Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania







The Pennsylvania Department of Environmental Protection

Edward G. Rendell, Governor • Kathleen A. McGinty, Secretary

PENNSTATE

Materials Research Institute

A Message from Secretary Kathleen A. McGinty



You hold in your hands the culmination of many years of research into the use of coal ash in mine reclamation throughout the Commonwealth. This information has been gleaned from various reclamation projects and meticulously reviewed and analyzed by members of the scientific community, and has contributed to the formation of Pennsylvania's stringent regulatory program, a program so effective it could serve as a basis for coal ash regulations under development by the federal government. The attention to detail demonstrated by the Commonwealth ensures the appropriate use of coal ash, which can be extremely beneficial in reclaiming mine sites that would otherwise threaten the health and safety of Pennsylvania's residents and environment.

It is estimated that Pennsylvania has over 5,000 abandoned mine sites, effecting hundreds of thousands of acres of land, many of which are located near local communities. The Commonwealth is also home to several thousand miles of streams impaired by acid mine drainage. The information presented in this book, the most up-to-date statewide data currently available, demonstrates that alkaline coal ash can help remediate acid mine drainage and reclaim abandoned pits and other mine sites.

Based on this information, the Rendell Administration is including the consumption of waste coal in its high-priority Pennsylvania Energy Harvest grant program, which provides the last increment of financing for clean and renewable energy projects to be built in Pennsylvania from sources such as waste-coal, coal-bed methane, landfill methane, biomass, wind, solar and small-scale hydroelectric. The Commonwealth is home to thousands of acres of coal refuse piles as a result of its mining legacy, and these piles commonly cause acid mine drainage and refuse bank fires. By enabling the consumption of these piles in waste coal-fired power plants, the Rendell Administration is removing an environmental hazard and creating alkaline coal ash that can then be used to reclaim mine sites.

Put simply, there are still many years worth of reclamation work left to be accomplished, and if we're going to continue to enjoy success in reclaiming these sites, we need to thoroughly examine every possible tool available to us. The information presented here clearly shows that coal ash, when used appropriately, is a very effective one.

We at the Pennsylvania Department of Environmental Protection salute the members of academia, government, industry and the scientific community who participated in these studies and for their dedication to reclaiming our abandoned mine legacy and restoring our environment.

Sincerely,

Kathleen A. McGinty, Secretary
Pennsylvania Department of Environmental Protection

PREFACE

The Department of Environmental Protection (DEP) and its predecessor, the Department of Environmental Resources (DER), have regulated coal ash as a residual waste since the establishment of DER in 1970. The enactment of Act 241, the Pennsylvania Solid Waste Management Act of 1968 provided the Department with the first statute to regulate the disposal of ash generated by power plants. However, regulations adopted under Act 241 were limited and primarily directed at managing the proper disposal of ash. Since more than 50 percent of Pennsylvania's electrical power production comes from coal-fired power plants, large amounts of coal ash from these power plants traditionally were disposed of in slurry impoundments and large monofill disposal areas at these plant sites. The amendment of the Solid Waste Management Act in December, 1986, and the promulgation of the residual waste management regulations (25 Pa. Code Chapter 287) on July 4, 1992, resulted in the development of numerous other options for the beneficial use of coal ash including the placement of coal ash in reclamation of active and abandoned coal mine sites. The electrical power industry, the coal mining industry, and DEP have participated in a transformation from the traditional practices of residual waste disposal to an emphasis on the beneficial uses of coal ash, especially abandoned mine reclamation. As the beneficial use of coal ash in mine reclamation has increased in the past 20 years, the amount of monitoring data on the ash and ground water quality in DEP files has increased proportionally.

In recent years, the environmental effects of the use of coal ash in mine reclamation have become a controversial issue on the local and statewide scale in Pennsylvania, and on the national scale involving major environmental groups and federal agencies. DEP believes that we have a commitment to make our monitoring data and related research results available in a readable form for scrutiny and use by the scientific community, government agencies, environmental groups, and the general public. Therefore, it was determined that DEP would publish this book in cooperation with the Pennsylvania State University, as a peer-reviewed document on the beneficial use of coal ash in mine reclamation and mine drainage remediation in Pennsylvania.

Most of the contents of this book were compiled, written, peer-reviewed, and edited during the past two years. However, the two main elements of the foundation of the work presented in the book represent more than 20 years of research and data evaluation on coal ash. They are: 1) coal ash research at the Materials Research Institute (MRI) of the Pennsylvania State University, and 2) the collective permitting and compliance monitoring experience and permit file data of the Pennsylvania Department of Environmental Protection (DEP), pertaining to the beneficial use of coal ash at mine sites in Pennsylvania. While the Penn State researchers and DEP staff have cooperated on numerous projects during that 20 year period, a specific contract was developed in 1999 to have MRI conduct a rigorous scientific evaluation of coal ash placement and mine drainage interactions on three waste management demonstration permit sites in the Anthracite Coal Region of Pennsylvania. That research effort, led by Dr. Barry E. Scheetz and Dr. William B. White of MRI, resulted in a M.S. thesis in 2000 and a Ph.D.

dissertation in 2003 by Dr. Caroline M. Loop. It was determined that this research work would make up the core of the book (i.e. Chapters 7, 8, 9 and 11) and that additional chapters would be written by DEP authors and other scientists and engineers to set forth the full range of beneficial uses of coal ash in mine reclamation and mine drainage remediation in Pennsylvania.

An editorial committee composed of five DEP staff and two Penn State professors was formed to insure consistency in the technical content, format, and quality of the written material. The members of the committee were: Dr. William B. White and Dr. Barry E. Scheetz of MRI and Roger J. Hornberger, Alfred Dalberto, Timothy Kania, Michael J. Menghini, and Dr. Scott Walters of DEP. The editorial committee also coordinated the peer review process.

The editorial committee wishes to acknowledge the support of the following DEP staff in producing this book. J. Scott Roberts, Deputy Secretary for Mineral Resources Management, provided significant support and encouragement for the preparation and publication of the book as well as several years of support for the research effort conducted by the Materials Research Institute of Penn State on the three Waste Demonstration Permit sites. Joseph G. Pizarchik, Director of the Bureau of Mining and Reclamation and Michael Terretti, Director of the Bureau of District Mining Operations ensured that the project received critical staff and management support to complete the writing and editing of numerous chapters of the book. As this book was produced as a cooperative effort with the DEP waste management program staff, significant support was also provided by Nicholas A. DiPasquale, former Deputy Secretary of Air, Recycling and Radiation Protection, Thomas K. Fidler, Acting Deputy Secretary of that deputate, and Michael Forbeck, Acting Director of the Bureau of Land Recycling and Waste Management. Within the waste management program staff, special credit is owed to William F. Pounds, Chief of the Division of Municipal and Residual Waste of the Bureau of Land Recycling and Waste management and William Tomayko, Regional Waste Management Manager of the Northeast Regional Office, for their many years of practical experience and significant expertise with coal ash, as well as their good judgment in regulatory affairs, that led to the issuance of the three one-of-a-kind Waste Demonstration Permits.

The Office of Surface Mining (OSM) of the U.S. Department of the Interior has established a multi-interest group steering committee on the placement of coal-combustion byproducts (CCB) at mine sites, and has conducted national interactive forums on CCB placement since 1996. Mr. Kimery C. Vories (of OSM Mid-Continent Regional Coordinating Center) Chairman of the CCB Steering Committee recommended numerous peer reviewers to the editorial committee. The members of the CCB Forum Steering Committee are affiliated with the American Coal Ash Association, the Council of Industrial Boiler Owners, the Illinois Department of Commerce and Economic Opportunity, Southern Illinois University at Carbondale, the Ohio State University, the Pennsylvania Department of Environmental Protection, TXU Energy, the University of North Dakota, the U.S. Department of Energy – National Energy Technology Laboratory (NETL), OSM, and the U.S. Geological Survey. The peer reviewers for individual

chapters of this book were Kimery C. Vories, Peter Michael, and Jay Hawkins of OSM, Viktoras Skema of the PA Geological Survey, Dr. Tarunjit Butalia of Ohio State University, Dr. Ann Kim and Dr. Sai Golakota of U.S. DOE-NETL, Ishwar Murarka of Ish, Inc., David Martin of Anthracite Regional Independent Power Producers Association (ARIPPA), Deborah Pflughoeft-Hassett of the University of North Dakota, Dr. W. Lee Daniels of the Virginia Polytechnic Institute and State University, and Keith B.C. Brady of the Pennsylvania Department of Environmental Protection.

In addition to the work of the national committee organized by OSM, there have been other efforts on a national and state-wide scale to evaluate coal ash placement at mine sites during the past two years while this book was being written. The U.S. Environmental Protection Agency (EPA), OSM, and the Interstate Mining Compact Commission (IMCC) have collaborated on a national committee project to evaluate coal ash "mine fills." EPA has held several "listening sessions" throughout the U.S. to solicit public comments on these coal ash mine fill placement practices. In Pennsylvania, the Joint Legislative Air and Water Pollution Control and Conservation Committee (JCC) conducted a public hearing on July 9, 2003, concerning a request for a statewide moratorium on the use of coal ash for mine reclamation. They issued a report to the Pennsylvania General Assembly on February 5, 2004. The report included a finding that "The requests for a moratorium on the use of fly ash for mine reclamation, in effect, seek protection from a danger than 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 complete text of the JCC report is included as an appendix in this book.

Draft review copies of the book were released to all of the participants of the Technical Interactive Forum on State Regulation of CCB Placement at Mine Sites held in Harrisburg, PA, on May 4-6, 2004. Copies were also made available for further public review after the Technical Interactive Forum. DEP considered all comments submitted to the Bureau of Mining and Reclamation by June 30, 2004. The final publication incorporates these comments as well as those received from the peer reviewers.

William B. White, Chair
Editorial Committee

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April 1, 2004

The Honorable Kathleen A. McGinty
Secretary
Department of Environmental Protection
Rachel Carson State Office Building
P. O. Box 2063
Harrisburg, PA 17105-2063

Dear Secretary McGinty:

I recently had the opportunity to review a draft of a report prepared by the Pennsylvania Department of Environmental Protection entitled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania". This comprehensive and thorough analysis of the beneficial use of coal ash in Pennsylvania could not come at a better time with regard to the on-going debate about the value and use of coal combustion by-products as part of the mine reclamation process. As you know, IMCC and its member states have been engaged over the past several years in a dialogue with the Environmental Protection Agency and the Office of Surface Mining concerning the need for national regulations or guidelines addressing mine placement of coal combustion by-products at both coal and noncoal mines. Our position has been that additional federal regulations are unnecessary given the quality and comprehensive nature of existing state regulatory programs. We have also emphasized our overriding concern that any regulatory program not inhibit or undermine efforts to use coal combustion by-products in mine placement situations, given the significant environmental benefits that attend this use.

The recent report completed by the Department of Environmental Protection, together with the Pennsylvania State University, stands as a ringing endorsement for the beneficial use of coal ash and supports the arguments of the states that we are effectively and comprehensively regulating this activity, while ensuring that the opportunities for beneficial use are not unduly restricted. As the report notes, in many instances, mine placement of coal ash not only alleviates the creation and use of unsightly refuse piles (which are a legacy we are still struggling to find answers for, including co-generation), but more importantly it allows us to address abandoned mine land problems that would otherwise go unattended, due to limited amounts of money available to address all AML sites. In particular, coal ash placement has allowed us to address the pervasive problem of acid mine drainage, as the report demonstrates in elaborate detail. The success of these projects in Pennsylvania is

legendary and has been an encouragement to other states, while serving as a textbook example of how to remediate acid mine drainage problems using coal ash.

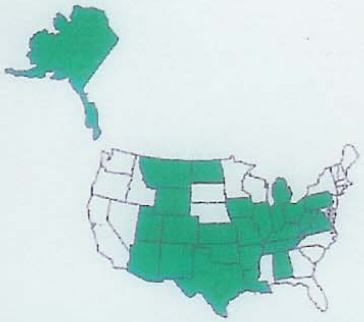
We are indeed fortunate that the authors of this impartial and objective report have taken the time and effort to publish their findings and information, which can now be shared with others and hopefully stimulate further efforts to beneficially use coal ash. They are to be commended for a job well done and Pennsylvania is to be lauded for its continuing efforts to seek and implement pollution prevention technologies and solutions that not only address your own situation, but that inspire others to do so as well.

We are delighted to endorse this important contribution to the debate on the beneficial use of coal ash and intend to distribute the report to as wide an audience as possible so that others can benefit from this excellent work. We also believe that the report can serve as the basis for setting objective and meaningful criteria for where various types of coal ash can be used and placed as part of the mining and reclamation process in order to achieve desired results.

Sincerely,

Gregory E. Conrad
Executive Director

cc. J. Scott Roberts
All Commissioners



NATIONAL ASSOCIATION OF ABANDONED MINE LAND PROGRAMS

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WYOMING

August 23, 2004

The Honorable Kathleen A. McGinty
Secretary, Department of Environmental Protection
Rachel Carson State Office Building
P.O. Box 2063
Harrisburg PA 17105-2063

Dear Secretary McGinty:

I have reviewed the draft report prepared by your department entitled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania". This report is a very thorough analysis concerning the beneficial reuse of coal combustion by-products in mine reclamation.

Many of the States and Indian Tribes that are members of the National Association of Abandoned Mine Land Programs (NAAMLP) will find the information and technology presented in the report useful in their mine reclamation efforts. Most notable to our members are the portions of the report that detail the use of coal ash for reclamation fill and acid mine drainage abatement.

Almost all NAAMLP member states are struggling with shrinking AML budgets. The use of coal ash in abandoned mine reclamation may help to lessen the coast of AML reclamation projects and simultaneously dispose of a waste product in a beneficial way.

The NAAMLP is happy to endorse the report and its findings. We hope that the report sparks expanded interest in the beneficial reuse of coal combustion by-products so that use of these products is common in the near future.

Sincerely,

Steve Hohmann

Steve Hohmann, President
National Association of Abandoned Mine Land Programs

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April 6, 2004

The Honorable Kathleen McGinty, Secretary
Department of Environmental Protection
Rachel Carson State Office Building
PO Box 2063
Harrisburg, PA 17105-2063

Dear Secretary McGinty:

The American Coal Ash Association is a non-profit organization whose members include electric utilities, ash marketers, members of academia, researchers and others interested in the beneficial use of coal ash. Our mission is to promote the management and use of coal combustion products (CCPs) in ways that are environmentally sound, technically viable and economically competitive. Our members represent approximately 47% of the total CCPs produced by the electric utility industry and more than 90% of the CCPs marketed and managed within the United States.

We recently had the opportunity to review the draft document prepared by the Pennsylvania Department of Environmental Protection titled, "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania." This comprehensive document does an excellent job of portraying Pennsylvania's model program for the use of CCPs in mining applications. The DEP has thoroughly documented numerous examples of CCP beneficial uses, uses that would otherwise require disposal of the same material as waste.

This draft document is another example of thorough analysis and fact-based decision making. It supports the conclusions recently issued by the Joint Legislative Air and Water Pollution Control and Conservation Committee (JCC) on the use of coal combustion materials in mine reclamation projects. We were pleased to read that the committee advised against a statewide moratorium on the ash use. The use of CCPs for mine reclamation has been successfully demonstrated in many states across the United States. Those groups in Pennsylvania who continue to oppose the use of coal ash in mine reclamation do so, despite the strong evidence to the contrary that this is a practice of great

C2P2 COAL COMBUSTION PRODUCTS PARTNERSHIP

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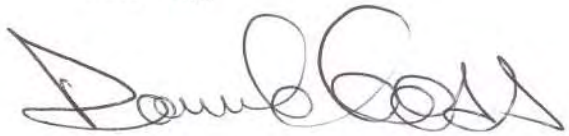
environmental and economic benefit. The groups also would be well served to read the data contained in the DEP draft report to better understand the objective, scientific details of the issue rather than depending on their subjective feelings and confusion.

It would seem obvious that removing large piles of waste coal and burning it in power generation stations would, of itself, be a good thing. Then, to take the ash from these power plants and use it to remediate, and in some cases eliminate an environmental problem would be of greater value. The specific details described in this report of projects at a number of sites across Pennsylvania bear out this wisdom. The citizens of Pennsylvania should be re-assured that the data and research that is contained in this document validates the oversight and implementing actions that have taken place over many years.

Our association is most appreciative of the leadership role that Pennsylvania has taken in mine reclamation activities and especially in the use of coal ash to remediate abandoned and active mine sites. We believe that the staffs of the DEP and the faculty and students at The Pennsylvania State University are to be commended for their outstanding efforts in assembling this data.

We appreciate very much the opportunity to review this fine document and have committed to assist in the distribution of the document on CD, when it is finalized. Please do not hesitate to contact us if we can be of any further assistance.

Sincerely,



David Goss
Executive Director

EPCAMR

Eastern PA Coalition for Abandoned Mine Reclamation

Robert E. Hughes
Regional Coordinator
Eastern PA Coalition for Abandoned Mine Reclamation
Luzerne Conservation District
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April 20, 2004

The Honorable Kathleen A. McGinty
Secretary
PA Department of Environmental Protection
Rachel Carson State Office Building
PO Box 2063
Harrisburg, PA 17105-2063

Dear Secretary McGinty:

I have recently had a chance to review a draft of the report entitled, "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania", prepared by the PA DEP and the Pennsylvania State University. The detailed and comprehensive analysis of the beneficial use of coal ash in PA will surely serve as a highly regarded technical report given the on-going debate and rhetoric about the value and beneficial use of combustion fluidized bed (CFB) by-products specific to abandoned mine reclamation projects.

As you are well aware, the Eastern PA Coalition for Abandoned Mine Reclamation (EPCAMR), is a non-profit organization that was created by representatives of the Conservation Districts encompassing sixteen eastern PA counties, the anthracite industry, watershed associations, sportsmen's groups, conservation clubs, co-generation facilities, and representatives from the general public. The mission of the Eastern Coalition is to encourage the reclamation and redevelopment of abandoned mine lands and remediation of waters affected by past practices of the mining industry in Eastern PA and to provide technical support to the community groups that have an interest in restoring their watersheds impacted by abandoned mine drainage.

An increasingly important role for EPCAMR has been to serve as a liaison between the local grassroot watershed organizations, private businesses, the mining industry, DEP, BAMR, OSM, EPA, and other state and federal agencies involved in abandoned mine land reclamation activities and acid mine drainage remediation. EPCAMR has also been actively involved in raising the awareness of the general public, our schools, and our elected officials on a local, state, federal, and national level regarding environmental issues related to abandoned mine land reclamation and abandoned mine drainage.

EPCAMR works to provide technical and administrative support to the Conservation Districts, coordinate reclamation activities, establish a public education outreach program within the schools, and to rejuvenate local watershed groups, primarily in those areas where streams are adversely affected by abandoned mine siltation and abandoned mine drainage. EPCAMR works together with nearly 75 local groups to inform and educate the public and to organize environmental interests relative to the purpose and value of specific reclamation, remining, and remediation techniques being proposed for sites in their local community.

EPCAMR has been engaged over the past several years in positive interactions and openness with the US EPA Region III, specifically, and the US Department of Interior's Office of Surface Mining concerning the need for uniform national guidelines to address coal ash placement on abandoned mine lands.

The Pennsylvania Department of Environmental Protection (DEP) comprehensively regulates use of the ash in reclamation and soil amendments under the SMCRA of 1977; and no adverse impacts have been discovered despite a decade of monitoring. There are significant environmental benefits to be gained through the continued use of the coal ash in abandoned mine reclamation. The data collected by the US EPA has shown that combustion fluidized-bed (CFB) wastes do not meet the criteria of hazardous wastes, therefore do not warrant additional federal regulations under RCRA and are unnecessary, given the comprehensive oversight and rigid quality control that currently exists under state programs.

By burning waste coal for fuel, co-generation plants are also cleaning up abandoned mines sites and waste coal piles across PA. 15 States have created regulations and policies encouraging the beneficial use of fly-ash. As you know, waste coal sites seriously impact water quality, contribute to the formation of abandoned mine drainage (AMD) and threaten public health and safety. EPCAMR believes, in general, that the electric generating industries manage fossil fuel combustion waste in a responsible manner and the coal ash waste do not represent a significant hazard requiring more stringent regulation.

A byproduct of the combustion is an alkaline ash that Pennsylvania DEP has approved for use in reclamation programs for active and abandoned mines. The ash is returned to the site to neutralize other pyritic and acid bearing materials that could not be used as fuel, and to supplement native soils to promote site revegetation. The sites are backfilled, contoured, and vegetated. CFB material enhances the revegetation of the sites as a soil amendment with important agronomic benefits.

By reclaiming these sites, the electric power generating industry is also eliminating many potential safety and health hazards in the community. The abandoned waste sites pose the threat of accidental fires, and they are sometimes used as trash dumps or recreational areas for people using all-terrain vehicles. Sedimentation and erosion problems are also eliminated in areas where streams are located nearby. Data collected at many reclaimed sites indicate improvements in surface water quality and elimination of AMD. Reclaimed abandoned mine sites also help to reduce the surface infiltration of water in to the underground mine workings that eventually discharge into streams and rivers as AMD.

Potential closure of the co-generation plants would create adverse environmental and economic consequences for dozens of small communities across the state. The common beneficial use of ash from CFB combustion boilers from electric co-generation plants in PA serves as a vital component in the reclamation of abandoned mine sites in our State and it has made a meaningful contribution toward addressing this urgent environmental need in many coal field areas of PA. Deregulation of the electric utility industry over the next 10-15 is going to seriously hamper the amount of abandoned mine lands and culm banks that are currently being reclaimed. In the Anthracite Region, we can not thank some of our regional co-generation facilities enough for the great job they do in reclaiming abandoned mine lands. These private companies are not obstacles, they should be considered one of the greatest assets we have in our region.

Let us not forget that much of this work has been completed at no cost to the state or taxpayers. The backlog of reclamation needed for the nearly 250,000 acres is projected to cost more than $3,000,000,000 in PA, and that only includes the Priority 1 and Priority 2 Sites. PA DEP estimates that is costs around $20,000 to clean up just one acre of abandoned mine lands. To date, more than 2,300 acres have been cleaned up, saving PA residents nearly $460,000,000. This estimate does not include the elimination of AMD that has detrimentally impacted our streams and rivers.

For example, in the Wyoming Valley, Luzerne County, PA, hundreds of acres of abandoned culm banks have literally disappeared. The once dirty, ominous, abandoned mine land features that have dominated the landscape for nearly eight decades and blocked the beautiful view of the Susquehanna River from the East side of the Valley from the West, have been reclaimed utilizing coal ash for abandoned mine reclamation. People can travel the local highways and Interstate I-81 and now see clear cross the Wyoming Valley. Northampton Generating Supply Company, separated the culm, hauled it away, brought back the ash, compacted in lifts on the same site in which it came from, filled the mine voids, and reclaimed the site. It was a win-win situation. In the land beneath these culm banks, there's economic and environmental value.

Within the culm banks, there is energy to be recycled, and in the continued removal of these eyesores, EPCAMR sees great satisfaction in the reclaimed aesthetic look for Northeastern PA and across the State of PA as a whole. We should concentrate our efforts on reclamation of these undeveloped acres for social, economic, as well as environmental uses. Expanding and reconnecting our communities separated by mountains of culm, creation of open space areas, wildlife habitat enhancement, water quality improvements, improving the areas quality of life, recreational opportunities, stream restoration, and economic development of these abandoned mine lands should be of the utmost importance.

EPCAMR believes that PA has ample and effective waste disposal and management regulations already in place. It is important that we continue to support private business and industry that successfully balance economic development with environmental protection. Innovative solutions to environmental problems should be applauded, not restricted, or overly regulated.

The reclamation of abandoned mine sites in the Anthracite Coal Fields of Northeastern PA and throughout the Western PA Bituminous Coal Fields is crucial to the restoration of the ecological values and water quality improvements in thousands of miles of streams and rivers in the Susquehanna, Delaware, and Ohio River watersheds. These efforts using CFB ash in the reclamation process are also key to the economic redevelopment and cultural recovery of the human conditions and communities that were adversely affected by the extractive history of the coal industry in the past.

EPCAMR agrees with the PA Joint Legislative Air & Water Pollution Control & Conservation Committee's recommendations, the most significant of which are as follows:

- continuing research into the effects of coal ash placement on abandoned mine lands;
- third party oversight of reclamation projects;
- studying the risks of not reclaiming hazards and threats posed by the legacy of past mining practices, and;
- providing public education on the beneficial use of coal combustion waste products.

This report completed by the PA Department of Environmental Protection, along with the Pennsylvania State University, lends great credibility for the beneficial use of coal ash and supports the position that PA is regulating the activity effectively, while ensuring that the opportunities for beneficial use are not disproportionately restricted. EPCAMR is also willing to provide materials on the beneficial use of coal combustion waste products for public education and outreach that are true, accurate, and based on factual information to community groups in our Region, including copies of this document.

EPCAMR understands that without clean water, land, and water, the social, recreational, economic, and environmental vitality of the Commonwealth will be severely disadvantaged for our future generations. PA should continue to be the true leader in the continuing efforts to research and implement remediation and reclamation techniques on abandoned mine lands. Other states should follow our lead.

EPCAMR is pleased to endorse this publication and intend to pass around copies of the completed report and make reference to it to the many watershed organizations and other abandoned mine reclamation supporters in the Northeast. This report should serve as the model for other states to set objective, unbiased, meaningful criteria for where coal ash can be utilized and placed as part of today's mineral resource extraction industry and abandoned mine reclamation processes in order to achieve the ultimate goal of land reclamation.

Respectfully Submitted on behalf of the EPCAMR Board of Trustees,

Robert E. Hughes

Robert E. Hughes-Regional Coordinator
Eastern PA Coalition for Abandoned Mine Reclamation

Cc: J. Scott Roberts, PA DEP MRM
Roger Hornerberger, PA DEP MRM-DMO
EPCAMR Board of Trustees

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August 4, 2004

The Honorable Kathleen McGinty, Secretary
Department of Environmental Protection
Rachel Carson State Office Building
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Harrisburg, PA 16105-2063

Dear Secretary McGinty:

The Western Pennsylvania Coalition for Abandoned Mine Reclamation has had over a 20 year history as a non-profit organization whose sole focus is to reverse the ravishes of past mining practices in the Commonwealth. We work as a coalition of 24 Conservation Districts in the bituminous coal fields of western Pennsylvania and support watershed associations and other conservation minded organizations who are willing to become involved in abandoned mine reclamation efforts. We embrace public-private partnerships as a means of getting the job done.

Pennsylvania's legacy of abandoned mine lands and polluted waters is well known. The reclamation costs associated with these problems are measured in billions of dollars and even the most optimistic projections place complete clean-up and remediation decades into the future. In spite of the tremendous battle before us, Pennsylvania has made significant strides and commitments in reclaiming our lands and waters from the ravages of old mining practices. We recognize that the problems are so large that no single source, be it federal, state, of local governments, or private industry, can provide the necessary recourses in totally cleaning up the mess. To ever get the job done means strategically working together and working smarter.

A prime example of working together and working smarter comes from the power industry where material from coal refuse piles is burned in specialized facilities known as co-generation plants. Power is produced from the residual energy in the refuse and in the process coal refuse piles are eliminated, a great service to the Commonwealth to be sure. An additional benefit is also realized: the combustion product is an ash containing significant levels of alkalinity. This product has acid-neutralizing and other useful properties that make it useful in land and water reclamation projects. What would normally be a waste product becomes an asset to remediation efforts and avoids unnecessary land filling.

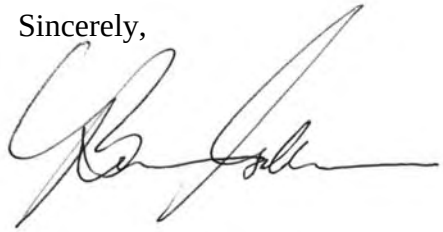
As should be the case, combustion ash must be certified by the DEP for beneficial use for specified purposes in specified situations. When held to the rigors of oversight, this ash has been shown to be a safe and beneficial product for its intended use. Research by credible workers and institutions support this view. Indeed, ash has helped in the reclamation of approximately 150 sites in

Pennsylvania in a variety of ways without problem. It can be used in making soil substitutes, can limit water infiltration into acid and metal producing materials (such as a coal refuse pile) thus reducing the amount of pollution formed, and be can used in filling mine voids while reducing subsidence potential and neutralizing acids. Contaminants in ash such as arsenic generally approximate those in natural soils and leaching into surrounding soils has not been observed to any appreciable level when used as prescribed. This ash has proven to be environmentally safe and an important tool in abandoned mine reclamation projects. Its continued use should not only be allowed, but encouraged.

I have recently reviewed a draft document prepared by the Pennsylvania Department of Environmental Protection titled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania." We commend the Department and the authors of this outstanding document for the thorough and comprehensive treatment on the use of coal combustion products in abandoned mine reclamation. The document successfully encapsulates the science and practice of this product's use. Additionally, the document supports the conclusions reached by the Joint Legislative Air and Water Pollution Control and Conservation Committee that deemed the product as safe and beneficial for reclamation projects when used as prescribed in Pennsylvania's model regulatory program. The draft document promises to become the definitive work on the beneficial use of coal ash in reclamation.

This story of cooperation and partnerships with industry, government, academia, and organizations is a shining example of how, when working smarter and together, great things can happen in reclaiming and protecting the environment. We applaud the Department of Environmental Protection for its leadership and its role in this most important and timely subject. Congratulations on a job well done!

Sincerely,



Bruce Golden,
Regional Coordinator

cc: J. Scott Roberts, R. Hornberger, A. Dalberto

Wildlands Conservancy

20 April 2004

Kathleen A. McGinty, Secretary
Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street, 16th Floor
Harrisburg, PA 17105

Re: "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania"

Dear Secretary McGinty:

We recently had the opportunity to review a draft of the book prepared by the Pennsylvania Department of Environmental Protection entitled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania." This topic has been an important one for some time, of course, but recently has received focused attention in the Lehigh River watershed – the area of Pennsylvania served by Wildlands Conservancy – as well as in other parts of the state.

As a non-profit conservation organization, Wildlands' mission is to preserve, protect, and enhance the land, water, biological, and recreational resources of the Lehigh Valley and the Lehigh River watershed, and to ensure a "quality of place" through education, land preservation, watershed planning, environmental restoration, and recreational-trail and greenway development. In carrying out our mission, we frequently deal with abandoned-mine-drainage issues in the Southern and Eastern Anthracite coal fields, and are nearing the completion of several mine drainage-abatement projects.

We feel this book should be useful for watershed associations and others interested in abandoned mine reclamation and abatement. We applaud the Department of Environmental Protection and the Pennsylvania State University for their continued commitment to exploring potential ways to minimize the impact of mine drainage across the commonwealth.

Sincerely,

Thomas J. Kerr
President

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E-mail: info@wildlandspa.org

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April 13, 2004

The Honorable Kathleen A. McGinty
Secretary, Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
PO Box 2063
Harrisburg, PA 17105-2063

Re: Beneficial Use of Coal Ash in Abandoned Mine Restoration

Dear Secretary McGinty:

Due to the devastation caused by abandoned mines to water and land resources, participants of the Slippery Rock Watershed Coalition have focused on the implementation of environmentally-friendly, and sustainable, restoration methods.

In less than a decade, through the use of alkaline, circulating fluidized-bed coal ash, over 125 acres of essentially barren spoils have been restored to productive farmlands or vital wildlife habitat. In addition, over 200,000 tons of acidic coal refuse have been neutralized.

Coupled with other restoration efforts, coal ash has been instrumental in the remarkable improvement in more than 11 miles of streams in the Slippery Rock Creek headwaters, with fish returning in 6 miles, probably for the first time in over a century.

To date, our comprehensive restoration efforts would not have been possible without the use of coal ash, and, future efforts are dependent on the continued availability of this resource.

The role of the Pennsylvania Department of Environmental Protection in providing a valued publication relating to the appropriate utilization of coal ash is not only appreciated but also necessary for the continued success in restoring our watersheds.

Very truly yours,

Margaret H. Dunn, PG, President, Stream Restoration Inc.

Copy: J. Scott Roberts, Dep. Sec., Office of Mineral Resources Management, PA DEP

SCHUYLKILL HEADWATERS ASSOCIATION

To Protect, Preserve, and Restore the Schuylkill Watershed within Schuylkill County
PO Box 1385, Pottsville, PA 17901

April 16, 2004

Honorable Kathleen A. McGinty
Secretary
Pennsylvania Department of Environmental Protection
PO Box 2063
Rachel Carson Building
Harrisburg, PA 17105-2063

Ref: Beneficial Use of Coal Ash in Abandoned Mine Reclamation

Dear Secretary McGinty:

Schuylkill Headwaters Association, Inc. (SHA) was formed in 1997 to help identify acid mine drainage (AMD) problem areas of the headwaters and tributaries of the Schuylkill River and to recommend and implement AMD abatement projects and stream restoration projects. Our objective is to bring life back to streams in an effort to enhance benefits such as the enjoyment of fishing and ecotourism for the region's communities.

SHA partnered with the Schuylkill Conservation District, Eastern Pennsylvania Coalition for Abandoned Mine Reclamation, and Schuylkill Riverkeeper on completing an assessment of the Schuylkill River Watershed within the boundaries of Schuylkill County. The assessment identified over 160 AMD discharges within the headwaters of the Schuylkill. The assessment also pointed out many recharge areas, sites where water can enter the mine pool to become acid mine drainage.

The watershed assessment has given our organization a unique perspective of problems concerning reclamation of abandoned mine discharges and mine sites in our area. We have invited guest speakers to our meetings and taken field trips to cogeneration stations, coal breakers, reclamation sites and abandoned pits. Our watershed includes several reclamation projects (Wheelabrator - Morea, Gilberton Power - Ellengowan, NEPCO – Big Gorilla Pit) that have shown positive results from the use of coal ash.

The members of our organization believe coal ash used for mine land reclamation is safe and can be beneficial for the environment. We have seen the elimination of culm banks and

reclamation of mine scarred areas while adding an economic benefit to our region. There has been a reduction in culm banks that add sediment, acidity, and metals to our streams. There also has been a reduction in recharge areas to the mine pools thereby preventing surface water from being impaired. Coal ash has also been utilized to eliminate hazardous crop falls on Sharp Mountain in very close proximity to residences in the city of Pottsville.

SHA recently had the opportunity to review the draft document titled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania." This document provides a thorough analysis of the use of coal ash. The document also supports the fact-based decision making of the Pennsylvania Department of Environmental Protection (Pa DEP) in its oversight of coal ash use in these reclamation projects. Pa DEP is to be applauded for its efforts to seek innovative, cost effective, beneficial uses for coal ash in mine land restoration.

Sincerely,

William Reichert/Br

William Reichert
President

Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania

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LIST OF ACRONYMS

AMD	Acid mine drainage
AML	Abandoned mine lands
AMLIS	Abandoned Mine Land Inventory System (OSM)
AOC	Approximate original contour
ASTM	American Society for Testing Materials
BAMR	Bureau of Abandoned Mine Reclamation (PA)
BTU	British thermal units
CCB	Coal combustion byproducts
CCE	Calcium carbonate equivalence
CFB	Circulating fluidized bed
CKD	Cement kiln dust
DEP	Department of Environmental Protection (PA)
EM	Electromagnetic terrain conductivity
ET	Evaprotranspiration
FBC	Fluidized bed combustor
FERC	Federal Energy Regulatory Commission
FGD	Flue gas desulfurization
LKD	Lime kiln dust
MCL	Maximum contaminant level
MPA	Maximum potential acidity
msl	mean sea level
NALIS	National Abandoned Land Inventory System (PA DEP)

NNP	Net neutralization potential
OSM	Office of Surface Mining, Reclamation and Enforcement (Federal)
PC	Pulverized coal
PCB	Polychlorinated biphenyls
PURPA	Public Utilities Regulatory Policies Act (1978)
RCRA	Resource Conservation and Recovery Act (1976)
SER	Schuykill Energy Resources
SMCRA	Surface Mining Control and Reclamation Act (1977)
SMP	Surface mining permit
SPLP	Synthetic Precipitation Leach Procedure
TCLP	Toxicity Characteristic Leach Procedure
TDS	Total dissolved solids

CHAPTER 1. OVERVIEW: COAL ASH BENEFICIAL USE AND MINE LAND RECLAMATION

Alfred D. Dalberto, Barry E. Scheetz, Roger J. Hornberger, Timothy C. Kania, Michael J. Menghini, Scott E. Walters

1.1 INTRODUCTION—PENNSYLVANIA'S ABANDONED MINE LAND PROBLEM

Since commercial coal mining began in Pennsylvania prior to 1800 (Dodge & Edwards, 2003), the Commonwealth's miners have extracted approximately 16.3 billion tons of coal from the Anthracite and Bituminous Coal Fields combined (PA DEP, 2002). The efforts of Pennsylvania's miners helped fuel the nation's industrial revolution and fed families for generations. However, the other legacy of the state's rich mining heritage is an unparalleled abandoned mine land (AML) problem.

Prior to the enactment of the federal Surface Mining Control and Reclamation Act (SMCRA) in August 1977, laws and regulations governing surface mining and the surface effects of underground mining, were largely ineffective in achieving reclamation of mined lands. SCMRA, which applies to all surface mining conducted after August 1977, requires complete reclamation of surface mine-affected lands and requires the posting of financial assurances, usually in the form of bonds, to ensure reclamation. While present-day mine sites are occasionally abandoned, the Pennsylvania Department of Environmental Protection (DEP) has well-established programs in place to reclaim those sites.

However, much of the vast AML problem from the pre-1977 mining remains. There are more than 5000 abandoned, unreclaimed mine problem areas encompassing more than 189,000 acres in Pennsylvania, according to the DEP Bureau of Abandoned Mine Reclamation (BAMR). BAMR's inventory of abandoned mine sites also identifies over 820 abandoned coal refuse piles. Often called culm in the anthracite fields and gob in the bituminous fields, these refuse piles encompass over 8,500 acres and have a volume of over 212,465,000 cubic yards (NALIS, 2003). These numbers are likely conservative in that many smaller piles are not fully accounted for. It is estimated that Pennsylvania suffers from up to 3,100 miles of streams degraded by acid mine drainage (AMD) as a result of abandoned mines. AMD is Pennsylvania's most serious stream pollution problem. The BAMR-estimated price tag to eliminate Pennsylvania's AML problems is a staggering $14.6 billion.

Over the years, both the federal and state governments have attempted to tackle Pennsylvania's AML problem. For example, Pennsylvania authorized the expenditure of more than $200 million for the Operation Scarlift Program in 1967. Under Operation Scarlift, the former Departments of Mines and Mineral Industries and Environmental Resources funded abandoned mine reclamation projects, including mine fire suppression and surface subsidence repair. Currently, Pennsylvania operates a program called Growing Greener, which funds environmental clean-up efforts through grants to nonprofit groups and local governments. While not all Growing Greener funds go to AML problems, a significant portion do, especially for projects that use passive treatment technologies to clean up abandoned mine discharges. At the federal level, since 1977, the Office of Surface Mining (OSM) has allocated to BAMR

approximately $587 million for abandoned mine reclamation projects. This funding, currently averaging about $30 million annually is obtained from a per-ton fee paid to OSM from active mine operators, which is then distributed back to states with AML problems. The abandoned mine reclamation fund will expire in 2004, but will likely be re-authorized in some form by Congress. While substantial, these reclamation efforts to date have only dented Pennsylvania's $14.6 billion AML problem.

One approach Pennsylvania has taken to help address the AML problem is to encourage private funding of the reclamation of abandoned mine lands. To this end, Pennsylvania has encouraged re-mining of abandoned mine lands in settings where technical data show that additional problems are unlikely to occur, and, where in the normal course of re-mining, abandoned mine features will be reclaimed. Pennsylvania uses a program of re-mining incentives called Reclaim PA to encourage reclamation through re-mining in appropriate settings under appropriate conditions.

Waste coal piles represent a significant subset of AML sites in Pennsylvania. These sites present both some unique problems and opportunities. The piles are typically toxic to plant life, and thus are barren and highly erosive. The bituminous piles in particular can leach highly concentrated AMD with acidity values in the thousands of mg/L, and which can include, in addition to typical AMD parameters, elevated levels of some trace metals such as arsenic, lead, copper, and chromium. The cost of reclaiming these piles using conventional AML techniques is high, and the extremely poor water quality is often beyond the reach of current passive treatment technology. However, the key to reclamation of many of the piles may be in the fuel-value of the material.

1.2 FLUIDIZED BED COMBUSTION (FBC) POWER PLANTS

There have been sixteen fluidized bed combustion (FBC) power plants constructed in Pennsylvania in the past seventeen years. The locations of these plants are shown on Figure 1.1. The Kimberly Clark FBC plant is an industrial site-power plant, and the remaining plants are all commercial power producers. Some are also cogeneration facilities in that they supply heat to one or more customers. (An FBC power plant is also considered a cogeneration project if it markets at least five percent of its steam to a thermal energy user.) The Archbald power plant was decommissioned in June 1997, and the Reliant Energy Seward FBC power plant started operating in the spring of 2004, so there currently are 15 FBC plants operating in Pennsylvania.

1.2.1 Creation of the FBC Power-Generating Industry

In response to oil and gasoline shortages and significant price increases during the 1970's, the United States Congress passed The Public Utility Regulatory Policies Act (PURPA) in 1978. This act required that the electric utility companies buy the electric power produced by facilities that met certain qualifications, such as the use of non-traditional fuels. Coal mine refuse is considered a non-traditional fuel. The electric industries were required to pay for this electricity at a rate that matched the traditional power plant cost to produce the electricity.

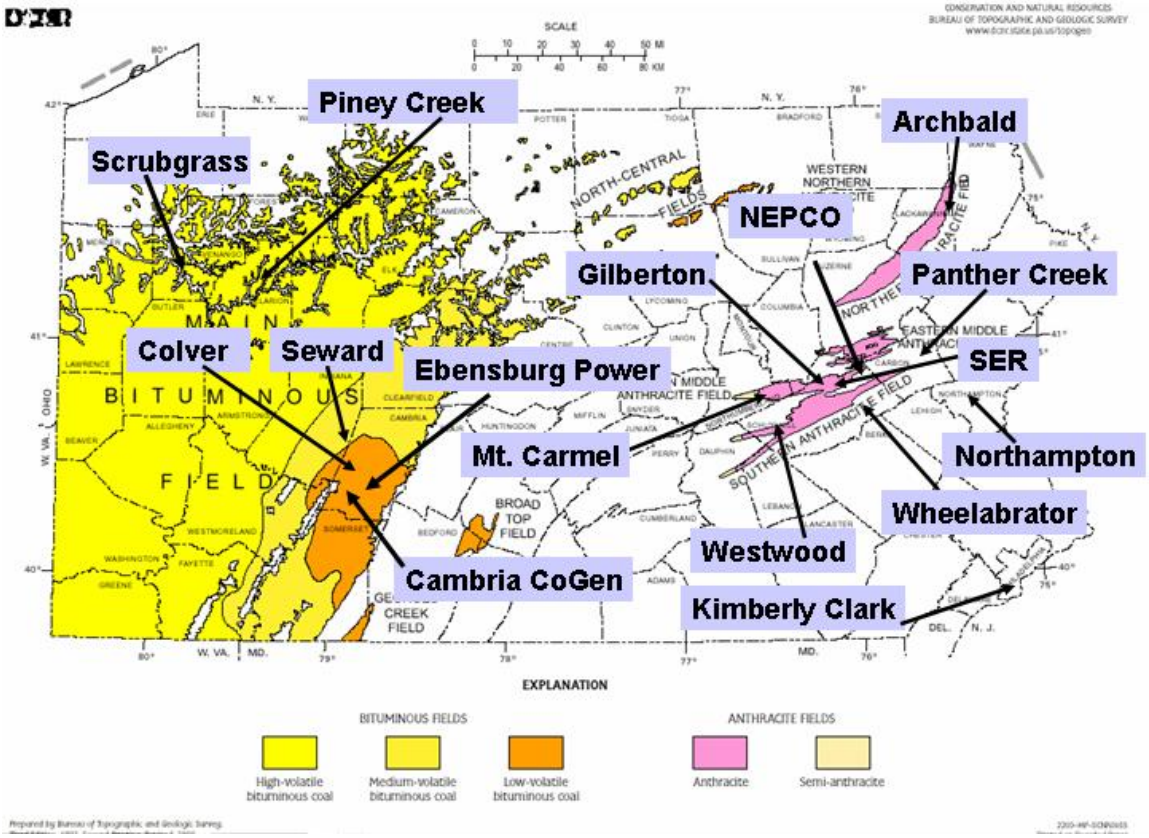


Figure 1.1. Distribution of the 16 FBC power plants in Pennsylvania.

PURPA thus created a great deal of financial interest in the production of electricity by using the waste coal in Pennsylvania's abandoned refuse piles

At about the same time, researchers in the United States and in Europe were developing a new kind of combustion unit capable of utilizing low heating value waste material to produce the steam necessary to drive a steam turbine-generator. The new combustion technology, circulating fluidized bed combustion, was also capable of emissions control that enabled these combustion units to meet the most stringent of the emissions regulations mandated by the Clean Air Act of 1970.

1.2.2 Operation of FBC Power Plants

FBC boilers are atmospheric pressure combustion units capable of burning fuels that contain as little as one-quarter of the heating value of commercial coal, while controlling the emissions of sulfur oxides and nitrogen oxides, the two primary causes of acid rain. These combustion units are designed to burn coal refuse that is crushed to a top-size of approximately five millimeters. The fuel particles are introduced into the bottom of the combustion chamber and high-pressure air is forced through nozzles in the bottom, or bed plate, of the chamber, suspending the fuel particles in mid-air. The fuel particles then swirl around, acting like a fluid, hence the fluidized bed part of the name. With this process all surfaces of the particles are in

intimate contact with the air necessary for combustion. This bubbling mass of air and fuel is then heated to the ignition temperature of the fuel by a start-up burner system. Upon reaching its ignition temperature, the primary fuel ignites and the start-up burners are turned off. The primary fuel temperature is then increased to the design combustion unit temperature of approximately 800 to 900 degrees centigrade by the addition of more coal refuse fuel and more air. These relatively low combustion temperatures allow the units to operate with very low emissions of nitrogen oxides.

Along with the fuel, crushed limestone is injected into the bottom of the combustion chamber where the calcium carbonate in the limestone is converted into calcium oxide. The calcium oxide then reacts with the sulfur in the coal refuse, thereby reducing the sulfur oxides emissions. The calcium sulfate, formed by the reaction of calcium oxide and sulfur, is an inert substance that in the presence of water becomes gypsum, which is captured in the particulate control system.

The heavier waste fuel and limestone particles that cannot be retained in the circulating fluidized bed drop to the bottom of the chamber. This burned fuel, known as the bottom ash, is removed from the combustion chamber.

At the top of the combustion chamber, the gasses created by burning the coal refuse fuel and the smallest particles of burned fuel, exit the combustion chamber and enter a solids separation device called a cyclone. Here, the smallest of the particles of burned fuel are separated from the larger particles by centrifugal force, as the hot gasses swirl around in a circular path. The hot gasses and smaller particles of burned fuel, fly ash, are then directed into the convection section or back passes of the combustion unit, where the heat contained in the hot gasses is used to create the high-temperature high-pressure steam necessary to turn a steam turbine and generator. The larger particles are returned, or circulated, back to the bottom part of the combustion chamber where they are reheated and any remaining carbon in the coal refuse fuel is burned. This circulation cycle may take place many times over several hours and greatly contribute to the complete combustion of the carbon in the waste coal fuel, and hence the inclusion of the word “circulation” in the name of this combustion system.

1.2.3 Distribution of FBC Plants in Pennsylvania

Fifteen of the sixteen FBC plants range in size from 18 megawatts to 107 megawatts, however the most recent FBC plant (Seward) to come on line is 520 megawatts. The FBC power industry in Pennsylvania began in the Anthracite Region in 1987 when the Kimberly Clark plant in Chester, Pennsylvania went on line. This industrial plant was quickly followed by the start up of the Westwood Energy power plant in Tremont in July 1988. The Gilberton FBC power plant, which quickly followed, started operation in the fall of 1988. The Wheelabrator plant began operating in June 1989. In 1990, the Mount Carmel plant began operating in February, the Schuylkill Energy Resources plant in July, and the Archbald plant in September. (The Archbald FBC power plant was decommissioned in June 1997.) The most recent FBC plants to go on line in the Anthracite Region were the Panther Creek plant, in June 1992, and the Northampton plant, in August 1995 (Inners et al., 1996).

In the Bituminous Region the Cambria CoGen FBC power plant started operation in March 1991, followed by the Ebensburg Power Company plant in May 1991. The Piney Creek FBC power plant started operating in December 1992, the Scrubgrass plant in June 1993, and the Colver (Inter-Power/Ahlcon Partners) plant in October 1995. The Seward FBC power plant, which started operating in spring, 2004, is the most recent addition. The locations of all sixteen FBC power plants are shown in Figure 1.1.

1.2.4 Coal Refuse Consumption by FBC Power Plants in Pennsylvania

The FBC power plants in Pennsylvania have been consuming coal refuse since the first one began operations in 1987. Collectively, they have burned more than 88,551,000 tons of refuse up through 2002, the last full year for which figures are currently available. The re-mining of coal refuse piles for use as fuel for FBC plants has increased the rate of AML reclamation in Pennsylvania with no cost to the taxpayer. Figure 1.2 shows the amount of waste coal consumed per year by Pennsylvania's FBC plants and Figure 1.3 displays the same data on a cumulative basis. Currently, the FBC plants consume an average of 7,500,000 tons of coal refuse annually. However, with the addition of Reliant Energy Seward's FBC power plant, another 4,000,000 tons of coal refuse will be burned yearly, which is about a 50% increase to 11,500,000 tons per year.

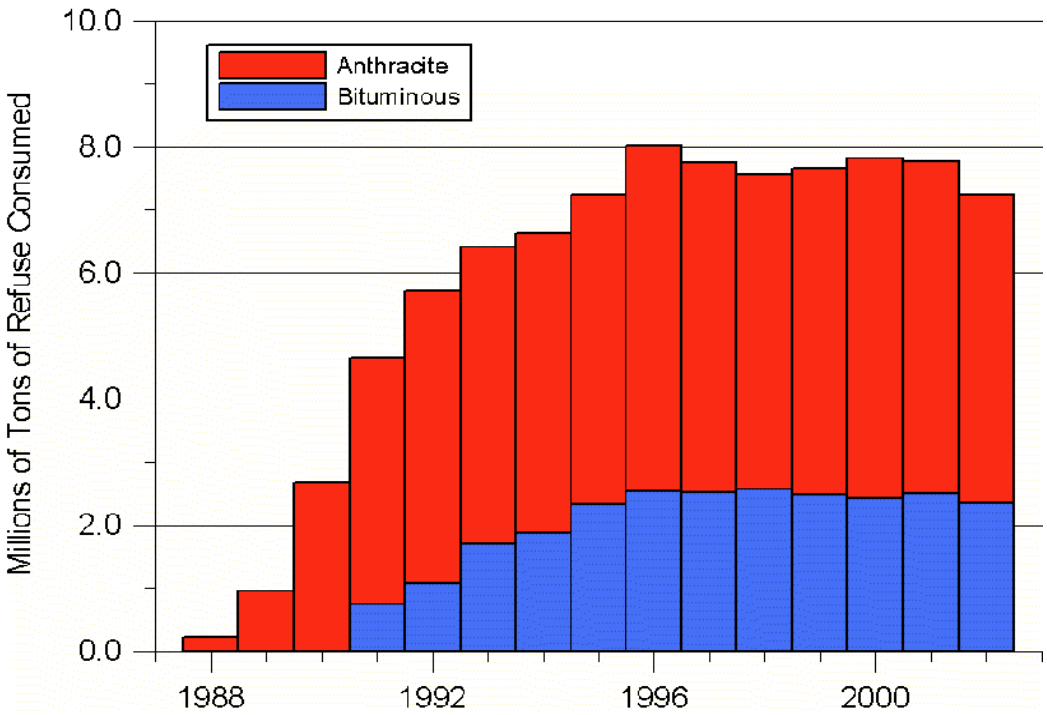


Figure 1.2. Annual consumption of coal refuse by FBC power plants.

1.2.5 Ash Production by FBC Plants in Pennsylvania

The FBC industry in Pennsylvania has generated over 58,188,000 tons of ash between 1988 and 2002, as shown in Table 1.1. Reliant Energy's Seward project, which started generating ash in spring 2004, is not included in Table 1.1.

Because limestone is injected into FBC boilers during combustion, FBC ash is typically highly alkaline. The availability of large volumes of this material has provided a feasible method for restoring some abandoned mine lands, the reclamation of which, until recently seemed almost out of reach.

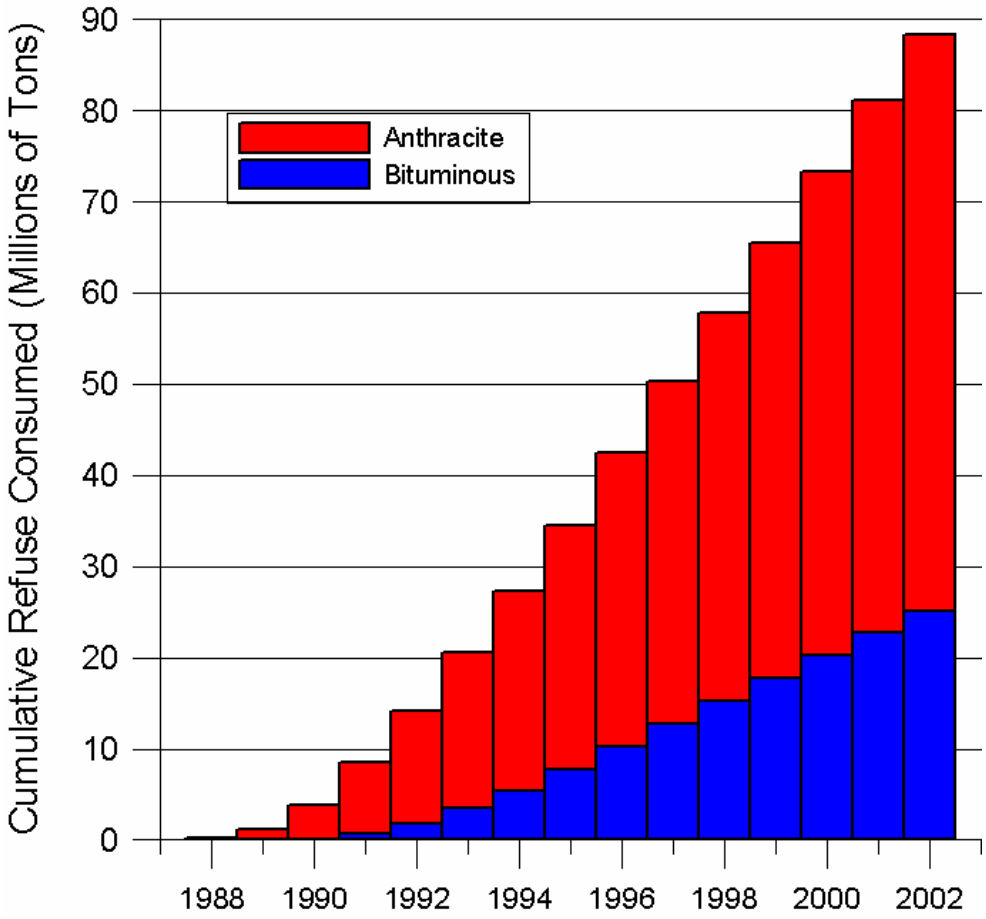


Figure 1.3. Cumulative consumption of coal refuse in the Anthracite and Bituminous Regions.

The case for returning suitable (as determined by proper testing procedures) FBC ash to abandoned or active mine lands for use in reclamation is compelling:

- The alkaline nature and encapsulating ability of the material make it particularly useful for some mine reclamation applications.

- Reclaiming waste coal piles without the benefit of adding FBC ash does little to address the often-severe water quality problems that emanate from some of the piles.
- Putting the FBC ash to a valuable use, often on areas from which it was derived, is classic recycling, virtually eliminating a potential waste stream and converting it into a useful material.
- The reclamation of AML with FBC ash is often completely privately funded, freeing up scarce government AML resources for other applications.
- Not only are abandoned mine lands reclaimed on the back end of the process through utilization of FBC ash; the reclamation realized at the front end of the process, converting polluting waste coal into an energy resource, could not economically occur if the FBC ash was landfilled.
- The ash from FBC plants has chemical and physical properties that greatly limit the potential for the ash itself to become a source of environmental contamination.

For the above listed reasons, most of the FBC ash that has been produced by Pennsylvania's waste coal industry has been beneficially used rather than landfilled.

The sixteen FBC power plants in Pennsylvania have contributed to the reclamation of approximately 3,400 acres of abandoned mine lands within the past fifteen years. See Figure 1.4 for the annual number of acres reclaimed by the ten anthracite FBC power plants and the six bituminous FBC power plants as of the end of 2002. In the Anthracite Region, where the abandoned mine pits are significantly deeper than in the Bituminous Region, the number of acres of abandoned mine acres reclaimed is less, but the depth of the pits are greater.

1.3 CONVENTIONAL COAL-FIRED POWER PLANTS

Conventional pulverized coal-fired power plants burn high heat value coal that is usually crushed and pulverized (75% less than 74 microns in particle size) before being fed into the combustion unit. Although both anthracite and bituminous coal is burned for energy, only bituminous coal is used in Pennsylvania for fuel for electrical power. The coal varies in heating value, in moisture content, percent of ash, and percent of sulfur. Most plants vary in size, operate at around 1400^{o}C, and have a combustion zone retention time less than a fraction of a second. Burning of coal generates both fly ash and bottom ash. The fly ash is captured from the flue gas by pollution control devices, primarily electrostatic precipitators (ESPs), fabric filters, or baghouses.

The bottom ash is the heavier component that is collected at the bottom of the combustion unit. The relative amount of fly ash to bottom ash produced by coal-fired power plants varies, but a typical breakdown between the two is about 80% fly ash to 20% bottom ash.

1.3.1 Distribution of Conventional Coal-Fired Power Plants

In Pennsylvania, there are 21 coal-fired electric generating power plants ranging in size from 100 megawatt (Mw) to 2700 Mw. The locations of the power plants are shown in Figure 1.5. These coal-fired power plants burn about 45 million tons of coal annually, resulting in the

production of about 5 million tons of coal ash (Bidden, personal communication, 2004). The wet scrubber sludge generation is about another 2.0 million tons. Pulverized coal-fired plants produce much less ash per ton of fuel burned than do waste coal plants because waste coal contains much more noncombustible material, and because the FBC process includes the addition of lime into the boiler.

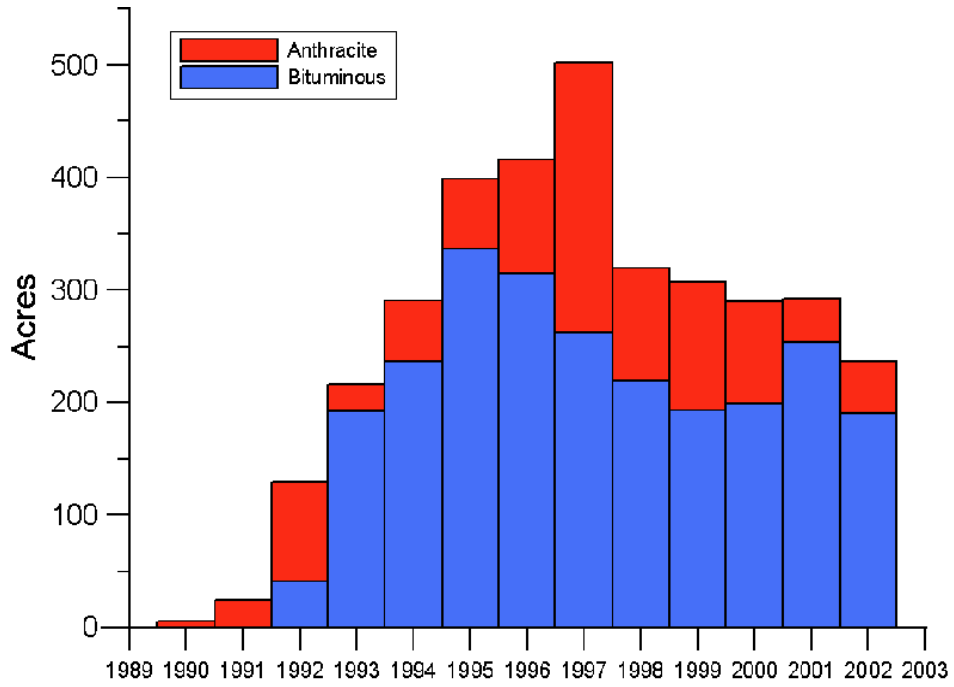


Figure 1.4. Acres of abandoned mine lands reclaimed by FBC plants in the Anthracite and Bituminous Regions.

1.3.2 Beneficial Use of Coal Ash from Conventional Coal-Fired Power Plants

While coal ash from conventional power plants is sometimes used beneficially on mine sites in Pennsylvania, much more FBC ash is so used. In 2002, the last full year for which figures are currently available, about 6.4 million tons of ash were beneficially used on mine sites, of which about 5 million tons were FBC ash. Of the approximate 5,000,000 tons of conventional coal ash produced that year in Pennsylvania, only a little over 1,000,000 tons or twenty percent was used beneficially. For that reason, much of the information provided in the remainder of this book focuses on FBC ash. However, opportunities do exist for the beneficial use of traditional PC ash on mine sites, where the ash has appropriate chemical and physical properties.

1.4 THE BENFICIAL USE OF COAL ASH ON PENNSYLVANIA MINE SITES

Each year Pennsylvania's power plants presently generate approximately ten million tons of coal ash, with about half coming from traditional plants and half coming from FBC plants. Table 1.2 shows the amounts of coal ash beneficially used on mine sites for the years 1998-2002.

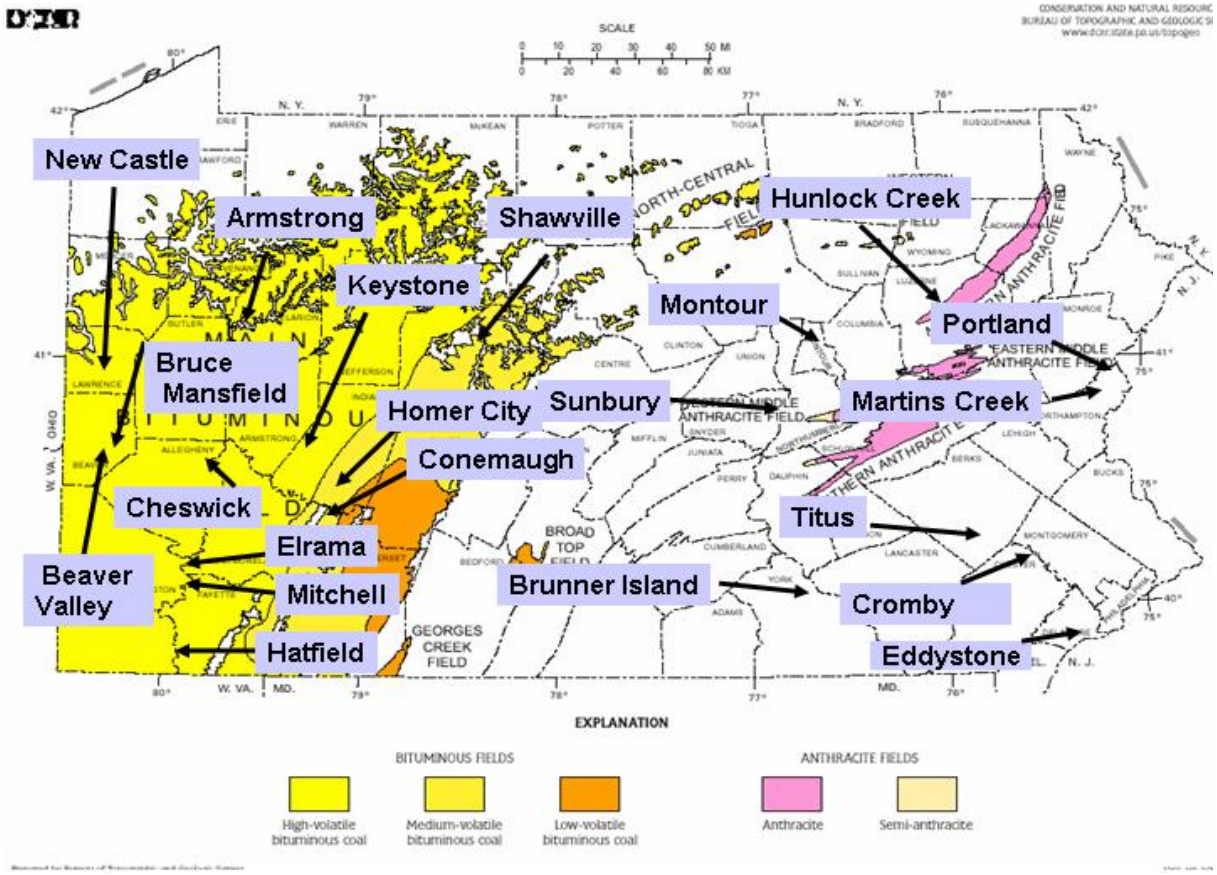


Figure 1.5. Distribution of 21 conventional PC coal-fired power plants in Pennsylvania.

