Susquehanna Subbasin's AMD problems. Accordingly, SRBC took those factors into account and developed the remediation strategy as a guide to help resource agencies and organizations achieve comprehensive, region-wide environmental results over the long term.

SRBC developed the strategy using pre-existing (historical) data and information compiled from a wide range of sources to characterize existing conditions in the West Branch Susquehanna Subbasin. From the outset, the purpose of this strategy was to avoid duplicating the efforts of other agencies and organizations in their problem-identification and problem-prioritization initiatives. Instead, the goal was to help identify overlapping goals and opportunities for remediation efforts. To maximize resources, SRBC coordinated strategy efforts while developing a Total Maximum Daily Load (TMDL) assessment for West Branch Susquehanna River AMD impairments.

Scope of the West Branch Susquehanna Subbasin AMD Remediation Strategy

The strategy focuses on water quality and targets opportunities for improving existing conditions. At the outset, SRBC divided the scope of work into the following three major categories to ensure an effective and efficient process:

Formulate Scope of Work -

SRBC was to develop the Scope of Work based on input from TU, PADEP, PADCNR, Task Force, and West Branch Susquehanna Restoration Coalition (Coalition). Information was gathered through meetings with agency and TU technical staff and citizen representatives and SRBC used the input to develop a database, model, and prioritization scheme. SRBC assisted with the coordination and planning process with respect to acquiring Task Force input, either as a group or with separate meetings of individual entities. At a minimum, SRBC met quarterly with Task Force members. In addition, SRBC promoted Task Force goals and encouraged additional partnerships with other relevant entities throughout the process of developing the West Branch Susquehanna Subbasin AMD Remediation Strategy.

Inventory and Analyze Water Quality Data -

SRBC was to compile pre-existing information related to water quality using both instream data and AMD discharge data. PADEP BAMR and District Mining Operations were the two primary sources of information; however, other relevant datasets were incorporated as certain data standards were met. SRBC designed and maintained the database, based on input received from Task Force members. The database contains other subbasin information important to the project, such as extent of active and abandoned mining areas, facility contact information, and information on the receiving waters. SRBC used all the information gathered for the project to formulate options when developing the model.

Develop a Database, Model, and Final Report -

SRBC was to develop an integrated database and model that applies the compiled information to determine existing water quality conditions. Depending on scale considerations, instream and discharge water quality conditions were to be characterized according to severity and extent of influence. The final model has the capability to simulate changes to water quality conditions given a select number of potential water quality improvement options. Input for those options was to be acquired from Task Force members. In addition, SRBC was responsible for developing a process to maintain and update the database and model as conditions change in the watershed.

SRBC participated in several meetings with stakeholders to gather the information used to develop the database and model. More than 20 organizations, representing government, industry, and citizen groups, contributed data for the strategy.

S. Buda

Winter in the West Branch.

■ DESCRIPTION OF THE WEST BRANCH SUSQUEHANNA SUBBASIN

The West Branch Susquehanna Subbasin drains 6,978 square miles of all or portions of 22 counties: Blair, Bradford, Cambria, Cameron, Centre, Clearfield, Clinton, Columbia, Elk, Indiana, Jefferson, Huntingdon, Lycoming, McKean, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, Union, and Wyoming Counties. The larger developed areas include Bellefonte, Clearfield, Lewisburg, Lock Haven, Montoursville, Renovo, State College, Wellsboro, and Williamsport.

The West Branch Susquehanna Subbasin contains 17 major watersheds. Listed in order from headwaters to the confluence with the Susquehanna River, they include Chest Creek, Anderson Creek, Clearfield Creek, Moshannon Creek, Mosquito Creek, Sinnemahoning Creek, Kettle Creek, Young Woman's Creek, Bald Eagle Creek, Pine Creek, Larry's Creek, Lycoming Creek, Loyalsock Creek, Muncy Creek, White Deer Hole Creek, Buffalo Creek, and Chillisquaque Creek.

The subbasin is dominated by forested land (about 83 percent or ~5,800 square miles) (Figure 3). Agriculture accounts for about 10 percent (~700 square miles) of the subbasin. The remaining seven percent (~500 square miles) of land use is developed and disturbed lands, where most of the abandoned mine land (AML) impacts exist. Land use is primarily rural, containing more than 1.4 million acres

Appalachian Regional Reforestation Initiative (ARRI)

ARRI is a coalition of groups dedicated to restoring productive forests on coal mined lands in the Eastern United States. ARRI partners pledge to promote the three goals of the initiative: (1) planting more high-value hardwood trees on reclaimed surface mines in Appalachia; (2) increasing the survival rates and growth rates of trees planted; and (3) expediting the establishment of forest habitat through natural succession.

Research conducted by several leading universities has confirmed that highly productive forestland can be created on reclaimed mine lands when proper site preparation and tree species are used. ARRI advocates these techniques with a five-step reclamation process called the Forestry Reclamation Approach (FRA). The ARRI Team and other state and federal regulators have determined that all facets of the FRA comply with existing laws and regulations.

The five steps of the FRA are: (1) restoring a suitable rooting medium using topsoil and/or the best available material; (2) preventing or minimizing compaction of the top four feet of backfill material; (3) using vegetative species as ground cover compatible with growing trees; (4) planting early successional and commercially valuable tree species; and (5) using proper tree planting techniques.

P. Angel

Red oaks growing in an ARRI Forestry Reclamation Approach (FRA) research site in Kentucky.

Prior to being mined for coal, the majority of the land in Appalachia was forested. Coal mining activities have converted thousands of acres to other habitats, including crop land, pasture, and unmanaged wildlife areas. Decades of federal and state mining and reclamation regulations and practices have promoted site stability and erosion control by compacting the mine spoil, which is used to backfill pits and highwalls, and planting thick grasses and other vegetative species. These traditional reclamation methods have worked against the successful restoration of forest lands.

The West Branch Susquehanna Subbasin overlies significant deposits of bituminous coal and continues to be the subject of extensive coal mining activities. In the future, thousands of acres of land will either be newly mined, re-mined or reclaimed through Pennsylvania's Abandoned Mine Land Reclamation Program. This represents an enormous opportunity to help assure the return or restoration of these lands to productive forest use, with the associated benefits of a healthy and diverse wildlife habitat, improved stream quality and fish habitat, increased recreational and tourism opportunities, and provision of forest products.

ARRI Core Team members in Pennsylvania are David Hamilton of the Federal Office of Surface Mining, and Doug Saylor of the Pennsylvania Department of Environmental Protection. David can be reached at **dhamilton@osmre.gov**, (717) 782-4036. Doug can be reached at **lsaylor@state.pa.us**, (814) 342-8200. Contact your ARRI state representative for any questions or suggestions or visit ARRI's web site at **http://arri.osmre.gov** for further information.

David Hamilton, Program Specialist
Molly Sager, Program Specialist
Office of Surface Mining

of state forest land, more than 280,000 acres of state game lands, and nearly 28,000 acres of state park land.

The average annual precipitation is about 40 inches. The region is characterized by warm summers and long, cold winters. Temperatures change frequently and sometimes rapidly.

