEP/BAMR
3894	Dents Run	\$ 560,684	5.3 ha (12.6 ac) of AML w/Alk Addition	DEP/BAMR
3895	Dents Run	\$ 391,297	12 ha (29 ac) of AML w/Alk Addition	DEP/BAMR
3898	Dents Run	\$ 1,156,042	21 ha (52 ac) of AML w/Alk Addition	DEP/BAMR
3893-1	Dents Run	\$ 311,000	3.2 ha (8 ac) of AML Reclamation	ACOE
0521	Caledonia	\$ 550,605	7 ha (18 ac) of AML w/Alk Addition	DEP/BAMR
3895-2a	Dents Run	\$ 407,477	Passive AMD Treatment	ACOE
3888-1	Dents Run	\$ 295,543	Passive AMD Treatment	ACOE
1934	Dents Run	\$ 1,300,000	544.3 million kg (600k tons) Limestone	DEP/BAMR
0519	Hollywood	\$ 2,684,487	36 ha (88 ac) of AML w/Alk Addition	DEP/BAMR
0525	Caledonia	\$ 2,644,948	38 ha (94 ac) of AML w/Alk Addition	DEP/BAMR
3890	Dents Run	\$ 829,925	20 ha (50 ac) of AML w/Alk Addition	DEP/BAMR
3893-2a	Dents Run	\$ 515,987	Passive AMD Treatment	ACOE
Dents Run	Dents Run	\$ 3,027,926	Box Cut, Limestone, Lime Dosers	DEP/BAMR
3888-2	Dents Run	\$ 158,133	Passive Treatment Upgrade	ACOE
6955	Hollywood	\$ 2,500,000	CEDTI - Bark Camp Dredge/Ash Project	Industry
3895-2b	Dents Run	\$ 600,000	Passive Treatment Upgrade	ACOE
DMF16	Hollywood	\$ 204,359	Stream Enclosure Removal	DEP/BAMR
3896/3897-1	Dents Run	\$ 1,182,887	16 ha (40 ac) of AML w/Alk Addition	DEP/BAMR
	Total	\$ 19,597,684		

Table 3. Summary of the projects under construction in the Bennett Branch Restoration Project.

Projects under Construction - (As of January 1, 2010)				
Problem Area	Watershed Area	Project Cost	Project Description	Funding Agency
1934	Dents Run	\$ 2,634,860	P&N Remining & Reclamation	Industry
0520	Caledonia	\$ 97,900	Waroquier Caledonia GFCC	Industry
0502/6957	Hollywood	\$ 1,494,383	Mill Run Reclamation w/Amfire	Industry
0504	Hollywood	\$ 597,319	17 ha (43 ac) of AML w/Alk Addition	DEP/BAMR
3896	Dents Run	\$ 47,000	Relocate Doser to Seep 18	BBWA/DEP
	Total	\$ 4,871,432		

Table 4. Summary of the projects under design in the Bennett Branch Restoration Project.

Projects under Design - (As of January 1, 2010)				
Problem Area	Watershed Area	Project Cost	Project Description	Funding Agency
3893-2b	Dents Run	\$ 500,000	Passive AMD Treatment	ACOE (?)
0515	Caledonia	\$ 1,732,000	18 ha (44 ac) of AML w/Alk Addition	DEP/BAMR
1416	Hollywood	\$ 14,250,000	Hollywood Treatment Plant	DEP/BAMR
0514	Hollywood	\$ 1,350,000	~19 ha (46 ac) of AML w/Alk Addition	DEP/BAMR
	Total	\$ 17,879,000		

Table 5. Summary of the projects in planning for the Bennett Branch Restoration Project.