Not all coal ash and other by-products are suitable for beneficial use. Those wastes that are not beneficially used are disposed in landfills or surface disposal impoundments. There are three classes of residual waste landfills in Pennsylvania: natural attenuation (unlined), single-lined, and double lined landfills. The class of landfill required for a waste's disposal depends on the levels of leachability of toxic waste constituents. Most coal combustion ash in Pennsylvania is disposed in natural-attenuation or single-lined landfills

Table 1.1 Annual and total summary of FBC ash generated in Pennsylvania to date.

Facility	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	*	*	50,000	117,000	132,000	149,000	159,000	145,000	144,000	75,000	#	#	#	#	#
2	*	*	*	422,000	554,000	563,000	563,000	563,000	478,000	499,364	555,333	513,982	515,562	517,974	538,538
3	*	*	*	*	*	*	*	300,000	443,492	507,318	540,655	508,458	431,562	536,694	572,224
4	*	*	*	130,000	296,000	284,000	274,000	288,000	310,000	331,450	349,568	345,583	341,207	316,024	310,141
5	88,643	163,379	198,051	235,229	240,948	239,531	287,306	301,724	304,000	316,537	310,000	295,350	288,290	281,460	283,994
6	?	?	?	?	?	?	?	?	?	210,000	187,000	205,000	223,995	195,994	
7	*	*	136,677	470,322	484,699	496,242	480,377	443,442	433,785	440,899	450,178	425,211	467,249	439,380	264,514
8	*	*	*	294,949	308,000	280,000	254,471	293,637	306,955	283,713	325,090	320,831	326,619	337,669	332,392
9	*	*	*	*	*	*	*	122,000	400,056	405,423	416,024	409,887	421,106	407,531	442,105
10	*	*	*	*	75,000	243,626	356,366	394,094	299,775	305,777	349,259	343,655	355,452	364,860	346,392
11	*	*	*	*	14,000	165,055	159,116	140,000	175,000	173,324	166,000	168,583	174,535	175,281	174,885
12	*	29,315	626,889	940,345	1,040,604	963,208	867,030	817,773	844,352	825,177	790,296	858,616	857,345	857,068	904,066
13	*	*	*	*	*	231,000	454,751	356,862	381,847	362,558	384,008	385,262	394,372	425,441	269,144
14	?	?	231,961	229,058	241,200	197,642	258,309	253,177	224,552	110,019	#	132,667	221,105	217,780	189,281
15	*	134,750	365,904	299,448	334,671	313,355	314,575	274,493	284,358	279,741	311,992	295,107	268,647	280,675	287,356
Total by Year	88,643	327,444	1,609,482	3,138,351	3,721,122	4,125,659	4,428,301	4,693,202	5,030,172	5,126,300	5,135,403	5,208,192	5,287,046	5,353,831	4,915,032
Total to Date	**58,188,180**														

Table 1.2 Coal ash use at mine sites in Pennsylvania (annual use rates).

Year	1998	1999	2000	2001	2002
Tons Of Ash Used	6,068,000	5,965,000	6,460,000	6,628,000	6,390,000

1.4.1 Identification of Beneficial Use Sites Discussed in This Book

This book will discuss fourteen of the many mine sites where coal ash has been beneficially used in Pennsylvania. The locations of the fourteen sites are shown on Figure 1.6. The Alden, Wheelabrator, B-D, and Susquehanna mine sites are discussed in Chapter 4. The Relvoc, McDermott and Abel-Dreshman sites are discussed in Chapter 5. Centralia (mine fire), Sharp Mountain, McClosky, and Fran are discussed in Chapter 6. The demonstration projects, Shen Penn, Knickbocker, and Big Gorilla are discussed in Chapters 7, 8, and 9, respectively.

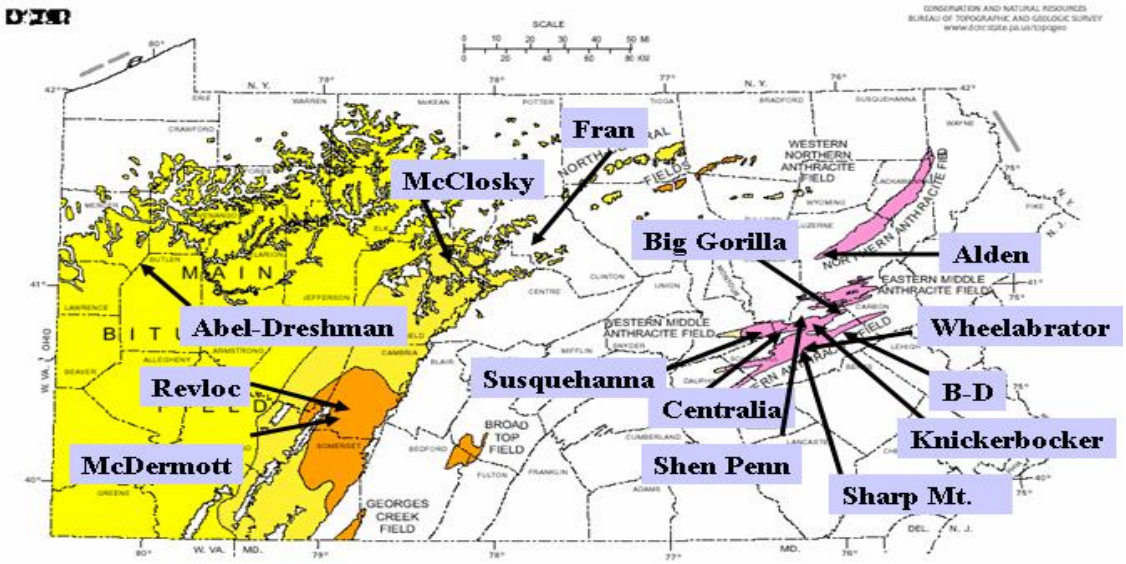


Figure 1.6. Locations of beneficial use sites discussed in this book.

1.4.2 Regulatory Framework

Coal ash is defined in Pennsylvania's Solid Waste Management Act as fly ash, bottom ash, or boiler slag resulting from the combustion of coal. This includes the ash generated from coal refuse; however, ash generated from burning waste material (e.g. petroleum coke) with coal is not considered coal ash under this definition. The addition of waste from pollution devices (e.g. wet scrubber sludge) to the coal ash also excludes that ash by this definition.

The beneficial use of coal ash in Pennsylvania is regulated under the Solid Waste Management Act, the Surface Mining Conservation and Reclamation Act, the Coal Refuse Disposal Act, the Clean Stream Law, and Air Quality Control Act.

Beneficial use of coal ash was authorized under the 1986 amendment to the Solid Waste Management Act (SWMA). SWMA authorized the beneficial use of coal ash for mine site reclamation along with other beneficial uses. Prior to 1986, DEP required a waste disposal permit for the use of coal ash at mine sites. In 1992, the residual waste management regulations were amended in accordance with SWMA to regulate the beneficial use of coal ash at mine sites (under 25 Pa. Code Sections 287.661 to 287.666). The regulations were further revised in 1997 in regard to water monitoring, volumes of ash that may be used at mine sites, and certification guidelines for ash. In addition, the DEP developed a Memorandum of Understanding between its waste and mining programs and three technical guidance documents to further coordinate and manage the beneficial use of coal ash on both active and abandoned mine sites.

1.4.3 Types of Beneficial Uses Permitted on Mine Sites

Pennsylvania currently defines the following four uses of coal ash on active mine sites as beneficial uses: 1) alkaline addition; 2) low permeability material; 3) soil substitute or additive; 4) 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 of chapter 5.) 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 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 pozzolonic characteristics and should be capable of achieving permeability equal to or less than 1.0×10^{-6} cm/sec under laboratory conditions.

As a soil supplement, alkaline coal ash is 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 soil/ash mixture must result in a pH between 6.5 and 8.0 to be considered suitable, and the amount of ash used must otherwise be commensurate with the need to establish a growth medium.

The term "ash placement" involves the use of coal ash on a mine site to backfill pits or re-contour refuse piles on re-mining sites. The pH of the coal ash must be in the range of 7.0 to 12.5 at the generator's site for placement approval.

In practice, coal ash use on a 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), as a soil additive, and for re-contouring.

1.4.4 Summary of Present Permitting Requirements

The following discussion presents only some of the most significant of the permitting requirements for coal ash use on mine sites. For more detailed information the reader should view the program guidance documents, permit modules and regulations, (especially 25 Pa Code Chapter 287.661-287.666) that are pertinent to ash use on mine sites and that are available on DEP's website at www.dep.state.pa.us. The reader should keep in mind that each mine site is different, and the data and information requirements may vary according to site-specific considerations.

1.4.4.1 Administrative requirements

Beneficial use of coal ash on a surface mine site can be requested as part of an original permit application or as a permit amendment. Either way, public notice and public participation are an integral part of the review process for all beneficial uses of coal ash on mine sites, with the exception of use as a soil amendment or supplement, which involves the use of very small volumes of ash.

For mine sites where ash is used as an alkaline addition agent, low permeability material or for placement, the applicant must place a public notice in a local newspaper explaining the proposal. The public has the right to comment on the proposal and may request a public meeting, if desired. The applicant must provide written approval from the landowner for the proposal, and the DEP office reviewing the application provides notice of the proposal to the local municipality, the county planning agency, and other state agencies. The review process is an open one with opportunity for input from individuals and local governments and other state agencies.

The application for use of coal ash on a mine site must include a detailed operational plan, which includes:

- Identification of the ash source(s);
- A certification from the ash generator(s);

- Amount of ash to be used;
- Purposes(s) of ash utilization;
- Operational details of how the ash is to be handled and incorporated into the site;
- A demonstration that the ash is chemically and/or physically suitable for the proposed use;
- Documentation of the hydrogeology of the ash-use area;
- A monitoring program, including background data collection, designed to show any influence of ash use on surface and groundwater quality.

1.4.4.2 Pre-testing of ash

An application for use of coal ash on mine sites must include chemical analyses of the ash proposed for use. Appendix 5.A includes a copy of the detailed quality analyses required. Analyses are performed on a dry-weight basis for pH plus sixteen metals. An SPLP [synthetic precipitation leach procedure] leachate analysis is required for pH, sulfate, chloride, plus seventeen metals. Coal ash must meet the maximum acceptable leachate limits for contaminants, based on the minimum requirements for an acceptable waste at a Pennsylvania Class III residual waste landfill. 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. Ash generators may obtain pre-certification of their ashes for specific uses through DEP's Bureau of Mining and Reclamation by submitting a request along with the analyses discussed herein, or the analyses data may be submitted to a DEP district mining office as part of a specific mine permit proposal. Periodic (typically biannual) re-certification and/or monitoring of the ash quality are required as long as the ash is being used on the mine site. The ash shipped from most power plants usually includes proportions of both fly ash and bottom ash, and analyses should be provided of both.

When the proposed use of ash on a site is as a soil supplement or additive, the applicant must also provide a soil analysis for pH, PCB's, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc so that potential plant up-take levels may be considered as part of the permitting process.

1.4.4.3 Monitoring

Groundwater monitoring is required for all ash applications on mine sites, except for sites where the only application is as a soil amendment. The volume of ash used on soil application sites is so small as to negate the need for water monitoring.

For all other applications of coal ash on mine sites, groundwater monitoring is required before, during and after ash placement on the site. Monitoring points are chosen so as to best show the effects, if any, of ash placement on the site. On many sites, especially re-mining sites, directly downgradient groundwater seeps, springs and discharges may provide the most representative monitoring points for the site. Typically, the hydrologic connection of such

groundwater discharges to the site is relatively clear, especially in re-mining cases, where the water quality data often prove the connection. Care should be taken to choose points that are perennial under most climatic conditions and that are not subject to complicating influences. The monitoring program should include monitoring wells, where existing groundwater discharge points are inadequate in number or character to fully monitor the site. Special attention should be given to well location, depth and construction to ensure that what is being monitored will reflect any influence from the ash placement site that may occur. Upgradient wells, while they may not need to be as numerous as the downgradient points are important, especially in an area where potential upgradient influences on water quality, such as other mine sites are present. In some upland settings, upgradient groundwater monitoring is not possible.

For most mine sites, Pennsylvania requires a minimum of six monthly background samples for each monitoring point, and ash monitoring points are no exception. The ash monitoring points must be sampled for a suite of standard mine drainage parameters plus aluminum, arsenic, cadmium, calcium, chloride, chromium, copper, lead, magnesium, mercury, nickel, potassium, selenium, sodium, and zinc. During operations, monitoring must be done, at a minimum, quarterly for the mine drainage parameters and annually for the additional metals and chloride. More frequent monitoring is required on some sites. Once the site is completed, monitoring continues until the site is judged stable.

Coal ash generally must be placed no closer than within eight feet of the top of the regional groundwater table. However, this requirement may be waived under the regulations if there is a demonstration that contamination will not occur or if DEP approves the placement as part of a demonstration project.

1.5 DEMONSTRATION PROJECTS

Under requirements of 25 Pa. Code Sections 287.501-287.506, waste management permit applications have been approved as Waste Management Demonstration Permits which may allow the demonstration of new or unique technologies for the processing or disposal of residual waste at permitted facilities. The remainder of this chapter will discuss the role of demonstration projects in the beneficial use of ash on mine sites.

1.5.1 Regulatory Requirements for Waste Management Demonstration Projects

Each application for a demonstration project permit must include the following:

1) An economic analysis indicating benefits to the Commonwealth and the applicant from the proposed project, including an economic analysis of the benefits of alternative methods of processing or disposal.
2) A technical analysis of the proposed project in comparison to the existing state-of-the-art for processing or disposal of the waste that will be received by the project.
3) A complete operational plan, including design details and a timetable for completing various phases of the project from initiation of construction to completion of the project.

4) An evaluation of the anticipated contribution of the project to the field of solid waste management.

5) An evaluation of the potential applicability to the Commonwealth of the technology to be demonstrated.

6) A demonstration that the applicant has the financial ability to remove the project and clean up the affected area in the event of pollution.

7) A plan for corrective action utilizing conventional technology in the event of pollution.

8) A statement of the optimal size and capacity for a project using the proposed technology.

9) A plan for assessing the effectiveness and environmental effect of the proposed project.

Three such demonstration project permits have been issued in the Anthracite Region of Pennsylvania. One project is for the placement of high-density ash/water slurry into standing mine water (wet-to-wet placement) in the Shen Penn Demonstration Project. The second is for placement of a high-density ash/water slurry into a dry mine pit (wet-to-dry placement) in the Knickerbocker Demonstration Project. The third is for dry ash placement into standing mine water (dry-to-wet placement), the Big Gorilla Demonstration Project. If DEP determines that these demonstration facilities adequately achieved their objectives and satisfactorily protected public health, safety, welfare, and the environment, the agency subsequently may grant a permit for the new or unique technologies.

1.5.2 The Need for Demonstration Projects

Pennsylvania's residual waste regulations include the requirement that any waste, which is placed on a site, must be a minimum of 8 feet above the regional groundwater table and 4 feet above any perched water table. The regulations concerning waste demonstration permits enable DEP to issue permits that deviate from these required separation distances (among other things), providing that the demonstration project is a justifiable evaluation of alternative methods of solid waste management, and that an economic and technical analysis of benefits is considered as well as potential environmental effects.

In July 1994, an eleven-year-old boy drowned while swimming in the shallow end of the Shen Penn mine pool impoundment adjacent to the city of Shenandoah, PA. The water depth at the site of the drowning accident was approximately 11 feet; the deepest portion of the 40-acre impoundment has been measured at 238 feet depth by DEP staff. The Shen Penn mine water impoundment is in a very large abandoned surface mine pit connected to the abandoned underground mine workings of the Kehley Run, Indian Ridge and Shenandoah City collieries. It is also the site of the Kehley Run mine fire extinguishment project that was completed by the DEP Bureau of Abandoned Mine Reclamation in the 1970's. In the aftermath of the drowning tragedy, a State Senator and DEP were presented with a petition signed by thousands of local residents, imploring the Commonwealth to backfill the pit to eliminate the mine hazard and prevent further fatalities.

The Director of the Office of Surface Mining Reclamation and Enforcement from Washington, D.C. and the DEP Deputy Secretary of Mineral Resources Management toured the Shen Penn abandoned mine site shortly after the fatality and expressed interest in backfilling the impoundment and reclaiming the site. However, they also announced that the reclamation estimates for that single project ranged from $20 million to $28 million, which is about the annual appropriation for all abandoned mine reclamation projects in Pennsylvania. Therefore, they stated that it was nearly impossible to fund a project that large, and it would be a long time before the project could be undertaken with federal AML funds.

An overlook adjacent to Route 924 north of Shenandoah provides a view of the Shen Penn pit below and three FBC power plants to the south. The Schuylkill Energy Resources (SER) FBC plant is so close to the Shen Penn pit that the reflection of the stack at the plant can sometimes be seen on the surface of the mine water impoundment. The corporate officers of SER and Reading Anthracite Coal Co. (RAC) contacted DEP with a proposal to backfill the Shen Penn pit, at no cost to the state or federal government, with an ash slurry from the SER FBC power plant. The abandoned pit and the FBC power plant are located within a large surface mining permit issued to Reading Anthracite. RAC is the landowner of the Shen Penn pit, but the company has no legal obligation to backfill the pit under the state and federal surface mining laws because the mine pit existed prior to these laws. The Reading Anthracite/SER proposal was timely because it suggested an innovative method of eliminating the mine hazard, and possibly providing environmental, social, and economic benefits in a win/win solution for the community, the company and the DEP.

Two significant challenges confronted the Executive Staff of DEP: 1) the problems of significant abandoned mine hazards that threaten public health and safety, without sufficient funding to remediate them; 2) the challenge of advancing acceptable ash disposal practices to allow a promising but untried technology of filling an acid mine water impoundment. In 1995, after much deliberation, the Executive Staff and the technical staff of the waste management and mining programs made two key decisions: 1) a testing phase for three waste demonstration projects would be established to test the range of coal ash/mine pool interactions; 2) DEP would fund a research project to scientifically evaluate the physical and chemical properties of these coal ash demonstration permit sites. This book is the product of those two prudent decisions.

The Shen Penn proposal was for a wet coal ash slurry pipeline to transport ash from the SER FBC plant and emplace it in the wet mine pool environment (i.e. wet-to-wet alternative). Conventional coal ash placement in beneficial use mine reclamation involves the placement of relatively dry (i.e. optimum moisture content) coal ash into a relatively “high and dry” mine environment. The other two alternatives are the placement of relatively dry ash into a wet mine, and the placement of a wet coal ash into a relatively dry mine. The DEP Executive Staff recognized that if the Shen Penn proposal was approved other mining companies, who had to comply with the eight-foot separation distance, would file requests for similar approvals. Hence, the decision was made to limit the waste demonstration permit approvals to one example of each of the three alternative placement techniques, until the three alternatives could be tested through extensive monitoring and data analysis of the demonstration sites.

On September 22, 1995 DEP entered into an Agreement with SER and RAC to approve the proposal and, provide among other things, $5 million in comprehensive general liability insurance and an additional $2 million in third-party environmental impairment liability insurance covering non-sudden pollution occurrences for the Shen Penn site. That agreement was followed by a Waste Management Demonstration Permit (No. 301289) which was issued on August 6, 1996, that included details on testing and monitoring the physical and chemical properties of the coal ash slurry and its interactions with the mine pool impoundment. Unfortunately, Waste Management Demonstration Permit No. 301289 was never activated, due to the impediment of a $5 per ton coal ash tax imposed by the local school district. That tax may have been established to generate revenue for the school system, but it essentially prevents the beneficial use of ash and revenue generation from cogeneration plants within the district, due to the costs it adds to reclamation projects. Chapter 7 describes the small-scale ash slurry demonstration project completed within the permitted ash placement area on the Ellengowen permit (at the SER cogen site) that was conducted as a precursor to the Shen Penn project, and also provides additional information on the mine pool chemistry and monitoring data relevant to the Shen Penn and Knickerbocker sites.

On June 16, 1997, DEP issued Waste Demonstration Permit No. 303104 to Northeastern Power Co. (NEPCO) for the second of the three coal ash placement alternatives. This project placed optimum moisture content ash into an abandoned water-filled pit known as the Big Gorilla pit, a 16.6 acre area within the 876 acre surface mining permit site at the NEPCO FBC power plant site near the borough of McAdoo. The mine water impoundment in the Big Gorilla pit was 80 feet deep in most places. It has been completely eliminated by the coal ash placement project. As described in Chapter 9, the coal ash was placed directly in the acid mine drainage impoundment and the physical and chemical results were excellent.

On July 21, 1998, DEP issued the third of this series of permits, Waste Demonstration Permit No. 301301, to Reading Anthracite Co. for the 44-acre Knickerbocker pit area within the Ellengowan surface mining permit near the SER FBC power plant site. The Knickerbocker pit is a dry abandoned surface mine above the mine pool level, located on the same surface mine permit as the Shen Penn pit to the east along the strike of the syncline, and in West Mahanoy Township (outside of the boundaries of the school district and the ash tax). This permit approval authorized RAC and SER to demonstrate their coal ash slurry concept in a dry pit. It also enabled DEP to obtain scientific and engineering data on a relatively large-scale slurry project, for possible future use into a water-filled pit (i.e. the original wet-to-wet alternative). The results of the Knickerbocker demonstration project, including an evaluation of the effectiveness of the use of various percentages of a cement kiln dust (CKD) admixture as an activator for cementitious behavior of the ash in test cells, are described in Chapter 8.

The second key decision of the DEP Executive Staff in 1995 was realized by executing a contract with the Materials Research Institute (MRI) of the Pennsylvania State University to conduct scientific study of these three waste demonstration permit sites. MRI is an interdisciplinary, intercollegiate research consortium at Penn State that has top-level scientists, state-of-the-art laboratory equipment, and 40 years of advances in the material sciences, including nuclear waste management and leaching behavior, cement chemistry and coal ash utilization. Dr. Barry E. Scheetz, Dr. William B. White and Dr. Caroline M. Loop of MRI

conducted the coal ash research presented in Chapters 7 to 9, and summarized in Chapter 11. Dr. Loop's M.S. Thesis and a large part of her Ph.D. Dissertation are devoted to the study of the NEPCO site. The participation of MRI in the demonstration projects has assured the scientific rigor of the evaluation of those sites.

1.6 CONCLUSION

It was out of the collaboration between MRI and DEP that the concept for this book originated. The initial intent was to produce a publication that presented the results of the demonstration projects. From there the scope broadened to include the results from other active and abandoned mine sites where coal ash has been beneficially used in Pennsylvania. One reason for broadening the scope of this publication is that the beneficial use of coal ash on mine sites has become somewhat controversial on a national level. That controversy has been fed, in part, by the misreporting and partial reporting of information and data, some of which have been from sites in Pennsylvania. Thus, it became even more important to present the facts and the science behind the beneficial use of coal ash in Pennsylvania. While the scope of the book grew, the underlying goal remained the same, and that is to present the results of Pennsylvania's experience with recycling coal ash for beneficial use in mine site reclamation to others in the scientific, government, business, and public-interest communities. It is the shared hope of all the authors that this book advances understanding of the potential uses for coal ash in mine site reclamation.

CHAPTER 2. GEOLOGY OF THE PENNSYLVANIA COAL REGIONS

Roger J. Hornberger, Caroline M. Loop, Keith B. C. Brady, Nathan A. Houtz

The geology of the Anthracite and Bituminous Coal Regions of Pennsylvania is fundamental to most of the contents of this book. Since most of the coal ash placement sites described in this book are in the anthracite coal fields, the geology of the Anthracite Region is emphasized. However, the significant differences and similarities between the anthracite and bituminous regions, in their regional-scale physiography and local-scale topography, geologic structure, stratigraphy and hydrogeology will be briefly discussed in this chapter.

2.1 PHYSIOGRAPHY AND TOPOGRAPHY

Pennsylvania's Anthracite Region is located in the Valley and Ridge Province of the Appalachian Mountains as shown on Figure 2.1. The Valley and Ridge Province and other provinces and sections of the Appalachian Highlands were described in Fenneman (1938) and delineated on a U.S. Geological Survey Map by Fenneman and Johnson (1946). The province extends for a distance of 1200 miles from the St. Lawrence Lowland to Alabama, according to Thornbury (1965) who calls it the Ridge and Valley Province. This province is generally divided into three sections: a northern section also known as the Hudson-Champlain section; a middle section reaching from the Delaware River to the New River in southern Virginia; and a southern section from southern Virginia to the end of the highlands in Alabama. The width of the Valley and Ridge Province ranges from about 20 miles in New York near the Hudson River to about 80 miles wide in central Pennsylvania between Williamsport and Harrisburg, according to Hunt (1974) and Thornbury (1965).

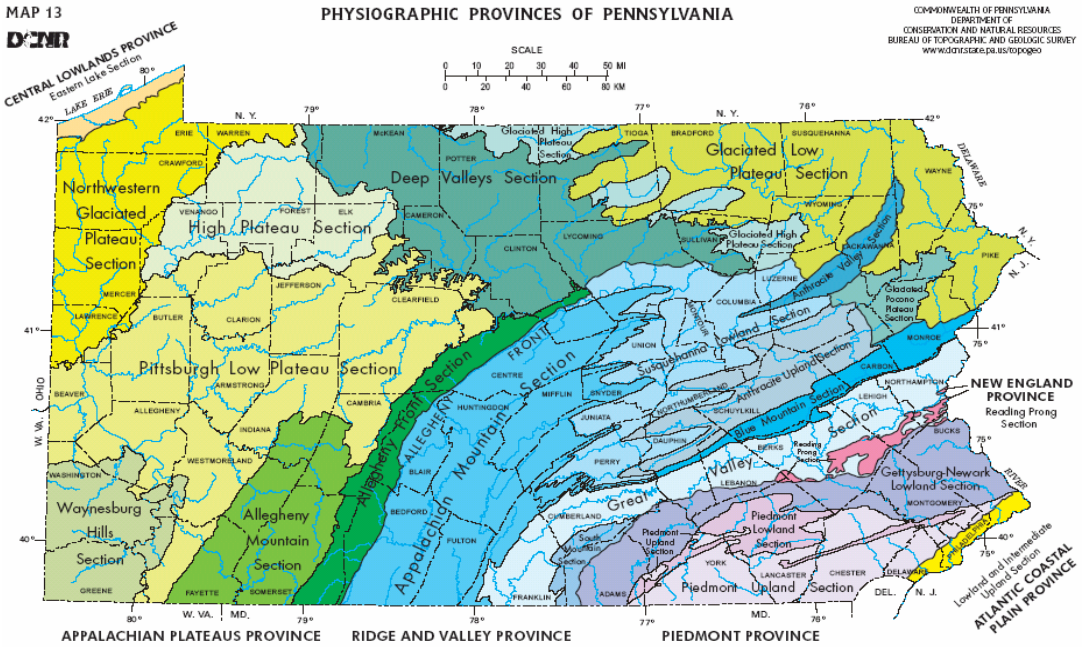


Figure 2.1. Map of Physiographic Provinces of PA.

In a classic work on the evolution of North America, King (1977) divides the Appalachian Mountains into two parts, referred to as the "sedimentary Appalachians" including the Valley and Ridge Province and the "crystalline Appalachians" in the New England Upland and Piedurant Plateau. King (1977, p. 45) states: "In the humid climate of the eastern states, the limestones and dolomites are more susceptible to erosion than are the sandstones and shales; wherever deformation has raised them to view they are worn down to low ground, whereas the adjacent sandstones and shales project in ridges. Characteristic topography of the sedimentary Appalachians is thus a succession of parallel valleys and ridges which form the Valley and Ridge province". This pattern of alternating ridges and valleys, with many cross-cutting water gaps and wind gaps in the ridges is very distinctive on the USGS digital shaded relief map of land forms of the conterminous United States by Thelin and Pike (1991). Additional description of the Appalachian Mountain Section of the Ridge and Valley Province, including the topographic features of the Anthracite Regions is included in Way (1999).

The Anthracite Region consists of 4 major coal fields: the Northern, Eastern Middle, Western Middle, and Southern Anthracite Fields as shown on Figure 1.1. The anthracite coal fields contain approximately 95% of the remaining identified anthracite and semianthracite resources in the United States (Averitt, 1975). The anthracite fields are of Pennsylvanian age and are time equivalent to the bituminous fields of western Pennsylvania. The time equivalence and other stratigraphic relationships between the Anthracite and Bituminous Coal Regions of Pennsylvania will be discussed in the stratigraphy section of this chapter. The principal difference between the anthracite and bituminous regions is the geologic structure, with the anthracite coals located within the extensively folded and faulted terrain of the Valley and Ridge Province and the bituminous coals located on the adjacent Allegheny Plateau Province shown on Figure 2.1 which was considerably less affected tectonically.

The four anthracite fields are preserved in synclinal basins that are essentially surrounded and "defended" by sandstone ridges. These ridges are more resistant to erosion than the shales and coals of the Pottsville and Llewellyn Formations. The slope forms of the ridges are typically mature (i.e., convexo-concave), but some free faces occur, such as the Harveys Creek water gap in the Northern Field. Descriptions of Appalachian slope form development are contained in Hack (1960, 1979). Additional information on weathering in the Ridge and Valley is found in Thornbury (1965, 1969), Clark and Ciolkosz (1988), and Sevon (1989, 2000a).

The bituminous coal fields of Western Pennsylvania lay within the Appalachian Plateau Physiographic Province, which in Pennsylvania extends from the western state border to the Allegheny Front, the prominent southeast-facing escarpment of approximately 1000 feet of topographic relief that clearly defines the boundary of plateau with the adjacent Valley and Ridge Province.

The major and most typical section of the plateau in Western Pennsylvania is termed the Unglaciated Allegheny Plateau by Fenneman (1938). It has a smooth, undulating surface with narrow, relatively shallow valleys. Highest hilltops are typically about 1600 feet throughout the section. Relief is usually several hundred feet and as much as 400 to 500 feet along the larger streams. This area is designated as the Waynesburg Hills Section and Pittsburgh Low Plateau Section by Sevon (2000b) on Figure 2.1. Between this section and the Valley and Ridge

Province of the Appalachian Mountains to the east lies a strip of the plateau known as the Allegheny Mountains Section, which is much higher in elevation, attaining 3,213 feet of elevation atop Mount Davis, the highest point in Pennsylvania and whose topography, though distinctly plateau-like, is much affected by open folds (Fenneman, 1938 p. 283). Northward, starting at approximately 41º latitude, the land surface of Fenneman's Unglaciated Allegheny Plateau exhibits a steady increase in altitude all the way up to the New York border where the elevation is greater than 2100 feet (640 meters). This area comprises the High Plateau Section and part of the Deep Valleys Section on Figure 2.1 (Sevon, 2000b). It has broad, rounded to flat uplands separated by distinctively deep, angular valleys.

According to Thornbury (1965 p. 130): "The Appalachian Plateaus have not been subjected to the intense deformation that affected the other Appalachian provinces. A few mild folds exist, particularly adjacent to the Ridge and Valley Province, but they are broad open folds and not strongly compressed or faulted like those in the Ridge and Valley Province." Briggs (1999) provides additional description of the sections of the Appalachian Plateaus Province in Pennsylvania, including maps of generalized topography and topographic relief classes.

2.2 GEOLOGIC STRUCTURE

The structural geology of the four anthracite coal fields within the folded and faulted Valley and Ridge Province is much more complex than the relatively flat-laying strata of most of the bituminous coal fields within the Allegheny Plateau of western Pennsylvania, shown on Figures. 1.1 and 2.1.

Intense orogenic activity in the Ridge and Valley Province occurring during the Permian Period resulted in: (a) substantial increase in rank of the anthracite coals due to metamorphism as compared to time-equivalent coal beds in the Appalachian Plateau Province of the bituminous region, and (b) the preservation of the anthracite coal fields within synclinal basins which are essentially surrounded by sandstone/conglomerate ridges that are more resistant to erosion than the coal and associated finer-grained sedimentary rocks. Though there were three major orogenies responsible for the formation of the Appalachian Mountains, only the final one, the Alleghenian Orogeny, had any effect on the rocks of the Ridge and Valley Province in Pennsylvania. According to Rodgers (1970, Chapter 11) who summarized the tectonics of the Appalachian Mountains, there were three major orogenic movements which resulted in the development of the Valley and Ridge Province of the Appalachian Mountains in Pennsylvania, including the Anthracite Region; the Taconic Orogeny occurring from approximately 450 through 500 million years ago, the Acadian Orogeny occurring during the Devonian Period from approximately 360 through 400 million years ago, and the Allegheny Orogeny occurring from approximately 230 through 260 million years ago.

The Allegheny Orogeny was the most significant mountain-building development in the present geologic structure of the Valley and Ridge Province of central and eastern Pennsylvania (including the anthracite coal region). The anthracite coal beds were deposited during the Pennsylvanian Period approximately 275 million years ago. At the type section of the Pottsville Group strata located on Sharp Mountain at Pottsville, Pennsylvania, the Mammoth coal seam and associated strata have been uplifted from a horizontal, to a nearly vertical structural orientation.

Orogenic deformation preceding Pennsylvanian sedimentation did not structurally affect Pennsylvanian rocks. As the Allegheny Orogeny postdated the deposition of these coal seams, it is responsible for most of the structural deformation.

A comprehensive description of the geologic history of the north-central Appalachians, is contained in Faill (1997a, 1997b, 1998a 1998b). The most recent orogenic episode, the Alleghenian, commenced in the Early Permian (Faill, 1997b). Faill (1997a, p. 552) states that "(l)ate in the Allegheny orogeny, rock thrust northward over the Carboniferous rocks in the Anthracite Region of northeastern Pennsylvania and caused anthracitization of the underlying coals."

Following these significant orogenic episodes during Paleozoic times, the Appalachian Mountains continue to mature. Concerning the post-Paleozoic history, Rodgers (1970, p. 218) states: "Our next glimpse of the Appalachians is in the Late Triassic; they were now a chain of mountains, though not necessarily lofty ones, and the core areas were already deeply eroded.… Only in the Cretaceous or the Late Jurassic did the sea once more enter the region, and then only to wash the southeastern and southern margins of the Appalachian chain, which repeated arch-like uplifts kept high and subject to erosion …. During this period the mountains approached the forms we see today.".

For the past approximately 65 through 100 million years Sharp Mountain in Schuylkill County, Pennsylvania and other Appalachian ridges have been undergoing further weathering and erosion to produce the mature slope forms seen today. During these millions of years of weathering the rough edges of the tops of these mountains were worn down and colluvium developed as a veneer over the bedrock on the middle to lower slopes of the ridges.

A concise description of the structural geology of the Ridge and Valley Province in Pennsylvania is provided by Faill and Nickelsen (1999), including a tectonic map of the province, a cross-section of the Minersville Synclinorium, and other relevant information about the Anthracite Region. Much of the Southern and Western Middle Fields has been geologically mapped by Wood and associates (e.g., the Minersville Quadrangle, Wood, et al., 1968). The maps depict the synclinoria and other complex geologic structures. The geologic structure and stratigraphy of the Southern Anthracite Field are described in Wood et al. (1969) and the depositional and structural history of the entire Anthracite Region are presented in Wood et al. (1986). The complexity of the geologic structure, particularly the nearly vertical beds of rocks in many areas of the anthracite fields, has impeded the acquisition of stratigraphic data from routine exploration drilling.

According to Wood et al. (1986): "Each coal field of the Anthracite Region is a complexly folded and faulted synclinorium, with structural trends between N55°E and N85°E…. The Southern field is the most highly deformed, with several highly faulted, closely spaced synclinal basins. Deformation is most complex toward the southeast, where it is characterized by hundreds of thrust, reverse, tear and bedding plane faults and tightly compressed, commonly overturned folds." (p. 45).

The principal structural features of these four anthracite coal fields are shown on Figure 2.2, from Wood et al. (1986, p. 44) and Wood and Bergin (1970, p. 150). The tremendous structural complexity of the Southern Field is described in greater detail in Wood et al. (1969), including descriptions of the largest structural features, the Minersville Synclinorium, the New Bloomfield Anticlinorium and the Broad Mountain Anticlinorium, plus detailed descriptions of individual anticlines, synclines and fault complexes within these three major structural features. Of the many hundreds of anticlines, associated synclines and significant faults present in the area, (Wood et al., 1969, p. 87) examples include: the Donaldson Syncline, with an amplitude of 4,000 to 7,800 feet in the Tower City, Donaldson and Tremont area (p. 91), and the Mine Hill fault complex (in the area of the Lytle, Oak Hill and Wadesville Collieries) which has, in places, a klippe composed of beds of the Schuylkill Member overlying the Upper Mine Hill fault and upright beds of the Llewellyn Formation (p. 102).

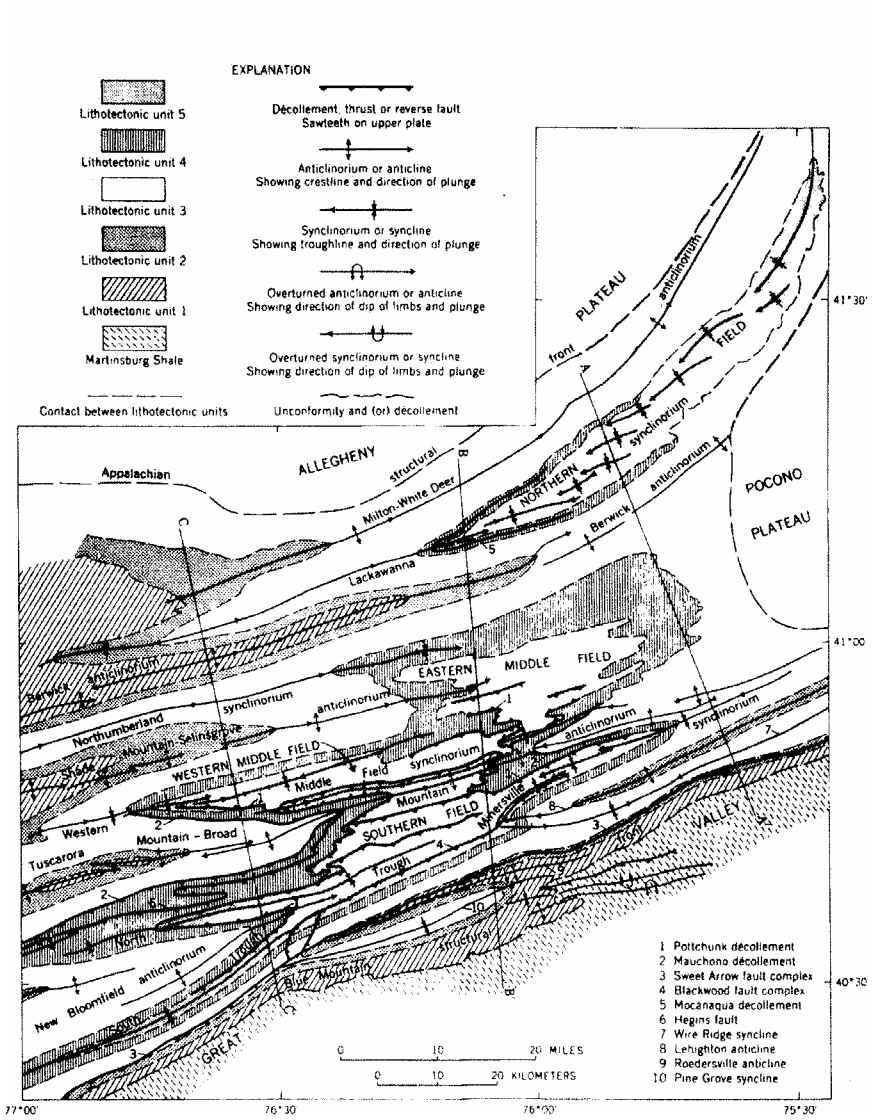


Figure 2.2. Principal structural features of the Anthracite Coal Fields (from Wood et al**.,** 1986).

The distinct contrast between the geologic structure of the Allegheny Plateau and the Valley and Ridge Plateau is depicted in the series of Appalachian cross-sections constructed by King (1977) as shown in Figures. 2.3a, and 2.3b. The entire area east of the Findley Arch in Ohio on Figure 2.3a, labeled the Allegheny Synclinorium, is termed a foreland basin by King (1977, p. 44), who describes this basin extending southward from Pennsylvania into Kentucky, and states: "Surface rocks of the plateau and synclinorium are largely Pennsylvanian continental and coal-bearing strata…. The Pennsylvanian and associated rocks have been warped into a series of anticlines and synclines by the Appalachian movements, but most of the deformation is so light that over wide areas the strata appear to lie nearly flat." (p. 45).

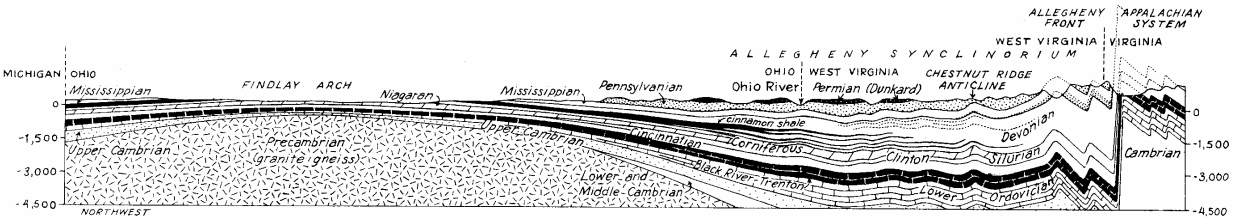


Figure 2.3(a). Cross-section of the geologic structure of the Allegheny Plateau (from King 1977).

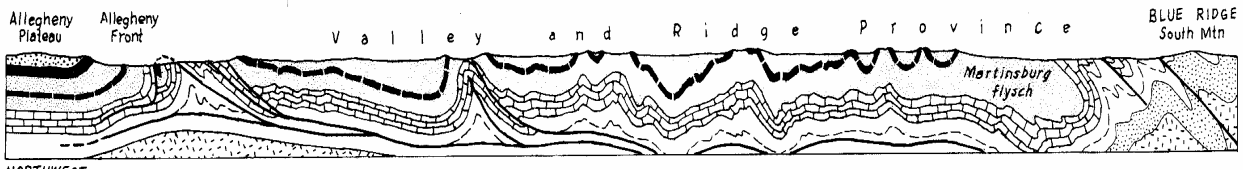


Figure 2.3(b). Cross-section of the geologic structure of the Ridge and Valley Province.

The entire Allegheny Plateau in western Pennsylvania is part of a major structural basin referred to as the Appalachian Coal Basin (Rodgers, 1970) or Allegheny Synclinorium (Kay, 1942) or as the Pittsburgh-Huntingdon Basin (Richardson, 1928). According to Gwinn (1964, p. 866): "Viewed on a regional basis the surface structure of the Plateau is a broad asymmetrical synclinorium, steeper on the southeast …. the surface axis of the synclinorium plunges southwestward in a smooth arc from Binghamton, New York, through Pittsburgh, Pennsylvania, and south-southwestward toward Parkersburg and Huntington, West Virginia."

Although the axis of the structural basin is known to curve in plan view and plunge toward the southwestern corner of the state, the basin may be three-dimensionally visualized as a broad spoon-shaped structure, in which the youngest strata are at the center of the spoon and successively older strata become exposed toward the outer edge of the spoon (Richardson, 1928; Ashley, 1928; Piper, 1933). Consequently a bed such as the Upper Freeport Coal of the Allegheny Group, which is present at the land surface at elevations of approximately 2,000 feet above sea level at the northern and eastern margins of the bituminous coal field in western Pennsylvania, is present in the southwestern corner of Pennsylvania at an elevation several hundred feet below sea level and beneath hundreds of feet of younger rocks, including the Pittsburgh Coal, which may be mined at the land surface.

The asymmetry of the basin is evident in the contrast between the northwestern and southeastern sides in terms of the intensity and manner of production of folds and other geologic structures. The folds and smaller scale irregularities manifested in the surficial configuration of the basin have been described by Gwinn (1964), Rodgers (1970), Fettke (1954) and others. Rodgers (1970) divides the basin into a northwest flank and a southeast flank which are both about 60 to 80 miles (37 to 50 kilometers) wide. The north-west flank generally has a gentle and persistent regional dip toward the basin center. At a more detailed scale, irregular minor structural features become evident on the northwest flank which have been described by Rodgers (1970, p. 15) as "scattered and apparently planless irregularities – folds of erratic trend, domes, noses, etc. – whose structural relief is rarely more than a few tens of meters (a hundred feet)." A belt of transition (i.e. the bottom of the basin) separates the northwestern flank from the markedly different structure of the southeastern flank which Rodgers (1970, p. 16) describes as "a succession of roughly parallel anticlines and synclines, mostly many times longer than broad…. As these folds are superposed on the southward regional dip they show a consistent asymmetry, the southeast flanks of the anticlines being the steeper."

According to Gwinn (1964) structural relief decreases north-westward in a step-like fashion from the well-defined folds of the southeastern side of the plateau where anticlines rise 800 to 2500 feet (244 to 1067 meters) above adjacent synclines. Gwinn (1964) provided the decollement interpretation of the mechanics of formation of the high folds and other structural features of the Appalachian Plateau in western Pennsylvania, which involved movement associated with major thrust faults along bedding planes in the sedimentary rock sequence. Rodgers (1970) provides additional description of the manner of production of structures of the plateau, confirming Gwinn's interpretation as applicable to the southeastern flank of the plateau in Pennsylvania, while relating the irregular structures of the northwestern flank to a contrasting interpretation involving tectonics of the basement rocks.

The axes of anticlines and classes of structural relief associated with the anticlines and synclines of the Appalachian Plateau in western Pennsylvania have been described by Gwinn (1964), Berg et al. (1980) and Beardsley et al. (1999). Figure 2.4 from Beardsley et al. (1999) shows the major Chestnut Ridge, Laurel Hill anticlines and the Smethport-Sharon anticline labeled CR, LH and SS respectively. The importance of linear structural features of various scales in western Pennsylvania has been discussed by Nickelsen and Williams (1955), Hough (1959), Poth (1963), Nickelsen and Hough (1967), Gold et al. (1974), Kowalik (1975) and others. Nickelsen and Hough (1967) illustrate regional joint patterns in Pennsylvanian aged coals and shales of western Pennsylvania. The systematic joint pattern defined by Nickelsen and Hough (1967) was found to be generally east-west trending, perpendicular to major fold axes, and somewhat arcuate in north-central Pennsylvania, presumably in response to a Paleozoic doming episode in that area.

The structural and topographic transition between the Allegheny Plateau and the Valley and Ridge Province to the east is the Allegheny Front, which is shown on the eastern side of Figure 2.3a and the western side of Figure 2.3b, and is described by King (1977) as follows: "On the southeast the Allegheny Plateau breaks off along the Allegheny Front (Fig. 2.3b), an imposing escarpment that overlooks the more varied, linear ridges and valleys of the true Appalachians. The front marks an abrupt change in style of deformation; the strata now turn up

abruptly, and beyond they are heavily folded and faulted; we pass here from the foreland into the main deformed belt." (p. 45).

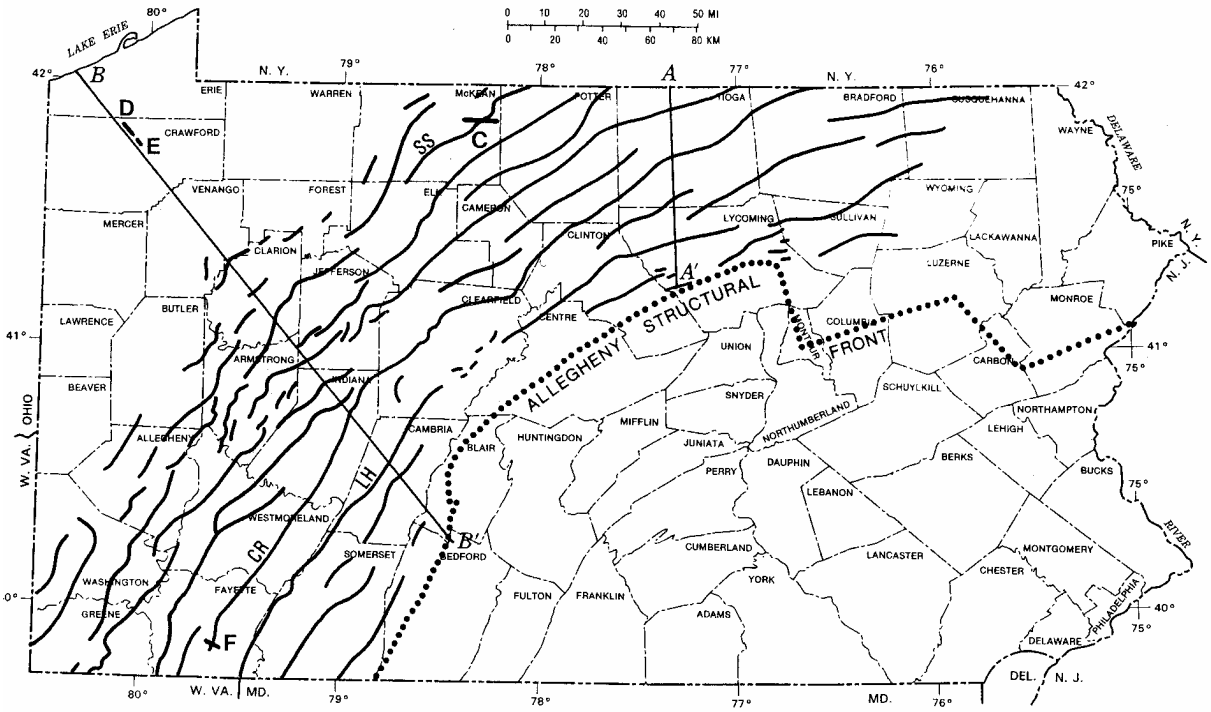


Figure 2.4. Generalized location of surface anticlines in the Appalacian Plateau's Province. (from Beardsley et al., 1999).

2.3 STRATIGRAPHY

Far more is known about the stratigraphy of the Bituminous Coal Region of western Pennsylvania than the Anthracite Coal Region for several reasons, including the abundance of drill hole data, the availability of paleontological information, and the fact that it is less difficult to correlate strata between drill holes and other exposures in the relatively flat-lying strata of the Allegheny Plateau than in the structurally complex anthracite coal region. The stratigraphy of the Anthracite Region of eastern Pennsylvania has not been studied as extensively as that of Pennsylvania's bituminous coal region. Geologic and mining engineering work done in the Anthracite Region over the past 150 years documents some significant stratigraphic differences between the Anthracite and Bituminous Coal Regions. The complexity of the geologic structure, resulting in nearly vertical beds of coal and other rocks in some areas of the anthracite fields, has impeded the acquisition of stratigraphic data from routine exploration drilling. Detailed mine maps of the abandoned underground mines and cross-sections through vertical shafts and nearly horizontal tunnels have added to the understanding of the structure and stratigraphy of the anthracite coal fields, however most stratigraphic efforts have been directed toward coal seam delineation.

The coal-bearing rocks in Pennsylvania are from the Pennsylvanian and Permian Periods of geologic time. The rocks of the Bituminous Coal Field of western Pennsylvania are divided, from oldest to youngest, into the Pottsville, Allegheny, Conemaugh, Monongahela, and Dunkard

Groups. The majority of mineable coal occurs in the Allegheny and Monongahela Groups. The strata in the Anthracite Region are divided, from oldest to youngest, into the Pottsville and Llewellyn Formations.

Generalized stratigraphic sections of the Allegheny Formation and the Conemaugh Group of western Pennsylvania are depicted on Figure 2.5 from Edmunds et al. (1999). The graphic drill logs and overburden analysis data for the entire Pennsylvania coal bearing sequence are included in a series of figures in Brady et al. (1998), examples of which are shown in Figures 2.6a and 2.6b. These figures were constructed from overburden analysis drill holes with percent sulfur and neutralization potential (NP) that were obtained from the permit files of the Department of Environmental Protection's District Mining Offices.

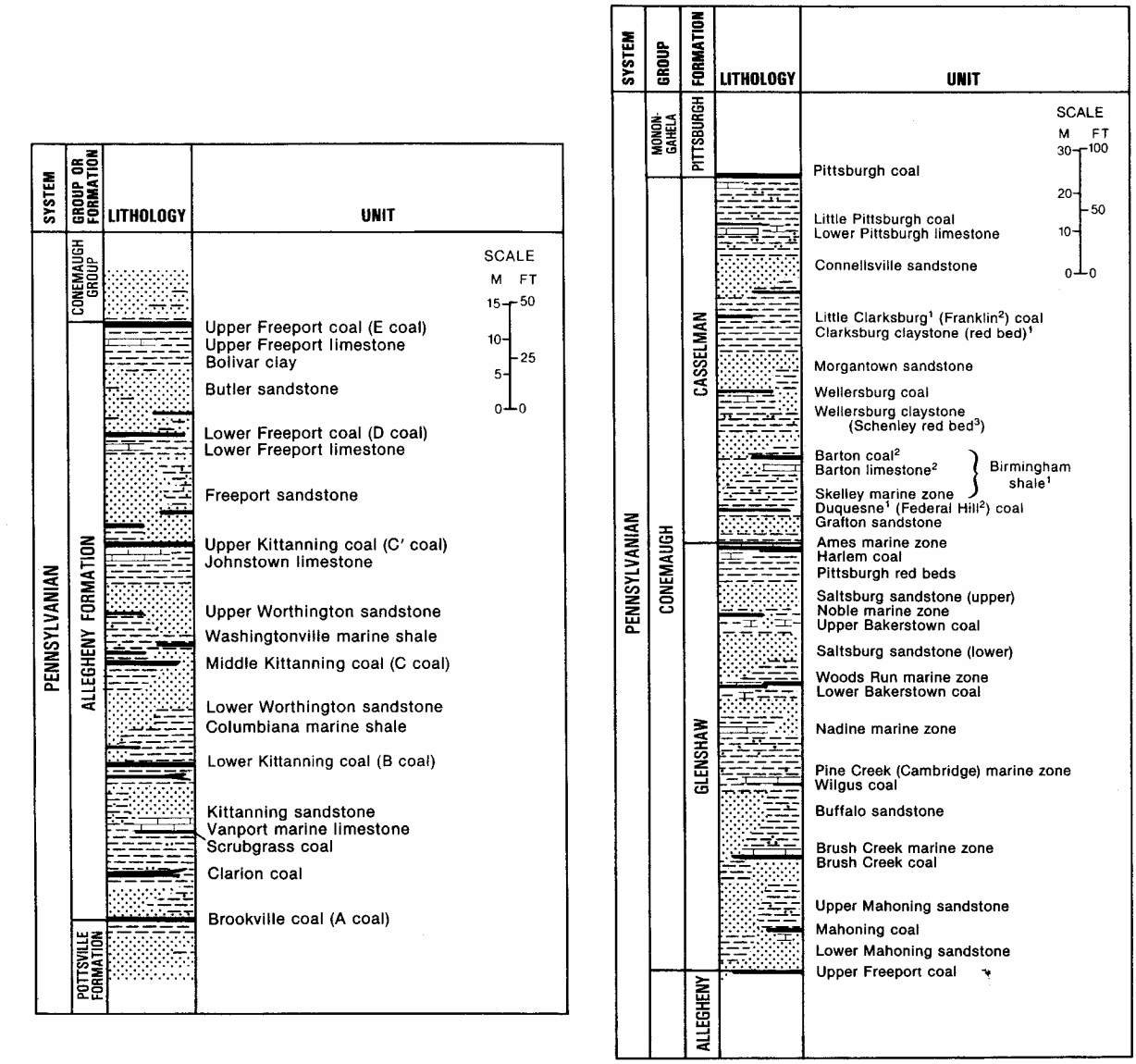


Figure 2.5. Generalized stratigraphic sections of the Allegheny and Conemaugh Group (from Edmunds et al., 1999).

2.3.1 Pottsville Group – Bituminous

The Pottsville Group is variable in thickness. For the most part, it is dominated by sandstone, and the coals are discontinuous. Because of the discontinuous nature of these coals, and the fact that they are often thin and split with numerous partings, mining is not common in the Pottsville Group. The principal coal that is mined is the Mercer. Edmunds et al. (1999) discuss the Pottsville of western Pennsylvania in terms of strata below the Mercer Coal and above the Mercer Coal: "In practice, the western Pottsville is usually divided into an upper sequence consisting of the Mercer coals and associated and overlying rocks, and a lower sequence dominated by sandstone." They also report that "The Pottsville Formation in western Pennsylvania ranges from 20 ft (6 m) to at least 250 ft. (75 m) in thickness. Its basal contact is apparently everywhere disconformable and from south to north overlies increasingly older Mississippian and possibly uppermost Devonian rocks…." (p. 150-151).

2.3.2 Allegheny Group – Bituminous

The Allegheny Group is one of two groups within the Pennsylvanian that contains the majority of economically mineable coals. For the purpose of discussion, the Allegheny has been divided into the upper and the lower Allegheny. The lower Allegheny extends from the base of the Brookville coal to the base of the JohnstownLlimestone (or Upper Kittanning Coal where the limestone is absent). The upper Allegheny extends from the base of the JohnstownLlimestone to the top of the Upper Freeport Coal. This division is made because "marine units occur only below the upper Kittanning underclay…. and, with minor exceptions, nonmarine limestones occur only at or above that unit" (Edmunds, et al., 1999, p. 154). This distinction of "marine" and "nonmarine" is to a large extent based on the work of Williams (1960). Williams defined four faunal groups, inferred as "fresh-water", "restricted marine or near-shore marine", and two marine groups, one having a more diverse fauna than the other. Williams also relied on the geochemical investigations of Degens et al. (1957, 1958) in defining his depositional environments.

According to Edmunds et al. (1999) the Allegheny Group: "was specifically defined to include all of the economically significant coals present in that part of the Pennsylvanian sequence. The thickness of the formation is between 270 (82 m) and 330 feet (100 m) in Pennsylvania, and there is no obvious regional trend. The Allegheny Formation is a complex, repeating succession of coal, limestone, and clastics, ranging from claystone or underclay to coarse sandstone.... No individual bed or lithosome is universally persistent, but some coals, marine shales, and limestones seem to be fairly continuous over thousands of square miles (thousands of square kilometers). The group is fairly uniform in its lithologic diversity.… The Allegheny Formation contains six major coal zones. The coal in each zone may exist as a single, more-or-less continuous sheet, as a group of closely related individual lenses, or as a multiple-bed complex in which the various beds can be separated by tens of feet or merge into a single thick coal" (pp. 153-154).

The major coal zones in the Allegheny Group, from oldest to youngest are the Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport and Upper Freeport. Geochemical data for overburden strata of Allegheny Group coals are shown in Figures 2.6a and

2.6b. The numbers on the left side of each drill hole represent the total sulfur (%) content of the stratigraphic unit, and numbers on the right side of the drill holes represent the Neutralization Potential (parts per thousand). A comparison of the overburden strata in Figures 2.6a and 2.6b shows that the brackish strata of the lower Allegheny are characterized by high total sulfur contents and relatively low NP values, while the nonmarine (freshwater or continental) overburden strata of the upper Allegheny are characterized by relatively low total sulfur content and relatively high NP (calcareous) overburden strata.

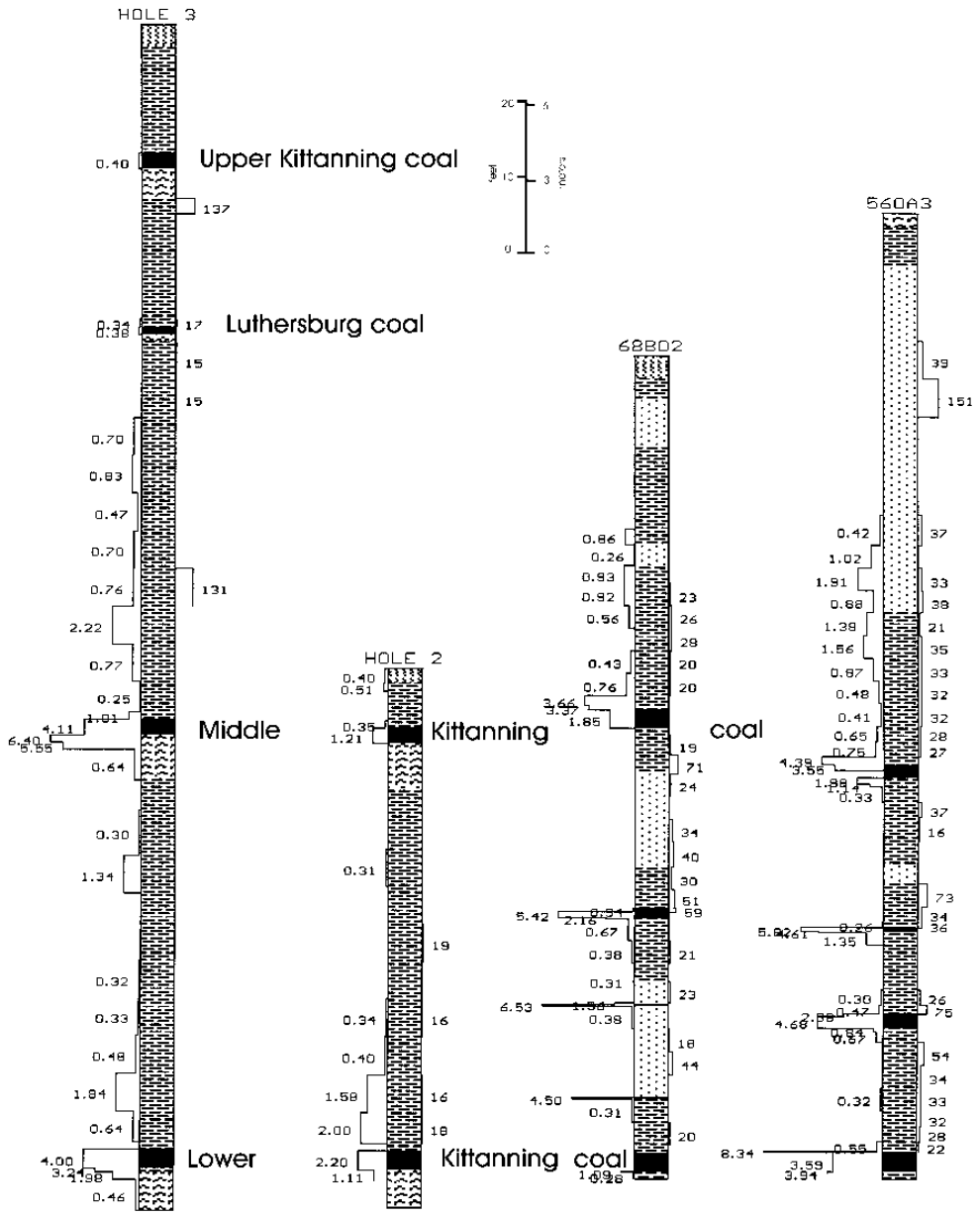


Figure 2.6(a). Lower Kittanning and Middle Kittanning Coals and brackish overburden strata from Clearfield County, PA. (from Brady et al., 1998).

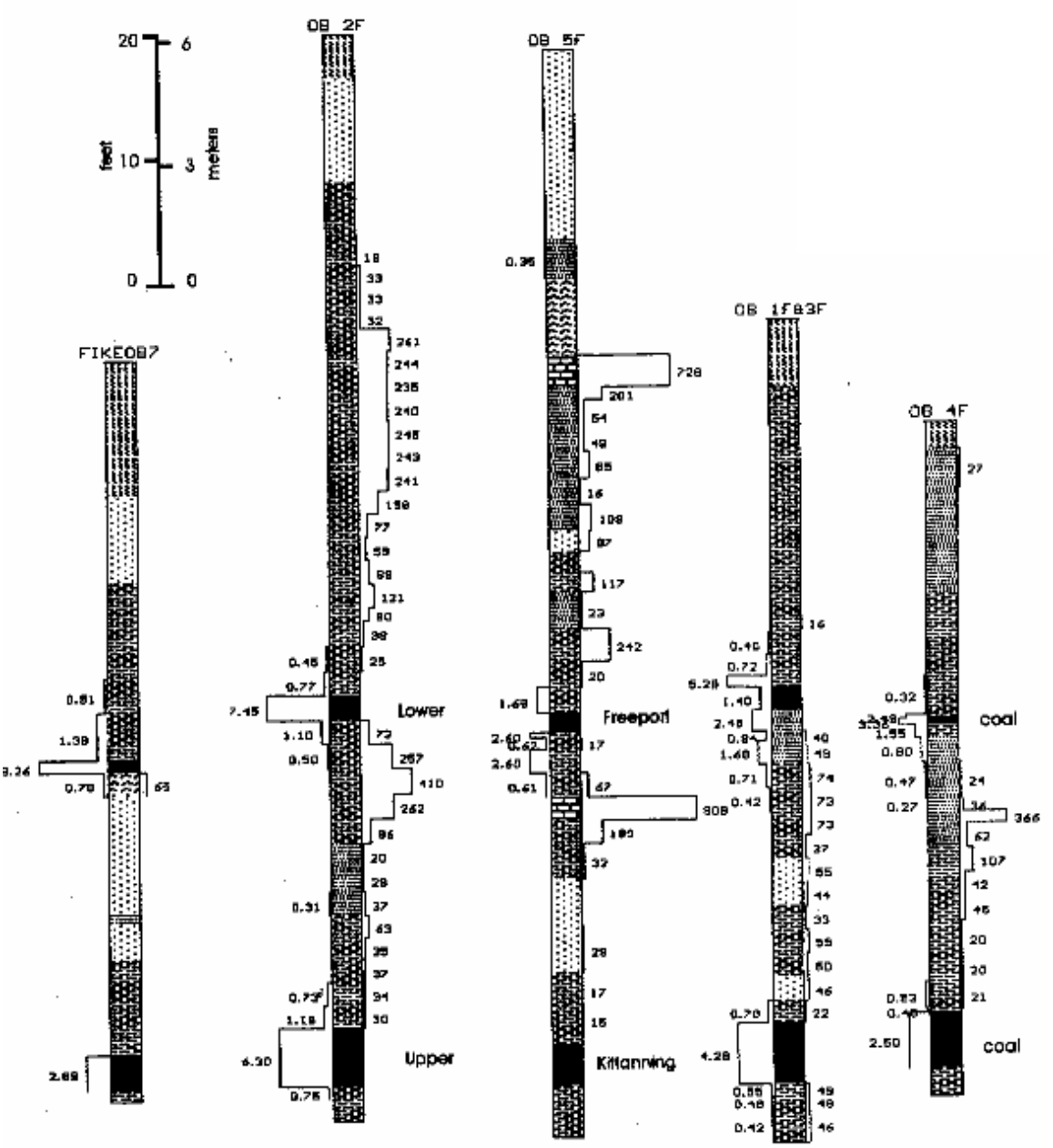


Figure 2.6(b). Upper Kittanning and Lower Freeport Coals and nonmarine overburden strata from Fayette County, PA.

