Water Quality Changes

The tremendous improvements documented in the West Branch Susquehanna River and its tributaries are a result of a combination of factors that primarily include a gradually diminishing amount of pyrite available for oxidation, remining and reclamation activities, better permitting for mining projects, and passive and active treatment projects. In the subsequent sections improvement is allocated to contributing factors where supporting data exist and several specific watershed changes are discussed.

Geochemical Weathering of Pyrite and Remining

Photo: R. Dunlap

KC2O4 mine pool in the Kettle Creek watershed.

A majority of the large-scale improvements observed in the West Branch Susquehanna River and some of its major tributaries can be allocated to the geochemical weathering of pyrite and remining activities over the last 25 years. Pyrite, a mineral found in coal seams and the surrounding rock strata, oxidizes when in the presence of water and oxygen to produce acidity, dissolved iron, and dissolved sulfate. This reaction, the basis for acid mine drainage production, is limited by the amount of and exposure of reactive pyrite on fragmented surfaces. Over time it is expected that the geochemical weathering of pyrite will naturally decrease or demonstrate a natural attenuative-like effect, thereby reducing the amount of acidity produced from abandoned mine sites. However, the exact amount of time required for natural attenuation to substantially reduce the amount of acid mine drainage produced depends on geologic and environmental factors including coal seam, overburden thickness and geochemistry, mine location relative to the regional water table, and initial acidity. While these influencing factors make it such that not all mines will attenuate pyrite and improve over time in homogenous increments, general long-term pyrite attenuation trends have been characterized for both below and above drainage mines (Donovan et al 2003, Mack and Skousen 2008). Of particular significance to the West Branch Susquehanna is research completed by Mack and Skousen (2008) characterizing 44 above-drainage mines, the typical mine-type found in the West Branch Susquehanna watershed, in the Pittsburgh and Upper Freeport coal seams. Despite varying initial concentrations of acidity, the average annual decrease in acidity in these mines over a 38-year period was determined to be a result of natural attenuation at an average rate of 2.1% per year (Mack and Skousen 2008).

Six control tributaries, AMD polluted tributaries located in subwatersheds that are known to have experienced no known treatment and have had no mining activity over the last 25 years (DEP personal communication) were selected to estimate natural attenuation or the rate of pyrite oxidation typical for AMD in the West Branch Susquehanna watershed. These tributaries all enter the West Branch in Clearfield and Centre Counties near the mouth of Moshannon Creek (Figure 2). Initial acidity concentrations as measured by the USGS in 1984 in these tributaries ranged from 40 to 397 mg/L as $CaCO_3$. All six tributaries showed marked decreases (12.5% to 81.3%) in acidity concentrations in 2009 (Figure 13). Rupley Run and UNT 25611 were measured to have the highest initial acidity in 1984. These streams demonstrated the most improvement with reductions in acidity of 81.3 % and 47.4% respectively while Laurel Run, the tributary with the least amount of acidity in 1984 (40 mg/L as $CaCO_3$) demonstrated the lowest percentage (12.5%) of acidity reduction over the 25-year period.

This control data set confirms that the variation of total percent attenuated per stream is dependent both on season and initial concentration. However, the amount attenuated on a per year basis is less influenced by these variables. Evaluation of the acidity attenuated per year by the exponential decay equation $N = N_o e^{kt}$ where N represents the 2009 acidity concentration, N_o the 1984 acidity concentration at 2009 flows based on the slope of the inverse log-linear relationship of decreasing acidity and increasing discharge rate, and t the 25 years spanning the data collections, produced results that ranged from 0.5% to 6.7% per year and an average annual percent attenuation of 3.8% per year. Sulfate, another proxy for pyrite oxidation that is less affected by neutralization processes, demonstrated similar attenuation rates. The range of sulfate attenuated per year ranged from 2.6% to 11.1% and averaged 4.7% per year in the control tribu-