The headwaters of the West Branch Susquehanna River are located in West Carroll Township, near Carrolltown, Cambria County. This area lies within the Appalachian Plateau Physiographic Province. From its origins, the river flows north into Clearfield County, turns northeast to Renovo, Clinton County, then turns southeast to Lock Haven, Clinton County. At Lock Haven, the West Branch Susquehanna River cuts through the Allegheny Front and turns to the northeast to flow along the northern flank of Bald Eagle Mountain to Muncy, Lycoming County. At Muncy, the river turns south and flows toward its confluence with the Susquehanna River at Northumberland, Northumberland County. The total length of the West Branch Susquehanna River mainstem from headwaters to the confluence with the Susquehanna River is about 245 miles.

At an average slope of about 0.14 percent, the elevation of the river drops 1,800 feet from the headwaters to the confluence with the Susquehanna River.

Coal Geology of the West Branch Susquehanna Subbasin

About 60 percent (~4,200 square miles) of the subbasin is underlain by sandstone rock. The remaining 40 percent (~2,800 square miles) of the subbasin is underlain by inter-bedded sedimentary rock, which can include sandstone, shale, limestone, and coal.

Coal in the West Branch Susquehanna Subbasin is found in three geologic units: the Conemaugh, Allegheny, and Pottsville (Figure 4).

The Conemaugh Group is stratigraphically defined as the rocks located between the Upper Freeport Coal horizon (lower elevation) and the Pittsburgh Coal (Edmunds et al., 1998).

The Conemaugh is subdivided into a lower formation called the Glenshaw, and an upper formation called the Casselman. The division is made at the top of the Ames Marine Limestone. Economically mineable coals are uncommon in the Conemaugh Group; consequently, so are AMD-related issues.

The Brush Creek Coal, or Gallitzin Coal, of the Glenshaw Formation is mineable in portions of the southcentral and southeastern sections of the bituminous coal field; however, this availability is rare (Brady, Hornberger, and Fleeger, 1998). Only a few coals of the Casselman Formation are thick enough to mine economically, and they are mainly centered in the southern and western portions of Pennsylvania, outside of the West Branch Susquehanna Subbasin.

The Allegheny Group contains the majority of economically mineable coals found in the West Branch Susquehanna Subbasin; consequently, this group is the source of much of the AMD pollution affecting the subbasin.

The Allegheny Group contains seven important coal seams. These seams have been mined to some extent in the West Branch Susquehanna Subbasin, and continue to be mined today (Table 1). The seams include, from the deepest to shallowest, the Brookville, Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport, and the Upper Freeport (Figure 5) (Reese and Sisler, 1928).

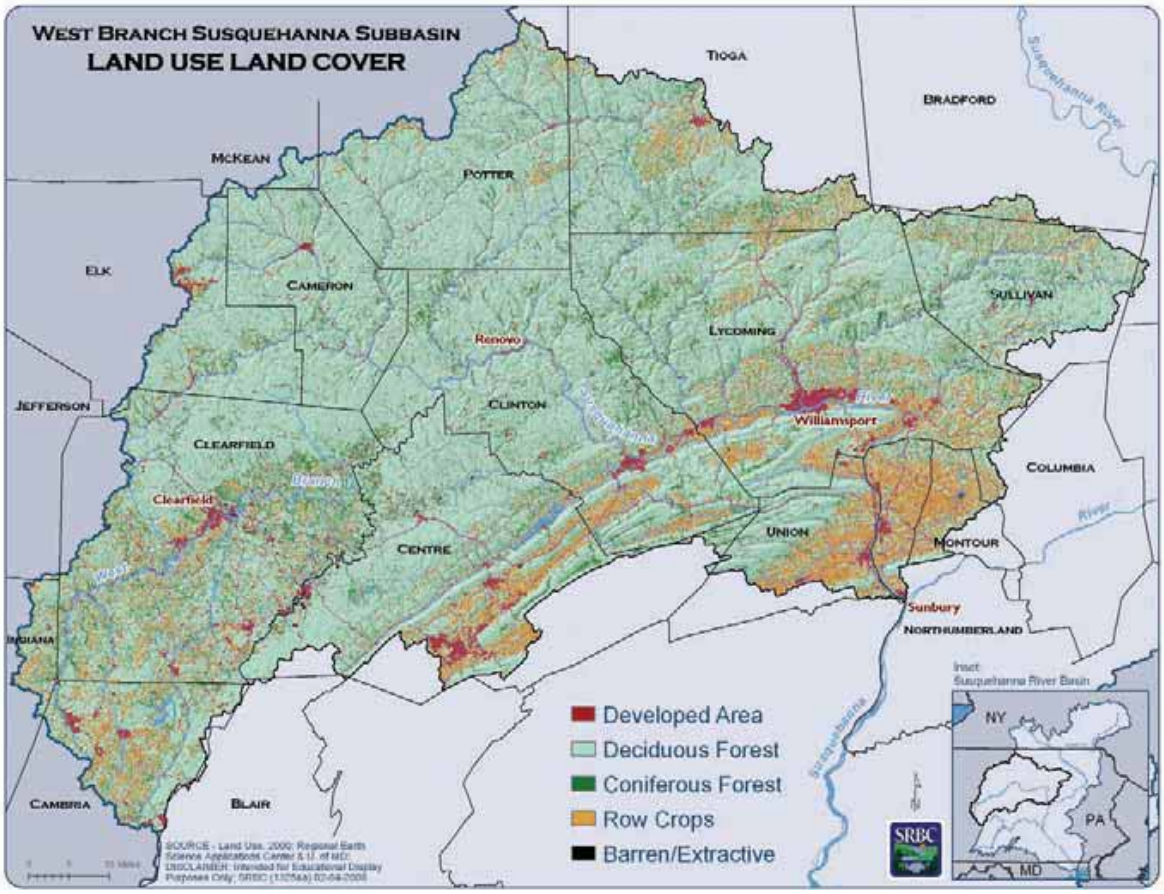
Cambria and Clearfield Counties contain a majority of the total coal reserves found in the West Branch Susquehanna Subbasin, 5,300 and 3,920 million short tons, respectively (Table 1) (Dodge and Edmunds, 2003). Two other counties, Indiana and Jefferson, also contain large reserves; however, a majority of these two counties are not in the West Branch Susquehanna Subbasin.

Generally, more severe AMD is created by the Lower Kittanning, Middle Kittanning, and Clarion seams. While generally less severe and usually alkaline, AMD also originates from the Upper Kittanning, Upper Freeport, and Lower Freeport seams (Pennsylvania Department of Conservation and Natural Resources, 2007).

The Pottsville Formation contains only one important coal seam, the Mercer, which has been mined in areas of the West Branch Susquehanna Subbasin and can be very problematic in terms of AMD production. However, the Mercer coal exhibits lower recoverability than most other coal seams, making it less significant in terms of AMD production (Reese and Sisler, 1928).