2.3.3 Conemaugh Group – Bituminous

The Conemaugh Group contains two formations, the older Glenshaw Formation and the overlying Casselman Formation.

2.3.3.1 Glenshaw formation

The Glenshaw contains several widespread marine zones, the most prominent of which include the Brush Creek, Pine Creek, Woods Run, and Ames. There are also several less

prominent and obscure marine zones , bringing the total of possible marine zones within the Glenshaw to as many as seven (Edmunds et al., 1999). The Glenshaw is thickest in Somerset and southern Cambria Counties, where it reaches 400 to 420 ft (122 to 128 m). It is thinnest near the Ohio border where it is about 280 ft (85 m) thick (Edmunds et al., 1999). The mineable coals of the Glenshaw Formation, from oldest to youngest, typically are the Mahoning, Brush Creek, Lower and Upper Bakerstown.

2.3.3.2 Casselman formation

According to Edmunds et al., (1999) "The thickness of the Casselman Formation ranges from 230 feet (70 m) in the extreme western part of the Appalachian Plateaus province to 485 feet (148 m) in southern Somerset County" (p. 156). With the exception of the marine shales above the Ames limestone, and the Skelly horizon, which occurs about 30 to 60 ft (9 to 18 m) above the Ames marine zone, the Casselman is made up of exclusively fresh water rocks. Redbeds, which are regionally discontinuous, are scattered throughout the Casselman in the western portion of Pennsylvania. "Eastward they become thinner and fewer in number. This trend continues into eastern Somerset and Cambria Counties, where large areas are completely devoid of red beds in the Casselman Formation . Conversely, coals are nearly absent or very thin in the west but increase in quantity eastward. In Somerset County, a few coals are thick enough to mine" (Edmunds, et al., 1999, p. 156). The coals of the Casselman Formation, typically include from oldest to youngest, the Duquesne (or Federal Hill), the Barton (or Elk Lick), Wellersburg, Little Clarksburg (or Franklin), and the Little Pittsburgh. Except for the Federal Hill, the Barton, the Wellersburg, and the Little Pittsburgh Coals in portions of Somerset County (Shaulis, personal communication, 2004), these coals are generally not mineable.

2.3.4 Monongahela Group – Bituminous

The Monongahela Group extends from the base of the Pittsburgh Coal to the base of the Waynesburg Coal. It is divided into the Pittsburgh and Uniontown Formations at the base of the Uniontown Coal. According to Edmunds et al. (1999): "The group is about 270 to 400 feet (82 to 122 m) thick in Pennsylvania, increasing in thickness irregularly from the western edge of the state to western Fayette County.... It is entirely nonmarine and dominated by limestones and dolomitic limestones, calcareous mudstones, shales, and thin-bedded siltstones and laminites.... The only sandstone of significant thickness within the formation lies directly above the Pittsburgh coal complex. A major fluvial channel system flowing north to northwest through what is now Greene and Washington Counties, deposited an elongate sandstone body up to 80 feet (24 m) thick and several miles (kms) wide" (Edmunds et al., 1999, pp. 156-157).

The Pittsburgh Coal is unusually continuous, covering thousands of square miles (km^2) and is unusually thick (4 to 10 ft.; 1.5 to 3 m, Edmunds et al., 1999) for a coal of western Pennsylvania. The other major coals are the Redstone and Sewickley. In Somerset County an additional coal, the Blue Lick, occurs between the Pittsburgh and Redstone Coals. Shaulis (1993) believes the Blue Lick Coal is a split of the Pittsburgh Coal.

2.3.5 Dunkard Group – Bituminous

The Dunkard Group is found only in the most southwestern corner of Pennsylvania in Greene and Washington Counties. It is made up of Waynesburg, Washington and Greene Formations (Berryhill et al., 1971). The Dunkard reaches a maximum thickness of about 1120 ft (340 m) in Greene County and the upper surface is the modern day erosional surface. The lower boundary of the Dunkard Group is defined as the base of the Waynesburg coal, which is the only coal routinely mined in the Dunkard.

The Dunkard is generally composed of fine-grained clastics which are frequently calcareous. Thick lacustrine limestones are especially prevalent in the Washington Formation. The only significant interval with sandstone is above the Waynesburg coal. This sandstone is often, but not always, calcareous.

2.3.6 Pottsville Group – Anthracite

Pennsylvanian age rocks contain all the coal seams of the Anthracite Region of Pennsylvania, and have been divided into two major formations, the Pottsville and the Llewellyn. Generalized columnar sections of the Pottsville and Llewellyn Formations are shown on Figure 2.7.

The Pottsville Formation ranges in thickness from a maximum of approximately 1600 ft (490 m) in the Southern Field to less than 100 ft (30 m) in the Northern Field. The Pottsville Formation is subdivided into three members, from oldest to youngest, they are the Tumbling Run Member, the Schuylkill Member and the Sharp Mountain Member. The Tumbling Run and Schuylkill Members of the Formation are not present in the Northern Anthracite Field (Wood et al., 1969, 1986; Meckel, 1967, 1970; and Edmunds et al. 1979, 1999).

The Pottsville Formation contains up to 14 coal beds in some areas, but most are relatively discontinuous and only a few persist outside of the Southern Field (Edmunds et al. 1999). Figure 2.7 shows the mineable coals of the Pottsville Formation. The Lykens Valley Coal Numbers 4 through 7 are within the Tumbling Run Member; the Lykens Valley Coal Numbers 1 through 3 are within the Schuylkill Member; and the Scotty Steel and Little Buck Mountain Coals are within the Sharp Mountain Member of the Pottsville Formation (Fig. 2.7). The base of the Buck Mountain Coal is considered the top of the Pottsville Formation in the anthracite fields of eastern Pennsylvania. The Buck Mountain Coal is tentatively correlated with the lower Kittanning Coal within the lower Allegheny Group in western Pennsylvania, and since the upper boundary of the Pottsville Formation in western Pennsylvania is defined as the base of the Brookville Coal, positioned below the Lower Kittanning Coal, the Pottsville of eastern Pennsylvania and the Pottsville of the western Pennsylvania main bituminous field are not precisely equivalent (see Edmunds et al., 1999). The type section of the Pottsville Formation (located near Pottsville) is described by C.D. White (1900) and more recently by Wood et al. (1956) and Levine and Slingerland (1987).

The Pottsville Formation in eastern Pennsylvania is entirely of a nonmarine depositional environment (Edmunds et al., 1999). As in western Pennsylvania, the dominant lithology of the Pottsville Group is sandstone and conglomerate; but the Pottsville Formation of the Anthracite

Region contains significantly more pebble conglomerates derived from an orogenic source area relatively close to the southeast (Meckel, 1967, 1970; Edmunds et al. 1999; and Faill, 1997a,b). The Tumbling Run Member is composed of approximately 55% conglomerate and conglomeratic sandstone, about 30% fine- to coarse-grained sandstone, and about 15% shale and siltstone. Conglomerate and conglomeratic sandstone comprise about 50% of the Schuylkill Member, and the sandstone in the member ranges from very fine to very coarse, constituting approximately 30% of the member. The Sharp Mountain Member in most of the Southern Anthracite Field is composed of about 45% conglomerate, 25% conglomeratic sandstone, 15% sandstone, 5% siltstone, 9.5% shale, and 0.5% anthracite (Wood et al. 1969, 1986). The carbonate content of the rocks has not been determined, except for a few localities.

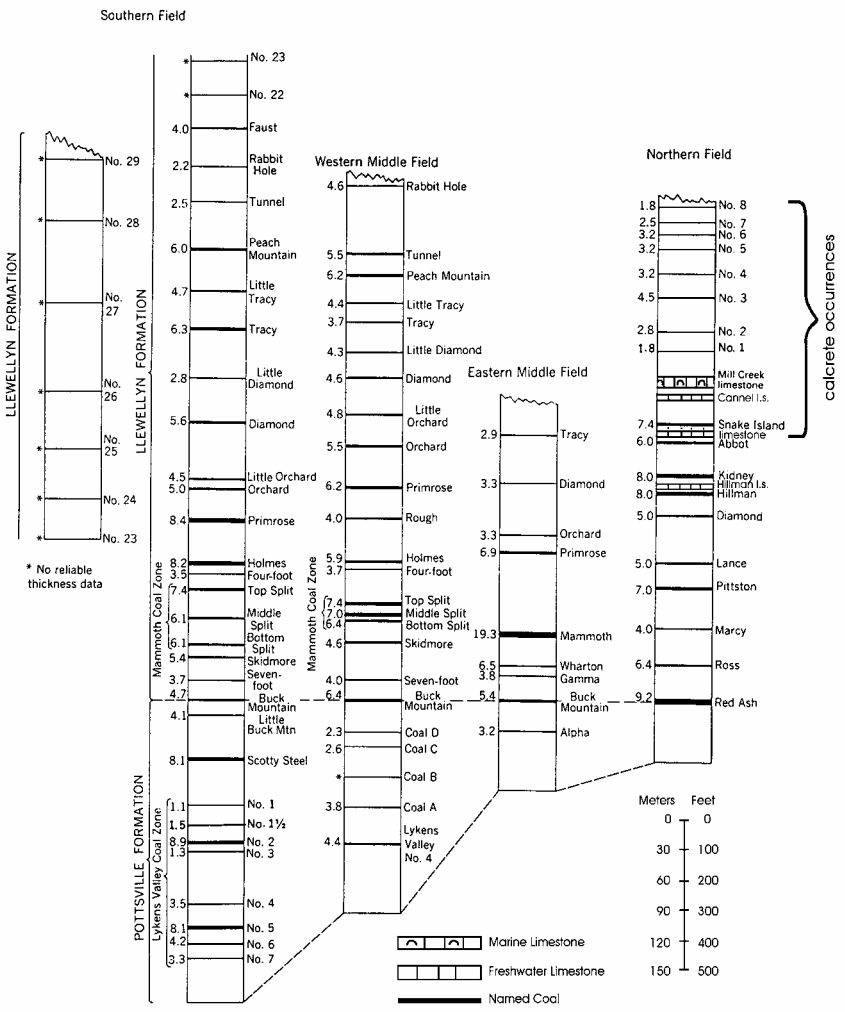


Figure 2.7. Generalized columnar sections showing names, average thickness of coals (in ft), and intervals between coal beds in the Pennsylvania Anthracite fields. Figure is primarily from Wood et al. (1986). Information on calcareous zones in the Northern Field has been supplemented by data from Edmunds et al. (1999) and Inners and Fabiny (1997).

2.3.7 Llewellyn Formation- Anthracite

The Llewellyn Formation is as much as 3500 feet thick. The maximum known thickness of the Pennsylvanian in Pennsylvania is approximately 4400 ft near the town of Llewellyn in Schuylkill County (Edmunds et al., 1999). The Llewellyn Formation contains up to 40 mineable coals (Edmunds et al., 1999), most of which are shown on Figure 2.7. The thickest and most persistent coals occur in the lower part of the Llewellyn Formation, particularly the Mammoth Coal zone. The Mammoth Coal zone typically contains 20 ft of coal, and thicknesses of 40 ft to 60 ft. are not unusual. A local thickness of greater than 125 ft has been reported in the Western Middle Field. This was attributed to structural thickening in the trough of the syncline. The nomenclature and stratigraphy of the coal bearing rocks of the Llewellyn Formation in the Northern Anthracite Field are different than in the Southern and Middle Fields (Fig. 2.7).

The dominant lithology of the Llewellyn Formation is sandstone, including conglomerate units, as in the Pottsville Formation. According to Edmunds et al. (1999, p. 159): "Lithologically, the Llewellyn is a complex, heterogeneous sequence of subgraywacke clastics, ranging from conglomerate to clay shale and containing numerous coal beds. Conglomerates and sandstones dominate". The Llewellyn Formation in the Southern and Middle Fields is believed to be entirely terrestrial in depositional environment (i.e., lacking any marine beds). The Llewellyn Formation in the Northern Field, however, contains one known marine bed, the Mill Creek Limestone (Fig. 2.7). I.C. White (1903) suggested that the Mill Creek was correlative with the Ames Limestone in the Conemaugh Group of western Pennsylvania. This belief is generally held to the present. The Mill Creek Limestone is a one- to three-ft, richly fossiliferous marine limestone (Chow, 1951). The Llewellyn Formation contains several nonmarine limestones in the Northern Field in a 330 ft thick zone directly below the Mill Creek Limestone, including the Cannal and Hillman Limestones (Chow, 1951, and Edmunds et al., 1999). Additionally, Inners and Fabiny (1997) have identified calcareous paleosols ("calcrete") in the uppermost Llewellyn Formation in the Northern Field. They have tentatively correlated this portion of the stratigraphy with the Conemaugh of western Pennsylvania. These two zones combined potentially provide an appreciable amount of calcareous material in the top approximately 850 feet of the Llewellyn Formation of the Northern Anthracite Field.

Deep drill holes of the stratigraphic sequence of the Pottsville and Llewellyn Formations in the AnthraciteRegion are rarely included in the permit files for anthracite coal mine permits. However, DEP cooperated with the Pennsylvania Geologic Survey, Reading Anthracite Company and Mr. Louis DeNaples (a landowner in the Northern Anthracite Coal Field) to obtain two significant cores and several deep air-rotary drillholes in the Southern Field (at Reading's Wadesville mine) and in the Northern Field (on Mr. DeNaples' land). A graphic drill log for 500 feet of the Llewellyn Formation above the Mammoth Coal is shown in Figure 2.8, for one of the air-rotary drill holes at Wadesville.

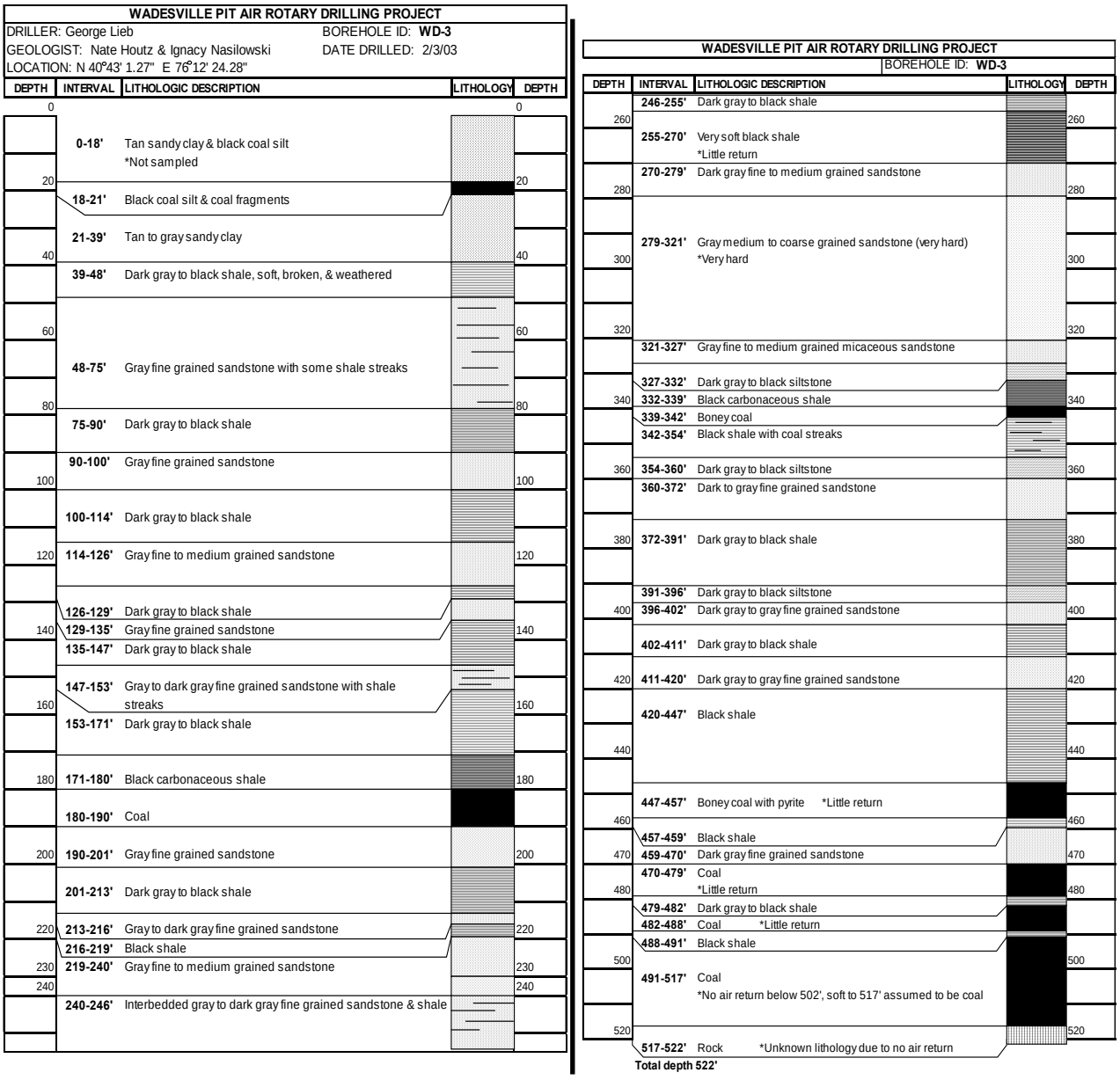


Figure 2.8. Stratigraphic interval from the Mammoth Coal zone up to the Primrose Coal bed at the Wadesville site.

2.3.8 Stratigraphic Observations and Inferences in the Anthracite Coal Fields

Bedrock formations exposed near the Eastern Middle Field are the products of weathering to the southeast. A poorly understood tectonic event in the early Carboniferous produced uplift to the southeast that was the primary source of clastic material to the basin. It is speculated that the cause of this possible orogeny may have resulted from strike slip movement generated by the approaching African plate (Faill, 1997a,b). While these highlands were eroding, the Mauch Chunk Formation and the overlying Pottsville Formation were deposited. The Mauch Chunk consists of predominantly fining upward alluvial cycles of interbedded

sandstones, siltstones, mudstones, and conglomerates (Inners, 1988), and can be recognized in the field by its characteristic red color. The contact between the Mauch Chunk Formation and the Pottsville represents a transition from the warm, seasonally dry climate present at the time of Mauch Chunk red bed deposition to the much wetter climate in which the Pottsville coal forming peat swamps flourished (Edmunds et al., 1999). Sedimentary structures, thickness patterns, and a southeastward increase in grain size indicate that the Pottsville Formation was also derived from a southeastern source (Wood et al., 1986).

Figure 2.9 shows a schematic of the Spring Mountain cut along I-81, approximately 4 miles south of Hazleton. The outcrop exposes the contact between the Mauch Chunk and the Pottsville Formation as part of a large syncline (Bolles and Geyer, 1976). Superimposed on the syncline in Figure 2.9 is a large fault, which occurred during the rock's burial during the Permian. The resistant Pottsville Formation forms many of the high ridges around each field, and the overlying less resistant Llewellyn Formation occupies the valley floors within each field (Eggleston et al., 1999).

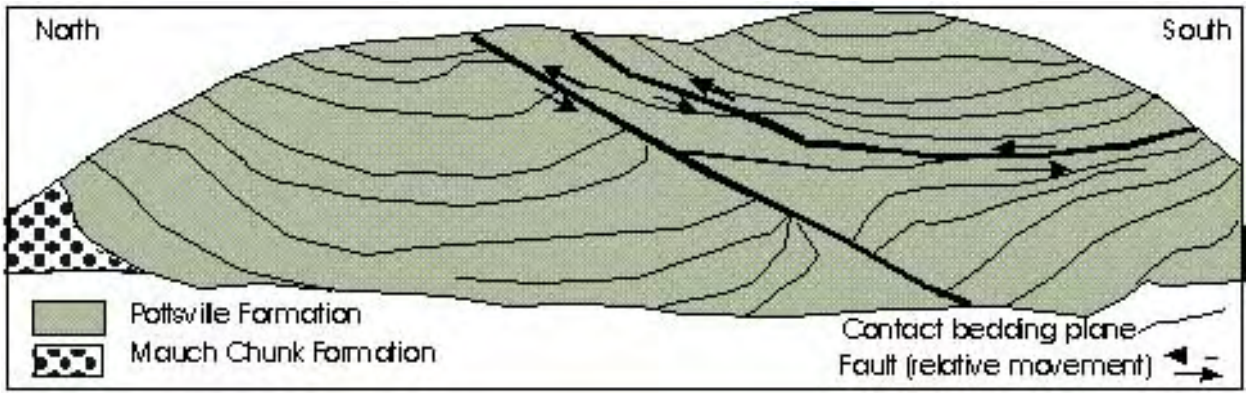


Figure 2.9. A schematic of the outcrop at mile marker 138 along Interstate 81, near McAdoo, PA, showing the contact between the Mauch Chunk and Pottsville Formations (modified from Bolles and Geyer, 1976).

The identification and mapping of limestone and other calcareous rocks in the Southern and Middle Fields have not been reported in the literature; however, some large mine pool discharges such as the Wadesville Colliery (Table 2.1), have alkalinity of several hundred milligrams per liter, which must be attributed to some carbonate minerals in the overburden. Discharges in the Eastern Middle Field have little if any alkalinity (Table 2.1). This strongly suggests a lack of calcareous rock in this coal field. Kochanov (1997) has found calcareous sandstones in the lower part of the Llewellyn in the Northern Field. Further study of carbonate minerals and identification of calcareous lithologic units in the Southern and Middle Fields is needed.

2.4 HYDROGEOLOGY

The hydrogeology of the Anthracite and Bituminous Coal Regions of Pennsylvania is the product of the topography, geologic structure and stratigraphy of these regions. Whereas the Bituminous Region has a more conventional integration of these geologic factors, the hydrogeology of the Anthracite Region is largely controlled by the hydrology of the mine pools

related to large abandoned underground mine complexes, or collieries as they are called in the region.

2.4.1 Regional Hydrogeology of the Bituminous Coal Region

Regional and local patterns of groundwater flow on the Allegheny Plateau of western Pennsylvania are established in response to topographic, structural and stratigraphic controls, some of which were discussed separately in preceding sections on the regional geology, but which are briefly integrated below at various scales to comprise the hydrogeologic setting. In addition to the stratigraphic controls on the general configuration of the flow system, lithologic variations within the Pottsville and Allegheny Groups can be related to factors that influence the quantity and quality of ground and surface water supplies available on the Allegheny Plateau in western Pennsylvania.

Groundwater flow of the Appalachian Plateau of Pennsylvania is described in detail in Callaghan et al. (1998), including several mining case studies. A similar comprehensive chapter on the hydrogeology of the Appalachian Bituminous Coal Basin is in Callaghan et al. (2000). Hawkins (1998) provides additional valuable information on the hydrogeologic characteristics of mine spoil within the Appalachian Coal Basin.

In the regional geomorphic setting of the Allegheny Plateau, variations in relief and the configuration of the topographic surface are closely related to the drainage pattern. The regional topographic highs are the major groundwater recharge areas while the elevation and configuration of regional groundwater discharge areas are controlled by the depth of incision of the major streams and rivers such as the Allegheny and Monongahela Rivers. Within this regional flow system, local and intermediate scale flow systems exist, wherein local and intermediate scale topographic lows are usually groundwater discharge areas, while corresponding topographic highs are usually groundwater recharge sites, (Fig. 2.10).

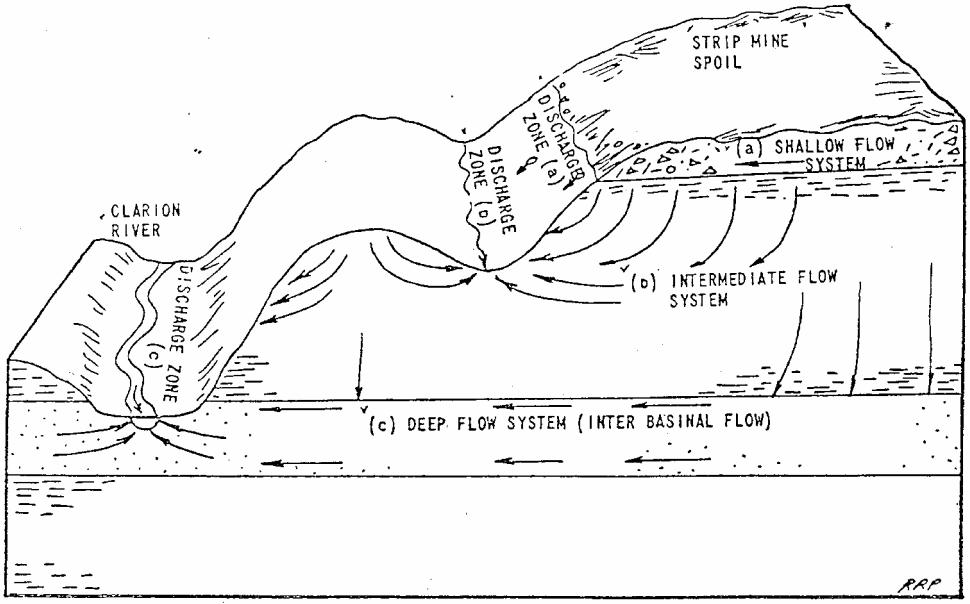


Figure 2.10. Block diagram showing shallow, intermediate, and regional (deep) groundwater flow systems in the Bituminous Coal Region of western PA, (from Parizek 1979).

Groundwater flow systems of various scales and configurations for various geologic settings have been discussed by Hubbert (1940), Toth (1962), Meyboom (1966), Brown and Parizek (1971), Freeze and Cherry (1979) and others. Parizek (1979) provides a review of the flow systems cited above and discusses a high-relief, coal-field, flow-system model as shown on Figure 2.10. That model of groundwater flow is most appropriate for most of the Allegheny Plateau and the bituminous case study sites described in Chapter 5.

As the bedrock structure is often closely related to the present topography, the structural configuration may be related to the groundwater flow system as with topography above. For example, the crests of anticlines or other structural highs may be groundwater recharge areas, with the discharge areas located in the synclinal lows coincident with the topographic lows. However, numerous interacting geologic and hydrologic factors produce flow-system behavior which deviates considerably from the ideal case where the groundwater is flowing through isotropic, homogeneous media. In a typical geologic setting for Pottsville and Allegheny Groups strata in western Pennsylvania where a cyclical sequence of varying rock types outcrops in a gently dipping or folded configuration, a three-dimensional representation of the groundwater flow system may reveal structurally-induced flow pattern controls. The uplands may still be the principal recharge areas with the lowlands as the principal discharge areas, but groundwater flow may follow preferred avenues, such as along bedding planes and selected lithologic units of contrasting permeability, to down-dip discharge sites.

Strong control on the patterns of groundwater flow also may be exerted by the orientations and the frequency of joints, zones of fracture concentration (revealed by fracture traces), and other linear structural features which introduce a secondary porosity and permeability to the bedrock. The dramatic influence of these linear features on groundwater flow has been shown by Lattman and Parizek (1964), Parizek (1971, 1976), Brown and Parizek (1971), Parizek, et al. (1971), Lovell and Gunnett (1974), Cline (1968) and others. The relationship of fracture-trace intersections and/or lineament intersections to high productivity of water supply wells has been documented by Siddiqui and Parizek (1971a, 1971b) and others.

The general stratigraphy of the Pottsville and Allegheny Groups in western Pennsylvania and the lithologic characteristics of specific stratigraphic intervals therein are interrelated with the topographic and structural controls on regional and local groundwater flow systems. The most resistant lithologic units generally form the topographic highs while the most easily weathered units form the topographic lows. The fundamental or primary properties of the sedimentary rocks, such as the mineralogical composition of the rock and the size, shape, orientation and packing of the mineral grains, (Griffiths, 1967), not only determine the relative resistance to weathering, but also greatly influence other derived or secondary lithologic properties such as the intergranular porosity and permeability. Hence, the variations in lithology of the Pottsville and Allegheny Groups (as discussed in the preceding section on stratigraphy), are highly related to variations in the potential to store and transmit groundwater. For example, the large sandstone units may be the best aquifers regionally, while the shales and underclays tend to be confining beds. The coal seams, which often occur in a highly-jointed condition between the underclays and thick sequences of overlying shale, may readily transmit groundwater accumulated by vertical leakage from the overlying beds. The prevalence of springs and seeps at the outcrop line of coal seams in some topographic settings reflects the role

of these beds in the transmission and discharge of infiltrating groundwater as part of shallow and intermediate flow systems.

The relationship between the stratigraphy and permeability of rocks of the Pottsville and Allegheny Groups has been discussed by Caruccio and Parizek (1967), Brown and Parizek (1971) and Schubert (1978) who found horizontal permeability greatly exceeds vertical permeability and thus causes a predominantly lateral groundwater movement. A multiaquifer hydrogeologic setting on the Allegheny Plateau, in which the shallow flow system is significant, has been investigated by Poth (1963), and Brown and Parizek (1971) Emrich and Merritt (1969).

In a detailed study of the geology and hydrology of the Pottsville and Allegheny Groups in a portion of Mercer, Lawrence, and Butler counties, Pennsylvania, Poth (1963, p. 88) describes the relationship between patterns of groundwater flow and the major stratigraphic units as follows: "The mature dissection of the bedrock divided the Mercer quadrangle into a number of "hydrologic islands", each with its own pattern of groundwater circulation. Precipitation enters the upper part of the "islands" and is discharged through the outcrop areas of the aquifers along the perimeter of the "islands."

According to Poth, the "hydrologic islands" are a few square miles in area, and are composed of rocks younger than the lower member of the Connoquenessing Formation which is generally the highest hydrologically-continuous stratigraphic unit throughout the area. As shown on Figure 2.11 (from Poth, 1963, p. 58), infiltrating groundwater is discharged into glacial deposits in valleys around the margin of the "islands", or is carried downward into the deep circulation system of Connoquenessing Sandstone and lower aquifers through the aid of fracture zones.

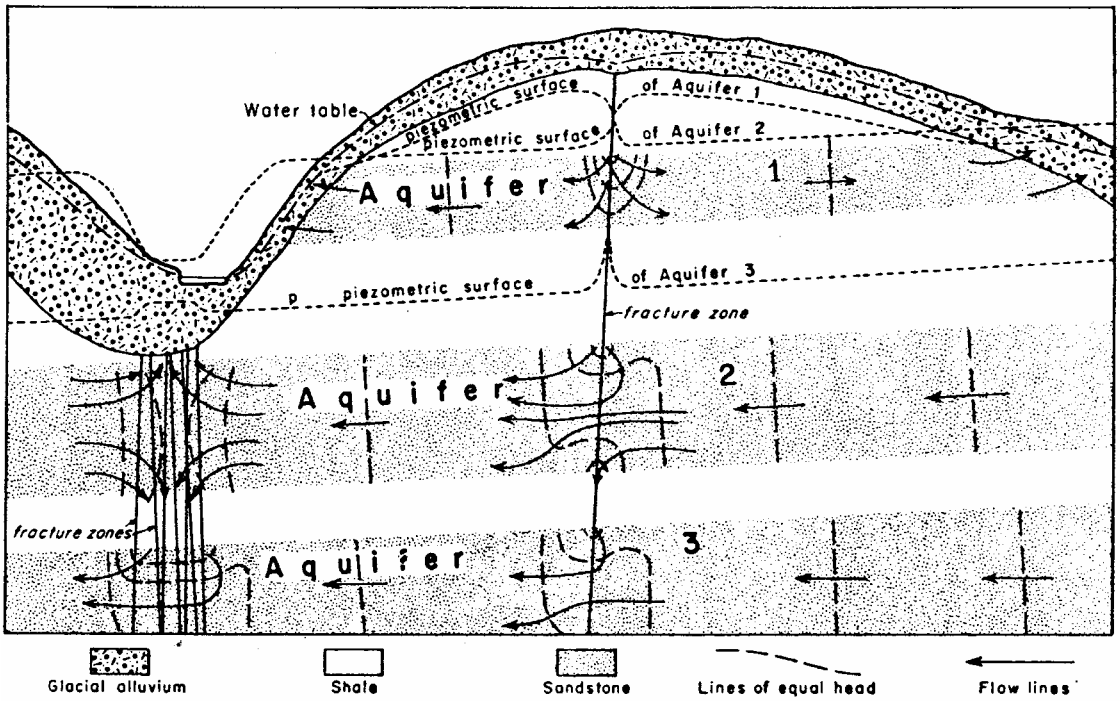


Figure 2.11. Idealized pattern of groundwater flow in the Mercer Quadrangle, PA**.**

Several studies have been completed within the Allegheny Plateau of western Pennsylvania, which relate the above hydrogeologic principles and associated topographic, structural and stratigraphic factors to the mining of coals from the Pottsville and Allegheny Groups as well as to coal mining in other areas. Parizek and Tarr (1972) provide a survey of existing and proposed techniques of mine drainage pollution prevention and abatement, employing naturally occurring hydrogeological and geochemical systems which are prevalent in western Pennsylvania and elsewhere.

The relationship between stratigraphy and mine drainage quality in the bituminous and anthracite mining regions of Pennsylvania are described in Brady et al. (1988). A bimodal frequency distribution of the pH of coal mine drainage was first reported by Brady et al. (1997). Figures 2.12a and 2.12b from Brady et al. (1998) shows the bimodal distribution of pH for bituminous and anthracite mine discharges. Table 2.1 shows the relationships between mine drainage quality and stratigraphic intervals for water samples representing the coal-bearing Pennsylvania and Permian stratigraphic sequence in western and eastern Pennsylvania. Table 2.1 in this chapter is an abridged version of mine drainage quality data compiled in Table 8.2 and 8.14 in Brady et al. (1998).

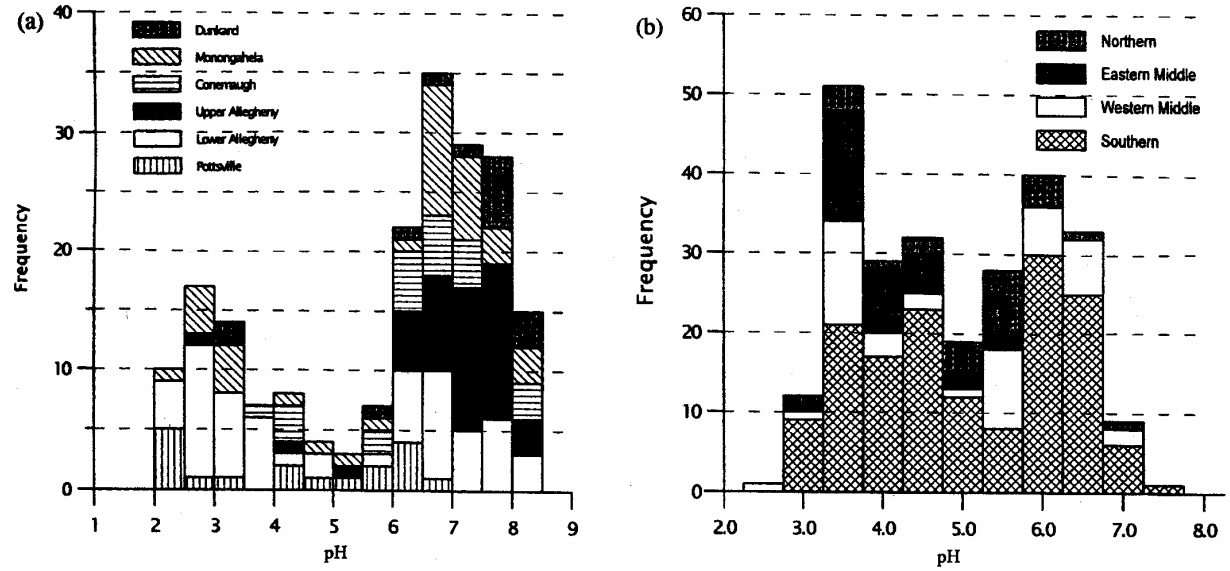


Figure 2.12. Bimodal distribution of pH for (a) bituminous mines and (b) anthracite mine discharges in PA. (Bituminous data are from Table 8.2 in Brady et al. (1998) and anthracite data are from Growitz et al., (1985). Bituminous data are displayed by stratigraphic group and anthracite data by coal field.)

2.4.2 Regional Hydrogeology of the Anthracite Coal Region

The hydrogeology of the Anthracite Coal Region of eastern Pennsylvania is similarly the product of the topography, geologic structure and stratigraphy of the region, as described for the bituminous region. However, in considering the integration of these geologic factors, the hydrogeology of the Anthracite Region is much simpler in some respects, while being more complex than the bituminous regions hydrogeology in other respects. Part of the simplicity is

that a large portion of the groundwater in the four anthracite coal fields is accounted for by about 100 large mine pool discharges, in comparison to the many thousands of mine drainage discharges and AMD seeps in the bituminous coal fields of Pennsylvania. Also, much is known about the areal extent, depth and other aspects of the geometry and hydrology of the anthracite mine pools along with their interconnections from the detailed mine maps that are available for most of the abandoned deep underground mines.

The complexity of the Anthracite Region hydrogeology is largely a result of the complexity of the geologic structure and how that complex structure is translated into an elaborate system of mine development patterns, including numerous overlapping gangways, chutes or breasts, and slopes, that are interconnected by nearly horizontal rock tunnels and vertical shafts. The configuration of anticlinal and synclinal folds and the presence of significant faults can often be interpreted from the mine development patterns on the colliery maps. The gangways are frequently significant components of groundwater flow patterns, analogous to the conduit and sinkhole systems in karst hydrology, because the gangways are long voids developed parallel to the strike of the beds, that are often connected vertically to the land surface by cropfalls (mine subsidence features), which resemble sinkholes and promote infiltration of surface water into the groundwater flow system.

Adding to the complexity of the Anthracite Region hydrogeology in some areas is the presence of local-scale shallow groundwater flow systems, that may be somewhat independent of, or interconnected with, the more regional-scale underlying mine pool flow systems (similar to Figure 2.10). Examples of these shallow groundwater flow systems are found along ridges in the Southern Anthracite Field near Tamaqua, where abandoned, relatively small pits on the flanks of the ridges, and the sandstone ridge tops themselves, serve as groundwater recharge areas, and the discharge areas are through the collovium or underlying bedrock into the underlying mine pool system in the valley bottom.

The configuration of the mine pools and associated barrier pillars for most of the Anthracite Region were documented in a series of reports by S.H. Ash and associates at the U.S. Bureau of Mines (Ash and Eaton., 1947; Ash et al., 1949; Ash et al., 1950a,b; and Ash, 1954). These reports contain delineations of the shorelines of the mine pools, locations of documented breeches in the barrier pillars, and estimations of the volume of water impounded in specific mine pools. Two USGS reports contain data for most of the large anthracite mine pool discharges from 1975 (Growitz et al., 1985) and (Wood, 1996) that allow comparison of water quality changes through time.

The work of J.R. Hollowell of the Susquehanna River Basin Commission (SRBC) and associates provided significant hydrogeological information on the Northern and Eastern Middle Coal Fields. Hollowell (1971) described the mine-water hydrology for the Wyoming Basin of the Northern Field, and Hollowell and Koester (1975) contains a similar description of the mine-water hydrology of the Lackawanna Basin of the Northern Field. Figure 2.13 from Hollowell (1971) is a map of the collieries of the Wyoming Basin, and Figure 2.14 from the same publication is a companion schematic plumbing diagram of mine water flow through these abandoned underground mines of the Wyoming Basin. Hollowell and Koester (1975) contains a

large water-table contour map (Plate 2 of that publication) showing the collieries of the Lackawanna Basin and the associated mine pool shoreline, plus the mine pool elevations in key shafts and the associated potentiometric surface contours.

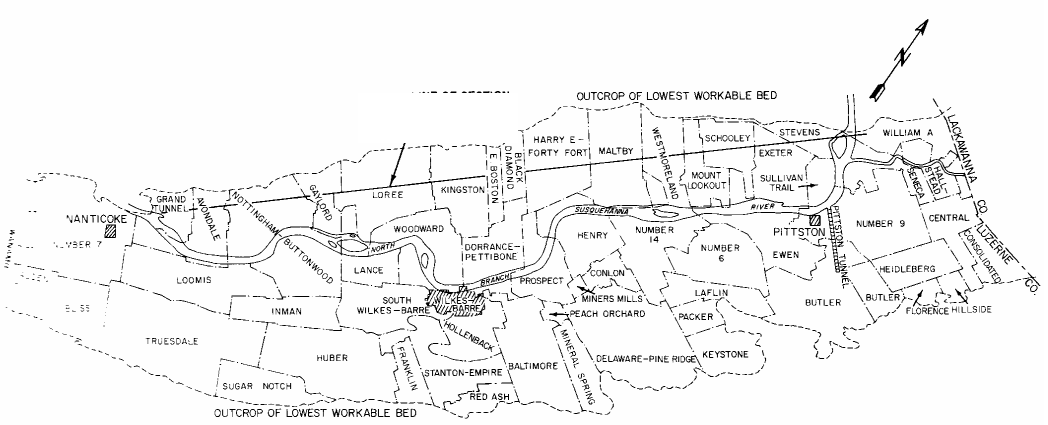


Figure 2.13. Map of collieries in Wyoming Basin of the Northern Field (from Hollowell,1971).

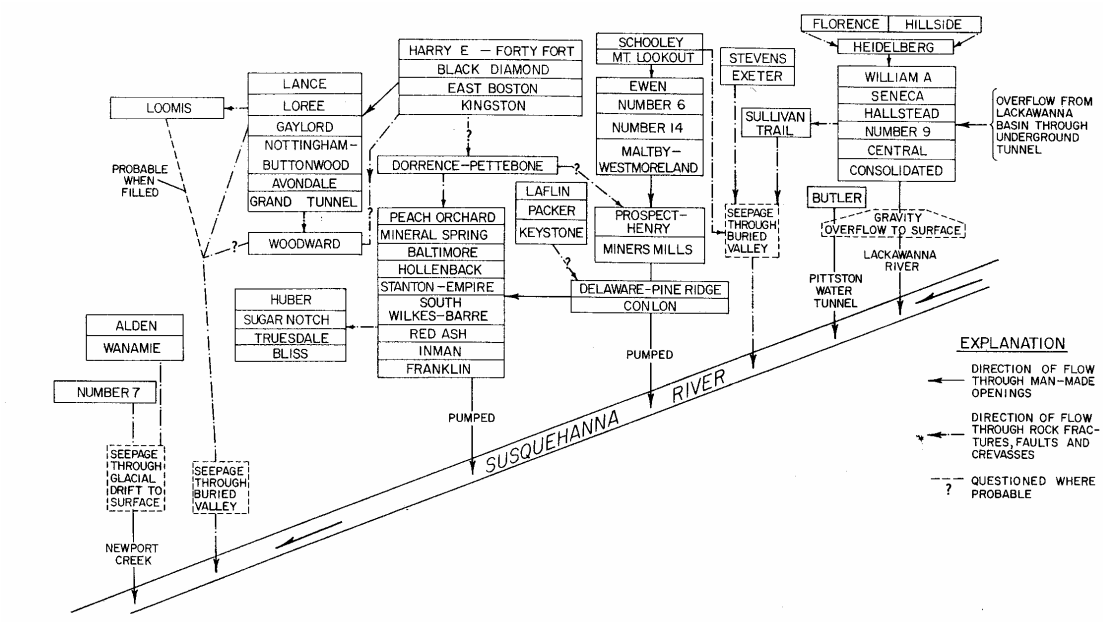


Figure 2.14. Schematic diagram of water flow through the mines (eg. Barrier pillar breaches) in the Wyoming Basin, (from Hollowell 1971).

Hollowell (1999) describes the mine drainage outfalls of the Eastern Middle Field, and delineates the individual coal basins, the locations of the outfalls and the extent of the Jeddo drainage tunnel system, as shown on Figure 2.15. According to Hollowell (1999, p. 1), there are 13 functional mine drainage tunnels in the Eastern Middle Field that were specifically driven to dewater the mine workings. This drainage system was most successful in the Eastern Middle Field because of the comparable elevation of the drainage tunnel discharge to the receiving streams. The Jeddo Tunnel is by far the most extensive of these. The other discharges each yield a comparatively minor amount of water.

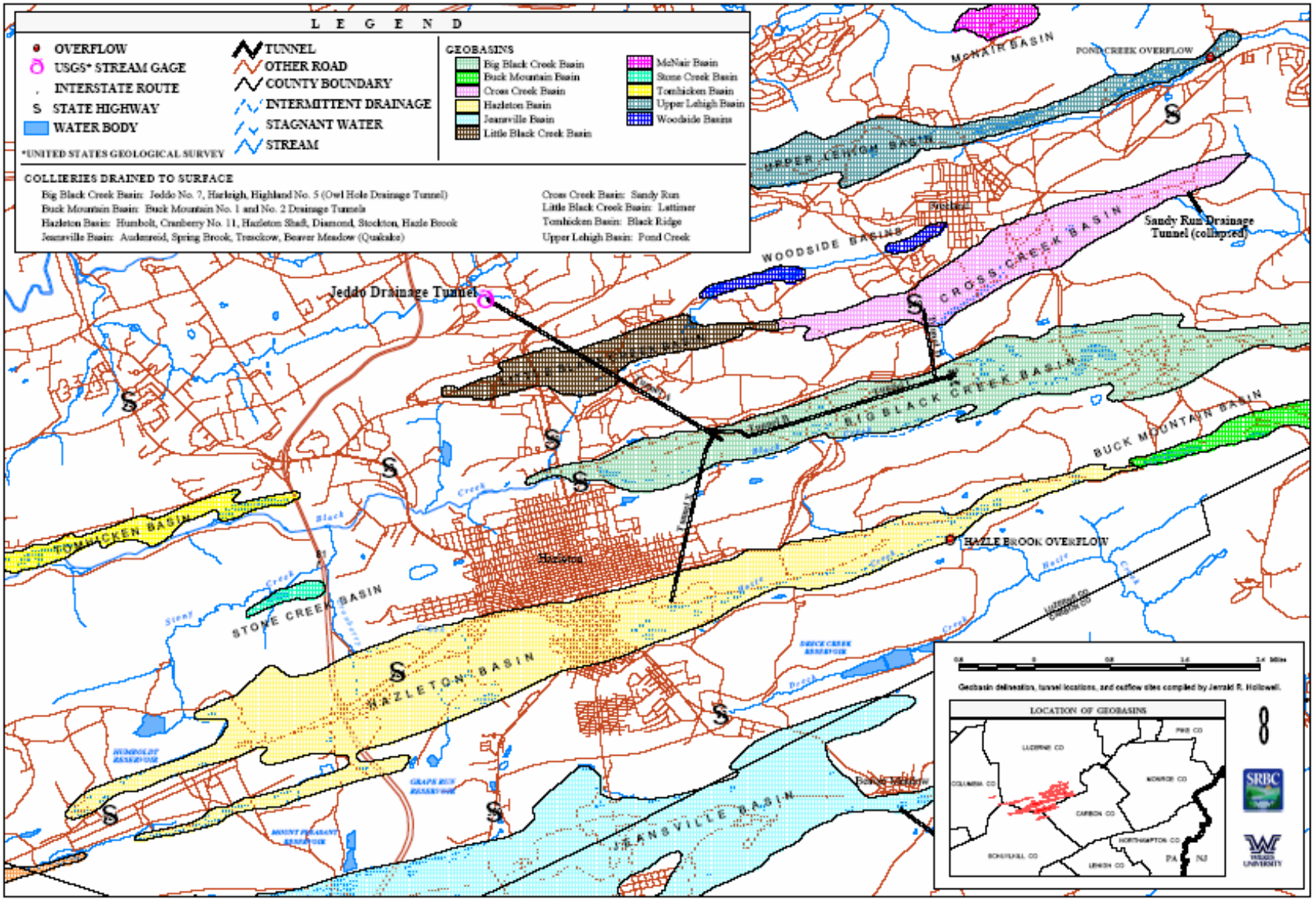


Figure 2.15. Jeddo Tunnel drainage system (from Hollowell 1999).

The report by Hollowell (1999) includes plots of the flow and pollution load (i.e. acidity, sulfate, iron, manganese, aluminum, magnesium, zinc) of the 16 major mine drainages of the Eastern Middle Field for 3 water years. In a companion report by the SRBC, Ballaron (1999) describes a hydrologic budget for the Jeddo Tunnel Basin that was done in cooperation with USGS, DEP and the Little Nescopeck Watershed Association.

Few detailed hydrogeologic studies have been completed for the Southern Field and the Western Middle Field, except for some unpublished hydrogeologic reports in DEP files, and some thesis publications including the groundwater modeling study by Bair (1980) of an area near Tamaqua in the Southern Field. However, a number of significant geochemical and hydrologic studies have been completed by C.A. Cravotta and associates at USGS for the Swatara Creek Watershed and other selected watersheds in the Southern Field and Western Middle Fields including Cravotta (2000), Cravotta and Watzlaf (2002), Cravotta (2003) and Cravotta et al. (2004).

2.4.3 Jeddo Tunnel Discharge

Much has been written about the Jeddo Tunnel, in terms of an extraordinary engineering feat, the eventual success of dewatering the coal basins (Ash et al., 1950b) and more recently, its environmental impact. The Jeddo Tunnel mine discharge near Hazleton, Pennsylvania is the largest abandoned underground mine discharge in the Eastern Middle Field of the Anthracite Region, and is among the largest mine drainage discharges in Pennsylvania. The Jeddo Tunnel has a total drainage areas of 32.24 square miles, and its underground drainage system collects and discharges more than half of the precipitation received in the drainage area (Ballaron et al., 1999).

The flow of this discharge was monitored with a continuous recorder from December 1973 through September 1979 by the USGS in cooperation with Pennsylvania Department of Environmental Resources. The results of that monitoring for the water year from October 1, 1974 through September 30, 1975 are shown in Figure 2.16 (Growitz et al., 1985). During that year, the discharge ranged from 36 to 230 cfs (16,157 to 103,224 gpm).

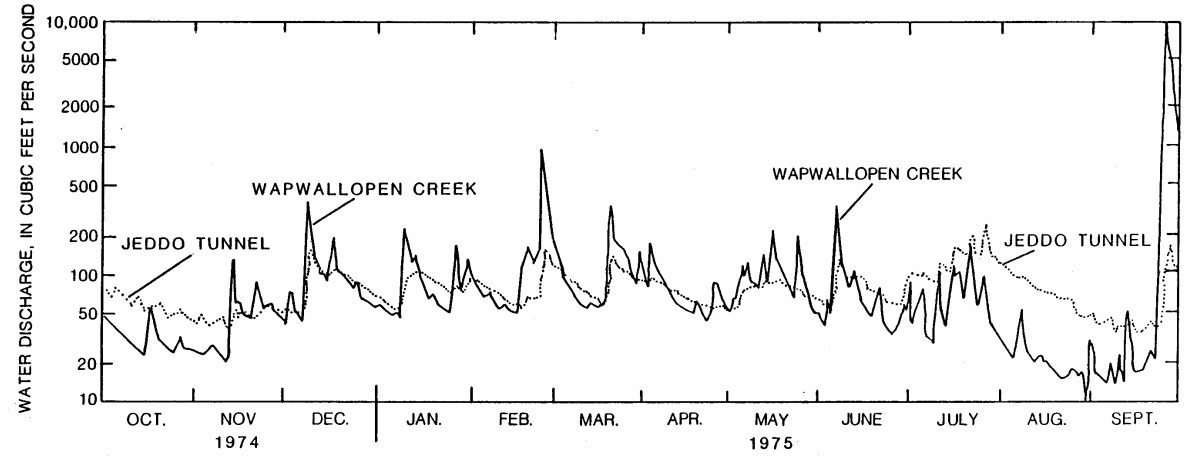


Figure 2.16. Water discharge from the Jeddo Tunnel in Hazleton, and Wapwallopen Creek near Wapwallopen, PA, October 1, 1974 to September 30, 1975 (from Growitz et al. 1985).

The Wapwallopen Creek, ten miles north of the Jeddo Tunnel drains an area of 43.8 square miles and has a measured mean discharge of 78 cfs (35,008 gpm) (Growitz et al., 1985). The Jeddo Tunnel discharge flows are compared to the stream-flow of Wapwallopen Creek (approximately 10 miles north of the Jeddo Tunnel) on Figure 2.16. Growitz et al. found that the response of the Jeddo Tunnel discharge to precipitation events is considerably less than that of the Wapwallopen Creek, and that during large storm events, the Jeddo Tunnel data peaked later than the stream discharge.

The continuous flow recording station at the mouth of the Jeddo Tunnel was reconstructed and operated by USGS from October 1995 through September 1998 in cooperation with PA DEP, the Susquehanna River Basin Commission, US EPA and other project cooperators. Figure 2.17a (from Ballaron et al., 1999) shows variations in the flow of this discharge during this period. The average annual discharge flow was 79.4 cfs (35,635 gpm) and the range of recorded flow measurements was between 20 cfs (8,976 gpm) in October 1995 and 482 cfs (216,322 gpm) in November 1996, following 3.89 inches of rainfall (Ballaron, 1999). In comparison, Figure 2.17b shows a graph of precipitation data from Hazelton Pennsylvania for the period from October 1995 through September 1998. This graph was plotted from data contained in Ballaron (1999). Additional information on the Jeddo Tunnel discharge is contained in Fox et al. (2001).

2.4.4 Anthracite Region Water Quality

Regional variations in mine drainage quality of the Anthracite Region are shown in Table 2.1. The relationships between the post-mining water quality and specific stratigraphic intervals of the Anthracite Region are much less well known than those of the Bituminous Region for at least two reasons: 1) the complexity of the geologic structure has impeded the acquisition of stratigraphic data from routine exploration drilling and made correlations of units and associated mine drainage difficult; and 2) a large portion of the mining hydrology of the four anthracite fields is controlled by large-volume, mine pool discharges. The mine drainage from gangways developed in multiple coal beds is commingled in rock tunnels (that crosscut the geologic structure and strata), which interconnect the mine workings. Thus discharges are often a composite representing water from multiple coal seams throughout a large mine complex. Despite this, some significant regional variations in mine drainage quality are evident for the anthracite fields (Figure 2.18). These are probably related to mineralogic differences between the fields.

Some Northern Anthracite Field mine waters have significant alkalinity (e.g., Plains Borehole, Table 2.1). This may be attributable to the presence of marine and freshwater limestones and other calcareous rocks in the Northern Field. A few post-mining discharges of the Northern Field have low pH and high acidity (Loomis Bank discharge), although high acidity discharges are relatively rare in the anthracite fields. Many large volume discharges of the Northern Field have circumneutral pH with nearly equal concentrations of acidity and alkalinity. However, some of these discharges have relatively high concentrations of iron, manganese or aluminum, and because of large flows they have high pollution loads.

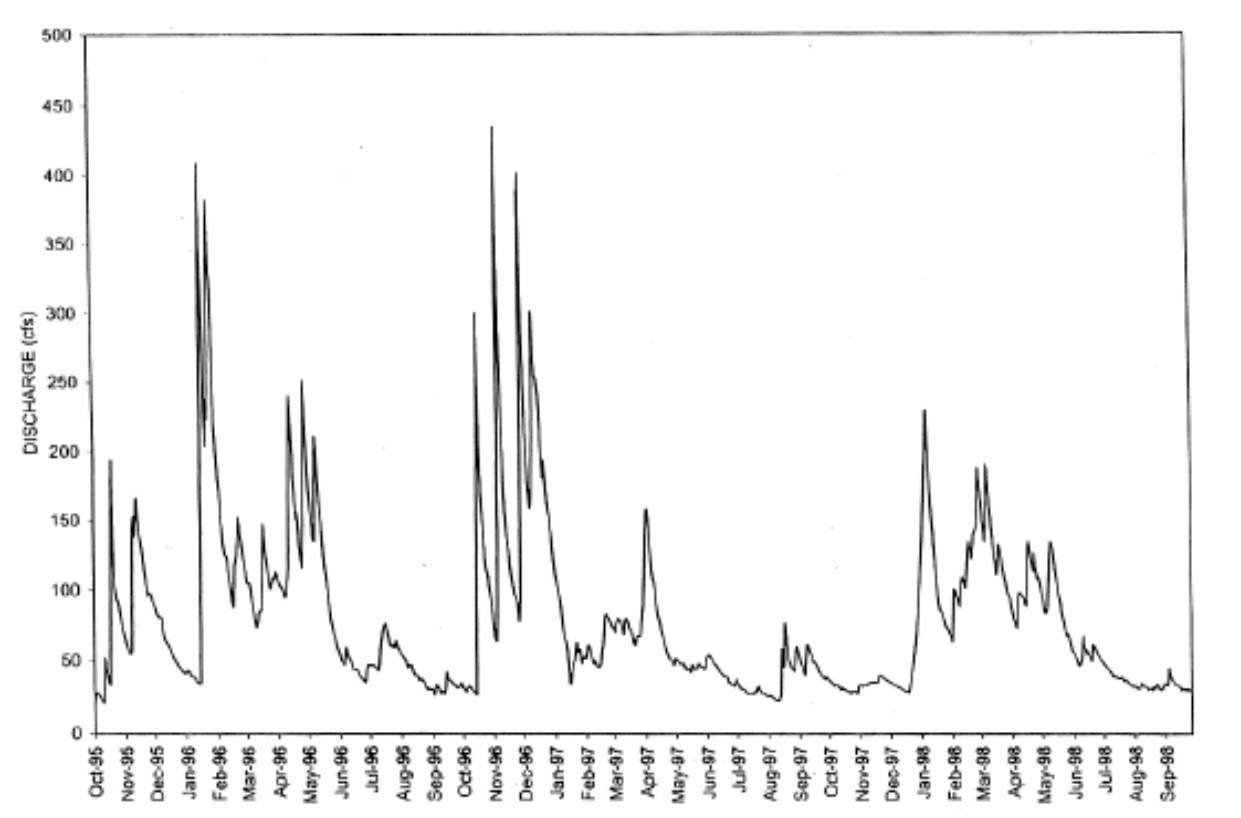


Figure 2.17(a). Discharge from the Jeddo Tunnel - water years 1996-1998 (from Ballaron 1999).

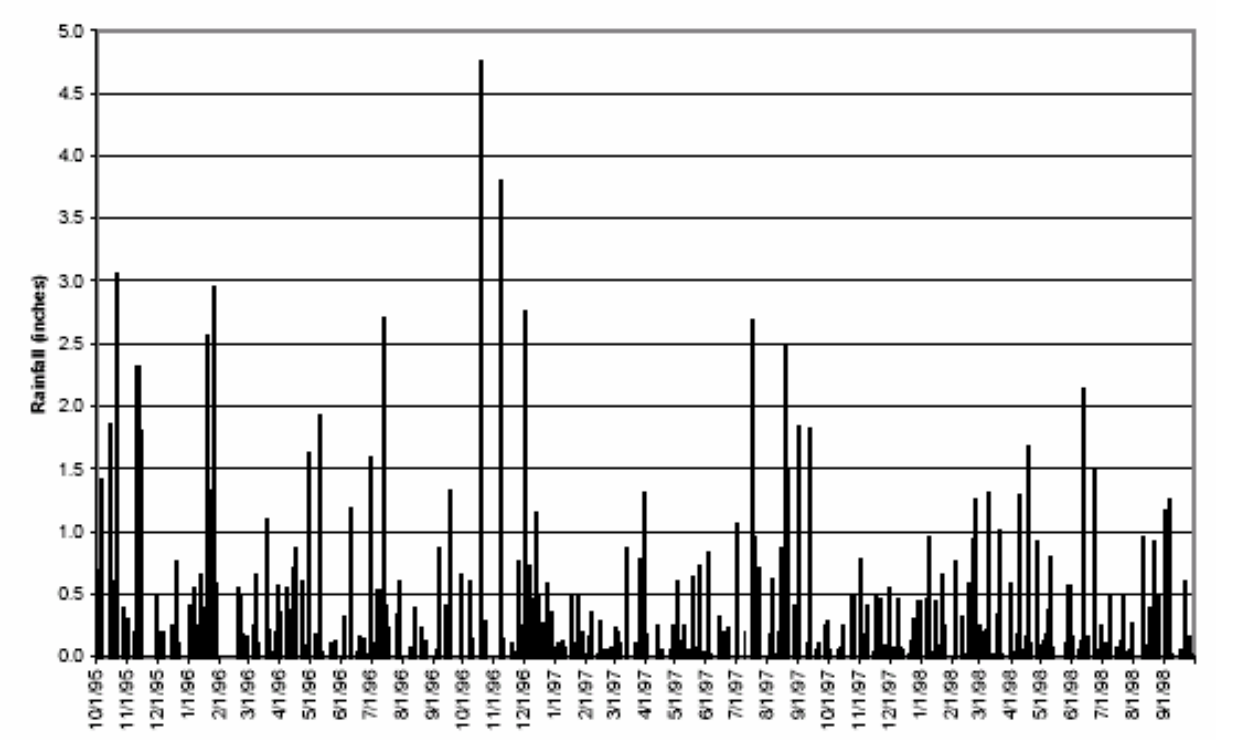


Figure 2.17(b). Precipitation data from Hazleton, PA 1996-1998 (from Fox et al., 2001).

Table 2.1. Mine drainage quality of the Bituminous and Anthracite Coal Regions of PA
(Bituminous mine sites are identified by major coal seams mined: WY= Waynesburg, RS = Redstone, PT = Pittsburgh, UB= Upper Bakerstown, BC = Brush Creek, UF = Upper Freeport, LF = Lower Freeport, UK = Upper Kittanning, LK = Lower Kittanning, CL = Clarion, MR = Mercer. Anthracite mines are identified by coal field: N = Northern Field, EM = Eastern Middle Field, WM = Western Middle Field, S = Southern Field.

Site Name	County	Coal ID	Sample Date	pH	Alkalinity mg/L	Acidity mg/L	Iron mg/L	Mn mg/L	Al mg/L	SO_4 mg/L	TSS mg/L	Flow (gpm)
Susan Ann	Greene	WY	10/24/91	7.9	286	0	2.61	17.60	<0.50	1392	15	<1
Smith	Westmoreland	RS	7/16/92	7.7	246	0	1.47	0.27	1.22	122	57	0
Brown	Fayette	RS	8/17/93	7.4	626	0	1.65	1.05	<0.50	1440	12	
Trees Mills	Westmoreland	PT	10/6/88	2.4	0	2,086	371.00	20.04	159.90	2409	26	8
State Line	Somerset	UB	4/29/96	8.1	210	0	<0.30	1.37	<0.5	416	<3	
Hager	Fayette	BC	7/12/95	6.9	189		0.21	0.40	0.07	68	1	4
Laurel Hill #1	Cambria	UF	1/6/97	8.1	484	0	0.97	1.98	1.04	590	34	0
Chanin	Fayette	LF	1/4/89	4.3	7	186	0.30	28.40	24.60	1152	8	
Morrison	Fayette	UK	6/22/89	7.0	308	0	0.63	3.49	<0.50	327	5	<1
Swisscambria	Cambria	LK	10/25/90	4.2	5	88	0.09	24.20	10.00	1070	36	
Albert #1	Clearfield	LK	1/30/89	3.1	0	1,335	186.00	111.00		3288	0	55
Snyder #1	Armstrong	LK	7/24/90	6.9	114	0	1.10	3.14		264	127	0
Lawrence	Fayette	LK	1/18/82	2.2	0	5,938	2,060	73.00	146.00	3600		0
Phillipsburg	Centre	CL	2/5/96	3.0	0	1,063	153.70	20.92		1796		900
Old 40	Clarion	CL	11/12/85	2.2	0	10,000	3,200	260.00	550.00	1400		well
Horseshoe	Cambria	MR	4/3/84	2.3	0	1,835	194.00	27.00	88.00	2510	0.2	700
Duryea Ditch	Lackawanna	N	11/1/85	5.9	90	2	35.20			464		11,670
Alden Strip #2	Luzerne	N	7/28/92	7.1	168	7	0.90	0.30	<0.50	628	22	
Jeddo Tunnel	Luzerne	EM	10/24/96	4.3	6	104	7.20	4.50	11.10	346	22	50,150
Oneida #3	Schuylkill	EM	12/30/96	4.7	9	26	0.10	0.30	1.10	22	<2	7,415
Packer V	Schuylkill	WM	7/29/97	6.4	160	0	20.90	7.80	0.10	597	30	1,200
Richards	Northumberland	WM	8/19/97	3.7	0	70	7.50	2.50	4.80	82	2	1,672
Scott Overflow	Columbia	WM	8/19/97	5.9	54	68	28.30	4.10	0.30	254	2	4,386
Goodspring #1	Schuylkill	S	9/27/95	6.2	66	0	15.20	2.50	<0.50	112	6	127
Goodspring #3	Schuylkill	S	9/27/95	6.0	54	32	22.20	3.40	<0.50	323	26	516
Markson	Schuylkill	S	9/27/95	3.4	0	82	18.30	5.60	1.60	491	4	844
Wadesville	Schuylkill	S	5/19/86	7.1	330	0	1.90	2.60	<0.50	1164	14	

There are 16 major discharges in the Eastern Middle Field. Mine drainage from two of these are shown in Table 2.1. There is no significant alkalinity in any of the discharges. As far as is known, there are no limestones or other calcareous strata in this region. No severe AMD (pH < 3.0, acidity > 1000 mg/L) is known in the Eastern Middle Field. The Eastern Middle Field appears to lack both calcareous rocks and high-sulfur rocks. The Jeddo Tunnel discharge, in the Eastern Middle Field, (Table 2.1), generally has an acidity concentration > 100 mg/L and a flow > 40,000 gpm. Though the acidity concentration is not "high", the acid load is large because of the high flow.