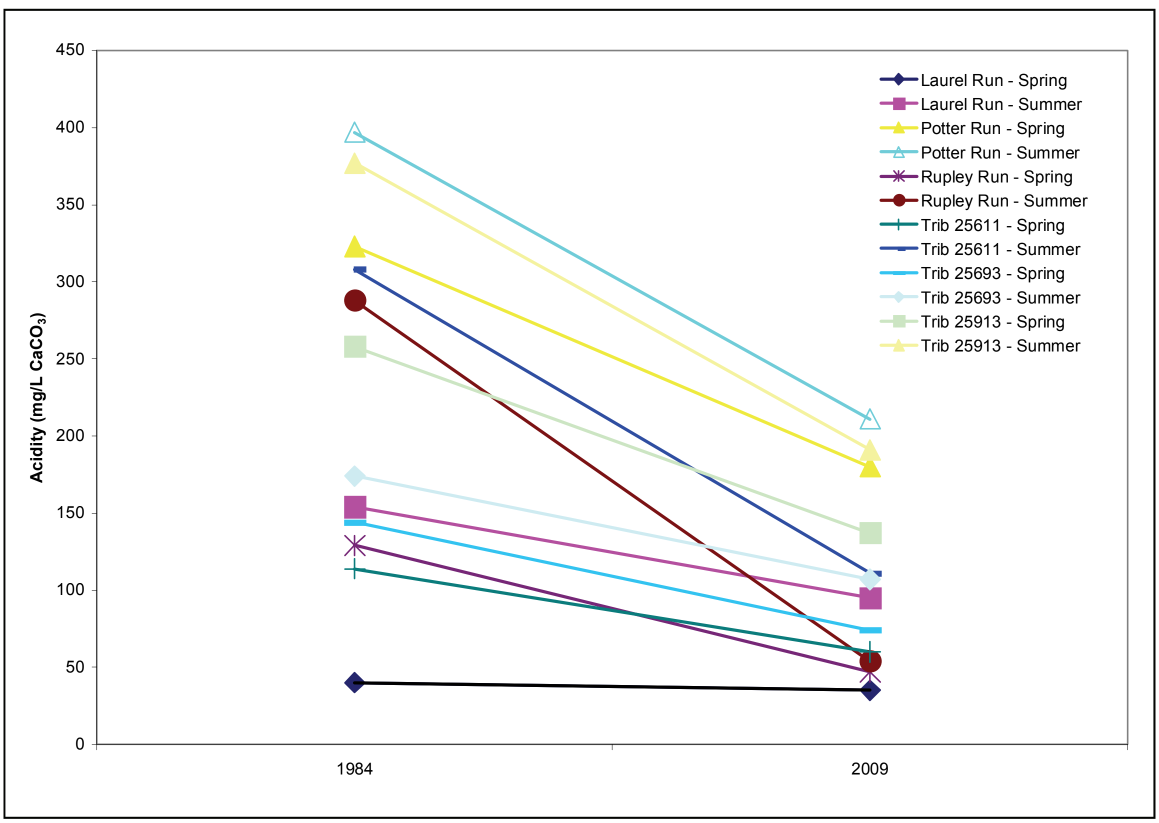


***Figure 13** — Acidity reduction in six control tributaries between 1984 and 2009.*

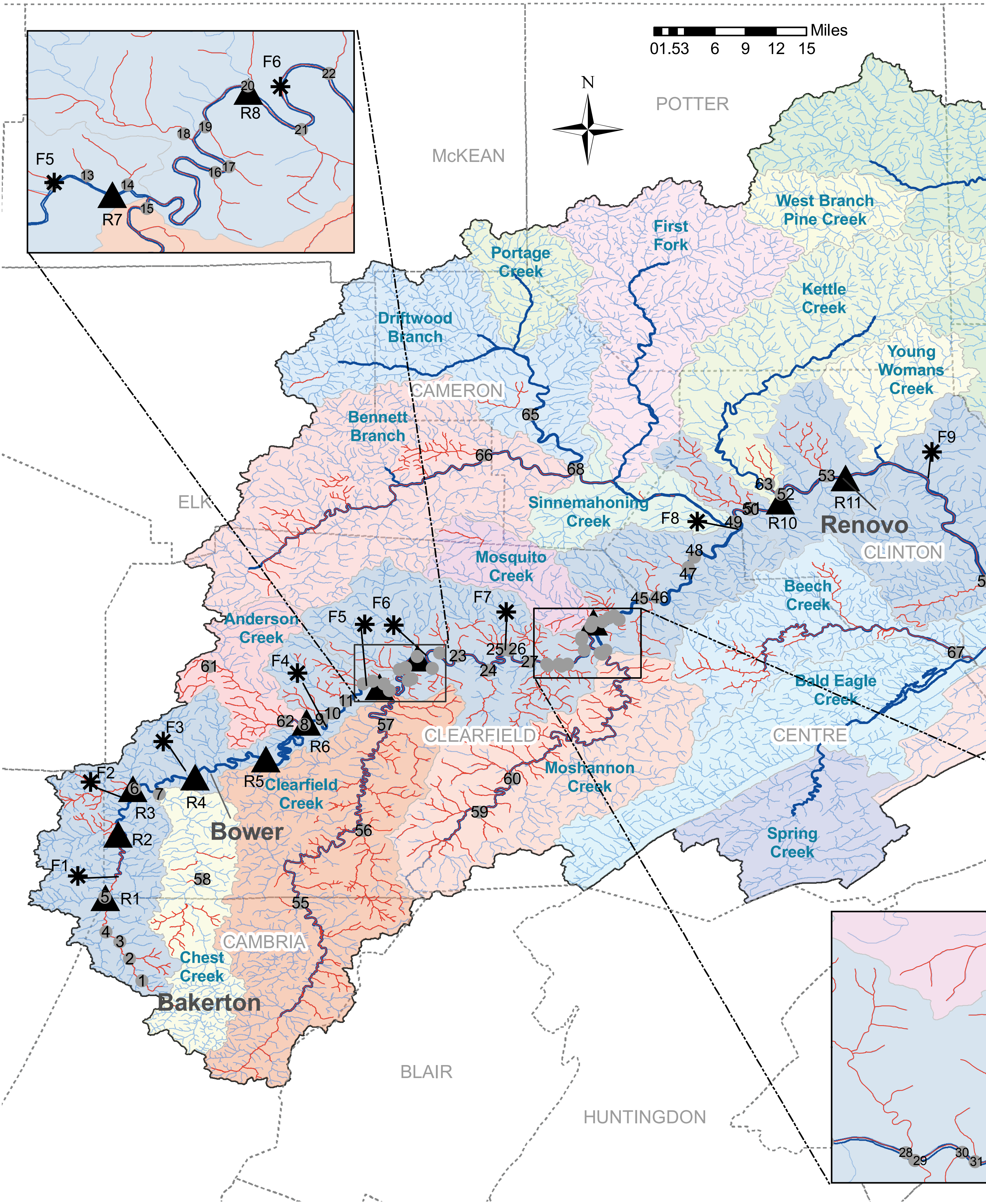
taries using the aforementioned decay equation. These average annual percent attenuation rates are slightly higher than the 2.1% per year reduction observed in other studies (Mack and Skousen 2008). However, because the 1984 concentrations of acidity and sulfate utilized in these calculations were presumed based on the 2009 flows and only two data points, effort was made to avoid over-estimating the effects of natural attenuation. Therefore, a conservative 2.0% exponential reduction rate based on Mack and Skousen (2008) was used to predict attenuation at other sites within the watershed in subsequent analyses.

The Commonwealth has identified remining as a potential reclamation practice since the early 1980s (Office of Resources Management 1983). In fact, according to Pennsylvania's 1983 Abandoned Mine Reclamation Plan, "It shall be the environmental policy of the Commonwealth to strongly encourage additional federal, state, and private activities directed to the abatement of the environment in any areas degraded by previous coal mining activities" and that possible related activities include "tax incentives for remining and restoring previously degraded areas" (Office of Resources Management 1983).

Remining typically involves the surface mining of the remaining economically minable coal reserves found in abandoned surface and underground mines (Smith et al. 2002) and has become routine practice in eastern states (Zipper et al. 2002). In remining operations, the mining operator assumes the liability for reclaiming the mine to current standards. In order to encourage the remining of abandoned mine lands, the operator may obtain a limitation of liability for pre-existing pollutional discharges. That waiver limits liability to increased pollution loading, but requires the implementation of BMPs designed to abate mine drainage pollution. The principal BMPs utilized in remining that affect water quality are surface reclamation and revegetation of abandoned surface mines, alkaline addition, encountering or redistribution of alkaline overburden, daylighting of abandoned underground mines, coal refuse removal, special handling of acid-forming overburden, and special water handling (EPA 2001).

Photo provided by DEP

Remining project near Mill Run in the Bennett Branch watershed.



Miles
0 1.5 3 6 9 12 15
N
POTTER
McKEAN
CAMERON
ELK
CLEARFIELD
CLINTON
CENTRE
CAMBRIA
BLAIR
HUNTINGDON
West Branch Pine Creek
First Fork
Portage Creek
Kettle Creek
Driftwood Branch
Young Womans Creek
Bennett Branch
Sinnemahoning Creek
Mosquito Creek
Beech Creek
Anderson Creek
Bald Eagle Creek
Clearfield Creek
Moshannon Creek
Spring Creek
Chest Creek
Renovo
Bower
Bakerton
R1
R2
R3
R4
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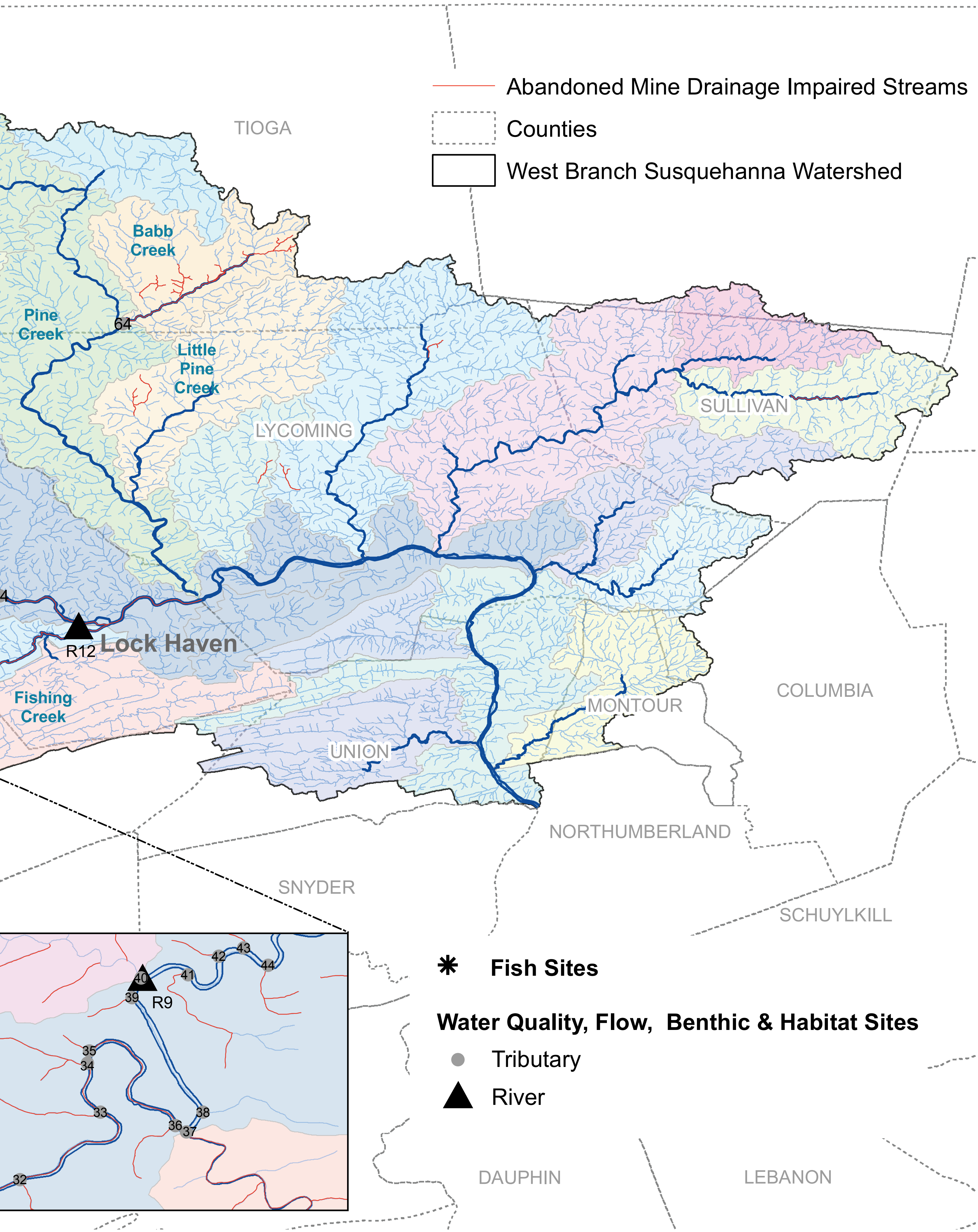
Abandoned Mine Drainage Impaired Streams
Counties
West Branch Susquehanna Watershed
TIOGA
Babb Creek
Pine Creek
64
Little Pine Creek
LYCOMING
SULLIVAN
Lock Haven
R12
Fishing Creek
MONTOUR
COLUMBIA
UNION
NORTHUMBERLAND
SNYDER
SCHUYLKILL
DAUPHIN
LEBANON
42
43
44
41
40
39
R9
35
34
33
38
36
37
32
Fish Sites
Water Quality, Flow, Benthic & Habitat Sites
Tributary
River

