APPENDIX P*

Coal Refuse Remediation – Ash Application Studies

New appendix added for Final EIS.

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Table 1. Summary of Case Studies of Ash Application for Mine Land Reclamation and AMD Mitigation.

Case	Name	Description	Results
1	Wyodak Mine, WY	Placement of coal ash in an active surface mine.	No significant change in groundwater quality following placement.
2	Keenesburg Mine, CO	Placement of coal ash in a closed surface mine.	No significant change in groundwater quality.
3	Trapper Mine, CO	Placement of coal ash in an active surface mine.	Elevated sulfate levels in groundwater. No significant change in other analytes.
4	Savage Mine, MT	Placement of coal ash in an active surface mine.	Slight increase in arsenic at two wells, as well as TDS and sulfate.
5	Storm Strip Mine, WV	Placement of coal ash in an active surface mine.	No significant change in groundwater quality.
6	Universal Mine, IN	Placement of coal ash in a closed surface mine.	*Groundwater*: Arsenic and boron increased slightly; iron, sulfate and manganese decreased. *Mine seep*: Boron, pH and alkalinity increased; acidity, iron, manganese and sulfate decreased.
7	Midwestern Abandoned Mine, IN	Capping of an abandoned and reclaimed mine using an ash mix.	Recharge of water into AMD site reduced, resulting in reduced AMD generation.
8	Arnold Willis Mine, IN	Injection of scrubber sludge into a closed underground mine.	Heavy metals in groundwater unaffected but TDS increased.
9	Clinton County, PA	Injection of CFB ash to encapsulate AMD-producing materials in a reclaimed surface mine.	Groundwater pH increased temporarily, and As, Cd and Al decreased. pH later decreased and Al increased, but As and Cd remained low.
10	Red Oak Mine, OK	Injection of FBC ash into a closed underground mine.	pH of mine seep increased, Al, Mn, Fe decreased.
11	Frazee Mine, MD	Injection of ash grout into a closed underground mine.	pH of mine seep increased by 1 unit. Fe, Al, sulfate and trace metals decreased; Na, K, Ca and Cl increased.
12*	Ebensburg, PA	Use of bituminous coal refuse (gob) from an abandoned deep mine, followed by FBC ash application to reclaim the disturbed land.	Acidity, aluminum and sulfate declined steadily, as well as volume of flow. As and Se increased early on, but have declined steadily since.
13*	McDermott, PA	Remining and use of alkaline ash to reclaim a closed surface mine.	Acidity, sulfate and iron increased in groundwater as well as mine seep.
14*	Abel-Dreshman Site, PA	Use of alkaline ash to reclaim a closed surface mine.	Alkalinity and pH in mine seep increased and aluminum decreased.
15	Wheelabrator Frackville, PA	Use of anthracite coal refuse (culm) as fuel, followed by FBC ash application to reclaim the refuse site.	No significant change in water quality.
16	Mount Carmel, PA	Use of anthracite coal refuse (culm) as fuel, followed by CFB ash application to reclaim the refuse site.	Acidity and sulfate in groundwater decreased, while alkalinity increased.

**Discussed in greater length in this appendix – in paper "Coal Ash Beneficial Use on Bituminous Mine Sites" (Kania and Tarantino)*

PENNSYLVANIA GENERAL ASSEMBLY

JOINT LEGISLATIVE AIR AND WATER POLLUTION CONTROL AND CONSERVATION COMMITTEE

REPORT ON

A PROPOSED MORATORIUM ON THE USE OF FLY ASH IN MINE RECLAMATION PROJECTS

(Without Appendices)

February, 2004

TO: **All Members of the General Assembly**

FROM: **Representative Scott E. Hutchinson, Chairman**
Senator Raphael J. Musto, Vice Chairman

SUBJECT: **A Proposed Moratorium on the Use of Fly Ash in Mine Reclamation Projects**

DATE: **February, 2004**

The following report is a result of a public hearing held by the Joint Legislative Air and Water Pollution Control and Conservation Committee on July 9, 2003 in Tamaqua, Pennsylvania. The purpose of the hearing was to discuss a proposed moratorium on the use of fly ash in mine reclamation projects. The recommendations presented in this report are the result of that hearing.

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2003-2004 Session

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EXECUTIVE SUMMARY

The Joint Legislative Air and Water Pollution Control and Conservation Committee (Committee) has been asked to offer the Pennsylvania General Assembly a recommendation on whether there should be a statewide moratorium on the use of coal combustion waste (CCW), also referred to as fly ash and coal ash, for mine reclamation purposes. In order to gather the necessary information to make such a recommendation, the Committee conducted a public hearing on July 9, 2003 in Tamaqua, Pennsylvania, a site where fly ash is being used to reclaim an abandoned mining pit, and where expanded use of fly ash is being considered.

The issue is both an emotional and technical one and the debate over the use of CCW is marked by impassioned opinions as much as empirical evidence. There have been many questions posed and a number of questions unanswered. The Committee has sought diligently to find the facts using solid, peer-reviewed science to make its recommendations surrounding the use of fly ash in an attempt to answer the many questions posed. While the facts are foremost, they are not the only consideration. Testimony received by the Committee indicated there are many concerns about the use of fly ash, but there are also serious statewide implications about coal mine safety in terms of acid mine drainage, pedestrian safety around abandoned mine workings, and mine subsidence. Just as there are concerns about the impact of fly ash on water quality, there are concerns about the future of cogeneration and its impact on jobs and the economy in Pennsylvania. And, just as there are concerns about the dirt, dust, and transportation impacts, there are concerns about the progress of abandoned mine reclamation throughout the state.

These issues were the subject of testimony at the Committee's public hearing. The testimony reflected differences in opinion and presented differences in matters of fact and interpretation. It is our mandate to weigh the facts, both agreed upon and subject to debate, consider both shared and conflicting concerns, seek reconciliation and use good science to make judgment and recommendation.

The Committee prides itself on its rich history and vital role in offering legislation and recommendations to the General Assembly that have helped strengthen and enhance Pennsylvania's environment over the past 35 years. The Committee has been a pioneer in assisting in the cleanup of abandoned coal mines and has offered legislative recommendations regarding mining and reclamation practices in the past.

The protection of water quality and the conservation of natural resources in Pennsylvania is a Committee priority. Ample evidence has been provided by industry, environmental organizations, academia, federal and state regulatory agencies demonstrating the significant economic and environmental benefits fly ash plays in the reclamation activities of abandoned mine lands if properly managed. The Committee believes that the *improper* use of fly ash can pose a significant environmental and public health threat. However the Committee also believes that proper fly ash use can and is adequately enforced by state and federal regulatory agencies in Pennsylvania.

After reviewing the issue surrounding the use of fly ash for coal reclamation projects, it has become increasingly obvious that Pennsylvania has a carefully crafted regulatory scheme that is a model for the nation. It draws upon 30 years of experience in using fly ash for mine reclamation and integrates the state's residual waste management program with its federally approved surface mining program. The effects of the program on the environment, natural resources, public health and safety, and the economy have been evaluated by the General Assembly and reviewed by related agencies, the Environmental Quality Board and the Independent Regulatory Review Commission, as part of their adoption of legislation, regulations, policies and guidance.

The program, as set forth in historical detail to follow, has peer-reviewed uniform standards for fly ash quality and placement that are implemented in the permitting process and incorporate site-specific considerations of geology and hydrology. The program mandates frequent and detailed monitoring of both fly ash quality at its source and the groundwater quality at the mine site as part of the permitting conditions. Finally, the Pennsylvania Department of Environmental Protection (DEP) exercises extensive oversight, inspection and enforcement power to ensure compliance with the requirements of Pennsylvania's Solid Waste Management Act, 35 P.S. Chapter 6018.101 et seq., the Surface Mining Conservation and Reclamation Act, 52 P.S. Chapter 1396.1 et seq., and the Clean Streams Law, 35 P.S. Chapter 691.1 et seq.

Therefore, the Committee makes the following recommendations with regard to a moratorium on the use of fly ash in Pennsylvania:

1. **The Committee does not recommend or support a statewide moratorium on the use of fly ash in coal mine reclamation projects as requested in the public hearing on July 9, 2003. The beneficial use of coal ash, including mine reclamation, has been well documented and the potential risks have been thoroughly examined and these results have been reported to local, state and federal agencies. The Committee has researched data from a dozen sites in Pennsylvania and found that coal ash can be effectively and safely used when properly managed. The information also demonstrates the significant economic and environmental benefits coal ash plays in the reclamation activities in the Commonwealth.**
2. **The Committee recommends the continued research into the environmental effects of fly ash on soils and waters of the Commonwealth and the impacts posed by trace elements contained in the material. While the Committee believes that improper use of fly ash can pose a threat to public health and the environment, proper fly ash use is being adequately enforced by state and federal regulatory agencies. However, there is room for improvement. The Committee does, in fact, recognize citizen questions and concerns about the possible presence of certain chemicals in fill material (i.e., hexavalent chromium) and has therefore requested an independent study to be conducted to further investigate the biology, chemistry, placement and use of the ash material in mine reclamation projects in Pennsylvania.**
3. **As an added protection measure to the current regulatory program, the Committee recommends that a statewide, third party oversight subcommittee be established through the Mining Reclamation and Advisory Board or the Citizen's Advisory Council with a specific charge to oversee the state regulatory program. The subcommittee would include representation from groups or individuals concerned with the beneficial use of fly ash on abandoned mine lands. The statewide subcommittee would review results of biological, chemical and physical tests, and make necessary recommendations for changes to the current regulatory standards set by DEP and the United States Environmental Protection Agency (EPA).**
4. **DEP, environmental organizations, industry and the newly established oversight subcommittee should also consider and study the undocumented threat coal refuse piles themselves pose to human health and the environment and evaluate the safety hazards posed by abandoned mines throughout the Commonwealth such as dangerous high walls and water filled pits. The question of whether these unremediated sites may pose significantly more hazards to the environment if they are not beneficially remediated needs to be addressed.**
5. **The electric utility industry needs to address the issue of public education and the utilization of CCW. Environmental performance data needs to be developed and made available to the public from full-scale demonstrations of beneficial use applications. The information that industry, federal and state governments have generated needs to**

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be made more available to regulators and the citizens of the Commonwealth and others.

6. **The CCW industry needs to be vigilant about the use of appropriate testing and monitoring methods and interpretation of data, and to communicate with state and federal agencies on the further development of regulatory guidelines for CCW management.**

LEGISLATIVE AND REGULATORY REVIEW OF COAL ASH USE IN PENNSYLVANIA

Prior to examining the regulatory program, it may be important to look at the legislative and regulatory pathway that led to Pennsylvania's coal ash management program. In deciding under what circumstances a material may be beneficially used, the General Assembly has to examine all sides of an issue and balance environmental impacts with social and economic concerns, public health and safety issues, along with the use of our natural resources. Legislative and regulatory control of the beneficial use of CCW began in 1986 when the overwhelming passage of House Bill 2274 amended the Solid Waste Management Act to include the recycling and beneficial reuse of CCW. (Following an extensive review process, HB 2274 passed the House by a 195-2 vote and the Senate by a 49-0 vote and was signed into law as Act 168 on December 12, 1986.)

Such amending legislation authorized the establishment of siting criteria and design and operating standards for the beneficial use of coal ash for use as structural fill, soil substitutes and additives. In its mandate to fulfill Article I, Section 27 of the Pennsylvania Constitution, the General Assembly looked at the nature of coal ash, the economic and environmental impacts of coal ash disposal in landfills, the public health and safety benefits of removing mine hazards, the economic and environmental benefits of abating acid mine drainage and the reclamation of mine sites versus the impact of beneficial uses of coal ash. The General Assembly concluded that any potential adverse impacts associated with the beneficial use of coal ash for mine fill and other purposes were minimal compared to the environmental and social benefits of its use.

At the same time, the Environmental Quality Board (EQB) an independent legislative body charged with promulgating regulations for the management of coal ash adopted the regulations governing coal ash in 1992, and the subsequent amendments in 1997 and 2001. EQB's rulemaking, which provided the public with comment periods that extended well beyond the required periods mandated by the Regulatory Review Act, 71 P.S. Chapter 745.1 et seq, made a reasoned judgment based on scientific, technical environmental and social benefits to adopt the regulatory program now in place.

In conjunction with the General Assembly and the EQB, the Independent Regulatory Review Commission (IRRC), an independent executive agency, reviewed the beneficial use regulations on three separate occasions and in doing so, also considered all of the same impacts that the previous legislative bodies had considered and concluded that the regulations were in fact, in the public interest.

All three separate bodies reviewed the science, technology and data associated with the beneficial use of coal ash and concluded that the regulatory program is protective of the environment and public health and the adverse impacts, if any, are minimal and balanced by the overall environmental, economic and social benefits of the current program. Nothing that has been presented to the Committee has altered that conclusion.

However the list of oversight doesn't stop there. The General Assembly created the Mining and Reclamation Advisory Board (MRAB) in 1984 by Act 181. The purpose of the board's creation was to assist DEP in expanding reclamation funds provided by the Surface Mining Conservation and Reclamation Act and to *advise* DEP on public matters pertaining to mining and reclamation and abandoned mine reclamation issues.

DEP also solicits and receives input on proposed changes to the mining program from the Citizen's Advisory Council (CAC). The council, created in 1971, is the only legislatively mandated advisory committee with the comprehensive charge to review all environmental legislation, regulations and policies affecting DEP. Both the MRAB and the CAC have weighed in on this issue. Both the MRAB and the CAC are supportive of DEP's regulatory program and do not support a moratorium on the use of fly ash.

DEP REGULATIONS

CCW is regulated under Pennsylvania's Solid Waste Management Act (PASWMA). In 1986, the act was amended to establish provisions for the beneficial use of the material. The provisions for beneficial use apply not only to fly ash but also other ash materials derived from the combustion of coal. Regulations regarding the beneficial use of CCW were adopted in 1992 as a part of Pennsylvania's Residual Waste Management Regulations for the use of coal ash as a soil substitute or soil additive and as placement for fill material at surface mines, coal refuse reprocessing operations and coal refuse disposal sites.

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DEP administers the program and the Bureaus of Mining and Reclamation and District Mining Operations have the responsibility of managing coal ash on active coal mining operations. The Bureau of Abandoned Mine Reclamation has program responsibilities for use of the material on abandoned mines. The Bureau of Land Recycling and Waste Management has the program responsibility for the beneficial use of coal ash at sites other than coal mining operations.

The Solid Waste Management Act and the residual waste management regulations authorize the beneficial use of coal ash as a structural fill; soil substitute or additive; for reclamation at an active surface coal mine site, a coal reprocessing site, or a coal refuse disposal site; for reclamation at an abandoned coal or an abandoned non-coal industrial mineral site; in the manufacture of concrete; for the extraction or recovery of one or more materials contained within coal ash; for mine subsidence and control, mine fire control and mine sealing as a drainage material or pipe bedding and as a stabilized product where the physical and chemical characteristics are altered so that the potential of the coal ash to leach constituents into the environment is reduced. All of these uses must comply with specified state regulations.

The Pennsylvania regulations reference the federal regulations exempting fly ash and other waste generated primarily from coal combustion or other fossil fuels as hazardous waste (25 PA Code Chapter 261.A.1.4). As mentioned above, CCW is regulated under the Solid Waste Management Act and the residual waste management regulations. In December 1986, this act was amended to authorize the beneficial use of coal ash. Beneficial use of coal ash was implemented through DEP guidelines under the residual waste management regulations, 25 PA Code Chapter 287, which was amended in July 1992 to include the beneficial use of coal ash, 25 PA Code Chapter 287.661-287.666. In January 1997, the beneficial use of coal ash regulations 25 PA Code Chapter 287.663 and 287.664 were amended to change the requirements concerning groundwater monitoring, reporting requirements, beneficial uses and the amounts of coal ash that can be used at active coal mine and abandoned mine sites.

Coal ash is defined in Pennsylvania as fly ash, bottom ash or boiler slag resulting from the combustion of coal.

Pennsylvania residual waste management regulations provide that coal ash may be beneficially used:

- As structural fill upon approval from DEP.
- As a soil substitute or soil additive.
- For reclamation at an active surface coal mine site, a coal refuse reprocessing site, or coal refuse disposal site if the use complies with all the specified requirements under PA Code Chapter 287.663, the Clean Stream Law and regulations promulgated there under, the Surface Mining Conservation and Reclamation Act (52P.S. Chapter 1396.1-1396.19a), the Coal Refuse Disposal Control Act (52 P.S. Chapter 30.51), and the applicable provisions of 86-90.
- For reclamation at an abandoned coal mine site, the use must comply with 25 PA Code Chapter 287.664 and the applicable environmental statutes stated above.
- In the manufacture of concrete.
- For mine subsidence control, mine fire control and mine sealing, as a drainage material or pipe bedding, if the person or municipality proposing the use gives advance written notice to the DEP and the range of pH of the coal ash is in a range that will not cause or allow the ash to contribute to water pollution and is consistent with applicable DEP requirements.

Much of the criticism of Pennsylvania's regulatory program voiced during the Committee's public hearing focused on isolated regulations taken out of a larger context of the residual waste management and mining activity regulatory programs. Critics focused on groundwater quality issues and criticized legislation addressing remining of areas with preexisting pollutional discharges. Clearly, the residual waste regulations at 25 Pa. Code prohibit the placement of coal ash within specific distances (eight feet) of the regional groundwater table, unless it can be proved to DEP that groundwater contamination will not occur as part of an abatement project.

When addressed specifically, the allegations made against the program proved to be unsubstantiated, without technical, scientific or peer-reviewed facts. After examination of the three most significant sites alleged to have caused damage relating to the placement of ash at mine reclamation sites, Ernest, Revloc, and Maple Coal, the sites showed no evidence of environmental damage. In fact, information relating to the groundwater damage cited in testimony were temporary results related to initial disturbance and removal of coal refuse and monitoring of water quality. In some cases, water quality improved over pre-placement levels.

With regard to ash placement versus common soils in the area, independent tests, studies and agency monitoring data all show levels of trace elements and major elements in soils including arsenic, mercury, lead, chromium, cadmium, and others that are comparable to the levels of those elements in ash produced at power plants in the area. If the volume of exposed area of the local soils is compared with ash placement, the soils in the surrounding area contain greater amounts of

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background elements than is contained in the placement of ash. This also holds true for culm and gob piles. Although concentrations of trace elements in refuse coal are similar to ash, burning of coal refuse decreases the mobility and toxicity of these elements. Therefore the amount of mobile toxic elements in the abandoned coal refuse piles exceeds the amount in the ash.

Pennsylvania's program has been crafted in cooperation with the federal Office of Surface Mining Enforcement and Reclamation and EPA. The program takes into account the potential for groundwater degradation and effects on human health and the environment by addressing site-specific characteristics prior to ash placement at any mine site. The use of coal ash *must* comply with the SMCRA and the provisions of the regulations and meet certification guidelines for acceptable chemical and physical properties of the ash as set in 25 Pa Code. Those guidelines, which specify maximum leachate concentrations are outlined in the Certification Guidelines for Beneficial Uses of Coal Ash Documents (Document 563-2112-224) and the Coal Ash Beneficial Use Application (Form 5600-PM-MR0011). Coal ash quality data must be submitted as a part of the mining permit application and certified every six months.

In addition to the information regarding the coal ash quality, the permit application must include information regarding the "geology, hydrology and water quality… of all lands within the proposed permit area, the adjacent area and the general area" (25 Pa Code Chapter 88.23) and the geology of the proposed permit area and the adjacent areas, down to and including the aquifer must be described in detail in the permit application. The description must include coal seam thickness, location of mine pool or subsurface water, chemical analysis of the coal, groundwater hydrology, including depth to groundwater, uses of groundwater, and the chemical characteristics (25 Pa Code Chapter 88.25). The permit applicant must describe the placement of the coal ash in relation to the regional groundwater table. The permit application must also include a plan for collecting groundwater and surface water data, including monitoring location and testing frequency.

As mandated by regulation, DEP must conduct a thorough review of site-specific geology and hydrology prior to ash placement. It is evident that Pennsylvania's regulatory program as it has operated for over 15 years, and through testimony presented and a review of the program, has all the elements to ensure that coal ash of the appropriate quality is placed at mine sites with suitable geologic and hydrologic characteristics and is in compliance with approved reclamation plans and permit conditions. The quality of coal and the groundwater is routinely and frequently monitored by the generator/operator.

DEP routinely inspects this data and has the authority to immediately act on any issue that may arise from the placement of coal ash at a particular site. Under DEP's mine regulations, monitoring is required up until Stage II bond release, which does not occur until backfill and revegetation is completed. On the average, this is usually several years after the ash work is finished. After completion of Stage II, if any signs of discharge appear, the Stage III of the bond release is initiated which requires further monitoring for five years from the time of revegetation.

FLY ASH GENERATION, USES AND BENEFITS

Approximately 90 million tons of CCW are generated annually by the electric utility industry in the United States. Of the amount generated, approximately 19 million tons are beneficially used, primarily as a Portland cement replacement in concrete and concrete products. The remaining 71 million tons is disposed of in surface impoundments (special purpose, on-site landfills) or commercial landfills. The identification of cost-effective, technically sound, and environmentally responsible programs for the beneficial use, rather than disposal, of these materials has been the goal of many power generating facilities and research and demonstration projects in Pennsylvania and throughout the United States.