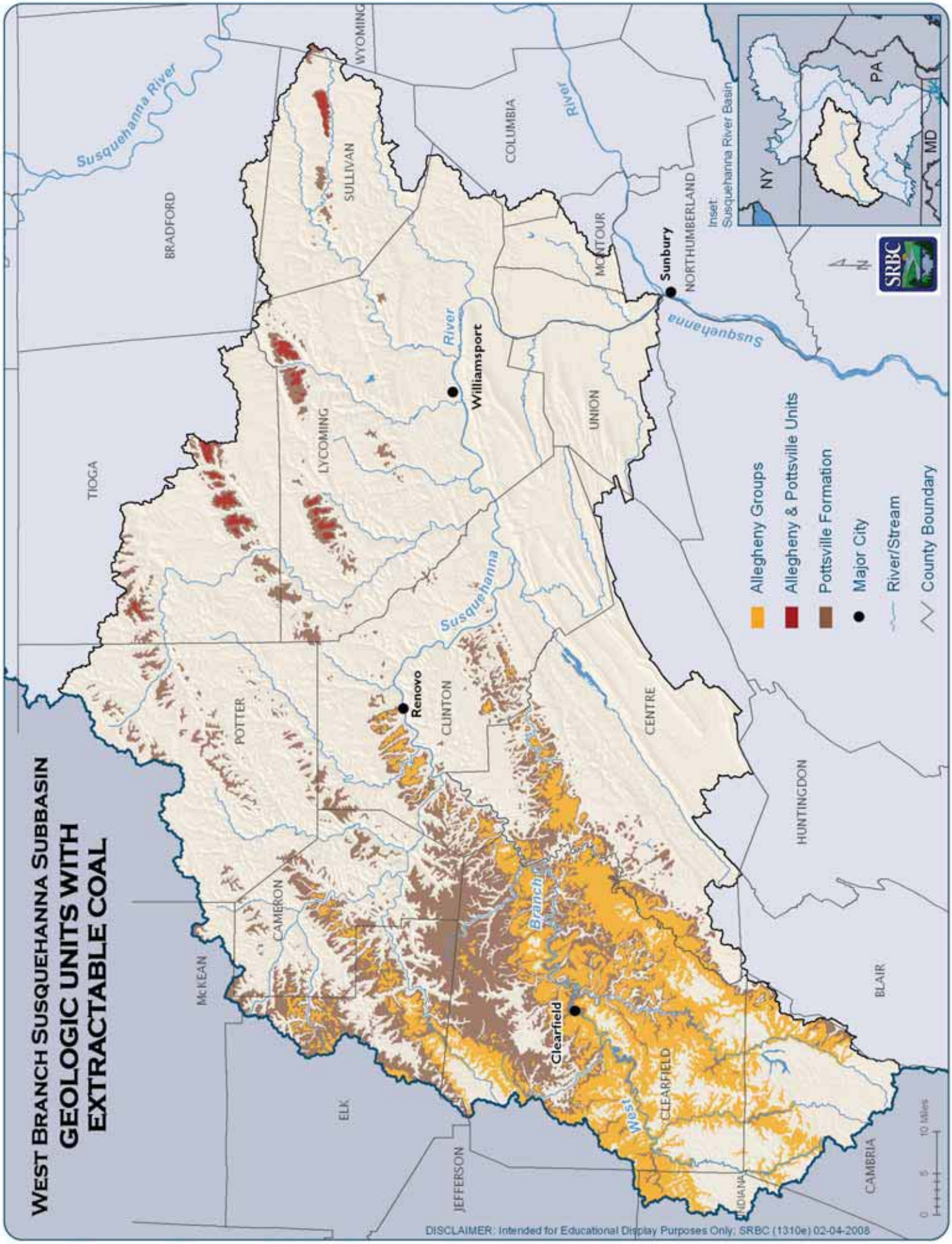
Clay mining within the West Branch Susquehanna Subbasin is another source of AMD production, particularly relevant in the Clearfield Creek and Anderson Creek Watersheds.

Most of the AMD loading entering the West Branch Susquehanna Subbasin is from abandoned underground coal and clay mines.



J. Zimmerman

Figure 3. *Land Use in the West Branch Susquehanna Subbasin.*



J. Zimmerman

Figure 4. *Geologic Units with Extractable Coal in the West Branch Susquehanna Subbasin.*

History of Mining in the West Branch Susquehanna Subbasin

According to Captain Thomas Hutchins, 1760 is the earliest record of bituminous coal mining in Pennsylvania. At that time, a mine was opened on the Monongahela River opposite Fort Pitt, now Pittsburgh (Sisler, 1926).

In the West Branch Susquehanna Subbasin, historical records indicate that in November 1785, Samuel Boyd initiated the idea of furnishing coal to the eastern markets. He purchased a tract of land along the West Branch of the Susquehanna River about three miles upstream of Chincleclenoose, now the Borough of Clearfield (Sisler, 1926). Samuel's son, William, built an ark in 1803, and in the following spring, loaded this ark with coal and transported it 260 miles down the West Branch Susquehanna River and the Susquehanna River proper to Columbia, Pennsylvania (Sisler, 1926).

In 1813, P. A. Karthaus began mining coal at the mouth of "Little Moshannon Creek" and in 1828, he commenced sending coal to Philadelphia by way of Port Deposit, Maryland, through the Chesapeake and Delaware Canals (Sisler, 1926). Mr. Karthaus also sent coal to Baltimore using the Union Canal. This coal sold for 33 cents per bushel.

System	Unit	Member	Character of Member	Unit Description
PENNSYLVANIAN	CONEMAUGH	Lower Mohoning sandstone	Sandstone and sandy shale sometimes separated by thin lenses of coal. Red shale occurs - 40' above Upper Freeport.	Only the lower part of the unit is present - about 40'.
	ALLEGHENY	Upper Freeport coal	Widely persistent average thickness 3' to 3$^1/_2$'.	A variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal. Average thickness is about 300'.
		Lower Freeport coal	Variable, average 2' to 2$^1/_2$' thick.	
		Freeport s.s. Upper Kittanning coal	Thin, about 1' to 1$^1/_2$' thick.	
		Middle Kittanning coal	About 3 seams present at this horizon. Usually 1' to 1$^1/_2$' thick.	
		Lower Kittanning coal	Very persistent. Average thickness 2' to 2$^1/_2$'.	
		Clarion coal	Thin, variable, about 1' thick.	
		Brookville coal	Thin, variable.	
	POTTSVILLE	Homewood s.s.	Massive s.s. often separated by shale.	Only the upper part of the formation is shown here - about 140'.
		Mercer coal	Variable, often several thin beds present at this horizon.	
		Mercer clay		

100
50
0

Figure 5. *A Stratigraphic Column of the Geologic Units Containing Mineable Seams of Coal.*

County	Coal Mined Out and Lost by 1998 Million Short Tons	Remaining Coal Reserves by 1998 Million Short Tons	Total Historic Coal Resource Million Short Tons	Portion of County in Subbasin Percent
Indiana	1,200	5,100	6,300	7.5
Cambria	1,700	3,600	5,300	40.7
Clearfield	820	3,100	3,920	90.6
Jefferson	510	2,800	3,310	0.2
Elk	120	430	550	32.7
Centre	180	330	510	72.5
McKean	1	420	421	2.5
Tioga	44	110	154	42.9
Clinton	49	65	114	100.0
Blair	39	40	79	0.6
Lycoming	17	55	72	99.1
Cameron	2	59	61	99.7
Bradford	21	23	44	2.0
Sullivan	27	8	35	82.9
Totals	**4,730**	**16,140**	**20,870**	

Table 1. *Estimated Bituminous and Anthracite In-Place Coal Resources by Counties within the West Branch Susquehanna Subbasin (Dodge and Edmunds, 2003).*

Pennsylvania Wilds Initiative and the West Branch

Restoration and conservation efforts over a century in the 12-county northcentral region called the Pennsylvania Wilds have helped shape the character of the people and the region, and have defined the region's legacy of natural resource abundance.