Photo: R. Dunlap

Unreclaimed abandoned mine area.

Photo: M. Smith

Reclaimed remining site.

Typically, the water quality of acidic and/or metal-laden discharges is improved after remining because the discharge rate and/or the concentration of the mine drainage is reduced, erosion and sedimentation control problems are abated, and reclamation sites are revegetated (Smith et al. 2002). Frequently, the addition of alkalinity via $CaCO_3$ containing overburden or imported alkaline material causes post-remining water quality to be alkaline rather than acidic.

The DEP has been issuing surface mining permits that authorize remining in areas contributing to pre-existing AMD discharges since 1984. The beneficial effects of remining in abating acid mine drainage are widely documented. Smith et al. (2002) provide quantitative estimates on load reductions from remining based on a study of 112 completed remining operations in Pennsylvania. That study documented an average acid load reduction of 61% when post-remining water quality was compared to the pre-remining baseline. Approximately 38% of the observed reduction was due to reduced flow rates. The other 62% was due to actual changes in chemistry. Those results, combined with the remining acreage in the West Branch Susquehanna watershed and major subbasins, can be used to approximate the amount of pollution load reduction which is expected to have occurred due to remining.

For example, in the 12-year period from 1998 through 2010, permits authorizing the remining of 4,353 total acres of abandoned mine lands with pre-existing AMD discharges (averaging 335 acres/year) were issued by the DEP in the West Branch Susquehanna watershed above Karthaus (Figure 14) (DEP unpublished data). Records detailing acres remined prior to 1998 were not kept. Thus, assuming that the rate of remining has been relatively constant on a yearly basis, there were an estimated 8,375 acres of remining authorized in DEP permits over the 25-year period from 1984 through 2009. In actual practice, not all of what is permitted actually gets mined and reclaimed. A rate of 85% is a close approximation of what ultimately gets reclaimed under a remining permit. As such, the best approximation of the acreage remined in the West Branch watershed upstream of Karthaus during the period from 1984 through 2009 based on current data is 7,119 acres.

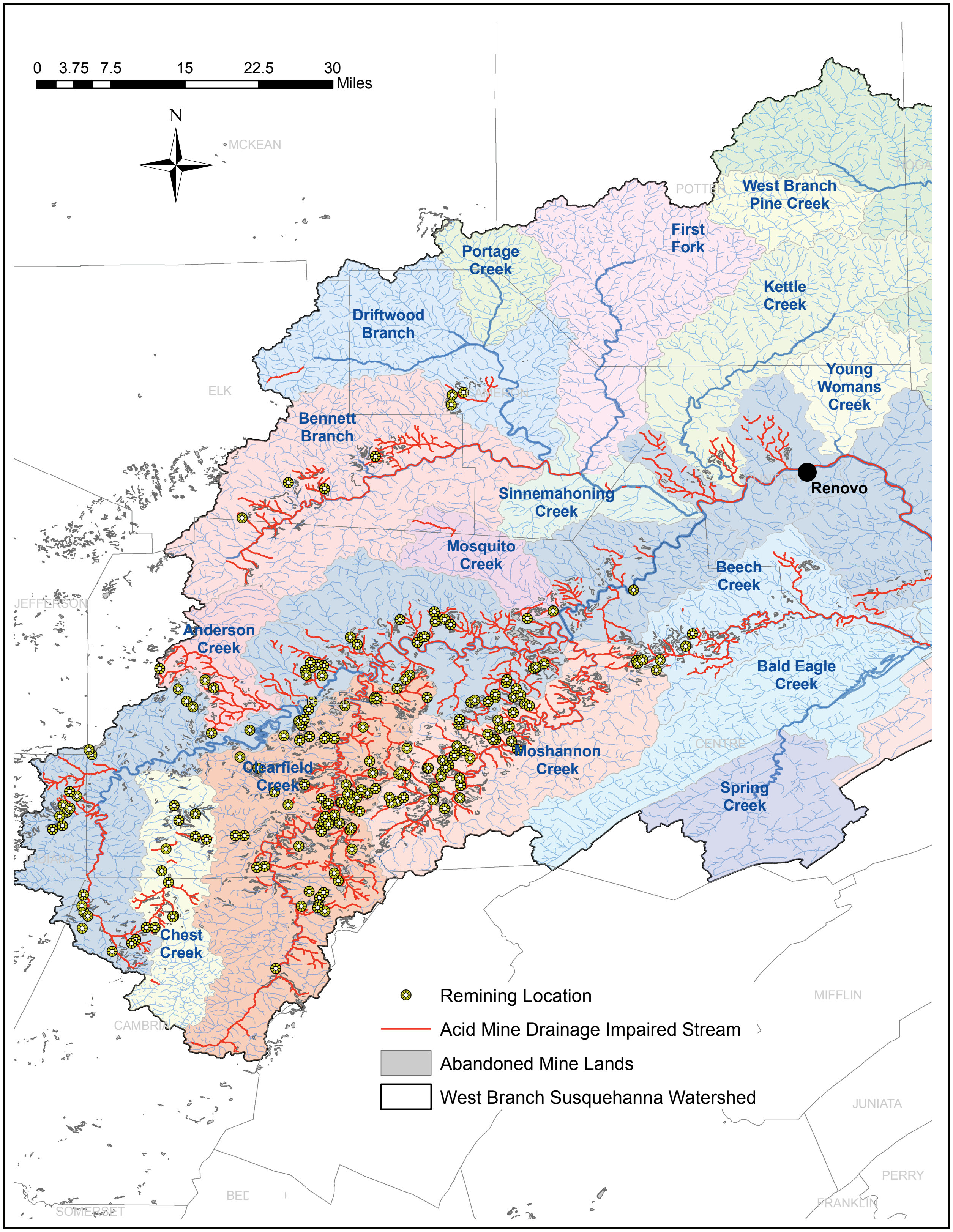

***Figure 14** — Remining locations in the West Branch Susquehanna river watershed between 1998 and 2009.*

The approximate remining acreage, combined with an acid load reduction of 61%, can be used to estimate the portion of the water quality improvement which can be expected to have resulted from remining. The average annual groundwater recharge within the West Branch Susquehanna River basin is 15 inches per year (Taylor et al. 1983). This equates to an average groundwater recharge rate of 0.775 gallons per minute per acre. Lastly, the Smith et al. (2002) remining study identified an average pre-remining acidity concentration of 500 mg/l. Thus the average pre-remining acidity load from the remined acres is approximated to be 33,000 lbs/day. Using the average 61% load reduction in Smith et al. (2002), remining would be expected to reduce acidity loads by approximately 20,000 lbs/day.