Approximately 5 million tons of fly ash is produced by Pennsylvania's cogeneration plants each year. Approximately 90 percent or more of this is used for mine reclamation projects and filling of pits and the reclamation of abandoned coal refuse areas. (See Appendix A.) One reason that Pennsylvania dedicates a much higher percentage to mine reclamation is due to the abundance of coal refuse and the many abandoned mines found within the state. Another 5 percent to 8 percent is used as a replacement for lime for acid mine drainage prevention or as a soil amendment/replacement at mining sites. The remaining 2 percent (approximately) is used for other beneficial uses such as anti-skid for roadways and pipe bedding, and other uses as previously mentioned.

Today the Federal Highway Administration (FHWA) recognizes CCW as a valuable material for utilization in concrete, road sub-bases and structural fills including embankments. In doing so the FHWA has stated, *"The trace element concentrations in many fly ashes are similar to those found in naturally occurring soils. Although the leachates of some fly ashes may contain trace elements that exceed drinking water quality standards, this is also true of certain soils. State environmental regulatory agencies can guide you through applicable test procedures and water quality standards…"*

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What would happen to this material if it were not beneficially used? The material would be landfilled. Landfilling this material, as discussed later in this report (see Economic and Environmental Consequences of a Moratorium), would be cost prohibitive for waste coal facilities and utilities, and would not utilize a valuable mine reclamation material. If ash can be used for other purposes that are publicly and environmentally safe, cost-effective and productive, then the material should be beneficially used. Keep in mind, that 15 of 19 cogeneration plants in the United States are located in Pennsylvania. (See Appendix B and B1.) Much of the reason for that is the abundance of waste coal piles in close proximity to the cogeneration plants. As a result, as mentioned above, 90 percent or more of the ash produced from cogeneration facilities is used for mine reclamation in Pennsylvania. (See Appendix C.) Elsewhere in the nation, currently between 10 percent and 15 percent of the coal ash produced from power plants is used in some type of mine reclamation and another 20 percent goes to other beneficial uses such as asphalt filler, cement sand, anti-skid material and structural fill. Between 65 percent and 70 percent of the ash generated from power plants is landfilled.

REVIEW OF TESTIMONY

The management of Pennsylvania's ash program, its implementation, its history and enforcement brought us to the event of July 9, 2003. The following is a brief summary of the testimony presented at the public hearing in Tamaqua:

Pennsylvania Department of Environmental Resources

The department was represented by **Mr. Jay Scott Roberts, Deputy Secretary of the Office of Mineral Resources Management, and Nicholas A. DiPasquale, Deputy Secretary of the Office of Air, Recycling and Radiation Protection**.

Mr. Roberts testified that Pennsylvania carries the nation's heaviest burden of abandoned coal mines, and an attendant variety of serious health and safety problems, including water-filled pits, dangerous vertical highwalls, open shafts, 800 abandoned coal refuse sites, mountains of coal waste, acid mine drainage and the threat of buildings collapsing into subsidence holes. On average, four persons are killed each year in accidents related to abandoned mine lands. Mr. Roberts estimated a cost of $4.6 billion just to rectify extreme danger and health and safety problems at land reclamation sites and to restore some but not all streams and rivers. Still unaccounted for are the costs of subsidence stabilization and infrastructure replacement. Federal funding from Title IV of the Surface Mining Reclamation and Control Act is the mainstay of reclamation efforts, but that funding amounts to only about $25 million each year.

The department further testified that to supplement inadequate funding, the department has sought innovative programs to encourage private industry to reclaim abandoned mine sites. Coal combustion products, particularly the coal or fly ash produced by the burning of waste coal at cogeneration facilities, has proven effective in reclamation and has been used at about 150 mine reclamation sites in Pennsylvania to help address these problems. Approximately 21 million tons of coal ash are produced annually in Pennsylvania from both coal burning power plants and cogeneration plants. The amount being used beneficially amounts to about 25 percent to 28 percent of the total. Beneficial uses, aside from mine reclamation, include concrete products, asphalt production, construction and anti-skid materials, and grout or structural fill. Because limestone is mixed with waste coal during burning, the ash produced is of an alkaline nature good for remediation of acid mine drainage, in the department's opinion.

Mr. Roberts and Mr. DiPasquale stated that extensive research by state and federal agencies, various universities and the private sector, and years of monitoring data, have found that, "…coal ash, when regulated and used properly, does not pose a threat to the environment or the residents of the Commonwealth." Not all coal ash is appropriate for use in mine reclamation, and before coal ash can be used for that purpose, it must be analyzed and receive a Beneficial Use Ash Certification from DEP. Prior to placing the ash, the department conducts reviews of local hydrogeology to ensure there will be no contamination or pollution of nearby aquifers or groundwater sources. Post-placement sampling is done and the department has accumulated 15 years of groundwater monitoring with no detrimental effects.

The department acknowledged the possibility of adverse impacts in cases where the ash is not properly managed, tested and monitored. The department disputed claims of sites in western Pennsylvania where the placement of ash caused groundwater contamination, saying contamination is due to acid mine drainage that existed prior to remining and reclamation of the sites.

The department's (and other nationally recognized) testing and monitoring data indicated the following:

- coal ash is an effective means to reclaim abandoned mine sites when used properly and closely monitored;

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- use of coal ash eliminates public safety hazards associated with highwalls, subsidence and mine collapses, reduces acid mine drainage, improves water quality and removes the visual blight of historic mining operations.

United States Environmental Protection Agency

Mr. Paul Gotthold, Chief, PA Operations Branch of the U.S. Environmental Protection Agency (EPA) Region III (Philadelphia) made three specific points regarding EPA's stance on the use of coal combustion products.

The first is that EPA has affirmed three times (in 1980, 1993 and 2000) that coal combustion products do not warrant regulation under the federal hazardous waste program. The agency has concluded, however, that regulation of coal combustion products as a non-hazardous waste is warranted.

The second point is that EPA has not confirmed any specific project where placement of coal combustion products in coal mines has caused damage to human health or to the environment. No failures of minefilling projects have been confirmed. EPA is still developing national regulatory guidelines, but does not expect future rules to ban the use of coal combustion products in minefilling, but rather to how best manage and control its use – probably on a case-by-case basis.

The third point is that EPA is allowing states to assess the environmental impacts of minefilling and assessing the states' effectiveness in doing so. In Mr. Gotthold's opinion, Pennsylvania ranks "…at the top tier of states for regulation of these [coal combustion products] issues."

ARIPPA

Ms. Billie Ramsey, Executive Director and General Counsel for ARIPPA, a Pennsylvania trade association comprised of 13 power plants that use coal refuse for fuel presented testimony to the Committee.

Ms. Ramsey summarized the work performed by Pennsylvania's cogeneration circulating fluidized bed (CBF) combustion system plants as follows: ridding the state of coal refuse; emitting NOx at extremely low rates; capturing particulate emissions efficiently in state-of-the-art bag houses; capturing sulfur through limestone injections; and converting an acid bearing material (waste coal) into an alkaline material (coal or fly ash) ideal for use in mine reclamation.

She testified that coal combustion products have been used for mine reclamation since 1988, with no adverse effects on groundwater, well water or surface water.

She testified that a statewide moratorium on the use of fly ash in mine reclamation would hurt Pennsylvania's environment and economy in the coal regions because it would shut down cogeneration plants – putting some 1,000 people out of work (at an average annual wage of $50,000 per employee). As explained in more detail under "Economic and Environmental Consequences of a Moratorium", based on a survey of costs of landfills, forcing cogeneration plants to landfill ash would impose a cost increase equivalent to 75 percent of gross revenues, a blow the industry could not withstand.

A moratorium would also end the reclamation work that cogeneration facilities are doing. That reclamation work includes: removal of 8 million tons of coal refuse each year, reclaiming an average of 240 acres of abandoned mine lands each year, and providing 5 million tons of alkaline ash each year for reclamation at no cost to taxpayers. She challenged moratorium supporters to explain how such a volume of work would be done if a moratorium were imposed.

Pennsylvania State University

The ensuing witness was **Dr. Barry E. Scheetz, Ph.D, Professor, Graduate Materials Program – Materials Research Institute Civil and Environmental Engineering and Mechanical and Nuclear Engineering Departments, at Penn State University (PSU)**.

After describing the peer-reviewed research that he and his students had conducted over the past 10 years into the large-volume utilization of coal combustion by-products, Dr. Scheetz stated that coal combustion by-products should not be considered as a hazardous waste. Dr. Scheetz, who is in his 28th year at PSU, concludes, "I have worked with coal ash in a variety of applications for the past 25+ years and found coal ash to be a useful and valuable material whose many environmental and construction benefits far out strip potential negative connotations that may be attributed to it from rare, isolated examples."

He provided details of a recent project at the "Big Gorilla" site in McAdoo, Schuylkill County, PA, where the addition of fly ash to the mine pool there increased the alkalinity of the deep mine water, lowered levels of aluminum, magnesium, manganese and iron, and, except for sulfate residual content, created water of almost drinking water standards. The Big Gorilla pool was also filled in by cementatious product. He noted that he did not test for PCBs and dioxins

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because they are pre-screened out of the ash under the Commonwealth's screening procedures.

(According to DEP, the Big Gorilla project is basically completed in that the backfilling has eliminated nearly all of the mine pool water. More coal ash, to be performed under DEP's Surface Mine Permit, will be added to reach the approximate original contour. Monitoring will continue and a report on the demonstration project will be prepared.)

Earthtech, Inc.

Mr. Dennis Noll, President of Earthtech, Inc., a consultant to ARIPPA, presented testimony. Mr. Noll is also a Registered Professional Geologist with 15 years experience with coal ash placement.

Mr. Noll described a study his firm prepared in 2000 for ARIPPA that looked at the occurrence and fate of selected trace elements in CBF combustion byproducts. After extensive literature and on-site research at 14 ash-placement sites, the conclusions were that combustion and utilization of fly ash for mine reclamation (versus not disturbing abandoned waste coal piles) "significantly diminishes the risk of environmental pollution" from arsenic, cadmium, chromium, lead, mercury, nickel and selenium. Updating of the study data upholds the validity of the conclusions regarding the trace elements, as well as for additional parameters tested to include pH, acidity, alkalinity, iron, manganese, sulfates, calcium, chloride, copper, magnesium, potassium, zinc, total dissolved solids and total suspended solids and other chemistries.

Mr. Noll also described water testing performed by ARIPPA-member plants from 1987-1999 at the 14 placement sites (854 water samples from 66 sampling sites), where a preponderance of CFB generated ash is placed. Noll related that he had personally visited 10 of the 14 sites and for the others relied on maps, logs and interviews. After noting that the median value of the trace elements listed above in the water from coal refuse areas exceeded the median value found in ash placement areas in every instance except for mercury – which was well below laboratory detection limits in both cases- the conclusion was that there was no negative effect upon Commonwealth waters with respect to both the toxic trace elements and more common mine-related pollutants. Conversely, allowing coal refuse piles to remain undisturbed will continue "the negative effect upon the environment that has led to contamination of the waters of the Commonwealth by the pollutants discussed above."

Mr. Noll theorized that if there were to be negative environmental effects from ash placement at the sites described above, he would be "very surprised" if such effects did not appear in the first 14 years.

Schuylkill Headwaters Association

Testimony was presented by **Mr. William Reichert, president of the Schuylkill Headwaters Association** and a part-time employee of the U.S. Department of Agriculture.

Mr. Reichert testified that studies the association, in conjunction with other agencies, had conducted in 2000 and 2001, identified more than 160 acid mine drainage (AMD) discharges within the headwaters of the Schuylkill River. The assessments won Governor's Awards for Watershed Stewardship.

Based on the organization's studies, its members believe that fly ash used for mine land reclamation is safe and can be beneficial for the environment. Mr. Reichert testified that finding a beneficial use for the ash is "just plain common sense." He noted that 15 years of testing by DEP and plant operators has found no negative impact on the water or the environment.

Mr. Reichert stated that cogeneration plants provide economic activity and employment, waste piles are reduced and backfilling mine pits with fly ash eliminates safety hazards, reduces outflow from mine pools and restores natural beauty.

Mr. Reichert acknowledged fly ash issues regarding dust and truck traffic, but suggested these issues are like any other trucking operation and could be solved by relocating truck traffic patterns and more vigilant dust reduction efforts.

Army for a Clean Environment

The following witnesses were Dante Picciano, who works for the law firm of Bell, Boyd and Lloyd in Chicago and who represents the Army for a Clean Environment (ACE) in Tamaqua, Pennsylvania, and Farley Toothman, an attorney and a Greene County Commissioner.

Mr. Picciano stated ACE's opposition to the following: dumping of hazardous and toxic waste into unlined stripping pits as an excuse for mine reclamation; electric utilities dumping fly ash into stripping pits to reduce expenses and maximize profits; uncontrolled and unproven dumping of fly ash

into stripping pits as an excuse for treating acid mine drainage; mixing and dumping of fly ash with hazardous and toxic waste under the guise of beneficial use.

Mr. Picciano presented letters regarding the plans of the Lehigh Coal and Navigation Company to use cement kiln dust to reclaim a stripping pit, citing and criticizing language that would make it a beneficial use if the dust were to be mixed with fly ash.

Mr. Picciano stated the ACE believes there is a coordinated plan among DEP and the states of New York and New Jersey to dump a "toxic mixture" of fly ash and NY-NJ harbor sludge into stripping pits throughout Pennsylvania, and submitted several pieces of correspondence and press clippings he stated proved the existence of such a plan.

Under questioning, Mr. Picciano at first indicated that he had never said anything about a statewide moratorium on the use of fly ash, but later stated he favored a "…moratorium on dumping fly ash into the water table."

In response to a question about whether he [Mr. Picciano] was not willing to look at any use of fly ash at all in mine reclamation as part of a cost-benefit analysis, Mr. Picciano stated, "No, I would be willing to consider the use of fly ash. If it could be shown to be properly placed under proper conditions, it could be properly used."

While providing no written testimony, Mr. Toothman spoke generally of the impact of coal mining in his home county - Greene County in Southwest Pennsylvania. He acknowledged that Greene County had no fluidized bed power plants and he was not sure if Greene County had the same fly ash as that described as being produced by cogeneration plants.

He spoke of the output of toxic materials from coal burning power plants, suggesting that the industry is improperly regulated.

Geo-Hydro, Inc.

Mr. Charles Norris, Licensed Professional Geologist with Geo-Hydro, Inc., a geologic consulting firm from Denver, Colorado, was the next witness. His appearance was supported by the Clean Air Task Force of Boston and ACE.

Mr. Norris supports a moratorium on coal ash placement in mines and testified that Pennsylvania has moved the use of coal ash from proposal to practice to policy with insufficient evaluation. He further claims that water degradation is "frequently" associated with ash placement in mines in Pennsylvania. He cited four examples: the McDermott site in Cambria County; the "Big Gorilla" in Schuylkill County; the Revloc Refuse Site in Cambria County and the Ernest Mine in Indiana County.

Mr. Norris further claimed that contrary to studies of the beneficial uses of coal ash due to its alkaline nature, coal ash is not effective at abating acid mine drainage, citing the Ernest Mine as evidence. Further, he stated, testing for in-field behavior of fly ash is insufficient, inappropriate and of insufficient duration.

Mr. Norris also called for a moratorium on DEP's General Permit system, which he stated allows for the disposal in non-mine settings of the same or similar ash. He stated that the General Permit system is based on DEP's faulty science in regard to the properties of fly ash.

Under questioning, Mr. Norris stated that he had looked at 10 sites in Pennsylvania without finding evidence of successes in the use of fly ash.

Under further questioning, he acknowledged that he had not conducted any testing on trace elements on any materials or sites in Pennsylvania. The performance criteria Mr. Norris cited came from statutes and regulations as published on DEP's website, through a review of permit documents, and with few exceptions, discussion with DEP staff.

Graphs, charts, and examples accompanied Mr. Norris' testimony.

Clean Air Task Force

The final witness at the hearing was **Mr. Jeffrey Stant, a consultant with the Clean Air Task Force of Boston**. Mr. Stant, whose place of work is Indianapolis, Indiana, provided no written testimony at the hearing.

Mr. Stant testified that there are 17 heavy metals in trace amounts commonly found in coal combustion waste and power plant waste that if not handled properly could do harm.

Mr. Stant presented overhead slides focusing on changes in certain fish species in other states, which he stated were caused by the leaching of fly ash. He cited the Ernest Mine in Pennsylvania, as well as cases in Indiana and New Mexico in which his studies blamed water degradation on fly ash placement.

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He submitted a list of sites, the number of which had varied from 56 when first compiled three years ago to 69 sites presently, that he stated represented cases of contamination from coal ash. He noted differences of opinion on the causes with the EPA.

Under questioning, he noted that some of the problems were caused by improper placement of fly ash.

Mr. Stant concluded that there should be a moratorium on the use of fly ash in mines until there is further review of data and more monitoring, including tissue analysis of populations such as amphibians, clams and fish. He advocated more extensive use of passive treatment projects at mine sites.

ECONOMIC AND ENVIRONMENTAL CONSEQUENCES OF A MORATORIUM

Although the environmental and public health issues of coal ash placement have been addressed, we cannot overlook the economic impact a suggested moratorium would have on the utility industry in Pennsylvania. The issue begs the question, "What would happen to the waste coal industry in Pennsylvania if a moratorium were to be enacted?"

The answer is short and simple. A moratorium, as suggested, would have an immediate and devastating impact on all of Pennsylvania's coal waste facilities. It not only has the potential to result in their immediate closure, in all actuality it would result in their closure. This conclusion is drawn with the understanding that the disposal cost per ton of material at a commercial residual waste facility (landfill) is between $45 and $90, including transportation. These cost figures are based upon a survey of landfill costs. Taking the mid range of cost to be $67.50 per ton, the cost of landfilling 5 million tons of ash produced each year by the Commonwealth's waste coal facilities would be approximately $337.5 million per year. Estimating an internal cost of $5 per ton for using the ash for mine reclamation (an industry accepted figure), the incremental cost to Pennsylvania's coal waste plants would be $312.5 million per year. That is equivalent to approximately 75 percent of the total annual gross revenue of the waste coal facilities. Demanding that such a facility absorb an additional expense of 75 percent or more of its gross revenue is in fact demanding its closure. This would lead to the elimination of more than 1,000 direct jobs with an average salary of $50,000 per year.

The cost of shipping the material to a hazardous waste facility as suggested in testimony would result in even higher costs, and the cost to dispose of the ash in a hazardous waste landfill, as suggested in testimony, would actually exceed the plants' gross revenues.

In a nationwide study of the coal-fired utility industry, consultants Resource Data International, Inc. (RDI) estimate similar impacts. The RDI study estimates that designation of CCW as hazardous waste requiring landfilling would increase annual coal combustion wastes management costs by 60-70 percent. The impact would be even greater, according to the report's estimates, if coal-fired power plants are more fully utilized.

Cogeneration and the independent power producers in Pennsylvania differ from that of the traditional power industry, and this bears some explanation. Cogeneration is a process that uses a single energy source to produce electricity. Traditionally, electricity and heat energy come from separate sources. With cogeneration, heat (in the form of steam) and electric power are produced at the same time. Typically, the steam is used in an industrial process or to heat nearby buildings. Cogeneration is an extremely competitive industry. In Pennsylvania's deregulated electric utility industry, cost increases quickly affect a plant's competitive position. Because coal waste plants must burn a much greater volume of fuel to create BTU's, and create a higher volume of ash, they are more susceptible to cost fluctuations, particularly if required to haul CCW greater distances to landfills. Conventional coal plants, with the much smaller volume of ash, do not face the same landfilling costs as waste coal plants do.

In addition, waste coal plant sizes are generally smaller than conventional coal and gas-fired power plants, but require the same operational oversight. The unique Circulating Fluidized Bed (CFB) boilers are expensive to maintain, and the nature of the coal refuse and the 60 percent rock found in the fuel is abrasive and hard on the machinery, further increasing sensitivity to economic factors.

However cogeneration facilities are not permitted to increase or decrease prices when their facility costs fluctuate. Federal legislation known as the Public Utility Regulatory Policies Act of 1978 (PURPA) created the framework that allowed independent power facilities to be developed. Under this act, cogeneration and other small power production facilities are entitled to sell electricity to utilities at a negotiated price. Utilities purchase this electricity from cogeneration facilities through long-term contracts at a fixed price per kilowatt hour. The contracts typically fix the price for a 20 year period, therefore any cost increases must be absorbed by the facility and cannot be passed on to the rate payer, as with traditional power producers.

The economic benefits associated with waste coal facilities cannot be ignored. For example:

- Capital investments by waste coal facilities in Pennsylvania exceed $4 billion.
- Pennsylvania waste coal facilities have a direct annual payroll of $50 million (1,000 jobs X $50,000 salary).
- More than $57 million is spent each year by these plants for materials, goods and services.
- Approximately $1.9 million is paid in local and school taxes by these facilities.
- Subcontracted jobs by these facilities add approximately $7 million annually to the payrolls of Commonwealth employers.