Projects in Planning - (As of January 1, 2010)				
Problem Area	Watershed Area	Project Cost	Project Description	Funding Agency
3897	Dents Run	\$ 300,000	Passive AMD Treatment	ACOE (?)
3896-2	Dents Run	\$ 1,000,000	Passive AMD Treatment	ACOE (?)
0522	Hollywood	\$ 1,272,000	~27 ha (66 ac) of AML w/Alk Addition	DEP/BAMR
0529	Dents Run	\$ 100,000	Passive AMD Treatment	DEP/BAMR
0524	Caledonia	\$ 500,000	~5 ha (12 ac) of AML w/Alk Addition	DEP/BAMR
3888-3	Dents Run	\$ 1,100,000	~13 ha (32 ac) of AML w/Alk Addition	DEP/BAMR
0520	Caledonia	\$ 250,000	Caledonia Hollow Lime Doser(s)	DEP/BAMR
	Total	\$ 4,522,000		

Partnering with the Active Mining Industry to Promote Remining and Reclamation

Approximately 30 refuse piles located throughout the watershed were grab sampled at several points and analyzed for percent ash, Btu value, and percent sulfur. The results were compiled into an excel spreadsheet along with other site-specific data. The final report was made available to coal companies and cogeneration facilities to evaluate the potential for reprocessing each pile as a potential fuel source. Property owners for each were also identified and contacted to determine interest in having these piles reclaimed. Several refuse piles have been reprocessed and reclaimed at no cost to Pennsylvania's AML Program as a result of this effort and several other refuse piles are being considered for reprocessing by local coal companies. Figures 22 and 23 show two of the refuse piles located in the Bennett Branch Watershed.

Contacts with a number of coal companies with various surface or mineral interests in the area were completed, and meetings were held to jointly evaluate remining potential at several AML sites. Opportunities for partnering with the active mining industry are being pursued to maximize reclamation and watershed restoration, and to reduce overall project costs. Figures 24 through 26 show various remining operations currently being conducted within the Bennett Branch Watershed. To date, the active mining industry has completed restoration or reclamation work that totals more than 15 percent of the total estimated cost of implementing the Bennett Branch restoration plan. Additional partnering is expected to increase the contribution of the active mining industry to the restoration effort.



Fig. 22. Refuse pile cast along Tyler Reservoir Run south of the village of Hollywood in Huston Township, Clearfield County.