By utilizing the above equations paired with the data collected in 1984 and 2009, it is estimated that between 43% and 44% of the acidity load reduction in the river at Karthaus can be allocated to natural attenuation and another 22% and 9% of the reduction to remining activities (Figure 15). Similar allocations were found in the Moshannon Creek watershed where natural attenuation explained between 53% and 56% of the improvements and remining another 4% to 8% .

The reduction residual, or the observed reduction that is not accounted for by natural attenuation or remining, serves as both a check on the reasonableness of the estimated attenuation and remining figures as well as an estimation of other load-influencing factors. These factors include reductions from passive and active treatment of AMD, surface reclamation, coal refuse pile removal, and other alkalinity-generating activities such mining in alkaline rock. Additionally, these factors include potential increasing variables such as the post-1984 production of new sources of acid mine drainage as well as acid precipitation. The residual noted in the West Branch Susquehanna at Karthaus is between 36% and 47% (Figure 15).

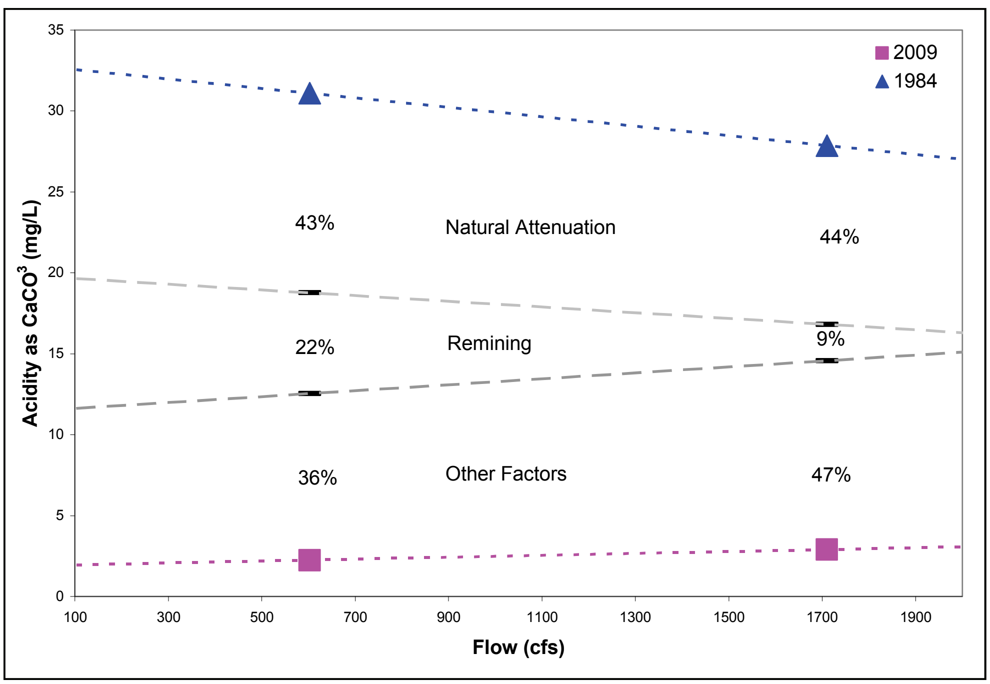

***Figure 15** — Acidity change in the West Branch Susquehanna at Karthaus and allocation of change to natural attenuation, remining, and other factors.*

By applying the expected reductions from natural attenuation and remining to various subwatershed scales the relative importance of the activities responsible for the load reduction residual is highlighted. For instance, residual values of 69% and 74% in the Clearfield Creek watershed suggest that other factors beyond attenuation and remining have provided important contributions to the improved water quality in that area (Figure 16). It is theorized that in this watershed the large amount of active surface mining on previously unmined lands and on unreclaimed lands that did not have pre-existing AMD problems has had a prominent effect on water quality. Mining in this watershed between 1984 and 2009 predominantly occurred in the Middle Kittanning to Upper Freeport coal seams which tend to have increased alkalinity over background conditions and characteristically produce alkaline drainage. As a result, this mining appears to have liberated additional alkalinity which subsequently neutralized some of the acidity in the Clearfield Creek watershed.

Photo: R. Dunlap

Confluence of Little Clearfield Creek and Clearfield Creek.

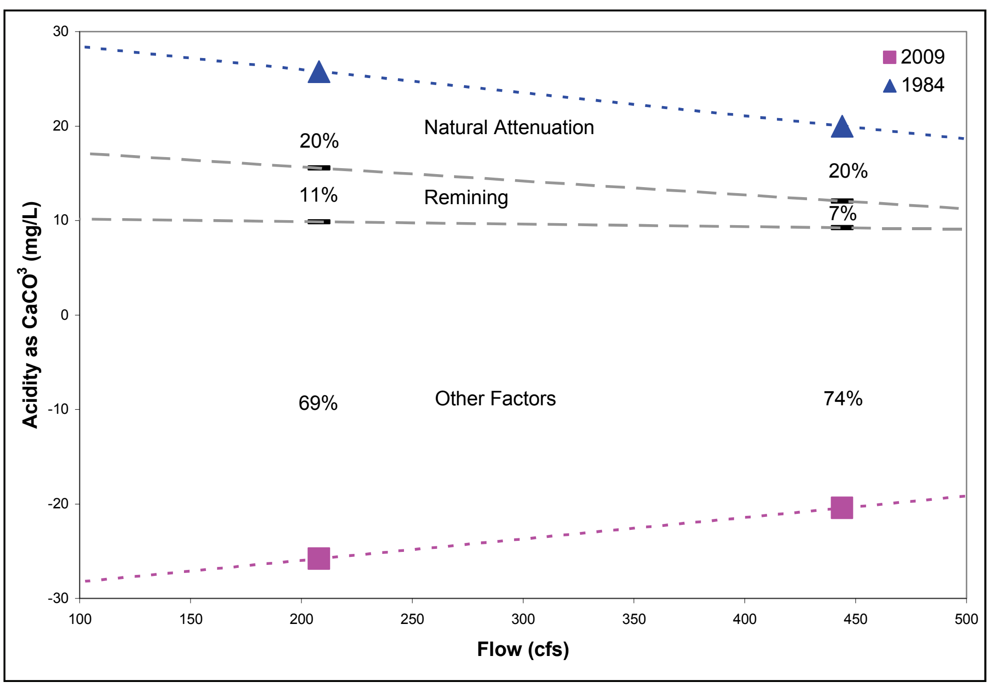

***Figure 16** — Acidity change at the mouth of Clearfield Creek and allocation of change to natural attenuation, remining, and other factors.*