These benefits would be lost with the issuance of a moratorium, as well as the environmental benefits these facilities provide. These facilities have greatly improved the local environment. Independent power production facilities that use abandoned mine refuse piles as fuel sources are required by the same federal act that governs their prices, to also remediate the abandoned site, implement erosion and sedimentation control measures and improve aesthetics. More importantly, reclamation makes this land available for other uses and suitable for investment in areas where economic development is needed. (See Appendix D, E and F.)

EXPLANATION OF POSITION/CONCLUSION

The final purpose of the Committee's investigation has always been clear, specific and simple – to issue a recommendation regarding a statewide moratorium on the use of fly ash in mine reclamation. The process of reaching a point where a recommendation can be made has been more complex. It has entailed listening to opinions from many different sources, amassing information, clarifying information, sorting out facts, reviewing the facts and using the facts to reach a conclusion.

It is the conclusion of the Committee that a statewide moratorium is not warranted. The Committee makes that recommendation for several reasons, based on facts garnered during the July 9, 2003 public hearing and from the Committee's subsequent follow-up study.

Prominent among the facts is the long-standing and well documented history and proven use of fly ash, particularly here in Pennsylvania. Coupled with that is the well established and comprehensive regulatory program in the Commonwealth. That regulatory program is marked by detailed design and performance standards, monitoring and review requirements. A review of testimony reveals a consistent theme voiced by nearly all of those testifying – proper use and proper placement of fly ash is key to its beneficial use. Unlike some other states, Pennsylvania has an organized and tested system to provide for proper use and placement.

Also part of the history of fly ash use is the positive environmental and economic benefits resulting from the industry which generates the fly ash. Such a record is rare and needs to be preserved. The record of the cogeneration industry includes the removal of 88 million tons of acid bearing coal refuse and countless culm piles from the Pennsylvania landscape, and the reclamation of 3,400 acres of abandoned minelands at no cost to taxpayers (It is estimated that the cost of such actions would otherwise average $11,000 per acre - a cost savings of $37 million.) The industry is also a sizable employer, providing close to 1,000 jobs with annual salaries averaging approximately $50,000, many in former mining areas hard hit by industry declines due to mine abandonment.

The use of fly ash for mine reclamation in Pennsylvania has a 15-year history, without controversy until recently. As a matter of fact, as cited elsewhere in this report, its use in reclamation in other parts of the state has received high praise from community leaders. The call for a statewide moratorium now is puzzling and inconsistent with Pennsylvania's historical use of fly ash.

It begs the question of whether local issues are not a driving force in this situation. Using site-specific issues, such as noise, dust, traffic and fill materials for example, to formulate statewide policy is not good policy. There are local government agencies whose responsibility it is to deal with local issues, working with the appropriate statewide regulatory bodies, in this case DEP. Both need to exercise their respective authority in regard to site-specific concerns.

The Committee is not ignoring and has not ignored the questions raised about the chemical content/composition of certain materials used in minefill projects as pointed out by the Jefferson Action Group, Inc. in supplemental material provided to the committee. That is why the Committee has recommended further independent study. However, given the extensive level of regulation of fly ash in Pennsylvania and its record, merely raising the question does not justify a statewide moratorium on use. Nor does the mere presence of certain materials necessarily differentiate fly ash from any other soil or allow for the presumption of

harm. Once again, regulation is prudent and further study sensible, but a moratorium would be misguided, albeit well intentioned, given the facts.

Further, it is the conclusion of the Committee that the testimony presented and subsequent study by Committee staff have answered the questions posed by those requesting a moratorium. The requests for a moratorium on the use of fly ash for mine reclamation, in effect, seek protection from a danger that does not exist. A moratorium, however, would allow very real dangers – acid mine drainage, dangerous highwalls, water-filled abandoned pits, open mine shafts and the like – to go unremediated and untouched.

The Committee thanks all of the individuals and organizations who testified at the hearing, offered written testimony and comments and otherwise communicated concerns and information to the Committee. The issue addressed in this report is not and should not be misconstrued as an "us versus them" argument. It is a situation that the Committee has sought to approach on a scientific basis, in which facts are drawn upon to reach a conclusion. No doubt, concerns, often passionate ones, continue to exist. The Committee stands ready to work with community leaders to address those concerns and broaden the scope of scientific knowledge regarding fly ash and mine reclamation in an effort to improve the administration of public policy for the Commonwealth of Pennsylvania.

Appendix P

CHAPTER 5. COAL ASH BENEFICIAL USE ON BITUMINOUS MINE SITES

Timothy C. Kania, Joseph M. Tarantino

5.1 INTRODUCTION

Beneficial use of coal ash on bituminous coal mine sites in Pennsylvania is not a new concept and has been practiced for at least 15 years. In 2002 approximately 6,390,000 tons of coal ash were beneficially used on 42 bituminous and anthracite surface mine sites and 5 refuse disposal sites (Dalberto et al., Chapter 1). Several considerations make the recycling of coal ash for use in bituminous mine reclamation a natural fit:

- Coal ash is material that originated on mine sites, although it has been physically and chemically altered through combustion and sometimes through the addition of other materials, such as limestone.
- Some coal ash has chemical and physical characteristics that enhance mine site reclamation.
- Recycling suitable coal ash through mine site beneficial use preserves valuable space at waste disposal sites.
- Coal ash often can be hauled to mine sites by trucks on return trips from power plants, making it an economical form of recycling.

Much of the coal ash currently beneficially used on Pennsylvania surface mine sites is from waste coal power plants using fluidized bed combustion (FBC) technology in which limestone is injected into the boiler with the fuel stream. In 2002 approximately 79 per cent or 5,054,000 tons of the coal ash beneficially used on Pennsylvania coal mine sites was FBC ash (Dalberto et al.,Chapter 1). FBC ash is typically highly alkaline giving it chemical and physical properties, described in Chapter 3, that make it particularly useful in mine reclamation.

Pennsylvania currently defines the following uses of coal ash on active mine sites as beneficial uses: alkaline addition; low permeability material; soil substitute or additive; placement.

Alkaline addition takes advantage of the potential for some coal ashes to generate alkaline leachate and is used to offset the potential for on-site materials to generate acid mine drainage. Brady and Hornberger, (1990), Perry and Brady (1995) and Skousen et al., (2002) have shown in empirical studies of completed mine sites that post mining water quality correlates more strongly with the amount of alkaline material on a mine site than with the amount of sulfur in the rocks. According to Pennsylvania's current guidelines, to qualify for use as an alkaline addition agent the ash should have a neutralization potential (NP) of at least 100 parts per thousand and a pH of between 7.0 and 12.5. (NP and its determination will be discussed in more detail in section 5.2.2.1.) The amount of coal ash needed to offset potential acid production can be calculated using the methods described by Smith and Brady (1998).

Using ash as a low permeability material usually entails sealing or encapsulating materials on site that have the potential to produce acid mine drainage. Potential uses for ash as a low permeability material on a mine site include paving the pit floor, capping material segregated from the rest of the mine spoil due to its potential to generate acid mine drainage (AMD), encapsulating reject material on coal refuse reprocessing operations, and in some cases capping entire sites or significant parts of sites. For use as a low permeability material on a mine site an ash should have significant pozzolanic characteristics and should be capable of achieving a permeability equal to or less than 1.0×10^{-6} cm/sec under laboratory conditions.

As a soil supplement alkaline coal ash can be used as a liming agent and also to improve the physical characteristics of the soil or soil substitute being used as site cover. In some re-mining settings soil is not readily available, especially on coal refuse reprocessing operations, and coal ash can be used to enhance the characteristics of other on-site material to produce an acceptable growth medium.

The term "placement" covers uses of coal ash on a mine site that do not clearly fit into one of the above categories, such as using ash to re-contour pits or refuse piles on re-mining sites. In practice, coal ash use on a bituminous mine site typically fulfills more than one of the above beneficial use criteria. For example, coal ash being returned to a refuse reprocessing site may serve as an alkaline addition agent, an encapsulating agent (capping), and as a soil additive.

An application for use of coal ash on bituminous mine sites must include chemical analyses of the ash proposed for use showing that the ash is not likely to cause water quality degradation. Appendix 5.A includes a copy of the detailed quality analyses required. Analyses performed on a dry-weight basis are required for pH and sixteen metals. An SPLP leachate analyses is required for pH, sulfate, chloride, plus seventeen metals. In addition, results of a neutralization potential test must be provided if the proposed use is for alkaline addition, and a hydraulic conductivity test must be provided when the proposed use is as a low conductivity material.

5.2 CASE STUDIES

The following sites were chosen as examples of various types of applications of coal ash that have been performed on bituminous coal mine sites. They are intended to illustrate some types of situations where coal ash has been used on bituminous mine sites in Pennsylvania. The results from not one of these sites can be applied to the general class of coal ash usage that they represent. These are site-specific results. One of the primary criteria for choosing the sites was that operations had been completed or had at least progressed enough so that monitoring results could be meaningfully interpreted.

5.2.1 Refuse Pile Reclamation—Ebensburg Power Company Revloc Site

Abandoned coal refuse piles, large and small, dot the landscape of Pennsylvania's bituminous coal region. Coal refuse (also known as gob) is the nonmarketable material that was removed from mines along with the coal. Many of the piles occur near old mine mouths or cleaning plants; most, but not all, are associated with deep mines, but surface mined coal that

was cleaned prior to being marketed also contributed to some piles. In addition to the above ground piles, some coal refuse was also historically buried in abandoned surface mine pits. The aboveground piles typically are toxic to any colonizing vegetation and are highly erosive. Often the refuse was deposited in the lowland areas, below mine entries or cleaning facilities, frequently on stream banks, and sometimes directly in the stream channel. Even decades after refuse placement, each significant precipitation event washes fresh refuse onto adjacent properties and into streams. Most coal refuse contains relatively high percentages of sulfur and, therefore, leaches severe quality AMD. Because the oxidation of pyrite is exothermic, some refuse piles catch fire and burn for decades, adding air pollution to the list of problems they create for the small mining communities that often exist next to them. Under today's regulations, refuse disposal sites must be carefully engineered. They usually are constructed with an under drain system so that leachate can be collected and treated; the piles are also carefully compacted to limit infiltration and prevent combustion and are covered with soil, and planted so that they do not erode.

Abandoned coal refuse piles are especially challenging from the abandoned mine land reclamation (AML) standpoint. To put out the fires, the entire pile sometimes has to be reworked. They can be graded, covered with soil and capped, and while that may solve the erosion problems, it typically does not address the acidic leachate problem. Treating the discharges from abandoned refuse piles is especially challenging for two reasons: First, the discharges usually occur at the interface of the pile with original ground, and because the piles often were placed in stream valleys, those discharges often occur at the stream bank, leaving no room for treatment facilities. Second, the leachate from refuse piles often is extremely poor, very expensive to treat with conventional chemical treatment and beyond the effective capability of present passive treatment technology. Even if the discharges can be treated, that does not address polluted groundwater that leaves the site as diffuse flow.

It was the advent of the use of fluidized bed combustion technology to burn bituminous waste coal as a fuel to generate electricity that provided the first hope for full remediation of coal refuse piles, and their associated environmental impacts on a large scale. Coal waste burning plants can burn low-grade fuel of varying sulfur content and relatively low BTU content. Because ground limestone is injected into the boilers to capture air pollutants, the resulting ash is typically very alkaline (pH 11-12) and contains significant $CaCO_3$ equivalency, most in the form of CaO and $Ca(OH)_2$. So, not only are many waste coal piles now a potential fuel source, the ash generated by burning the piles is a material that can be useful in remediating the sites from which the refuse is extracted.

5.2.1.1 Site characterization/ setting

The Ebensburg Power Company Revloc site is located directly east of the village of Revloc and south of highway US 422 in Cambria County, Pennsylvania. The South Branch of Blacklick Creek (South Branch), a tributary of the Conemaugh River, bisects the pile. The South Branch supports a native brook trout population directly upstream of the Revloc pile, but has been virtually devoid of aquatic life below the pile for decades. Refuse in the pile is from the Bethlehem Mines Corporation Mine 32 Lower Kittanning deep mine that operated during the middle decades of the twentieth century. The refuse was placed in a lowland area where an

unnamed tributary entered the South Branch; the refuse actually dammed the South Branch, producing a pond on the upstream side of the pile.

The depth to the deep mine varies from about 350 to nearly 400 feet beneath the Revloc site. Bedrock of the original land surface beneath the pile is of the Glenshaw Formation, Conemaugh Group. None of the coal seams that occur between the base of the pile and the Lower Kittanning coal has been deep mined. The northwest-southeast trending Johnstown syncline lies just to the southeast of the site, so rock strata beneath the site dip gently to the southeast, at about 2 percent. The shallow monitoring wells drilled for this site show that bedrock immediately beneath the site consists of interbedded shales and sandstones. Ebensburg Power Company reported that no groundwater was encountered when the pile itself was drilled during the exploration. (Ebensburg Power Company, 1988). However, the occurrence of persistent seeps at the refuse pile/soil interface indicates at least a thin saturated zone existed at the base of the pile, prior to present operations. The shallow groundwater flow immediately beneath the pile is likely topographically controlled, with fracture flow dominating over diffuse flow, as is usually the case in these strata. Because the pile in its original configuration is porous, has a complex topography, is visibly heterogeneous (fine compacted refuse, lenses of porous-looking red dog and coarse rock, massive, welded red dog bodies) groundwater flow within the pile, both saturated and unsaturated, is likely to be highly complex. The nature of the pile materials and their effects on water flow through them is an important consideration in attempting to interpret monitoring results from sites such as this. One should expect that once a site is disturbed by a reclamation effort, either through re-mining or otherwise, water quality at down-gradient monitoring will likely fluctuate until a substantial part of the reclamation is completed.

Ebensburg Power Company obtained separate mining permits on the northern and southern sections of the Revloc pile, which are separated by the South Branch. The company permitted the larger northern pile under Surface Mining Permit # 11880201 (Revloc 1), which DEP issued in 1989. Revloc 1 contained approximately 3.8 million tons of coal refuse spread over approximately 56 acres. In 1997, the company obtained Surface Mining Permit # 11960202 (Revloc 2), which included 0.7 million tons of coal refuse (Ebensburg Power Company, 1996).

The Revloc 2 site contained primarily reject material from an earlier, unsuccessful reprocessing attempt by another company on the Revloc 1 area; that previous operation had placed its reject on the Revloc 2 area, covered it with a thin soil layer, and planted it. The planting largely failed, the reject caught fire, and the pile developed two small, but extremely poor quality seeps. So, despite its relatively small size, the Revloc 2 site presented some significant environmental liabilities.

Ebensburg Power Company began removing refuse from the Revloc 1 site at the end of 1990 and began bringing ash back to the site in very early 1991, when its 50-megawatt fluidized bed cogeneration facility, located in Ebensburg, PA, went online. Mining began on the northern end of the site adjacent to Route 422 and has advanced toward the southwest on multiple working faces. The company activated the Revloc 2 site in the fall of 1997; excavation on Revloc 2 began on the eastern side of the pile, in the area known to be burning. Thus, the fire

was extinguished early in the operations to end that source of air pollution and to preserve the useable fuel in the pile. The company operates the two piles concurrently as fuel needs warrant.

5.2.1.2 Mine operations

The mining plan for both Revloc sites is similar. The refuse is screened to remove oversized material. The oversized material and already burned material (red dog) is set aside. While only the Revloc 2 site was actively burning when permitted, sections of the Revloc 1 pile had burned in the past. The fine refuse is sent to the power plant for fuel, and ash is trucked back to the site. The ash is mixed, layered and compacted with the oversized reject and the red dog in an area behind the working face. On the Revloc sites, the operator has been removing the refuse material down to original ground, even in areas where the pile has been extensively burned. This practice, which results in virtually all potentially acid-forming material being encapsulated in alkaline ash, insures that there are no coarse–grained pathways for water or air within the reclaimed site. In some areas, soil buried beneath the pile is recovered for use in final site reclamation.

Once an area has been re-graded to its permitted configuration with the ash/reject mixture, a layer of soil typically one foot thick is spread and then seeded. Because of its large size, obtaining enough soil to reclaim the site is a challenge. Soil used to date has come from beneath the pile, from areas adjacent to the Revloc 2 refuse area, and, in the early stages of the operations was purchased from off site. Once the soil is spread, the area is seeded with a grass/legume mixture. A portion of the Revloc 2 site has also been planted in black locust.

Mining operations on the Revloc 1 site are nearing completion, with about one to two years of mining and reclamation to be completed. The Revloc 2 site is about ½ completed as of this writing, but because of its small size, and because it is being mined concurrently with Revloc 1, it too will likely be completed in the next 1 to 2 years.

Figure 5.1 is a photograph of the Revloc 1 site taken from the Revloc 2 site looking toward the village of Revloc to the northwest. The lighter green area in the center of the photo is recently planted area, while the darker green area on the right side of the photo is area that has been planted for at least two years. The dark area on the left of the photo is an area awaiting soil and vegetation. The refuse in the foreground is a yet-to-be-reclaimed area on the Revloc 2 site, and the small tree line at the base of the reclaimed pile marks the location of the South Branch.

5.2.1.3 Monitoring results to date at the Revloc 1 site

Because the Revloc 1 site has been active for ten years, there is a large body of data available from the site. When DEP permitted the Revloc 1 site, the emphasis on ash site monitoring was on monitoring wells, rather than downgradient discharges, so most of the ash monitoring data available for the Revloc 1 site is from three monitoring wells. (The approximate locations of the monitoring points discussed herein are shown on Figure 5.2.) Well MW-1 is a downgradient well, located just off the south-central edge of pile and between the pile and the South Branch. MW-2 is located along the western side of the pile, between the pile and the village of Revloc, and is located upgradient of the site. Well 3 is located along the north central

edge of the pile, between, the pile and US Route 422, and MW-3 is located transverse to the direction of groundwater flow. The shallow groundwater flow direction at the site is from the northwest toward the southeast, from an upland recharge area in and to the north of the village of Revloc toward the discharge area at the South Branch.

Figure 5.1. Photograph of the reclaimed portions of the Revloc 1 refuse site. Note the contrast with Figure 5.2.

The three monitoring wells on the Revloc 1 site were similarly constructed. Each is a 7-7/8-inch hole drilled approximately 60 feet deep, and is cased to the bottom with 4-inch slotted PVC surrounded by clean sand to within 5 feet of the surface. A 1.5-foot bentonite plug sits atop the sand, with a short section of 6-inch steel casing set in concrete finishing off the top of the hole. The steel casing is fitted with a locking cap. The wells are designed to measure water quality in the shallow groundwater system surrounding the site.

Some of the results from the earliest background data at the Revloc 1 site (primarily the data up through mid-1988) are erratic, and the data include sampling dates for which the analyses for individual parameters are not in agreement with one another. For example, acidity/sulfate ratios are not what one would expect, and there is not good agreement between specific conductance and TDS levels; DEP identified the issue during review of the permit application. After split sampling between DEP and Ebensburg Power Company, the company changed its sampling procedures and the laboratory doing the analysis. For that reason the data collected for the Revloc 1 site prior to June of 1988 are not considered valid, were not relied upon during review of the permit application, and are not included in this discussion. However, inclusion of that data would not substantially change the conclusions regarding the site.

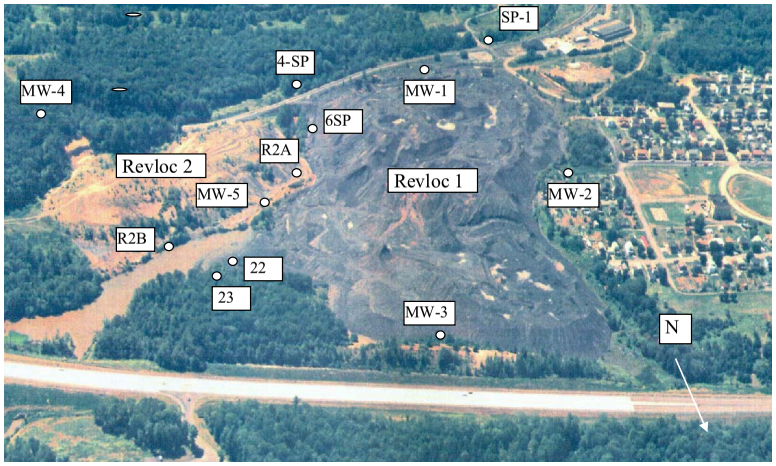

Figure 5.2. Aerial photo circa 1988 showing the Revloc sites and key associated monitoring reports. The photo was obtained from the permit application for Revloc 1.

Water quality results presented in this chapter will sometimes be compared to the maximum contaminant levels (MCL's) for drinking water supplies. This is done because the MCL's are a common benchmark with which many people are familiar. MCL's tend to be conservative to protect human health. Results that exceed an MCL must be considered in terms of cause/effect relationships, the use(s) or lack thereof of the water being tested, the volume of the water if it is a discharge, background conditions that existed prior to the condition being studied, and the overall setting of the project and sample point(s).

Where metals data are discussed in this chapter, they are in terms of total metals; some dissolved metals determinations are available for some parameters, but there are more totals metals data available for review. Where acidity is referred to in this chapter, it is hot acidity.