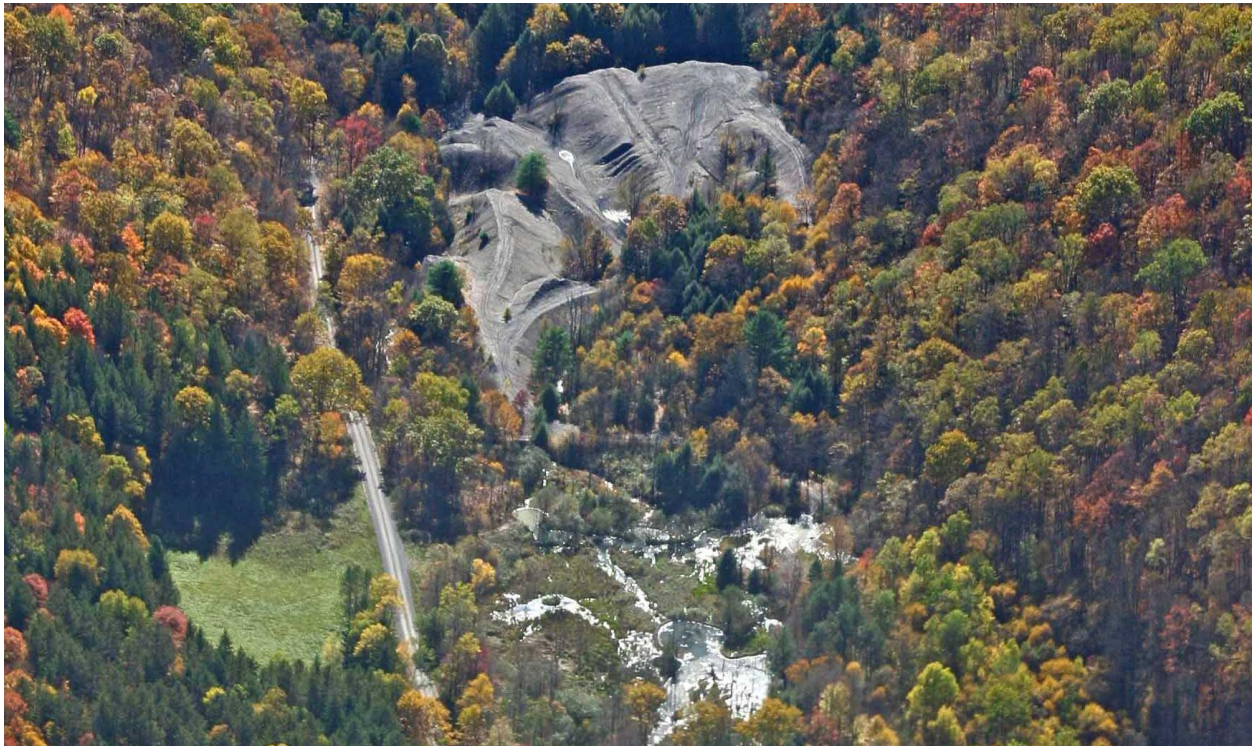


Fig. 23. Refuse pile cast directly into stream valley near the headwaters of Mill Run in Fox Township, Elk County.



Fig. 24. Amfire Mining Company surface mine in the Mill Run Tributary to Bennett Branch in Huston Township, Clearfield County.



Fig. 25. Waroquier Coal Company surface mine in the Caledonia Run Tributary to Bennett Branch in Jay Township, Elk County.



Fig. 26. P&N Coal Company surface mine in the Dents Run Tributary to Bennett Branch in Benezette Township, Elk County.

Bennett Branch Restoration Project Summary

The PA-DEP evaluated mine drainage impacts in the Bennett Branch Watershed in Clearfield, Elk and Cameron Counties. A Bennett Branch team was established to develop a detailed mine drainage abatement plan with the goals of restoring water quality in the main stem of the stream, improving water quality in the mine drainage impacted tributaries to the extent practicable, and maximizing reclamation of AML features within the watershed. The PA-DEP is also actively pursuing partnerships with the active mining industry to evaluate areas with remaining potential that could result in water quality improvements or in the elimination of abandoned mine land features that pose a threat to the health and safety of the general public.

Since beginning efforts to restore the Bennett Branch back in 2004, much has been accomplished, including but not limited to: the restoration of the Dents Run Tributary to net alkaline water quality for the first time in over a century eliminating approximately 27 percent of the acid load to Bennett Branch; restoring over 324 hectares (800 acres) of abandoned surface mine land into rangeland for Pennsylvania's growing elk herd; partnering with the active mining

industry to reclaim several coal refuse piles and several hundred acres of AML at no cost to Pennsylvania's AML Program; and completing development and design of the Hollywood Mine Drainage Treatment Plant that should eliminate an additional 40 percent of the acid load to Bennett Branch. State funding for capital construction of the plant was approved in June 2009. The project was originally advertised for bids on November 6, 2009 and the bid opening was January 28, 2010. Due to an inconsistency in the understanding by the bidders of the specifications for the pumps required for the project, a decision was made reject all bids and re-bid the project. The project was again advertised for bids on March 19, 2010 and the new bid opening is scheduled for April 13, 2010. Construction should begin by mid-summer of 2010. Table 6 summarizes the costs for the entire restoration of the Bennett Branch including the restoration work completed by the Army Corps of Engineers (ACOE) in the Dents Run Tributary and the value of the reclamation being completed by the active mining industry. To date, funding for over \$36 million of the nearly \$45 million has been committed. Figures 27 and 28 show Dents Run just upstream of its confluence with the Bennett Branch before and after restoration.

Table 6. Summary of the Total Costs of the Bennett Branch Restoration Project.

Project Totals - (As of January 1, 2010)			Completed, Under Construction, or Funded	Pending
15.0%	Industry	\$ 6,727,143	\$ 6,727,143	\$???
75.8%	PA-DEP	\$ 33,908,819	\$ 28,157,819	\$ 5,751,000
9.1%	COE	\$ 4,088,140 ¹	\$ 1,788,140	\$ 2,300,000
100.0%	Total	\$ 44,724,102	\$ 36,673,102	\$ 8,051,000
Note - The COE has exhausted the Sec. 206 funds and it is unclear if they will provide any more funding.				

Source: ¹ – U.S. Army Corps of Engineer, 2001



Fig. 27. Dents Run just upstream of its confluence with the Bennett Branch prior to restoration.



Fig. 28. Dents Run just upstream of its confluence with the Bennett Branch following restoration.

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