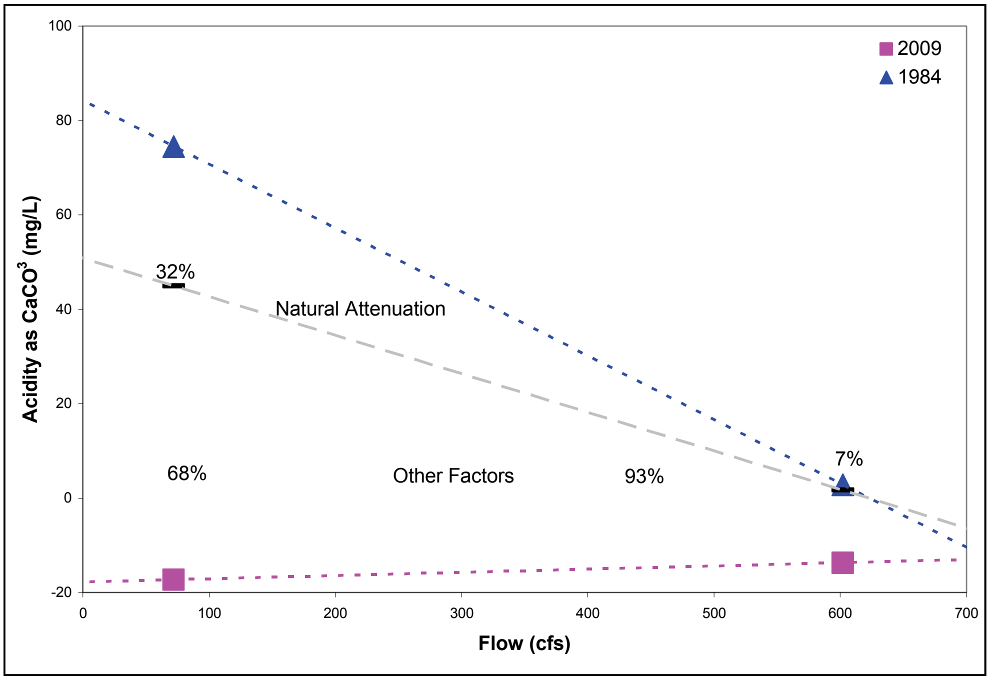

Figure 17 *— Acidity change at the mouth of Kettle Creek and allocation of change to natural attenuation and other factors.*

Photo: R. Wykoff

Deep mine complex in the Kettle Creek watershed.

The application of the expected reductions in watersheds where no remining or active mining activities occurred over the last 25 years can be used to support other known acid-changing events. For example, in the Kettle Creek watershed, large scale surface and deep mining of coal ended before 1984 yet a very high percentage of improvement (68% and 93%) cannot be allocated to natural attenuation (Figure 17). Here it is thought that a mine subsidence event at a deep mine complex on the west side of Kettle Creek played a key role in the acidity reduction noted at the mouth of the watershed. Until at least 1978 the deep mine complex discharged significant amounts of AMD to Kettle Creek. At some point between 1978 and 2002, but likely after 1984, the mine drain became blocked from the subsidence and the discharge flow ceased causing a mine pool to form. As a result, when the mine pool would fill, it would spill out another drain to Kettle Creek, as well as flow out of entries to Milligan Run. The portion of flow discharging to Milligan Run represents a decrease in loading to Kettle Creek. In addition, the formation of the mine pool post-subsidence allowed the mine to store large inputs of water and release them more slowly. This decrease in loading combined with the change in the discharge hydrograph of the mine would have produced a net reduction in pollution loading to Kettle Creek and caused positive changes in water quality.

In other subwatersheds water quality did not improve as much as is predicted from natural attenuation and remining. In these areas the predicted amount of acidity loading reduced from natural attenuation and remining exceeds what was observed, indicating that a load-increasing variable had an effect on overall water quality. Such was the case believed to have also occurred in the Alder Run watershed. While the concentration of acidity in Alder Run did improve based on the data collected in 1984 and 2009, this improvement was less than what was expected to be improved by natural attenuation alone. This lack of improvement is a result of mine drainage creation in the early 1980s.

Photo: A.Brison

Alder Run, Clearfield County.

In 1977, SMCRA regulations were put in place so that pollution would no longer be created by coal mining operations. In addition, Pennsylvania assumed primacy of SMCRA in 1983 and required the prediction of the probable hydrologic consequences of new mining permits and also required a demonstration of no potential pollution (25 Pa. code section 86.37(a)(3)) thereby requiring the mining permit applicant to do the analysis necessary to show that coal could be extracted without resulting in post-mining discharges of acidity or metals. Although these regulations were in place in 1983, it took science nearly a decade to catch up with the law as industry and state regulators learned to use tools such as overburden geochemical analysis to make this determination. Subsequently, in the late 1970s and early 1980s, approximately 20% of mining permits issued resulted in post-mining AMD, oftentimes very severe in quality and difficult or impossible to treat. By 1996, fewer than 1% of new permits resulted in AMD, and those that did were generally mild forms that were readily amenable to passive treatment (Smith et al. 1999).

** Note: So as to appropriately compare the 1984 and 2009 data at the same flows, acidity values were estimated in 1984 at the flow rates measured in 2009 by using the slope of the inverse log-linear relationship of decreasing acidity and increasing discharge rate based on the 1984 data. In addition, because the applicability of the hot-peroxide method of measuring acidity can be erroneous in waters with near-neutral pH and low metal concentrations, calculated net acidity based on metals (Hedin 2004) and reported alkalinity was utilized instead of the reported hot-peroxide acidity in 2009 for Clearfield Creek, Kettle Creek, and the West Branch Susquehanna at Karthaus. Since Alder Run was still severely polluted with AMD in 2009, the reported hot-peroxide acidities were utilized when evaluating why conditions changed in the aforementioned calculations.*

Passive Treatment

Passive treatment abates acid mine drainage via naturally occurring chemical and biological processes that require minimal operation and maintenance. Passive treatment typically utilizes a combination of components such as wetlands, limestone-filled channels or ponds, and ponds containing both limestone and organic compost. This is the most common form of remediation used by watershed groups throughout the Commonwealth, as well as across the West Branch Susquehanna watershed.

According to Datashed, a fully-featured, GIS enabled, Internet database designed to assist in the operation and maintenance of passive treatment systems, there are approximately 300 passive treatment systems in Pennsylvania treating AMD (Datashed 2011). Of these, 167 are characterized by Datashed to remove approximately 3.5 million lbs/year of iron, 200,000 lbs/year of aluminum and manganese, and 23 million lbs/year of acidity from the Commonwealth's waterways (Datashed 2011). In addition, 46 passive treatment systems have been built in the West Branch Susquehanna since the mid-1990s (Figure 18). Data characterizing these systems were not readily available to quantify their effect on the West Branch Susquehanna watershed. However, the many success stories of improved water quality conditions and recovering fisheries that are direct results from passive treatment projects point to the importance of passive treatment in the overall effort to restore the West Branch Susquehanna River and tributary watersheds from AMD pollution.