Data from MW-1, and other monitoring points from the Revloc site discussed herein, are presented in Appendix 5.B. Figure 5.3 displays the historical results for acidity, iron and sulfate, three of the parameters most commonly elevated in mine drainage. The data show that groundwater downgradient of the pile was, not surprisingly, severely degraded by acid mine drainage prior to the Ebensburg Power Company operation. The data show a steady trend of declining concentrations for acidity, iron and sulfate throughout the monitoring period. The decline appears to have begun prior to initiation of Ebensburg Power Company's operations in early 1991. The site had been disturbed by another operation approximately 10 years before Ebensburg Power Company permitted the site; it is possible that some of the earlier declines in

concentrations are due to the natural attenuation of the results of that earlier disturbance of the pile.

Table 5.1 compares the median background values (N=9) for the parameters displayed in Figure 5.3 to the median values nine most recent samples, as of this writing. While water quality in MW-1 continues to show an influence from mine drainage, groundwater quality at the well has markedly improved.

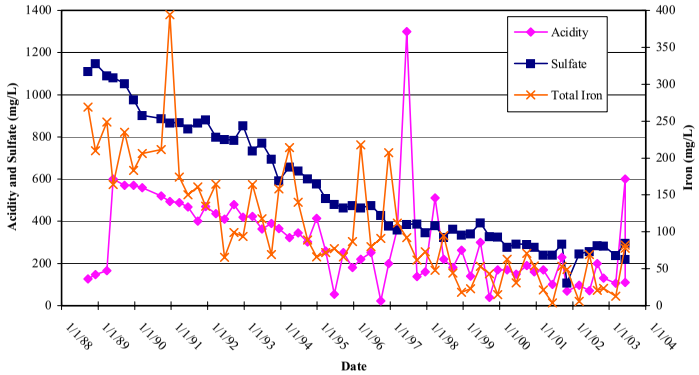

Figure 5.3. Graph of acidity, sulfate and iron at MW-1.

Table 5.1. Comparison of background and recent pollutant concentrations in MW-1.

Revloc 1, MW-1	Acidity (mg/L)	Fe (mg/L)	Mn (mg/L)	Sulfate (mg/L)
Background Median	520	211	18.6	1052
Recent Median	106	23	6.3	257
% Change in Median	-80	-89	-66	-76

The data for MW-1 (Appendix 5.B) show that specific conductance, aluminum, zinc and TDS have declined at MW-1 during the monitoring period, which is consistent with the decline in mine drainage parameters. pH has remained largely unchanged, despite the decrease in acidity and AMD metals. Both calcium and magnesium remain similar to background levels and are relatively low for mine drainage contaminated water; recent samples show Ca concentrations

in the 30 to 40 mg/L range, with Mg concentrations in the 10 to 20 mg/L range. Chloride concentrations may have increased during the monitoring period, but remain below 25 mg/L. Most other metal concentrations remained unchanged during the monitoring period. Chromium, copper, and barium, with an occasional exception, have remained below detection limits, and below the maximum contaminant level (MCL) for drinking water supplies. Cadmium has consistently been below the detection limit, but the limit reported by the laboratory in this case (0.05mg/Ll) is in excess of the MCL. The available data show no trends in lead concentrations; the lab reporting the data has used a relatively high detection limit of 0.1 mg/L.

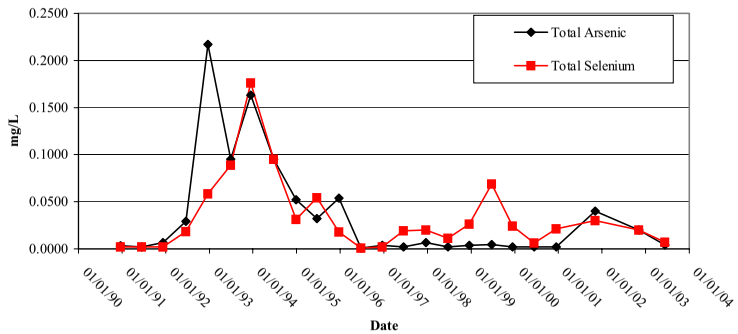

Figure 5.4. Graph of selenium and arsenic concentrations at MW-1.

Arsenic and selenium concentrations in MW-1 increased, beginning in 1992, peaking in 1992 for arsenic and in 1993 for selenium, then returned to background levels by mid-1996 (See Fig. 5.4.) Since 1996, both arsenic and selenium have remained below the MCLs, with the exception of one spike in selenium in 1999. The coal refuse ash is an unlikely source for the elevated arsenic and selenium during the early 1990's for the following reasons: 1) When the increase began, ash had been placed only on the northern end of the site, most distant from MW-1; 2) during the time when selenium and arsenic concentrations were declining from their peak values, then stabilizing, large volumes of ash were being placed directly upgradient of MW-1; 3) the selenium and arsenic data from both MW-2 (clearly upgradient of the site) and MW-3 show similar spikes, although of a lesser magnitude during the same time period as MW-1, suggesting that sampling or laboratory procedures may also have been a factor.

Monitoring well MW-2 is an upgradient well for the Revloc 1 site. The data from it show low TDS water with no mine drainage influence, confirming its upgradient position. The data are generally unchanged with time. The data for MW-2 are provided in Appendix 5.B, but will not be discussed in detail here.

Monitoring well MW-3 is located immediately adjacent to the north-central part of the Revloc 1 site. The available data for MW-3 are included in Appendix 5.B. The permittee reports that MW-3 is a low-volume well from which it is difficult to obtain a clean sample. Water quality in MW-3 has been variable throughout the monitoring period. The initial background samples show some influence from mine drainage, indicating that groundwater at the well was receiving some contamination from the refuse pile. However, for much of the monitoring period the mine drainage influence in the well was slight (sulfate values typically less than 100 mg/L), and at times the well produced very low TDS water (TDS <100 mg/L). Then, beginning in 1998, the acid mine drainage influence in the well increased significantly, only to decline to background levels again during 2003. Even though the location of MW-3 is toward the upgradient end of the pile, because it is located directly adjacent to the pile, it is still at times influenced by contaminated groundwater associated with the pile. The heavy metal concentrations in MW-3 do not show any noticeable trends, with the possible exception of selenium, which may have increased in the 1999 through 2002-time period. Selenium concentrations, however, have remained below the MCL of 0.050 mg/L, and the latest available analysis from a sample collected in June 2003 was below the detection limit of 0.007 mg/L.

The Revloc1 abandoned refuse site was producing six discharges of very poor acid mine drainage leachate, when the site was permitted by Ebensburg Power Company. Data for each of these points, designated 4SP, 4SPA, 4SPB, 6SP, 22SP, and 23SP, are included in Appendix 5.B. The discharges all emanate from the pile in proximity to the South Branch. The most significant of these discharges in terms of both flow volume and pollution load is 4SP, which flows directly into the South Branch from an abandoned railroad grade that forms the southern boundary of the pile. Six samples were collected from discharge 4SP prior to the site being activated by Ebensburg Power Company, however, during the first year of operations, disturbance of the site was limited to the northern end, most distant from 4SP. Therefore, the twelve samples collected from 1991 are included in Table 5.2, which compares the median concentration values of the first 18 samples collected to the most recent 18 samples collected for key acid mine drainage parameters.

Table 5.2. Reduction in flow and concentrations at discharge 4SP.

Discharge 4SP	Flow (gpm)	Acidity (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)
1990-91 Data	31.6	2860	2.23	11.1	435	3820
2002-03 Data	19.2	600	0.80	5.7	17	1221
% Change	-39	-79	-64	-49	-96	-68

Flow and mine drainage pollutant concentrations are both reduced when the earliest data are compared to the most recent data at 4SP. The mine drainage emanating from the Revloc 1 site is characterized by very high acidity and sulfate values, moderate iron concentrations, and very high aluminum concentrations. Some refuse piles leach higher manganese and iron concentrations than does the Revloc 1 site, and the aluminum concentrations at the Revloc 1 site are at the high end of what is typically seen. Figure 5.5 is a graph showing the change in flow and pollution load from 4SP with time. Acid and aluminum loads both have been reduced substantially during the monitoring period. The decline in pollution load is the result of both improved water quality and a decrease in the discharge flow.

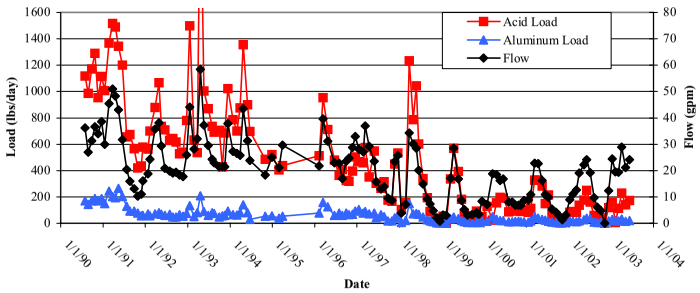

Figure 5.5. Flow, acid load and aluminum load at discharge 4SP.

The monitoring data for discharges 4SPA and 4SPB show similar reductions in both flow and pollutant concentrations and load to those observed at 4SP. In the case of 4SPB, the reductions are due more to a reduction in concentrations than flow. 4SPA and 4SPB are located in the same general area of the site as 4SP.

Discharge 6SP was located along the southeastern portion of the pile; it was eliminated by the operation in 1998, removing its pollution load from the site.

Seeps 22SP and 23SP were the smallest of the discharges emanating from the Revloc 1 site and they occur along the east-central edge of the pile. Water monitoring data for these two points are shown in Appendix 5.B. While concentrations for some parameters have increased at 22SP, pollution loading has decreased due to a reduction in flow. At 23SP both concentrations and loading have increased for some parameters, but the increases are dwarfed by the decreases seen at the larger discharge points. Table 5.3 summarizes the flow and pollution load data for the seeps at the Revloc 1 refuse pile.

When the median values of the first two years of monitoring data are compared to the median values of the last two years of data (Table 5.3), the pollutant load reductions to the South Branch Blacklick Creek from the discharges downgradient of the Revloc site are: 1935 lbs/day of acidity; 283 lbs/day of aluminum; 3675 lbs/day sulfate; lesser amounts of other pollutants. These values show only the decrease in pollutant load in terms of the measurable discharges from the site; additional reductions in pollutant loads in terms of direct groundwater baseflow to the stream are also likely occurring.

Table 5.3. Summary of flow and AMD pollutant load data for the discharges from the Revloc 1 site. Background data were collected in 1990-1991 and recent data were collected in 2002 to mid 2003. N=18 for most of the background and recent data sets. Flows are in gpm and loads are in lbs/day.

	Totals	4SP	4SPA	4SPB	6SP	22SP	23SP
Background Flow	67.8	31.6	13	17	2.7	2.9	0.6
Recent Flow	38.4	19.2	2.6	15.3	0	0.4	0.9
Background Acid Load	2137.7	1060	578	430.9	62.2	6.4	0.2
Recent Acid Load	203.4	116	28	58.3	0	0.7	0.4
Background AL Load	312.5	168.8	83.9	51.9	7.2	0.7	0.01
Recent AL Load	29.9	17.1	5	7.7	0	0.1	0.06
Background Fe Load	3.4	0.89	0.4	2	0.1	0	0.01
Recent Fe Load	0.45	0.15	0	0.3	0	0	0
Background Mn Load	8.61	4.1	2	2	0.3	0.2	0.01
Recent Mn Load	2.24	0.99	0.2	0.9	0	0.1	0.05
Background SO4 Load	5084	1406	724	2854	87	12.4	0.4
Recent SO4 Load	1409	260	51	1091	0	4.1	3.1

5.2.1.4 Monitoring results to date at the Revloc 2 site

The Revloc 2 site, located directly across the South Branch from the Revloc 1 site, has four ash monitoring points associated with it. They are: MW-4, an upgradient well; MW-5 a downgradient well; R2A, a down-gradient discharge; R2B, a downgradient discharge. Monitoring data for all four of these points are included in Appendix 5.B.

The upgradient well is located on the hilltop to the south of the site, and the water quality shows it to be unaffected by mine drainage. The data also show that the water quality at MW-4 has not been affected by the Ebensburg Power operation. MW-4 does show chloride concentrations higher than what may be expected, as high as 175 mg/L. MW-4 is located within 500 feet of an interchange for US Route 219, and road salt may explain the relatively high chloride concentrations in the well.

MW-5 is located between the Revloc 2 site and the South Branch along the north-central edge of the pile. Background data on MW-5 show that it was affected by mine drainage from the pile prior to Ebensburg Power Company's operation. The data also show that water quality in MW-5 has improved, since the well was established to the point where it is now uncontaminated. The change in water quality at MW-5 began before Ebensburg Power Company had substantially affected the Revloc 2 site, so factors other than the re-mining and reclamation, possibly site preparation work and well construction and purging techniques, apparently have contributed to the improvement in the water quality at MW-5. The data for MW-5 show no trends in terms of any toxic metals, while Ca and Mg have decreased.

Discharge R2B is located directly downgradient of an area of the Revloc 2 site that has been mined and partially reclaimed. R2B was low-flow, with extremely poor acid mine drainage

quality prior to Ebensburg Power Company's operations. As re-mining and reclamation of the area upgradient of R2B has progressed, the water quality at the point has improved. Acidity values have fallen from several hundred mg/L, and higher, to 0 in recent samples, while concentrations of metals typically found in mine drainage have also declined. pH has risen, while sulfate values have declined. Calcium, potassium, sodium, and chloride levels have increased. Among the toxic metals, copper, lead, and zinc concentrations appear to have declined, while selenium concentrations appear to have increased. For the years 1998 through 2002, selenium concentrations were elevated when compared to background data.

Discharge R2A is located along the northern edge of the Revloc 2 site, downgradient of an area where re-mining and reclamation are, as of this writing, in progress. The background data from this point show it to be of very poor acid mine drainage quality. While the discharge remains contaminated with mine drainage, the quality has improved in terms of acid mine drainage contamination over the past two years and flows have decreased. For example, the median acidity concentration of the first 12 samples collected was 2600 mg/L while the median acidity concentration of the last 12 samples was 1900 mg/L; the flows also appear to have declined with the median value for the first 12 samples being 12.4 gpm and the median flow of the last 12 samples being 6.1 gpm. Calcium and pH levels may have increased in R2A during the past two years. Magnesium concentrations have been as high as 580 mg/L at R2A. The quality at R2A is representative of very concentrated AMD leachate from the Revloc 2 pile. The concentrations of some heavy metals in R2A are relatively high. For example, arsenic concentrations exceeded the MCL during every sampling event, except for June 10, 2003, and have been as high as 0.67 mg/L. Lead concentrations have typically exceeded the MCL, and chromium, copper, and cadmium have also done so on occasion; the results for each of these heavy metals is variable without any clear trends. The elevated toxic metal concentration in R2A existed prior to Ebensburg Power Company's operation and illustrates that severe bituminous coal AMD, especially from coal refuse piles, can include significant toxic metal concentrations. Zinc concentrations at R2A have increased during the sampling period. Selenium concentrations at R2A have been highly variable, were less than detection limits during the background-sampling period, exceeded the MCL of 0.050 mg/L during much of the monitoring period, but returned to less than the MCL during 2002 and 2003. Table 5.4 presents a summary of the monitoring data on R2A and R2B for AMD parameters.

Sampling Point SP-1 is located on the South Branch below the Revloc 1 and Revloc 2 sites. This point is influenced by the direct discharges and groundwater baseflow from the piles into the stream. Monitoring data for SP-1 are available in Appendix 5.2. Table 5.5 compares the data in terms of median values collected from SP-1 prior to 1992 (N=14) to the 14 most recent samples at the time of this writing.

Table 5.4. Summary of flow and AMD pollutant load data from the Revloc 2 site discharges. Background data were collected from April 1996 through March 1997 (N = 12), and recent data were collected from June 2002 through June 2003 (N = 12). Flows are in gpm and loads are in lbs/day.

Parameter	Total	R2A	R2B
Background Flow	14.6	12.4	2.2
Recent Flow	6.14	6.1	0.04
Background Acid Load	298.2	281	17.2
Recent Acid Load	106	106	0
Background Iron Load	5.3	5	0.3
Recent Iron Load	0.05	0.05	0
Background Mn Load	7.2	6.5	0.7
Recent Mn Load	2.4	2.4	0
Background Al Load	47.7	45.9	1.8
Recent Al Load	16.6	16.6	0
Background SO4 Load	839	777	62
Recent SO4 Load	206	204	2.4

Table 5.5. Comparison of background median flow and mine drainage pollutant concentrations at SP-1, the monitoring point on the South Branch directly down stream of the Revloc 1 and 2 sites.

	Flow (gpm)	pH (su)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	Sulfate (mg/L)
1988-91 Data	3261	4.30	134	1.61	1.03	21.0	191
2000-03 Data	2427	5.55	16	0.50	0.55	1.50	73

Figure 5.6 shows graphically the reductions in aluminum, acidity and sulfate at SP-1, when the background data medians are compared to the most recent data medians.

The data from SP-1 show the improvement to date in terms of mine drainage pollution in the South Branch that has resulted directly from the Ebensburg Power Company operations at the two Revloc sites. Note especially the reduction in aluminum and acidity concentrations along with the increase in pH. During times of low flow, the stream still experiences spikes in pollutant concentrations, but that condition should only improve as re-mining and reclamation continues.

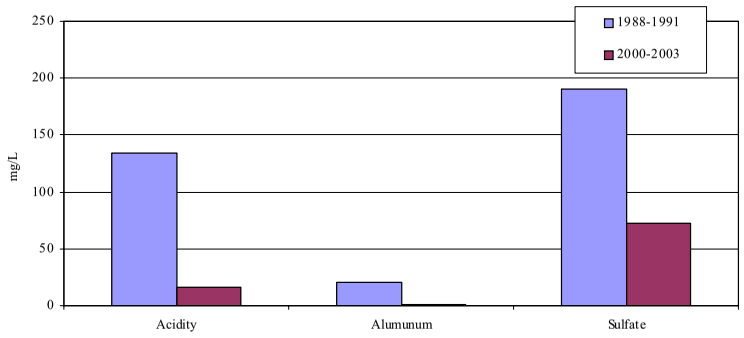

Figure 5.6. Comparison of background and recent median acidity, aluminum and sulfate concentrations at monitoring point SP-1, downstream of the Revloc sites.

While most toxic metal concentrations at the Revloc sites show no change or some decrease, selenium concentrations have increased at some points. Figure 5.7 shows the available selenium concentrations for downgradient ash monitoring points at the Revloc sites. Selenium concentrations at the upgradient points, MW-2 and MW-4 (not included in Fig. 5.7) show no increase during the monitoring period and have been consistently low.

Selenium concentrations at wells MW-1 and MW-3 at the Revloc 1 site have generally been higher than background, and on occasion have exceeded the MCL of 0.05 mg/L, although not since 1999. MW-2 is not shown in Figure 5.7, since selenium concentrations are of a lesser magnitude, but the MW-2 data do show a spike in selenium in 1993-1994 that suggests the elevated selenium shown in MW-1 and MW-3 in that time period may be, in part, related to sampling/laboratory considerations. This conclusion is based on MW-2 being clearly up gradient of the Revloc site and showing no other signs of influence from the pile. The highest selenium values are at R2A and R2B, seeps downgradient of the Revloc 2 site. Both of these points are low volume, and at times intermittent, with the median flow of the last 12 samples from R2B being 0.04 gpm and the median flow of the last 12 samples from R2A being 6.1gpm. Areas upgradient of R2A and R2B were disturbed early in the mining on the Revloc 2 site, in part to accommodate extinguishing the on-site fire. Some areas where ash and refuse reject have been placed above those points remain exposed and unvegetated. It seems likely the elevated selenium in these points is related to the exposed ash/refuse mixture on the surface, which is flushed with each runoff event. Once reclamation of this area is completed, it is reasonable to expect that water quality at the two points will further improve, including a reduction in selenium concentrations. MW-5 is located between R2A and R2B and also appears to be influenced, but to a lesser degree. While selenium concentrations are clearly elevated at R2B and R2A, it is important to view these data in light of the low flows from these points; while concentrations are relatively high, the amounts of selenium discharging at these points are low. Samples collected

by DEP on December 1, 2003 and on February 18, 2004 at SP-1, directly down stream from the Revloc sites, showed a selenium concentration below the detection limit of 0.007 mg/L; copper, chromium, arsenic, mercury, lead, and nickel also were all below detection limits at SP-1 on those dates.

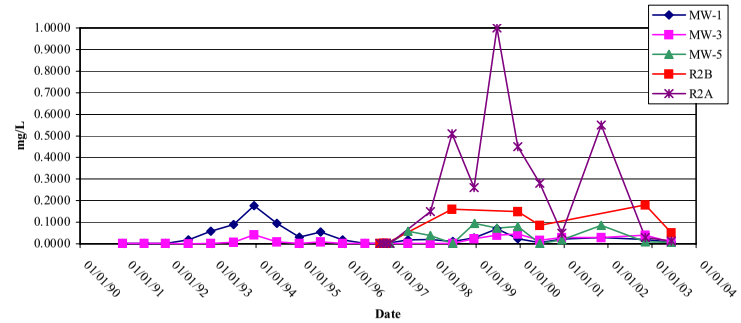

Figure 5.7. Selenium concentrations at downgradient ash monitoring points at the Revloc sites.

5.2.1.5 Conclusions regarding the Revloc site

- Pollution loads have decreased at the 4 largest seeps from the Revloc 1 site (4SP, 4SPA, 4SPB, and 6SP); loading has increased somewhat at the smallest seep (site 23), but the net change has been a clear decrease in pollution loading from the site discharges.