The region has some of the most wild and scenic areas east of the Rocky Mountains represented by:

- More than 1.3 million acres of state forest and 500,000 acres of national forest;
- 300,000 acres for hunting and wildlife on more than 50 state game lands;
- Twenty-seven state parks and hundreds of miles of recreational trails;
- Eight wild areas and 24 natural areas that cover about 150,000 acres;
- 16,000 miles of flowing water and three designated Pennsylvania Water Trails including the 228-mile West Branch;
- The largest elk herd in the northeast; and
- The darkest skies in the eastern U.S. at Cherry Springs State Park, Potter County.

When the unparalleled and diverse natural resource assets of the region and their potential were brought to the attention of Governor Edward G. Rendell back in 2001, the Pennsylvania Wilds initiative was launched as a strategic approach to protect and conserve these treasured natural resources, enhance visitor experiences, and revitalize communities in the region.

Today, the vision of the Pennsylvania Wilds initiative is to be well-known throughout the country as a region that offers authentic recreational experiences, interesting towns, hospitable hosts, and other heritage and cultural attractions in one of the most remote and beautiful settings in the northeast.

The degree of cooperation that is evident in joint funding from multiple state agencies, combined marketing efforts by tourist promotion agencies, proactive and collaborative planning by counties, and efforts to improve business development and support locally-made products is truly refreshing and a national model for how to work together to reap the benefits of nature tourism as an effective economic development strategy.

The West Branch Susquehanna Subbasin, which comprises 48 percent (~ 4,000 square miles) of the Pennsylvania Wilds, is a spectacular natural, scenic, and recreational resource for the region. Through this first-ever comprehensive cleanup plan to address mine drainage pollution on more than one thousand stream miles in the subbasin, we are continuing the region's legacy of restoration and stewardship, ensuring the quality and value of this splendid resource for generations to come.

Michael DiBerardinis, Secretary
Pennsylvania Department of Conservation and Natural Resources

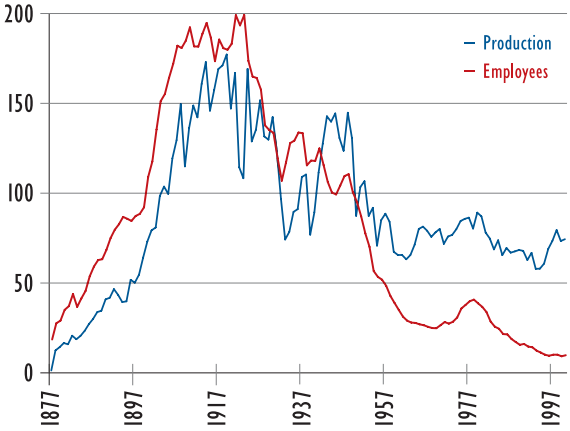


Figure 6.
Pennsylvania Coal Production in Millions of Tons and Number of Mining Employees in Thousands, from 1877 to 2000 (Pennsylvania Department of Environmental Protection, 2006).

Coal demand in the Pennsylvania coal fields exploded due to the necessities of World War I and the reconstruction of Europe (Figure 6). For instance, the town of Windber in Somerset County was formed by the Berwind-White Coal Company in 1897. At its height in the mid-1900s, the population of Windber swelled to more than 12,000 people comprised mainly of an immigrant workforce (Clark, 2006). Annual coal production in Pennsylvania reached its zenith in 1918, when nearly 276.7 million short tons were mined—a record that stood until 1996, when Wyoming produced 278.4 million short tons (Dodge and Edmunds, 2003). Eventually, however, European countries began to meet their own production needs and coal prices fell as world demand for Appalachian coal declined. This event coincided with the onset of the Great Depression.

With America's entry into World War II, coal demand exploded again, and more extensively than the first boom surrounding World War I. Coal became a strategic mineral in winning the war since it was used to offset fuel needs due to gas shortages, particularly for home heating and transportation. Coal also fueled the steel mills that supplied the armaments industry.

Following World War II, Appalachian mining again declined, although not as abruptly as the earlier decline following World War I. The effects, however, were just as severe. Low coal prices caused company owners to use savings from the previous boom. Those companies not able to update mining equipment could not compete with the combination of increasing costs and mechanization. With the closing of many of the mines by 1970, people from areas like Windber migrated to other parts of the country where employment was stable. By the 2000 census, the population of Windber had dropped to 4,200 residents, one-third of its peak only several decades before (Clark, 2006).

Over time, advances in the coal extraction process through the use of technology allowed companies to increase or maintain production while decreasing their payrolls (Figure 6).

An increase in surface mining activity also contributed to this trend. In addition, regulatory requirements under Pennsylvania's Clean Streams Law and the Federal Surface Mining Control and Reclamation Act (SMCRA) in 1977 created additional costs that needed to be absorbed by coal companies. Coupling these new technologies and reclamation responsibilities with the dramatic decrease in the price of coal, many coal miners lost their jobs.

At present, both surface and deep mine operations are active throughout the West Branch Susquehanna Subbasin. Production has increased slightly in the last decade as energy demands have increased. In addition, electrical cogeneration plants can now utilize lower quality coal for energy production. This lower quality coal was commonly discarded as waste in refuse piles, commonly referred to as culm banks in eastern Pennsylvania or gob piles in western Pennsylvania.

The removal of waste coal and the remining of unreclaimed areas have improved water quality in many areas of the West Branch Susquehanna Subbasin—providing both economic and environmental benefits.

S. Buda

Impacted headwaters of the West Branch Susquehanna Subbasin in Cambria County.

PA Department of Environmental Protection

Tankers hauling alkaline material, which was dumped into Curwensville Lake following the Lancashire #15 (Barnes and Tucker) mine breakout in 1970.

What Exactly is AMD?

AMD is Pennsylvania's largest source of water impairment. Its actual chemical makeup encompasses a spectrum of possibilities, but typically is characterized by high levels of acids with the presence of dissolved metals, especially iron, aluminum, and manganese. Antiquated and unregulated mining practices of the past too often set up the circumstances for AMD's formation. A century's worth of extensive mining of Pennsylvania's rich coal reserves has made AMD ubiquitous in the coal regions.

At the root of AMD formation is the mineral pyrite, commonly and aptly called fool's gold for its yellow, lustrous appearance. Pyrite is comprised of the chemical elements sulfur and iron. Usually found in small percentages in coal seams and surrounding geologic strata, pyrite undergoes a natural chemical reaction similar to rusting when in contact with both water and oxygen. This reaction produces acidity, dissolved iron, and a dissolved ion called sulfate. The dissolved iron goes on to further combine with still more water and oxygen to produce a form of rust called iron hydroxide, with a distinctive rusty yellow to dark orange appearance. The acids can go on to dissolve other minerals, liberating other metals into the water. Clays, for example, are rich in the element aluminum, and result in dissolved aluminum when attacked by acids.

Mining activities expose pyrite to water and the oxygen in air, which in turn promote the chain of pyrite reactions at levels thousands of times greater than would occur naturally, and for very long periods of time. If these reaction-products find their way to waterways, they deliver a one-two punch of acidity and dissolved metals to ecosystems ill-equipped to handle the onslaught. What results is a stream seriously compromised in its ability to sustain aquatic life and water not suitable for human use or consumption.