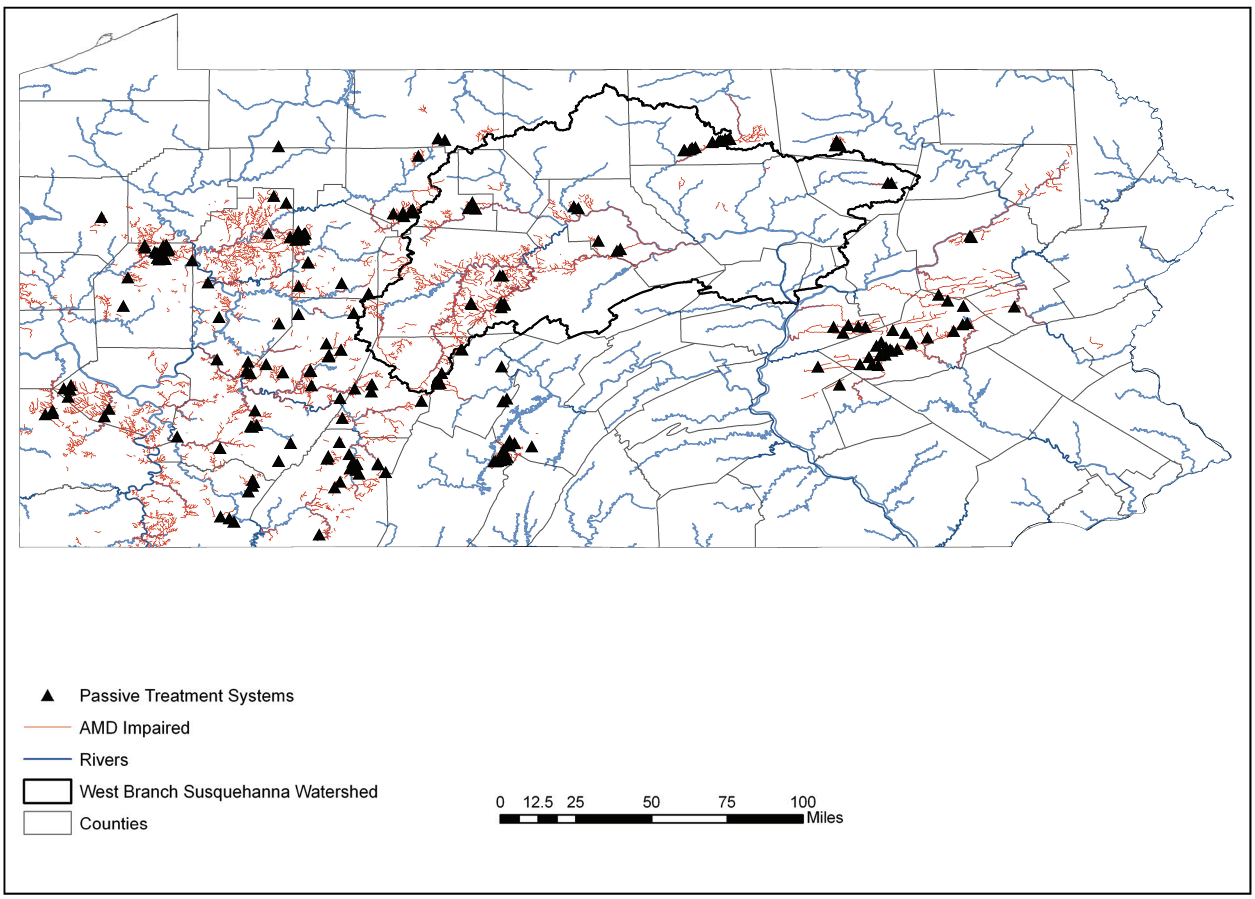

Figure 18 *— Passive treatment systems in Pennsylvania.*

One such example is Middle Branch, a tributary to Twomile Run in the lower Kettle Creek watershed. In 1995 the average acidity at the mouth of Middle Branch was 48 mg/L as $CaCO_3$. Following a rehabilitation to the Middle Branch Passive Treatment System that addressed these AMD discharges to Middle Branch, the average acidity at the mouth was observed to be 4 mg/L (as measured via hot peroxide methods) – a difference of 92% when compared to acidity measured prior to successful passive treatment of the AMD (TU 2010 unpublished data). Without passive treatment this stream would have predictably taken until the year 2111, or 116 years, to achieve the low levels of acidity currently present considering the natural attenuation rate of 2.0% per year discussed in previous sections of the report (Figure 19).

Several existing passive treatment systems in the West Branch Susquehanna watershed have been used Commonwealth-wide as examples of how the science related to the design and construction of this type of treatment is both effective and evolving. In addition to the effectiveness of passive treatment technologies, the Middle Branch Passive Treatment System in the Kettle Creek watershed also serves as a an example of the need for adequate mine drainage characterization for treatment design. This system was initially constructed in 2000 to treat two highly acidic discharges characterized by high metal concentrations. TU in partnership with the Kettle Creek Watershed Association established a monitoring program to evaluate the system's efficacy and documented that the system was declining in treatment performance within one year post-construction. Subsequently, a system "autopsy" was performed and it was determined that during peak flows, the system was being severely overloaded (Hedin Environmental 2007).

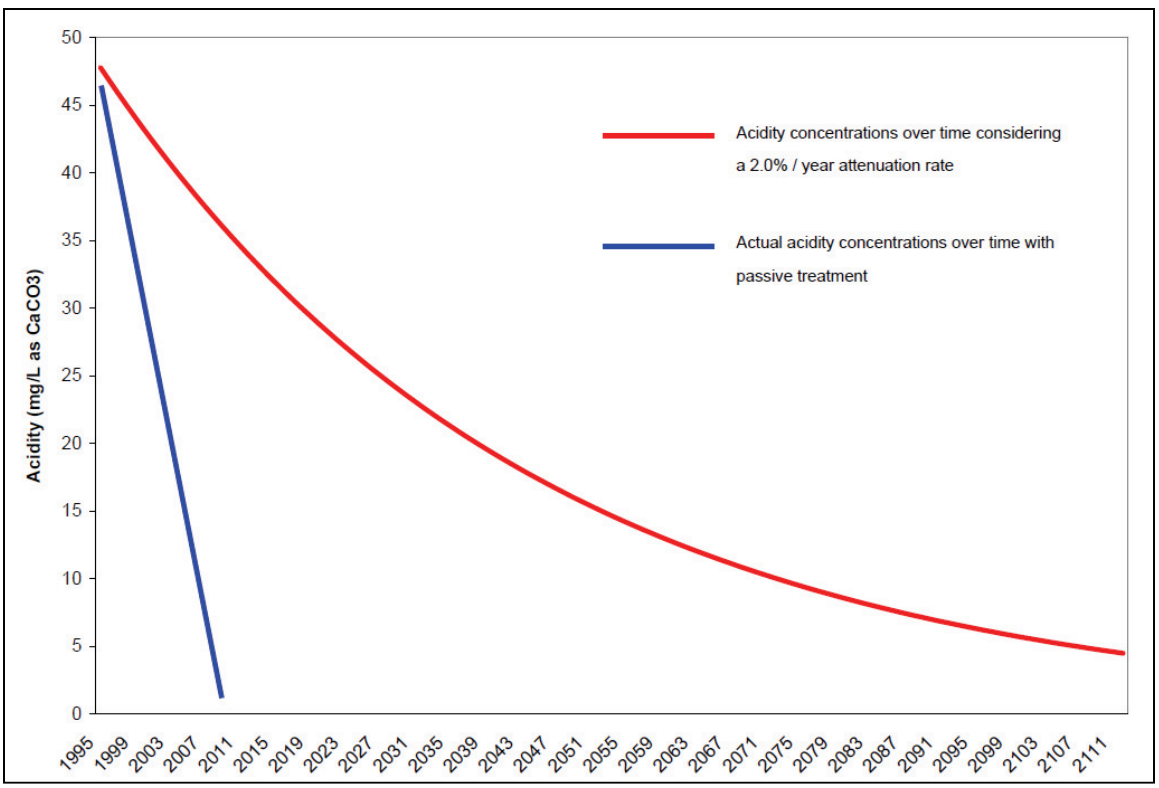

Figure 19 *— Observed acidity concentration reduction in Middle Branch post-passive treatment and expected acidity concentration reduction from natural attenuation.*

Therefore the system was rehabilitated in 2007 and presently, the Middle Branch Passive Treatment System utilizes four vertical flow ponds, an oxidation / settling pond, and an aerobic wetland to treat AMD with a pH of 3.2 to a pH of 7.1 and effectively remove metals. Within one year of the system rehabilitation, mayflies were discovered downstream of the treatment system and within 3 years, brook trout were documented in a stream segment considered lifeless for more than 100 years.

Photo: A. Wolfe

Middle Branch passive treatment system.

The Pine Glenn East Passive Treatment System in the Sterling Run subwatershed in Centre County is another testament to the efficacy of passive treatment in the West Branch Susquehanna watershed. Constructed in 2005, this treatment system consists of a vertical flow limestone bed and a settling pond (Milavec 2010) and treats water consisting of pH between 4.0 and 4.7 (Spotts 2009). The Pine Glenn East Passive Treatment System improved Sterling Run to a point so that just over 12 stream miles were removed from the DEP's impaired streams list and a reproducing brook trout fishery was naturally re-established downstream (Milavec 2010).