- Groundwater quality at the downgradient well, MW-1, for the Revloc 1 site has improved; water quality at the upgradient well MW-2 remains unchanged; quality at MW-3 also upgradient, but located at the base of the pile has been variable, and presently shows an influence from acid mine drainage.

- Groundwater at the downgradient monitoring well, MW-5, at the Revloc 2 site has improved, but the timing of the changes suggest factors other than re-mining and reclamation are responsible. Quality at the upgradient well, MW-4, remains unchanged.

- Data collected from the two seeps from Revloc 2, R2A and R2B, show that the abandoned coal refuse at the Revloc site leaches worst-case acid mine drainage that also includes metals such as arsenic, lead, and sometimes chromium, cadmium, and copper in excess of the respective MCL's for those parameters. This condition, including the occurrence of some heavy metals well in excess of their respective MCL's, existed prior

to the Ebensburg Power Company operation, and the abandoned coal refuse is the source for those metals.

- Seep R2B has improved substantially in quality and declined in flow as a result of re-mining and reclamation on the Revloc 2 pile. Seep R2A has improved to a lesser degree, but has also decreased in flow as a result of re-mining and reclamation conducted upgradient of it. Reclamation is not completed upgradient of either of these two points. Most heavy metal concentrations appear to have declined at R2B, and remain relatively unchanged to this point at R2A.

- Taken collectively, the Revloc data indicate that selenium is one parameter for which concentrations may have increased as a result of the re-mining and reclamation with ash. Selenium at downgradient wells MW-1 and MW-5 is slightly elevated relative to background concentrations, although selenium has been below the MCL at MW-1 for the past three years and at MW-5 for the past two years. Selenium concentrations at R2B have been elevated relative to background and have consistently exceeded the MCL. Selenium concentrations at R2A have been highly variable, and for the past two years have been less than the MCL. R2A and R2B are both low volume seeps. Two recent downstream samples at SP1 show a selenium concentration of <0.007 mg/l. Selenium concentrations at R2A and R2B will likely decline with final reclamation of the upgradient areas, and monitoring of these points will continue.

- The major mechanism for decrease of mine drainage at Revloc 1 appears to be the removal of the marketable coal refuse and encapsulation of the remaining reject in the compacted FBC ash rather than the neutralization of mine drainage by alkaline leachate from the ash. This conclusion is supported by: 1) pH has remained low, while acidity and sulfate, as well as other mine drainage parameters, have declined at MW-1 and the larger of the pile discharges; 2) the flows of the primary discharge points at both the Revloc 1 and 2 sites have decreased, indicating that, as expected, the permeability of the areas reclaimed is less than that of the abandoned coal refuse.

- At point R2B at Revloc 2, pH, calcium and potassium have increased, while acid mine drainage parameters and manganese have decreased, indicating that alkaline leachate from the ash is having some influence on that point. Some of the same influence, although less pronounced, can be seen at R2A. R2A and R2B are subject to direct runoff from partially reclaimed areas where the ash/refuse mixture is exposed at the surface. Reclamation of areas directly upgradient of these seepages is not yet completed, so the final effects of reclamation and ash placement cannot be judged, although the results thus far are encouraging.

- Re-mining and reclamation of the Revloc sites using coal refuse ash has substantially improved the quality of the South Branch Blacklick Creek by reducing the concentration of acid mine drainage parameters in the stream. There are no other sources AMD to the stream up stream of the Revloc sites, and no other mechanism that would account for the pollution reduction in the stream.

5.2.2 Alkaline Addition to Surface Mine Overburden--Laurel Land Development, Inc. McDermott Site

As mentioned in section 5.1, the amount of calcium carbonate in the overburden of a surface mine site has been shown to be the primary factor determining if the site produces acidic or alkaline drainage, more so than the amount of sulfur in the overburden. For this reason, importing alkaline material onto mine sites with alkaline deficient overburden has often been seen as a potential way to make otherwise unmineable sites permitable. However, Pennsylvania's experience with alkaline addition has yielded, at best, mixed results, with several alkaline addition sites having unexpectedly produced substandard water quality, especially during the early years of alkaline addition (Smith and Brady 1998; Brady and Hornberger, 1990). Some of the reasons include difficulty in determining how much alkaline addition is enough, determining the best application methods, and the reality that the cost of importing enough alkaline material frequently exceeds the profitability of the job. Pennsylvania's current approach to alkaline addition on surface mines is described in Technical Guidance Document 563-2112-217 available on DEP's website.

5.2.2.1 Site characterization /setting

The McDermott Mine is located in Jackson Township, Cambria County, PA, just to the north of US Route 22, and just east of the summit of Laurel Ridge. The site has previously been described by Kania (1998) and by Schueck et al., (2001), however, mining was on going during both of those investigations, which, thus were preliminary. In the initial submission and through subsequent permit amendments, mining was proposed on 26.5 acres of Lower Kittanning Coal (LK), 32.1 acres of Middle Kittanning Coal (MK) and 8.6 acres of Upper Kittanning (UK) Coal (Laurel Land Development, SMP# 11950102, 1995). The operator also proposed to remove shale and sandstone (Worthington) from the operation. Little shale was removed, but an unknown tonnage of sandstone was removed, processed, and marketed as aggregate.

In the area of this site, the LK and MK overburden rocks are generally brackish water deposits. Channel sandstone deposits frequently exist within a framework of finer grained sediments such as shales and mudstones. Usually the only significant zone rich in carbonates is the Johnstown limestone horizon (freshwater), which is located at or a few feet below the bottom of the UK coal. The shale units, especially those that directly overlie the LK and MK coals frequently include significant amounts of sulfide minerals. With the lack of carbonates in the overburden and the high-sulfur shales located around the coals, one would expect that LK and MK mining might produce poor quality water, although the role of the Johnstown limestone has to be considered in that conclusion.

Surface and deep mining on the LK and MK seams in the area of the McDermott Mine generally has resulted in acid mine drainage. Because of its persistence, thickness and quality, the LK seam has been extensively deep mined, so is generally available for surface mining under thinner overburden. The MK seam, while usually of good quality, is usually not thick enough for deep mining and often occurs in multiple benches. Surface mining on these seams, therefore, often cannot take place to a high enough overburden to encounter much, if any, of the Johnstown

Limestone. While the overburden quality for these seams can be problematic, the previous mining that has occurred and the resultant unreclaimed spoil, deep mines and discharges present re-mining opportunities at appropriate locations with appropriate mining plans.

The exploratory data on the McDermott site show that over most of the site, the LK coal is directly overlain by a shale unit of 0 to12 feet thick. Above that is sandstone, which in places cuts down to the top of the coal. There is a thin clay layer beneath the MK coal. The MK overburden over most of the site is shale with minor sandstone units in places. The Johnstown limestone is not present on the site, but at the horizon where it would be expected, there is a shale unit that contains significant amounts of carbonate. Unfortunately, the high-carbonate shale exists in an unweathered state only at the highest cover, and only a limited amount of it became part of the mine spoil on this site. The UK coal was encountered only incidentally to the MK mining. The McDermott site is located near the crest of the eastern flank of the Laurel Ridge Anticline, and strata on the site dip shallowly to the northeast.

The McDermott Mine included a proposal to daylight some of the abandoned deep mines, and to reclaim old spoil and an abandoned highwall on the site. The mining plan also proposed alkaline addition in the form of FBC ash from two power plants located in Cambria County, which burn coal refuse to generate electricity (Laurel Land Development, SMP# 11950102, 1995).

Mining previous to the McDermott operation had degraded the headwater areas of the receiving stream, Hinckston Run, a tributary of the Conemaugh River. However, Hinckston Run does improve enough approximately 4 to 5 miles downstream to allow for stocking of brook trout, and some limited trout reproduction.

The permittee performed an acid-base account overburden analysis as part of the pre-permit requirements. Researchers in West Virginia began applying acid-base accounting results to coal mine overburden during the 1970's (Skousen et al., 1990). Interpretation of acid-base account data is complex, partially subjective, evolving, and dependant on the experience level of the interpreter. The approaches to interpreting acid-base account data currently used by Pennsylvania DEP permit reviewers are described in Brady et al., (1994), Perry and Brady (1995), and Perry (1998).

Acid-base accounting is intended to measure the potential of the disturbed rock to generate both acidity and alkalinity. The maximum potential acidity (MPA) is determined stoichiometrically from percent sulfur in the rock. The rock's ability to neutralize acid is measured in the laboratory and is termed neutralization potential (NP). NP and MPA are reported in terms of tons $CaCO_3$ per 1000 tons of material (or parts per thousand, ppt). Sites are frequently characterized in terms of net NP (NNP=NP-MPA). Site-wide NNP is one of the more effective ways to evaluate acid-base account data (Perry and Brady, 1995; Skousen et al., 2002). These terms can be used to characterize a single rock horizon, a drill hole, an entire mine site, or parts thereof. Pennsylvania experience has shown that strata with NPs < 30 ppt $CaCO_3$, or NPs without a fizz (does not effervesce with 25% HCl) are typically not significant alkalinity producers. Likewise, strata with percent sulfur less than 0.5 are not generally significant producers of acidity. An approach sometimes taken is to evaluate the ABA data by including

only those strata greater than these "thresholds" in the calculations (Brady and Hornberger, 1990). This is the approach that was taken here. Overburden data summaries referenced in this chapter were derived using a computer spreadsheet program (Smith and Brady, 1990).

Based on the mining plan submitted in the permit application, DEP interpreted the data to show an average site-wide $CaCO_3$ deficiency (i.e., a prevalence of potential acid producing material over potential alkaline producing material) of approximately –320 tons/acre and a net neutralization potential (NNP) of -3.07 tons calcium carbonate equivalence per 1000 tons of overburden. Sites with an NNP of less than zero have a high probability of producing acid water. (There are exceptions, such as low-cover sites in settings otherwise unlikely to create AMD (Perry and Brady, 1995).) For this study, the overburden data for the site were re-evaluated in light of how the site was actually mined; for example, more LK coal was mined, and thus more LK overburden was disturbed on the site than proposed. The recalculation shows a site-wide deficiency of –418 tons/acre and a NNP of –2.98 tons/1000 tons. The NNP (tons/1000 tons) is essentially unchanged by the recalculation, despite the increase in the tons per acre deficiency, because the total tons of overburden disturbed also increased with the recalculation. The recalculated site overburden data are summarized in the first row of Table 5.6.

Initially, the proposed ash (from the Interpower-Ahlcon plant at Colver, PA) had a neutralization potential (NP) of about 200 tons/1000 tons (ppt). The proposed ash addition rate was 2160 tons per acre averaged over the site, which equates to approximately to 500 tons of calcium carbonate addition per acre. During a later permit revision (December of 1997) the ash addition rate was increased to 3200 tons per acre. Also, the source of the ash was changed to the Cambria Reclamation Plant in Ebensburg (average NP 174 tons/1000 tons). The operator further increased the rate of ash application as mining progressed, due, in part, to emerging water quality problems on site. The ash was to be added to the pit floor, mixed with the spoil, and added to special-handled material at different rates for each coal seam being mined. In some areas ash was added to the surface prior to spreading topsoil. Records show that 28,775 tons of Colver power plant ash were used on the site, and 288,155 tons of Cambria Reclamation ash were applied. The total tons of ash added to the site were 316,930. Weight averaging the two different ashes results in the conclusion that the ash put on the site had the calcium carbonate equivalence of approximately 56,000 tons of pure calcium carbonate. The operator removed coal from approximately 48 surface acres, so ash was applied at approximately 6,600 tons per acre, which is theoretically equivalent to about 1,165 tons per acre of pure limestone. The material was not evenly distributed over the site, however. Areas mined early in the operation received substantially less ash than areas mined later in the operation, and the operator placed a large amount of ash in the west-central part of the site after final coal removal. The second row of table 5.6 summarizes the site overburden with the alkaline ash addition factored in.

Table 5.6. Summary of overburden analysis data for the Laurel Land Development McDermott site.

McDermott Site OBA	MPA (tons)	NP (tons)	Available NP (tons/acre)	NNP (tons/1000 tons)	NP/MPA Ratio
Raw Overburden	31679	11574	-419	-2.98	0.37
With Alkaline Addition	31679	67497	746	5.31	2.13

5.2.2.2 Mine operations

The McDermott permit was issued in January of 1996 and activated in April of that year. The site was mined primarily with a combination of a dragline and dozers. As is sometimes the case with dragline operations, spoil material was exposed to weathering in an un-graded state for extended periods. Mining began in the north-central part of the mine site, advanced first to the north, and then to the south. The higher cover portions of the job in the west-central part of the site were mined last. Toward the end of the operation, reclamation slowed considerably, and the operator eventually abandoned the site, leaving it partially unreclaimed, the state in which it currently remains.

5.2.2.3 Monitoring results to date at the McDermott Site

Soon after mining began, so did water quality problems. Mining had started in the north-central part of the permit application along the Lower Kittanning cropline. The nearest downgradient monitoring points to that location are a well, MW-2 and a spring, MD-12. Water monitoring data for the McDermott site monitoring points are presented in Appendix 5.C. Monitoring point locations relative to the McDermott site are shown in Figure 5.8.

Figure 5.9 displays the results for some standard mine drainage parameters at MD-12. While the data are highly variable, sulfate, acidity, iron, and manganese clearly increased soon after mining began upgradient of the point. Other parameters such as calcium, magnesium, and chloride increased also. Among the heavy metals, zinc and nickel (typically associated with AMD) increased somewhat. Copper spiked during late 1996 through 1999, but has been near background levels for the past four years, and remained well below the MCL at all times. Lead concentrations showed a similar spike, and frequently exceeded the MCL of 0.015 mg/L from 1997 into early 1999, but have since declined to below the MCL. (Lead concentrations at the monitoring points for the McDermott site will be discussed in more detail later in this chapter.)

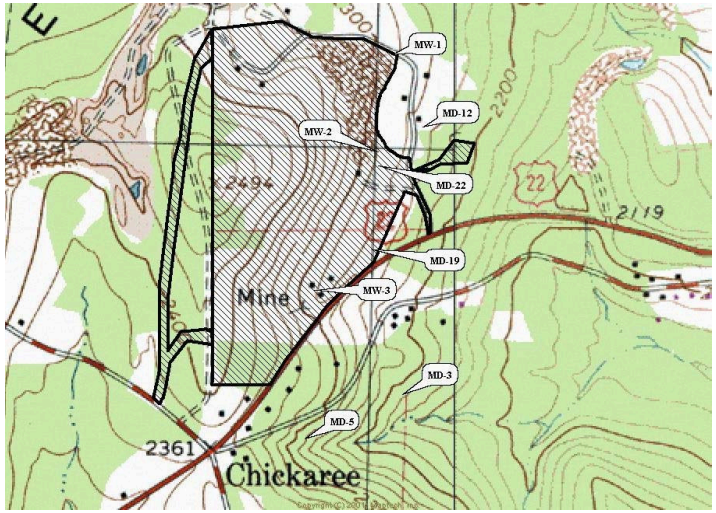

Figure 5.8. Map showing the locations of the McDermott Mine monitoring points.

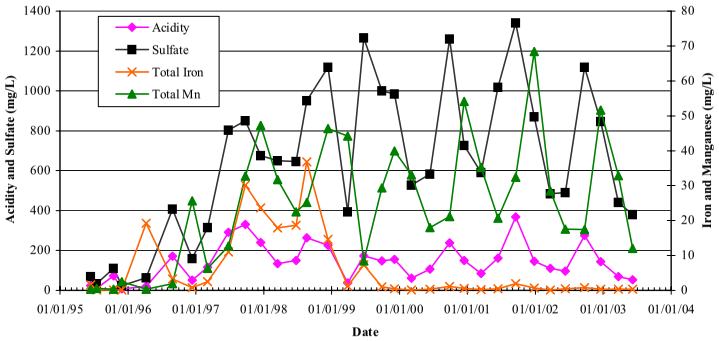

Figure 5.9. Mine drainage parameters at spring MD-12.

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Monitoring well MW-2 is one of three monitoring wells placed downgradient of the McDermott site to monitor the results of the re-mining and ash placement effort. Each of these wells is drilled down slope of the LK cropline into the Kittanning sandstone formation. Monitoring well MW-2 showed similar results to those at MD-12. Shortly after mining began, mine drainage parameters began to increase (Fig. 5.10). Calcium, magnesium and chloride increased. Copper increased, although it remained well below the MCL of 1.3 mg/L. Nickel and zinc increased somewhat. As was the case with MD-12, lead concentrations also increased at MW-2, peaking in 1997 at around 0.08 mg/L and declining since.

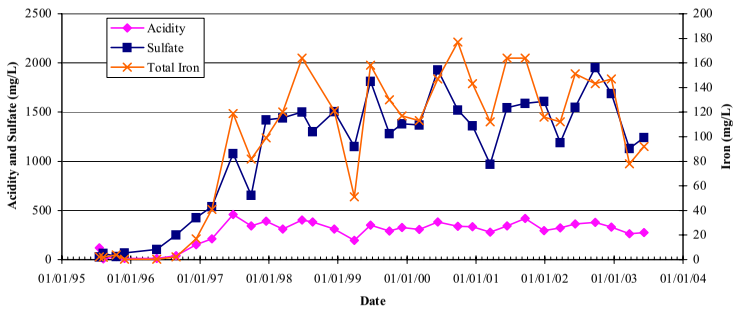

Figure 5.10. Acidity, sulfate and iron at MW-2.

Monitoring well MW-1 is located along the northeastern corner of the McDermott site and is located downgradient of area mined on the McDermott Mine. MW-1 is also located directly downgradient of an area of abandoned mine lands that had been mined prior to the McDermott site. The McDermott Mine reclaimed the abandoned highwall that had been left by the pre-law operation. The monitoring data show that MW-1 was affected by mine drainage by the abandoned mine lands prior to the initiation of the McDermott operation. The data also show that mining on the McDermott site further affected the water quality at MW-1. Figure 5.11 shows the monitoring results for MW-1 for acidity, iron and sulfate.

The McDermott Mine affected areas upgradient of MW-1 early in the operation, during 1996, and the influence on the well in terms of increasing sulfate can be seen as early as the beginning of 1997. Note in figure 5.11 that sulfate increased, while acidity did not. This could be explained either by attributing the increased sulfate to the coal ash, or by an increase in acid mine drainage production, which is being neutralized by the ash.

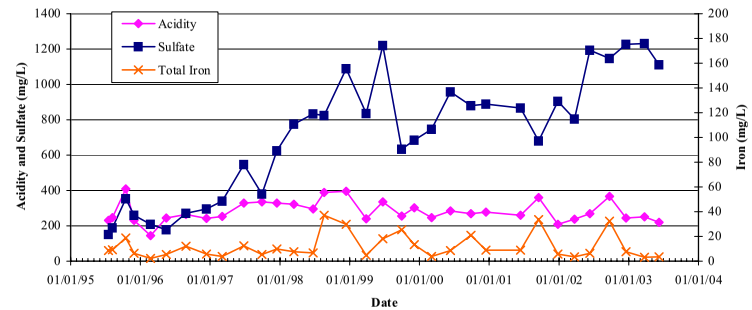

Figure 5.11. Acidity, sulfate and iron at MW-1.

Figure 5.12 shows the sampling results at MW-1 for calcium, magnesium, aluminum, and manganese. The McDermott operation clearly caused an increase in manganese in MW-2, with concentrations increasing about 4 times from near 5 mg/L to near 20 mg/L. The increase in manganese confirms an increase in acid mine drainage production as a result of the disturbance of the site overburden. The increase in manganese concentrations, without an increase in acidity, suggests that the additional mine drainage being produced is being neutralized by the ash. The increase in sulfates could be due to either an increase in pyrite oxidation, dissolution of the ash, which in laboratory tests leaches elevated sulfates, or, most likely a combination of both.

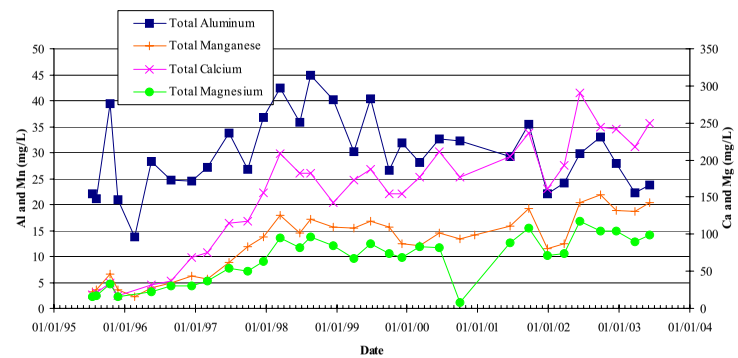

Figure 5.12. Calcium, magnesium, aluminum, and manganese at MW-1.

Calcium and magnesium levels also have increased in MW-2. Aluminum concentrations were elevated prior to the McDermott operation and remain unchanged. Nickel and zinc concentrations at MW-2, although not particularly high have increased somewhat, also suggesting an increase in mine drainage, which is then being neutralized. pH has remained constant in the low 3's. Lead concentrations did not show an increase in MW-1 as they did in MW-2 and MD-12, however, they were relatively elevated in MW-2 in the background and frequently exceeded the MCL throughout the monitoring period, including before the McDermott Mine affected the area.