The water quality of the post-mining discharges of the Western Middle and Southern Anthracite Fields is somewhat more mysterious than that of the Northern and Eastern Middle Fields. Some discharges have significant alkalinity, but no carbonate stratigraphic units have been reported in these fields. The Packer V discharge in the Western Middle Field has alkalinity of 160 mg/L and iron of 20.9 mg/L (Table 2.1). The Richards discharge near Mt. Carmel has a pH of 3.7 and an acidity of 70 mg/L. Because some of these discharges drain large interconnected underground mines spanning square miles, various anthropogenic sources may also contribute to water quality. However the North Franklin and the Doutyville Tunnel discharges are located in a mostly rural area, and questions remain.

Several mine discharges of the Southern Anthracite Field have significant alkalinity concentrations, including the Wadesville, Eagle Hill, and Kaska discharges. For example, the water pumped from the Wadesville shaft has an alkalinity of 330 mg/L, in Table 2.1. This is one of the most alkaline mine waters found in Pennsylvania. It is almost certain that a detailed study of stratigraphy in this area would reveal calcareous strata or calcareous secondary mineralization. Several Southern Field discharges have significant acidity concentrations (Bell, Newkirk, Porter Tunnel and Markson discharge). Promisingly, a study by C.R. Wood (1996) shows that many abandoned underground mine discharges in the anthracite fields have improved in water quality between 1975 and 1991.

A final factor that may affect the relationships between post-mining water quality and stratigraphy in the Anthracite Region is the stratification of mine pool water. The mine pools consist of water accumulated in void spaces within abandoned underground mines, and deep pools or lakes in abandoned surface mines that are hydrologically connected to abandoned underground mines. These mine pools typically become chemically stratified into “top water” and “bottom water”. The stratification of anthracite mine pools is discussed in Barnes et al. (1964), Erickson et al. (1982) and Ladwig et al. (1984). Additional discussions on the areal extent and volume of impounded water in the mine pools are contained in a series of studies by Ash et al. (1949) and Ash (1954).

The top water discharges are typically of circumneutral pH, although some samples in Table 2.1 may have elevated iron, manganese or aluminum. Top water is believed to reflect shallow groundwater systems, with relatively short residence times, where most of the flow is confined to the upper part of the mine pool. The bottom water typically has higher concentrations of acidity, metals, and sulfate than the top water of the same mine pool. Bottom waters are indicative of longer residence times, less circulation (and less oxygen). For example, the Markson and Good Spring No. 1 mine pool discharge samples shown in Table 2.1 are from adjacent collieries within the Donaldson Syncline in the Southern Anthracite Field. The mine maps of these two collieries indicate that the coal seams mined, mining engineering factors, and geologic conditions of the collieries are essentially the same; yet the Good Spring No. 1 discharge has a pH of 6.2 (and sulfates of 112 mg/L) and the Markson discharge has a pH of 3.4 (and sulfates of 491 mg/L) (Table 2.1). The Good Spring No. 1 and Good Spring No. 3 discharges are top water and the Markson discharge is bottom water with a distinct hydrogen sulfide aroma. The samples of the Markson, and Good Spring No. 1 and Good Spring No. 3 mine pool discharges were collected on the same date in relatively low flow conditions and are within a few mg/L of the average sulfate values from five years of monthly samples.

Figure 2.18a depicts variations in the pH of mine discharges for the four anthracite fields. The Eastern Middle Field has the lowest median pH and the least variability in pH, consistent with an absence of carbonate strata. Figure 2.18b shows that the Eastern Middle Field discharges also have the lowest sulfate concentrations and the least variability in concentration. The other fields show a wider range in pH and sulfate, although the Southern Field typically has lower sulfate than the Northern and Western Middle Fields.

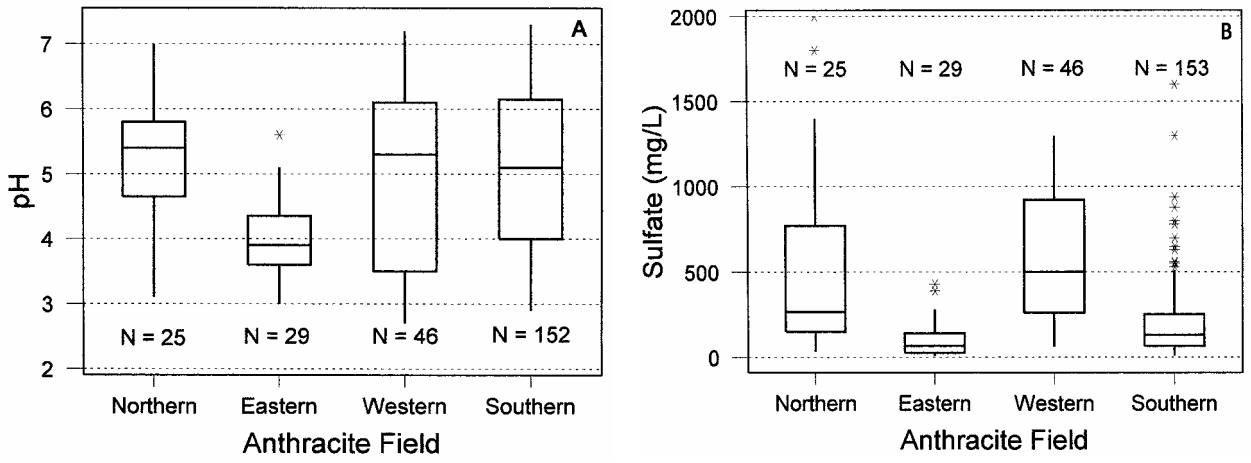


Figure 2.18 (a) and (b). Boxplots showing differences in pH and sulfates from the four anthracite fields in eastern PA (from Brady et al., 1998).

2.5 ANTHRACITE MINING

The Anthracite Region has been mined commercially from the late 1700s until the present. Anthracite mining peaked in 1917 (Fig. 2.19), and has declined significantly since then due to: 1) competition from cheaper and cleaner fuels; 2) labor disputes that disrupted supplies at critical times; 3) labor intensive mining methods; 4) depletion of more accessible coal beds; and 5) liability for water treatment and environmental concerns.

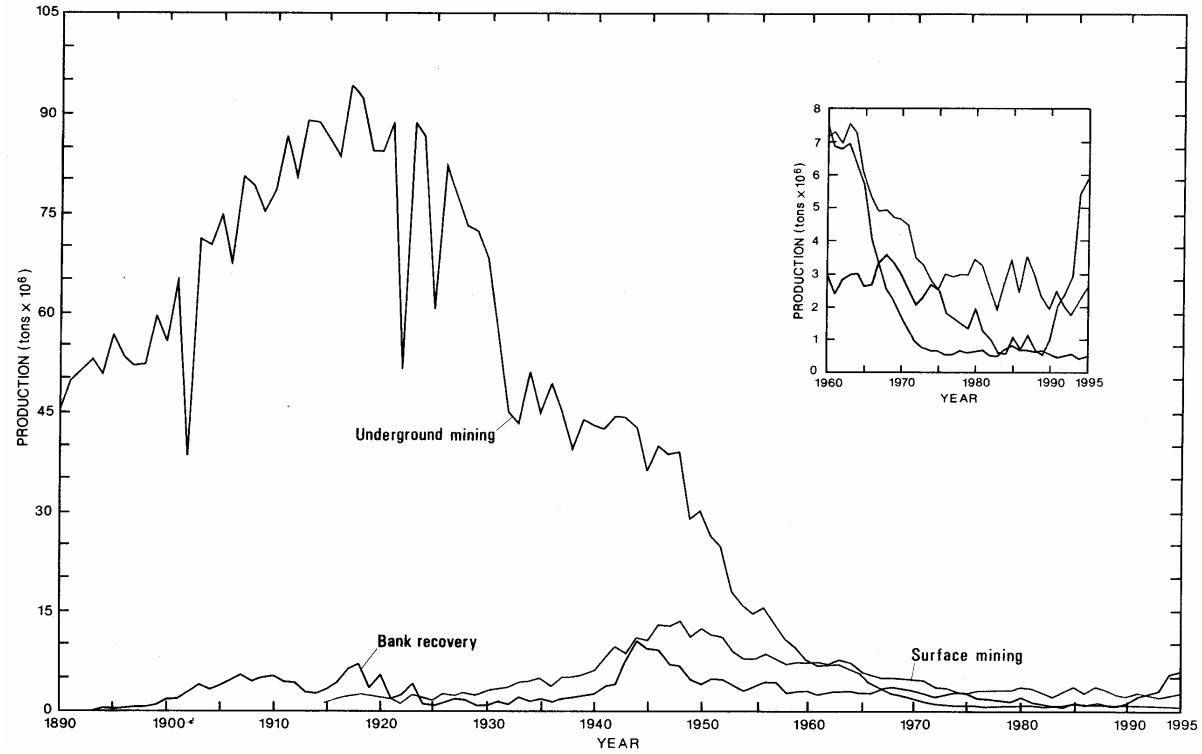


Figure 2.19. Anthracite production, 1890-1995 (from Eggleston, et al., 1999).

Anthracite production in 2001 was reported as 2,979,287 tons. Of this total amount, underground mining, once the dominant method for extraction, accounted for 154,111 tons, only 5 percent of Pennsylvania's total anthracite production, and surface mines produced 725,452 tons (Dodge and Edmunds, 2003). Eggleston et al. (1999) describe the process of underground mining anthracite coal in the following steps: 1) miners enter by a tunnel, slope, or shaft, 2) two horizontal headings are driven parallel to the strike of the coal bed from the shaft, 3) the upper heading, called the monkey, provides access to drill and blast upwards in the coal bed dip for distances of 200 to 300 feet (breast development), 4) coal then falls by gravity into coal cars in the lower heading, called the gangway, and 5) coal is hauled out through the gangway (Figure 2.20). The breast-and-pillar method just described is very labor intensive.

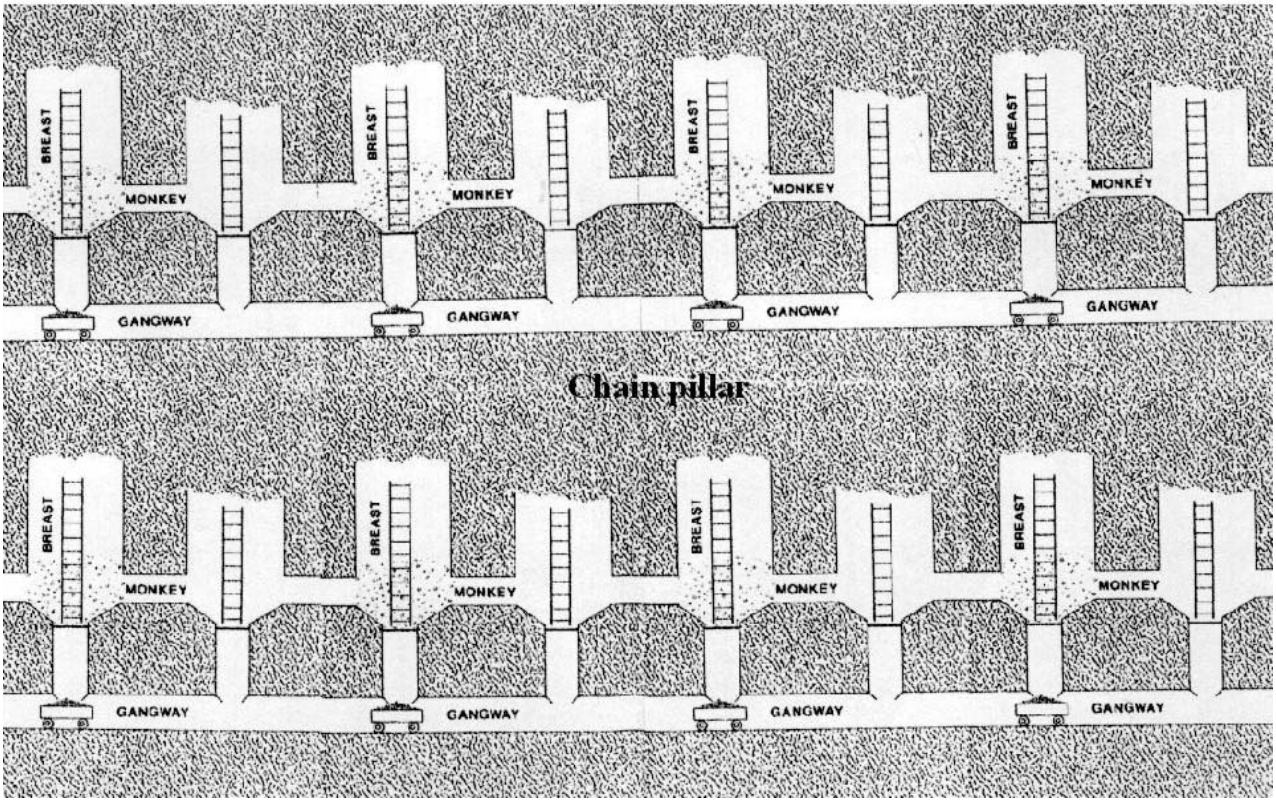


Figure 2.20. Typical anthracite underground mining practices (modified from Eggleston et al., 1999).

Neither surface mining nor bank recovery has surpassed the quantity of coal historically extracted by underground mining in the Anthracite Region of Pennsylvania. Surface mining dominated anthracite production in Pennsylvania between 1961 and 1991 (Eggleston et al., 1999). Bank recovery of coal silt and waste anthracite (culm) currently accounts for the largest percentage of anthracite production, 10,661,043 tons of coal extracted in 2001 (Dodge and Edmunds, 2003). Small (18 to 108 MW) co-generation plants have been constructed throughout the Anthracite Region in order to make use of this formerly discarded material (Inners et al., 1996). The culm-burning plants have provided a number of benefits to the region, including: 1) a reduction in AMD production from the culm, 2) reclamation of land, 3) a regional increase in jobs, and 4) an increase in the attractiveness of the landscape. Because many of these waste piles were created prior to SMCRA (1977), little money has been available to remove them.

2.6 SUMMARY

The geologic setting of the Anthracite and Bituminous Coal Fields of Pennsylvania provides a foundation for much of the subject matter in this book. Pennsylvania was blessed with abundant coal reserves. Along with this blessing, Pennsylvania was also bestowed with a curse of abundant abandoned mine land problems----including greater than 189,000 acres of abandoned, unreclaimed surface mines, more than 3,100 miles of stream polluted by acid mine drainage, and thousands of mine subsidence features, mine fires and other mine hazards. The physiography, geologic structure, stratigraphy and hydrogeology of the Anthracite and Bituminous Coal Regions are significantly different, but there are substantial similarities in the beneficial use of coal ash in these regions to reclaim abandoned mine lands and remediate acid mine drainage problems. The Anthracite Coal Fields have the most significant abandoned mine land reclamation problems due to the complexity of the geologic structure, the thickness of these coals, and the hydrology of the minepool systems. The Bituminous Coal Fields have the greatest number of acid mine drainage discharge problems and the most severe concentrations of acidity, iron and other parameters of the acidic drainage, due to the stratigraphy and depositional environments (i.e. greater sulfur contents) of these coals and overburden strata.

An attempt was made in the preceeding sections of this chapter to include sufficient information from the current scientific literature and older relevant references in order to provide an understanding of the geologic setting of the coal ash sites described in Chapters 4 through 9. The section on anthracite mining was included because most of the sites featured in these chapters are from the Anthracite Region, and an understanding of the underground mining methods is useful in relating the geology to the abandoned mine land reclamation problems. Additional information on the geology of the Anthracite and Bituminous Coal Regions of Pennsylvania is contained in two recent comprehensive publications: *The Geology of Pennsylvania* published by the Pennsylvania Geological Survey and the Pittsburgh Geological Society in 1999, and *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania* published in 1998 by Pennsylvania Department of Environmental Protection.

CHAPTER 3. ENGINEERING PRACTICES OF COAL ASH PLACEMENT

Thomas D. Owen, Lawrence L. LaBuz, John F. Beadle
David A. Williams, James D. Berger, Terry D. Killian

3.1 FUNDAMENTALS OF SOILS ENGINEERING

Soils engineering or geotechnical engineering focuses on assessment of a site from an engineering standpoint to determine essentially what can be built there or how the site can be used. Geotechnical engineering also provides various engineering methods and practices used in the actual design and construction of skyscrapers, dams, roads, and airports as well as homes, industrial facilities, and commercial buildings. In this regard, it is necessary to first investigate the site to determine what types of soils and bedrock exist, and estimate the strengths and other relevant properties of the earthen materials in the underlying "strata" (consisting of underlying layers of specific rocks and soil types in various potential conditions) for construction purposes. Some soils ("weak" soils) and rock types (carbonates) are not suitable for construction without potentially expensive modification or additional design requirements in regard to foundations. Once the site has been assessed, engineers can look at a variety of means to allow for construction including alternative foundation designs and/or importing off-site soils or coal ash to serve as fill and/or construction materials. The American Society for Testing Materials (ASTM, Standard Guide for Design and Construction of Coal Ash Structural Fills, E2277-03, 2003) references applicable Laboratory Test Procedures and Design Methods.

3.2 COAL ASH AND EARTHEN MATERIALS

Earthen materials are widely variable in physical and chemical properties and "in-place" strata conditions. Soil engineering methods have been developed that can be applied to coal ash as shown by decades of academic evaluation and practical experience in the Commonwealth of Pennsylvania. For purposes of engineering, uniformly placed coal ash can be considered as an artificial "soil" type that is usually more uniform than a natural soil layer. Additional testing is needed if different coal types, sources or burning processes may have generated the coal ash being evaluated, and also in the event of visible changes in natural soil types. For example, some coal fired boilers segregate lighter "fly ash" from the heavier "bottom ash" that falls to the bottom of the combustion unit during the combustion process. The physical properties of the segregated ash differ because of the different sizes and shapes of fly ash as compared to bottom ash. Therefore, the DEP regulations differentiate between several potential beneficial uses of the coal fly ash and bottom ash in 25 Pa. Code §287.665 (other beneficial uses of coal ash) because of the different properties. The pH of the coal ash is less important for foundation engineering purposes than the other mechanical properties of the coal ash, but is considered in the design process for any given usage per good engineering practice.

3.3 COAL ASH CLASSIFICATION

In general, coal ashes can be classified into coal source types (bituminous or anthracite), coal ash source (segregated or unsegregated fly and bottom ash), coal ash "gradation" (classification based upon the sizes of the ash particles), and other coal ash properties such as pH

(relative "acidity" or "alkalinity") relevant to the proposed usage. Engineering methods to determine gradation generally classify a soil or coal ash by the percentages of particles that can pass through standardized sieve opening sizes via comparison to a USDA Soil Triangle Classification Chart (Fig. 3.1)**.** Coal ash generally contains approximately 60 to 70 percent silt, and 30 to 40 percent sand size particles depending on the characteristics of the fuel burned by the plant (see Table 7.4 in Chapter 7). The coal ash classification is normally that of a silt loam. Other nationally recognized standard test methods then determine the properties of the coal ash relevant to the proposed engineering use or project as further described below. Continued testing is required for both soils and coal ash to ensure that the materials remain consistent with any required engineering specifications or design assumptions. For example, weathered coal ash may have lost the cementing ("pozzolanic") coal ash properties desired in some applications.

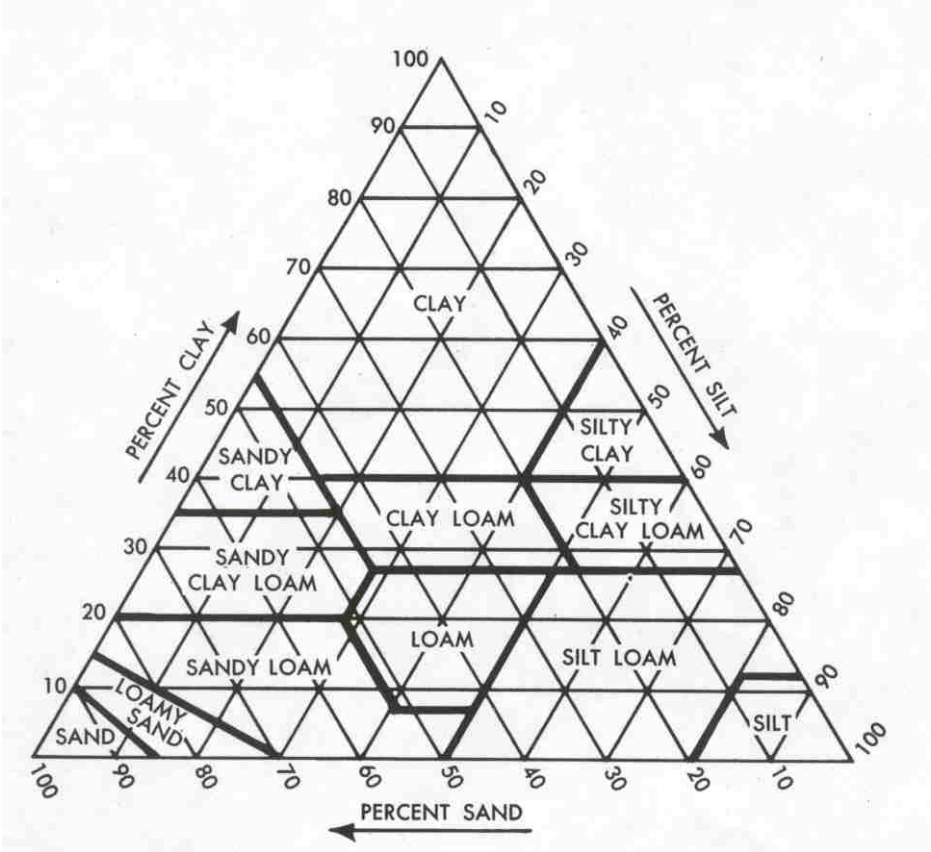


Figure 3.1. USDA Soil Triangle Classification Chart (The Asphalt Institute, 1978).

As mentioned in Chapters 1, 4, and 5, the DEP's Regulations and Permit Conditions require regular monitoring of coal ash physical properties for conventional ash placement. DEP's files contain a large amount of monitoring data, and periodically field checks are performed by DEP personnel, utilizing a Troxler nuclear moisture density gauge to determine accuracy and compliance of data submitted.

3.4 ENGINEERING TESTING AND EVALUATION

In coal ash monofills at both conventional ash disposal sites and demonstration ash sites, nationally recognized engineering standard tests are run and data is gathered. From this, an estimate of the ash's strength or bearing capacity can be made. The coal ash strength and bearing capacity sets the upper limit on potential building types, and other future uses.

Initially, if a certain ash is to be utilized, then a laboratory test must be run on the coal ash which is called a "Proctor Density Test" (either standard or most commonly the modified version). From this test, the theoretical Maximum Dry Density and the Optimum Moisture Content can be determined. Figure 3.2 illustrates a laboratory compaction test adapted from Bowles (1970).

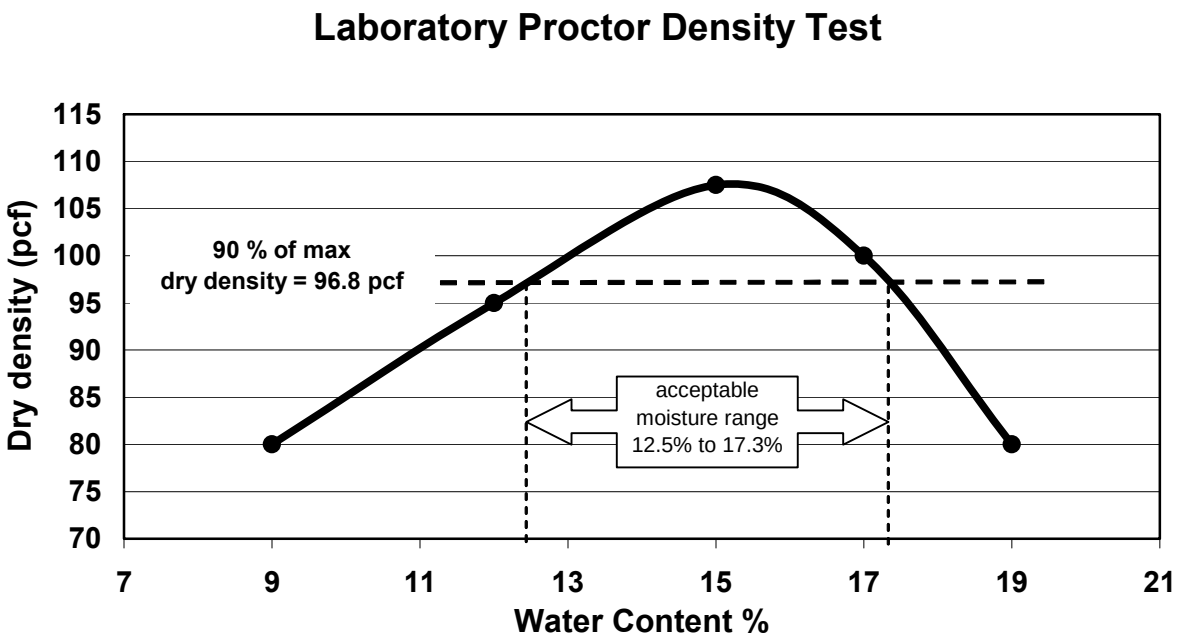


Figure 3.2. Typical display of compaction test data.

DEP requires that field compaction results achieve 90 percent of this laboratory maximum density of 107.5 pcf, in this example. By projecting a line through the curve at this point it is seen that, the acceptable moisture range needed in order to achieve the required compaction in the field is between 12.5 and 17.3 percent for the example in Figure 3.2. Therefore, the moisture content of the ash can be adjusted in order to place it on site within this moisture range**.** These numbers can then be used to ensure that the material is brought to the placement site at a moisture content which will allow adequate on-site compaction. In short, the test method usually shows a narrow range of density and optimum moisture for coal ash that has the desired engineering qualities for the proposed usage of the material**,** however the results can be different for fly ash and bottom ash. As can be seen on Figures 3.3a and 3.3b the maximum dry density was 75.9 lbs/cu.ft. for fly ash and 105.0 lbs/cu.ft. for bottom ash at the NEPCO site**.**

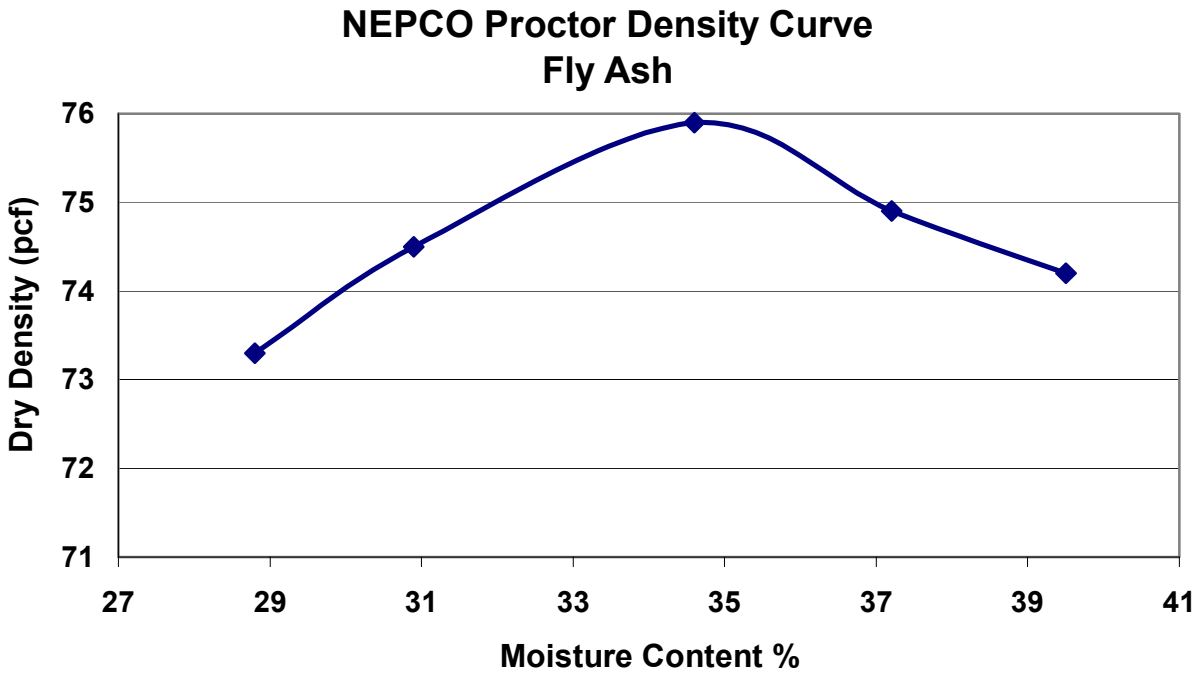


Figure 3.3(a). Plot of Proctor Density lab test results.

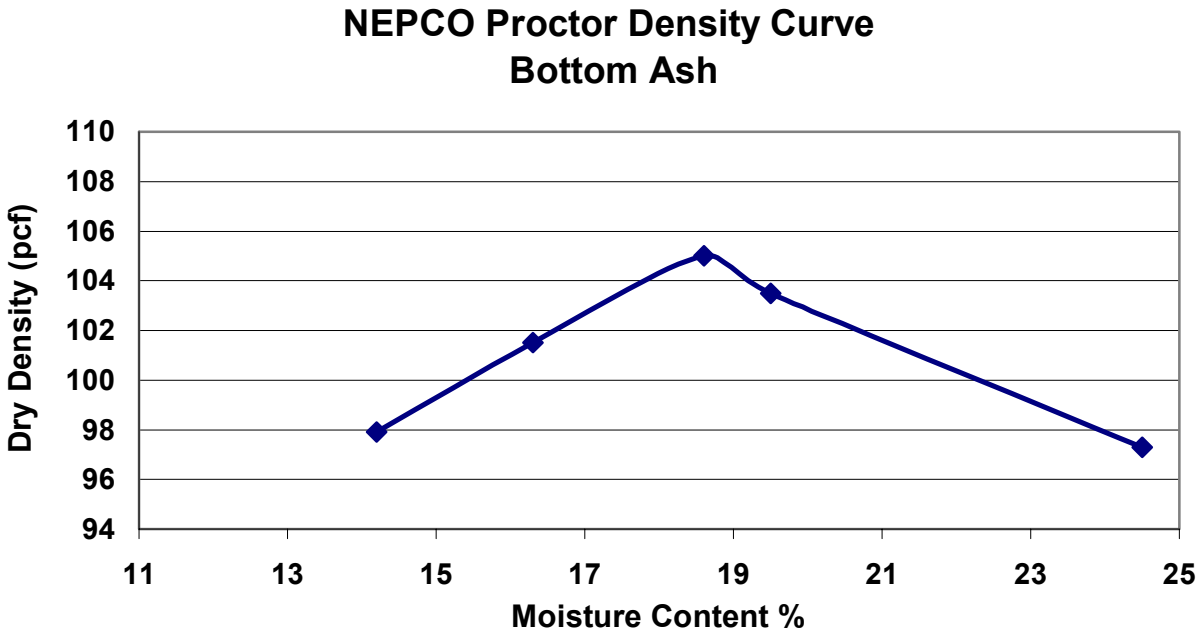


Figure 3.3b. Plot of Proctor Density lab test results.

An analysis of the maximum density, optimum moisture content, and field compaction test results for fly/bottom ash for four different ashes over time (Figs. 3.4a and 3.4b) indicates the maximum dry density varies from approximately 70 lbs/cu.ft. to 105 lbs./cu.ft. (mean value of 85 pcf), the optimum moisture content varies from approximately 16% to 38%, (mean value

of 25%) (Fig. 3.4c). Field compaction tests reveal that compaction percentages are almost always 90% or higher. Other engineering properties can often then be correlated to the same maximum range of dry density, compaction and optimum moisture due to the uniformity of the coal ash materials.

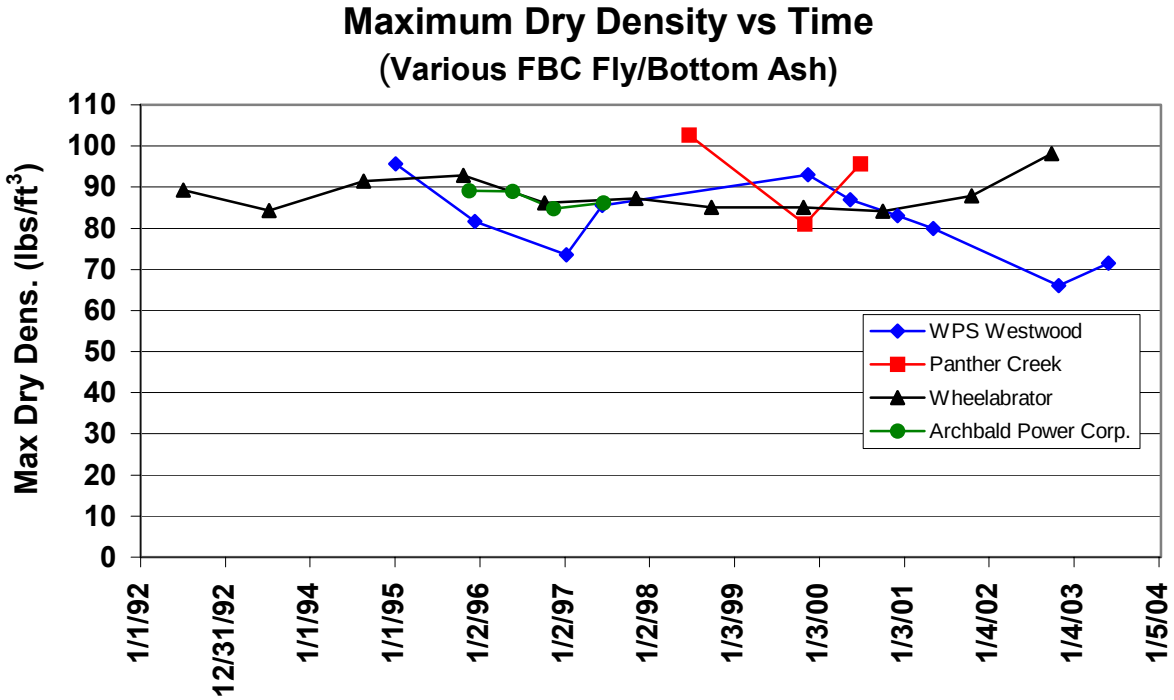


Figure 3.4(a). Plot of Maximum Dry Density.

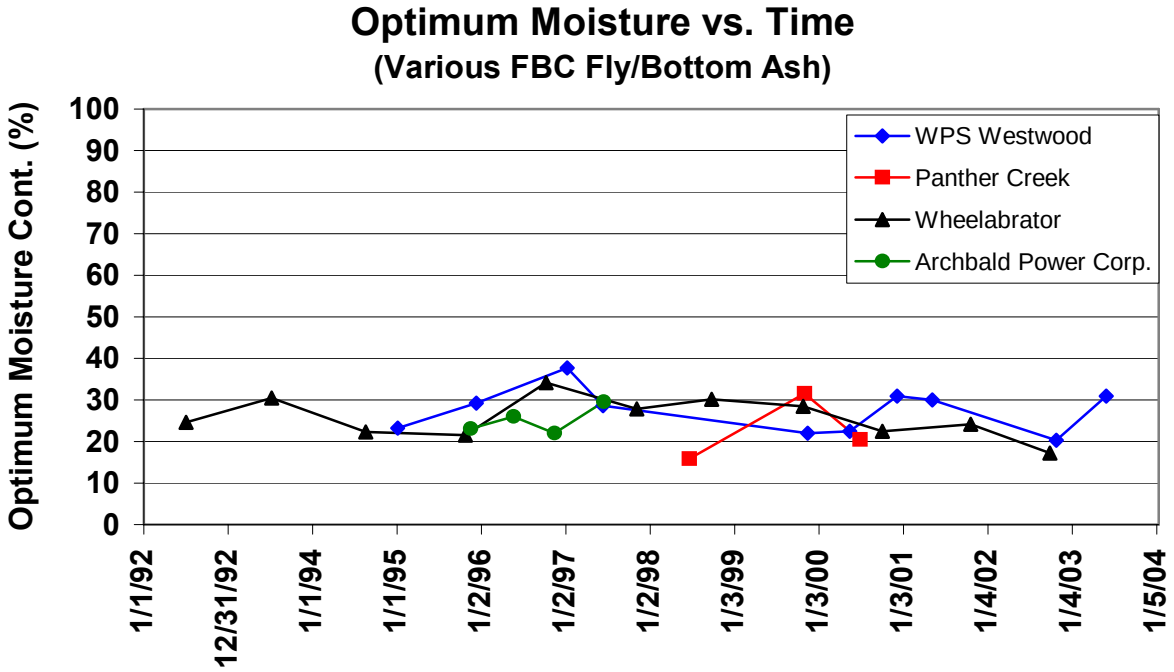


Figure 3.4(b). Plot of Optimum Moisture Content.

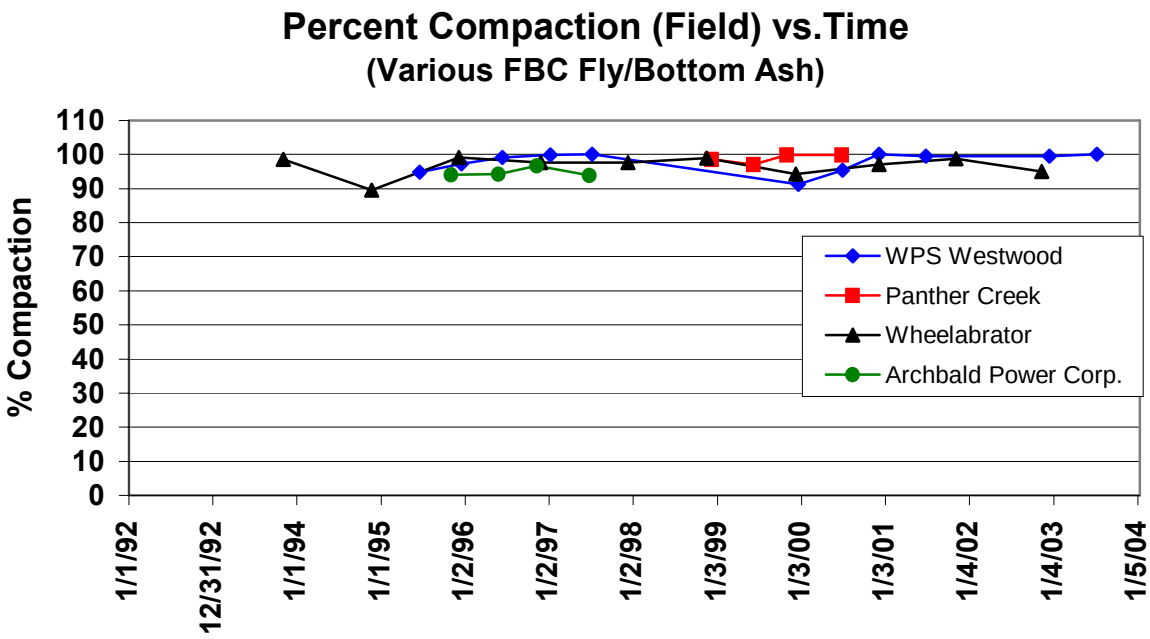


Figure 3.4(c). Field compaction tests of ash from various ash sources.

3.4.1. Compaction

The maximum dry density is that point where there is little potential for additional compaction. Therefore, long-term settlement of the coal ash is minimized if the coal ash is already near or at maximum density. Minimizing settlement avoids potential stresses on future buildings or other structures that might require eventual repairs.

3.4.2 Permeability

When coal ash is used as a construction material for sub-base at a coal ash landfill, the coal ash can be tested for permeability at different densities and moisture contents to determine a range where the desired landfill sub-base permeability requirements are met (see 25 Pa. Code §288.533(b)(ii)). By correlating the permeability to the coal ash density, optimum moisture content, and compaction, the engineer can reduce potential additional testing costs because the simpler and less expensive Troxler nuclear moisture density gauge tests can then be used to verify whether the material meets the permeability requirement.

3.4.3 Slope Stability

The “internal angle of friction” of the coal ash is obtained by testing at the proposed moisture content, density and compaction. The internal angle of friction sets a limitation for potential stable slopes of coal ash or other materials for purposes of retaining adequate stability. This can be an important consideration for non-reclamation projects.

After the ash is spread and compacted, field density tests can be performed with a nuclear densometer or other test method to determine or verify that the ash fill is meeting the 90% requirement. Results of these tests are summarized in a report from a certified testing laboratory. **(**see Table 3.1)

Table 3.1. Field Density Test Data at Panther Creek Energy.

Date	Optimum Moisture	Maximum Dry Density	Percent Compaction (field)
12/10/98			98.5
6/08/99			97
11/02/99	31.6	81	99.8
6/27/00			99.8

Occasionally direct readings are taken with a hand held pocket penetrometer (Sowers and Sowers, 1970), which gives a rough estimate of the bearing capacity of the material at the surface (e.g. in tons/square foot). This type of testing is primarily useful as a spot check for the surface layer of the placed ash. It must be supplemented with the Troxler nuclear moisture density gauge or other test methods giving results that are accurate for below the exposed surface of the coal ash.

Finally, in some cases, and for the demonstration permit sites, Soil Boring Tests are performed which utilize a split-spoon for sampling at depth intervals (usually 5 feet) and Standard Penetration Tests (U.S. Department of the Interior, Bureau of Reclamation, 1974) are performed at these same intervals which measure the number of times (i.e. the blow count) it takes to drive the spoon through a specified vertical interval with a standard weight hammer and drop distance on the drill rig (i.e. the "blow"), (ASTM Standard Penetration Test – ASTM D 1586-2003). From these numbers, the engineer can use technical literature (Tschebotarioff, 1974) in order to "ball park" estimate the "in-place" bearing capacity of the material at depth and can make recommendations as to design of footing foundations for structures, etc. (Table 3.2a and Table 3.2b and Table 3.3 Soil Boring Logs, and Figures 3.5 and 3.6 Location Maps). The two locations of the split-spoon sampling tests (TB-1 and TB-2) are shown on Figure 3.5 and the bearing capacity test locations which are identified as "x" on Figure 3.5 are quantified in Table 3.6. The Standard Penetration Test is a "qualitative" test method with potential for field errors that should not be used for any critical design without cross-checking by means of a different "quantitative" (more numerically precise and accurate) test method such as a plate loading test. While this is a widely used test method, there is no generally accepted conversion between "blow counts" (i.e. "N" value for the number of blows per foot of penetration) to bearing capacity for a soil although some technical sources have provided tables correlating the "blows per foot" for different soil classification (sand, silt, clay) and/or cohesionless versus cohesive soils for relative density (loose, medium, dense, very dense) and/or consistency (very soft, soft, firm, stiff, very stiff, hard). Other sources have provided empirical equations for estimating maximum allowable bearing capacity which may be utilized in less critical design situations. The available Standard Penetration Test data from the demonstration projects shows the uniformity of the placed coal

ash whereas natural soils tend to increase in density and compaction the deeper the strata is located under the surface level. It is interesting to note that the laboratory "California Bearing Ratio" test (CBR) is based upon similar logic and is often used to design pavements (The Asphalt Institute, 1978).

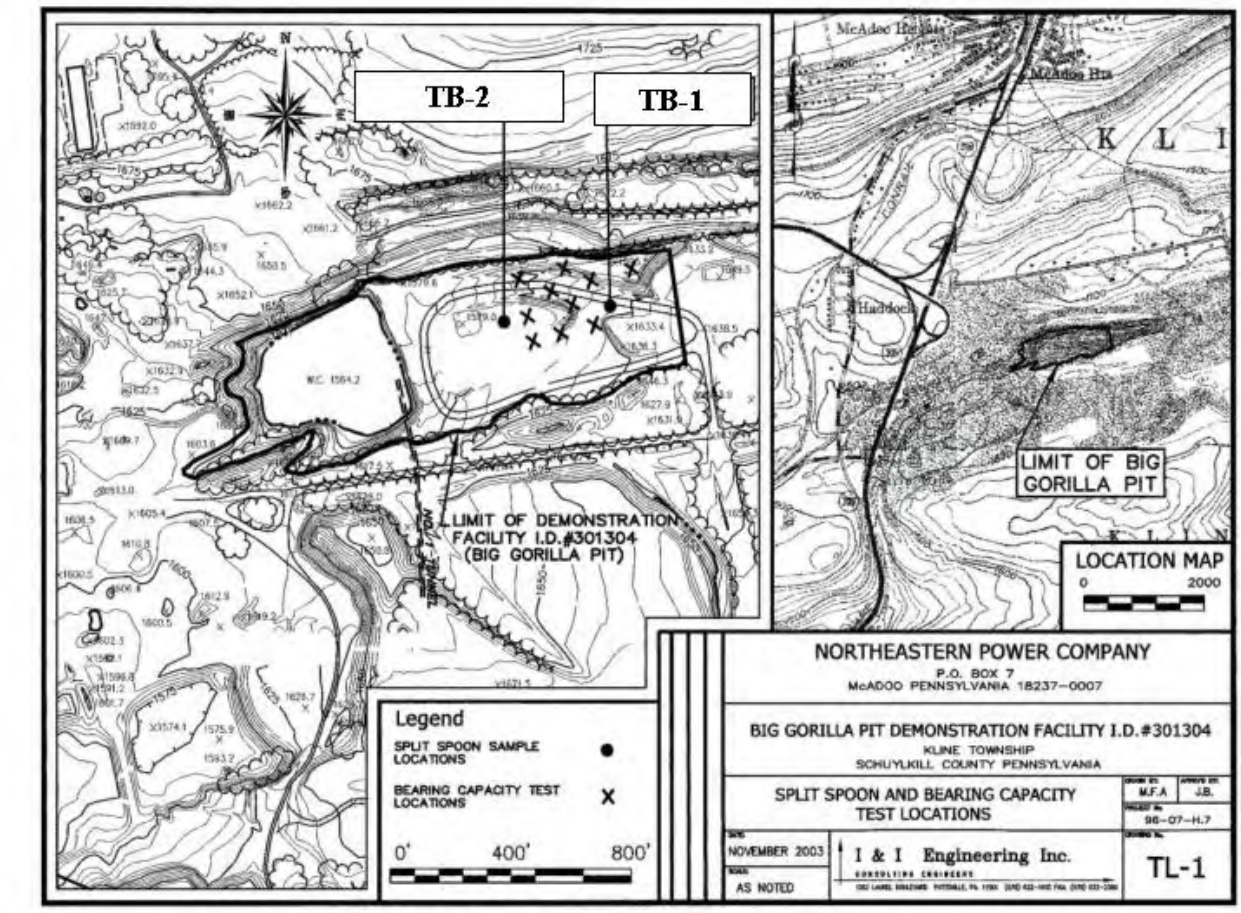


Figure 3.5. Map of NEPCO site showing Big Gorilla Pit.

Table 3.2(a). Soil boring logs from NEPCO site TB-1.

	Depth (ft) From-To	Sample No.	Recovery	Recovery	Blows / 6"	Blows / 6"	Blows / 6"	Blows / 6"
			Feet	%	0/6	6/12	12/18	18/24
7/16/2003	0-2	S-1	1.42	70.8	9	22	21	18
	5-7	S-2	0.58	29.2	2	2	1	2
	10-12	S-3	1.17	58.3	1	2	2	5
	15-17	S-4	0.67	33.3	8	7	4	3
	20-22	S-5	1.50	75.0	4	5	2	2
	25-27	S-6	1.25	62.5	8	11	10	9
	30-32	S-7	1.75	87.5	2	5	4	3
	35-37	S-8	1.42	70.8	6	6	2	2
7/17/2003	40-42	S-9	0.83	41.7	10	11	10	10
	45-47	S-10	1.25	62.5	10	11	7	11
	50-52	S-11	0.92	45.8	11	13	12	18
	55-57	S-12	1.25	62.5	18	13	18	21
	60-62	S-13	1.08	54.2	19	23	21	21
	65-67	S-14	1.00	50.0	18	14	18	16
	70-72	S-15	0.75	37.5	19	22	17	17
	75-77	S-16	0.83	41.7	10	12	13	15
	80-82	S-17	1.25	62.5	11	13	12	12
	85-87	S-18	1.42	70.8	7	8	8	12
	90-92	S-19	1.42	70.8	6	6	13	21
	92-94	S-20	1.00	50.0	16	23	19	20

Table 3.2(b). Test boring logs from NEPCO site TB-2.

	Depth (ft) From-To	Sample No.	Recovery	Recovery	Blows / 6"	Blows / 6"	Blows / 6"	Blows / 6"
			Feet	%	0/6	6/12	12/18	18/24
7/18/2003	0-2	S-1	1.67	83.3	7	9	10	14
	5-7	S-2	0.58	29.2	4	3	3	3
	10-12	S-3	1.00	50.0	2	1	1	2
	15-17	S-4	1.67	83.3	4	5	4	6
	20-22	S-5	1.58	79.2	6	3	2	2
	25-27	S-6	1.33	66.7	2	1	1	2
	30-32	S-7	1.25	62.5	4	3	1	5
	35-37	S-8	1.67	83.3	3	3	4	3
	40-42	S-9	0.75	37.5	11	6	8	6
	45-47	S-10	1.42	70.8	5	2	1	4
	50-52	S-11	1.83	91.7	3	1	1	2
	63-65	S-12	1.67	83.3	1	1	1	1
	65-67	S-13	1.83	91.7	1	1	1	1
	70-72	S-14	1.92	95.8	1	*	*	*
	84-87.5	S-15	2.25	64.3	*	*	*	*
	90-92	S-16	2.00	100.0	1	1	*	*
	100-102	S-17	1.92	95.8	2	2	2	2
	105-107	S-18	2.00	100.0	3	3	4	4

3.5 CONVENTIONAL ASH PLACEMENT

The disposal of coal ash in Pennsylvania is regulated under the Commonwealth's Residual Waste Regulations (25 Pa. Code Chapters 287 - 299). Permits are required to build, operate, expand, and close coal ash landfills and surface disposal impoundments. Permitted facilities must have an operating plan that contains procedures for the inspection and monitoring of incoming ash, the placement and compaction of the ash, the placement of cover materials and revegetation.

Although new coal ash disposal facilities are subject to the same design and operating standards as all other residual waste disposal facilities in Pennsylvania, the regulations contain specific standards and criteria addressing the beneficial use of coal ash.

In 1986, the Pennsylvania Solid Waste Management Act was amended to exclude coal ash that is beneficially used from the definition of "solid waste." Specifically, the definition excludes "fly ash, bottom ash or boiler slag resulting from the combustion of coal, that is or has been beneficially used, reused, or reclaimed for a commercial, industrial or governmental purpose".

The Act also gave the DEP the authority to establish standards and criteria for the beneficial use of coal ash. The amendment was subsequently implemented through the residual waste regulations. Provisions for the Beneficial Use of Coal Ash are found in 25 Pa. Code Section 287.661-666.

The regulations contain specific standards and criteria for three general categories of use:

- Structural Fill
- Soil Substitute and Amendment, and
- Mine Reclamation

The beneficial use of coal ash as structural fill is addressed in Chapter 287.661. The regulations require prior notification and submission of information on ash quality and site conditions for proposed structural fill applications. The notice must also contain construction plans prepared by a registered professional engineer and landowner consent. Coal ash may be beneficially used as a structural fill, as long as the proposed site meets environmental siting restrictions (e.g., separation from streams, groundwater, wetlands, etc.), the ash is spread uniformly and compacted in layers not exceeding two feet, and covered with a minimum of twelve inches of soil. An Erosion and Sedimentation Control Plan must also be developed for the project and approved by the local Soil Conservation District.

The beneficial use of coal ash as soil substitute or soil additive is addressed in 25 Pa.Code Sections 287.662 to 287.664 and Chapter 10 of this book. The use of coal ash as a soil substitute or soil additive is important at mine sites which often lack suitable quantities of cover soils. However, coal ash can only be used for this purpose if the constituent loading rate does not exceed the loading rate that would cause a pollution incident. In addition, for the use as a liming agent (soil additive use) the coal ash must also have at least a 10% calcium carbonate equivalency.

Table 3.3 Soil Boring Logs from Knickerbocker Site.

Reading Anthracite Test Boring Report - Cell 5-1				
	Blows / 6"	Blows / 6"	Blows / 6"	Blows / 6"
Depth (ft) From-To	0/6	6/12	12/18	18/24
0-2	2	3	4	5
2-4	12	12	10	11
4-6	9	10	9	10
6-8	10	12	15	16
8-10	13	11	12	14
10-12	10	11	11	11
12-14	12	11	12	14
14-16	12	11	10	11
16-18	10	10	10	11
18-20	11	11	10	11
20-22	9	12	13	12
22-24	12	13	11	10
24-26	10	11	10	9
26-28	9	9	8	6
28-30	7	8	6	7
30-32	7	5	6	7
32-34	5	6	7	4
34-36	8	8	8	6
36-38	5	6	5	5
38-40	5	6	4	5
40-42	3	2	2	3
42-44	3	4	4	3
44-46	4	2	3	3
46-48	4	3	5	4
48-50	4	5	5	5
50-52	1	2	1	1
52-54	2	3	2	3
54-56	2	1	3	4
56-58	4	5	4	7
58-60	8	9	9	10

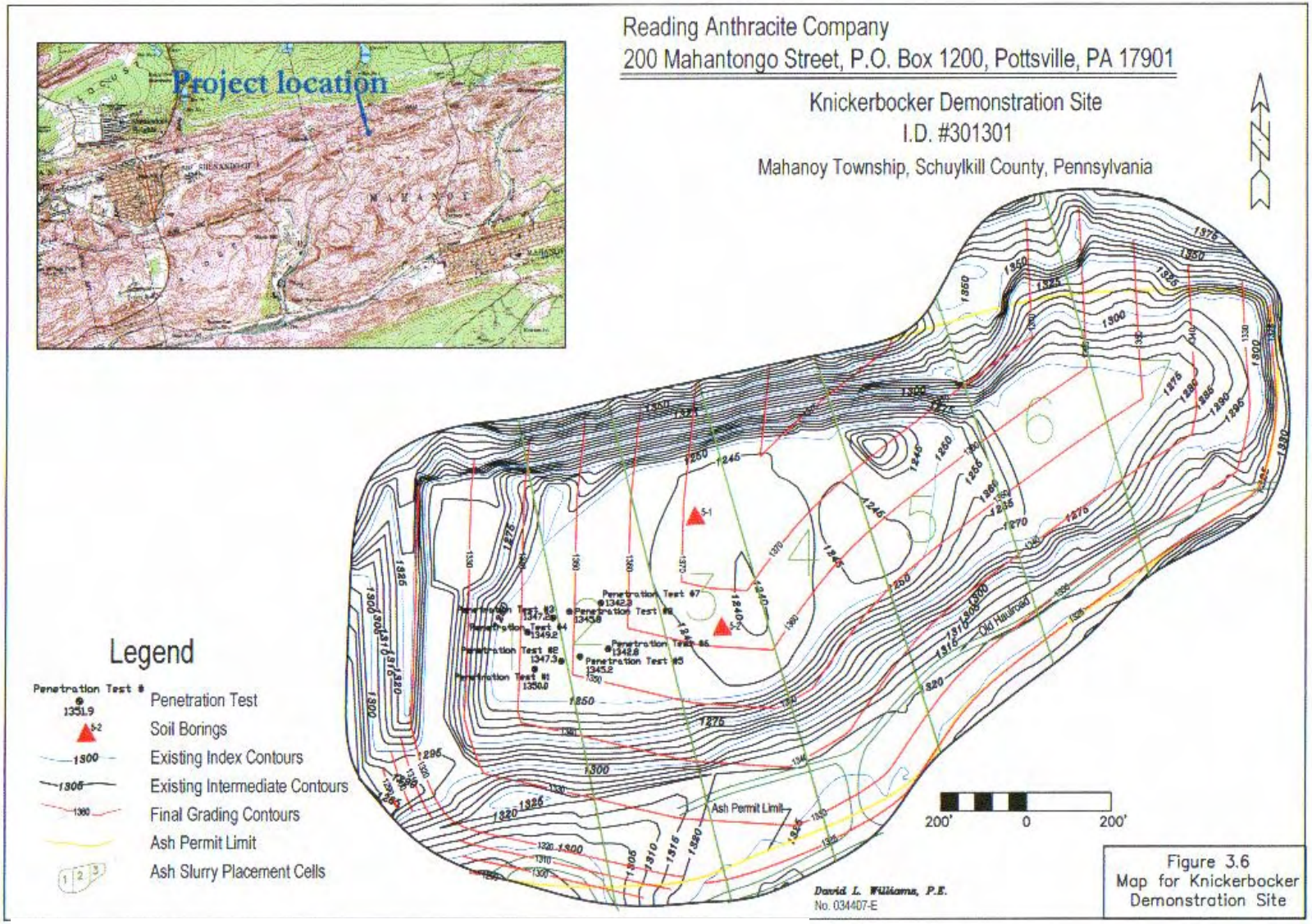


Figure 3.6. Map of Reading Anthracite Co., Knickerbocker Site.

The beneficial use of coal ash for mine reclamation is addressed in Sections 287.663-664 and subject to the requirements outlined in Table 3.4 Coal Ash Special Conditions. Coal ash may be beneficially used at active coal mine sites and abandoned mine sites to improve water quality or prevent degradation. In addition, coal ash is capable of eliminating public health and safety hazards at mine sites. Basically, the ash must be placed in allowable areas, spread and compacted in two foot lifts, covered with four feet of suitable material and graded to a 3% minimum final slope. On-site field densities are required during construction of the fill as mentioned in Section 3.4 to ensure a controlled, engineered fill.

Table 3.4. Key Items of Coal Ash Special Conditions used in DEP Permits.

KEY ITEMS OF COAL ASH SPECIAL CONDITIONS

- Grade the disposal area to create a stable base.
- Keep the coal ash disposal area free of standing, running, or impounded water at all times.
- All coal ash must be within the acceptable moisture content range in order to achieve a minimum compaction of 90% of the maximum dry density.
- Coal ash is not to be deposited within eight feet of any coal outcrop, vein or seam, pit floor, high wall, low wall or highest regional groundwater elevation.
- Complete chemical analysis and leachate analysis of the coal ash shall be conducted on a semiannual basis.
- Modified Proctor or Standard Proctor tests of each separate source of coal ash to be disposed shall be conducted on a semiannual basis, to determine the optimum moisture content and the acceptable moisture range needed to achieve a minimum compaction of 90% of the maximum dry density as determined by the Modified Proctor Test or 95% of the maximum dry density as determined by the Standard Proctor Test.
- Approved monitoring points shall be analyzed on a quarterly basis for Coal Ash Groundwater Quality Parameters.
- The final cover layer on the coal ash disposal area shall be a minimum of four feet.
- Field density tests (minimum of one test per acre of active coal ash disposal areas) shall be conducted to insure that proper field compaction is being achieved within the disposal area.
- All coal ash conveyed or hauled to the coal ash disposal area must be spread and compacted in lifts of two feet or less.

Finally, the regulations address a variety of uses that are deemed to be beneficial and do not require a permit from DEP as long as the requirements accompanying the specified use are met. Uses in this section include the replacement of cement in concrete, the use of bottom ash for anti-skid and construction aggregate (Fig. 3.7), and the use of fly ash as a stabilized product.

3.6 STABILIZATION OF FLY ASH WITH LIME OR CEMENT

Fly ash stabilized with lime or cement can be beneficially used to safely and economically replace conventional materials such as soils and aggregates in many construction applications. For example, PPL Generation, LLC developed a lime-stabilized fly ash product which consists of moisture-conditioned fly ash from PPL's pulverized coal-fired power plants that has been stabilized with a minimum of one percent hydrated lime. This has been beneficially used to construct foundations for commercial/industrial buildings; embankments for highways and airport runways; athletic fields and recreational facilities; and many other applications requiring a compacted fill material. It is often preferred over natural soils due to its low unit weight, relatively high compressive strength, ease of handling, and availability in bulk quantities.

The beneficial use of fly ash as a stabilized product is authorized under 25 Pa. Code §287.665(b)(3) of the residual waste regulations. Specifically, the person or municipality proposing the use must give advance written notice to the DEP, the ash cannot be mixed with solid waste, and the use must result in a demonstrated reduction of the potential of the coal ash to leach constituents into the environment.

PPL conducted studies on its fly ash documenting that the addition of a minimum of one percent hydrated lime results in a significant improvement in leachate quality. Representative samples of fly ash were split and amended with increasing amounts of hydrated lime, in one-half percent increments. Samples were extracted using the Synthetic Precipitation Leaching Procedure (SPLP) for leachate analysis (USEPA, 1998). The effect of lime addition on the leachability of minor and trace constituents in fly ash is shown in Figures 3.8 and 3.9.

The concentration of a few constituents, such as barium and selenium, increased at higher lime additions. However, concentrations are well within limits that the DEP has established as acceptable for mine reclamation and placement in natural attenuation landfills.

Since fly ash is a pozzolan, the addition of hydrated lime also improves the physical properties of the material making it more attractive than traditional soil-based fill materials. Pozzolans are siliceous and aluminous materials which, when mixed with lime and water, form cementitious compounds at ordinary temperatures. Figure 3.10 shows that the long-term unconfined compressive strength of the material (i.e. lime added to fly ash) is about twice that of unstabilized fly ash, and four times greater than ordinary soils.



Figure 3.7. Coal ash conveyor at left of photo delivers ash from Gilberton Power Company FBC plant to mineral processing equipment shown in center of photo to produce an aggregate which meets PA Department of Transportation specifications.

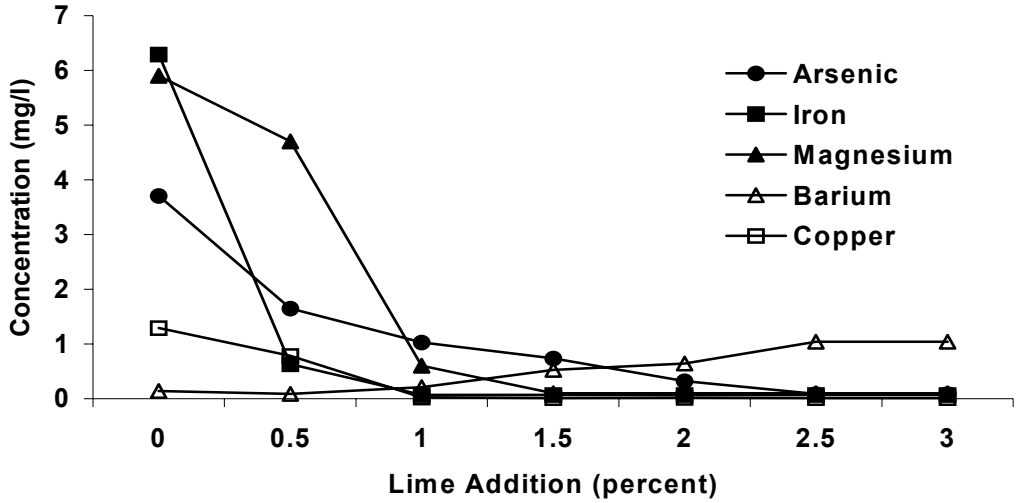


Figure 3.8. Effect of Lime addition on leachability of minor constituents and trace constituents.

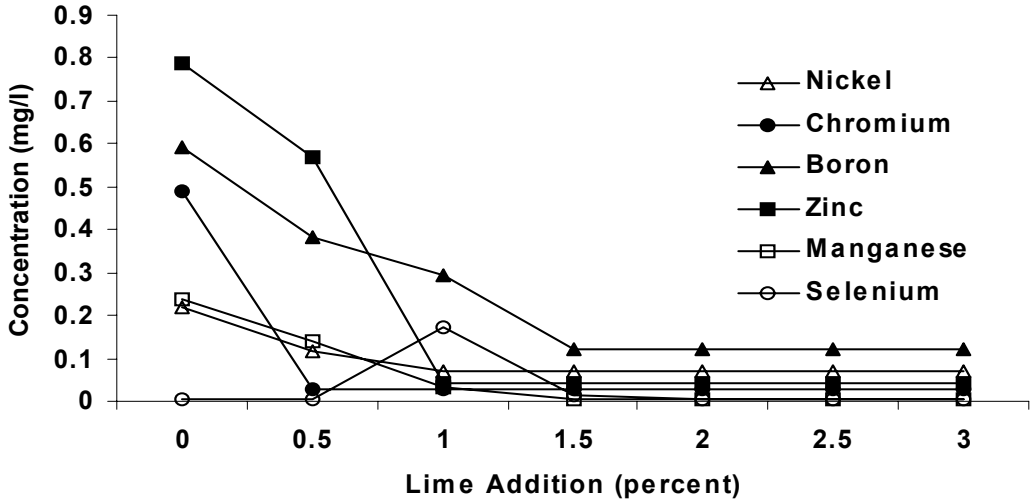


Figure 3.9. Effect of lime addition on leachability of minor constituents and trace constituents.