While most passive treatment systems are utilized to treat moderate AMD pollution, the breadth of conditions suitable for this type of treatment are becoming clearer as technologies advance. As an example, the Anna S Mine Passive Treatment Complex in the Babb Creek Watershed in Tioga County is the largest passive treatment system in the Commonwealth spanning over 20

Photo: S. Koser

Photo: R. Dunlap

Brook trout found downstream of the Middle Branch passive treatment system.

acres and treating an average of 520 gpm (Hedin et al. 2010). The Anna S mine encompasses an abandoned 840-acre mine with mine drainage characterized by a pH of 2.8 to 3.6 and high metal concentrations. The Babb Creek Watershed Association constructed the Anna S Mine Passive Treatment Complex to treat three discharges from the mine. The passive treatment complex consists of two systems, each containing four parallel vertical flow ponds followed by aerobic wetlands (Hedin et al. 2010). Despite the voluminous flow and severe chemistry discharged into the system, the passive treatment complex has treated the AMD to a neutral pH, effectively removed metals, and discharged measurable alkalinity for six years (Hedin et al. 2010). While this passive treatment complex is only one component to Babb Creek Watershed Association's stream restoration program, it is one of the major factors in the removal of 14 miles of Babb Creek from the Commonwealth's list of impaired waters in 2010.

Photo: W. Beacom

Anna S passive treatment complex in the Babb Creek watershed.

Photo: A. Wolfe

Babb Creek Watershed Association celebrates removal of Babb Creek from the impaired streams list.

Active Treatment

Acid mine drainage abatement via active treatment generally refers to the continuous application of alkaline material to raise the pH of the water, accelerate the rate of chemical oxidation of ferrous iron, and precipitate many of the metals present in solution as hydroxides and carbonates (Johnson and Hallberg 2005). A variety of substances including limestone, hydrated lime, pebble quicklime, soda ash, caustic soda and ammonia are typically used to treat acid mine drainage in this manner.

Photo provided by DEP

Lime dosers in the Dents Run watershed.

Pennsylvania oversees the treatment of 34 active treatment facilities to treat AMD that was created by previous mining operations, but where the mining operator is no longer in existence and 117 facilities on permitted mining sites (DEP personal communication). In addition, several high-priority but pre-SMCRA active treatment operations are maintained by BAMR using abandoned mine restoration funds, also known as the Title IV Acid Mine Drainage Set-Aside Funds, provided through a per-ton fee on coal.

Compared to passive treatment technologies, fewer active treatment systems have been utilized by watershed groups in the West Branch Susquehanna watershed to treat AMD owing to the high cost of alkaline material and continuous operation and maintenance needs. However, there are examples of active treatment system presently in operation in the West Branch Susquehanna watershed in which watershed groups play an active role. In addition, the DEP has several additional active treatment systems either in the planning or construction phase.

The Babb Creek Watershed Association has successfully operated the Antrim Number One Mine Treatment Plant in the Babb Creek watershed for more than 15 years under an agreement with the DEP. This system is cited to be responsible for abating 50% of the pollution in Wilson Creek, a tributary to Babb Creek in the Pine Creek drainage in Tioga County (Barr 2004). The treatment system treats two abandoned mine discharges: one characterized by an average flow of 2,000 gpm and a pH of 3.14 and the other characterized by an average flow of 119 gpm and a pH of 2.99. The polluted water is treated with lime kiln byproduct slurry and the precipitated metals and limestone grit are settled in a clarifier before the resulting effluent ranging in pH from 8.0 to 10.0 is discharged into the receiving stream (Bill Beacom and Mike Smith, personal communication). This treatment system was put into operation in late 1991 and is managed by the Antrim Treatment Trust, primarily with funds established under an agreement with the PA DEP when Antrim Mining Company went out of business. As corroboratory proof of the importance of this active treatment system, within two years after the plant became operational, mayfly hatches were noted in Pine Creek, downstream of the confluence with Babb Creek, where none existed previously (Barr 2004).

Another example of active treatment of AMD in the West Branch Susquehanna watershed is the "Swedish Tipping Buckets" in the Dents Run and Bear Run watersheds in Elk and Cambria Counties. In contrast to the Antrim Number One Mine Treatment Plant, which utilizes electricity, these automatic tipping bucket-type lime dosers add pulverized limestone using the inertia of the water being treated and subsequently require no external power (Cavazza and Smoyer 2008). The dosers in the Dents Run watershed are located on a discharge known to contribute 40% of the total acid load in the Dents Run watershed and were installed in 2008 by BAMR and the Bennett Branch Watershed Association.

Photo provided by DEP

"Swedish Tipping Bucket" in the Dents Run watershed.

The first Bear Run lime doser was placed online in April 2011 to treat the discharge originating from the Banks #2 Mine, a high acidity and aluminum concentrated discharge. Success was immediate as effluent water quality to the South Branch of Bear Run was documented at pH greater than 7.0 with low metal concentrations. This success was also realized without the current use of a sedimentation pond. However, a future sedimentation pond may be built for sludge disposal. The two other lime dosers that will be placed on mine discharges are scheduled for fall 2011 installation. Those dosers will restore the final AMD impacted tributary to the South Branch of Bear Run and may be the final project needed for a near restored Bear Run watershed.

Three additional active treatment systems are in the process of being constructed to treat AMD in the West Branch Susquehanna watershed. The Hollywood plant will be located in Clearfield County near the villages of Hollywood and Tyler and is expected to reduce approximately 41% of the acid load to 33 miles of impacted waters in the Bennett Branch of the Sinnemahoning Creek watershed. Currently, AMD emanates from over 20 individual mine openings from four different underground mine complexes near the plant's proposed location. BAMR intends to collect these discharges via more than 18,000 feet of gravity sewer and numerous wet mine seals and convey them to a centralized location in Hollywood where they will be collectively treated with two ferrous oxidation reactors, a clarifier, two sludge conditioning reactors, and a 4.5 acre polishing pond (Milavec 2010).

Photo: T. Clark

Active treatment in the Bear Run watershed.

In addition, BAMR has entered into an agreement with the SRBC to provide 15.7 million gallons per day of treated AMD to the West Branch Susquehanna River via two active treatment systems to mitigate for agricultural consumptive use under low-flow stream conditions. The Lancashire No. 15 plant will treat a discharge that emanates from a 7,100 acre mine complex which naturally drains to the West Branch Susquehanna River watershed (DEP 2009). Despite the geographic origin of the waters in the mine complex, the discharge has been received into Blacklick Creek in the Ohio River Basin since approximately 1970 (SRBC 2009). BAMR has relocated the discharge back to its original receiving water and will be treating it at the Lancashire No. 15 active treatment plant (Milavec 2010). The active treatment facility consists of an equalization basin, lime storage and supply system, clarifiers, and settling ponds and has the ability to treat up to 10 million gallons per day of AMD and is expected to improve the water quality in at least 35 miles of the West Branch Susquehanna River.

Photo: R. Dunlap

Future Hollywood treatment facility location.

A second AMD treatment facility, currently in the pre-design phase, is being proposed for Clearfield Creek to provide 5.7 million gallons per day of treated AMD water for low-flow stream conditions. Construction and operation of the treatment plant in the headwaters of Clearfield Creek, near Cresson Borough, is expected to restore water quality in the main stem of Clearfield Creek to a level that will support a viable fishery from the headwaters downstream to the confluence with Brubaker Run. This facility will also collect and treat the most significant source of mine drainage to Sugar Run, a tributary of the Juniata River, thereby allowing for biological restoration with the completion of other priority projects within the Sugar Run restoration plan.