Monitoring well MW-3 is located along the southeastern edge of the McDermott site. Mining and ash placement did not advance to areas upgradient of MW-3 until mid-1998. Shortly thereafter, acid mine drainage began to show up in the well (Fig. 5.13). Hot acidity, iron, and sulfate all increased substantially. Much of the acidity increase in MW-3 is apparently mineral acidity; pH at MW-3 has not declined and has remained in the low 5's.

Calcium, magnesium, manganese, chloride, specific conductance, and TDS have all increased in MW-3. Among the other metals, nickel and zinc have increased. Copper, chromium, arsenic, and cadmium show no discernible increase. Lead concentrations have been highly variable, but also show no trends and consistently have been below the MCL.

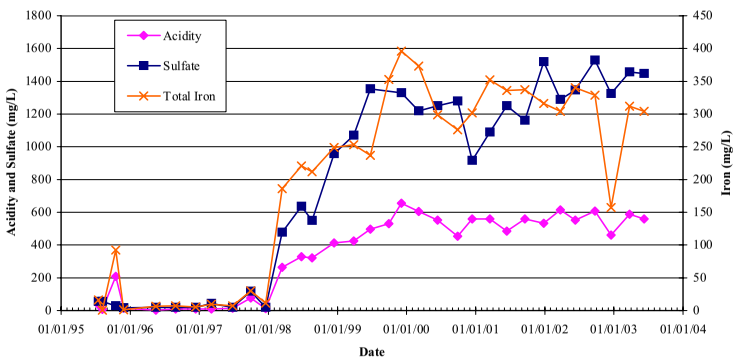

Figure 5.13. Acidity, sulfate and iron at MW-3.

The lead results from the various monitoring points at the McDermott site warrant some discussion, because lead concentrations increased at both MW-2 and MD-12 after mining took place on areas of the site upgradient of those two points. Figure 5.14 shows the lead concentrations with time at various key monitoring points on the McDermott site. Lead concentrations at the monitoring points not included in Figure 5.14 were not remarkable in that

they generally were typical of background conditions and showed no discernible change during the monitoring period. Among the three site monitoring wells, the highest lead concentrations prior to the McDermott operation were found in MW-1, the one well that was affected by mine drainage prior to the McDermott operation. (MW-1 was located directly downgradient of a small abandoned surface mine, and its background water quality showed an influence from mine drainage pre-McDermott (Fig. 5.11)). Lead concentrations in MW-1 frequently exceed the MCL (0.015 mg/L), and are unchanged by the additional mining and ash placement conducted directly upgradient of the well by the McDermott operation.

Among the other various sample points where lead concentrations were measured prior to the McDermott operation, lead concentrations were also relatively high in MD-2, a small seep from a deep mine entry, also located on the northern section of the McDermott site. MD-2 was mined out soon after operations began, thus the short monitoring period for that point. The background data collected prior to the McDermott operation show no other points with elevated lead, including deep mine discharges MD-3, MD-5 and MD-1. MD-1 was located near the center of the McDermott site, and MD-3 and MD-5 are located to the southeast of the site. After Laurel Land Development re-mined the McDermott site, lead concentrations increased in MD-12 and MW-2, located on the northern end of the site, but did not increase in MW-3, MD-3, and MD-5, despite the latter three points being clearly degraded by mine drainage generated by the McDermott operation. All areas of the site, north and south, had FBC ash used in reclamation, and because the southern part of the job was mined after the northern part, the ash application rates were generally greater on the southern area. Given all these facts, the source of increased lead in MD-12 and MW-2 appears to be in the coal overburden on the northern end of the site rather than the coal ash.

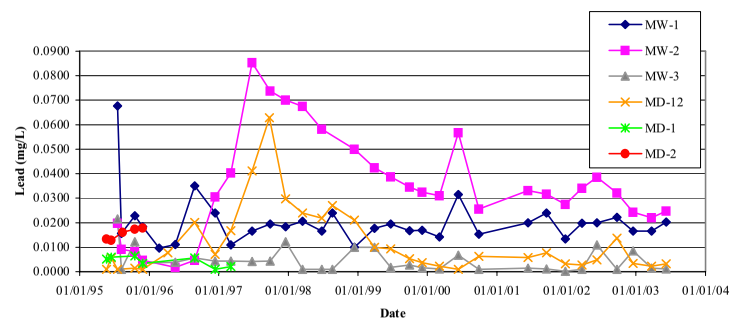

Figure 5.14. Lead concentrations at various monitoring points on the McDermott Mine site.

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MD-22 is the discharge from a pit floor drain that the operator installed on the south central section of the site; the pit floor drain was installed as part of an abatement plan in response to the water quality problems that the site monitoring showed were occurring. Water quality for MD-22 is available in Appendix 5.C. The pit floor drain was excavated into the pit floor and filled with limestone. It was intended to collect water flowing across the pit floor, treat it by neutralizing acidity and imparting alkalinity, and discharge it at a location that additional treatment could be applied, if needed. The pit floor drain was partially successful in that it produces a discharge with less acidity than the water seen in the monitoring wells. The discharge from the drain is net alkaline during lower flow periods. As would be expected, the drain discharges water with very high conductivity, sulfate, TDS, calcium, and magnesium. Iron, manganese, aluminum, nickel and zinc, metals typically found in mine drainage, are elevated in MD-22. The sodium and chloride concentrations in the drain discharge are above levels typically seen in mine drainage from shallow flow systems, and may be influenced by the ash. (The chloride levels are consistently well below the recommended level for drinking water supplies, and the sodium levels are much less than would be found in water treated with a conventional water softener.) Metals in MD-22 are relatively low and consistently below the MCL's for those parameters. The metal concentrations are likely affected by the fact that MD-22 is partially treated by the limestone in the trench. However, even during sampling events when the discharge from MD-22 is net acid with a low pH, the heavy metals are low.

In addition to the monitoring points discussed in detail in this chapter, a downgradient spring (MD-19) and two other downgradient abandoned deep mine discharges (MD-3 and MD-5) were further degraded by the McDermott operation. The degradation is in terms of mine drainage parameters, and there is no significant increase in any heavy metal, including lead, or other parameter attributable to the ash placement on the site. Data for MD-3, MD-5 and MD-19 are available in Appendix 5.C.

The McDermott site is located downgradient of an area previously mined by Ace Drilling Coal Company in the late 1970's. Laurel Land Development has asserted that poor water quality on its site is solely due to the Ace Drilling operation, however, several lines of evidence contradict that conclusion, including 1) mine drainage is pervasive across all affected areas of the McDermott site; 2) mining on Ace Drilling occurred about 20 years prior to that on McDermott, yet points downgradient of the McDermott site sequentially worsened only after overburden was disturbed on the McDermott site; 3) mine drainage at points downgradient of McDermott appeared rapidly after overburden disturbance on McDermott.

5.2.2.4 Conclusions regarding the McDermott site

- Re-mining and partial reclamation of the McDermott site caused an increase in acid mine drainage degradation in most downgradient monitoring points; points that were AMD-impacted prior to the McDermott operation worsened (MW-1, MD-3, MD-12, and MD-5), and points that showed no influence from AMD prior to the operation (MW-2, MW-3 and MD-19) became AMD-contaminated shortly after mining occurred upgradient of them.

- Both DEP and the permittee were aware prior to the operation that the site overburden analysis identified the potential for AMD production, thus the applicant formulated the alkaline addition plan to address this concern.
- In terms of total tons of ash and total calcium carbonate equivalence, the amount of alkaline ash imported to the site met and exceeded that originally proposed. A re-evaluation of the overburden analysis results showed that, although the original mining plan was not completely followed, that fact did not significantly worsen the site NNP deficiency, as compared to the pre-mining prediction.
- Some operational practices likely exacerbated AMD production from the site: 1) reclamation of affected area was not always timely; 2) ash delivery was intermittent, leading to the need to stockpile ash, which was then subject to pozzolanic hardening prior to its use; 3) the site was ultimately abandoned by the operator leaving an unreclaimed area open to accelerated weathering and high infiltration rates. However, monitoring data show that AMD formation began almost immediately with overburden disturbance on the site, and AMD production would likely have occurred even had good mining practices been followed.
- An ash addition rate of 6600 tons per acre (calcium carbonate equivalence of 1165 tons per acre) did not prevent AMD formation on this site. The alkaline addition rate achieved a site-wide NNP of 5.31 tons/thousand tons, however, the ash application rate was not uniform across the site.
- For at least some monitoring points, the data suggest that ash is neutralizing some AMD, but not enough to cause the site to produce net-alkaline water, and AMD production was clearly not prevented.
- A review of the water quality data for this site shows no evidence of contamination from ash utilization. Sodium and chloride concentrations are elevated at some points relative to levels typically found in acid mine drainage from shallow flow systems, indicating that ash may be the source of those parameters, however, the levels are not high enough to be considered contamination. Ash is probably contributing to the elevated calcium levels seen at some points. Lead levels increased at two monitoring points as a result of the operation, but the pattern of its occurrence, and an evaluation of background data, point to the overburden on the northern end of the site as the source. It is possible that the ash is contributing to sulfate concentrations, but that is difficult to separate from the AMD influence.
- Results at this site were similar to those at sites where alkaline addition in the form of waste lime was added to sites in the face of clearly poor overburden quality, and the result was production of additional AMD.

5.3.3 Reclamation of A Bituminous Coal Bond Forfeiture Site—Abel-Dreshman Site

Pennsylvania's significant abandoned mine reclamation obligation has been widely documented. The total cost of reclaiming the state's abandoned mine lands has been estimated as high as $15 billion. The vast majority of that legacy of polluting discharges is attributable to older sites that were either mined before or shortly after the advent of modern permitting requirements that were brought into effect in 1978-1982. In an evaluation of post-mining water quality associated with the surface mine permits issued by Pennsylvania DEP between 1977 and 1996, Smith (1999) found that predictive capabilities improved markedly with time. Less than

1% of the permits issued between 1987 and 1996 resulted in a discharge requiring treatment, while the failure rate for sites from 1977 through 1986 was 10-20%. Very few surface mining permits issued today in Pennsylvania results in water quality problems. The McDermott site described in section 5.2.2 is an example of one that did.

The Abel-Dreshman site is an example of a site that was permitted just prior to modern understanding of acid mine drainage and its prevention, and the Abel-Dreshman site also produced pollution and was left partially reclaimed by the original permittee. Coal ash was not placed on the Abel-Dreshman site, when it was mined, but was subsequently used as an alkaline addition agent, when the site was reclaimed. The Abel-Dreshman site was previously reported on by Schueck et al., (2001), however, additional water quality data are now available, which are included in this chapter. (See Appendix 5.D for the raw water sampling data from the Abel-Dreshman site.)

5.3.3.1 Site characterization/ setting

DEP issued the Abel-Dreshman Surface Mining Permit # 10800101 to Chernicky Coal Company on June 17, 1980. The permit authorizes mining of 55.5 acres of Middle Kittanning Coal (MK). The prevalent rock type on this site is sandstone, which was deposited in a brackish water environment. The site is located on Seaton Creek in the Ohio River drainage basin.

The Abel-Dreshman site was permitted at a time when overburden analysis was rarely used, and no overburden analysis was performed for the initial site application. However, in 1984, after Chernicky Coal Company had mined and abandoned a significant portion of the site, another company proposed to take over the site to finish the mining and reclamation. Because the mining done to that point on the site had created water quality problems, DEP required overburden analysis as part of that attempt to transfer the site. Two holes were drilled, both on the Abel tract, since the Dreshman tract had little recoverable coal remaining on it.

DEP did not authorize the additional proposed mining, because the overburden analysis showed a strong potential to generate additional mine drainage pollution if mining continued. The data show a clear deficiency of NP (neutralizing material in terms of calcium carbonate equivalence) on the site, as shown by the negative NNP in terms of both tons/1000 tons and tons/acre. The information provided in Table 5.7 under the heading "Tons $CaCO_3$/needed to provide:" shows for each drill hole how much calcium carbonate would need to be added to each acre represented by that drill hole to meet certain benchmark values shown to have significance by Brady et al., (1994) and Perry and Brady (1995).

On a mass-average basis, the two overburden holes on the site, OB-1 and OB-2, included 56% sandstone and 91.1% sandstone, respectively. In a study of Allegheny Formation rocks in West Virginia, diPretoro and Rauch (1986) reported a propensity for sites with high percentages of sandstone in their overburden to produce acid mine drainage.

Table 5.7. Summary of the overburden analysis data for the Abel-Dreshman site.

Drill Hole #	Highwall Cover Height	Net Neutralization Potential			Tons $CaCO_3$/acre needed to provide:		% SS
		tons/1000 tons	tons/acre		6 ton/1000 ton excess	12 ton/1000 ton excess	
		Thresholds			Thresholds		
		without	with	without	with	without	
OB-1	56	-2.33	-227	-215	780	1320	56.5
OB-2	46	-9.27	-612	-740	1090	1696	91.1

5.3.3.2 Mine operations

Chernicky Coal Company took the first cut on the Abel-Dreshman site in July 1980, and mining continued intermittently until June 1982. Approximately 65 of the 74.5 bonded acres were affected. The site was mined as two operations, with one pit on the Abel parcel and one pit on the Dreshman parcel. Routine sampling by the DEP inspector on July 29, 1982 revealed the first signs of AMD contamination on the site at a sediment pond and at a spoil discharge (Table 5.8).

Table 5.8. Sample results of July 29, 1982 showing the quality of AMD occurring on that day. Flow is in gpm, pH is in standard units, and all other parameters are in mg/L.

Description	Flow	pH	Alk.	Hot Acidity	Total Fe	Total Mn	Total Al	SO_4	Net Alk.
Sediment Pond		3.3	0	359	5.5	91.7	25.3	1300	-359
Spoil Discharge	5	5.4	17	105	33.1	43.6	0.81	900	-88

Samples collected by DEP during 1982 and 1983 further documented that the site was producing AMD. Due to a variety of problems with the site, DEP initiated bond forfeiture proceedings in March 1983. The initial operator had abandoned two pits on the site, one of which flooded with groundwater. On March 1984 the Department measured the impoundment's dimensions at 150 ft. L x 60 ft. W x 40 ft. and measured the other pit at 75 ft. L x 50 ft. W x 40 ft.

On February 3, 1997, DEP entered into a landowner reclamation agreement through which Amerikohl Mining Company, Inc. would complete the reclamation on the abandoned site. The reclamation was performed from September 1997 until September 1998. Amerikohl did no additional mining on the site, so there was no additional disturbance of acid-producing overburden. The reclamation plan included the mixing of 200,000 tons of Scrubgrass Generating Project CFB ash to the mine spoil as an alkaline addition agent in an attempt to offset the deficiency in the mine spoil that had been documented by the site overburden analysis. The Scrubgrass facility is located in Scrubgrass Twp., Venango County. As part of the plan, the entire site was to be reclaimed to the standard typically required in Pennsylvania, known as

approximate original contour or AOC. Records show that only 83,600 tons of ash were actually mixed with the site overburden. According to NP tests performed on the ash, it had approximately 600 tons per 1000 tons of $CaCO_3$ equivalent. This number is quite high for CFB ash, but apparently, because the plant was still being adjusted at that point, lime utilization was rather inefficient. Approximately 1235 tons of ash were added to each of the 50 affected acres equating to 1003 tons of 100% $CaCO_3$ equivalent. This amount would provide a little more than a 6 tons/1000 ton excess NP (calculated with thresholds) across the site (Table 5.7).

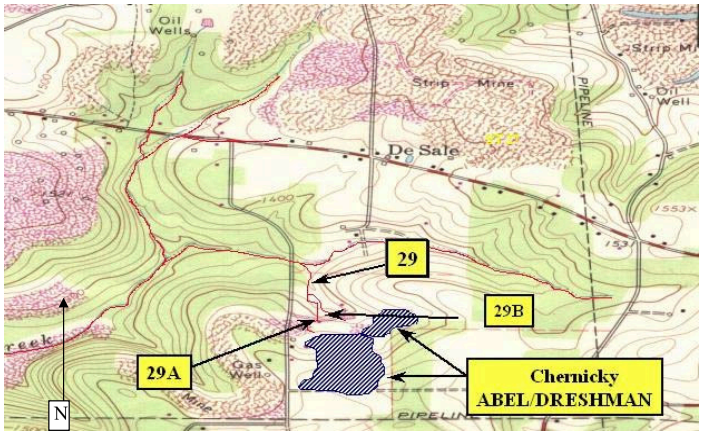

Figure 5.15. Map of the Abel-Dreshman site and monitoring points.

The Abel-Dreshman site consists of two parcels, and placement of the ash was slightly different on the two areas. The ash generator added water at the plant to condition the ash for dust control, sufficient to bring the ash up to a moisture content of about 21%. Bottom dump trucks transported the ash to the site. A bulldozer then promptly mixed the ash and spoil while pushing both into the pit. The floor of the existing pits was covered with a layer of the ash, approximately 2 to 3 feet thick. (The flooded pit was pumped prior to ash placement.) On the Abel parcel much of the ash was spread in layers due to non-availability of equipment and breakdowns, where it was thoroughly mixed with the spoil on the Dreshman site. Amerikohl placed and compacted a layer of ash one to two feet thick on both parcels before placement of the final topsoil material.

5.3.3.3 Monitoring results from the Abel-Dreshman site.

The Department chose three downgradient springs as monitoring points for the Abel-Dreshman project. The springs are identified as sample points 29, 29A, and 29B. Point 29A is downgradient of the Dreshman tract, 29B is downgradient of the Abel tract, and 29 is located just below the confluence of the flows represented by 29A and 29B.

Table 5.9 summarizes water monitoring results for certain mine drainage parameters at point 29A. Comparing the period prior to ash addition and backfilling (prior to September 1997 – 1998) to the periods during and following the application of ash (after September 1998) shows a marked decrease in metals concentrations at monitoring point 29A. The data also show a significant increase in pH and net alkalinity. (Negative acidity values in this case were reported by the laboratory as 0 acidity, so where net alkalinity is referenced herein, it is alkalinity minus any acidity reported.) Sulfate concentrations are unchanged.

Table 5.10 shows summary mine drainage parameter results for point 29B, broken into the same subsets as were the data for 29A. In the case of 29B there was little change in pH, but net alkalinity did improve substantially, as did manganese.

Table 5.9. Summary of mine drainage parameter results at point 29A, comparing the periods, before, during and after ash application and reclamation.

MP-29A	Pre-Ash Application	During-Ash Application	Post-Ash Application
# of samples (n)	9	9	11
Median pH (su)	3.5	3.7)	6.1)
Average Net Alkalinity (mg/L)	-185.3	-207.	-35.2
Std. Deviation Net Alkalinity	56.9)	50.6	80.7
Average Total Iron (mg/L)	2.1	15.1	0.8
Std. Deviation Total Iron	1.5	13.7	1.2
Average Total Manganese (mg/L)	44.6	76.3	32.7
Std. Deviation Total Manganese	25.5	19.7	23.1
Average Total Aluminum (mg/L)	3.5	3.1	1.3
Std. Deviation Total Aluminum	1.0	2.1	1.5
Average Total Sulfate (mg/L)	835.6	942.7	817.2
Std. Deviation Total Sulfate	377.5	292.6	202.0

Table 5.11 includes summary data for point 29, which represents water quality of the combined flows of 29A and 29B. Net alkalinity and pH increased, while iron, manganese and aluminum decreased, when the pre-ash water quality data are compared to the post ash data. Sulfate concentrations have also decreased.

The pH at point 29A may have declined somewhat over the past two to three years (Fig. 5.16), while the pH values at 29B and 29 have been stable, and may still be increasing slightly.

Table 5.10. Summary of mine drainage parameter results at point 29B, comparing the periods, before, during and after ash application and reclamation.

MP-29B	Pre-Ash Application	During-Ash Application	Post-Ash Application
# of samples (n)	9	9	11
Median pH (su)	4.5	4.7	4.7
Average Net Alkalinity (mg/L)	-36.3	-18.7	-5.0
Std. Deviation Net Alkalinity	17.1	16.2	8.0
Average Total Iron (mg/L)	1.1	0.1	0.2
Std. Deviation Total Iron	1.7	0.1	0.3
Average Total Manganese (mg/L)	27.7	7.0	5.9
Std. Deviation Total Manganese	37.0	3.3	2.5
Average Total Aluminum (mg/L)	2.5	1.8	1.4
Std. Deviation Total Aluminum	0.6	0.8	0.7
Average Total Sulfate (mg/L)	335.1	190.6	213.1
Std. Deviation Total Sulfate	289.7	63.7	69.5

Table 5.11. Summary of mine drainage parameter results at point 29, comparing the periods, before, during and after ash application and reclamation.

MP-29	Pre-Ash Application	During-Ash Application	Post-Ash Application
# of samples (n)	9	9	11
Median pH (su)	3.6	3.8	4.8
Average Net Alkalinity (mg/L)	-117.8	-104.3	-2.8
Std. Deviation Net Alkalinity	39.5	58.1	11.8
Average Total Iron (mg/L)	1.5	6.4	0.2
Std. Deviation Total Iron	0.6	11.2	0.2
Average Total Manganese (mg/L)	43.3	38.3	9.5
Std. Deviation Total Manganese	18.2	18.8	4.1
Average Total Aluminum (mg/L)	2.9	2.7	0.9
Std. Deviation Total Aluminum	0.5	2.1	0.5
Average Total Sulfate (mg/L)	634.7	624.8	295.6
Std. Deviation Total Sulfate (mg/L)	237.1	258.7	75.2

Net alkalinity at all three points appears to have declined slightly over the past three years (Fig. 5.17), but still remains above pre-ash placement and reclamation values. Possible reasons for a decline in net alkalinity at the monitoring points could be a decline in available NP in the backfill with time, or it could be due to climatic effects (e.g., rainfall). The higher net alkalinities tend to occur during the wetter seasons of the year, and over much of Pennsylvania, 2001 and 2002 were relatively dry. Continued monitoring will reveal if net alkalinity stabilizes or continues to decline.