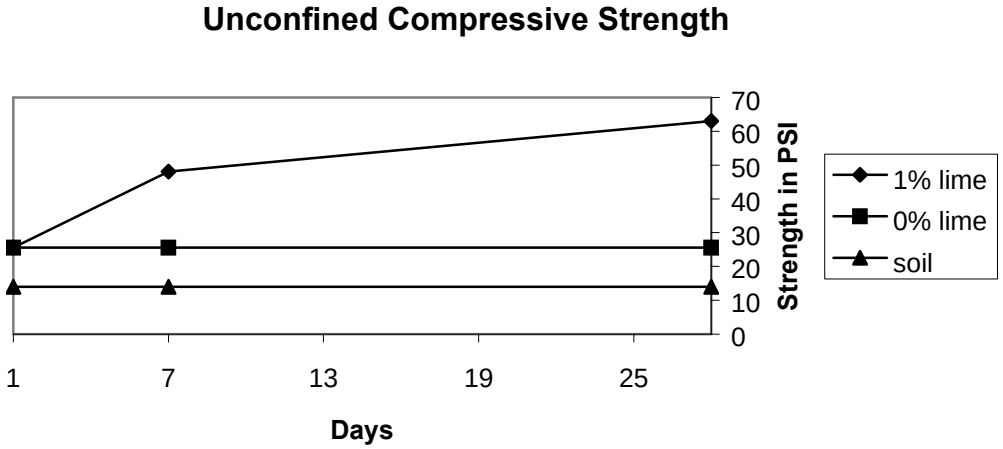


Figure 3.10. Effect of lime addition on compressive strength.

Table 3.5 compares other physical properties to unstabilized fly ash and conventional backfill materials. The loose and compacted unit weights are significantly lower than soil and clay, which is attractive in most fill applications where lighter materials are desired. The California Bearing Ratio (CBR) is a test used to estimate the bearing value of sub-bases and sub-grades. The CBR of coal ash is also significantly better than soil. Despite the formation of cementitious materials, it is still free draining. Permeability tests show that it has a hydraulic conductivity on the order of 10^{-5} cm/sec., comparable to fine-grained sand/silt.

Table 3.5. Comparison of physical properties of coal ash, sand and clay.

	Loose Unit Weight (pcf)	Compacted Unit Weight (pcf)	CBR (%)	Hydraulic Conductivity (cm/sec)
0 % Lime (ash)	45.3	88.5	0.6	3.5 E-05
1 % Lime (ash)	45.4	87.5	98	3.9 E-05
Sand	90	120	30	1.0 E-03 - E-05
Clay	75	105	5	<1.0 E-07

3.7 ENGINEERING PROPERTIES/ANALYSIS OF DATA

Analysis of the field density tests taken at conventional ash disposal sites has shown that their compaction consistently meets 90% or greater of the modified proctor densities with minimal compactive effort (i.e. dozers, trucks, etc) without the need for the usual steel drum, rubber tire, or sheeps foot roller equipment**.** This means that use of this extra equipment and labor are not routinely needed to achieve the required compaction and density for most sites. There may be some sites, however where compaction equipment may be needed.

At the demonstration permit sites, the soil penetrometer results consistently met or exceeded 3.0 tons/square foot (tsf) and commonly **"**maxed out**"** on the penetrometer gauge at 5.0 tsf, which more than satisfies the accepted minimum standard of 2.0 tsf listed in the permit. Available data from other test methods were compared to the penetrometer test results, and appear to support the high bearing capacities. The penetration results on the soil boring logs showed a sufficient value of "Blows/Foot" to adequately support a spread footing foundation at a design parameter of 2.0 tsf. Other test data from Scheetz (2001), shown in Table 3.6 below also support the high bearing capacity estimates.

Table 3.6. Bearing capacity results for NEPCO.

Plate Loading Test Results for Bearing Capacity at NEPCO						
Test #	0-6	6-12	12-18	18-24	Bearing Capacity	Location
1	15	53	50/2"		4,000 PSF +	see Figure 3.5
2	13	50/5"			4,000 PSF +	see Figure 3.5
3	15	43	50/4"		4,000 PSF +	see Figure 3.5
4	16	51	50/2"		4,000 PSF +	see Figure 3.5
5	17	59	50/2"		4,000 PSF +	see Figure 3.5
6	16	50/4"			4,000 PSF +	see Figure 3.5
7	15	50/5"			4,000 PSF +	see Figure 3.5
8	18	53	50/1"		4,000 PSF +	see Figure 3.5
9	14	48	50/2"		4,000 PSF +	see Figure 3.5
10	13	47	50/3"		4,000 PSF +	see Figure 3.5

In summary, the ash fills, whether at conventional or demonstration sites are more than suitable for construction purposes for residential or commercial buildings, roads, and most other

engineering applications, with perhaps the exception of “super-structures” such as heavy bridges or tall buildings, but even these uses could be investigated on a case by case basis.

3.8 INNOVATIVE ASH PLACEMENT PROJECTS

Ash has been utilized in other cases either with or without additives such as cement or cement kiln dust in a slurry form to fill in mine voids, narrow crop falls, etc. where equipment access is a problem.

Flowable fill is defined by the American Concrete Institute Committee as "controlled low-strength material" (ACI Committee 229). Flowable fill is produced by mixing fly ash and a small amount of cement, hydrated lime or other binder material with water to a flowable consistency. Since fly ash is a pozzolan, it reacts with calcium hydroxide and water to form cementitous compounds. Flowable fill is virtually self-leveling with the consistency of pancake batter. It can be placed by pouring or pumping at a high slump (7 to 10 inches) and does not require vibration for consolidation. As a slurry, the material flows into place, filling small voids and uneven spaces. The mixture sets-up and hardens in a relatively short period of time and develops strengths similar to or greater than that of surrounding soils.

The use of a stabilized fly ash flowable fill to reclaim inaccessible mine openings was successfully demonstrated in November, 1993 at a vertical mine opening near Harwood, Pennsylvania (Mackow and Van Ness, 1994). The opening was located close to a ballfield and despite the presence of hazardous mine subsidence warning signs, there was evidence that children played near, and perhaps even in the mine opening. The filling operation took a total of five days and 500 cubic yards of flowable fill to plug the entrance of the mine opening. The flowable fill mix consisted of 2.5% hydrated lime, moisture-conditioned fly ash from PPL's Montour Steam Electric Station and water.

PPL has also partnered with the DEP to reclaim some "crop falls" in the anthracite coal fields. Crop falls occur where steeply pitching anthracite coal seams outcrop at the surface. Underground mining progressed up the rise in the coal to near the surface. After years of weathering the coal at the outcrop "fell" into the underground mine sometimes to a depth of 600-feet. Crop falls can extend for miles along the side of the mountains. Lime-stabilized fly ash from Montour Station was used as bulk fill in these projects

DEP has found these types of uses to be successful and continues to look at other possible uses within the same realm. Please note that the use of non-coal ash “waste” additives may require some form of explicit DEP approval as not all sources of cement kiln dust (CKD) or other waste additives may have been approved for the particular type of potential beneficial use involved. This is described in more detail in Chapter 6. Portland cement is not a waste additive and does not require DEP approval.

CHAPTER 4. COAL ASH BENEFICIAL USE (CONVENTIONAL ASH PLACEMENT) ON ANTHRACITE MINE SITES

Roger J. Hornberger, Sharon A. Hill, Michael J. Menghini, Thomas D. Owen, Daniel J. Koury

4.1 INTRODUCTION

The spatial distribution of permitted beneficial use coal ash sites in the Anthracite Region is closely related to several key aspects of the mining history of the region. One hundred and five years of anthracite coal production (1890 – 1995) is shown in Figure 2.19 (from Eggleston, et al. 1999), wherein underground mining accounted for most of the coal production prior to 1950, and surface mine production increased steadily from the 1920's and surpassed deep mining by around 1960.

Underground mining in the Anthracite Region started out small in the late 1700's, but by 1850, there were 1000-foot deep shafts and extensive lateral development of gangways and rock tunnels in numerous collieries of the anthracite coal fields. Historical accounts of this early mine development in the region are found in Miller and Sharpless (1985) and Wallace (1981). The Department of Mines and Mineral Industries of the Commonwealth of Pennsylvania produced annual reports of coal production from 1870 to 1972, and its successors, the Pennsylvania Department of Environmental Resources and the Pennsylvania Department of Environmental Protection, produced these statistical reports from 1972 to the present. Those reports state that there was no accurate record of underground mine production prior to 1870, that anthracite coal production for that year was 14,172,004 tons, and that anthracite production peaked in 1917, at 100,445,299 tons.

In addition to the extensive network of colliery development features underground, the effects of all of this anthracite mining on the landscape of the anthracite region included thousands of large coal refuse (or culm) banks, and many thousands of mine subsidence features. For example, the giant refuse bank at the Westwood Colliery in the Southern Anthracite Field, located adjacent to Interstate 81 in Schuylkill County, marked the gateway to the Anthracite Region for northbound travelers; and the huge coal refuse banks of the Glen Burn Colliery in the Western Middle Field, draped over the nose of the Big Mountain water gap of the Shamokin Creek, tend to dwarf the community of Shamokin hundreds of feet below.

The statistical reports of the Department of Mines and Mineral Industries state that there were no accurate records of stripping (surface mine) production of anthracite prior to 1932. Stripping production for that year was 3,545,948 tons, and stripping production peaked in 1948 at 13,485,837 tons. By the 1940's advances in the development of large surface mining equipment, and the demand for anthracite related to World War II industrial development efforts, facilitated the development of large open-pit surface mines several hundred feet deep. Many of these large open-pit mines and thousands of smaller surface mine pits were abandoned prior to the enactment of laws requiring surface mine reclamation.

The Pennsylvania Clean Streams Law was passed in 1937, but the treatment of mine drainage from anthracite and bituminous coal mines (underground and surface mines) was exempted until an amendment to that law required the commencement of treatment in 1966. That amendment signaled the decline of the anthracite underground mining industry, because many of the large active collieries shut down to avoid constructing and operating large mine drainage treatment facilities for their voluminous pumped discharges. The Surface Mine Reclamation Act of Pennsylvania became law in 1945, but it lacked significant backfilling and revegetation requirements until the amendments of 1963 and 1971. By that time, most of the extensive damage to the lands and waters of the Anthracite Region had already been done.

The significant growth in the use of coal ash in mine reclamation in the anthracite and bituminous coal regions of Pennsylvania in the past 20 years is principally due to three regulatory developments: 1) the enactment of the federal Public Utility Regulatory Policies Act (PURPA) in 1978 and related regulations of the Federal Energy Regulatory Commission (FERC), which facilitated the development of the culm burning cogeneration plants, 2) the development of DEP policies and procedures in 1986 authorizing the Bureaus of Mining and Reclamation (BMR) and District Mining Operations (DMO) to issue permits for the use of coal ash in reclaiming active and abandoned mine lands within Surface Mining Permits (SMP) boundaries, pursuant to the Solid Waste Management Act of 1980, and 3) the promulgation of specific regulations for the beneficial use of coal ash in 1992 by the Pennsylvania Environmental Quality Board (25 Pa. Code Sections 287.661 through 287.666). These regulatory enhancements resulted in the construction of nine cogeneration plants in the anthracite region shown on Figure 1.1, and the issuance of 51 permits for coal ash use in mine reclamation by the Pottsville District Office of District Mining Operations from 1986 through 2003. The permitted coal ash placement sites are shown on Figure 4.1.

The nine anthracite region cogeneration plants account for 38.14 million tons of the coal ash beneficially used for abandoned mine reclamation shown in Table 1.1. The coal ash placement sites associated with these 9 fluidized bed combustion (FBC) plants represent the greatest volume of coal ash and the largest acreage of abandoned mine land reclamation with coal ash in the anthracite region. However, many of the 51 permits issued by the Pottsville District Office were for the use of coal ash from pulverized coal power plants in Pennsylvania and other states, which is transported to the anthracite region by truck and rail for use in the reclamation of active and abandoned pits on these surface mining permits. Many of the yellow dots on Figure 4.1 represent coal ash placement mine sites that are not located at or near a FBC plant, such as the Alden mine site shown in Figures 4.3 and 4.4.

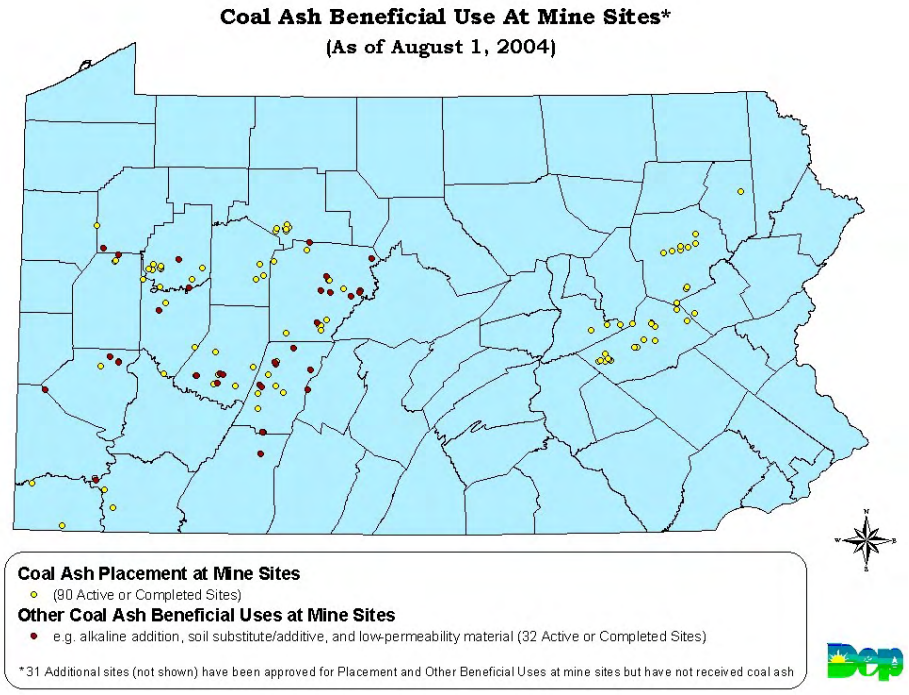


Figure 4.1. Location of coal ash beneficial use mine sites in PA.

The cogeneration plant concept is perfectly suited to the Anthracite Region because these facilities remove abandoned coal refuse banks, mix the culm with limestone in their circulating fluidized-bed combustors, producing an alkaline coal ash, and use the coal ash to reclaim abandoned pits and other abandoned mine land (AML) features. Therefore, multiple environmental benefits accrue from the removal of unsightly, acid-producing culm banks, the backfilling of AML features and the reduction of acid mine drainage pollution. In addition, social and economic benefits result from jobs related to the production of electrical power and by-product usage of steam (e.g. growing hydroponic flowers and tomatoes) in an area with a depressed economy. The cogeneration plants would be impossible without the development of the circulating fluidized bed boilers. PURPA created the business opportunity, and the circulating fluidized bed technology made it possible to burn the waste coal material. Figure 4.2 shows the Westwood FBC plant under construction in 1985 and the large coal refuse pile adjacent to Interstate 81 in Schuylkill County.



Figure 4.2. Westwood FBC plant near Tremont in Southern Anthracite Field.

Of the nine FBC plants constructed in the Anthracite Region, one was in the Northern Field, four are in the Western Middle Field, two are in the Southern Field, and two are located outside of the coal fields (but haul culm from the coal fields, and haul coal ash back for mine reclamation). These nine FBC plants in the Anthracite Region are generically called cogeneration plants, but three of them are actually classified as "small power producers", rather than cogeneration plants, under FERC regulations. That is because the term cogeneration implies the generation of steam or some other energy source, in addition to electrical power production. The millions of tons of coal refuse consumed by these plants, volume of coal ash produced and acres of mine land reclaimed are tabulated and graphed in Chapter 1. Additional information on the regulatory developments and requirements for beneficial use of coal ash is found in Chapter 1, 25 PA Code Chapter 287 and Scheetz et al. (1997).

4.2 MONITORING REQUIREMENTS

The physical and chemical properties of coal ash are monitored and evaluated by DEP through permitting and inspection activities at coal ash placement sites. The overall monitoring requirements are described in more detail in Chapter 1 and the interrelationships of the physical properties are described in an engineering context in Chapter 3. Groundwater monitoring associated with coal ash placement at anthracite mine sites generally depends upon an understanding of the minepool hydrology. Almost all of the refuse bank reprocessing and strip

mine sites overlie abandoned underground mines, and these individual collieries have minepools with gravity discharges, or are hydrologically interconnected to other minepools and downgradient discharge points.

A 1905 map by mining engineer A. D.W. Smith (in the archives of the DEP Bureau of Deep Mine Safety) identifies the locations and lists the ownership information for 363 collieries in the Anthracite Region at that time. The Northern Field had 173 of these collieries, of which about 90 were in the Wyoming Basin and the remainder in the Lackawanna Basin. In that listing, the Western Middle Field had 84 collieries, the Eastern Middle Field had 47 and the Southern Field had 56. Later maps and reports by the U.S. Bureau of Mines (Ash et al., 1949) and maps maintained by the DEP Bureaus of Abandoned Mine Reclamation and Deep Mine Safety show about 74 collieries in the Northern Field, 66 in the Western Middle Field, 37 in the Eastern Middle Field and 52 in the Southern Field. The reduction in the number of collieries between 1905 and later accounts is probably due to some smaller collieries coalescing into larger ones.

Determining the exact number of collieries in existence in any of the four anthracite coal fields is not really that important, because they do not function as separate and distinct hydrologic units. Originally, barrier pillars were surveyed and maintained to separate adjacent collieries for safety and pumping purposes. However, many of these barrier pillars have been breached by deep mines (especially small "bootleg" mines), and surface mines following cessation of pumping by the major underground mining companies. As a result of these unauthorized mining activities, numerous collieries in the four anthracite coal fields have been interconnected to form larger hydrologic units with common minepool discharge points.

The U.S. Geological Survey has identified and monitored approximately 100 major underground mine discharge points in the Anthracite Region in two reports (Growitz, et al. 1985 and Wood, 1996), and DEP open-file reports and permit documents confirm the occurrence of these larger multi-colliery hydrologic units, similar to the remining hydrologic unit concept explained in Smith et al. (2004). For example, at least 12 collieries in the eastern end of the Western Middle Field, including the Shen Penn and Knickerbocker collieries described in Chapters 7 and 8, drain to the downgradient Packer No. 5 colliery discharge to Mahanoy Creek in the town of Girardville. Similarly, about 7,000 acres in the western portion of the Western Middle Field, including at least 5 collieries, drains to the Sterling Colliery discharge near Shamokin.

In the Northern Field, Ash et al. (1952, p. 106) describes the Marvine pool in the Lackawanna Basin inundating a very large area including the Marvine Colliery and 9 other interconnected collieries. Hollowell and Koester (1975) contains a large map further delineating minepool interconnections in the Lackawanna Basin, and that study plus DEP open-file reports confirm that the majority of the collieries in the Lackawanna Basin drain to two major minepool discharges, the Old Forge Borehole (in the Lackawanna River) and the Duryea Ditch. Abundant minepool interconnections in the Wyoming Basin of the Northern Field are described by Hollowell (1971) and are shown in a schematic plumbing diagram in Figure 2.14 in Chapter 2.

In the Eastern Middle Field, approximately 21,000 acres (32.24 square miles) of the Hazleton Basin and several other basins shown on Figure 2.15 (from Hollowell, 1999 and Ballaron, 1999) drain to the Jeddo Tunnel through a series of rock tunnels. This tunnel system was engineered circa 1900 to interconnect the collieries and produce one major (average 40,000 gpm) gravity discharge, to avoid pumping costs and pumping problems prior to the Clean Streams Law of 1937. The Southern Field has gravity drainage tunnels of a smaller scale, (e.g. the Lausanne Tunnel, draining several collieries at the eastern end of that field directly into the Lehigh River). The Southern Field also has many breaches in the barrier pillars identified in Ash et al. (1949) and described in DEP open-file reports for other collieries throughout the Southern Field, in areas draining to the Schuylkill and Susquehanna Rivers. Therefore, these multi-colliery hydrologic units exist in all four anthracite coal fields.

The anthracite minepool interconnections are described above to provide illustrations of the potential difficulties and complexities of developing realistic groundwater monitoring plans for some anthracite surface mine and coal ash placement sites. The simplified residual-waste monitoring concept of an upgradient monitoring well to document ambient groundwater quality of the aquifer, and one or more downgradient monitoring wells to detect and capture any groundwater pollution emanating from the site, is not applicable to many anthracite mine sites. Thus, the configuration of voids within the underground mine workings (i.e. gangways, cross-cut rock tunnels, slopes, shafts, etc.) is evaluated to select potential upgradient and downgradient monitoring well locations and the presence of breaches in barrier pillars is considered in determining groundwater (minepool) flow patterns.

It is not difficult to locate good well sites on the detailed maps of the abandoned underground mines (i.e. on 1" = 100' scale maps in DEP and mining company archives), but it is often difficult to find the target subsurface mine voids in the field by drilling, and to complete the well to function effectively as a long-term groundwater monitoring point. Some of these difficulties may be related to coordinating the historical underground mine survey control points with present day land surface survey control points. Other difficulties may occur during drilling, where the correct surface point and correct subsurface target (e.g. gangways or rock cross-cut tunnel) are properly located, but voids are encountered before intercepting the minepool, which may result in collapse of the drill hole or loss of air in air rotary drilling. In other cases, a well is drilled to the correct subsurface target mine void in competent rock, but it does not capture the true representative water quality of the minepool, or the well is fouled or rendered useless after drilling. For example, in a recent cooperative drilling project involving DEP and a coal company in the Southern Field, a borehole was successfully drilled approximately 400 feet to intercept the minepool at the intersection of the main slope and a Mammoth seam gangway, but by the next day most of the drill hole was filled with fine coal silt that choked the hole. A coal preparation plant operated on that site after the major underground mine closed, and apparently it flushed coal fines down the main slope or a nearby borehole, which migrated into the new monitoring well overnight. These potential problems are presented here so the reader can appreciate the state of the art and science of drilling monitoring wells to intercept anthracite minepools, and to acknowledge the importance of coordinating expertise in mining engineering, geology, and borehole drilling procedures in successfully completing meaningful monitoring wells.

Monitoring wells are no doubt a primary tool for use in obtaining groundwater sample data to evaluate the performance of coal ash on mine reclamation sites. The goal is to develop a group of wells to facilitate sampling of background groundwater/minepool water quality, and to determine if there are any adverse or beneficial effects of coal ash upon minepool quality. At many of these surface mine sites, all of the monitoring wells drilled to intercept the minepool will yield samples of abandoned mine drainage pollution, regardless of whether the well is located upgradient or downgradient of the ash placement area, or the sample is collected before or after the placement of significant quantities of coal ash. Hence, groundwater samples from these wells are likely to exceed drinking water standards. for one or more analytes associated with mine drainage pollution, including acidity, sulfate, TDS, iron, manganese, aluminum, zinc and other metals of concern. These exceedances of numerical water quality guidelines may be temporary or permanent, based upon seasonal variations, and other factors that may be related to the "background" mine drainage pollution, the coal ash placement activities, or other sources of pollution introduced to the minepool flow system (e.g. industrial pollution, sewage, abandoned waste disposal/superfund sites, etc.). Therefore, it is ideal to develop, at least a pair of wells, located immediately upgradient and downgradient of the coal ash placement area, in order to obtain groundwater samples for comparison of analyte concentrations, as independent as possible of other sources of pollution. Past practice has demonstrated that this ideal case often cannot be achieved, so the industry, consultants, and regulatory agency geologists have to do the best they can to obtain and interpret groundwater/minepool data from reasonably available monitoring wells and other minepool sampling points (e.g. shafts, airways).

Shafts are major vertical openings into abandoned anthracite collieries. They were strategically located during underground mine development to be centers of activity within the mine, and typically were situated near to the center of the mine complex to serve as the main point of ingress and egress from the mine. During active mining these shafts functioned like elevator shafts, to lower men and equipment into the mine, and hoist the coal and men to the surface from the depths of the mine. Post-mining, these shafts are still significant windows to gain observations of the subsurface, and they can function as excellent groundwater monitoring points if the structural integrity of the shaft has not been compromised over time (e.g. it may no longer be plumb due to mining/robbing of the reservation pillar surrounding the shaft, or mine subsidence collapses may have occurred in coal veins near the shaft preventing access of sampling equipment to the full depth of the shaft). Therefore, shafts may function like big monitoring wells (e.g. a typical four-compartment shaft was 40 feet by 80 feet width), and may be the best locations to evaluate minepool quality changes with depth (minepool "top water" and "bottom water" stratifications are described in Barnes et al. (1964), Ladwig et al. (1984) and Fox et al. (2001). Of the four major entries into collieries (slopes, shafts, tunnels and drifts), see Chapter 2, and Wallace (1981), shafts are usually reliable as minepool monitoring points. However, there may be some disadvantages to using shafts as groundwater monitoring points for some coal ash sites, because all of the groundwater flowing through the abandoned underground mine complex does not necessarily pass through the shaft. Rock tunnels were routinely developed in most collieries, perpendicular to the strike of the coal beds, to cross-connect gangways in different coal beds. These rock tunnels and other abandoned underground mine features (e.g. collapsed/blocked gangways) may create groundwater flow pathways that bypass the shaft.

Of the four major types of entries into anthracite collieries, tunnels may generally serve as the best groundwater monitoring points, because they typically are gravity drainage structures for all of the abandoned workings, and are the main post-mining overflow s for the minepools. Drift entries into collieries also represent good groundwater monitoring points, but as they are constructed to connect to a gangway of a specific coal bed, they may not be the only groundwater discharge point or be indicative of all of the variations in water quality within the minepool.

Airways and other secondary openings of the abandoned underground mines also serve as major minepool overflow locations and excellent groundwater monitoring points. These secondary openings were situated at the lowest topographic elevation where the minepool can overflow to the land surface, and thence to receiving streams, so they become more important for groundwater monitoring than the main entry to the abandoned underground mine (i.e. main slope or shaft) that is located at a higher elevation. The Tracy Airway in the Good Spring No. 3 Colliery and the Markson Airway, both located in the Donaldson Syncline in the Southern Field, are good examples of high volume minepool overflows, and are described in Fox et al. (2001) and Brady et al. (1998). The creation of these anthracite minepools by the cessation of pumping during abandonment of the underground mine, and the subsequent flooding of the mine workings, is like filling a bathtub or trough; the impounded water will rise until it reaches the level of the lowest opening which becomes the main overflow point. Thus, a relatively minor opening in the colliery during mining may become the major post-mining minepool discharge point.

This group of minepool overflow structures: tunnels, drifts, airways and other secondary openings; are all gravity (i.e. not pumped) discharge points, which makes them good, long-term, accessible, groundwater monitoring points. One advantage of these minepool discharge points is that historical data on the flow and water quality of these discharges is often available (e.g. USGS reports by Growitz et al. 1985, and Wood, 1996 plus DEP permit file data) for use as background/baseline monitoring data for coal ash placement sites. Another advantage is that these minepool overflows are often the sole discharge point from a colliery or a multi-colliery hydrologic unit, thus they represent a composite of all of the upgradient groundwater quality and flow paths – nothing flowing from the minepool should escape these major exit points. A corresponding disadvantage of this groundwater composite characteristic of these overflow points is that the minepools, and abandoned surface mine pits hydrologically connected to them, were used as “dumping grounds” for decades, and a variety of inorganic and organic chemical pollutants from many industries, Superfund sites, and sewage systems have been introduced to the vast minepool volumes. Many of these historical pollution sources have ceased discharging to the minepools, but some illegal industrial waste discharges and unauthorized sewage discharges continue to exist in the four anthracite fields, despite compliance monitoring and enforcement efforts by DEP. Therefore, almost any inorganic or organic chemical compound may be present in some amount in a “composite” minepool sample, in addition to the chemical constituents attributable to mine drainage and coal ash. However, the advantages usually outweigh the disadvantages and these major minepool discharges often serve as the key downgradient monitoring points, particularly where monitoring wells are infeasible or unsuccessful in intercepting the groundwater flow from certain mine sites.

4.3 CASE STUDY SITES

Several coal ash case study sites were selected to represent a range of coal ash placement conditions, anthracite mine site types, and different groundwater monitoring scenarios. These mine sites are located in the Northern and Western Middle Coal Fields, and are comparable to the three waste demonstration permit sites in the Eastern and Western Middle Fields that are featured in Chapters 7 through 9. The case study sites in this chapter were not studied in the level of detail presented in Chapters 8 and 9 (e.g. geochemical equilibria modeling and Scanning Electron Microscope analysis of ash mineralogy); however, they represent the type of scientific and engineering data typically contained in surface mine permit files, pursuant to the requirements of the coal mining and waste management regulations. Most of this data and other coal ash information is contained in Module 25 of the surface mining permits, as described in Chapter 1.

4.3.1 Northampton Fuel Supply Company – Alden Mine Site

This site is located in Newport Township, Luzerne County, and consisted of one active strip mine pit and two adjacent abandoned mine pits. The total area affected by the active mining, coal ash placement, and abandoned mine reclamation encompassed 31.5 acres. The total acreage of Surface Mining Permit No. 40860101 is 115 acres, but the coal ash placement area is within the western half of the SMP, as shown on Figure 4.3. The surface mine site overlies the abandoned Alden Colliery workings, at the western end of the Wyoming Basin of the Northern Field.

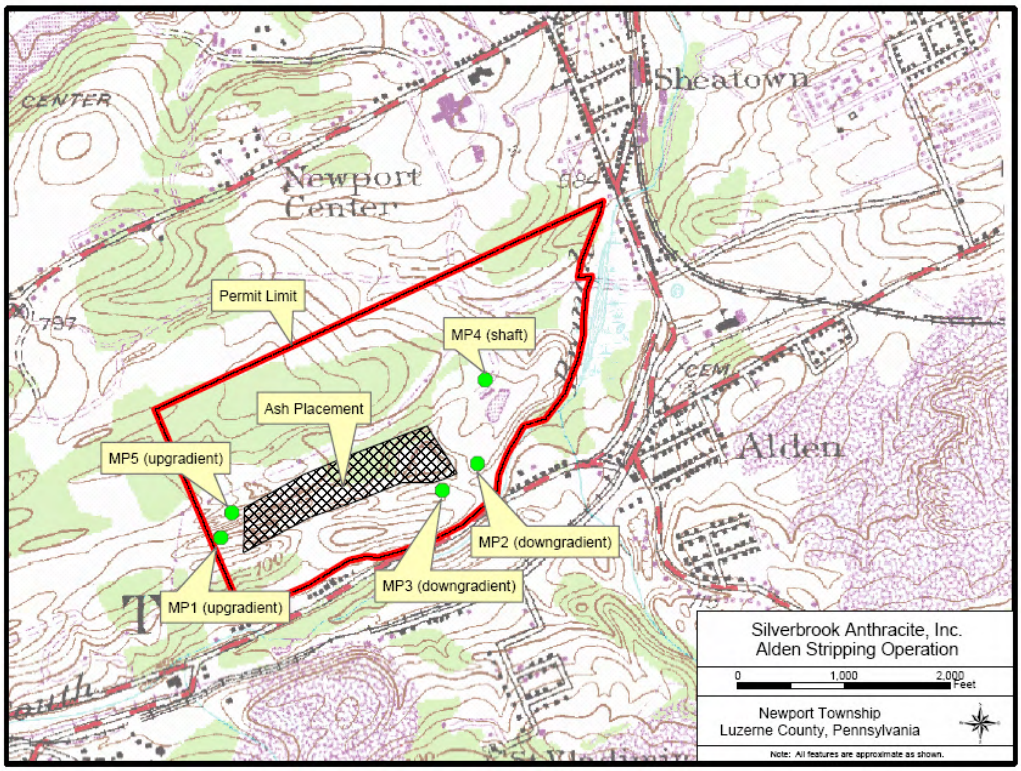


Figure 4.3. Site map of Northampton Fuels – Alden mine site.

The surface mining permit associated with this site was originally issued to Silverbrook Anthracite, Inc. in March 1987, and active strip mining began shortly thereafter. In January 1989 the permittee submitted a request (Module 25) to allow coal ash placement at the site. This submittal was approved in February 1990 and included two upgradient and three downgradient groundwater monitoring points. Coal ash placement began shortly after the Module 25 approval, and an additional coal ash source was added in March 1991. Only a small amount of coal ash was placed at the site, until it was transferred from Silverbrook Anthracite, Inc. to Northampton Fuel Supply Co., Inc. in July 1994. Northampton Generating Company, a FBC facility, was subsequently approved as an additional coal ash source in May 1995, at which time coal ash placement significantly increased at the site. This case study site was selected because: coal ash was used to augment backfill material at an active strip mine site, the site has been completed and reclaimed for several years, geotechnical data exists, and the groundwater monitoring scenario is relatively simple.

Coal ash from the Northampton Generating Co. source was also approved as a soil additive or replacement in May 1997, and utilization of coal ash for that purpose and as backfill material continued until October 1998. The site was reclaimed to forestland with grasses, legumes and trees, and was eligible for final bond release in October 2003. Approximately 1 million tons of Northampton coal ash was utilized on the 31.5 acres covered by this operation, and the groundwater monitoring at the site showed no degradation in relation to the pre-existing background samples. A photo of the reclaimed site is shown in Figure 4.4.



Figure 4.4. Reclaimed area at Northampton Fuels – Alden site.

A geotechnical investigation was conducted at the site in January 1998, with the results indicating more than adequate stability of the in-place material. These results indicate that the site should be stable over the long term for various post-mining uses, (such as industrial development), and that the ash does exhibit some pozzolonic and cementitous characteristics. The results of the geotechnical study are shown in Table 4.1. Similar tables of geotechnical data are included in Chapter 3, where blow counts and other methods are explained.

The five groundwater monitoring points are shown on the schematic map of the site in Figure 4.3. The upgradient monitoring wells, MP #1 and MP #5 are located relatively close together at the western edge of the SMP and these wells were drilled to a depth of 200 feet and 173 feet respectively, to intercept the minepool. The downgradient monitoring wells, MP #2 and MP #3 are in the south-central portion of the permit area (well depths are 150 feet), and the Alden Shaft is MP #4 in the eastern portion of the SMP.

Table 4.1. Geotechnical data from ash reclamation area at Alden site.

Northampton Generating Alden Ash Site – Borehole A-1				
Depth (ft) From-To	**Sample No.**	**Blows / 6"**	**Blows / 6"**	**Blows / 6"**
		0/6	**6/12**	**12/18**
0-5	S-1	15	38	50/0.3'
5-10	S-2	20	44	50/0.2'
10-15	S-3	24	47	50/0.2'
15-20	S-4	24	50	50/0.4'
20-25	S-5	20	42	36
25-30	S-6	15	25	29
30-35	S-7	3	5	6
35-40	S-8	5	6	6

Monitoring of upgradient and downgradient wells, plus the Alden Shaft point representing the minepool, has shown no major trends in overall quality. There were some very slight temporary increases observed at downgradient monitoring points for manganese and fluoride, but they returned to low levels at the end of the sampling period. Heavy metal levels remained essentially undetectable throughout the sample period of 1989 – 2000 with no discernable trend.

The results of twelve years of groundwater monitoring data are shown in Figures 4.5a and 4.5b. These figures show a dramatic decline in alkalinity and sulfates in upgradient MP #1 in 1993, prior to major coal ash placement, and an apparently small increase in alkalinity in upgradient MP #5. The alkalinity of downgradient MP #3 appears to be declining during and after placement of the alkaline ash, and is also inconsistent with the concentration range and behavior of nearby MP #2, that shows a more significant alkalinity decline. Monitoring well MP #3 also had three spikes in sulfate concentrations from 1993 to 1995, which match low-alkalinity events. Otherwise these data are unremarkable.

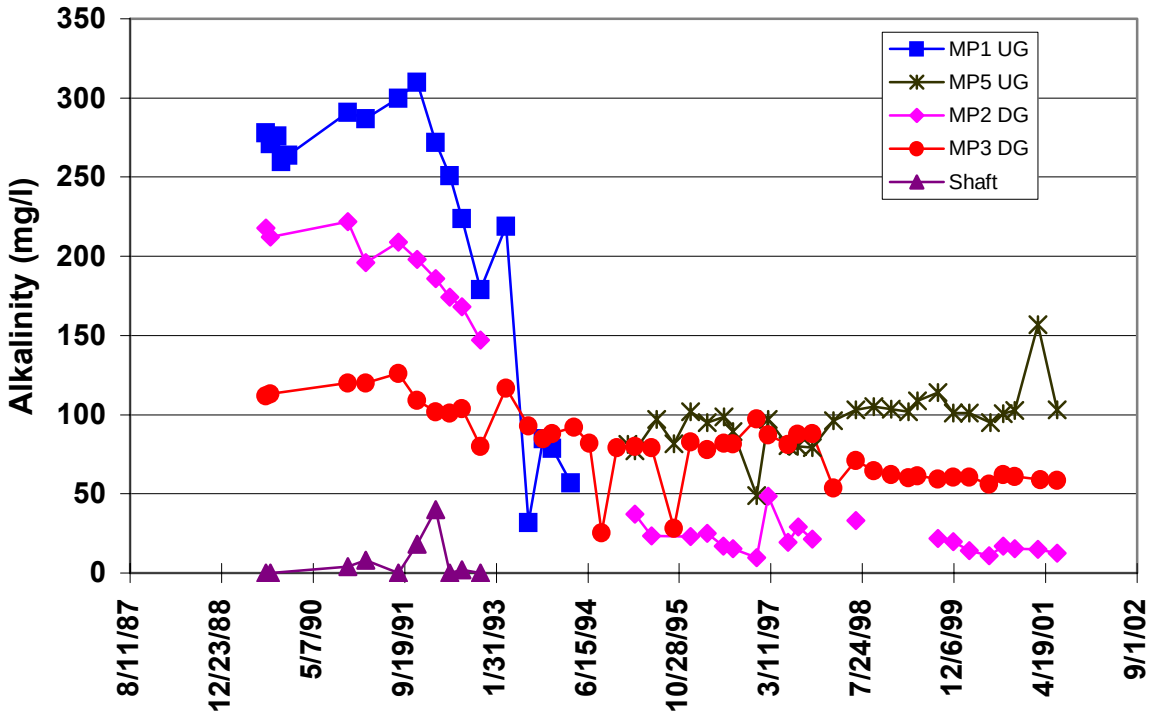


Figure 4.5(a). Alkalinity in groundwater monitoring points at Northampton Alden site.

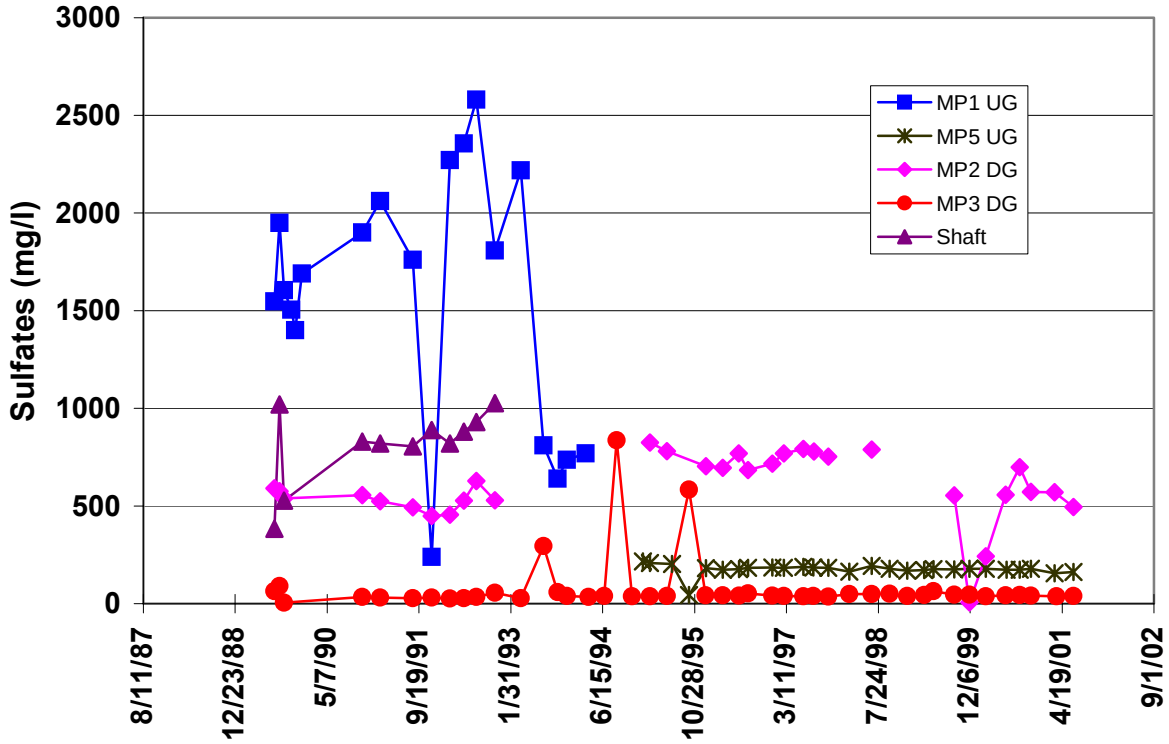


Figure 4.5(b). Sulfate in groundwater monitoring points at Northampton Alden site.

4.3.2 Wheelabrator Culm Services, Inc.

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 4.6. 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.

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.

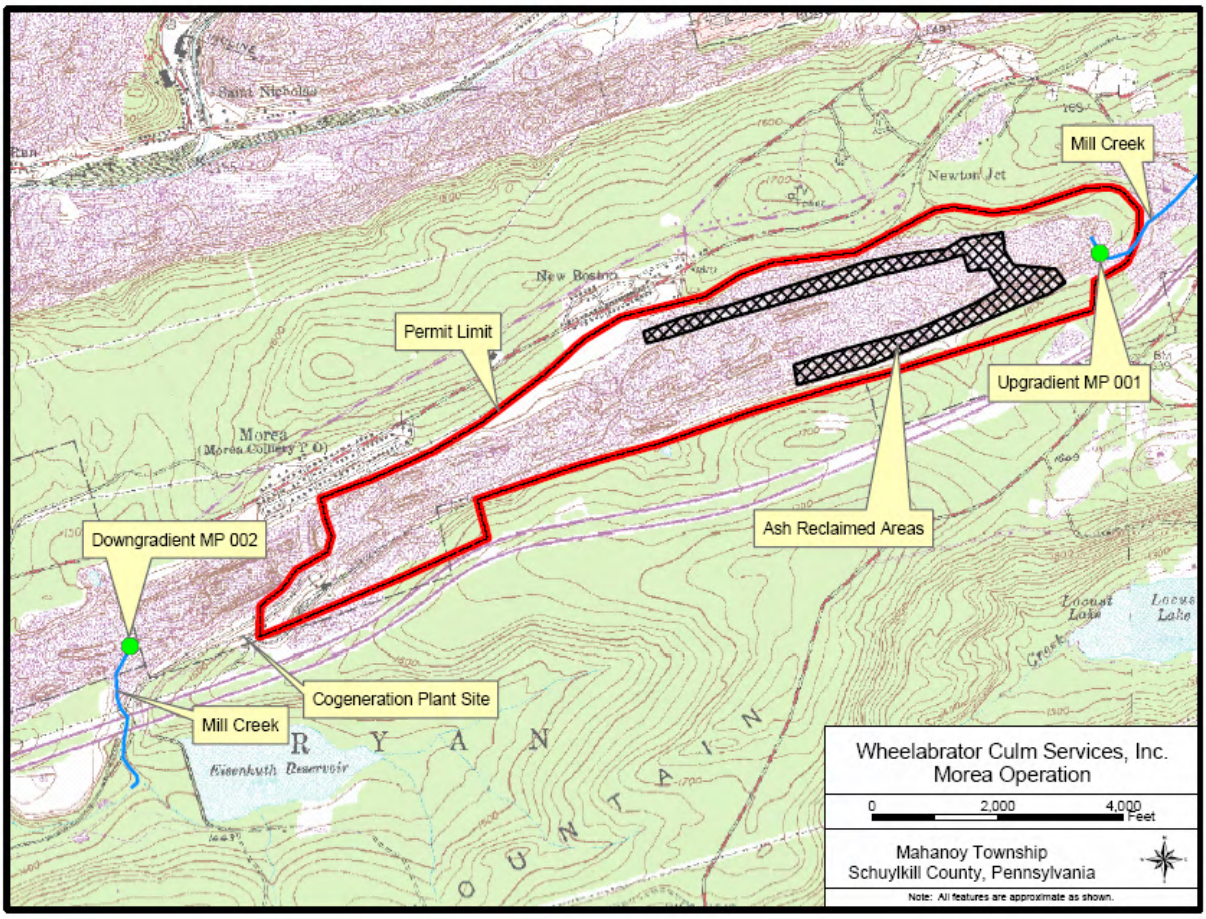


Figure 4.6. Site map of Wheelabrator – Morea mine site.

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 refuse reprocessing. At the end of 2002, the operator reported over six million tons of anthracite coal refuse burned in the plant, and over four million cubic yards of ash utilized for reclamation on-site, with 113 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 4.7. Extensive wildlife habitat plantings have been established on the reclaimed areas shown in Figure 4.7b. 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 4.7(a). Ash placement in pits.



4.7(b). Wildlife plantings.



4.7(c). Morea minepool and FBC plant.



4.7(d). Extensive reclamation area.

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 4.6. 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 a concomitant 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 4.6. 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 goes underground into the minepool complex. A point was picked on Mill Creek as an upgradient monitoring site, shown on Figure 4.6. The minepool overflows downgradient from the site and 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 into the 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 1 or 2 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, and during ash placement it has typically been about 50 to 80 mg/L as shown in Figure 4.8a. 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.

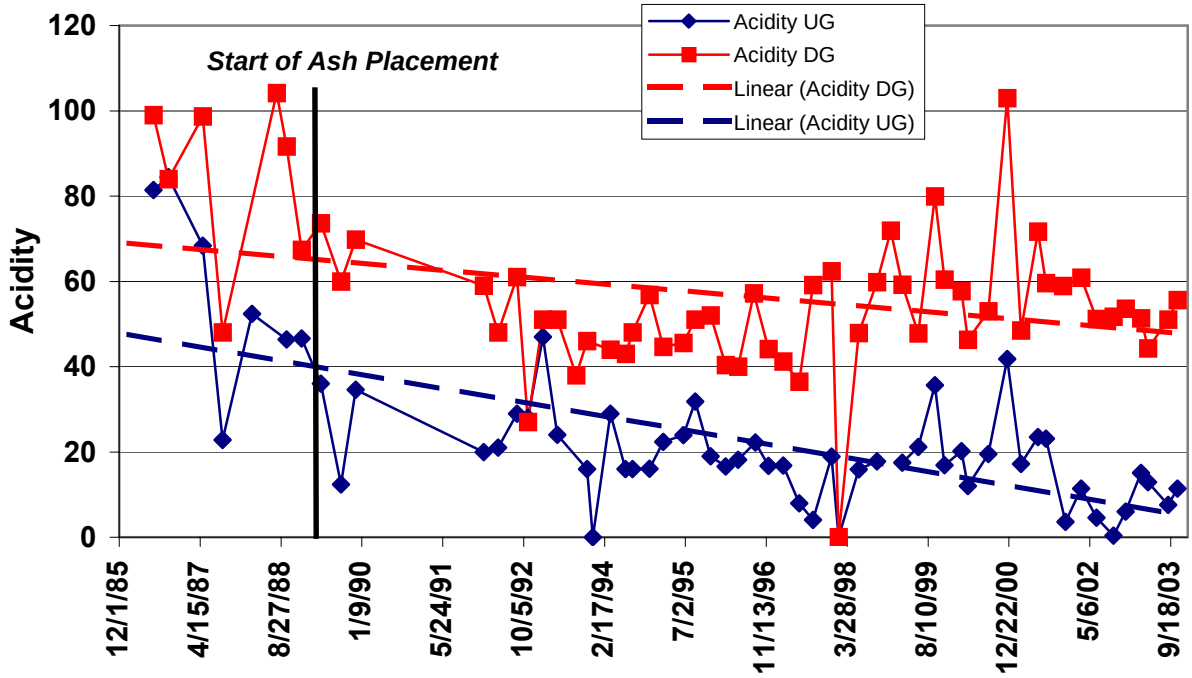


Figure 4.8(a). Acidity in minepool and stream at Wheelabrator site.

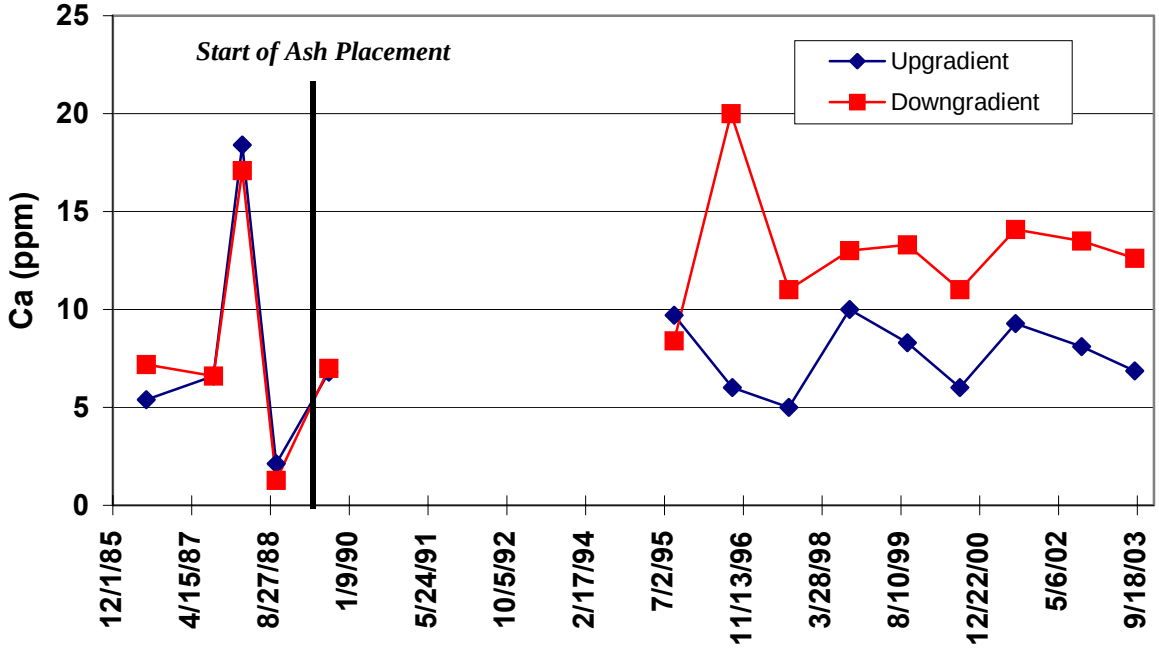


Figure 4.8(b). Calcium concentration in minepool and stream at Wheelabrator site.

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 4.8b 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 4.7. 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.

4.3.3 B-D Mining – Overall Plant Site and Reading Anthracite - Ellengowan Site

The large B-D Mining coal refuse reprocessing and coal ash placement site is located in Mahanoy and West Mahanoy Townships and Gilberton Borough in Schuylkill County. The surface mining permit (SMP #54850202) is for a total of 1,590 acres, including 809 acres of coal refuse removal and 175 acres of coal ash placement areas. This SMP was issued in December

1985 as a repermitting operation that encompassed five previous surface mining permits. The permit boundary and active and abandoned mine features are shown on Figure 4.9.

This site consists of a large area of abandoned mine lands containing extensive waste coal (refuse material) and coal silt deposits. The operator reprocesses coal waste and prepares it for utilization in various ways. The most significant use of the material is as fuel for the nearby cogeneration facility, Gilberton Power Company. The material is burned in this fluidized bed combustion plant and the fly/bottom ash that results is returned to this site for beneficial use in backfilling a silt dam. The silt was removed from the dam prior to ash placement which began shortly after the plant went on-line in 1988.

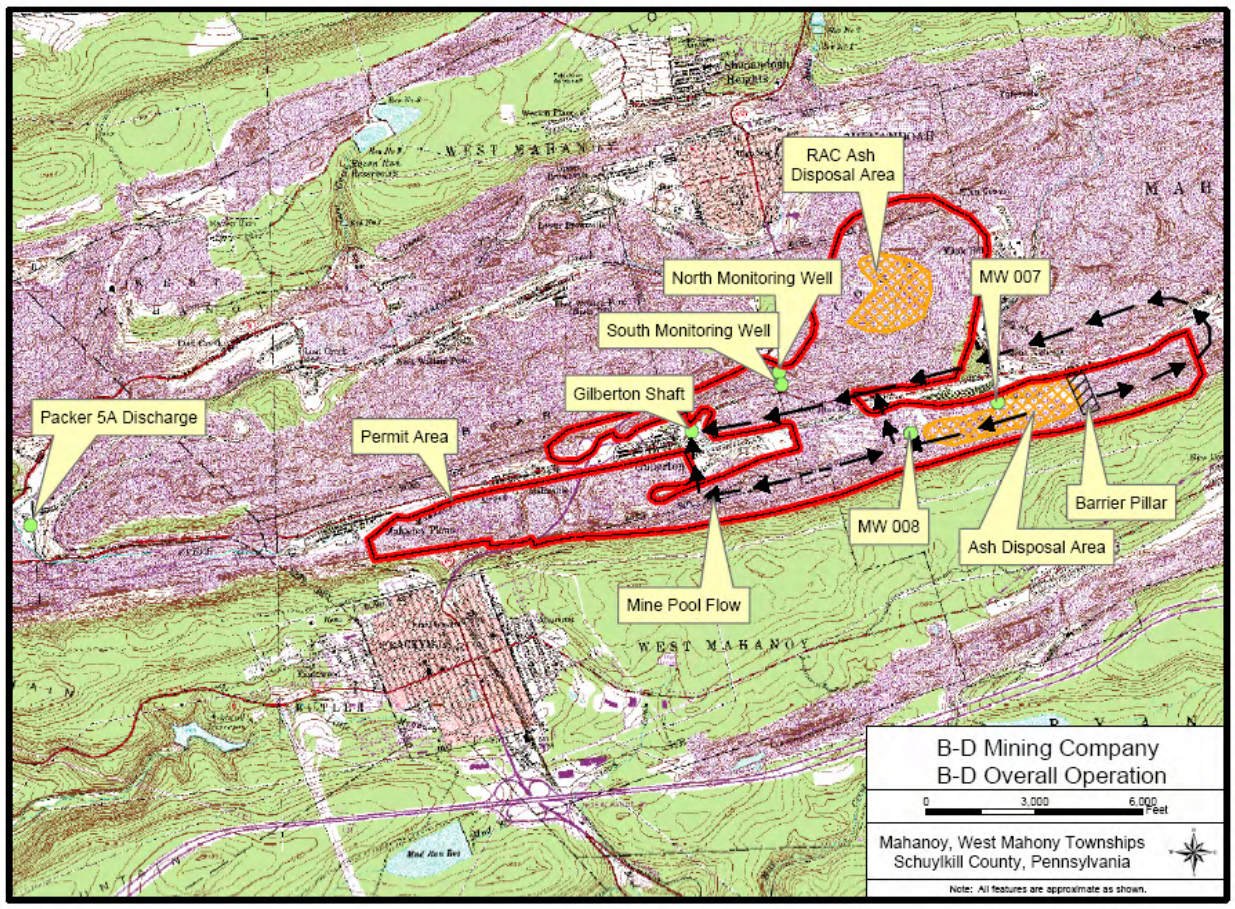


Figure 4.9. Map of B-D Mining site showing permit boundary, ash placement areas and monitoring locations.

The ash placement silt dam site overlies the abandoned mine workings of the Boston Run Colliery in the eastern portion of the Western Middle Anthracite Field. The silt dam/ash area is at the eastern end of the Boston Run Colliery, adjacent to the barrier pillar between the Boston Run and Tunnel Ridge Collieries, as shown on Figure 4.9. While the ash placement site overlies a single abandoned underground mine (Boston Run Colliery), the 1,590 acre SMP overlies a total of 8 collieries, and the Gilberton Shaft minepool monitoring point within the SMP receives mine drainage from at least 11 upgradient collieries and interconnected minepools. This case study

site was selected because it represents a large volume coal ash placement area within a large-scale refuse reprocessing operation with a complex groundwater monitoring scenario.

The ash from Gilberton Power Company placed in this silt dam is the only source of ash at this time, although other sources of ash have been approved for placement at this site. Filling of the dam has been on-going since 1988 in accordance with DEP's rules and regulations, and established engineering practice. The coal ash is placed in and compacted with on-site equipment, such as bulldozers, which has proven to be adequate to establish the required field densities of 90% of the modified Proctor density as determined in the laboratory for this ash material. As of the end of 2002, approximately 4 million cubic yards of ash and refuse material have been placed at this site, as shown on the photos in Figure 4.10.



Figure 4.10(a). Culm, fuel processing, and conveyor to Gilberton Power Plant.



4.10(b). Silt dam and adjacent ash reclamation area.



4.10(c). Extensive reclamation area.



4.10(d). Gilberton Shaft pumping station.

It was stated above that this site represents a complex groundwater monitoring scenario. Before describing the monitoring points and monitoring data, it is useful to put the B-D Mining site in perspective with the other coal mining and ash placement activities in the watershed. The 1,590 acre B-D Mining SMP shown on Figure 4.9 is adjacent to the 3,038 acre Reading Anthracite Co. Ellengowan SMP located to the northeast. That Reading Anthracite SMP contains the Schuylkill Energy Resources (SER) cogeneration plant and its large coal refuse bank fuel supply, plus the Shen Penn and Knickerbocker pits, and the Ellengowan silt dam coal

ash site within the SMP boundaries. Thus, there are three significant coal ash placement sites in the area as shown in Figure 4.11, the Knickerbocker pit to the north (see Chapter 8) the Ellengowan silt dam in the middle (see Chapter 7), and the B-D ash placement site to the south of the other two. The entire area underlying these two large surface mining pits is a series of interconnected abandoned underground mines. Surface mining activities within this area consisted of numerous small pits, several large open pit mines including the Shen Penn and Knickerbocker pits, and extensive coal refuse disposal and refuse reprocessing operations comprising the black and dark brown areas, that almost completely cover Figure 4.11. Annual records of refuse consumption and ash production from the Gilberton Power and SER cogeneration plants, show that more than 22 million tons of coal refuse have been removed from the permit areas, and more than 15 million tons of coal ash have been beneficially used from 1988 to 2002. All of these mining and ash placement areas drain to the Gilberton Shaft and ultimately the Packer V discharge at Girardville, shown on the map in Figure 4.9 and on the photos in Figure 4.10.

The coal ash material placed within the B-D permit area shown on Figures 4.9 and 4.11 has been regularly monitored and tested since 1988 for solid ash bulk chemistry and leachate analyses in accordance with the DEP's Module 25 requirements, and has shown that the solid ash and leachate parameters are consistently within allowable limits. Table 4.2 shows the chemical analyses for the solid ash expressed in milligrams per kilogram (i.e. parts per million) for the ash from the Gilberton Power FBC plant at the top of the table. The bottom half of the table shows the leachate concentrations from the Synthetic Precipitation Leachate Procedure (SPLP) test, expressed in milligrams per liter (i.e. parts per million), for the ash samples shown in the top half of the table. The samples included in the table are representative samples of the 38 samples contained in the permit file resulting from the semiannual testing requirements. The samples selected for inclusion in Tables 4.2, 4.3 and 4.4 represent the range in concentrations, the medians, the range in time, or sampling events when bottom ash or fly ash were separately tested. The writers determined that to include all available analyses in these tables would make them too voluminous for inclusion in the body of this chapter; plus, all of this data is public file information within the permit files, accessible to anyone who needs all of the analyses. However, the concentration plots of the ash, leachate and monitoring data in Figures 4.13a, 4.13b, and 4.15a, 4.15b and 4.15c show the entire range and median values of all of the data within the permit files.

The elements in the columns of the table are arrayed in the approximate order of their abundance in the solid ash samples. The major elements, aluminum, iron and potassium shown in the table are present in the range of thousands to tens of thousands of mg/kg. Other major elements in coal, coal refuse and overburden rock minerals (e.g. calcium, magnesium, sodium and silica) are not included in the table, because they are not routinely required in the Module 25 list of analytes; but they are known to be present in these approximate ranges (i.e. thousands of mg/kg) from other analyses discussed in Chapters 7 to 9, Scheetz et al. (1997) and other sources. Barium is relatively abundant in the hundreds of mg/kg range, followed by manganese, chromium, copper, zinc, nickel, boron, molybdenum and arsenic, generally in the tens of mg/kg range. Finally, the elements of selenium, cobalt, mercury, cadmium and silver are generally present in the range of a few mg/kg to trace quantities of a few hundredths of a mg/kg.

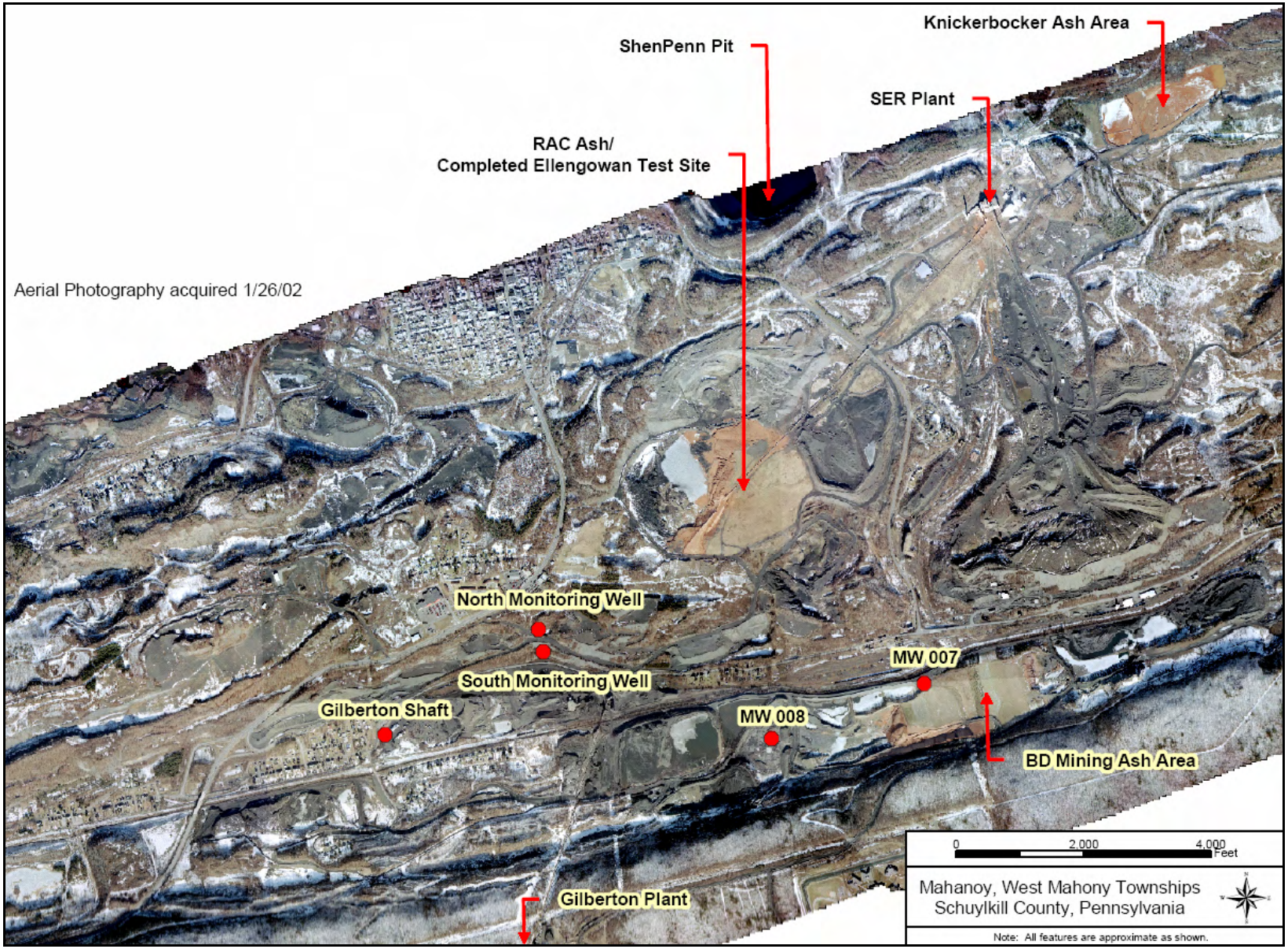


Figure 4.11. Aerial photograph of B-D Mining and Reading Anthracite permit areas and monitoring locations.

Table 4.2. Chemical analyses of Gilberton coal ash and SPLP leachate. (0.00 values = below detection limit).