Bruce Golden, Regional Coordinator
Western Pennsylvania Coalition for Abandoned Mine Reclamation

AMD and AML Impacts on Human Health

When studying the impairment that AMD creates on waterways, the investigation almost always is on the impacts to fish and macroinvertebrates, not humans. However, AMD does have some human health implications that can be easily overlooked.

It has been documented through numerous studies how metals, including iron, may increase the occurrence of neurodegenerative disease through increases in oxidative stress in the brain and other mechanisms. However, the correlation between AMD metals in water and increases in neurodegenerative diseases is just beginning to be investigated.

PA Department of Environmental Protection

The Barnes and Watkins Coal Refuse Pile, which is in the process of being removed, will not only improve water quality, but should improve the health of the surrounding communities.

Abandoned Mine Lands can contain very dangerous structures such as highwalls and open shafts, which have contributed to past injuries and deaths. Another possible area of concern is airborne exposure to contaminants originating from coal waste piles contributing to toxicity and lung disease.

Brian Schwartz, MD
Geisinger's Environmental Health Institute

GEISINGER HEALTH SYSTEM

Pennsylvania Coal – Fueling the Industrial Revolution

"Returns that have come to hand lead one to think that the United States has now acquired a position on a par with that of the first coal producing country in the world, having during the last year turned out a quantity equal to that of its former rival, Great Britain. By the returns received from the Secretary of Great Britain, it appears that the grand total of coal production in that country last year was 220,085,393 gross tons. At the same time the coal production of the United States last year was 188,108,012 net tons of bituminous coal and 54,034,224 gross tons of anthracite coal."

"It must be understood that the figures in regard to the anthracite production represent that of Pennsylvania alone, there being a small quantity produced in Colorado. At the same time there were produced in Pennsylvania 73,500,300 net tons of bituminous coal. It will thus be seen that the production of Pennsylvania more than equals that of all the other states, numbering perhaps twenty-six, combined. The next state in point of production last year was Illinois, with some 23,500,000 net tons."

Frederick E. Saward, New York Times, April 8, 1900

Previous Studies

The Pennsylvania Fish and Boat Commission (PFBC) first surveyed the West Branch Susquehanna River in 1931-1932 in Clearfield and Clinton Counties. The surveys found that AMD pollution in the river was so intense that fish could not survive (Sorenson, 1931 and 1932). Several tributaries to the river also were listed as polluted, including Cush Creek, Bear Run, Anderson Creek, Clearfield Creek, Millstone Run, Surveyor Run, Bald Hill Run, Moshannon Creek, and Saltlick Run (Sorenson, 1931). The survey also indicated that Sinnemahoning Creek, Cooks Run, and Kettle Creek were polluted by AMD (Sorenson, 1932).

The first recorded major fish kill on the river occurred in October 1957 in the vicinity of Williamsport, Lycoming County. The reports indicate that about 500,000 fish were killed due to a slug of acid created by heavy rains in the coal mining region of the West Branch Susquehanna Subbasin. Such an event would have normally been neutralized to an extent by Bald Eagle Creek, due to its high alkalinity concentration from limestone geology. The rain event, however, did not affect the Bald Eagle Watershed (Glover, 1957).

During these documented fish kills, the section of the West Branch Susquehanna River near Williamsport had a pH of 4.5 and elevated concentrations of sulfate and iron (Wilt, 1958). Periodic checks of pH in the river at Lock Haven during 1957 and 1958 also documented acidic conditions, with pH ranging from 4.2 to 4.8. For comparison, the pH of the river near Williamsport ranged from 6.2 to 6.8 under normal conditions. Periodic slugs of acid, and associated fish kills, occurred again in July 1958 (Roller, 1958), September 1960 (Drupieski, 1960), and October 1962 (Hempt, 1962). These acid slugs all occurred when heavy rains fell to the west, in the coal-bearing region of the watershed, without corresponding rain events in the neutralizing alkaline tributaries further east. The acid slugs typically had a pH ranging from 4.2 to 4.8, lasted for three to four days,

and were recorded downstream as far as Lewisburg, Union County.

The Federal Water Pollution Control Administration, now the United States Environmental Protection Agency (USEPA), performed a mine drainage study of the entire Susquehanna River Basin from 1964 to 1967. The study found that the headwaters of the West Branch Susquehanna River were acidic until the confluence with Chest Creek in Clearfield County. The major sources of acidity were the active Barnes and Tucker pumped discharge from the Lancashire #20 mine, and tributaries Lesle Run and Fox Run. The river was found to be essentially neutral below Chest Creek to Anderson Creek with fish and other aquatic life present, although populations were considered below normal (Federal Water Pollution Control Administration, 1968).

The PFBC initiated a program of continual surveillance on the river in August 1968, to ascertain water quality conditions (Bradford, 1969). The Pennsylvania Department of Environmental Resources (now PADEP) noted a trend in water quality improvement in 1969 at Bower, Clearfield County, due to the Lancashire #20 mine discharge treatment project. In 1969, the PFBC began a sport fish stocking program in Curwensville Lake that was largely successful (Gwin, Dobson, and Foreman, 1972).

In 1972, Gwin, Dobson, and Foreman completed the West Branch Susquehanna River Mine Drainage Pollution Abatement Scarlift Project for PADEP under the authority of the Land and Water Conservation and Reclamation Act (Act 443). The goal of this project was to "establish as accurately as possible a basis for evaluating the conditions and events in the Watkins, Cambria County, area leading to the serious breakout of mine drainage during the summer of 1970, which caused major fish kills in Curwensville Lake and in the West Branch Susquehanna River below Clearfield" (Gwin, Dobson, and Foreman, 1972). This project focused on the West Branch Susquehanna River from its headwaters to Cherry Tree Borough, Indiana County.

> ***"The most impaired site was found at Karthaus, Clearfield County, downstream of the entry of Moshannon Creek, where pH ranged between 3.9 and 4.1... (Hainly and Barker, 1993)."***

Additional Scarlift studies were completed on Alder Run, Anderson Creek, Babb Creek, Beech Creek, Bennett Branch Sinnemahoning Creek, Clearfield Creek, Dents Run, Kettle Creek, Loyalsock Creek, Moshannon Creek, Muddy Run (Clearfield Creek), and Philipsburg/Hawk Run and can be found digitally at www.amrclearinghouse.org, a website created and maintained by the Western Pennsylvania Coalition for Abandoned Mine Reclamation.

In 1984, the United States Geologic Survey (USGS) completed a study on the "Water Quality of the Upper West Branch Susquehanna River and Tributary Streams between Curwensville and Renovo" (Hainly and Barker, 1993). During baseflow conditions in May and July 1984, streamflow and water quality were measured at four sites on the West Branch Susquehanna River and near the mouths of 94 tributaries between the Boroughs of Curwensville and Renovo.

In general, the USGS found that Moshannon Creek, Sinnemahoning Creek, Clearfield Creek, and Kettle Creek were the largest tributary sources of acidity and total-recoverable iron to the river. During the May sampling, Moshannon Creek, Sinnemahoning Creek, and Clearfield Creek contributed 63 percent of the acidity loading to the West Branch Susquehanna River (Hainly and Barker, 1993). In addition, Moshannon Creek and Clearfield Creek were found to contribute a majority of the total-recoverable iron at 76 percent.