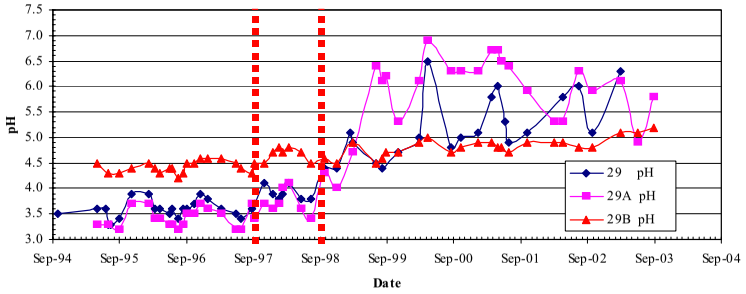

Figure 5.16. Graph of pH with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

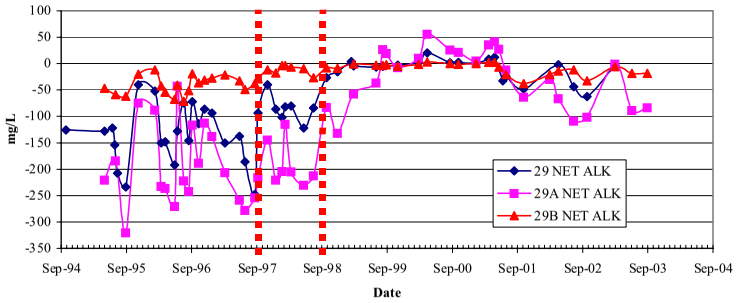

Figure 5.17. Graph of net alkalinity with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

The primary AMD metals (iron, manganese, and aluminum) declined at points 29, 29A and 29B after the site was reclaimed with the addition of ash. Figure 5.18 displays the available

data for aluminum at the three points. Aluminum concentrations at all three points appear to be stable since 1999. The removal of aluminum from down stream areas is particularly significant, due to aluminum's toxicity to aquatic life. The data for iron and manganese, while not presented in graphic form here, show similar patterns to that seen for aluminum.

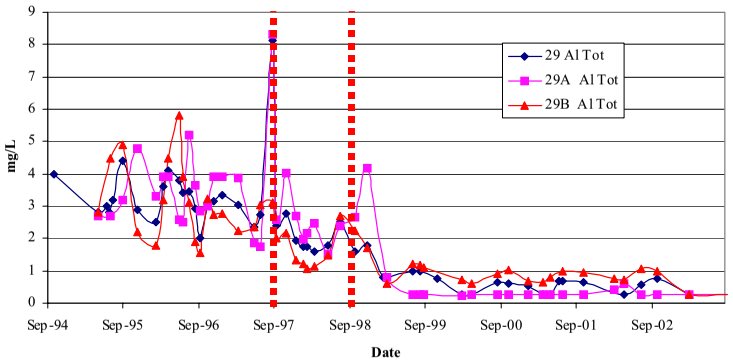

Figure 5.18. Graph of aluminum concentrations with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

Monitoring was conducted at 29, 29A, and 29B for additional parameters beyond the traditional AMD parameters (Appendix 5.D) Most of these additional results are unremarkable. Sodium concentrations appear to have increased at point 29A, which also showed the largest increases in pH and net alkalinity when compared to the other two monitoring points discussed here. Sodium concentrations also increased at the Revloc and McDermott sites at some points downgradient of the ash placement areas, but in no case were the numbers particularly high. The concentrations of toxic metals including selenium, mercury, copper, chromium, cadmium and arsenic are consistently below detection limits throughout the monitoring period at all three points. Lead concentrations have occasionally been at detectable limits, but are generally low, and show no increase after reclamation of the site with ash.

5.3.3.4 Conclusions regarding the Abel-Dreshman site

- Overburden analysis data for this site show that the site overburden had significant potential to generate acid mine drainage and little potential to generate alkalinity.
- Reclamation of the site with coal ash resulted in increases in pH and net alkalinity and decreases in AMD metals in monitoring points downgradient of the site.

- The ash used on the site appears to be generating alkalinity in that the overburden did not have the capability to do so. Reclaiming the site by backfilling it and adding a layer of compacted ash to the surface may also have contributed to water quality improvements.
- Net alkalinity has declined at the monitoring points over the past two to three years, but water quality appears to be otherwise stable, and remains substantially improved as compared to pre-ash placement.
- There is no indication of increases in heavy metals or other pollutants at downgradient monitoring points as a result of the use of ash on the site.
- Downgradient water quality is likely much better than it would have been had the site simply been reclaimed without the use of ash.

5.3 CONCLUSIONS

Abandoned coal refuse piles are a significant environmental liability in the Bituminous Coal Region of Pennsylvania, and traditional AML approaches toward reclaiming the piles do little to abate the associated water quality problems. Not only do these piles produce a leachate of highly concentrated AMD character, they also can leach elevated levels of toxic metals, such as arsenic, copper, and lead. The use of FBC ash in the re-mining and reclamation of two large refuse piles at Revloc, PA has resulted in a large reduction in pollution load from site discharges and in a substantial improvement in downstream quality on the South Branch Blacklick Creek. Both flows and concentrations of pollutants have declined at the largest discharge points. Re-mining and reclamation are on going at these sites, and further water quality improvements are expected. Monitoring data show no significant negative impacts to downgradient water quality from the use of FBC ash on the sites. Selenium concentrations have increased somewhat, however, the two points with the most-elevated selenium are low-volume seeps downgradient of an area where final reclamation has yet to be achieved. Burning of waste coal to generate electricity is now a common practice in PA. Not only does this practice turn environmental liabilities into an energy source, the by-product in the form of FBC ash is particularly suited to aid in the full reclamation of waste coal piles.

At the Laurel Land Development, Inc. McDermott site, the use of FBC ash as an alkaline addition agent was unsuccessful in preventing mine drainage formation. Water quality data indicate that the large quantity of ash placed in the backfill may be neutralizing some AMD, but has not prevented the formation of AMD, and has not generated net alkaline water. Several downgradient monitoring points have been degraded with AMD at the McDermott site. While operational complications, such as an intermittent ash supply, stockpiling of ash before incorporation into the backfill, and delayed and incomplete site reclamation may have contributed to the site problems, they likely are not the sole cause of the problems. Using alkaline addition in the form of ground limestone to prevent AMD on mine sites where predictive indicators strongly point toward AMD production has historically not been highly successful in PA. The production of AMD on the McDermott site, despite a relatively high rate of alkaline ash addition, suggests that it may be even more difficult to overcome an overburden deficiency with FBC ash than it is with limestone. FBC ash probably can be best utilized on active mine sites as a sealing or encapsulating material to limit the contact of water with high-sulfur pit floors and pit cleanings, or as a best management practice, where alkaline addition is not necessarily needed to prevent AMD production, but where it may be helpful in abating pre-

existing AMD problems. Water quality data at the McDermott site show that, while the ash did not prevent AMD formation, it also did not cause pollution in terms of increased non-AMD metals in downgradient monitoring points.

At the Abel-Dreshman site, the use of FBC ash in the reclamation of an abandoned surface mine resulted in an improvement in downgradient water quality. The use of ash appears to have increased the net alkalinity of downgradient monitoring points, increased the pH, and decreased metal concentrations. Net alkalinity appears to have declined recently, but remains above pre-ash placement levels. Overburden analysis on the Abel-Dreshman site indicates that the overburden is unlikely to generate any alkalinity on its own. The Abel-Dreshman ash project was purely a reclamation project, and no additional overburden was disturbed. That is one fundamental difference between Abel-Dreshman and McDermott. On the McDermott site, the area of fresh overburden disturbance was large relative to the area of re-mining and abandoned mine reclamation. Also, the NP of the ash used at Abel-Dreshman was much higher than the NP of the ash used at McDermott. Downgradient water monitoring at Abel-Dreshman shows that the use of ash in site reclamation caused no metal contamination.

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Beneficial Use of FBC Coal Ash for Mine Reclamation in the Anthracite Region at the Wheelabrator Frackville and Mount Carmel Co-Gen Sites

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ABSTRACT

The Wheelabrator Frackville and Mount Carmel Co-Gen sites are located in the Anthracite Region of Pennsylvania, utilize anthracite culm, silt and refuse as fuel and reclaim abandoned and active mine lands with the coal ash they produce. Since the plants have been operating, they have reclaimed over 300 acres of abandoned mine lands, and have also eliminated a large number of safety hazards via that reclamation work. Site monitoring has also revealed no degradation associated with the coal ash placement, and some groundwater and surface water improvements will be evident once the projects and all site related reclamation is completed.

INTRODUCTION

The remining and reclamation of abandoned mine lands in Pennsylvania increased significantly with the construction of waste coal fired power plants in recent years. The coal ash produced by these power plants has resulted in a significant growth in the use of coal ash for mine reclamation in the anthracite and bituminous regions of Pennsylvania. The nine anthracite region waste coal power plants account for over 39 million tons of coal ash beneficially used for abandoned mine reclamation via the remining of waste coal piles and the filling and reclamation of abandoned mine land pits. The majority of the reclamation associated with these plants is through the utilization of coal ash as fill material and the resultant reclamation of the abandoned mine land features. The reclamation associated with these sites has, in most cases, also improved the groundwater and/or surface water in the vicinity of the projects. All of this reclamation has been conducted at no cost to the Commonwealth and represents a significant monetary savings for Pennsylvania's Abandoned Mine Land Reclamation Program.

The Wheelabrator Frackville and Mount Carmel Co-Gen sites represent two sites where significant remining and reclamation of abandoned mine lands has and is occurring via the operation of the power plants, and the beneficial use of the coal ash produced by the plants. This paper will give a short description of each site, and the resultant effects of the remining and reclamation of the sites through the beneficial use of coal ash.

Wheelabrator Culm Services, Inc. – (Wheelabrator Frackville Co-Gen)
This 580 acre surface mining permit site, (SMP No. 54880202) was issued for coal refuse reprocessing with coal ash utilization in October 1991, and is located in Mahanoy Township,

Schuylkill County, as shown on Figure 1. Known as the Morea/New Boston Operation after the historic colliery names, the operation is situated entirely on previously mined areas. The land surface consisted of abandoned anthracite culm banks, multiple open strip-mined pits, and overall disturbed surface-water drainage. It is located in the southeastern portion of the Western Middle Anthracite Field.

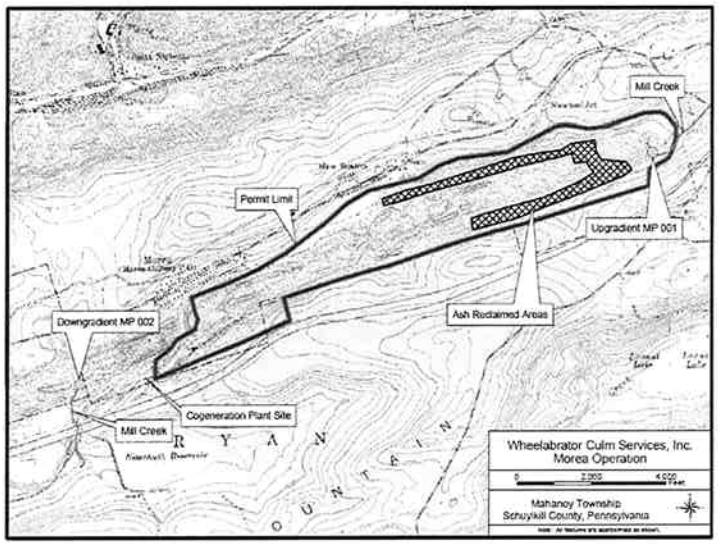

Figure 1. Site map of Wheelabrator – Morea mine site.

The minepool and groundwater flow system of the Morea and New Boston Collieries is somewhat isolated from the remainder of the Western Middle Field. These two collieries are located in a narrow basin on top of Broad Mountain. This case study site was selected because it is a good example of extensive abandoned mine reclamation with coal ash from a FBC plant, the ash reclamation project has significant potential for surface water and groundwater improvement (when completed), and the groundwater monitoring scenario is relatively simple.

Most of the permit area was taken over from the previous operator, Lehigh Valley Anthracite. The Wheelabrator Frackville Energy Co., Inc. constructed the circulating fluidized bed boiler plant (FBC) in 1988 on-site, near their primary fuel source – (anthracite culm) and potential ash placement areas. Coal refuse and coal silt from other local permitted areas is conveyed to the plant. Fly and bottom ash are then hauled from the plant by truck to the active ash placement area. The operation is conducted in phases of refuse recovery and ash utilization. Over 11 years, the operator has had nine phases approved for ash placement, various support activities and

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refuse reprocessing. At the end of 2004, the operator reported over six and a half million tons of anthracite coal refuse burned in the plant, and over four million cubic yards of ash utilized for reclamation on-site, with 123 acres of abandoned mine lands reclaimed.

The primary use of the coal ash produced by the plant was to fill the abandoned open pits on site. Several 10 to 20 acre pits were filled with ash. On-site spoil and abandoned coal refuse material is used to line the pits prior to ash placement, with the best material saved for final cover. Photographs of the abandoned surface mine pits reclaimed with coal ash are shown in Figure 2a. Extensive wildlife habitat plantings have been established on the reclaimed areas shown in Figure 2b. In addition, the coarse bottom ash from this plant is approved for use as anti-skid material for on-site access and haul roads. This material is stored separately and used during inclement weather.

Figure 2a. Ash placement in pits

Figure 2b. Wildlife plantings

Initially, 8 feet of fill (spoil and refuse material) was needed to line the pits. All ash conveyed to the active placement area was dumped into the working area and then spread and compacted in lifts of 2-4 feet within 24-48 hours of placement. The ash is conditioned at the plant with adequate moisture for compaction, which is achieved simply by the process of repeated passes of the haul trucks and dozers during spreading. Each daily cell is 150 by 200 feet. A final cover of 4 feet is placed on top, utilizing the adjacent spoil material, with the top one foot being the best available from the site. Daily and intermediate cover is used, as needed, to control dust before the final cover. Since the plant utilizes treated minepool water for cooling purposes, the sludge from the water treatment process is blended with the ash in a 1 to 467 ratio, and placed in the ash use areas.

The site was extensively affected by pre-Act mining. There is no point-source discharge or direct drainage to a stream – water percolates directly through the surface material or drains to the pits and ultimately is conveyed to the minepool underneath. Upgradient diversions are used to prevent runoff onto the site. There is essentially no natural soil present.

Of the nine mining and coal ash placement phases shown on the permit maps, three phases (1, 2 and 3) are substantially completed, and some reclamation work has been completed on two other phases (4 and 5), which are shown in the cross-hatched symbol on Figure 1. When this entire remining project is completed, significant surface-water and groundwater benefits should occur,

in addition to the extensive reclamation of abandoned mine lands. With every acre of abandoned surface mine pits that are reclaimed to approximate original contour on this site, there is a reduction in water infiltrating directly into the underlying minepool, and an accompanying increase in surface water runoff. The tributary to Mill Creek in the eastern end of the SMP presently flows to the subsurface through abandoned mine workings within the permit area, but this stream should be restored to the surface and emanate from the permit as a perennial stream before completion of the project. The elimination of stream loss (or dramatic reduction in stream bed leakage) and the reduction in direct infiltration to the abandoned underground mines through coal ash backfilling of abandoned surface pits is expected to significantly reduce the flow of the Morea Colliery discharge (downgradient monitoring point MP 002), shown on Figure 1. The reduction in flow of abandoned mine discharges by remining operations is one of the most common and significant benefits according to Hawkins (1995), Brady et al. (2001) and Smith et al. (2004). It is anticipated that the extensive placement of alkaline coal ash at the Wheelabrator site will improve the water quality of the Morea Colliery discharge. However, if the concentration of some water quality parameters does not change significantly, the overall pollution load of the discharge should decrease significantly due to the reduction in flow.

As part of the permit conditions, the permittee is required to conduct groundwater and ash monitoring. For this site, the minepool conditions are such that sampling points are easily identified. Mill Creek runs on the surface before it reaches the Wheelabrator site and then goes underground into the minepool complex. A point was picked on Mill Creek as an upgradient monitoring site, shown on Figure 1. The minepool overflows downgradient from the site which represents the emergence of Mill Creek to the surface. It is worse in quality due to acid mine drainage pollution of the minepool. This is the designated downgradient monitoring point that theoretically would reflect any changes in water quality due to the mining and ash placement activities. The DEP has monitoring data on these points from 1986 to the present. The major problem in comparing upgradient monitoring point 001 with downgradient monitoring point 002 is that they represent two different hydrologic regimes that are only interconnected because the stream (001) flows subsurface into the minepool, emanating at the minepool discharge (002). The concentrations of acidity, sulfates, manganese and other analytes have been consistently higher in the downgradient point since the start of monitoring (except for a few rare occasions), not due to degradation caused by Wheelabrator mining and reclamation activities, but due to the fundamental difference in analyte concentrations between the minepool and the stream. Thus, interpretations may be made from the presence of any trends within the data from either point. For example, it appears that the pre-mining acidity at the downgradient monitoring point was usually about 90 to 100 mg/L, whereas during ash placement it has typically been about 50 to 80 mg/L as shown in Figure 3a. However, alkalinity has not increased and is still negligible, because the acidity in the minepool is still overwhelming any alkalinity attributable to the coal ash placement.

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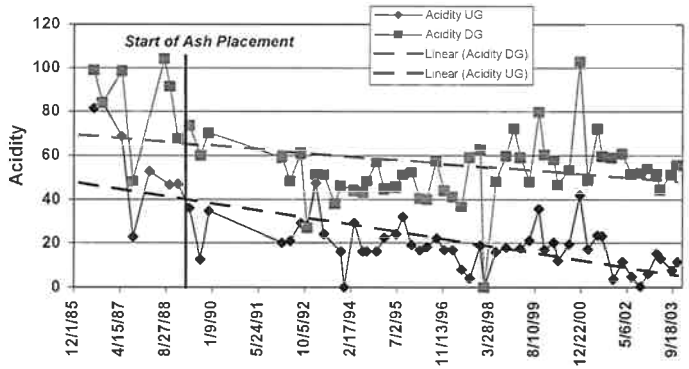

Figure 3a. Acidity in minepool and stream at Wheelabrator site.

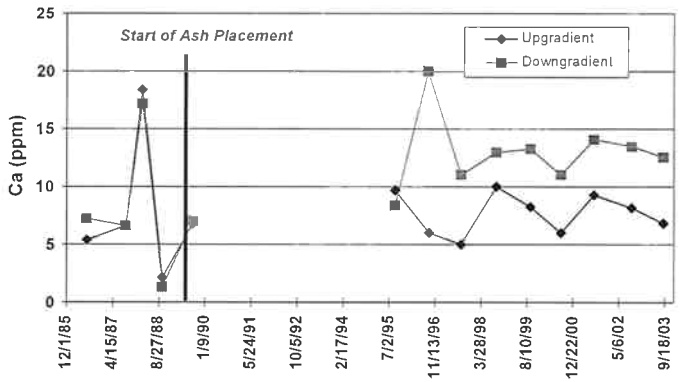

Figure 3b. Calcium concentration in minepool and stream at Wheelabrator site.

There has been no significant change in the overall water quality in an upgradient to downgradient comparison, but some trends of particular constituents are noticeable. The

upgradient pH is consistently between 4 and 5 whereas the downgradient is consistently between 3 and 4. For both points, specific conductance trends slightly upward and acidity trends slightly downward. Figure 3b shows that calcium concentrations in the upgradient stream monitoring point and the downgradient minepool discharge were nearly identical prior to 1990, while the data since 1995 show the calcium concentrations in the minepool discharge are consistently higher than the upgradient sample site. This difference, however subtle, may be due to dissolution of the calcium hydroxide in the coal ash.

Overall, the Wheelabrator mine site and cogeneration plant operations have resulted in the use of refuse material to produce energy while not only reclaiming the banks of waste material, but also providing stable fill, as ash, to decrease the safety and environmental hazard of open, abandoned pits. Formerly unusable land is being restored to a graded, vegetated condition for future use as shown in the photos in Figure 2a and 2b. It is not anticipated that the ash placement will result in an overall degradation of water quality. Over the long-term, further pollution resulting from flow to the minepool will be reduced as more natural overland drainage patterns are restored and Mill Creek is eventually returned to a surface stream across the site.