Solid Ash - Dry weight concentrations in mg/kg																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
5/24/90	10.7	31090	9860		240	54	39	31	16	12		0	0	9	6.2		0.7	0.0	0.0
6/5/95	10.7	18100	17000	3790	149	57	51	23	14	85	21	25	21	21	2.5	0.0	0.0	0.0	0.0
1/15/96	8.9	12000	12700	2120	78	35	22	19	10	14	19	26	61	13	0.0	5.2	0.4	0.0	1.4
6/13/97	10.2	159000	91000	3700	93	41	25	14	19	21	0	0	30	30	0.6	14.0	0.0	0.0	0.0
6/3/99	10.2	25000	26800		276	87	260	46	28	114	34	25	0	6	0.6		0.8	0.0	
10/27/99	10.2	31000	27200		242	98	57	45	35	31	13	30	14	7	0.8		0.3	0.6	
Boiler #1 Fly																			
9/29/88	11.2	48065	26670		294	86	59	53	28	25	50	40	0	2	0.5		0.3	2.0	2.0
9/30/90	12.3	32560	24810		267	82	70	31	20	22	18	43	0	26	0.0		0.3	1.3	0.0
Boiler #1 Bottom																			
6/29/88	11.2	34319	11299		169	49	42	18	18	9	0	26	0	2	0.6		0.0	1.3	1.0
9/30/90	11.6	24095	11440		217	53	35	12	10	10	6	17	0	10	0.0		0.0	0.0	0.0
Boiler #2 Fly																			
9/29/88	10.5	32216	19941		194	63	48	30	21	18	25	28	0	2	0.4		0.2	2.4	1.0
10/11/90	11.9	33340	31390		273	91	76	39	20	27	23	46	4	38	0.0		0.5	1.3	0.0
Boiler #2 Bottom																			
9/30/89	5.5	56700	14420		206	46	46	17	22	0	*20*	56	0	3	0.0		0.0	3.0	0.0
10/11/90	11.6	19160	12360		192	53	27	12	10	11	6	0	0	8	0.0		0.0	7.0	0.0
SPLP Leachate Concentration in mg/L																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
5/27/90	5.0	8.28	0.00		0.15	0.37	0.05	0.00	0.22	0.00		0.00	0.06	0.00	0.21		0.00	0.00	0.00
6/5/95	10.8	1.16	0.11	23.50	0.14	0.00	0.15	0.00	0.01	0.00	0.00	0.00	0.24	0.25	0.05	0.00	0.00	0.00	0.00
1/15/96	10.8	0.63	0.11	18.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.22	0.03	0.00	0.00	0.00	0.00	0.00
6/13/97	10.6	1.20	0.05	22.30	0.00	0.07	0.23	0.03	0.03	0.00	0.00	0.11	0.60	0.02	0.01	0.07	0.00	0.00	0.03
6/3/99	10.4	3.50	0.18		0.26	0.01	0.13	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01		0.00	0.00	
10/27/99	8.7	3.14	0.54		0.00	0.16	0.12	0.00	0.01	0.00	0.00	0.00	0.16	0.02	0.01		0.00	0.00	
Boiler #1 Fly																			
9/29/88	4.9	23.90	0.67		0.10	0.73	0.26	0.07	1.04	0.11	0.40	0.30	0.72	0.01	0.02		0.00	0.05	0.05
9/30/90	11.9	15.83	0.53		0.46	0.60	0.10	0.07	0.35	0.00	0.59	0.26	0.32	0.03	0.00		0.00	0.02	0.00
Boiler #1 Bottom																			
9/29/88	4.8	10.50	1.05		0.00	0.18	0.22	0.07	1.04	0.07	0.00	0.23	0.00	0.02	0.00		0.00	0.04	0.02
9/30/90	11.3	1.91	0.16		0.24	0.19	0.00	0.03	0.08	0.00	0.13	0.00	0.00	0.04	0.00		0.00	0.00	0.00
Boiler #2 Fly																			
9/29/88	5.0	20.60	0.68		0.15	0.53	0.32	0.13	4.46	0.16	0.55	0.29	0.61	0.02	0.01		0.00	0.03	0.02
10/11/90	12.1	16.62	0.38		0.59	0.57	0.17	0.07	1.20	0.00	0.65	0.31	0.40	0.04	0.00		0.00	0.02	0.04
Boiler #2 Bottom																			
9/30/89	5.0	0.00	0.00		0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
10/11/90	11.5	2.13	0.15		0.24	0.19	0.00	0.03	1.03	0.00	0.12	0.13	0.00	0.04	0.00		0.00	0.01	0.00

While some of these elements are not abundant in the solid ash or the SPLP leachate, they are included in Tables 4.2 and 4.4, and are routinely required in the Module 25 analyses because they are elements of concern in the federal RCRA program (i.e. As, Ba, Cd, Cr, Pb, Hg, Se, Ag). The leachate concentrations of all of these major, minor and trace elements in the bottom half of the table can easily be compared to the solid ash analyses, and it is evident that the relative abundance of certain elements in the solid ash is not matched by their relative abundance

in the leachate. For example, aluminum and potassium are more concentrated in the leachate than iron, and barium concentrations are no higher than manganese or zinc. In the 15 columns from barium to silver, the only concentrations greater than 1.0 mg/L are 5 values for zinc where fly ash concentrations were compared to bottom ash concentrations. The analyses for some of these elements that are shown as 0.00 in Tables 4.2 and 4.3 were reported that way in the monitoring data were submitted to DEP, but actually should be expressed as less than a specified analytical detection limit for that element.



Figure 4.12(a). Culm pile and fuel conveyor to SER power plant.



4.12(b). Shen Penn abandoned pit and SER plant.



4.12(c). Ash conveyor from SER plant to abandoned silt dam.



4.12(d). Reclaimed ash placement area and SER plant.

The ranges of concentrations of constituents in the solid ash samples from the Gilberton Power FBC plant can be compared to those of the solid ash samples from the Schuylkill Energy Resources FBC plant in Figures 4.13a and 4.13b. All 38 solid ash analyses for the Gilberton Power plant, and all of the 25 solid ash analyses for the SER power plant were used in computing the range and median for these data sets. The bold vertical lines express the range of concentrations and the bold horizontal lines represent the median values in these frequency distribution diagrams. These figures are graphed on a log scale because the range of concentrations of elements in the coal ash extends over 7 orders of magnitude for these two coal ash sources, and the patterns of variations for all these elements can then be viewed simultaneously as an "ash fingerprint" or chemical signature for that ash. These data plots are essentially simplified box plots, following the concepts developed by Tukey (1977) and McGill et al. (1978) for comparing batches of data, and used in the statistical analysis of mine drainage data by Griffiths et al. (2001), Fox et al. (2001), Smith et al. (2004) and Brady et al. (1998, see Chapter 2, Fig. 2.18). If these diagrams were truly box plots, the interquartile range of the data would be contained in a box. While the boxes are very useful in evaluating the shape of the frequency distribution of the data and in comparing large data sets, it was determined that the boxes were not essential in these diagrams.

The median values for numerous elements in Figure 4.13a are very similar to those in 4.13b, but the ranges in concentrations of barium, manganese, chromium, copper, zinc and nickel are broader in the SER ash, hence there are some identifying differences in these ash fingerprints. The data plots for those metals in the SER ash appear to be more skewed toward the low values, but that may be chiefly attributable to the log scale. In the Gilberton data for barium and zinc in Figure 4.13a, the median (horizontal line) is very close to the middle of the range (vertical line) indicating that the data are symmetrically distributed above and below the median (and mean), which would occur in a log normal frequency distribution of the data. The use of the median as the measure of central tendency is typical with asymmetrical frequency distributions; it also reduces the problem of dealing with outliers that may be typographical errors or lab errors in these data sets---these outliers may inflate the mean in data sets with few samples. For example, the ash sample in Table 4.2 for June 13, 1997 has an aluminum concentration of 159,000 mg/kg and an iron concentration of 91,000 mg/kg, both of which are much higher than the other values in the array, but not completely out of the question. Another example is the sample for conditioned fly ash at the SER plant on February 11, 1991 which had an aluminum concentration of 428 mg/kg and an iron concentration of 244 mg/kg, which are about 2 orders of magnitude lower than the other samples in the array, which could be a data reporting error of two decimal places.

The SER ash is generally lower in aluminum and iron than the Gilberton Power ash, but the median values are comparable. The Gilberton ash has a median aluminum of 31,608 mg/kg, while the SER ash has a median of 23,150 mg/kg. The Gilberton ash has a median iron of 19,995 mg/kg, while the SER ash has a median of 15,750 mg/kg. The medians for another parameter of interest, arsenic, are more similar. The Gilberton ash has a median arsenic of 11.6 mg/kg, while the SER ash has a median of 12.17.

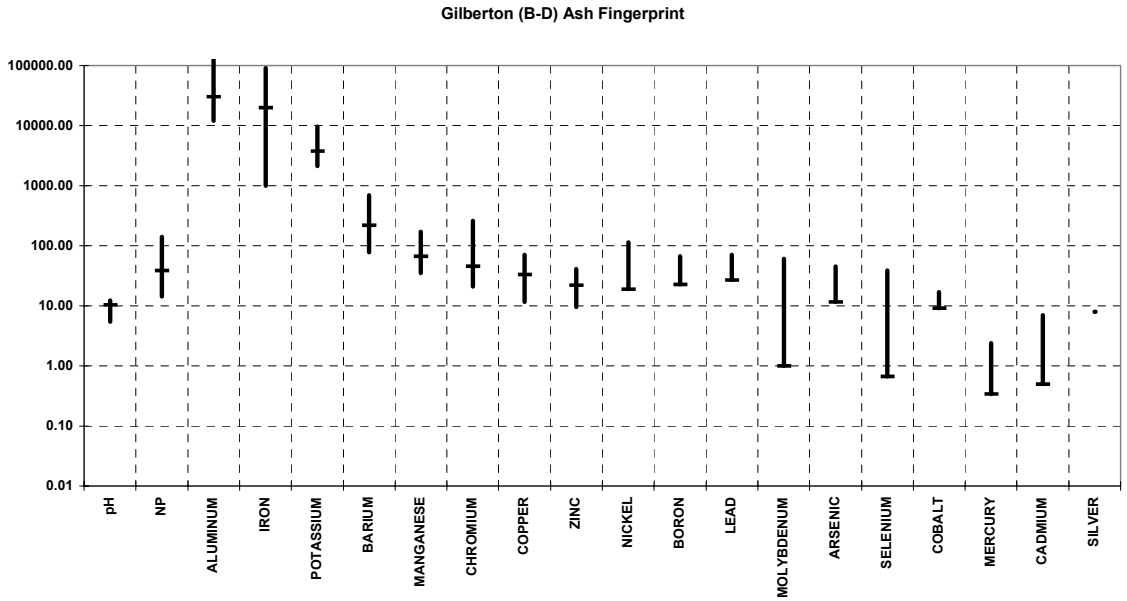


Figure 4.13(a). Ranges and medians of elements in Gilberton Power coal ash. (all parameters except pH and NP are expressed as mg/kg).

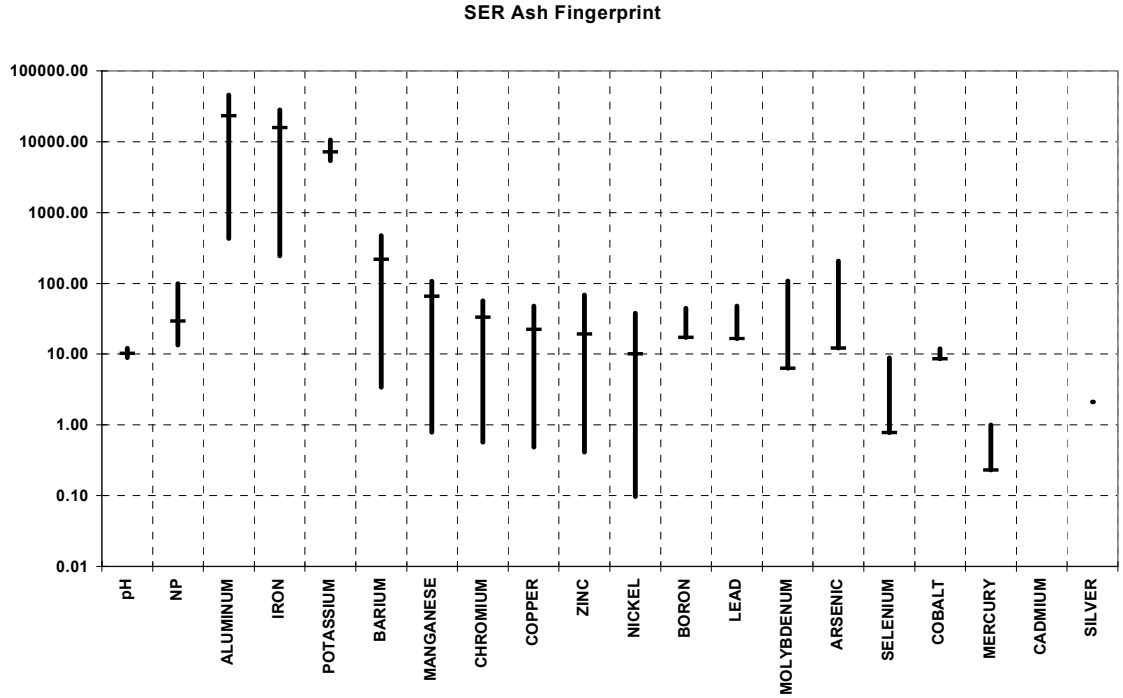


Figure 4.13(b). Ranges and medians of elements in SER coal ash. (all parameters except pH and NP are expressed as mg/kg).

Table 4.3. Chemical analyses of SER coal ash and SPLP leachate. (0.00 values = below detection limit).

Solid Ash - Dry weight concentrations in mg/kg																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
4/30/91	10.6	22100	8520		229	57	24	24	35	*10*	34	19	*12*	11	5.8		0.42	1.20	0.00
12/7/92	9.2	23150	16170		163	70	28	18	14	8	9	17	23	12	0.8		0.33	0.00	0.00
10/28/98	9.6	27900	24500	10600	287	62	47	48	23	15	0	45	13	13	0.0	11	0.00	0.00	1.00
11/30/99	10.2	13000	8360		121	50	16	10	8	38	0	0	0	7	0.0		0.41	0.00	
11/10/00	10.4	45600	26700		243	84	27	17	14	25	17	*10*	*10*	42	1.2		*0.02*	*0.50*	
4/17/02	9.1	10300	13200		108	87	25	14	17	10	45	18	*1*	10	*0.5*		0.15	*2.00*	
Bottom																			
1/10/90	11.3	17568	11160		156	59	23	21	19	9		0	62	206	0.0		0.00	0.70	1.80
Conditioned Fly																			
1/10/90	11.3	42470	28140		473	101	52	31	35	22		46	47	158	0.2		0.00	1.00	2.00
SPLP Leachate Concentration in mg/L																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
4/30/91	5.4	5.12	0.20		0.27	0.27	0.00	0.00	0.07	0.18	ns	0.09	0.05	0.01	0.12		0.00	0.00	0.00
12/7/92	5.4	9.88	0.04		0.00	0.40	0.00	0.00	0.14	0.08	0.37	0.00	0.23	0.02	0.01		0.00	0.00	0.00
10/28/98	10.1	1.72	0.00	10.40	0.24	0.03	0.08	0.02	0.00	0.04	0.00	0.12	0.15	0.01	0.08	0.00	0.00	0.01	0.01
11/30/99	8.8	2.85	0.12		0.00	0.02	0.07	0.03	0.00	0.20	0.22	0.00	0.45	0.05	0.01		0.00	0.00	
11/10/00	10.3	1.67	*0.03*		*0.10*	0.07	*0.05*	0.02	*0.01*	*0.04*	*0.20*	*0.10*	*0.10*	*0.01*	*0.01*		*0.00*	0.02	
4/17/02	10.2	1.64	0.02		0.03	0.01	*0.01*	*0.01*	0.06	*0.01*	*0.07*	0.05	*0.01*	*0.04*	*0.01*		*0.00*	*0.01*	
Bottom																			
1/10/90	5.00	13.82	4.26		0.00	0.56	0.00	0.12	0.17	0.00	0.40	0.42	0.63	0.00	0.00		0.00	0.30	0.04
Conditioned Fly																			
1/10/90	5.10	14.38	4.30		0.00	0.56	0.00	0.10	0.21	0.00	ns	0.44	0.54	0.00	0.00		0.00	0.32	0.03

Table 4.3 shows the chemical analyses for the solid ash from the Schuylkill Energy Resources (SER) FBC plant, located on the Reading Anthracite Co. Ellengowan permit site adjacent to the B-D Mining site. The FBC power plant is shown in the northeastern portion of Figure 4.11, and its primary ash placement area is shown within the B-D permit boundary on Figures 4.9 and 4.12. The top half of the table shows the solid ash chemistry and the bottom half shows the SPLP leachate chemistry, in the same format as described above for Table 4.2. The samples included in the table are representative samples of the 25 samples contained in the permit file, resulting from the semiannual testing since 1990. The patterns of variation in the SER ash analytes were described above in the discussion of Figure 4.13b, and the patterns of variation in the leachate analyses are similar to those described above for the Gilberton ash leachate in Table 4.2. However, none of the leachate concentrations in the 15 columns from barium to silver are greater than 1.0 mg/L.

Background water monitoring was performed at the B-D site of prior to placement of ash. Currently the monitoring program for the B-D Mining site consists the downgradient minepool point at Gilberton Shaft Pump, and two points up and downgradient in the minepool for characterizing groundwater flow from the ash placement area shown on Figure 4.9.

The location of the pools and the estimated direction of water flow in the pools is as shown on Figure 4.9. These pools are known to be interconnected and currently have their discharge at the Gilberton Shaft. The direction of water flow has been documented by the U.S. Bureau of Mines and also confirmed by DEP review of mine workings and pool elevations. A review of the mine water flow indicates that the B-D ash placement area, which is above the Boston Run abandoned mine workings, is located at the extreme upgradient portion of the minepool, adjacent to the barrier pillar between the Boston Run and Tunnel Ridge Collieries. Therefore, an upgradient monitoring point, which would sample pool water not affected by ash disposal, cannot be located.

The monitoring points for the adjacent Reading Anthracite Ellengowan permit are also shown in Figure 4.9 and 4.11, as well as the ultimate downgradient monitoring point at the Packer V minepool discharge at Girardville. Table 4.4 shows representative samples of these monitoring points from 1988 through 2002.

Up to this point in the data analysis the data sets from the B-D Mining/Gilberton Power FBC plant site and the Reading Anthracite/Schuylkill Energy Resources FBC plant site have been kept somewhat separate. As stated earlier, this case study site represents a complex groundwater monitoring scenario, and the minepool/groundwater flow from both sites goes to the downgradient Gilberton Shaft and Packer No. V Colliery discharge points. Fortunately, B-D and Reading Anthracite have some common corporate officers and there are some common ownership interests in the two FBC power plants (which accounts for the existence of the SER ash placement area on the B-D permit), which makes coordination of the groundwater monitoring activities somewhat easier. Therefore, the relevant groundwater monitoring data for both sites is combined in Table 4.4 below and in Figures 4.15a, 4.15b and 4.15c.

The groundwater monitoring samples included in Table 4.4 are representative samples from the B-D and Reading Anthracite permit files, including many of the median samples shown in Figures 4.15a, b and c, plus examples of the maximum values shown in those frequency distributions. The samples were selected from the quarterly groundwater monitoring data set with the intent to represent the entire time period that was monitored, and to match the annual samples that have more metals included in the analysis. MW007 was sampled from March 27, 1988 through September 12, 1996 and was replaced by MW008, which was sampled from January 16, 1996 to the present. The sample collected from MW007 on October 16, 1988 is the median iron concentration (66.7 mg/L) of all 40 samples in the DEP permit file; which is substantially higher than the corresponding median iron concentration (32.2 mg/L) of MW008 in the sample from February 9, 2002 (n = 34 samples).

Table 4.4. Groundwater monitoring data for B-D and SER sites in (mg/L) (0.00 values = below detection limit).

DATE SAMPLED	LAB pH	SPECIF. COND.	ALK	ACID	Fe	Mn	SO4	TDS	TSS	Al	As	Cd	Ca	Cr	Pb	Mg	Se	Ba	Ag
MP 007 Well																			
3/27/88	4.47	470	1.0	167.0	62.0	4.8	360	582	6	1.00	0.050	0.002		0.005	0.009	20.0	0.005	0.018	0.010
10/16/88	6.02	1555	79.0	57.0	66.7	12.7	268	1218	3										
8/29/90	5.85	900	25.0	172.0	81.4	6.5	407	727	145	33.62	0.002	0.000		0.000	0.000	28.7	0.000	0.000	0.000
6/28/94	5.04	1020	3.0	121.0	7.4	7.6	679	791	17										
8/9/94	5.37	1363	13.0	166.0	116.2	8.9	546	826	23										
12/8/94	5.71	912	24.6	124.7	70.9	6.7	459	773	31	4.34	0.000	0.000	84.2	0.000	0.000	31.8	0.000	0.000	0.000
MP 008 - Monitoring Well No. 2 upgradient																			
1/16/96	6.42	1136	10.0	204.0	108.0	3.6	517	818	78	0.28	0.000	0.000	70.0	0.000	0.000	40.9	0.000	0.172	0.000
3/5/97	6.41	852	55.3	159.0	67.4	2.8	395	582	566	12.80	0.000	0.000	40.0	0.000	0.000	33.9	0.000	0.000	0.000
2/7/02	6.42	222	38.8	*0.4*	32.2	0.7	58	202	47	0.22	*0.005*	*0.005*	7.8	*0.005*	*0.500*	7.6	*0.005*		
3/14/02	5.52	154	7.2	1.3	5.2	0.7	53	62	8	0.05	*0.005*	*0.005*	6.7	*0.005*	*0.050*	0.1	*0.005*		
2/25/03	6.10	568	104.2	*0.4*	50.9	3.2	265	421	75	1.85	*0.005*	*0.005*	31.7	*0.005*	*0.025*	32.0	*0.005*		
Gilberton Shaft																			
4/28/86	5.80	1450	2.0	600.0	38.0	8.7	622	1359	14										
2/3/87	6.21	1332	68.0	164.0	12.0	12.0	760	1145	11	0.10	0.008	0.010		0.010	0.010	88.0	0.001	0.020	0.140
8/14/88	5.68	1440	51.0	77.0	60.6	11.7	790	1222	10	1.16	0.003	0.000		0.000	0.000	68.1	0.000	0.195	0.029
2/27/91	4.54	1177	1.0	22.0	50.9	1.0	686	1042	55										
8/9/94	5.72	1596	10.0	26.0	46.9	9.1	707	984	48	2.15	0.017	0.000	143.7	0.000	0.000	70.1	0.008	0.000	0.000
6/5/95	6.15	1313	71.5	47.3	89.0	9.8	746	1070	195	16.12	0.063	0.000	154.5	0.000	0.000	78.1	0.000	0.000	0.000
9/19/95	5.88	1488	55.5	17.5	45.8	8.8	568	997	10	0.81	0.000	0.000	150.0	0.000	0.000	61.3	0.000	0.000	0.000
3/14/02	6.07	1186	67.7	14.7	44.8	8.4	614	951	5	0.42	*0.005*	0.006	96.3	*0.005*	*0.050*	63.4	*0.005*		
12/13/02	6.26	1137	26.8	9.7	49.6	7.9	438	824	95	4.53	0.012	*0.005*	116.0	*0.005*	*0.025*	63.5	*0.005*		
Monitoring Holes South Downgradient																			
9/3/87	6.33		101.0	163.0	174.0	15.4	546	1466		1.60	0.000	0.000		0.340	0.200	122.0	0.000	0.000	0.000
9/1/88	6.21		143.0	131.0	175.0	14.3	908	1555	282	6.8	0.027	0.030		0.440	0.300	118.0	0.000	0.000	0.070
12/17/91	6.52	915	8.0	6.0	34.3	58.2	528	839	62	0.46	0.000	0.000		0.000	0.176	1.1	0.000	0.000	0.013
12/19/94	5.17	1194	5.0	25.7	2.9	1.2	537	802	39	4.57	0.010	0.000	95.2	0.000	0.330	70.8	0.000	0.000	0.000
4/12/02	9.19	204	16.4	0.4	23.3	0.3	53	104	84										
Packer V Discharge Downgradient																			
7/16/96	6.30	1257	162.0	0.0	20.8	9.1	391	1518	0	0.00	0.000	0.000	182.0	0.000	0.000	103.0	0.000	0.014	
2/4/97	6.40	1236	166.0	1.0	75.0	8.2	577	1074	8										
2/18/97	6.40	1234	170.0	42.0	19.3	8.0	558	1016	18										
12/20/99	6.96	1177	104.7	0.0	4.3	5.1	506	971	12										
10/23/00	6.88	1142	66.3	0.4	2.1	6.1	529	968	7										
12/26/00	6.39	1336	144.0	0.4	19.1	8.1	568	995	8	0.12	0.005	0.005	160.0	0.050	0.100	82.6	0.005		
5/16/02	6.33	1257	149.2	0.4	17.0	6.6	661	1007	11										

Figures 4.14a through 4.14d exhibit the concentrations with time for acidity, alkalinity, iron and sulfate respectively. These figures show that the two monitoring wells located near to the B-D ash disposal site have water quality behavior different from the downgradient Gilberton shaft minepool monitoring site. Neither well is a true upgradient minepool monitoring point, as described earlier, and MW008 replaced MW007 as the downgradient monitoring well in 1996 when ash placement advanced to the west. The most dramatic change in water quality in these monitoring points is the significant reduction in acidity, iron and sulfate in MW008 after its first two years of existence. It cannot be readily discerned from these time plots or other information in the permit file, whether these water quality improvements in the well are related to the effects of the large volume of alkaline coal ash or other local factors influencing the well site. However, similar improvements in water quality occurred in the South monitoring well site downgradient from the Reading/SER ash disposal site two years after it was drilled in 1987.

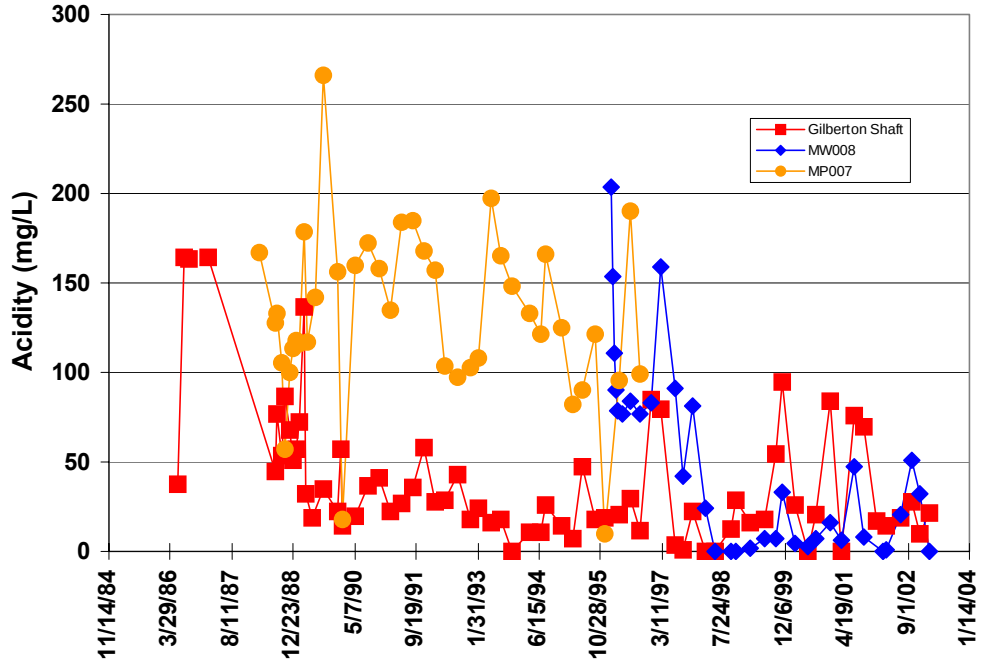


Figure 4.14(a). Acidity in groundwater monitoring points at B-D site.

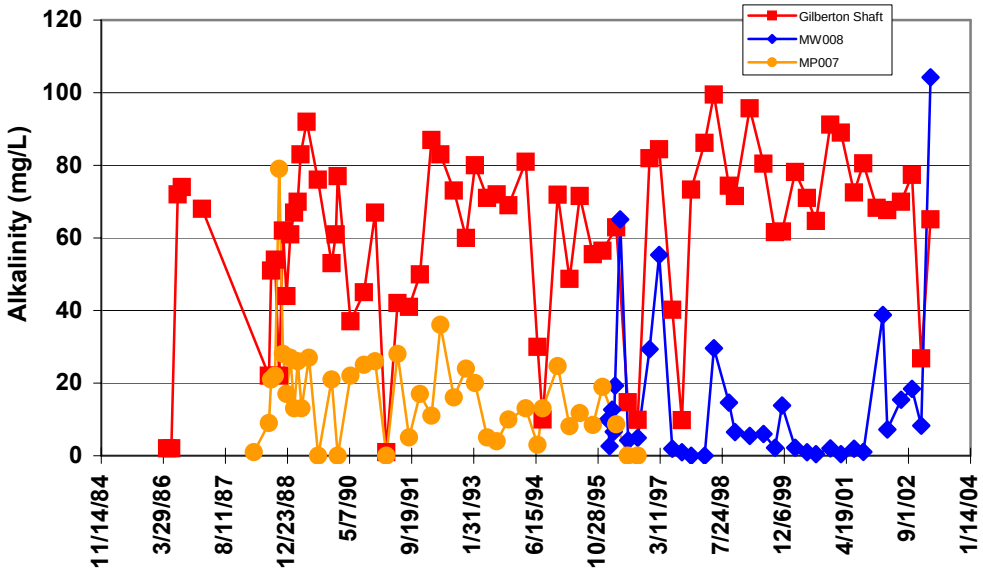


Figure 4.14(b). Alkalinity in groundwater monitoring points at B-D site.

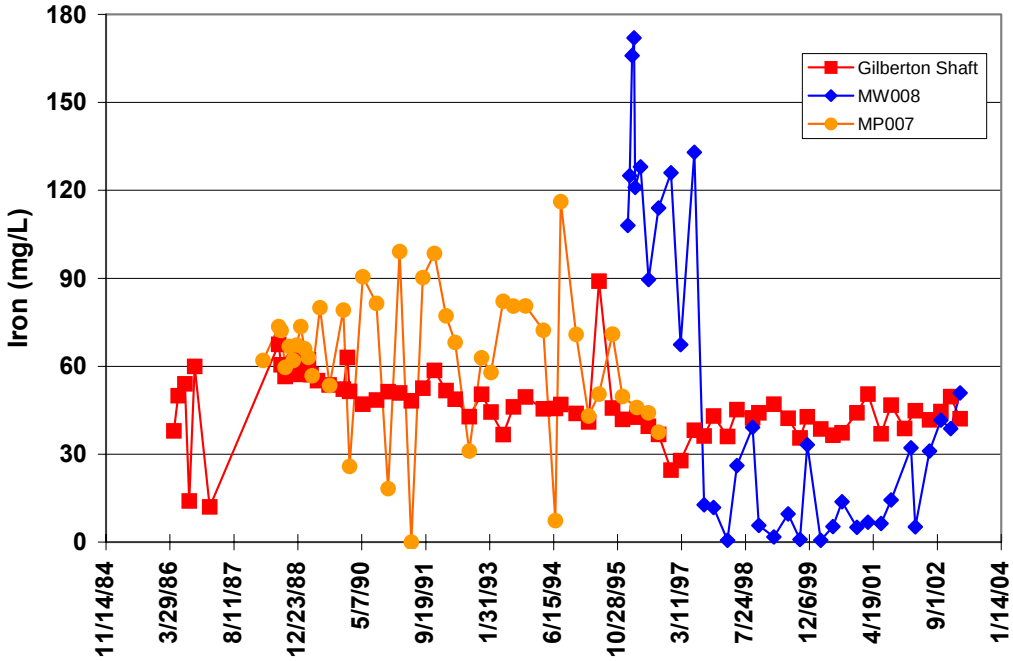


Figure 4.14(c). Iron in groundwater monitoring points at B-D site.

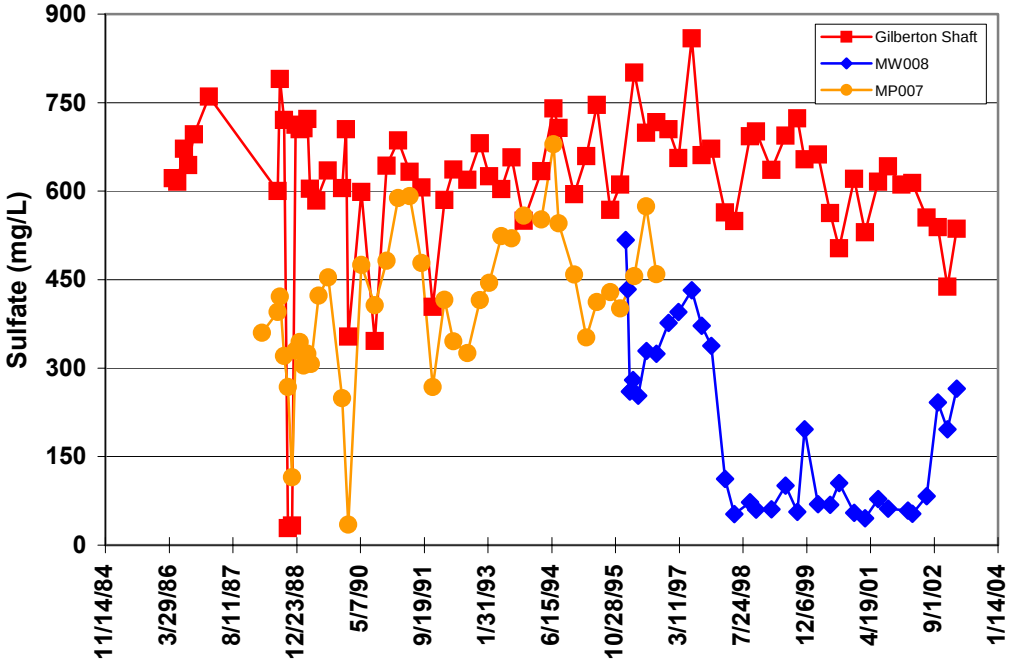


Figure 4.14(d). Sulfate in groundwater monitoring points at B-D site.

In MP008, acidity was much greater than alkalinity from January 16, 1996 through March 5, 1998, then alkalinity begins to exceed acidity. Later, acidity again exceeds alkalinity

but by a much smaller margin. In the South monitoring wells of the SER site, acidity exceeded alkalinity from September 3, 1987 to September 30, 1988 (with both parameters generally being greater than 100 mg/L), then acidity continues to exceed alkalinity, (but concentrations of both parameters are generally less than 50 mg/L) until November 8, 1995, after which alkalinity exceeds acidity from December 1995 to 2003, (generally alkalinity concentrations are more than double the acidity during this period). The median acidity concentration of the South borehole site for 1987 and 1988 is 161 mg/L and the median acidity for 1989 to 2003 is 4.10 mg/L, so there has been a significant reduction in acidity. The median iron concentrations for the same time periods were 168.5 and 22.6 respectively.

Figures 4.14a through 4.14d show that the water quality of the monitoring wells varies much more widely than the Gilberton shaft, except for alkalinity of the Gilberton shaft in Figure 4.14b. These data suggest that a more comprehensive and subtle approach to the groundwater data analysis is needed. Figures 4.15a through 4.15c were constructed to evaluate the patterns of variation for several analytes of concern (i.e. aluminum, iron and arsenic) in the solid ash, the SPLP leachate, and an array of groundwater monitoring points.

Figure 4.15a shows the patterns of variation for aluminum in the solid ash, the leachate and the groundwater samples occur over eight orders of magnitude. The median solid ash concentrations of the Gilberton and SER ash are 31,608 and 23,150 mg/kg respectively, while the corresponding median SPLP leachate concentrations for these samples are 2.24 and 2.27 mg/L. The three monitoring wells (South BH, MW7, MW8) are located downgradient of the B-D and SER ash sites and they were mostly installed after ash placement commenced and it was determined that these additional monitoring points were needed. Thus, the data from the first few years of monitoring were compared to the data for all of the later years to determine if there were any noteworthy changes. The data from the early years is shown as MW7-e, for example, and the later years as MW7-l. The median of the Gilberton shaft site from 1986 through 1990 is 0.88 mg/L, and the median of the data set from 1991 through 2003 is 0.81 mg/L. The median aluminum concentration of the Packer V discharge is 0.06 mg/L for 12 samples that are all below 1.0 mg/L. Therefore, the inference that can be made from the aluminum data arrayed in Figure 14.15a, (using medians of the frequency distributions as the measure of central tendency), is that the placement of more than 15 million tons of coal ash within the watershed did not result in significant aluminum increases in any of the downgradient monitoring wells, and the median aluminum concentration of the key downgradient minepool monitoring points at the Gilberton shaft and Packer V discharge have been relatively constant at less than 1.0 mg/L before ash placement to the present, despite the relatively high aluminum concentrations in the ash.

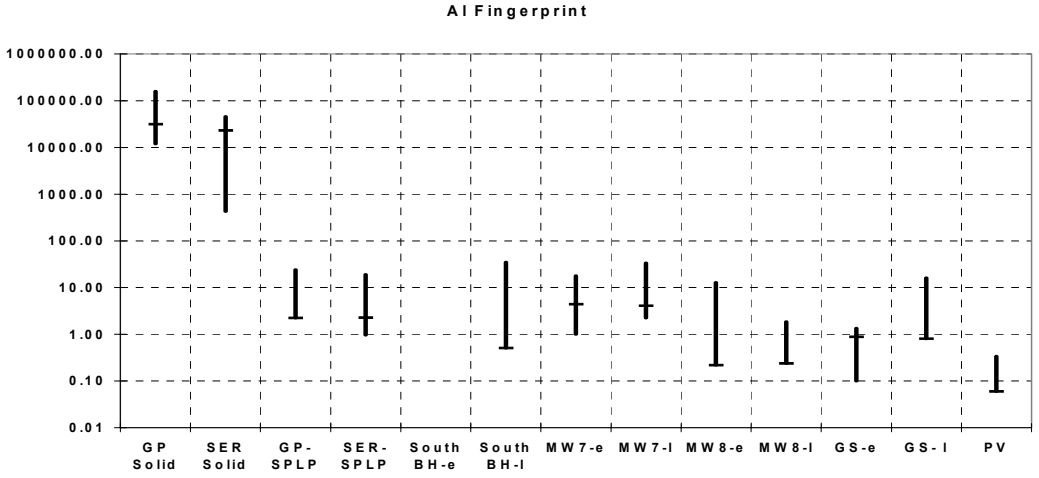
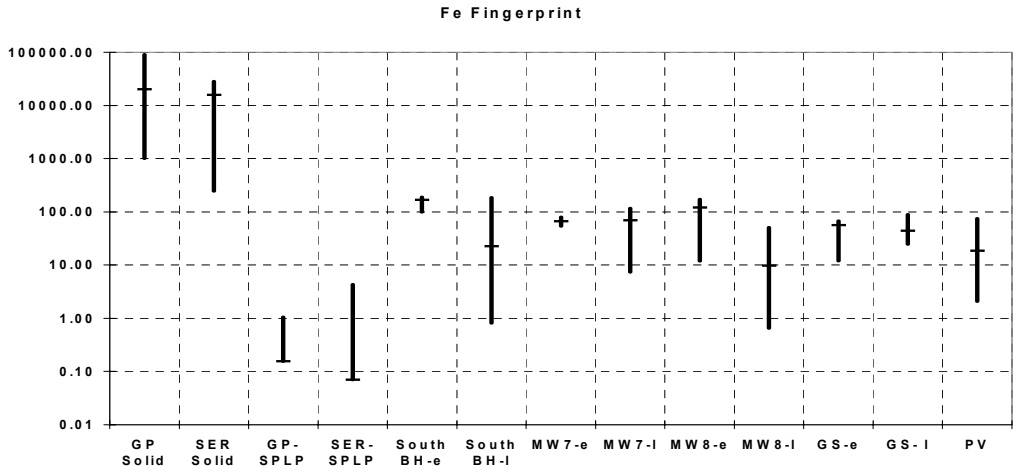
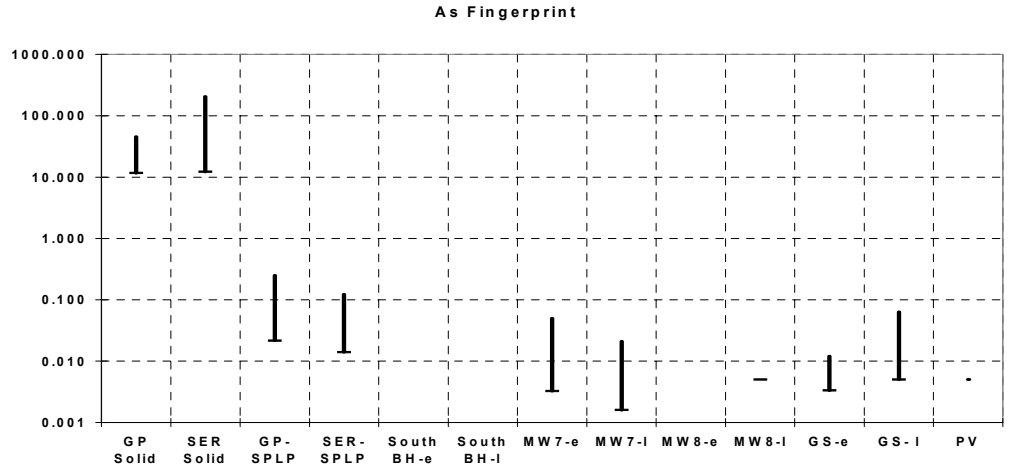


Figure 4.15(a). Aluminum content of solid ash, SPLP leachate and groundwater monitoring points (solid ash expressed in mg/kg, all other items expressed as mg/L).



4.15(b). Iron content of solid ash, SPLP leachate and groundwater monitoring points.



4.15(c). Arsenic content of solid ash, SPLP leachate and groundwater monitoring points.

The patterns of variation of iron concentrations in the solid ash samples from the two FBC power plants, the associated SPLP leachate, and the downgradient groundwater monitoring points are shown on Figure 4.15b. The median iron concentrations in the solid ash are similar at 19,995.5 for the Gilberton Power ash and 15,750 for the SER ash. The SPLP leachate medians for iron are both relatively low at 0.16 mg/L for Gilberton and 0.07 mg/L for SER. The three downgradient monitoring wells had interesting differences between median iron concentrations. MW007 had no significant change between the first 3 years of data and the remaining 6 years, because the median for the early years (MW7-e) is 66.7 mg/L and the median for the later years (MW7-l) is 69.5 mg/L. The median iron concentrations in the South BH and MW008 on Figure 4.15b show very substantial differences between the early and later years of monitoring. The first 2 years of data for the South BH downgradient of the SER ash site have a median of 168.5 mg/L (n=14), compared to the median for the later 14 years of 22.6 mg/L (n=80). The first 2 years of data for MW008 downgradient of the Gilberton ash site have a median of 121.5 mg/L, compared to the median for the later 5 years of 9.65 mg/L. The Gilberton Shaft pumped minepool discharge point is the key downgradient groundwater monitoring point for both coal ash placement sites and the median iron concentration for the first 4 years of monitoring is 55.83 mg/L (for 24 samples from 1986 to 1990), while the median for the last 12 years is 43.92 mg/L (for 49 samples from 1991 to 2003). The Packer V minepool overflow point further downgradient has a median iron of 18.5 mg/L. The conclusion that can be made for the entire data set of iron values shown on Figure 4.15b is that although more than 15 million tons of coal ash were placed in the drainage basin with high concentrations of iron in the solid ash samples, the median iron concentration at the downgradient Gilberton Shaft monitoring point decreased by 12 mg/L, and the median iron concentrations in two monitoring wells immediately downgradient of the two coal ash placement areas decreased by an order of magnitude (i.e. from >160 mg/L to <25 mg/L in South BH, and from >120 to <10 mg/L in MW008).

The patterns of variation of arsenic are shown in Figure 4.15c. The median arsenic concentrations in the solid ash are similar, with the Gilberton Power ash at 11.6 mg/L and the SER ash at 12.17 mg/L. The median concentration of the SPLP leachate for the Gilberton ash sample is 0.02 mg/L, while the medians for all of the other leachate and groundwater frequency distributions in Figure 4.15c are 0.01 mg/L or less than that. The highest arsenic concentration in 38 samples of SPLP leachate from the Gilberton ash was 0.25 mg/L, while the highest arsenic concentration in 25 samples of SPLP leachate from the SER ash was 0.123 mg/L. The highest arsenic concentration in any of the groundwater monitoring point data sets is 0.063 mg/L for one sample from the Gilberton Shaft.

4.3.4 Susquehanna Coal Company – Mt. Carmel Cogeneration Site

During a night of 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 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, Pennsylvania 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. 4.16). 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. 4.17b).

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 4.16. 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. 48 shown on Figure 4.16 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 4.16 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 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 dimension of the SMP boundary shown on Figure 4.16. Hence, the abandoned surface mine pits and the extensive abandoned coal refuse piles within the permit area shown on Figure 4.17, 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. 4.17). 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 4.16. Apparently, this groundwater flow system functions effectively as an underdrain for the site.

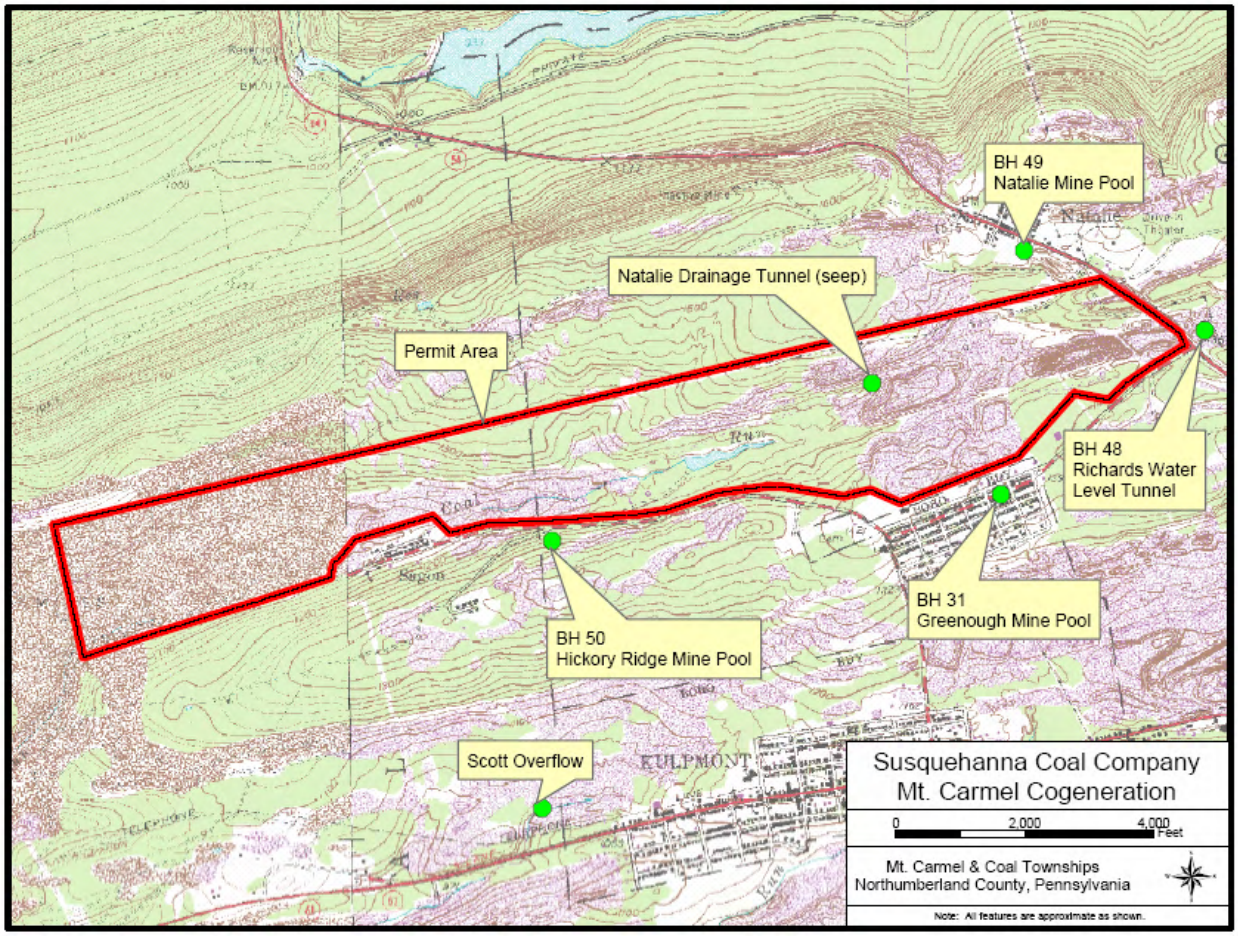


Figure 4.16. Site map of Susquehanna Coal – Mt Carmel Cogeneration site.

The Mount Carmel cogeneration plant consumed a total of 8,078,820 tons of coal refuse from 1990 through 2002, and produced 5,432,975 tons of alkaline coal ash for mine reclamation on-site during that 13 year period. The average yearly culm consumption was 621,448 tons, and the average annual coal ash production was 417,921 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. Recent permit maps show the active coal ash placement area is 21.26 acres.



Figure 4.17(a). Abandoned pits and refuse piles at start of ash placement.



4.17(b). 10 years of ash placement and reclamation of pit.



4.17(c). Coal ash deposit greater than 50 feet thick near conveyor.



4.17(d). Scott Overflow monitoring point.

Groundwater monitoring data for five of the monitoring points shown on Figure 4.16 are compiled in Table 4.5. These data are representative samples of quarterly and annual groundwater monitoring by the permittee from 1989 through 2003. Borehole No. 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. This upgradient monitoring well was intended to be a companion to the other upgradient well, Borehole No. 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 Borehole 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.

Table 4.5. 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						

Borehole No. 31 in the Greenough minepool and Borehole No. 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.

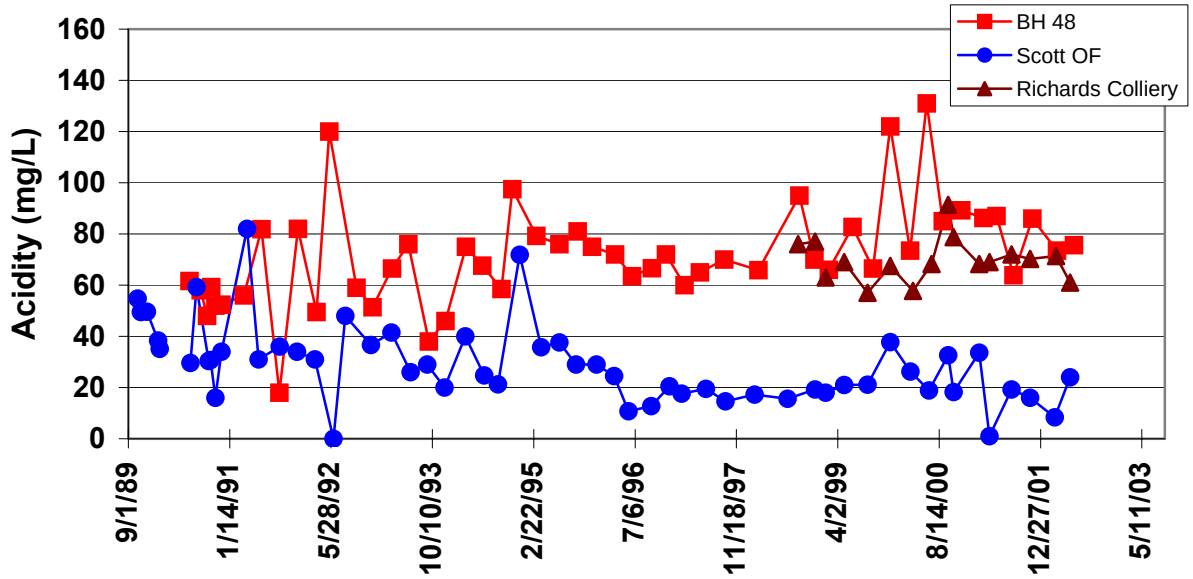


Figure 4.18(a). Acidity in upgradient monitoring points and downgradient Scott Overflow at the Susquehanna site.

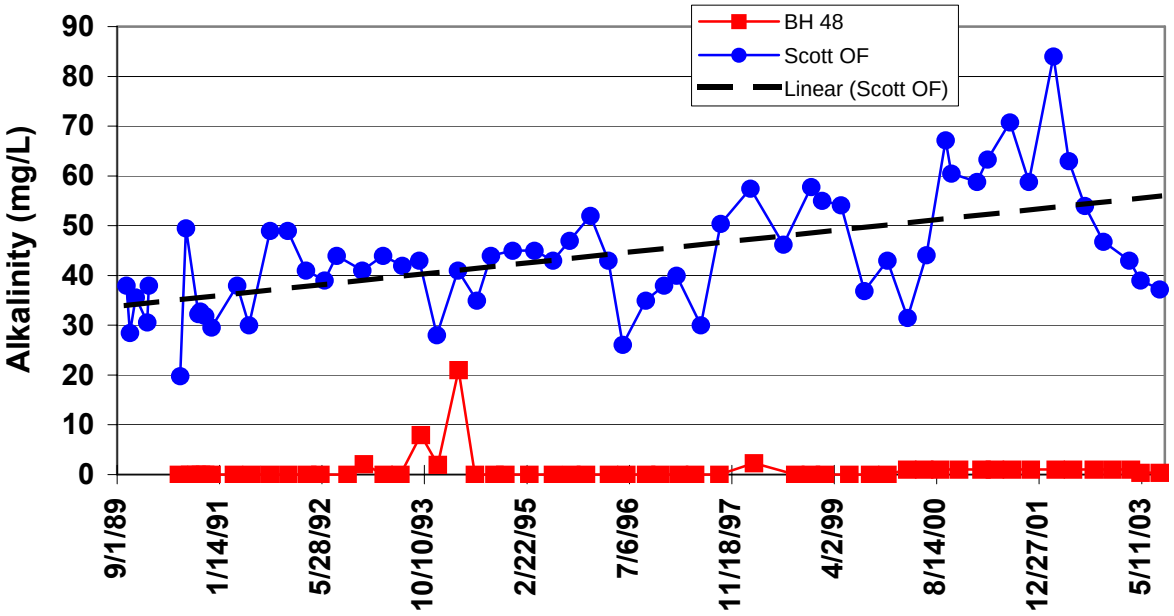


Figure 4.18(b). Alkalinity increase in downgradient Scott Overflow.

The location of Borehole 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 is little value in groundwater quality interpretation related to the surface mine and ash placement site. The sulfates in Borehole 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.

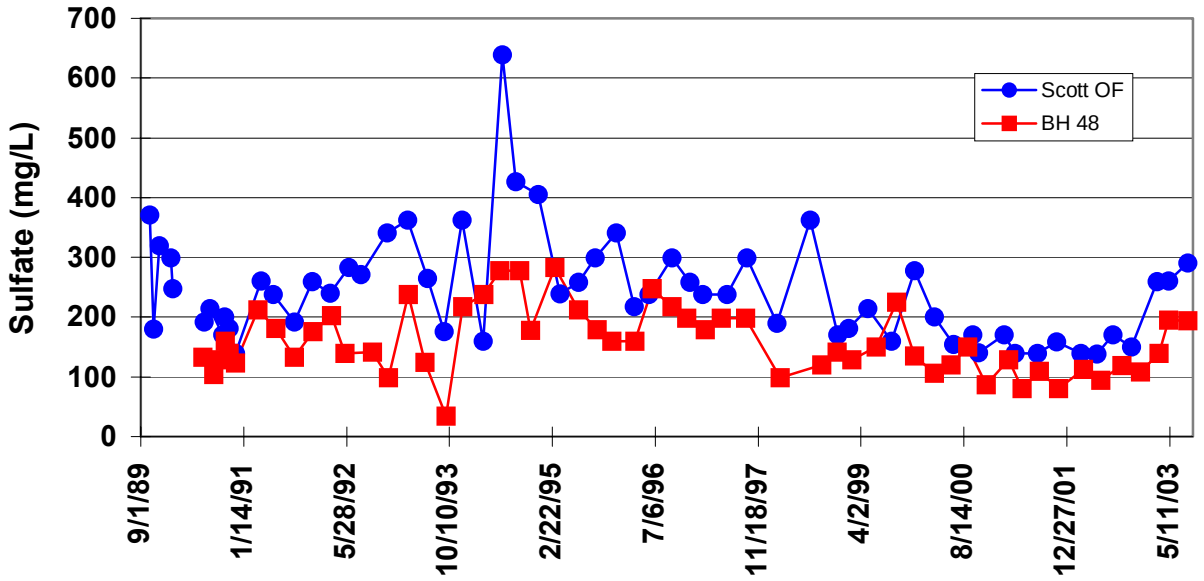


Figure 4.18(c). Sulfate in monitoring points at the Susquehanna Coal site.

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 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 4.18a 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 4.18b. 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 4.18c. 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.

4.4 DISCUSSION AND CONCLUSIONS

4.4.1 Groundwater Monitoring Summary

The potential difficulties and complexities of developing realistic groundwater monitoring plans for some coal ash placement sites in the anthracite region of Pennsylvania were discussed in Section 4.2. That section also described the multitude of abandoned underground mines (collieries) in the four anthracite coal fields, and the presence of large multi-colliery hydrologic units, that have resulted over time (during deep mining and post-mining) due to breached barrier pillars and other interconnections between adjacent collieries. Examples of major abandoned underground mine discharge points, draining thousands of acres of these hydrologically interconnected collieries, were given in Section 4.2, and minepool monitoring data for several of these large discharge points located downgradient from coal ash sites was tabulated for the Gilberton Shaft and Packer V discharges (Table 4.4) in Section 4.3.3, and for the Scott Overflow discharge (Table 4.5) in Section 4.3.4.

The potential problems of locating and drilling meaningful monitoring wells for upgradient and downgradient monitoring of coal ash sites was also discussed in Section 4.2. In each of the case study sites described in Section 4.3, there were some monitoring well difficulties related to the presence of problems with the well(s) or the absence of good monitoring well locations. On the Alden site the upgradient wells behaved erratically and appeared to be independent of the downgradient wells and the Alden shaft (Fig. 4.5), although all five of these monitoring points were located within the shoreline of the Alden minepool. On the Wheelabrator site, the downgradient Morea minepool discharge point showed some subtle signs of water quality improvements through time (Fig. 4.8) that may be related to coal ash placement, but the absence of one or more upgradient monitoring wells in the Morea or New Boston collieries make interpretation of the data more difficult. In the area of the B-D Mining permit site, it was stated that an upgradient minepool monitoring well location for the main ash disposal silt dam could not be located, due to the barrier pillar configuration between the Boston Run and Tunnel Ridge Collieries. In addition, the water quality fluctuated widely in downgradient monitoring wells MW007 and MW008 for the B-D ash area (Fig. 4.14) and the downgradient South well for the SER ash area, while some meaningful data were obtained from these three

wells. On the Susquehanna mine site, two of the four monitoring wells do not provide meaningful minepool data, and a third well is of questionable value. Upgradient monitoring well BH49 may be outside of the shoreline of the Natalie pool or influenced by other factors, because its water quality does not resemble mine drainage (Fig. 4.16). Downgradient Borehole 50 in the Hickory Ridge Colliery also lacks the chemical signature (i.e. it has very low sulfate concentrations) of acidic or neutralized mine drainage, and Borehole 31 in the Greenough pool is questionable. Fortunately, Borehole 48 appears to be a good upgradient monitoring well for this site, and the Scott Overflow is an effective downgradient groundwater monitoring point.

These observations from minepool monitoring wells lead to some conclusions and recommendations about the relative usefulness (advantages and disadvantages) of monitoring wells, shafts and minepool overflows as meaningful groundwater monitoring points. This also leads to the conclusion that monitoring wells are not the only tool or sole source of good groundwater data; shafts, tunnels, airways and other deep mine openings may be suitable groundwater monitoring points.

The Gilberton Shaft described in Section 4.3.3 is an ideal groundwater monitoring point, because the minepool there is continuously pumped at 11,300 gpm by the DEP Bureau of Abandoned Mine Reclamation (to prevent flooding of homes in the village of Gilberton) and discharged to the Mahanoy Creek. Thus, it functions like a giant pumped water well, drawing down the minepool, and inducing groundwater flow to it that might otherwise bypass a more static shaft location. It also serves as a very accessible groundwater sampling site (i.e. the pumped discharge). However, with respect to sampling accessibility, many shafts in the four anthracite fields were filled in by the state and federal government, to eliminate mine hazards and public health and safety problems. The Packer V minepool overflow in Girardville, as described in Section 4.3.3, and the Scott Overflow described in Section 4.3.4 are good examples of large minepool discharges from multi-colliery hydrologic units, that serve as useful downgradient monitoring points for coal ash placement sites.

The purpose of this groundwater monitoring summary is to illustrate that developing realistic groundwater monitoring plans for anthracite coal ash sites should include some combination of monitoring wells and shafts or minepool overflow discharges, because each of these groundwater monitoring tools has been shown, in the four case studies and the discussion in Section 4.2, to have some advantages and disadvantages – so there is no guarantee that any of these tools alone, is sufficient to get the job done. Also, the summary and case study sites data hopefully conveys the reality that interpretation of minepool monitoring data can be tricky business – so scientists from regulatory agencies, academia, industry and environmental groups should be mindful of the potential complexities, and careful and thorough in their interpretations and conclusions about the effects of coal ash sites upon the minepool chemistry.

4.4.2 Factors Influencing Detection of Beneficial or Adverse Effects of Coal Ash Sites Upon Minepool Discharge Quality

Some anthracite coal ash sites exhibit a distinct effect upon minepool chemistry (e.g. reduction in acidity/increased alkalinity) at downgradient minepool discharge sites; for other coal ash sites any effects are more subtle, ranging from barely discernable to non-detectable. The last

two categories include monitoring points where there is little to no apparent change in water quality parameters over time, and graphs where the sample to sample variation is so great and erratic that no trend can be discerned. The following characteristics of the coal ash placement site and the minepool system are believed to determine the magnitude of any water quality effects:

- The size of the minepool drainage area (for multi-colliery hydrologic units, the subsurface groundwater drainage area may be thousands of acres, and include more than one surface-water watershed, e.g. Jeddo Tunnel drains 32.24 square miles).

- The flow volume of the minepool discharge (should be proportional to the first factor of drainage area size; some minepool discharges are on the order of a hundred(s) of gallons per minute, the Jeddo Tunnel averages 40,000 gpm and was measured at 190,000 gpm in 1996 by USGS and DEP).

- The size of the coal ash placement area and ash volume (a 10 acre ash site may not produce a detectable change in the typical minepool discharge, but a 100 acre site might).

- The ratio of the coal ash site acreage to the minepool drainage area acreage.

- The thickness and permeability of the coal ash deposit (on the Wheelabrator site the coal ash was placed in relatively thin layers or lenses, less than 25 feet thick in relatively shallow abandoned surface mine pits; on the B-D Mining and SER ash sites, the ash was placed in abandoned coal silt dam structures, with a total ash thickness of 50 to 100 feet).

- The bulk chemistry and mineralogy of the coal ash deposit (if the coal ash is from a FBC plant and contains a significant amount of unreacted calcium hydroxide, the Neutralization Potential value of the ash will be high, and the ash deposit should produce high pH, high alkalinity groundwater flow to the minepool).

- The acidity to alkalinity ratio in the minepool (some anthracite minepool discharges have relatively high acidity and negligible alkalinity, some have relatively high alkalinity and negligible acidity, and some have appreciable acidity and alkalinity concentrations (50 mg/L to > 100 mg/L of both) – which is relatively rare in natural groundwaters in Pennsylvania (see the Gilberton Shaft and South boreholes in Table 4.4 and the Scott overflow in Table 4.5, compared to the Wheelabrator example in Fig. 4.8a)).

- The geologic structure underlying the surface mine coal ash site and the associated minepool (e.g. the Susquehanna site is in a relatively tight synclinal structure, and groundwater flow within this trough-like structure is apparently connected to the Scott Overflow).

- Underground mine development features (e.g. gangways, rock cross-cut tunnels, inside slopes) that may serve as conduits or pathways to direct minepool/groundwater flow from coal ash sites toward or away from (bypass) downgradient groundwater monitoring points.

Three possible interpretive scenarios emerge from interactions of the coal ash site and minepool characteristics listed above: (a) significant improvement in water quality parameters at minepool monitoring points from beneficial use of coal ash in mine reclamation, (b) no significant change in minepool chemistry associated with the coal ash, and (c) a significant degradation in minepool chemistry and pollution loading at downgradient minepool discharge locations attributable to the coal ash placement. Fortunately, for the interests of the coal mining/electrical power production industry, the environmental regulatory agencies, and the environmental/citizens groups, none of the type (c) environmental damage scenarios have been found in more than 15 years of compliance monitoring and inspections of anthracite ash sites by DEP staff. The Susquehanna and Westwood sites exhibit significant improvement in alkalinity (type (a) behavior) at downgradient minepool monitoring points (see Figs. 4.18 a and b, and Fig. 4.19), presumably due to a relatively small ratio of minepool drainage area size to coal ash placement area acreage, bulk chemistry of the FBC ash, and favorable geologic structure and underground mine development features, to convey groundwater flow from the coal ash site to the minepool monitoring points. The Northampton-Alden site, the Wheelabrator site, and the B-D/SER sites exhibit the type (b), no significant change, behavior in varying degrees, for a variety of known and unknown reasons. However, when hundreds of acres of abandoned mine lands on these sites are reclaimed (at no cost to the government or taxpayers) with millions of tons of FBC coal ash that contains large amounts (tens of thousands of mg/kg) of aluminum and iron, and there is no discernable degradation of downgradient minepool discharge points with these metals or other analytes of concern, the overall project still represents a significant environmental benefit.