During the July sampling, Moshannon Creek, Kettle Creek, and Clearfield Creek contributed 60 percent of the acidity loading, while Moshannon Creek and Kettle Creek contributed 51 percent of the total-recoverable iron loading to the West Branch Susquehanna River (Hainly and Barker, 1993).

Along the mainstem of the West Branch Susquehanna River, the least impaired site was found at the most upstream station of the study at Curwensville, Clearfield County, where pH ranged between 5.4 to 6.5 and specific conductance ranged between 267 and 310 microsiemens per centimeter (µS/cm). The most impaired site was found at Karthaus, Clearfield County, downstream of the entry of Moshannon Creek, where pH ranged between 3.9 and 4.1 and specific conductance ranged from 330 and 610 µS/cm (Hainly and Barker, 1993).

More recently, in 1985, 1994, and 2002, SRBC completed West Branch Susquehanna Subbasin Surveys, which assessed water quality, habitat, and biology at sites (137 in 2002) throughout the West Branch Susquehanna Subbasin. The findings of the 1994 and 2002 surveys are addressed in detail in the Present Conditions section of this document.

Since the late 1990s and early 2000s, there have been numerous efforts to develop assessment and restoration plans focused on AMD problems in the West Branch Susquehanna Subbasin. A list of these watershed plans and their status can be found in Table 2. A majority of these plans have been completed using funding from the PADEP Growing Greener Program and/or the USEPA 319 Program. Consequently, most of the plans are currently being implemented through those same funding sources.

In 2004, SRBC, under contract with PADEP, began developing a draft West Branch Susquehanna River Total Maximum Daily Load (TMDL) identifying specific river segments requiring load reductions. The TMDL will be completed and submitted to the USEPA for approval before April 2009. Other watershed TMDLs completed in the West Branch Susquehanna Subbasin can be found in Table 3.

Plan	Watershed	County	Year Completed	Completed By	Completed For
West Branch Susquehanna River Headwaters AMD Assessment and Restoration Plan	West Branch Susquehanna River	Cambria	2002	Vapco Engineering	West Branch Susquehanna Rescue
West Branch Susquehanna River Headwaters AMD Assessment	West Branch Susquehanna River	Cambria	2006	Hedin Environmental	West Branch Susquehanna Rescue
Chest Creek Assessment and Restoration Plan	Chest Creek	Cambria, Clearfield	In Progress	Cambria County Conservation District	Chest Creek Watershed Alliance
Bear Run Restoration Plan	West Branch Susquehanna River	Indiana, Clearfield	2006	Indiana County Conservation District	Indiana County Conservation District
Clearfield Creek Watershed Assessment Phase I and II	Clearfield Creek	Cambria, Clearfield	2004	Melius and Hockenberry Environmental Services Inc.	Clearfield Creek Watershed Association
Morgan Run Assessment and Restoration Plan	Clearfield Creek	Clearfield	2006	New Miles of Blue Stream	Clearfield Conservation District, Morgan Run Watershed Group
Restoration Plan for Little Laurel Run, Cambria County, PA	Clearfield Creek	Cambria	2005	Arthur W. Rose	Clearfield Creek Watershed Association
Anderson Creek Watershed Assessment, Restoration, and Implementation Plan	Anderson Creek	Clearfield	2006	Western Pennsylvania Conservancy	Anderson Creek Watershed Association
Hartshorn Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Montgomery Creek 319 Watershed Implementation Plan	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District, Montgomery Creek Watershed Association	Clearfield County Conservation District, Montgomery Creek Watershed Association
Lick Run Cold Water Assessment and Restoration Plan	West Branch Susquehanna River	Clearfield	2005	Allegheny Mountain Chapter of Trout Unlimited	Allegheny Mountain Chapter of Trout Unlimited
Deer Creek Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District, Deer Creek Watershed Association
Moravian Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Upper Alder Run Assessment	West Branch Susquehanna River	Clearfield	In Progress	Alder Run Engineering Inc.	West Branch Sportsman's Association
Hubler Run Implementation Plan	West Branch Susquehanna River	Clearfield	2007	Alder Run Engineering Inc.	West Branch Sportsman's Association
Emigh Run Assessment and Restoration Plan	Moshannon Creek	Clearfield	2004	New Miles of Blue Stream	Emigh Run Lakeside Watershed Association
Trout Run Assessment and Restoration Plan	Moshannon Creek	Centre	2006	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Headwaters of Moshannon Creek Assessment	Moshannon Creek	Clearfield, Centre	In Progress	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Shimel Run Restoration Plan	Moshannon Creek	Centre	In Progress	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Moshannon Creek Water Quality Data Clearinghouse	Moshannon Creek	Clearfield, Centre	2006	New Miles of Blue Stream	Moshannon Creek Watershed Coalition
Moshannon Creek Cold Water Assessment and Restoration Plan	Moshannon Creek	Clearfield, Centre	In Progress	Clearfield County Conservation District	Clearfield County Conservation District
Bennett Branch Watershed Assessment and Restoration Plan	Bennett Branch Sinnemahoning Creek	Clearfield, Elk, Cameron	2003	Gannett Fleming Inc.	Bennett Branch Watershed Association
Dents Run Watershed Ecosystem Restoration	Bennett Branch Sinnemahoning Creek	Elk	2001	U.S. Army Corps of Engineers	Bennett Branch Watershed Association
Sterling Run Assessment and Restoration Plan	Driftwood Branch Sinnemahoning Creek	Cameron	2004	Gannett Fleming Inc.	Cameron County Conservation District

Table 2. *AMD-Focused Watershed Restoration Plans in the West Branch Susquehanna Subbasin from Upstream to Downstream.*

Plan	Watershed	County	Year Completed	Completed By	Completed For
Lower Kettle Creek Restoration Plan	Kettle Creek	Clinton	2000	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
West Side of Lower Kettle Creek AMD Remediation Master Plan	Kettle Creek	Clinton	2007	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Huling Branch Mine Complex: Investigation of AMD and Recommendations for Remediation	Kettle Creek	Clinton	2004	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Twomile Run Watershed AMD Remediation Master Plan	Kettle Creek	Clinton	2007	Hedin Environmental	Kettle Creek Watershed Association, Trout Unlimited
Rapid Watershed AMD Assessment for Sandy Run, Woodley Draft, and Stony Run	Drury Run	Clinton	2006	Hedin Environmental	Western PA Coalition for Abandoned Mine Reclamation
Loop Run Restoration Plan	West Branch Susquehanna River	Clinton	2004	New Miles of Blue Stream	Rocky Mountain Elk Foundation
Tangascootack Creek Watershed Assessment	West Branch Susquehanna River	Clinton	1998	PADEP Moshannon District Mining Office	Clinton County Conservation District
Acid Mine Drainage Restoration Plan for the Beech Creek Watershed	Beech Creek	Clinton, Centre	2006	Hedin Environmental	Beech Creek Watershed Association
Jonathon Run Restoration Plan	Beech Creek	Centre	2003	Hedin Environmental	Beech Creek Watershed Association
Jonathon Run Site Evaluation	Beech Creek	Centre	2006	GAI Consultants	Penn DOT
Contrary Run and Butts Run Assessment	Beech Creek	Centre	2004	Bucek & Associates	Beech Creek Watershed Association
Lycoming Acidification Assessment	Lycoming Creek	Lycoming	2007	Hedin Environmental	Lycoming Creek Watershed Association

Table 2. *continued*

TMDLs and the West Branch Susquehanna Subbasin

A Total Maximum Daily Load (TMDL) is the maximum amount of any pollutant that a waterbody can receive and still meet state water quality standards. Water quality standards are set to protect and maintain aquatic uses such as drinking, fishing, swimming, irrigation, and others. The Clean Water Act requires states to list all waters that do not meet their water quality standards, as well as the source and cause of the pollution.