Susquehanna Coal Company – (Mt. Carmel Co-Gen Site)

During a night in December 1989, a woman was walking in a wooded area near Route 54 between the city of Mt. Carmel and the village of Marion Heights in PA when she fell into a 100 foot deep abandoned surface mine pit and was killed. That fatality elevated the backfilling priority of that abandoned mine land feature to the Priority 1 class on the OSM list of backfilling projects, in order to abate the mine hazard and prevent future fatalities. In April 1987, Susquehanna Coal Co. applied for a surface mining permit (SMP #49870202) to mine and process abandoned culm banks from the Natalie and Richards collieries to be used as fuel in the fluidized bed combustion boiler of the Foster Wheeler Mt. Carmel, Inc., cogeneration plant being constructed on-site (Fig. 4). That SMP was issued on August 24, 1987 and included approval to place fly ash and bottom ash from the cogeneration plant in the abandoned pit and adjacent areas. By 1995, all of the abandoned pits (except for an access area near the ash conveyor) were reclaimed to approximate original contour at no cost to the state or federal government (Fig. 5.1b).

The Susquehanna Coal Co. site is located in Mount Carmel and Coal Townships in Northumberland County. The SMP boundary of the 788 acre site is shown on Figure 4. The SMP overlies four abandoned underground mines. These mines are, from east to west, the Richards Water Level, Natalie, Hickory Ridge and Hickory Swamp Collieries. The area of the Richards Colliery within the SMP is very minor, and near to the cogeneration plant site adjacent to Route 54; thus Borehole No. (BH) 48 shown on Figure 4 serves as an upgradient monitoring well. Most of the permit area, including the ash placement areas, is overlying the Natalie and Hickory Ridge Collieries. These four abandoned underground mines and several additional adjacent collieries are all hydrologically interconnected through breeched, leaking barrier pillars, with the Scott overflow shown on Figure 4 being the major mine discharge point. The Scott discharge emanates from the Scott Colliery located south of the permit area. These collieries are within the western portion of the Western Middle Anthracite Field.

Geologically, the site is located within the Western Middle Synclinorium, which is depicted by Arndt (1971). Of the many anticlines and synclines within this synclinorium, the axis of the Hickory Swamp Syncline passes directly through the permit area and is parallel to the long

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dimension of the SMP boundary shown on Figure 4. Hence, the abandoned surface mine pits and the extensive abandoned coal refuse piles within the permit area shown on Figure 5a, sat within this relatively narrow trough-like geologic structure, and were underdrained through abandoned underground mine voids to the Scott Overflow. Millions of tons of these coal refuse deposits were mined, transported to the cogeneration plant by a conveyor system and combusted with limestone in the circulating fluidized bed boiler. The resultant alkaline coal ash has been returned to an abandoned surface mine pit by a conveyor system (with trucks currently used to transport ash to western portions of the SMP that are out of reach of the conveyor). The coal ash deposits on the site range from greater than 50 feet thickness in the area of prior deep abandoned pits, to relatively thin veneers of coal ash used to regrade and reclaim other abandoned mine land features (Fig. 5,1 a, 1b & 1c). Any water infiltrating through these reclaimed coal ash areas or active coal ash placement areas will flow within the synclinal trough, and thence through cross-connecting mine voids to the Scott Overflow shown on Figure 4. Apparently, this groundwater flow system functions effectively as an underdrain for the site.

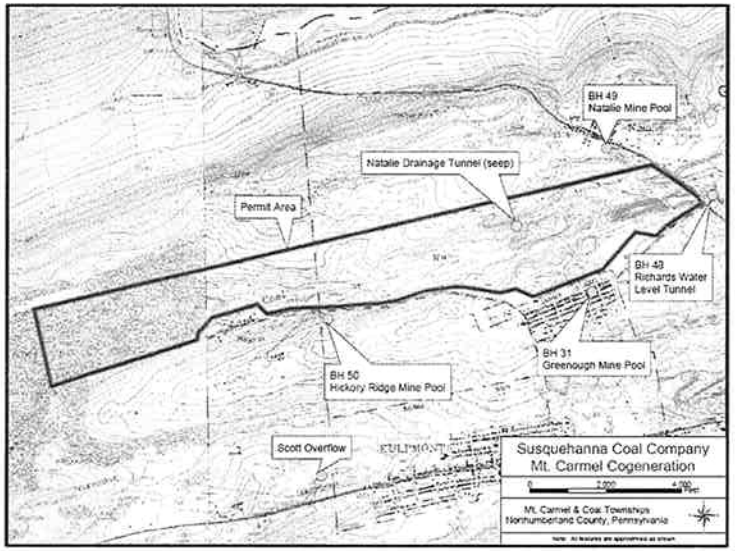

Figure 4. Site map of Susquehanna Coal – Mt Carmel Cogeneration site.

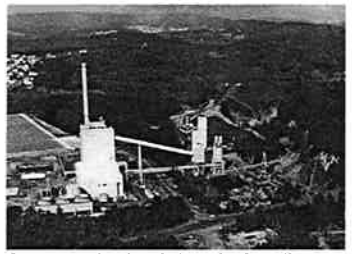

Figure 5a. Abandoned pits and refuse piles at start of ash placement.

5b. 10 years of ash placement and reclamation of pit.

5c. Coal ash deposit greater than 50 feet thick near conveyor.

5d. Scott Overflow monitoring point.

The Mount Carmel cogeneration plant consumed a total of 9,106,000 tons of coal refuse from 1990 through 2004, and produced 6,099,975 tons of alkaline coal ash for mine reclamation on-site during that 15 year period. The average yearly culm consumption was 607,067 tons, and the average annual coal ash production was 406,665 tons. A total of 209 acres of abandoned mine lands were reclaimed with coal ash within the SMP for an average of 16.1 acres reclaimed per year. Additional reclamation has also occurred through the remining of coal refuse banks in and around the plant area. These operations are permitted to supply fuel for the cogeneration plant and include an additional 50 acres of abandoned mine land reclamation directly associated with this cogeneration plant operation.

Groundwater monitoring data for five of the monitoring points shown on Figure 4 are compiled in Table 1. These data are representative samples of quarterly and annual groundwater monitoring by the permittee from 1989 through 2003. BH 48 in the Richards Colliery has characteristics of acid mine drainage with acidity from 18.0 to 131.0 mg/L (median 67.6 mg/L); sulfate from 34.0 to 283.0 mg/L (median 141.0 mg/L); and iron 0.41 to 380.0 mg/L (median 12.30 mg/L). These ranges and medians were computed from the 55 samples in the permit file.

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This upgradient monitoring well was intended to be a companion to the other upgradient well, BH 49 within the Natalie Colliery, but the water quality of these two wells is very different. The highest acidity in BH 49 is 40.0 mg/L but most of the samples were alkaline with alkalinity from 15.0 to 93.6 mg/L (median 47.0 mg/L). The iron in BH 49 ranges from 14.20 to 296.0 mg/L (median 58.0 mg/L), but the sulfate ranges from 1.51 to 362.0 mg/L with a median of 6.0 mg/L. Most of the sulfate values for BH 49 were less than 10.0 mg/L, thus this monitoring well does not exhibit acidic or neutralized mine drainage characteristics, and may not be intercepting the actual Natalie minepool. These two boreholes were used as downgradient monitoring wells for the Mount Carmel Township landfill located immediately east of the permit area. There is the possibility that the alkalinity in BH 49 is attributable to landfill leachate or sewage. However, significant influence from landfill leachate can probably be ruled out, based upon 18 groundwater analyses that were conducted for Chemical Oxygen Demand (COD). In these analyses, the COD for BH 48 ranged from 7.70 to 43.20 mg/L, while the COD for BH 49 ranged from 0 to 69.0 mg/L. According to a 1986 EPA study, which sampled leachate from municipal waste landfills throughout the United States, the median COD was 2,800 mg/L and the maximum was 50,450 mg/L.

BH 31 in the Greenough minepool and BH 50 in the Hickory Ridge Colliery are both of questionable value as long-term groundwater monitoring points for the Susquehanna Coal Co. site. This monitoring well has a chemical signature that resembles neutralized acid mine drainage, but there are no distinct trends of water quality improvement nor degradation. Further, from its location, BH 31 cannot be considered an upgradient well, but it is unlikely to be a reliable downgradient monitoring well.

The location of BH 50 within the Hickory Ridge Colliery should make it a suitable downgradient monitoring well, at the southern edge of the permit area (Fig. 4.16) and north of the Scott Overflow discharge. However, its chemical signature does not resemble mine drainage, and the well has little value in groundwater quality interpretation related to the surface mine and ash placement site. The sulfates in BH 50 are less than 10.0 mg/L in 47 of 55 samples in the data set. The median alkalinity is 45 mg/L and most of the samples fluctuate about that concentration from 1988 to 2003; thus, there is no apparent trend of increasing or decreasing alkalinity concentrations. Also, there were only 2 samples with detectable acidity concentrations. This water is not representative of acidic or neutralized minepool water quality, and clearly does not represent groundwater influenced by the area of coal ash placement. Thus the water quality data from BH 50 and BH 31 were deemed to be unworthy of further consideration.

Table 1. Groundwater monitoring data of the Susquehanna site in (mg/L). (0.00 values = below detection limit).

SAMPLED	pH	SPECIF. COND.	ALK	ACID	Fe	Mn	SO4	TDS	TSS	Al	As	Cd	Ca	Cr	Pb
B.H. #31 Greenough															
7/9/90	4.85	450	11.2	26.9	64.0	2.3	71	341	53						
3/10/92	6.60	380	79.0	0.0	22.9	1.5	26	215	24						
9/19/95	6.10	327	105.0	0.0	27.0	1.7	81	158	26	0.00	0.000	0.000	30.2	0.000	0.000
8/27/99	6.10	590	46.8	0.0	18.9	2.0	81	316	14	*0.70*	*0.005*	*0.010*	32.1	*0.040*	*0.100*
9/29/00	6.04	548	60.0	*1.0*	24.4	2.0	90	303	3	1.00	*0.005*	*0.010*	31.6	*0.040*	*0.100*
8/6/01	4.12	445	3.6	24.0	10.3	2.3	80	290	20	1.30	*0.005*	*0.010*	3.4	*0.040*	*0.100*
11/6/01	5.48	430	39.9	*1.0*	16.5	1.8	72	254	10						
B.H. #48 Richards Water Level															
6/29/90	3.55	700	0.0	61.6	60.0	4.5	133	452	229	5.20	0.000	0.000		0.000	0.000
6/13/94	3.70	557	0.0	67.6	8.6	4.7	278	524	25						
3/6/95	3.80	656	0.0	79.2	25.0	4.2	283	532	36						
9/26/95	3.60	684	0.0	81.0	28.0	5.1	179	559	45	7.20	0.000	0.000	20.7	0.000	0.000
12/8/98	3.67	1350	0.0	70.0	2.4	4.3	141	589	5						
9/23/99	3.61	1120	0.0	66.5	12.3	5.2	225	586	4	8.40	*0.005*	*0.010*	20.8	*0.040*	*0.100*
6/13/00	3.48	488	*1.0*	131.0	380.0	3.9	120	764	900						
B.H. #49 Natalie															
6/9/92	5.90	105	38.0	40.0	51.0	0.8	2	73	78						
9/30/93	6.20	98	45.0	0.0	44.0	0.9	362	58	86	0.00	0.000	0.000		0.000	0.000
12/22/96	6.11	246	47.0	2.5	53.4	1.0	152	114	40						
9/25/97	6.37	93	63.0	0.0	296.0	1.1	6	82	332	3.50	0.000	0.000	7.4	0.000	0.000
8/27/99	6.19	275	93.6	0.0	159.0	1.2	2	166	274	1.20	*0.005*	*0.010*	9.7	*0.040*	*0.100*
3/2/01	5.75	200	36.0	*1.0*	58.0	1.0	3	84	120						
B.H. #50 Hickory Ridge															
7/9/90	6.60	75	43.0	0.0	26.3	0.4	2	37	88	0.00	0.000	0.000		0.000	0.000
8/3/90	2.49	1200	0.0	464.0	21.0	0.3	5	105	15						
3/22/94	6.50	569	83.0	0.0	20.0	0.4	0	372	36						
12/14/94	5.87	472	43.0	22.0	31.0	4.0	341	435	1	0.00	0.000	0.000	47.2	0.000	0.000
12/17/99	6.00	127	45.0	0.0	34.2	0.3	0	50	54						
8/7/02	6.50	96	14.4	*1.0*	10.0	0.5	3	94	6	*0.70*	*0.005*	*0.010*	10.4	*0.040*	*0.100*
3/12/03	6.58	1060	56.0	*1.0*	7.4	0.6	25	756	18						
8/7/03	6.78	133	20.1	*0.4*	21.3	1.4	2	67	51						
Scott overflow															
10/16/89	6.52	660	38.0	54.8	31.2	4.6	371	200	4						
2/2/90	6.50	650	38.0	35.1	26.5	4.3	248	20	12						
10/3/90	6.05	658	32.3	30.4	23.5	3.8	170	546	0						
4/9/91	5.67	700	38.0	82.0	28.0	3.8	260	450	2						

The Scott Overflow is considered the most reliable downgradient groundwater monitoring point for the Susquehanna Coal Co. permit site. It exhibits a discernable trend of groundwater quality improvement, which is most likely attributed to the beneficial use of coal ash in mine reclamation, plus the removal of large volumes of coal refuse for combustion in the FBC power plant. USGS sample data of the Scott discharge from 1975 (Growitz, et al., 1985) and 1991 (Wood, 1996) show that the flow of the discharge was measured at 15 cfs (6733 gpm) on April 17, 1975 and a flow of 4.8 cfs (2154 gpm) on November 1, 1991. The acidity in the 1975 sample was 165 mg/L and 161 mg/L in 1991. The alkalinity concentration of the 1975 sample was 16 mg/L, and the

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1991 sample was 38 mg/L. Representative samples from the permittee's self-monitoring data are in Table 4.5. Of the 60 permittee's monitoring samples of the Scott Overflow in the DEP permit file, the median acidity is 26.15 mg/L and the median alkalinity is 43.0 mg/L. Acidity exceeds alkalinity in 12 out of 60 samples in this data set, but 7 of these are in 1989 and 1990, when ash placement on the site was in its infancy (Fig. 4.18a), and the last time that acidity exceeded alkalinity was the sample of December 15, 1994. The median alkalinity for the samples prior to 1991 is 32.3 mg/L as compared to the median alkalinity of 44 mg/L for all samples from 1991 to 2003. The corresponding median acidity values are 35.1 mg/L for pre 1991 samples, and 21.3 mg/L for the past 12 years. This trend of acidity reduction is shown on Figure 6a for the Scott Overflow discharge as compared to the relatively consistent acidity in upgradient monitoring well BH 48. The corresponding trend of increasing alkalinity concentration in the Scott Overflow discharge is shown in Figure 6b. The least- squares trend line fitted to the alkalinity data for the Scott Overflow indicates an increase through time, however, the plotted monitoring data are not equally spaced through time – so the slope of the line may not be an accurate representation of the actual time trend. There also has been a subtle trend of decreasing sulfate concentration in the Scott discharge since 1995 as shown on Figure 6c. This indicates that the acidity production at the Mt. Carmel cogeneration plant site may be decreasing due to the removal of the coal refuse and the concomitant addition of alkaline coal ash to reclaim abandoned pits on the site.

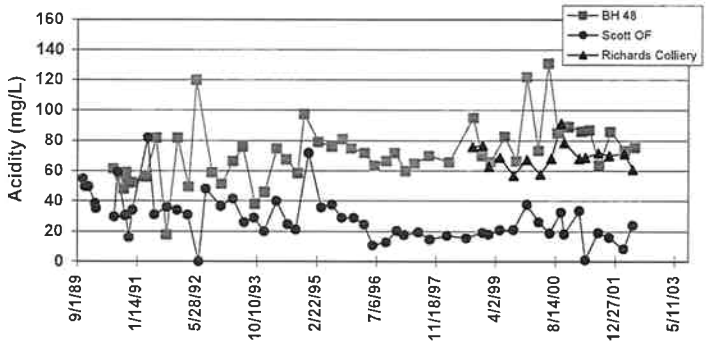

Figure 6a. Acidity in upgradient monitoring points and downgradient Scott Overflow at the Susquehanna site.

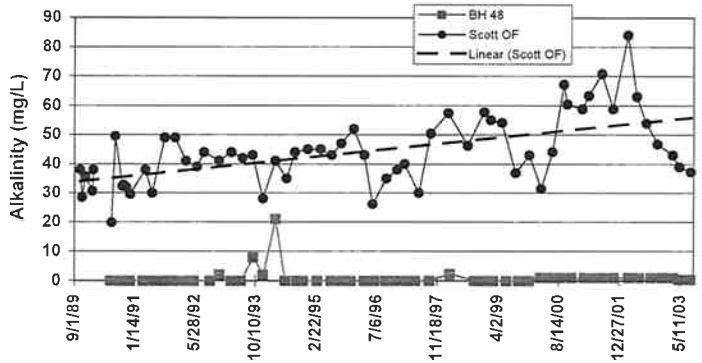

Figure 6b. Alkalinity increase in downgradient Scott Overflow.

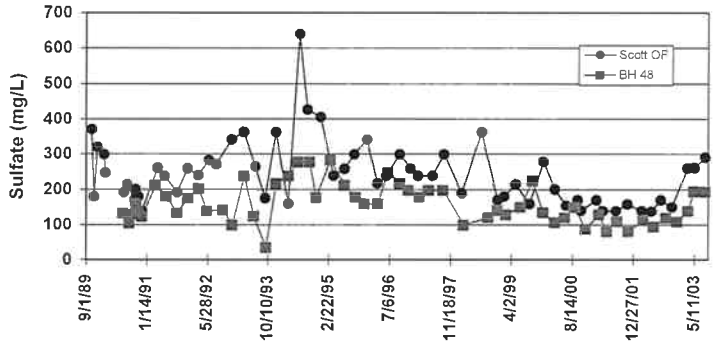

Figure 6c. Sulfate in monitoring points at the Susquehanna Coal site.

CONCLUSIONS

1. A very significant amount of abandoned mine reclamation in the four anthracite coal fields has been completed through the beneficial use of coal ash on remining sites. This extensive reclamation is significant, not only on individual sites associated with FBC power plants (e.g. the before and after photos in Fig. 5a and b, but also in the total acreage reclaimed at no cost to the government or taxpayers.

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2. The evaluation of more than 15 years worth of groundwater monitoring data for the case study sites presented in this paper, and other permitted sites throughout the anthracite region, has not resulted in any significant findings of environmental damage or groundwater pollution cases, as measured at key downgradient minepool monitoring points. Several sites discussed in this paper showed no significant change in groundwater/minepool water quality, despite extensive ash placement and land reclamation – although these sites significantly reduced infiltration to the minepool, and thus should represent a reduction in the flow and thereby the pollution load of acidity, iron and other metals in these high volume minepool discharges. At least one site discussed in this paper produced a significant increase in alkalinity concentrations, or reduction in acidity, iron or other analytes that is attributable to the beneficial use of coal ash on these sites.

3. The range of mine site characteristics, coal ash placement configurations and groundwater/minepool monitoring scenarios presented in this paper demonstrates that a "one size fits all" approach to the permitting and compliance monitoring of the sites is not practical or effective. Site specific application of engineering principles and evaluation of geologic factors is essential, particularly: (a) the soil-mechanics engineering of ash placement, (b) the mining engineering of the active surface mine and abandoned underground mines, (c) the geologic structure of the site and surrounding area (e.g. synclinorium), and (d) the hydrogeology of the site and underlying minepool system. Permit applicants, their consultants and regulatory agency scientists and engineers must collaborate to promote effective ash placement technology and to develop practical and realistic groundwater monitoring plans.

4. The groundwater monitoring data for various coal ash placement sites and a hydrologic budget review demonstrates that the "high and dry" concept of placing relatively dry (optimum moisture content) coal ash into a relatively dry mine environment is working well. It is feasible to develop a matrix approach that would match the range of physical and chemical properties of FBC and PC coal ash classes to various ash placement alternatives, in order to optimize cementitous behavior of specific ash types, or maximize alkalinity production in groundwater – and solve a variety of abandoned mine land and mine drainage problems.

REFERENCES

Arndt, H.H. 1971. Geological Map of the Mount Carmel Quadrangle, Columbia, Northumberland and Schuylkill Counties, Pennsylvania. Map GQ-919. Washington, D.C.: U.S. Geological Survey.

Brady, K.B.C., J.W. Hawkins, K. Miller and J.E. Cuddeback. 2001. Coal Remining – Best Management Practices Guidance Manual. EPA-821-B-01-010, Washington, D.C.: U.S. Environmental Protection Agency.

Growitz, D.J., L.A. Reed, and M.M. Beard. 1985. Reconnaissance of Mine Drainage in the Coal Fields of Eastern Pennsylvania. USGS Water Resources Investigations Report 83-4274, 54 pp.

Hawkins, J.W. 1995. Characterization and Effectiveness of Remining Abandoned Coal Mine in Pennsylvania. U.S. Bureau of Mines, EI 9562 37 pp.

Smith, M.W., R.J. Hornberger, K.B.L. Brady, J.W. Hawkins, W.A. Telliard, J.E. Cuddeback and K. Miller. 2004. The development of a national program to abate acid mine drainage through the remining of abandoned mine lands. In: Proceedings of 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, Lexington, KY.

Wood, C.R. 1996. Water Quality of Large Discharges from Mines in the Anthracite Region of Eastern Pennsylvania. U.S. Geological Survey, Water Resources Investigations Report 95-4243. 68 pp.

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