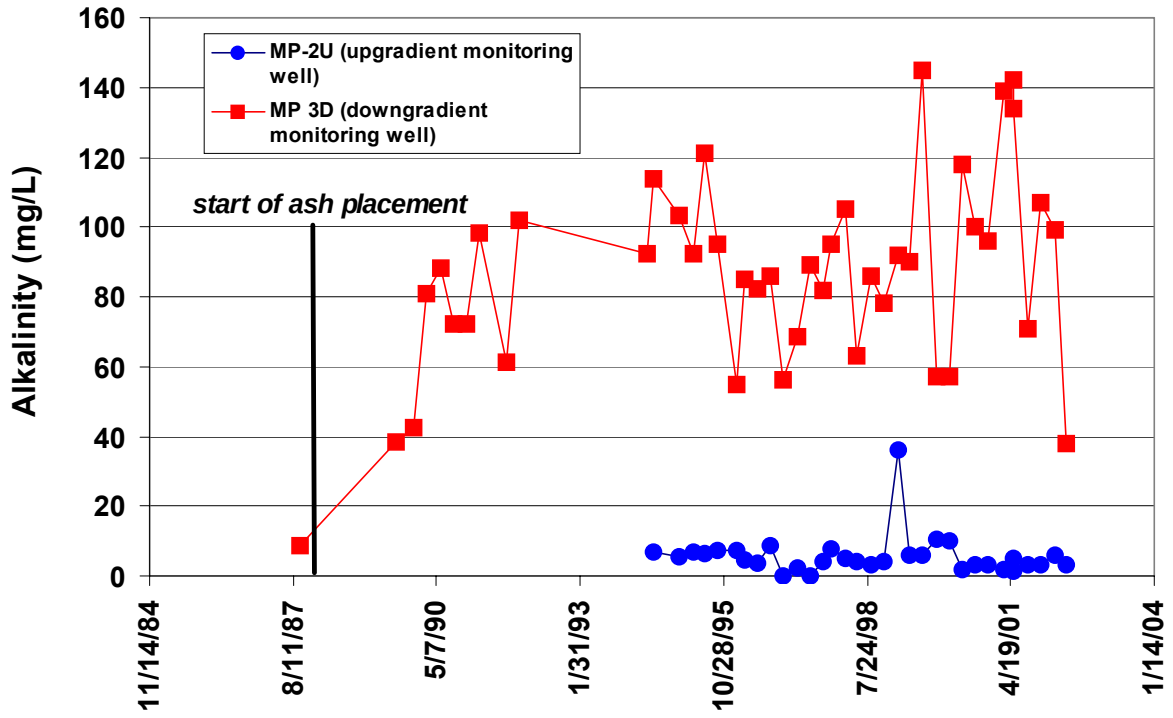


Figure 4.19. Alkalinity in upgradient and downgradient monitoring wells at the Westwood FBC power plant site.

4.4.3 Applicability of a Hydrologic Budget Approach to Beneficial Use of Coal Ash in Reclamation of Abandoned Surface Mines

The concept of a hydrologic budget and practice of constructing various types of these hydrologic budgets is described in numerous hydrogeology texts including Walton (1970), Davis and DeWiest (1966), Freeze and Cherry (1979) and White (1988). According to Walton (1970, p. 375), "A hydrologic budget is a quantitative statement of the balance between the total water gains and losses of a basin, for a period of time. The budget considers all waters, surface and subsurface, entering and leaving or stored within a basin. Water entering a basin is equated to water leaving a basin, plus or minus changes in basin storage". Typically a hydrologic budget is stated as an equation where precipitation equals the sum of numerous components such as surface runoff, groundwater runoff, subsurface underflow, evapotranspiration (ET), change in soil moisture and change in groundwater storage.

A hydrologic budget for the Jeddo Tunnel Basin in the Eastern Middle Field near Hazleton, PA was developed by Ballaron (1999) of the Susquehanna River Basin Commission. In that study, precipitation records were available from several weather stations in the Hazleton area; continuous flow measurements of the Jeddo Tunnel were recorded by USGS (see Fig. 2.17a; and surface runoff was computed based upon flow measurements of several creeks exiting the basin. Ballaron (1999) assumed that recharge equals discharge, so the storage factor in the equation could be ignored, and therefore evapotranspiration was calculated by difference, since surface runoff and groundwater runoff (Jeddo Tunnel discharge) were known from the measurements described above. From an average of three years of measurements (1996 to 1998) Ballaron (1999) computed precipitation of 48.5 inches, equals 3.46" surface runoff (7.1%), plus 32.18" Jeddo Tunnel discharge (66.4%), plus 12.87" evapotranspiration (26.5%). The percentages of water attributable to surface runoff and evapotranspiration in this budget are considerably lower than unmined, well-vegetated watersheds, but it was determined during the study that extensive acreages of abandoned surface mine pits and numerous mine subsidence features in streambeds, within the basin, account for a large percentage of infiltration to the minepool system – and consequently a small percentage of surface water runoff. It was also determined that the low rate of evapotranspiration was related to a lack of luxuriant vegetation, which is in turn related to the lack of well-developed soils on abandoned mine spoils.

The purpose of this hydrologic budget discussion is to briefly evaluate the effects of coal ash placement in abandoned surface mine reclamation as a component in the post-reclamation hydrologic budget. The Wheelabrator case study site described in Section 4.3.2 is selected for this purpose because it is near Hazleton, and the surface water/groundwater relationships are very similar to the Jeddo Tunnel basin, but on a smaller scale – so the hydrologic budget components in Ballaron (1999) are relevant for the pre-reclamation site conditions. Figure 4.6 and the site description in Section 4.3.2 document that there was very little surface runoff from the permit area because the tributary to Mill Creek entering the eastern end of the permit, goes subsurface to the minepool near to the upgradient monitoring point 001, and most of the permit area was covered by extensive abandoned surface mine pits and spoil piles prior to remining and coal ash placement by Wheelabrator. Therefore, the 7.1% surface runoff value used by Ballaron (1999) is probably reasonable and applicable here. Also, the 26.5% evapotranspiration used by Ballaron (1999) is probably applicable, and may be too low for the Wheelabrator site because

some areas of the 32.24 square miles of the Jeddo Basin study area were forest covered and would promote higher ET values than the extensively strip mined Wheelabrator site. Using the values from Ballaron (1999) to evaluate the before remining conditions of a 10 acre phase of the Wheelabrator permit area, the annual precipitation of 48.5 inches falling on that 10 acres equals 13.2 million gallons, the surface runoff would be 0.94 million gallons, and the evapotranspiration would be 3.5 million gallons. Therefore the amount of water infiltrating to the minepool from that unreclaimed 10 acre phase would be 8.76 million gallons.

During the coal ash placement and reclamation of cross-hatched areas shown on Figure 4.6 at the Wheelabrator site, the ash was dumped in the working area as shown on Figure 4.7a and spread and compacted in lifts of 2 to 4 feet. At least 8 feet of fill (abandoned mine spoil or coarse refuse material) was placed in the base of abandoned pits, for site preparation, prior to placing the ash in the pit, and 8 feet of that spoil material was placed against any highwall or low wall of the abandoned pit, with 4 feet of mine spoil cover material placed on top of the final compacted ash surface. Thus a cross-section through the relatively shallow abandoned pits (40 ft depth) on the Wheelabrator site would show a lens-shaped compacted ash deposit of about 20 to 25 feet thickness, with an estimated permeability in the range of 10^{-5} to 10^{-6} cm/sec groundwater flow, surrounded by more coarse mine spoil (bottom, side and top cover material), with an estimated permeability in the range of 10^{-1} to 10^{-3} cm/sec. These permeability estimates for the mine spoil are based upon summary statistics of hydraulic conductivity (K values) reported in Hawkins (2004) and related data in Hawkins (1998) and Hawkins and Aljoe (1991). Groundwater velocities ranging from 1 to greater than 370 meters per day have been recorded in mine spoil of the Appalachian Plateau, according to Hawkins (1998, 2004). Following final grading, with the top one foot of final cover being the best available spoil/soil material on site, the site was revegetated with a mixture of trees, grasses and legumes as shown in Figures 4.7b and 4.7d. The result of this regrading and revegetation of the abandoned mine lands is a significant increase in surface runoff and evopotranspiration, as compared to the hydrologic budget items computed above for site conditions before remining.

A reasonable figure for evapotranspiration from this type of reclaimed surface mine site would be 20 inches/year (M.W. Smith, personal communication, 2004), and an approximate surface runoff of 9.7 inches/year was computed from other hydrologic budget studies in central Pennsylvania (e.g. Taylor et al., 1983; Taylor and Werkheiser, 1984) where annual surface runoff was about 20% of the annual precipitation values. Therefore in the post-reclamation hydrologic budget for the Wheelabrator site area with the presumed annual precipitation of 48.5 inches; the surface runoff term in the hydrologic budget equation would be 9.7 inches (20%) and the evapotranspiration would be 20 inches (41.2%) with the remainder in groundwater runoff/minepool discharge of 18.8 inches (38.8%). The comparison of these revised hydrologic budget values to the unreclaimed site conditions for the 10 acre remining phase, would commence with the annual precipitation of 13.2 million gallons, minus the reclaimed site surface runoff of 2.64 million gallons, minus the revegetated site ET of 5.44 million gallons, to yield the reduced groundwater recharge amount of 5.12 million gallons (compared to 8.76 million gallons in the reclaimed mine site). Total reduction in mine recharge was 3.64 million gallons per year. Given the assumption that recharge to the minepool equals discharge, the flow of the Morea/New Boston minepool discharge at the downgradient monitoring point (002) should decrease by about 41.6 percent, after the entire site is reclaimed.

There may be some zones of saturation within the backfilled mine spoil or the coal ash deposit (i.e. groundwater storage), but the minepool is the regional groundwater table of the area, and pursuant to the residual waste regulations and permit conditions, the coal ash must be at least 8 feet above the regional groundwater level (i.e. the "high and dry" concept). Thus, most of the groundwater flow from the point of recharge to the minepool should be under unsaturated conditions, and given the permeability contrast between the compacted ash lenses/layers and the surrounding mine spoil, most of the infiltrating groundwater should run off of the upper ash surface or flow around the ash deposit (with mine spoil permeability 2 to 6 orders of magnitude greater than compacted ash) before entering the minepool flow system. The generally unsaturated conditions of the backfill and the sloping top surface of the ash deposit should result in very little head buildup on top of the ash deposit, and in the absence of substantial head it will be difficult to drive much infiltrating water through the ash deposit. If the pozzolanic reactions are occurring within the fine-grained, compacted coal ash deposit, it is even less likely that significant quantities of groundwater will flow through the ash deposit. Nevertheless, some groundwater will flow through the coal ash deposit, with a substantial residence time, and discharge to the minepool.

From the hydrologic budget calculations described above, a rough estimate is made here, that of 5.12 million gallons of recharge in the 10 acre reclaimed area, less than 0.5 million gallons per year would flow out of the ash deposit with a high alkalinity concentration. A much lower amount of groundwater draining from the ash deposit annually under this scenario would result if different permeability contrast values from the literature were used (i.e. greater spoil permeability and/or lesser ash permeability), or if the terms of the hypothetical case presented in Chapter 11 are applicable to the Wheelabrator site. However that high alkalinity groundwater flow component would commingle with the many millions of gallons of groundwater in the minepool, and would result in a modest acidity reduction in the downgradient groundwater monitoring point, as shown in Figure 4.8, rather than a significant alkalinity increase in the minepool discharge. The purpose of this discussion has been to document that the "high and dry" coal ash placement concept is apparently working well on mine sites like the Wheelabrator site.

4.4.4 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. 4.17 a and b), but also in the total acreage reclaimed (at no cost to the government or taxpayers) as shown in Chapter 1.

2. The evaluation of more than 15 years worth of groundwater monitoring data for the case study sites presented in this chapter, and other permitted sites throughout the anthracite region, has not resulted in any significant findings of environmental damage groundwater pollution cases, as measured at key downgradient minepool monitoring points. Several sites discussed in this chapter 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 two sites discussed in this chapter 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 chapter 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 some of the case study sites and the hydrologic budget discussion demonstrate that the "high and dry" concept of placing relatively dry (optimum moisture content) coal ash into a relatively dry mine environment is working well. The three other ash placement/minepool scenarios presented in this book (i.e. generally described in Chapter 1, and in detail in Chapters 7, 8 and 9) provide significant information for regulatory agencies to evaluate in determining whether the technology employed in these one-of-a-kind demonstration permit ash placement alternatives should be authorized for a range of other site-specific beneficial use applications. 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.

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.

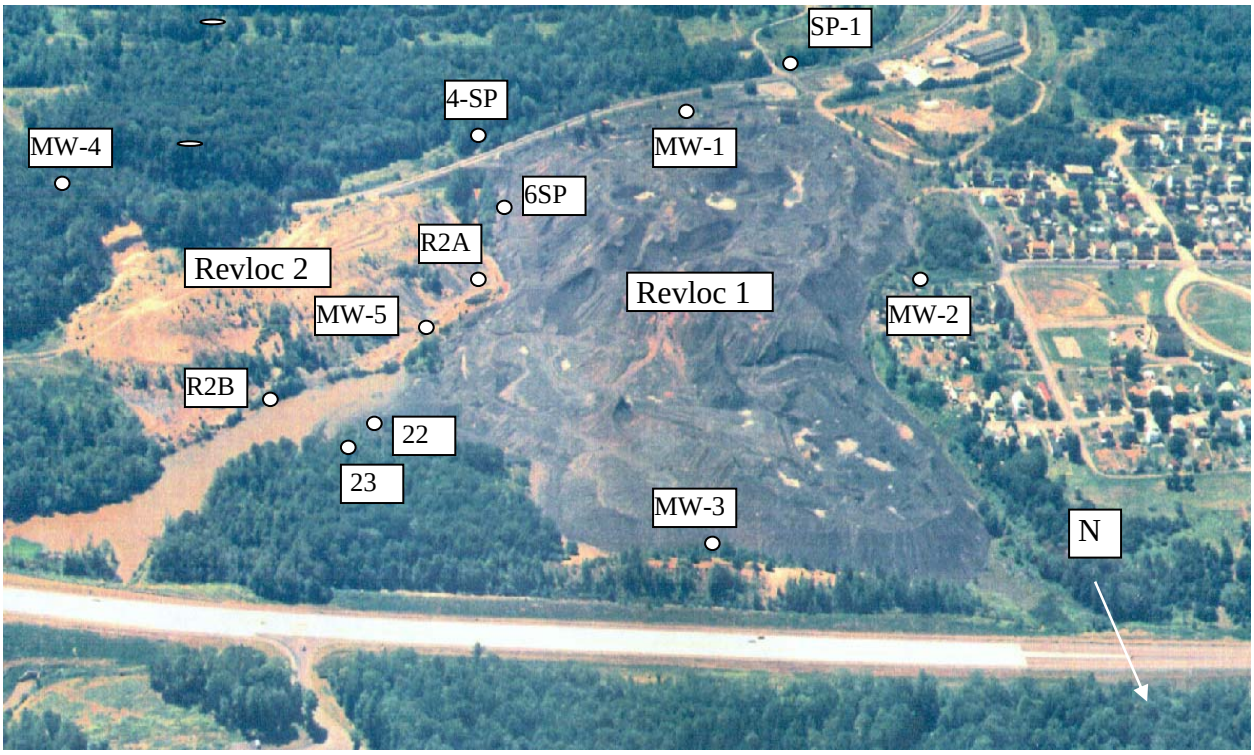


Figure 5.2. Aerial photo circa 1988 showing the Revloc sites and key associated monitoring reports. The photo was obtained from the permit application for Revloc 1.

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.

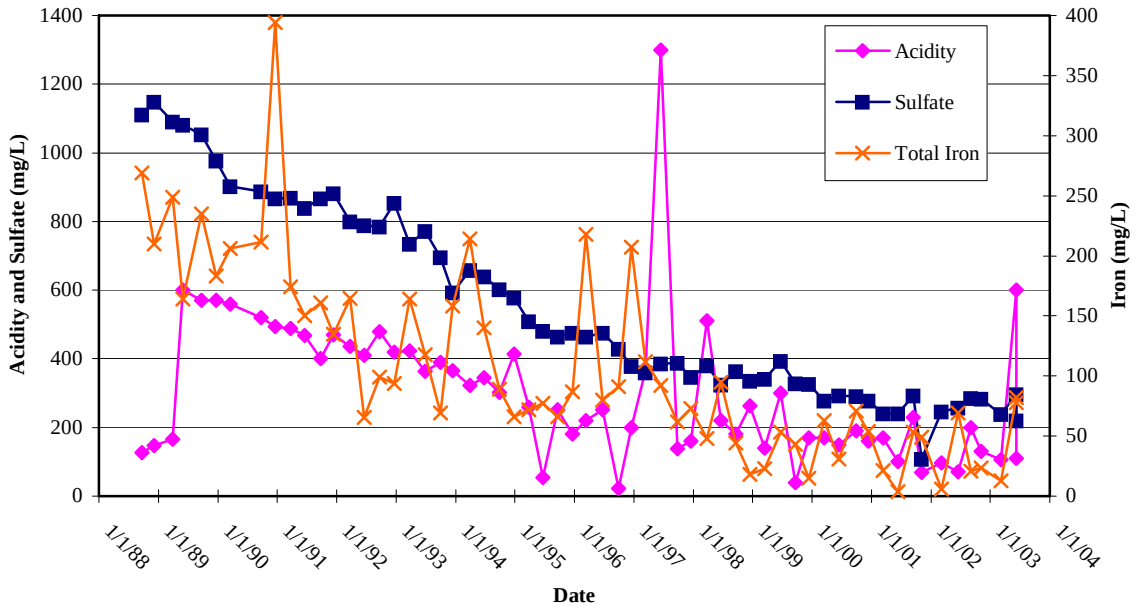


Figure 5.3. Graph of acidity, sulfate and iron at MW-1.

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.

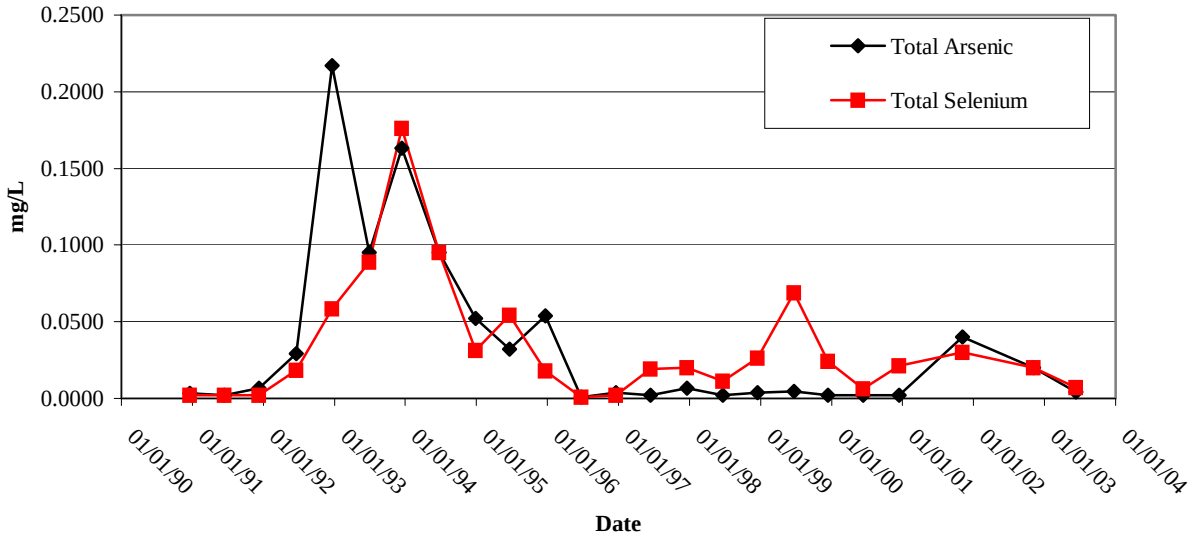


Figure 5.4. Graph of selenium and arsenic concentrations at MW-1.

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.

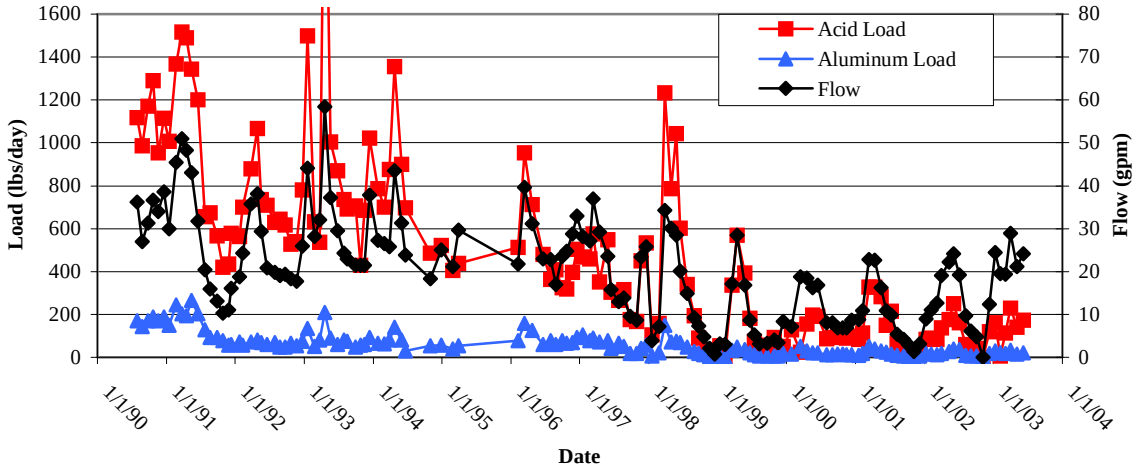


Figure 5.5. Flow, acid load and aluminum load at discharge 4SP.

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.

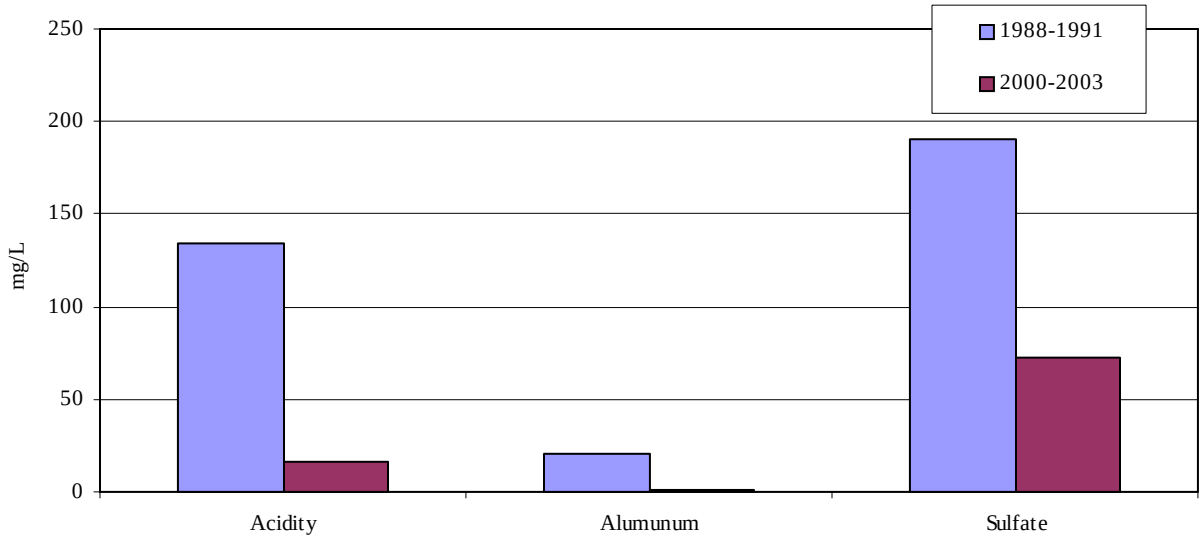


Figure 5.6. Comparison of background and recent median acidity, aluminum and sulfate concentrations at monitoring point SP-1, downstream of the Revloc sites.

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.

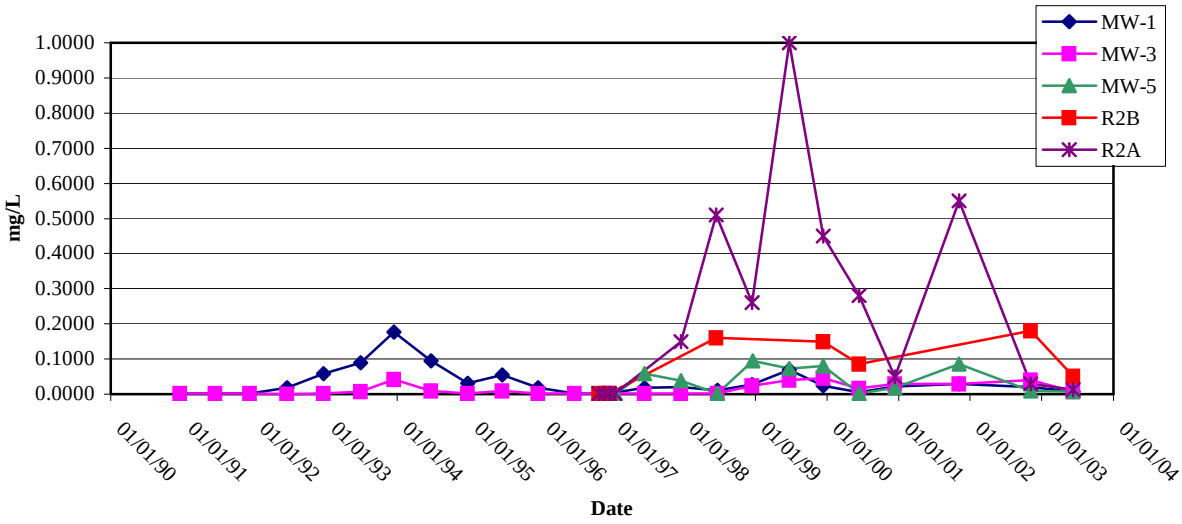


Figure 5.7. Selenium concentrations at downgradient ash monitoring points at the Revloc sites.

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.)

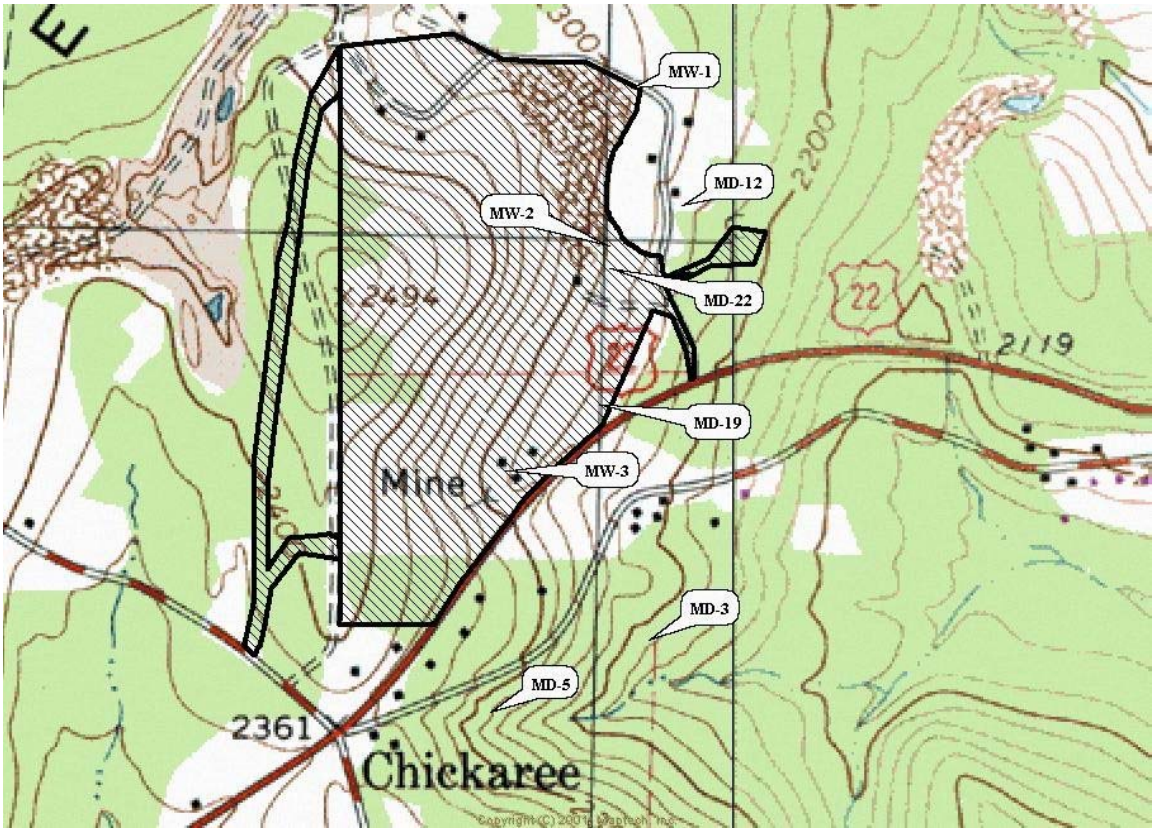


Figure 5.8. Map showing the locations of the McDermott Mine monitoring points.

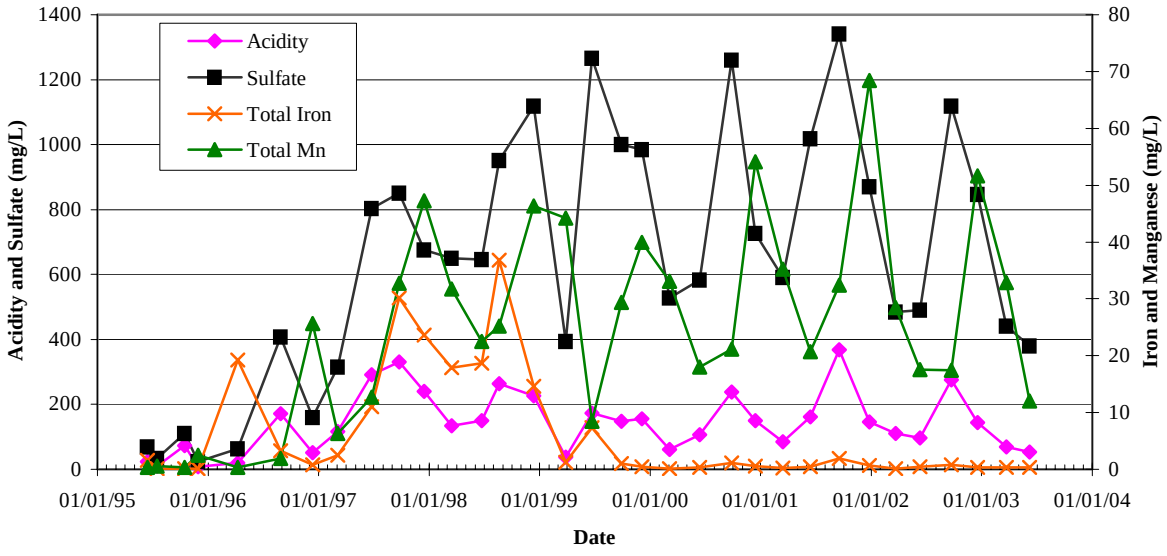


Figure 5.9. Mine drainage parameters at spring MD-12.

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.

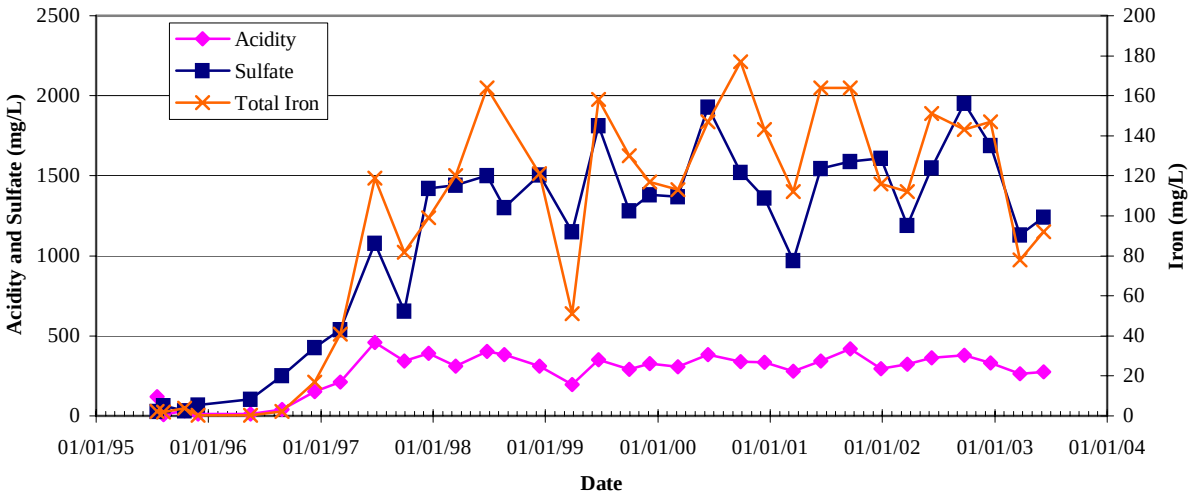


Figure 5.10. Acidity, sulfate and iron at MW-2.

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.

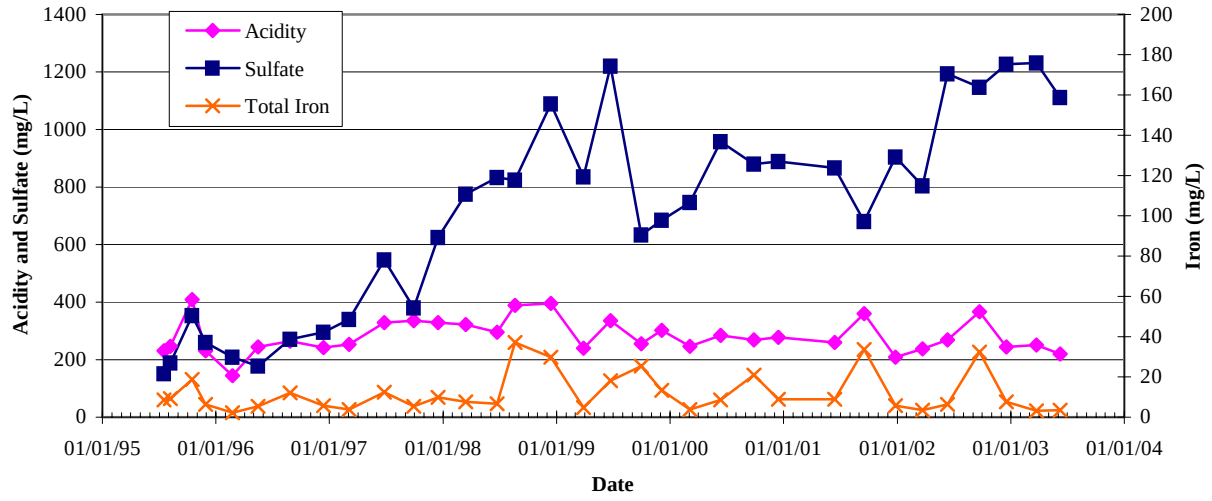


Figure 5.11. Acidity, sulfate and iron at MW-1.

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.

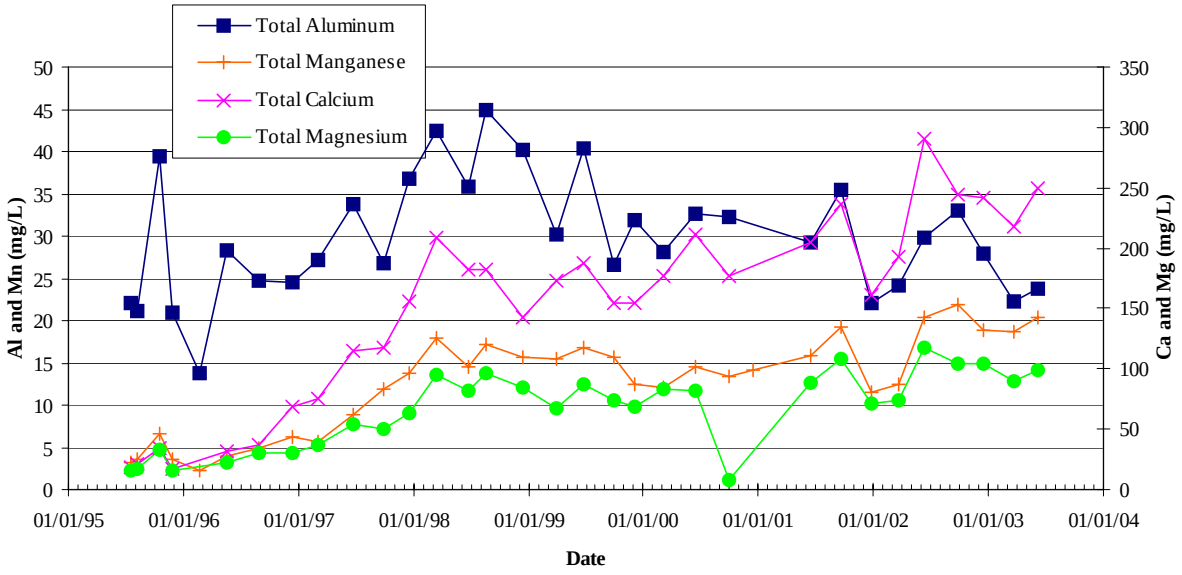


Figure 5.12. Calcium, magnesium, aluminum, and manganese at MW-1.

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.

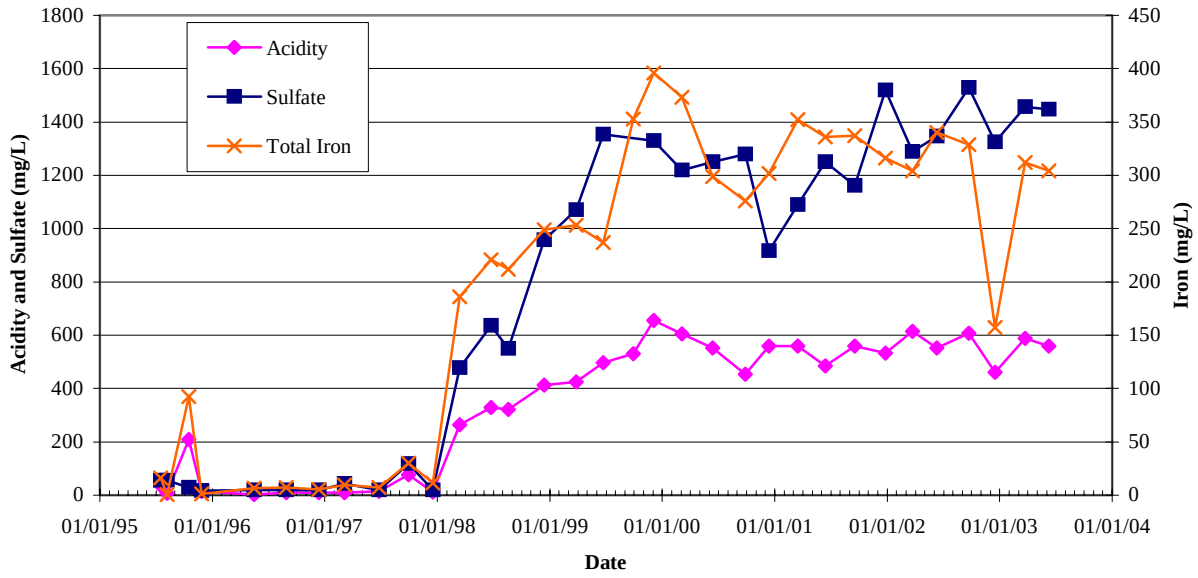


Figure 5.13. Acidity, sulfate and iron at MW-3.

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.

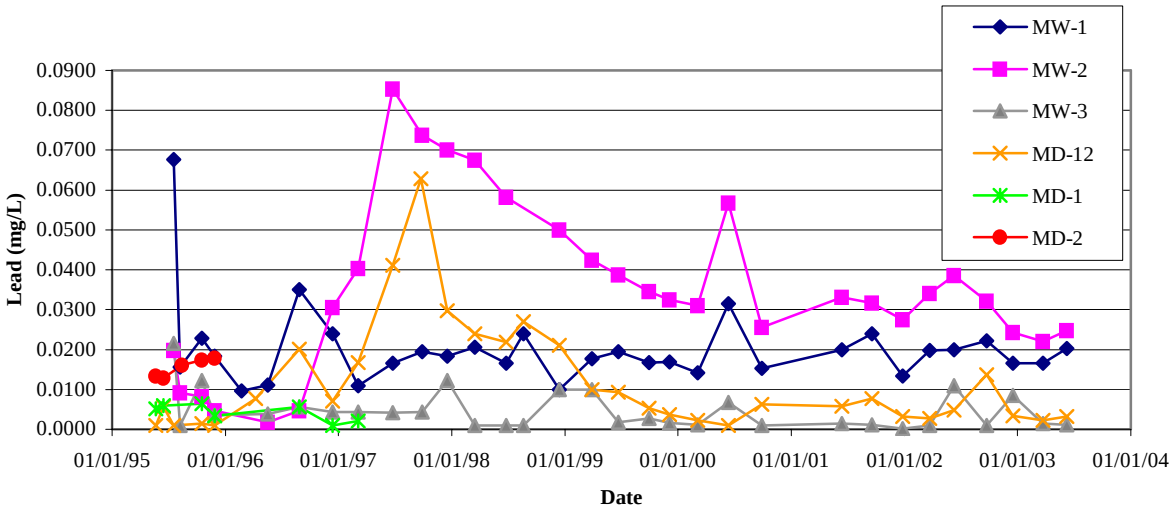


Figure 5.14. Lead concentrations at various monitoring points on the McDermott Mine site.

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).

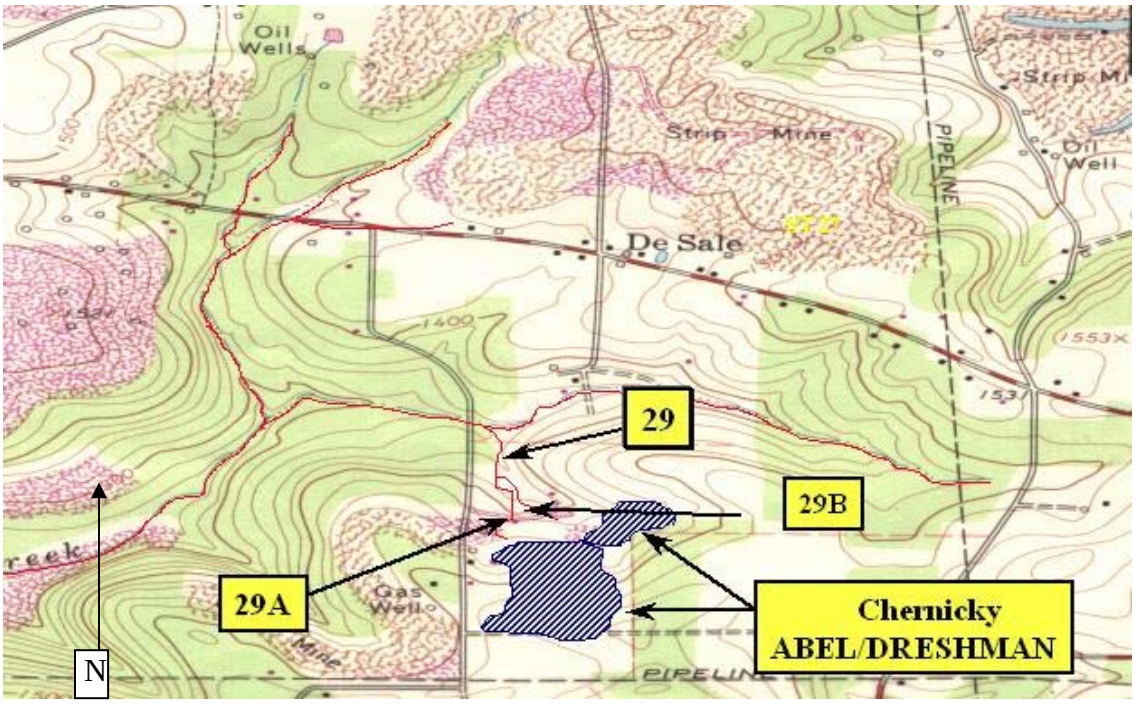


Figure 5.15. Map of the Abel-Dreshman site and monitoring points.

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.

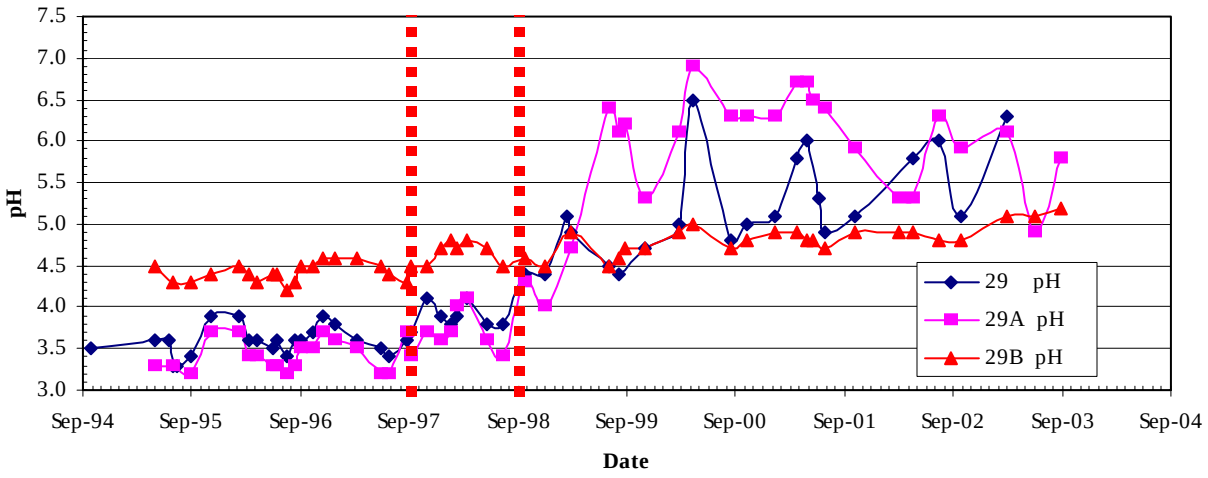


Figure 5.16. Graph of pH with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

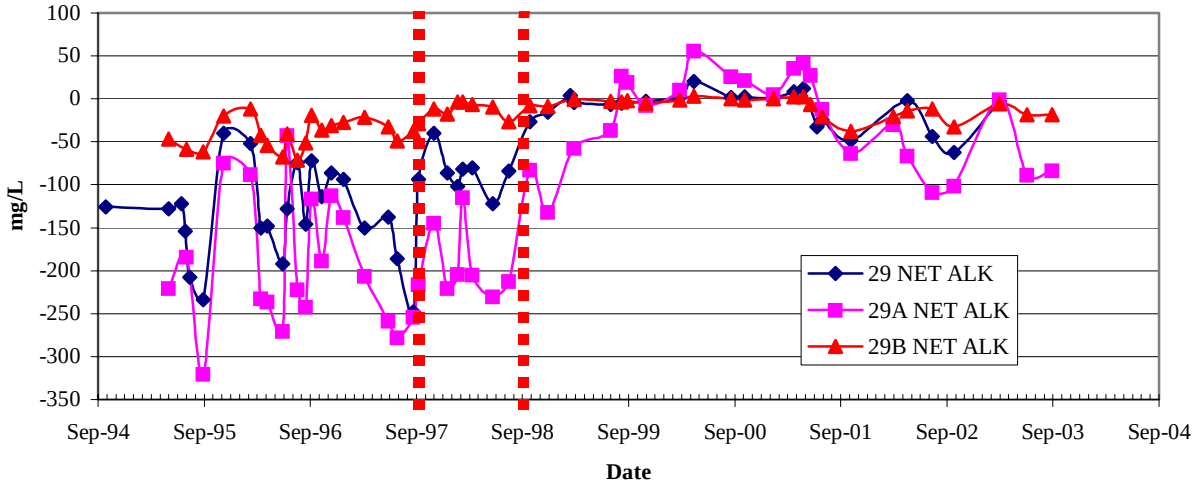


Figure 5.17. Graph of net alkalinity with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

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.

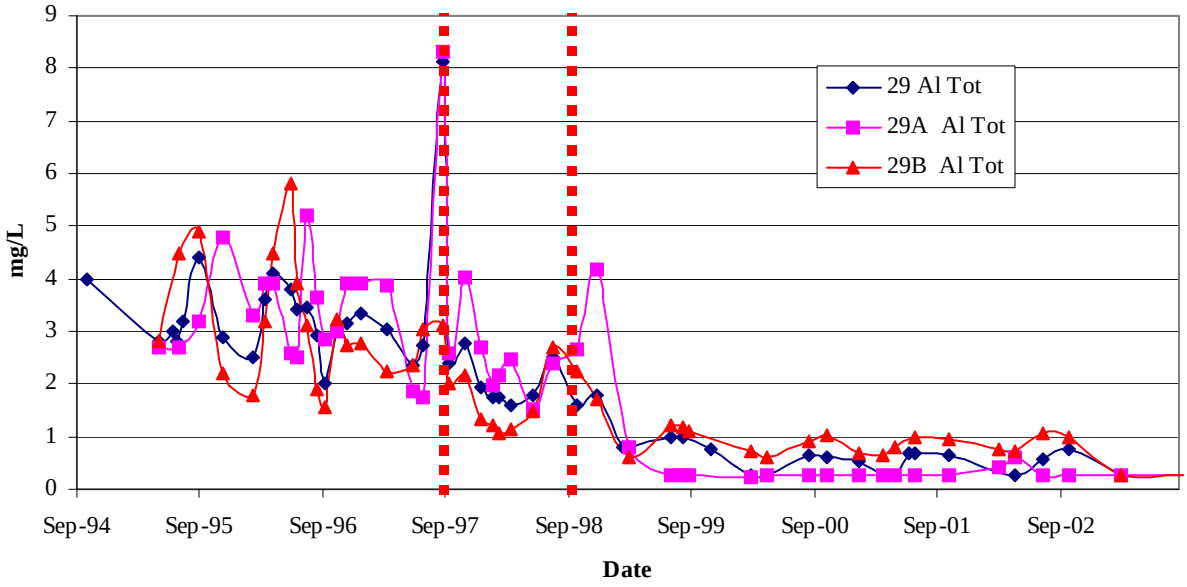


Figure 5.18. Graph of aluminum concentrations with time at points 29, 29A and 29B. The two vertical lines bracket the period during which ash placement and reclamation took place.

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.

CHAPTER 6. USE OF COAL ASH CEMENT GROUTS IN ABATEMENT OF ABANDONED MINE HAZARDS AND ACID MINE DRAINAGE

Daniel J. Koury, Joseph Schueck, Roger J. Hornberger, Kenneth R. Levitz, William B. Hellier Jr., Keith A. Laslow

6.1 INTRODUCTION

Coal ash has been used in a variety of abandoned mine reclamation projects in Pennsylvania for more than 30 years. This chapter will cover the range of those uses, but focus on three applications: mine subsidence control and abatement, mine fire control, and acid mine drainage (AMD) abatement. The historical use of coal ash in mine subsidence and mine fire control has been emphasized in the Anthracite Region, although examples of projects in the Bituminous Region are given. Conversely, most of the AMD abatement projects using coal ash are in the Bituminous Region because of the severe water quality degradation and the large number of abandoned mine discharges there.

The magnitude of the abandoned mine lands problem in Pennsylvania is enormous. Inventories of abandoned mine lands maintained by the DEP Bureau of Abandoned Mine Reclamation (BAMR) show that there were 175,000 acres of unreclaimed abandoned mines in Pennsylvania before the enactment of the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA). In the preamble to DEP remining regulations, it was stated, "In all likelihood, government funded reclamation of abandoned mine lands will not solve the estimated $15 billion in environmental problems caused by past mining in the Commonwealth." (PA Bulletin, Vol. 15, No. 26, June 29, 1995, p. 2379).

Federal and state funding of abandoned mine reclamation and AMD abatement projects has been significant and highly successful to date, but the major portion of the work remains to be completed. For example, BAMR cost records and information described in Devlin (1994) and Scheetz et al. (1997) show that construction costs for just two categories of the 935 completed projects within the 1980 to 1996 time period exceeded $202 million. These projects included mine fires, mine subsidence control, AMD abatement and mine hazards. The estimated cost of sites not yet reclaimed exceeds $987 million for 2,455 sites in the same categories.

The AMLIS database maintained by the Office of Surface Mining Reclamation and Enforcement (OSM) shows a total of 3503 acres of high priority mine subsidence features in PA, and a total of 2635 acres of high priority mine fires. The database shows that through 2003, 2455 acres of mine subsidence were abated and 1038 acres of mine fire projects were completed in PA.

A large part of this chapter is devoted to an innovative mine subsidence abatement project using coal ash and other materials to create a cementitious grout mixture for filling the cropfall subsidence features in the city limits of Pottsville in the Southern Anthracite Field. That project was funded through a grant from the Commonwealth's Growing Greener program to the City of Pottsville. The purpose of the project was to conduct a demonstration project (in cooperation with DEP and the Materials Research Laboratory (MRL)) to employ new technology

to prevent recent mine subsidence features from resubsiding near homes and roads, as well as address the backfilling of extensive historical cropfalls on the flank of the Sharp Mountain. The beneficial use of fluidized bed combustor (FBC) coal ash as the major component in the grout mixture, and pulverized coal (PC) power plant ash as the bulk fill material for more extensive backfilling of the cropfalls is an excellent example of solving a significant public health and safety problem, as well as associated environmental problems.

6.2 HISTORICAL USE OF COAL ASH IN MINE SUBSIDENCE AND MINE FIRE CONTROL

6.2.1 Background

The use of coal ash for mine subsidence or mine fire control in Pennsylvania by federal and state agencies can be traced back to 1969 when the U.S. Bureau of Mines (USBM) and the PA DEP of Mines and Mineral Industries commenced a project to construct a non-combustible barrier to control the spread of the Centralia Mine Fire. According to Chaiken et al. (1983), "This was to be the first application of fly ash for controlling a mine fire in the Anthracite Region, although this technique had been used successfully in the bituminous area." (p. 29). Since then, coal ash has been used in numerous mine fire and mine subsidence projects by the USBM, OSM and DEP, some of which are described in this chapter.

The use of coal ash in mine subsidence control and mine fire control is specifically provided for in the DEP residual waste management regulations, 25 PA Code Section 287.665, concerning the use of coal ash in the manufacture of concrete, stabilized products and other beneficial uses. That section of the regulation states that certain uses of coal ash are deemed to be beneficial and do not require a permit from the DEP as long as the uses are consistent with the requirements of this section, and Item (6) of the list of uses allows: "The use of coal ash for mine subsidence control, mine fire control and mine sealing, if the following requirements are met: ….(ii) The pH of the coal ash is in a range that will not cause or allow the ash to contribute to water pollution, and (iii) Use of the coal ash in projects funded by or through the DEP is consistent with applicable DEPal requirements and contracts."

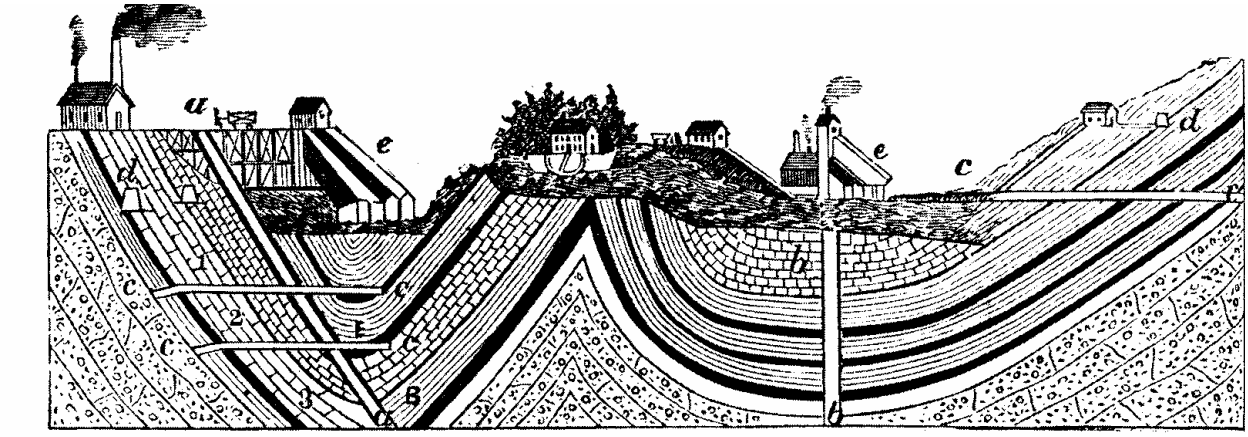
There are three types of mine subsidence features in the Anthracite Region: 1) regional or area-wide subsidence, 2) local subsidence incidents where a collapse occurs at or near the location of a shaft, airway or other abandoned underground mine feature, and 3) cropfalls.

The regional or area wide type of subsidence is prevalent in the Lackawanna Basin of the Northern Field, where coal beds in the relatively flat bottom of the canoe-shaped geologic structure of that basin were extensively mined beneath the city of Scranton and other towns. The area wide type of subsidence is not restricted to the Lackawanna Basin. There are numerous areas in the Western Middle Field, such as, the villages of Gilberton and William Penn where there are groups of homes that are leaning and are obviously structurally affected by subsidence.

The local incident type of subsidence can occur almost anywhere in the four anthracite coal fields (or the Bituminous Region of PA) where abandoned underground mines exist, but the subsidence incidents are more serious where shafts are involved. Many shafts in anthracite

collieries were more than 1,000 ft. deep; for example the Askam shaft and the Auchincloss shaft in the Wyoming Basin of the Northern Field were 2,117 feet and 1,697 feet deep respectively. There are numerous examples of the dangers of localized subsidence incidents involving shafts. One example in the Northern Field occurred in Scranton, in 1982, where a 35 ton crane was removing a concrete cap from a 288 foot deep shaft of the Pine Brook colliery when it disappeared as the ground suddenly gave way. Another example occurred in the Southern Field, in 1999, where a small pond adjacent to a recently completed home for the elderly subsided and exposed the underlying 84 foot deep shaft of the Coxe Colliery in the city of Pottsville

Cropfalls are subsidence features that are unique to the Anthracite Region of Pennsylvania, particularly the Southern and Western Middle Coal Field, because they occur in steeply dipping coal beds. Cropfalls occur where the outcrop of the coal bed "falls" into the subsurface underground mine, when adequate support is removed during mining or the support fails post-mining. To understand the concept of cropfalls it is important to understand the underground mining methods that were employed in the Anthracite Region. As explained in Chapter 2, the Anthracite Region consists of complexly folded geology. There are four alternative methods of access into underground anthracite mines that were used depending on the underground geology and the surface topography, as shown in Figure 6.1.



Methods of entry to veins of coal
Key: a–slope b–shaft c–tunnel d–drift e–breaker 1,2,3–lifts (i.e., levels)
E–Mammoth Vein B–Buck Mountain Vein

Figure 6.1. Methods of underground anthracite mining (from Wallace 1981).

A *slope* mine enters the coal vein at the outcrop (a in Fig. 6.1) and was driven down the dip of the coal vein at whatever pitch the vein was on. A *shaft* mine(b in Fig. 6.1) is a vertical hole sunk straight down through solid rock intercepting multiple coal veins, and usually terminating in the lowest vein worked in the colliery. A *tunnel* mine(c in Fig. 6.1) is a nearly horizontal entry that is driven through solid rock, intercepting numerous coal veins, generally perpendicular to the strike of the coal veins. Once the coal vein is accessed, a similar long nearly horizontal tunnel is excavated in the coal vein parallel to the strike of the vein, which is referred to as a gangway. A drift mine is the fourth type of entry, which is a straight gangway driven directly into the outcrop of the coal bed in a water gap along a ridge. Tilted slightly upward as it proceeds, the *drift* mine drains itself of whatever groundwater that flows into the gangway from

the rest of the mining complex. Gangways are tunnels usually 7 feet high and 10 feet wide (Wallace, 1981), driven along the strike of the coal. The drift mines enter above water level and are driven horizontally on a slight grade to allow positive water drainage from the mine. Once the main gangway is established the coal is mined up-dip creating a void or chamber called a breast or chute. Once the main gangway is established the coal is mined up dip creating a chamber called a breast. Breasts are usually up to 30 feet wide and are the thickness of the coal. Between the breasts, solid pillars of coal usually 15 to 40 feet are left in place for stability and support. The breasts are developed up the pitch of the coal approximately 300 feet and a chain pillar is left in place near the surface to prevent surface subsidence. This complex is known as a lift and is similar to room and pillar mining in the Bituminous Region, however it is tilted on the angle of the coal vein.

Figure 6.2 shows a mine plan for a typical anthracite underground mine. Depending on the 1) depth of coal, 2) economics of water pumping, 3) thickness of the coal vein, and 4) competence of adjacent rock, numerous lifts are often developed. Often times when the reserves are exhausted, the support pillars of coal are mined (robbing the pillars).

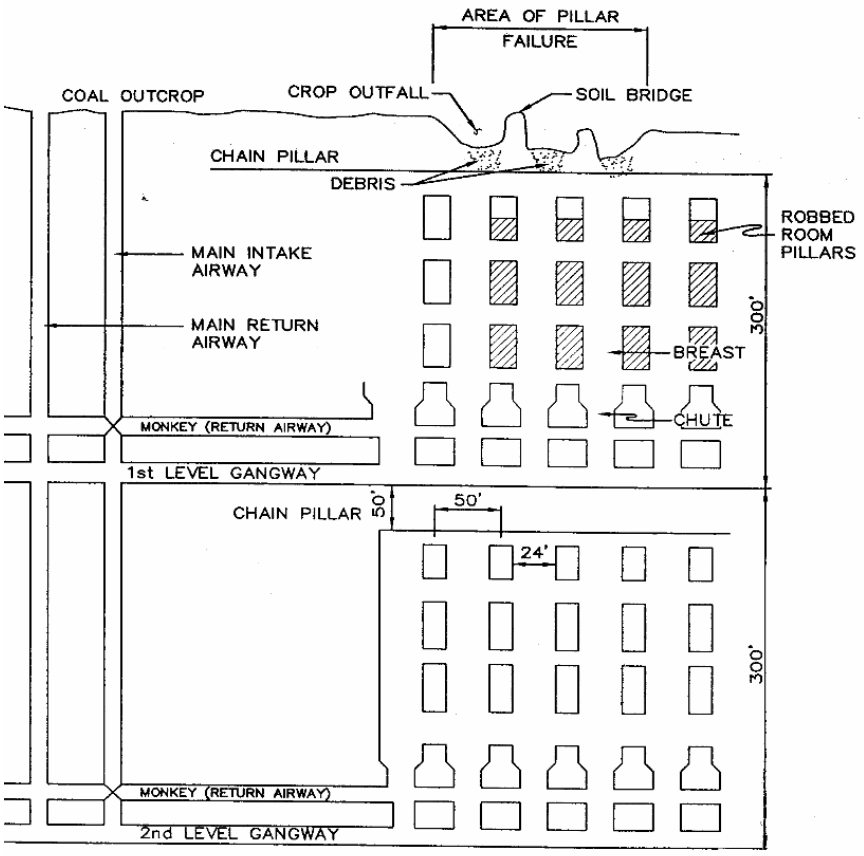


Figure 6.2. Typical mining plan of an anthracite underground mine (from Levitz, 2001).

These mining practices create the potential for large scale dangerous subsidence. If the support pillars or chain pillars fail or if they have been robbed out, the surface has the potential to fall 300 to 600 feet or further depending on how many lifts were developed. The result of the surface outcrop of coal falling into the abandoned voids below is known as a *cropfall*. In bituminous coal seams of western Pennsylvania, where the coal seams are generally flat lying, the vertical limit of subsidence is equal to the thickness of the coal seam. In the Anthracite Region, where the anthracite veins are steeply pitched, the subsidence is limited to the ultimate depth of the mining.

Cropfalls are dramatic features that often occur with little warning, resulting in deep narrow voids with near vertical walls as seen in Figure 6.3a. The tremendous underground exploitation of the coal during the industrial revolution and two world wars has created the potential for cropfalls that extend for several miles as seen in Figure 6.3b. The extensive cropfalls in Porter Township in western Schuylkill County shown in Figure 6.3b are in a relatively remote area unlike the cropfalls in the Pottsville area. When seen from the air, the cropfalls appear similar to a narrow surface mine. However, unlike most abandoned surface mines there is no overburden available to fill the hole.



Figure 6.3(a). Narrow cropfall.



Figure 6.3(b). View of extensive cropfalls on multiple veins.