A TMDL is a "pollution budget" that calculates the amount of the specific pollutant a stream or river can assimilate without violating the standard identified. It also characterizes the sources of pollution on a watershed basis, considering seasonal factors and environmental uncertainty, and provides a plan for use in improving and protecting water quality. Many TMDLs are implemented through the use of best management practices to prevent or remediate pollution.

The Clean Water Act requires states to submit their TMDLs to U.S. Environmental Protection Agency for approval. A complete list of TMDLs completed in the West Branch Susquehanna Subbasin by 2007 can be found in Table 3. A continuously updated list can be found at **www.dep.state.pa.us/watermanagement_apps/tmdl**.

A completed TMDL prioritizes a stream or watershed for state and federal funding, with the goal of achieving water quality standards and removing the stream from the state's list of polluted waters.

Jennifer Orr, TMDL Program Biologist
Pennsylvania Department of Environmental Protection

WATERSHED	TRIBUTARY	CAUSE	STATUS
Anderson Creek	Mainstem	Metals / pH	Approved
	Kratzer Run	Metals	Approved
	Little Anderson Creek	Metals	Approved
Beech Creek	South Fork Beech Creek	Metals / pH	Under Development
	Logway Run	Metals	Approved
	Middle Branch Big Run	Metals / pH	Approved
	North Fork Beech Creek	Metals / Other Organics	Approved
Chest Creek	Rock Run	Metals	Under Development
	North Camp Run	Metals / Other Organics	Approved
Clearfield Creek	Blue Run	Metals	Approved
	Brubaker Run	Metals / pH / Other Organics	Approved
	Mainstem	Metals	Approved
	Little Muddy Run	Metals / pH	Approved
	North Branch Upper Morgan Run	Metals	Approved
	Sanborn Run	Metals / pH / Other Organics	Approved
Kettle Creek	Mainstem	Metals	Approved
	Twomile Run	Metals / pH	Approved
Loyalsock Creek	Mainstem	Metals	Approved
Moshannon Creek	Cold Stream	Metals / pH	Approved
	Laurel Run	Metals / pH	Approved
	Moshannon Creek	Metals / Siltation	Under Development
Mosquito Creek	Grimes Run	Metals	Approved
	Curleys Run	Metals	Approved
Pine Creek	Babb Creek	Metals	Approved
	Wilson Creek	Metals	Approved
	Otter Run	Metals	Approved
	Right Fork Otter Run	Metals / pH	Approved
Sinnemahoning Creek	Dents Run	pH	Approved
	Spring Run	Metals / pH / Other Organics	Approved
	UNT 24679 to Trout Run	Metals / pH	Approved
	West Creek	Metals / pH	Approved
	Bennett Branch	Metals / pH / Siltation	Under Development
	Sinnemahoning Creek	Metals	Under Development
West Branch Susquehanna River	Mainstem	Metals	Under Development
	Bear Run	Metals	Approved
	Hartshorn Run	Metals / pH / Other Organics	Approved
	Montgomery Creek	Metals	Approved
	Moose Creek	Metals	Approved
	UNT 26641	pH	Approved
	Alder Run	Metals	Approved
	Deer Creek	Metals	Approved
	Lick Run	Metals / pH	Approved
	Big Run	pH	Approved
	Surveyor Run	Metals / pH	Approved
	Little Surveyor Run	Metals / pH	Approved
	Sandy Creek	Metals / Other Organics	Approved
	Trout Run		
	UNT 26041 to Trout Run	Metals / pH	Approved
	UNT 26053 to Pine Run	Metals / pH	Approved
	Cooks Run	Metals / Siltation / pH	Approved
	Camp Run	Metals	Approved
	Crowley Hollow	Metals	Approved
	Rock Run	Metals	Approved
	Cow Hole Run	Metals	Approved
	Drury Run	Metals / pH	Approved
	Milligan Run	Metals	Approved
	Tangascootack Creek	Metals / pH	Approved
	Birch Island Run	Metals / pH	Approved
	Little Birch Island Run	Metals	Approved
	Sterling Run	Metals	Approved

Table 3. *AMD TMDL Efforts Within the West Branch Susquehanna Subbasin.*

Present Conditions

In 2005, the Task Force completed the West Branch Susquehanna River State of the Watershed Report. In the report, the Task Force, citing data from SRBC's West Branch Susquehanna Subbasin Surveys of 1994 and 2002, concluded that water quality degradation is the main reason for impairment of aquatic life throughout most of the West Branch Susquehanna Subbasin, whereas the physical stream habitat is in relatively good condition (West Branch Susquehanna River Task Force, 2005). Of all the impaired stream miles in the subbasin, 1,205 miles are degraded by AMD. This represents 66 percent of the total AMD-impaired mileage in the entire Susquehanna River Basin. In addition, 42,062 acres of unreclaimed AML features, or nearly 23 percent of the entire Commonwealth's share, are found within the West Branch Susquehanna Subbasin. Nearly 6,462 of those acres are considered Priority I or II Health and Safety Problem sites, as designated by the U.S. Office of Surface Mining (OSM).

> ***"Two main stretches of the West Branch Susquehanna River are significantly influenced by AMD: the headwaters in Cambria County to about the town of Mahaffey, Clearfield County, and from the entry of Clearfield Creek to Williamsport, Lycoming County."***

This impairment causes massive losses in recreational uses and significantly impacts the economic potential of the region. In addition, PADEP BAMR has estimated that water quality restoration of the entire West Branch Susquehanna Subbasin will require capital costs ranging from $279 million to $464 million, with annual operation and maintenance costs ranging from $22 million to $55 million (West Branch Susquehanna River Task Force, 2005). Reclamation of all AML features is estimated at an additional $288 million (Pennsylvania Department of Environmental Protection, 2004).

S. Buda

AMD precipitate on Kettle Creek.

In 2003, SRBC published its West Branch Susquehanna Subbasin Survey, which was conducted between July and November 2002. This effort was similar to surveys completed for the West Branch Susquehanna Subbasin in 1985 and 1994. The study indicated only slight improvement in conditions between 1994 and 2002. Of the sections of the West Branch Susquehanna Subbasin studied, AMD degradation was documented in the headwaters region, as well as along the mainstem of the West Branch Susquehanna River from Clearfield Creek in Clearfield County, to Pine Creek in Lycoming County (LeFevre, 2003). Degraded watersheds included Muddy Run (Clearfield Creek Watershed), Clearfield Creek, Moshannon Creek, Beech Creek (Bald Eagle Creek Watershed), Twomile Run (Kettle Creek Watershed), Dents Run (Bennett Branch Sinnemahoning Creek Watershed), Cooks Run, Alder Run, Bear Run, Deer Creek, Little Anderson Creek (Anderson Creek Watershed), and Montgomery Run. The highest quality watersheds documented included Pine Creek, First Fork Sinnemahoning Creek, Driftwood Branch Sinnemahoning Creek, Young Women's Creek, Hyner Run, Paddy Run, Lick Run, and White Deer Creek.