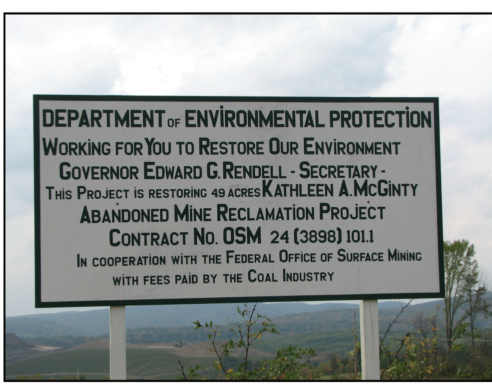

Photo: R. Dunlap

Photo: R. Dunlap

Abandoned mine reclamation project in the Bennett Branch watershed.

Coal Refuse Pile Removal and Surface Reclamation

Other methods commonly used to abate acid and metal loading resulting from AMD include surface reclamation and coal refuse pile removal. Coal refuse, or coal with high ash content and minimal heating value, was historically separated from the usable extractions and left in piles commonly referred to as "boney" or "gob"(garbage of bituminous) piles in the bituminous region of Pennsylvania (EPA 2008). When exposed to the elements, these coal refuse piles have the ability to generate enormous amounts of acid loading as documented in the 1972 Scarlift report for the West Branch Susquehanna River. As such, removal of these piles is a long-term, permanent solution to the generation of AMD. In the early 1970s there were 12 coal refuse piles each containing more than 100,000 cubic yards of refuse between the West Branch Susquehanna headwaters in Barnesboro and Cherry Tree. At that time, it was thought that these refuse piles accounted for 70% of the acid in the uppermost reaches of the West Branch (Commonwealth of Pennsylvania 1972).

The Barnes-Watkins coal refuse pile project is an example of the successes that can be realized by removing these refuse piles. The Barnes-Watkins coal refuse pile contained 1.3 million tons of refuse coal and covered an area of approximately 18 acres (Cambria County Conservation and Recreation Authority 2011). This refuse pile, located on the river, not only degraded water quality but also degraded local air quality as it burned for decades (Cambria County Conservation and Recreation Authority 2011).

Photo provided by DEP

Former Barnes Watkins coal pile.

Photo: R. Dunlap

Present-day site of former Barnes Watkins coal pile.

The Cambria County Conservation and Recreation Authority removed this coal refuse pile with a $4.4 million pass-through grant from BAMR. The coal was reprocessed and either utilized at a local co-generation power plant or deposited in a permitted disposal site (Milavec 2010). Surveys of benthic macroinvertebrates in the West Branch Susquehanna within one year of post-pile removal indicated an increased aquatic life population and young-of-the-year brown trout were found within two years in a section of the river assumed dead for decades (Milavec 2010; Commonwealth of Pennsylvania 1972).


Photo: A. Wolfe

Twomile Run surface reclamation site before reclamation.

Another simple and effective method to reduce mine drainage pollution is through reclamation of abandoned mine lands. Lands with unregraded mine spoil and/or sparse vegetation promote infiltration of precipitation and reduced evapotranspiration. In mine land environments these characteristics are associated with mine drainage production. Abatement, in many cases, includes recontouring of the surface to promote positive drainage, augmentation of the surface with alkaline material and topsoil substitutes to encourage vegetation growth, and planting of vegetation.


Photo: A. Wolfe

Twomile Run surface reclamation area after reclamation.

TU's Twomile Run surface reclamation project in the Kettle Creek watershed is a good example of this type of remediation. This project included the recontouring of 57-acres of abandoned surface mine to promote surface runoff of clean water from precipitation and addition of an alkaline byproduct to promote the growth of an elk food seed mix. The resulting new vegetation also allowed precipitation to more readily leave the site through evaportranspiration and inhibited the precipitation from infiltrating into the coal spoil and creating acidity. The Twomile Run surface reclamation project successfully reduced flow, acidity, and metal loadings to Twomile Run by 30-50% (TU 2010).

Prevention of Future Discharges

As discussed previously, Pennsylvania assumed primacy for the federal SMCRA in 1983. Despite the fact that it took several years for mining operations to consistently result in suitable post-mining water quality, the results of SMCRA have been remarkable. In the late 1970s and early 1980s, approximately 20% of mining permits issued resulted in post-mining acid mine drainage, oftentimes very severe in quality and difficult or impossible to treat. By 1996, fewer than 1% of new permits resulted in acid mine drainage, and those that did generally produced very mild mine drainage that is readily amenable to passive treatment (DEP 1999). This had the important effect, since around 1990, of largely preventing additional inputs of mine drainage into the West Branch, setting the stage for its future recovery.

Comparable to the rest of the state, surface coal mining has experienced a slow but steady downward trend within the West Branch Susquehanna watershed but continues to be a significant activity. By the early 1980s underground mining within the West Branch was far less extensive than surface mining. Total annual coal production in 1984 was approximately 14.5 million tons. It slowly declined over the next 25 years to an annual production of approximately 5 million tons (DEP personal communication). Notably, even though more than 190 million tons of coal had been extracted (an average of 7.5 million tons per year) (Figure 20) from within the West Branch watershed by the time of this study, water quality continued to improve rather than further deteriorate.

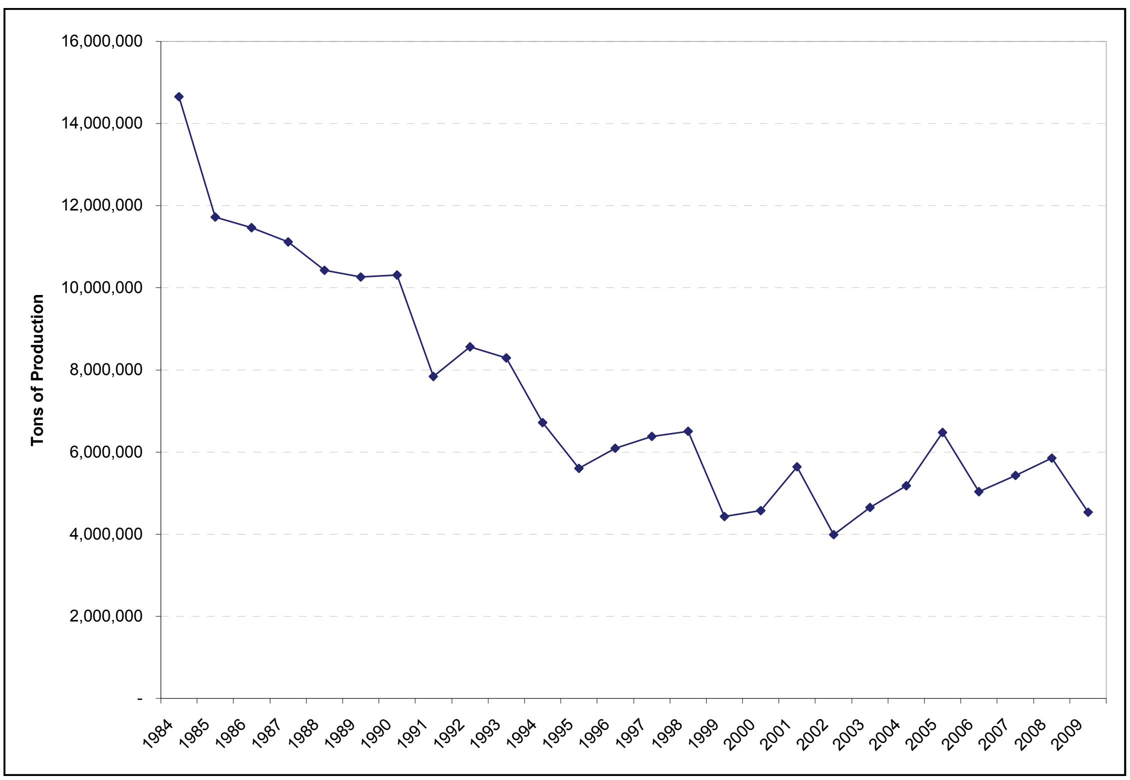

Figure 20 *— Estimated coal production in the West Branch Susquehanna watershed.*