In 1994, 47 percent of the sites sampled by SRBC were either classified as moderately or severely impaired in terms of water quality. The percentage of impaired sites decreased to 43 percent in 2002. In addition, of the eight sites that showed significant changes from 1994 to 2002, six were improved. Additionally, most of the sites in the West Branch Susquehanna Subbasin were classified as having excellent or supporting habitat; 91 percent in 1994 and 88 percent in 2002 (LeFevre, 2003).

During 2004 and 2005, streamflow and water quality data were collected at 33 locations along the mainstem of the West Branch Susquehanna River for the development of a TMDL assessment for metals pollution, specifically related to iron, aluminum, and manganese. This dataset represents the most recent source of information describing present water quality conditions along the West Branch Susquehanna River.

Two main stretches of the West Branch Susquehanna River are significantly influenced by AMD: the headwaters in Cambria County to about the town of Mahaffey, Clearfield County, and from the entry of Clearfield Creek to Williamsport,

The Babb Creek Watershed: An AMD Restoration Success Story

When the cleanup of the Babb Creek Watershed was started in 1990, more than 13 miles of the mainstem and parts or all of four tributaries were severely polluted due to AMD. The cleanup effort started with the installation of two limestone diversion wells on Lick Creek, near the village of Arnot, Tioga County.

Over the next 15 years, 2 more limestone diversion wells, 15 vertical flow ponds, 3 limestone cells, 1 anoxic limestone drain, and a treatment plant were constructed on AMD discharges within the watershed.

In 2005, the Pennsylvania Fish and Boat Commission did an intensive survey of the mainstem and found large numbers of fish and aquatic insects in the previously dead section. Naturally reproducing brook and brown trout were also found in the section upstream from the village of Morris. Due to these results, more than eight miles of the mainstem were reclassified by the Commission as a "wild trout stream" in July 2006.

After being polluted with AMD for more than 100 years, Babb Creek is again a productive stream.

William Beacom, President
Babb Creek Watershed Association

The late Bob McCullough, past president of the Babb Creek Watershed Association, stocking trout into Babb Creek for the first time in 100 years due to the restoration of AMD impacts.

Lycoming County. In between those sections, the river is still impaired, but in a state of recovery both in terms of water quality and biological communities.

In terms of net alkalinity concentration for the 33 TMDL sites, the West Branch Susquehanna River is net acidic from the vicinity of Carrolltown and Bakerton, Cambria County (River Mile (RM) 241.8), to just upstream of the town of Northern Cambria, Cambria County (RM 237.8). The remaining sections of the river are net alkaline, although just slightly along certain reaches. From the entry of Moshannon Creek (RM 132.6) to the entry of Pine Creek (RM 55.6), the net alkalinity is consistently below 20 mg/l, which is within the range that PFBC considers acid sensitive. Acid sensitive stretches account for about 88 river miles of the West Branch Susquehanna River, or nearly 36 percent of the total mileage.

In terms of total iron concentration for the 33 TMDL sites, the West Branch Susquehanna River exceeds the 1.50 mg/l water quality standard (Table 4) from the extreme headwaters of the West Branch Susquehanna River in Cambria County (RM 242.8) to just downstream of Cherry Tree, Indiana County (RM 228.4), and from the town of Karthaus, Clearfield County (RM 132.6), to downstream of the entry of Kettle Creek in Clinton County (RM 97.7). This represents about 49 river miles not meeting the designated water quality standard for iron, or slightly more than 20 percent of the total West Branch Susquehanna River mileage.

In terms of total aluminum for the 33 TMDL sites, the West Branch Susquehanna River exceeds the 0.75 mg/l water quality standard (Table 4) from the very extreme headwaters of the West Branch Susquehanna River near Carrolltown, Cambria County (RM 243.4), to downstream of the entry of Pine Creek in Jersey Shore, Lycoming County (RM 55.6). This represents about 188 river miles not meeting the designated water quality standard for aluminum, or nearly 77 percent of the total West Branch Susquehanna River mileage.

In terms of water quality trends throughout the West Branch Susquehanna Subbasin, most areas have seen a significant improvement in the last two decades (Table 5). For instance, at the town of Keating in Clinton County, the West Branch Susquehanna River has increased nearly three pH units, while iron and aluminum concentrations have dropped 38 and 81 percent, respectively. The pH at the mouth of Clearfield Creek has increased two and one-half pH units, while iron and aluminum concentrations have dropped approximately 46 and 79 percent, respectively. Moshannon Creek is an exception, with pH remaining fairly constant and aluminum concentrations increasing approximately 94 percent.

Parameter	Criterion Value (mg/l)	Total Recoverable/Dissolved
Aluminum (Al)	0.75	Total Recoverable
Iron (Fe)	1.50	30-Day Average Total Recoverable
	0.30	Dissolved
Manganese (Mn)	1.00	Total Recoverable
pH*	6.0-9.0	NA

**The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission).*

Table 4. *Applicable Water Quality Criteria (Commonwealth of Pennsylvania, 2005).*

WEST BRANCH SUSQUEHANNA RIVER STATIONS

Location	Sample Year	Collection Agency	pH SU	Total Fe mg/l	Total Al mg/l
Curwensville, Clearfield County	1984	USGS	6.0	0.4	0.2
	1994	SRBC	7.7	0.1	0.3
	2004/2005	SRBC	7.3	0.4	1.1
Karthaus, Clearfield County	1984	USGS	4.0	1.3	2.4
	1994	SRBC	3.8	0.7	2.9
	2004/2005	SRBC	6.6	2.0	1.3
Keating, Clinton County	1984	USGS	4.1	0.8	2.1
	1994	SRBC	4.1	0.1	1.0
	2002	SRBC	7.0	0.5	0.4
Renovo, Clinton County	1984	USGS	4.2	0.5	1.5
	1994	SRBC	4.7	0.2	1.0
	2004/2005	SRBC	6.6	0.5	1.4

MAJOR TRIBUTARY STATIONS

Location	Sample Year	Collection Agency	pH SU	Total Fe mg/l	Total Al mg/l
Anderson Creek	1984	USGS	4.4	0.6	1.5
	1994	SRBC	5.1	0.4	0.9
	2004/2005	WPC	6.0	0.3	0.5
Clearfield Creek	1984	USGS	4.9	2.6	2.4
	1994	SRBC	4.6	0.2	2.0
	2003/2004	SRBC	6.4	1.4	0.5
Moshannon Creek	1984	USGS	3.5	3.8	3.5
	1994	SRBC	3.4	2.9	5.5
	2002	SRBC	3.3	1.0	6.8
Mosquito Creek	1984	USGS	4.8	0.3	0.4
	1994	SRBC	6.2	0.1	1.2
	2002	SRBC	5.4	<0.1	<0.1
Sinnemahoning Creek	1984	USGS	6.3	0.3	0.3
	1994	SRBC	6.0	0.1	0.1
	2002	SRBC	7.2	<0.1	<0.1
Kettle Creek	1984	USGS	5.1	1.5	1.3
	1994	SRBC	6.4	0.2	0.3
	2001	TU	6.8	0.4	0.6

Table 5. *Water Quality Trends Over the Last Two Decades at Four Sites Along the West Branch Susquehanna River and at the Mouths of Six Major AMD Impacted Tributaries.*