The term “cropfall” is not recent, as it is clearly labeled on Figure 6.4, which is from a segment of the January 9, 1914 mine map of the Hickory Ridge and Hickory Swamp Collieries (see Section 4.2.4 in this book) in the Western Middle Field. The cropfalls delineated on Figure 6.4 are located at the updip end of the first lift workings of the Mammoth coal bed that is dipping at 80 degrees. This map and others like it document that some cropfalls occur during mining as well. Apparently some miners struggling to make their daily production quotas, did not adhere to the concept that the top of each breast on the first lift had to terminate 75 ft. from the land surface to prevent subsidence.

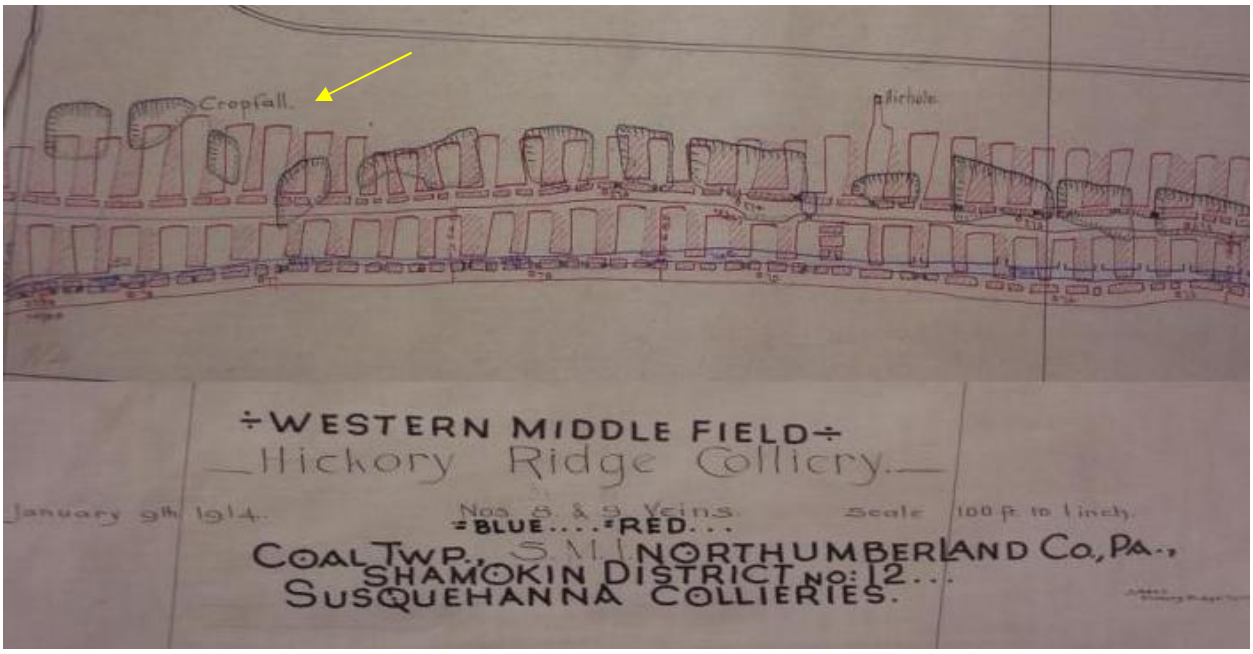


Figure 6.4. Map of Hickory Ridge Colliery showing cropfalls, January 9, 1914.

Most cropfalls developed after the major collieries closed (and thus are not shown on the maps). Many of the cropfalls occur as result of the work of "bootleg miners" that operated above minepool levels, or by geological and climatological processes over a number of years that weakens the support until it fails abruptly. In this respect, cropfall formation can be very similar to "cover-collapse" sinkhole formation in carbonate rocks, where the incipient removal of subsurface support over the years is not seen on the land surface until it's too late to prevent the subsidence. This type of cropfall feature frequently develops in the spring of the year, following freeze-thaw cycles, and can be very dramatic, considering that the gaping hole may extend downdip as much as 900 feet depth, or deeper, depending on how many lifts were mined and whether the chain pillars between the lifts were robbed during retreat mining. The magnitude of the extensive underground mine void system connected to the cropfall feature may make the abatement of the subsidence with coal ash or any other material problematic, as described in Section 6.3. In the years following the initial dramatic collapse of a cropfall, rock and soil materials gradually fall into the gaping hole and develop a weak or strong bridging system. This represents a mitigating factor in developing subsidence abatement plans (or may fool the unsuspecting hiker of lurking dangers beneath the rock and soil bridging material).

In addition to the safety hazard that cropfalls present, there are also hydrologic impacts. Since the cropfalls are linear features along the contour of the mountain, they essentially capture all runoff and surface water from the mountain ridge and direct it underground. As the captured surface water infiltrates into the abandoned underground mines, it chemically reacts with the pyritic material in the shale adjacent to the coal, producing acid mine drainage. The water collects in the mines and ultimately drains from the abandoned drift openings that were designed to provide a gravity flow discharge from the mines.

Subsidences occur in areas throughout the world and they present many challenges in their remediation and prevention. Whether they are naturally occurring from sinkholes in

limestone areas or they are the result of coal mining activities, it is critical to understand why they have formed and what the potential extent of the subsidence is, in order to effectively remediate their effects. In both the Anthracite Region of eastern Pennsylvania and the Bituminous Region in the western part of the state, underground mining practices were prevalent for over a century and a half. Since that time, these areas have been subjected to mine subsidence, which has threatened local communities and recontoured the landscape. Mine subsidences are often a reflection of the underground mines below. They range from mild sagging of the surface to large open collapses into an old mine shaft.

6.2.2 Mine Subsidence Control in the Northern Anthracite Field

Numerous area wide mine subsidence problems have occurred in the Scranton area and other urbanized areas of the Lackawanna Basin in the Northern Field, especially where multiple seams of coal have been third mined (i.e. retreat mining) above the minepool and close to the land surface. In areas where subsidences are prevalent and they threaten the integrity of buildings and public health and safety, the state and federal government have conducted mine flushing projects in order to abate, ameliorate or prevent subsidence effects.

There are two types of mine flushing projects that were conducted in the Northern Field: *controlled flushing* and *remote hydraulic flushing*. In controlled flushing, which is essentially outdated, workers went into safe underground mines, built masonry bulkheads within the mines, and flushed in crushed coal refuse and coal ash materials through pipes. In remote hydraulic flushing projects, boreholes are drilled from the surface to intercept the target mine workings; then water is pumped from the minepool, mixed with the flushing material and injected down the boreholes into the appropriate point of entry in the abandoned underground mine. The intent of these remote flushing projects was to use enough pressure to distribute the flushed material several hundred feet or more from the borehole injection site in order to fill voids within the mine, while allowing continued groundwater/minepool flow at critical points, such as drainage tunnels. Numerous boreholes were drilled within the rights-of-ways of streets in urban areas or other accessible locations, in a grid-like array when possible, and coal refuse and coal ash were injected into the underlying mines through the borehole system.

6.2.3 Anthracite Mine Fire Control

The use of coal ash in mine fire control in the Anthracite Region commenced on May 5, 1969 at the Centralia mine fire site in Columbia County according to Chaiken et al. (1983). The historical account of the Centralia mine fire is described in the USBM report by Chaiken et al. (1983) and a book by DeKok (1986). The fire was initially discovered in May 1962 burning in refuse material in a borough waste disposal site located in an abandoned strip mine pit southeast of the Centralia borough. By July 1962, the fire had spread into an outcrop of the Buck Mountain coal bed and progressed about 200 ft. along the strike, despite efforts by borough workers to extinguish the refuse fire with water and a clay blanket. From August 1962 through October 1963 the PA Dept. of Mines and Mineral Industries attempted to extinguish or isolate the mine fire by injecting fine refuse material through boreholes and by trenching. Unfortunately, the isolation trench and borehole flushing efforts were unsuccessful in isolating the fire. The Appalachian Regional Commission was created in March 1965 (Public Law 89-4) and on June 8,

1965 it approved $2.5 million in funding for a cooperative project to extinguish the mine fire, involving the U.S. Bureau of Mines, the PA Dept. of Mines and Mineral Industries and Columbia County. This project was conducted in two phases as shown on Figure 6.5. In 1966 and 1967, additional boreholes were drilled in the area represented by horizontal hatching lines on Figure 6.5, and 81,000 cu. yds. of sand was flushed/injected into additional boreholes, but it did not form an effective barrier of noncombustible material.

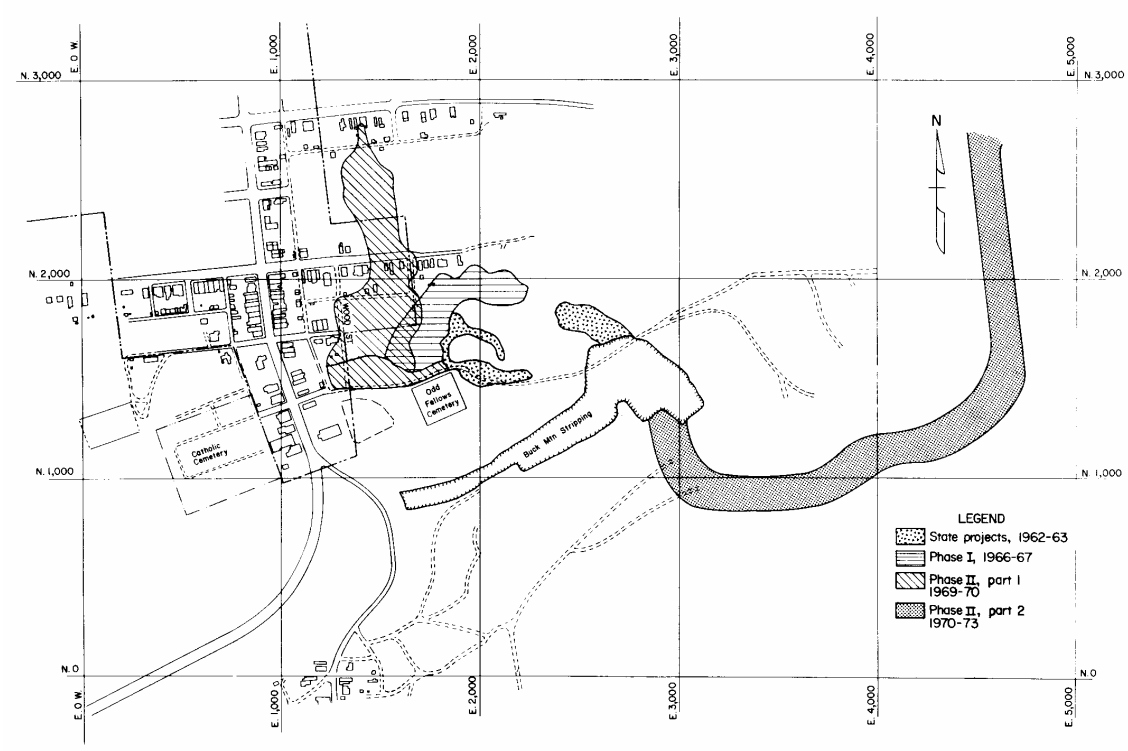


Figure 6.5. Composite of attempts to control the Centralia Mine Fire (Chaiken et al. 1983)).

Phase I, as originally planned, would have backfilled and sealed abandoned stripping pits at the southern edge of the mine fire, completed exploratory drilling in the northern, eastern and western edges to delineate the boundaries of the fire, and flushed sand down boreholes to form a temporary noncombustible barrier around the fire area to constrain its expansion until the second phase was completed. Phase II would have excavated a permanent isolation trench on the "cold" side of the temporary flushed barrier (2500 ft. long), and backfilled that trench with a lower layer of noncombustible material and an upper layer of mine spoil and refuse. Thus, at the completion of the project, the Centralia mine fire would be confined and eventually burn itself out within a confined area where it would not threaten structures, public health and safety, or to the remaining coal reserves. Unfortunately, Chaiken et al. (1983) reported that exploratory drilling conducted for Phase I showed that the fire had progressed further north and east than anticipated. In addition, the flushing operation encountered unusually large voids that swallowed more sand than anticipated and the flushed sand did not form an effective barrier or airtight seal. Also, the revised estimate to complete the Phase II trench significantly increased in time and would have almost doubled the total project costs (i.e. $4.5 million for the trench), due to the great depth of

the trench and the hardness of the rock to be excavated. Therefore, it was determined that the Phase II plan would be revised to attempt to control the mine fire by constructing underground barriers by pneumatically injecting coal ash into the underground mine voids through boreholes.

The initial use of coal ash for mine fire control in the Anthracite Region at Centralia was considered a demonstration project, according to Chaiken et al. (1983), although the installation of fly ash barriers had been successfully used to control a mine fire in the Bituminous Region of Pennsylvania. The coal ash demonstration project would allow the second phase of the cooperative project to be completed with the remainder of the available funds. The coal ash used in this demonstration project was supplied from pulverized coal powerplants to Columbia County, at no cost to the state or federal government.

The western coal ash barrier, represented by diagonal hatch lines on Figure 6.5, was constructed from May 1969 through August 8, 1970 by drilling a total of 362 boreholes (i.e. exploratory holes, fly ash holes, flushing holes) and pneumatically injecting 39,272 tons of coal ash into voids in the Buck Mountain, Seven Foot and Skidmore coal beds, according to Chaiken et al. (1983). In addition to the coal ash material used in the western barrier, approximately 12,000 cu. yds of screened coarse rock materials were hydraulically injected into the abandoned underground mine workings to form a buttress between the fly ash and the minepool. The total cost for the western noncombustible barrier was $582,693.

The eastern coal ash barrier, shown as the dark stippled pattern on Figure 6.5, was constructed from August 25, 1970 to December 14, 1973, using 83,084 tons of pneumatically injected coal ash, plus 36,220 cu. yds. of hydraulically injected sandy clay, through a total of 1,049 boreholes (1,017 ash boreholes, 32 flushing boreholes). The cost of this phase of the project was $1,858,391, according to Chaiken et al. (1983), and a total of 122,356 tons of coal ash were used in the Centralia mine fire project.

Coal ash has been used in at least 3 other mine fire projects in the Northern Field of the Anthracite Region since the historic Centralia Mine Fire project, as shown in Table 6.1. These more recent mine fire projects have been completed by the Wilkes Barre OSM Field Office using several coal ash grout specifications. A typical “fly ash-cement grout” mixture would consist of a ratio of 3 parts fly ash: 1 part Portland cement: 2 parts water, to achieve a water: solid ratio by volume of 0.5 for grouting mine voids. Several specific grout mixtures have been used in site specific mine fire applications, and there are several alternatives included in the generic specifications for these projects. A common mixture in these specifications consists of 282 lbs. dry cement, 1,903 lbs. (oven dry weight) flyash, and 800 lbs. (95 gallons) of water. Two alternative mixtures for large voids and “excessive take” holes include sand, or sand plus gravel, in addition to the fly ash, cement and water. One of these mixtures consists of 340 lbs. dry cement, 1,375 lbs. fly ash, 1,323 lbs. sand, and 458 lbs. (55 gallons) of water. The coal ash used in these grout mixtures is usually obtained from PC power plants. If FBC coal ash sources were used, the specifications could be revised to account for the differences in bulk chemistry, mineralogy and cementitious behavior of these different ash sources.

Table 6.1. Coal Ash use in Anthracite Mine Fire Projects.

Project Name	Location	Agency	Year	Tons of Ash Used
Centralia – West Barrier	Columbia County	USBM/PA-MMI	1969-1970	39,272 tons
Centralia – East Barrier	Columbia County	USBM/PA-MMI	1970-1973	83,084 Tons
Powderly		OSM		3,617 yds^3
Washington West		OSM		9,046 yds^3
Maffett Red Ash		OSM		10,413 yds^3

6.2.4 Bituminous Region Mine Subsidence and Mine Fire Control Project

Coal ash has been used for more than 35 years in the bituminous coal region of Pennsylvania in mine subsidence and mine fire control projects, in a manner that is very similar to the Centralia project described in the previous section. The results of five mine subsidence control projects at public school sites in the Bituminous Region are described by Jones and Kasi (1990), in which four of the sites used coal ash from PC power plants, and three of the five were done in cooperation with OSM. Several other large subsidence control projects involving the use of coal ash cement grout mixtures are located in the town of Belle Vernon in Fayette County, Plum Borough in Allegheny County and Chartiers Township in Allegheny County. There were three subsidence control projects in which coal ash was used in the area of Belle Vernon from 1987 to 1992. The Regency Park project in the area of Plum Borough was recently completed using PC power plant coal ash. These projects involved the pneumatic injection of the coal ash into the abandoned underground mine through boreholes, using ash cement grout mixtures and methods similar to those used in the Anthracite Region. The Chartiers Township project is a large proposed coal ash injection project involving about 300 homes, and an estimated cost of approximately $7 million.

Coal ash has also been used in mine fire control projects in the Bituminous Region. Two of these projects involved the Percy Mine Fire in North Union Township, Fayette County, near Uniontown, and were completed as a cooperative effort of OSM and DEP. The first Percy project was completed in 1997 and used 5,879 tons of coal ash, and the second was completed in 1998 and used 14,456 tons of ash. The beneficial use of coal in mine subsidence contracts has been more widespread and successful than mine fire projects in the Bituminous Region of Pennsylvania. A concern in the use of coal ash/cement grout injection techniques in abandoned mine voids in relatively flat-lying bituminous coal beds, is that the ash cement mixture shrinks or develops gaps near the roof of the mine which do not fully prevent the mine fire from spreading. The use of coal ash in bituminous mine subsidence control projects is presently occurring on a scale larger than the Anthracite Region.

6.3 USE OF COAL ASH IN CROPFALL REMEDIATION - SHARP MOUNTAIN, POTTSVILLE, PA

Coal ash has been used to fill mine subsidences and to create barriers to limit mine fire propagation for several decades. The particle size of the ash allows it to be used as a flowable fill material and its pozzolanic properties have made it a choice material in grout mixtures as a cement-like material on numerous projects. Typically, in subsidence remediation, the ash is

injected into the subsidence and the goal is to fill the void entirely. In the Anthracite Coal Region however, the unique cropfall phenomenon presents several difficulties that are quite a bit different than other subsidence features. The cropfalls are extensive subsidence features that can occur suddenly and often leave tremendous voids requiring large volumes of fill material. The potential for further subsidence is subject to the extent of the mining, which is often unmapped and unknown.

The City of Pottsville, in east-central Pennsylvania, has been plagued by cropfalls for decades. However, the accelerated occurrence of cropfalls in recent years, near residential areas, has prompted the need for immediate action. Attempts to backfill a few of the cropfalls under an OSM emergency project in 1999 on Sharp Mountain experienced failure after just a few months, when settlement occurred and the need for a more permanent solution became evident.

The City embarked on an effort to reclaim the mountain in a manner that would not only eliminate the safety hazard of the cropfalls, it would minimize or prevent future subsidence and reduce the amount of acid mine drainage that discharges to the Schuylkill River. In 1999, the City of Pottsville received a PA Growing Greener Grant to develop a demonstration project for backfilling the cropfalls in a manner that is both economically feasible and permanent. The project study area shown in Figure 6.6 is confined to the city limits and is bound by the crest of Sharp Mountain to the south, the Schuylkill River watergap to the east, the West Branch of the Schuylkill River watergap to the west, and the residential development to the north. The streets of Pottsville are numbered from east to west beginning with Center Street as number one and 30th street at the west end. Cropfalls exist from 3rd Street to 25th Street and the most recent subsidences have occurred between 20th and 25th street. The project study area encompasses a total of 340 acres and addresses 15,000 linear feet of cropfalls, which are occurring on several coal veins.

To understand the nature of the cropfalls and the potential dangers in their reclamation it is necessary to explore the local geology, historical mining in the area, the extent of the underground mining, and the mining methods employed which created the voids.

6.3.1 Historic Mining and Local Geology

The City of Pottsville lies on the northern exposure of Sharp Mountain along the southern boundary of the Southern Anthracite Coal Field. The mountain rises 400 feet above much of the city to a maximum of approximately 1,300 feet msl and elevations of the rivers at each water gap are approximately 600 feet msl at the east and 675 feet msl at the west. As the gateway to the Anthracite Region, Pottsville played an important role in the early shipment and mining of anthracite coal. Extensive coal mining in the 19th century under the City of Pottsville and along the Sharp Mountain not only provided millions of tons of anthracite coal, but also left significant voids. Since much of the mining was conducted prior to the 1930's, nearly all of the coal mining was underground mining. By the time heavy machinery was available for surface mining, the city was already well established and only shallow surface mines on the order of 20 to 30 feet were dug along the contour of the mountain slopes. The local geologic structure and the extent of the mining under Sharp Mountain left a hidden potential danger, which was dormant for decades until recently.

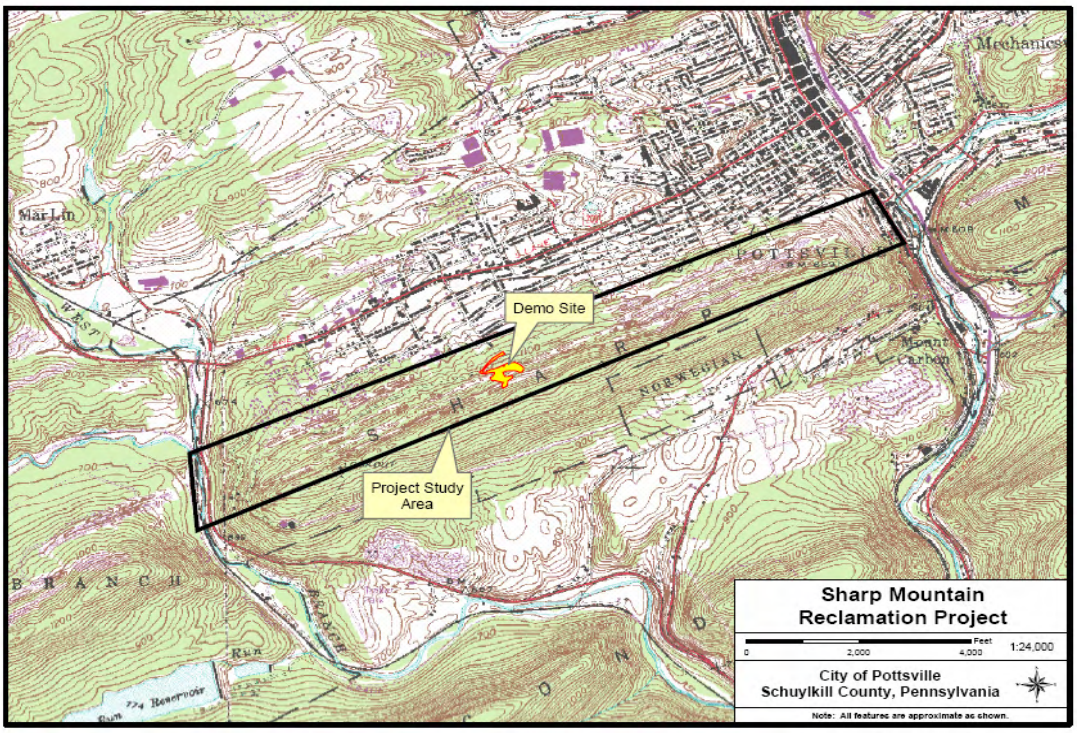


Figure 6.6. Site map of Sharp Mountain Reclamation Project.

In the mid-1800's, Pottsville was a significant metropolitan hub and the mines in the area were pioneers in both anthracite mining techniques and mining equipment. The York Farm Colliery (Lehigh Valley Coal Co.) mined significantly under the city of Pottsville and was the most extensive colliery in the United States from 1837-1845 (Wallace, 1987). Much of the York Farm workings were further north in the city, however, tunnels were extended to the veins under Sharp Mountain. Sharp Mountain was extensively mined from the mid-1800's to the 1950's in the Pottsville area primarily by underground mining methods. The earliest legible date on available mapping of the underground mine workings on Sharp Mountain was 1887, and there are indications of earlier and more significant mining activity (Levitz, 2001). The mountain was accessed primarily at the watergaps, by the Sherman Colliery at the Main Branch of the Schuylkill River to the east and by at least 14 different drift mines including the York Farm Colliery (Lehigh Valley Coal Co.) at the West Branch Schuylkill River from the west.

The coal veins mined on Sharp Mountain were all within the Pottsville Formation. As described in Chapter 2.3.6, there are 14 coal beds in the Pottsville Formation, however only 8 of the coal veins were mined significantly within the project study area shown in Figure 6.6. The southernmost mineable coal vein is the Buck Mountain vein (further north, and at correspondingly lower elevations, Skidmore, two splits of the Mammoth, Holmes, Primrose, Orchard and Diamond Veins. The cross-sectional map shown in Figure 6.7 demonstrates the steep pitch of the various coal veins and the relative distance of the cropfalls to the residential areas along Howard Avenue (Norris and Sons, 1927).

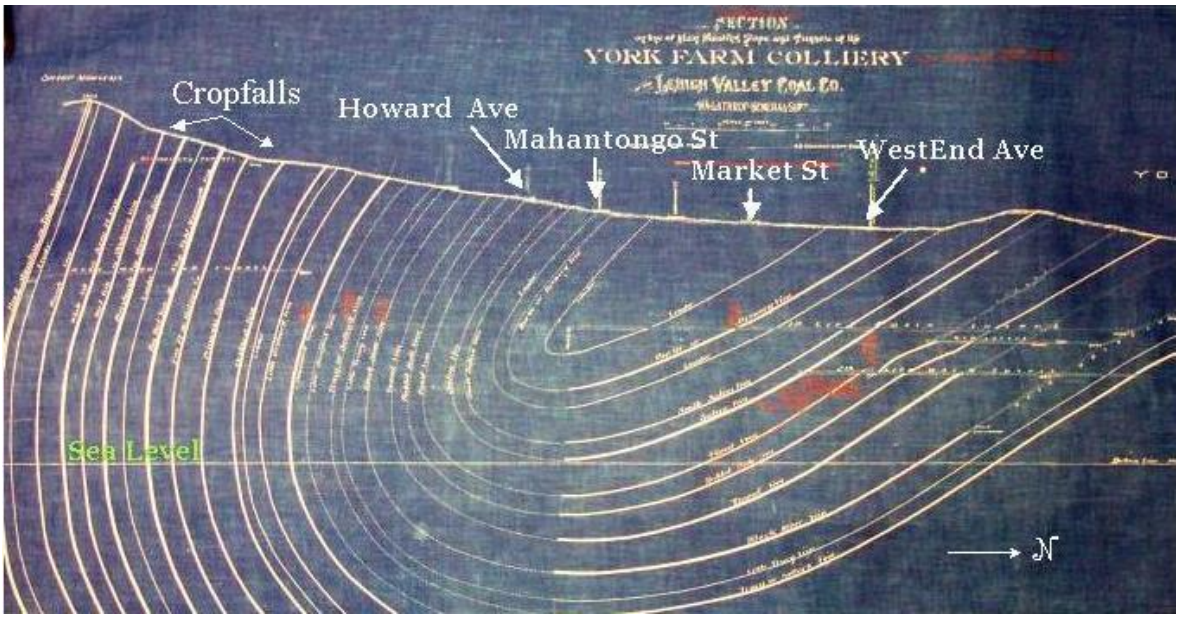


Figure 6.7. Cross-section of York Farm Colliery Pottsville, 1892.

The workable coal veins are of varying thickness as shown in Table 6.2 and the beds are overturned more than 30 degrees from vertical. The coal veins in Figure 6.7 are estimated to extend well over 1000 feet deep, far below sea level. The map also shows a tunnel at an elevation of 485 feet msl that extended over to the mountain from the York Farm workings to the north. The fact that the tunnel is over 800 feet below the surface indicates that there may be several lifts that were mined under the mountain. The mining on several of the coal veins is extensive. Due to the steep pitch of the coal, the mining was very efficient on the mountain with an 80% extraction ratio according to a Report on Property of the Sherman Coal Corporation, 1927. The report was an evaluation of the feasibility of mining multiple veins, on several lifts down to sea level, for the entire length of the mountain in Pottsville. The report concluded that it was not feasible at that time to invest the resources for mining to that extent.

The coal veins outcrop at the surface along the contour of the mountain. The steep nature of the rock units is demonstrated at the eastern water gap of the Schuylkill River along Route 61, as seen in Figure 6.8. It is in the vicinity of this photo that the type section of the Pottsville Formation was described by C. D. White (1900) and more recently by Wood et al. (1956) and Levine and Slingerland (1987).

Table 6.2. Thickness coal veins (from Norris and Sons, 1927).

Coal Beds	Estimated thickness of workable coal (feet).
Buck Mountain	3.50
Skidmore	5.75
Mammoth	9.00
Holmes	4.50
Primrose	7.00
Orchard	4.5
Little Orchard	7.00
Diamond	5.50
Tracy	5.25



Figure 6.8. Exposure of the Pottsville Formation, along Rt. 61, Pottsville.
Note the vertical stop sign at the bottom of the photo.

6.3.2 Extent of the Cropfalls

Although cropfalls occur throughout the Southern & Western Middle Coal fields, the cropfalls in Pottsville area are unique in that they are very close to residential areas. Cropfall features have existed on Sharp Mountain in the Pottsville and are shown on maps of the Sherman Coal Company as early as 1925. The cropfalls shown on those maps are located between 4th and

15th street in Pottsville and they currently appear stable with overgrown vegetation. In the 1990's however, the areas between 20th and 25th street began to collapse significantly. The subsidences have continually occurred and expanded causing an imminent danger to the safety of the public. From 20th street, westward there are 4 distinct continuous lines of subsidence that are dramatic and unstable, as seen in Figure 6.9. The active subsidences are within 300 feet of residential lots in the 20th street area.

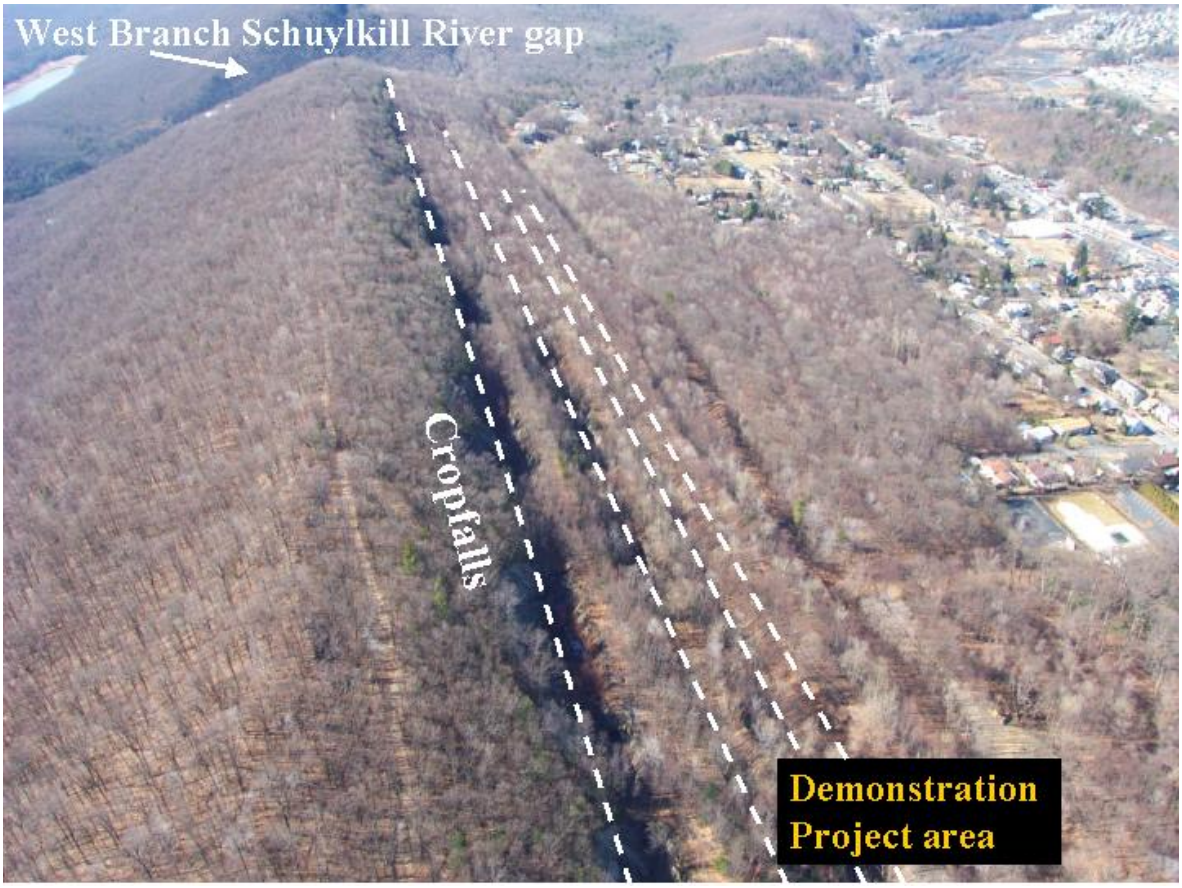


Figure 6.9. An aerial view of Sharp Mountain and the City of Pottsville from above 20th street looking west. Four lines of subsidence are evident. The demonstration project reclaimed 2.0 acres of in cropfalls in the black highlighted area.

East of 20th street these features are not as continuous, but there are 4 distinct lines of subsidence apparent. The extent of the cropfalls and shallow surface mines can be seen far beyond the project area. Research of existing mine maps and mine tonnage records of mines in the project study area conservatively estimate the volume of abandoned mine workings at 4,000,000 cubic yards. The length of the combined open voids is estimated at 15,000 linear feet. The affected zone is a maximum width of 400 feet and traverses 100 to 130 feet of elevation change. Generally, the width of the individual subsidences range from 40 to 100 feet and exceed depths of 50 feet. The total open void volume on the various coal veins is estimated at 500,000 cubic yards (Levitz, 2001).

Each year the normal weathering processes act on the existing voids and they continually expand. As the voids occur, they exhibit a funnel shape that is wider at the surface and narrows with depth. As the void tapers, it becomes blocked with rock, topsoil, trees and plant debris. The opening then remains camouflaged until there is further failure of the coal pillar and the debris clogging the void falls deeper. When the pillars fail underground, the surface failure can be catastrophic and it often causes instability of other pillars. As the cropfall matures, the hole widens and becomes more shallow as the debris from the walls accumulate in the void. It is difficult to determine the true depth of the void, as the debris may be only temporarily bridging the void.

The aerial view of the cropfalls in Figure 6.10(a) show very recent subsidences where the breasts collapsed, leaving the pillars intact (soil bridges). The upper "more developed" cropfalls expanded as the pillars failed and the cropfalls matured. In 1993, when a significant collapse occurred, a chainlink fence was installed around a portion of the hole to prevent access and warn the public of the dangerous condition. In a few years the hole expanded and the fence fell into the void as seen in Figure 6.10b. Note the dip and the thickness of the coal outcrop at the far end of the pit.



Figure 6.10(a). Recent and more mature subsidences.



Figure 6.10(b). Expanding subsidence, notice the hanging chainlink fence on the left. Wall at the far end represents a stable pillar.

6.3.3 Previous Backfilling Attempts

In 1999, a group of cropfalls began to subside, resulting in several significant holes that swallowed a well-traveled unimproved road that traverses the mountain (Fig. 6.11a). As an emergency project, the Office of Surface Mining imported durable rock and a high strength concrete mixture to backfill five subsidences. This was an attempt to create a concrete plug formed solely of cement. The purpose of the rock was to increase the frictional forces between the backfilled cement and the adjacent rock, and thus, slow the movement of the cement until it could set up and cure. During the project, the backfill material had subsided, requiring more fill than was originally anticipated. Within a few months of project completion, the fill material subsided once again to varying degrees in each of the five subsidences. Some of the failures resulted in minor sagging of only a few feet as in Figure 6.11b, while others were severe

collapses where nearly all of the fill material was lost, Figure 6.11 c. Figure 6.11d shows the area that became the main site of the demonstration project described in Section 6.3.4.



Figure 6.11(a). Emergency cropfalls.



Figure 6.11(b). Sagging of filled area



Figure 6.11(c). Severe collapse and loss of fill**.**



Figure 6.11(d). Subsidences. Site of Demonstration Pit A.

6.3.4 Demonstration Project

In order to address the problem of chronic failure of backfilling materials, the City of Pottsville employed a unique approach. The City evaluated two basic reclamation methods typically used in mine subsidence restoration projects. The first method considered, which is typical method, was to completely backfill or inject a non-structural bulk fill material to replace the coal that had previously been extracted. Since most of the mining on the Sharp Mountain was underground, there is very little onsite material available on the surface to use as a fill material. The efforts required to import and place enormous volume of material needed to fill the all the voids, an estimated 300,000 truckloads, would generate unrealistic demands upon funding sources, city infrastructure and ultimately the community's tolerance. For these reasons, the first option was impractical.

The second method was to partially backfill all open voids with fill materials that exhibited desireable structural characteristics (i.e. slurries, flowable fills and low grade cements), which may prevent further subsidence into the uncollapsed voids below. As part of the Growing Greener project, the city conducted a full-scale demonstration project to apply a concept similar to the OSM emergency project. However, the cement plug would include structural reinforcement components and measures to prevent material loss during the project.

The three main objectives of the project were to 1) prevent continued vertical displacement of the surface, 2) provide a stable platform upon which to proceed with future restoration efforts and to establish an acceptable final grade for revegetation and positive drainage, and to 3) minimize the total amount of required backfill material. The materials utilized were selected for their structural properties, availability, and cost effectiveness. The general concept was to use a cementitous grout mixture in conjunction with reinforcing material to form a structural plug at the current bottom of the void. A bulk fill material was to be placed upon the plug to fill the remainder of the void up to the surface grade, and then the area was to be planted. It was intend that the combination of these materials would form an adequate plug if the void would subside further.

Since funding was limited and fill material nonexistent on-site, discarded or recycled materials were used wherever possible to minimize costs. The concept of using a "discarded" material was a significant factor in the economic viability of the project. Various materials were explored for their physical characteristics, availability, cost and any potential permitting requirements that would be necessary to utilize the material. The list of potential materials included coal fire boiler ash, cement kiln dust (CKD), foundry sand, river and harbor dredge, coal refuse and various reinforcing material, including steel beams and specialty concrete products.

Various materials were tested to form the cementitious grout necessary for the plug. Coal ash, particularly that produced in a fluidized bed combustion unit with limestone injection, has long been noted for its cementitious behavior. Coal ash from five anthracite fired fluidized bed combustion (FBC) co-generation plants were tested at the Pennsylvania State University, Material Research Institute (MRI) for cementitious properties and potential strengths. The FBC ash from the Northampton Generating Company, L.P. in Northampton, PA ranked highest in potential strength tests. FBC ash is preferred since limestone is added in the combustion process to control sulfur emissions. The combustion of the coal and coal refuse in a fluidized bed combustor results in an ash that is chemically reactive when placed into contact with agricultural lime. The presence of chemically reactive thermally altered clays and excess lime in the ash from sulfur removal result in materials that exhibit chemical reactions similar to those seen in commercially available Portland cement.

Experience from the Knickerbocker Demonstration project discussed in Chapter 8 have shown that CKD enhances the strength of the coal ash. Data obtained from preliminary mechanical properties testing on grouts made from mixtures of FBC ash and CKD show a synergistic strength gain of approximately 30% from the mixture of the two components. Penn State conducted strength tests of FBC ash from Northampton Generating with CKD from Keystone Cement, Bath, PA at various ratios to provide an optimal formula for a grout mixture.

The mixtures were blended and placed in 2 inch cubes for laboratory testing. In addition, experiments including foundry sand in the mixture were also conducted to determine if the sand would provide improved cementitous strength. Results of the tests are shown in Table 6.3.

Table 6.3. Laboratory tests of various grout mixtures.

Mix #	formulation	7 day strength (psi)	28 day strength (psi)
1	60%FBC - 40%CKD	246	329
2	67%FBC - 33%CKD	347	466
3	67%Mixture 1 - 33%sand	94	92
4	67%Mixture 2 - 33%sand	97	105
	FBC Ash Alone	252	287

It was determined that a mixture of 2 parts FBC coal ash to 1 part CKD would be used to produce the grout mixture. Based on the achievable strengths in the laboratory tests a target of 275 psi in a 7-day period was the specification for the grout mixture.

As the project began, there were difficulties in achieving a mixing procedure that was practical for the size of the demonstration project. The scale of the demonstration project did not warrant the expense of setting up a pug mill to blend the grout mix. The initial mixtures of conditioned FBC coal ash and CKD were trucked to the site in one vehicle. The truck would load 2/3 full of ash from Northampton Generating and then fill the remaining 1/3 with CKD from nearby Keystone Cement. It was important that the ash was conditioned with approximately 20% water at Northampton to provide some dust suppression.

A hopper device was fabricated at James Quandel & Sons Concrete, Inc. to blend the grout components and additional water was added to the mixture. Quandel continually tested the strength of the blended mixture, but obtaining a consistent grout mixture that would meet the 275 psi in 7 days became very problematic. The mixture of ash/CKD showed very low strength of 70 psi in 7 days as seen in Table 6.4. It appeared that the grout mixture retained water and did not cure like the laboratory tests. It was preferred that the Northampton FBC ash would be used with the Keystone Cement CKD since both companies agreed to donate the material for the demonstration project and Northampton donated the trucking costs. Several truckloads of FBC ash/CKD were tested, however, obtaining a consistent mix was difficult.

Additional tests were conducted with various other materials and mixtures to achieve the target strength, as tabulated in Table 6.4. Portland cement was added in Mix 2 and 3 and the desired strength was achieved. Several tests were done to minimize the amounts of Portland. In Mix 4 and 5, the Northampton ash was replaced with a quartz rich bottom ash from another co-generation facility. Both mixtures were treated with equal amounts of a performance additive developed by Grace Construction Products specifically for controlled low strength materials. They yielded significantly different results, but neither met the target strength in a 7 day period. Due to time constraints and the fact that a consistent ash/CKD mixture that met the specification could not be attained, the CKD was eliminated from the project and was replaced with a relatively small amount of Portland cement. Ultimately, a blend of Northampton FBC ash with 9% Portland cement by weight was the mixture used. Varying amounts of water were added

depending upon the actual moisture content of the delivered ash. The total moisture content was adjusted by the operator to maintain a suitable slump of 6-7 inches.

Table 6.4. Summary of project-scale grout mixture strength tests (from Levitz, 2003).

Product	FBC Ash	CKD	Portland Cement	Water	7day (psi)	14 day (psi)	28 day (psi)	Observation
Mix 1	67%	33%			70	73		Grout did not dry
Mix 2	1100 lb		310 lb (18%)	290	700 (96 hr)			Significantly more than target 275psi
Mix 3	1100 lb		150 lb (9.4%)	333	320		1200	Displayed shrinkage Bulk density was 102 lb/CF instead of desired 60 lb/CF
Mix 4	5400		600 lb (8.5%)	1095	92			Quartz rich bottom ash + additive
Mix 5	5400		660 lb (9.1%)	1162	169			Quartz rich bottom ash + additive

Obtaining the proper grout mixture and establishing a handling procedure was a critical component of the project. Dust suppression and consistency of the materials are additional factors to be considered. The calcium content of the FBC ash from Northampton varied with changes in the fuel blend at the plant. The amount of limestone used at the plant varied directly with the amount of petroleum coke in the fuel blend. The CKD should be investigated further since it did show strength enhancing properties in the laboratory. A procedure for importing consistent CKD would be necessary. The CKD may possess different properties if it comes directly from the cement kiln or if it is weathered CKD from the stockpile. The handling of the materials, transportation costs, and placement of the material can significantly inflate the cost of the project.

The scope of the entire cropfall remediation project is enormous. The cropfalls selected for the demonstration project were at the location where the previous efforts under the emergency projects were experiencing failure. Since the previous measures taken were very short lived, it was obvious that a more permanent solution was needed. The sequence of the subsidences, their restoration, their failure, and the demonstration project are shown in Figure 6.12 a-c. The field conditions provided an ideal opportunity to test three slightly different methods of constructing a structural plug to seal the voids. The project area shown in Figure 6.12d consists of three distinctly separate areas, Pit A East, Pit A West and Pit B. The area referred to as Pit A was previously backfilled and failed. Pit B subsided in 2000 and had not been backfilled.

Pit A consisted of 2 subsidences within the previously backfilled area (Fig. 6.12c). The voids, one roughly rectangular, the second circular, were initially 41 feet apart and 64 feet long by 38 feet wide and 30 feet deep and 17 feet in diameter by 6 feet deep, respectively. The presence of tension cracks between the voids suggested that the voids would continue expanding, ultimately forming one cropfall. In order to install the structural plug, the subsidences were further excavated and prepared. Approximately 2,250 cubic yards of material was removed from Pit A to locate solid competent rock adjacent to the subsided coal vein. The excavation resulted in one hole separated into 2 fairly equal sections by a solid coal pillar that was exposed and intact as displayed in Figure 6.13a.



Figure 6.12(a). Subsidence in 1999.



6.12(b). Restoration effort, 2000.



6.12(c). Area resubsides, 2001.



6.12(d). Demonstration Area, 2002. An orange safety fence surrounds the construction area.

The method of backfilling in Pit A was to develop a wedge that if the potentially false bottom of the pit would fail, the wedge would become lodged and would not undergo catastrophic failure. Concrete panels were placed on the floor of the excavated pit in both the eastern and western portion of Pit A. The purpose of the concrete panels was not to create an additional structural member of the plug, but to provide a means to retard the flow of the grout until it had time to cure. The concrete panels were originally manufactured to be used as sound barriers along major highways. The panels were flawed or damaged and they were donated by Schuylkill Products, Inc. a nearby concrete fabrication operation. In the eastern portion of Pit A an inverted steel truss was fabricated to act as a structural support member that spanned the void and was wedged into the competent solid rock on the north and south end of the pit (Fig. 6.13b). The self leveling cementitious grout mixture, not unlike controlled low strength flowable fills, was then placed in the eastern portion of Pit A covering the steel member. The grout mixture of FBC ash, approximately 9% Portland cement, and water was blended at Quandel Concrete,

Minersville and imported to the site in cement mixers (Fig. 6.13c). The consistency of the grout mixture allowed it to flow throughout the east pit and it hardened relatively quickly allowing the vehicles to travel on the grout mixture (Fig. 6.13d).

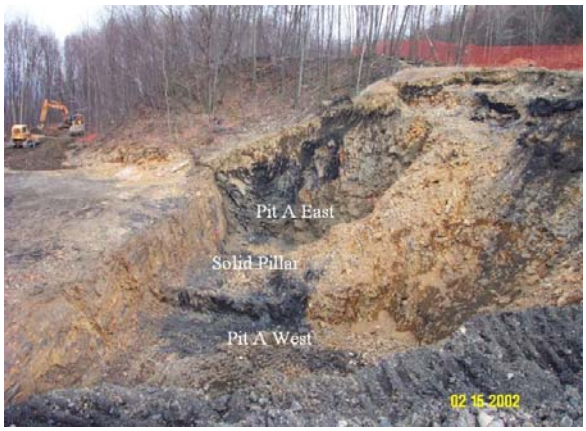


Figure 6.13(a). Pit A prepared.



6.13(b). Steel trusses installed in Pit A east.



6.13(c). Grout mixture placement, Pit A east.



6.13(d). Pit A east grout complete.

The west side of Pit A was prepared similarly in that reject concrete panels were placed in the floor of the pit. Instead of the fabricated steel trusses, recycled reinforcement bar (rebar) was imported from Glasgow, Inc. to form a wire mat similar to a large expanded Brillo pad in the grout mixture for structural support (Fig. 6.14a). The rebar was loosely packed and it allowed the grout to flow through it. The grout was placed and leveled with the eastern portion of Pit A. Grout depth in all of Pit A was approximately 10 feet. The remainder of the pit was then filled with coal ash from PPL Montour Station to serve as a bulk fill material that will also be beneficial due to its cemetitious properties (Fig. 6.14b). As with the Northampton ash, PPL donated the ash and delivered it to the site. Once the area was backfilled and graded to the adjacent contours, topsoil was added and the area was vegetated, Figure 6.14c-d.



Figure 6.14(a). Scrap rebar in replaces trusses, Pit A west.



6.14(b). Grout added. Notice the mixer is driving on previously poured grout.



6.14(c). Ash bulk fill placed.



6.14(d). Prepared for topsoil. Pit A complete**.**

Pit B is a subsidence feature on the upper, southern line of cropfalls as seen in Figure 6.12d. This cropfall was not previously addressed in any backfilling attempt. Unlike Pit A, this cropfall appeared somewhat stable. The bottom seemed well choked with large boulders. Therefore, the temporary floor of concrete panels was not used. Both the north and south walls of Pit B were well exposed and required little excavation. Only 180 cubic yards of material were removed from the hole to prepare it for grout placement. There were no reject concrete panels, steel trusses or rebar used in this void. The void was filled solely with 8-10 feet of the ash-based grout mixture. Coal ash was used as a bulk fill material and the area was revegetated. As the grout mixture was added, one load of grout material (8 yards) was lost as it flowed into cracks in the pit floor.

The demonstration project, Pit A was completed in September 2002, Pit B was completed June 2003 and the areas appear to be stable as seen in Figure 6.15. The project withstood one of the wettest years on record with no adverse effects. Already the area is visited by the unsuspecting public with little respect for the potential dangers that exist on the mountain, as evidenced by a dirt bike trail across the area. The 2.5 acre project set the stage for future phases

of reclamation within the 340 acre overall project area. The success of the stability of the demonstration project will be tested in time; however the methods and material employed in the project have provided very valuable information and direction for approaching the large amount of cropfalls that lie ahead.



Figure 6.15. Completed Sharp Mountain demonstration project.

6.4 USE OF COAL ASH IN MINE DRAINAGE REMEDIATION

Production of AMD requires the presence of pyrite, oxygen, and water. If a barrier can be configured that will isolate the pyrite from the oxygen and water, then AMD can be prevented or abated. FBC ash was used in two different applications on reclaimed mine sites in an attempt to isolate pyrite in the backfill from coming into contact with water and oxygen. One of the applications involved spreading a 3 ft. thick layer of FBC ash beneath the topsoil of a 100-acre mine site in Clearfield County to serve as an infiltration barrier. In the second application, buried piles of pyrite rich materials were identified using geophysics, and FBC ash was mixed with water and injected as a grout to encapsulate the buried pyrite piles of pyrite.

Acid mine drainage is formed by the oxidation of metal sulfides, primarily the oxidation of pyrite by the familiar mechanism (Stumm and Morgan, 1996):

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+ \quad (1)$$

$$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O \quad (2)$$

$$Fe^{3+} + 3\ H_2O \rightarrow Fe(OH)_3(s) + 3\ H^+ \quad (3)$$

$$FeS_2(s) + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+ \quad (4)$$

As shown in equations 1 and 2, oxygen must be present to initiate pyrite oxidation. At a low pH level (on the order of pH $\leq$ 3) the ferrous iron oxidation given in equation 2 is accomplished primarily by iron oxidizing bacteria, such as *Thiobacillus ferrooxidans*. This low pH level is promoted by hydrolysis, as shown in equation 3. The overall oxidation reaction in solution is accelerated as shown in equation 4, wherein Fe^{3+}, instead of O_2, is the oxidizing agent.

Guo and Cravotta (1996) point out that pyrite oxidation occurs mainly in the unsaturated zone of mine spoil. Although infiltrating H_2O carries dissolved O_2 at an equilibrium solubility of between 9.2 mg/L at 20° C to 14.6 mg/L at 0° C (Greenberg et al. 1992), oxidation by atmospheric O_2 (normal atmospheric volume = 21%, Perry, 1976) is more effective than oxidation in solution, considering the low solubility and the low replacement of dissolved O_2 by molecular diffusion (Diffusivity = 2.5 x 10^{-6} cm^2/sec: at 25° C, Perry, 1976). Guo and Cravotta observed at a mine where the spoil was a compacted, friable shale that the atmospheric oxygen diminished to less than 2% at a depth of about 33 ft. This suggests that initial AMD formation (equations 1 and 2) occurs in the upper layer of backfilled spoil, approximately 20 ft in depth. The remaining pyrite oxidation depends on molecular diffusion of O_2 from aqueous solution to the pyrite surfaces as well as dissolution of the reaction products (equations 1-4).

6.4.1 Use of FBC Ash to Form and Impermeable Cap – McCloskey Surface Mine

6.4.1.1 Site description

A watershed in north central Pennsylvania was being polluted by an acidic mine drainage discharge from a 100 acre surface coal mining operation. In an effort to abate the pollution, an application of a 3 ft. thick cap based on FBC ash/LKD cementitious grant was placed on the reclaimed surface prior to spreading the topsoil and revegetating the mined area. The FBC ash layer serves a dual purpose, first as an aquitard that prevents the infiltration due to precipitation from reaching acid forming materials in the backfilled mine. Secondly, the formation of acid from the oxidation of pyrite, FeS_2, is inhibited, and the concentrations in the groundwater and in the surface discharges of Fe, Mn, and Al are diminished substantially below levels present before the application of the FBC layer.

Original mining on this site began as a Lower Kittanning underground mine, which closed in the early 1950s. Surface mining began in the late 1940s. In 1976, John Teeter Coal Company received a permit to daylight the Lower Kittanning deep mine and to mine the Middle Kittanning coal seam as well. It was repermitted in 1985, renewed as River Hill Coal Company in 1991 and became known as the McCloskey operation.

The McCloskey surface mining operation is located in Karthaus Township, Clearfield County, Pennsylvania. Runoff from the mine drains to Saltlick Run; Marks Run (tributary of Upper Three Runs), an unnamed tributary of Upper Three Runs, and directly to Upper Three Runs, all tributaries to the West Branch Susquehanna River (Fig. 6.16). During active mining, it was necessary to pump and treat the pit water before it was discharged to Upper Three Runs.

The operator was left with the problem of treating or abating the acid mine drainage that formed within the backfilled McCloskey mine. The operator attempted to passively treat the resulting average 60 gpm polluted discharge with a horizontal flow aerobic constructed wetland having an area of 10,650 yd^2 and incorporating aeration at the inlet. This system had the disadvantage that the mine drainage must be pumped to the wetland inlet due to space and elevation constraints. Although the 1991 average sample results given in Table 6.5 shows substantial improvement in water quality by the constructed wetland, the wetland was not successful in meeting effluent limits.

Table 6.5. Influent and effluent water quality from aerobic constructed wetland.

Location	pH	Alkalinity mg/L	Acidity mg/L	Iron mg/L	Manganese mg/L	Sulfate mg/L
Influent	4.8	33	657.0	230.7	146.3	4766
Effluent	3.3	12	31.7	31.7	107.9	4752

With treatment costs approaching $100,000 a year and with mining completed, the mine operator was facing potential bankruptcy. In 1991, the operator attempted to abate the AMD discharge through the use of an impermeable FBC as cap on the backfilled surface mine.

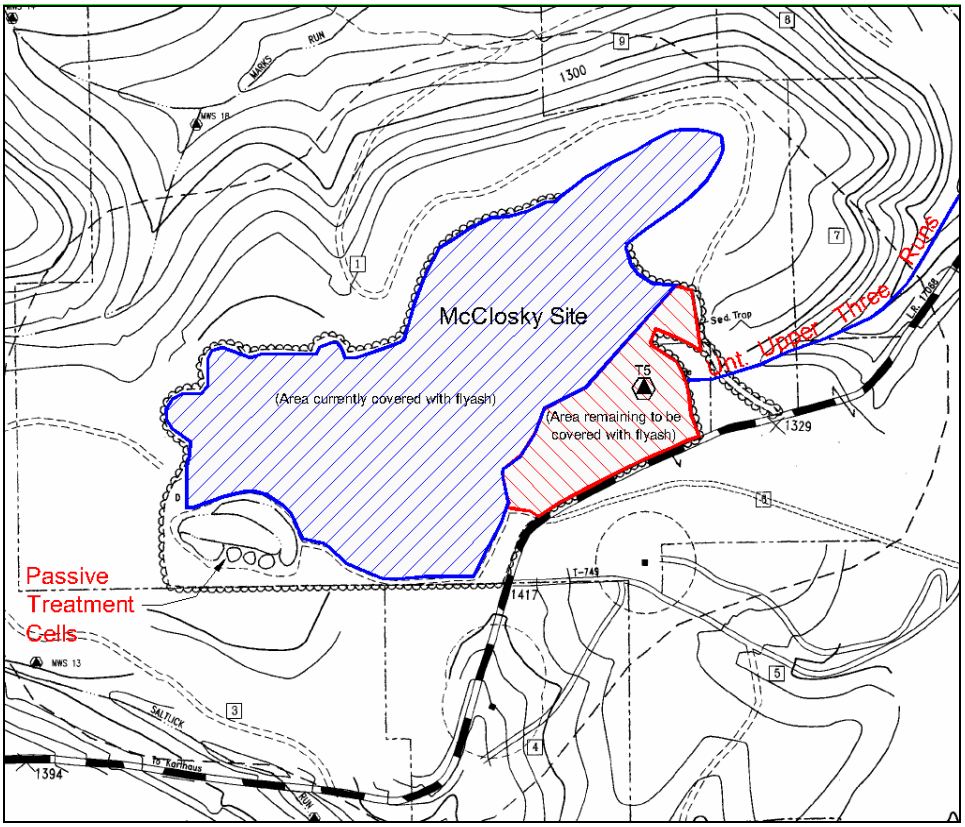


Figure 6.16. Map of McCloskey mine site. Areas already capped prior to 1998 is shown in blue and post-1998 are displayed in red.. T-5 discharge location is included.

The configuration of the reclaimed area of the McCloskey mine site is shown Figure 6.16. The mined area is a hilltop surrounded by drainage to the Saltlick Run and Upper Three Runs watersheds. Scheetz et al., (1997) discussed these and other hydrogeologic constraints and boundary conditions which revealed that there was no apparent horizontal groundwater contribution to the water balance at the site. The rainwater falling directly on the site percolated through the spoils with a detention time of approximately 2 days, with the major portion of the water exiting the site via the seep T-5 and some water exiting at seep T-6. This is consistent with the measured strike and dip varying from N43°E, 4.6° to N42°E, 1.5° for the Lower Kittanning "B" Coal.

6.4.1.2 Low permeability FBC ash cap project concept

The DEP observes that 40% to 50% of precipitation at a surface mine infiltrates vertically into the spoils, furnishing the medium for acid mine drainage production. This suggests that placement of a shallow, relatively impervious barrier as an upper layer of the surface mine backfill would inhibit the formation of acid mine drainage, both by creating an impermeable barrier to atmospheric oxygen and by redirecting the rainfall as uncontaminated surface runoff. An impermeable barrier could be fashioned from a conventional concrete made from Portland cement but the cost would prove prohibitive. However, FBC ash is pozzolanic, thus it has the properties necessary to be formed into a shallow, impervious barrier.

EPA priority pollutants Cr, Cu, Pb, Ni, and Zn are not present at detection limits in the receiving stream, while only a trace of Se is present (Table 6.7). Benthic macroinvertebrate populations have improved substantially since the fly ash application began. This reclamation effort offers the promise of abating pollution in numerous surface mine discharges whose primary hydraulic contributor is vertical flow from rainfall. It is expected that such discharges can be ameliorated to approach discharge limitations, or that the flow rate can be diminished sufficiently to facilitate treatment of pollution in the final discharges with passive systems.

This suggested that placing a FBC ash cap over the reclaimed area would intercept nearly 100% of the water that contributed to the mine drainage flow. In March 1992, the surface mine permit was revised to approve the use of FBC ash grout on site for the purpose of abating the acid mine drainage discharge.

6.4.1.3 Coal ash placement – capping of site

The application of the FBC ash began in July 1992 as a 5 acre experimental project. Prior to ash placement the test plot was evaluated by monitoring infiltration. Fifty five gallon drums (with the tops removed) were filled with clean silica stone, covered with geotextile fabric and buried in the backfill to serve as water collection points. A standpipe was installed which extended from the bottom of the drum to the surface. Water accumulation within the drums was monitored. Water accumulated in the drums on a regular basis. Once the ash cap was in place above the drums, they remained dry. This experiment indicated that an ash cap over the entire site should be successful in inhibiting infiltration below the cap.

The ash was mixed with lime kiln dust at a rate of 90% FBC ash to 10% waste lime by volume. It was spread and compacted primarily by rubber-tired graders over the reclaimed site. The 3 ft. FBC ash cap was applied in accordance with procedures developed by Scheetz under the direction of the DEP (Scheetz et al., 1997). Water was metered onto the fly ash formulation from water trucks during dry months; otherwise, rainfall furnished the necessary water. The FBC ash cap was compacted in 6 in. lifts to a total thickness of 3 ft. The permeability of the ash was determined by laboratory testing to be 10^{-7} cm/sec after a curing time of 515 days. Unconfined compressive strengths of this grant were routinely recorded in excess of 4000 psi during laboratory testing. The topsoil layer was then spread and the area was seeded.

Following completion of the test plot, approval was granted to cap the entire site (Fig. 6.16). By February 1998, an area of 74 acres received the fly ash cap. The cap was applied to a thickness of 3 ft. and covered with 3 ft. of topsoil or topsoil substitute, which in turn was revegetated. An estimated 222,850 tons of fly ash was used to construct that portion of the cap. Between February 1998 and January 2004 an additional 11.3 acres was capped. This included the filling of a 7-acre depression adjacent to the site that was directing precipitation into the backfill. It is estimated that another 35,600 tons of fly ash was utilized during this time period. A total of approximately 300,000 tons of ash was ultimately incorporated into the cap at the McCloskey Operation. In addition to the ash cap, three of the aerobic wetland cells were drained and lined with ash. This was in response to observations that water pumped to these cells was leaking back into the backfilled spoil rather than discharging to the stream.

The ashes approved for use were from several sources; Public Service Electric and Gas Company's Hudson Generating Station in Jersey City NJ; NYE&G Greenwich Plant, Milliken and Goudey Sources, and American Ref-Fuel Company in Essex County NJ; and the Lakeview Coal Bottom Ash Source. Ash from the Piney Creek and Scrubgrass cogeneration facilities and the Lancaster Millable Metals site, all in Pennsylvania, were applied as well. All ashes were approved by the DEP prior to being placed at the McCloskey Operation. Typical chemical characteristics of the ash are given in Table 6.6.

Table 6.6. Typical chemical characteristics of fly ash leachates used at the McCloskey site. (Data provided by B. E. Scheetz from TCLP extracts).

Parameter	**Concentration (mg/L)**	**Parameter**	**Concentration (mg/L)**
Al	0.48	Mn	0.41
As	0.08	Mo	0.53
B	1.05	Ni	0.15
Ba	0.41	Pb	0.65
Ca	970	Sb	1.28
Co	0.03	Se	0.056
Cr	0.07	Si	9.6
Cu	<0.02	Sn	0.61
Fe	0.06	Sr	6.1
Hg	0.004	Ti	<0.02
K	310	Zn	0.04
Mg	35		

6.4.1.4 Results

The chemical quality of the discharge are presented in Figures 6.17 and 6.18. Figure 6.17 presents the historical concentration for sulfate and acidity. Since the capping project began in 1992, sulfate concentrations have decreased by about 50%, from over 4000 mg/L in 1992 to a little over 2000 mg/L in 2004.

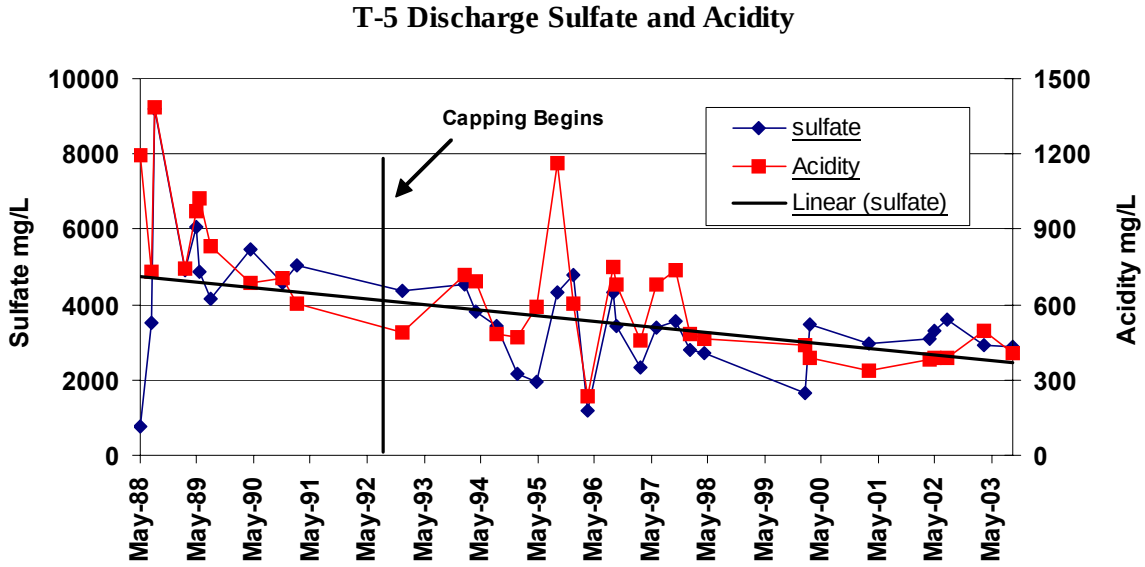


Figure 6.17. Historical quality of the T-5 discharge for sulfate and acidity. Ash placement began in 1992. The trend line for sulfate is included in the graph.

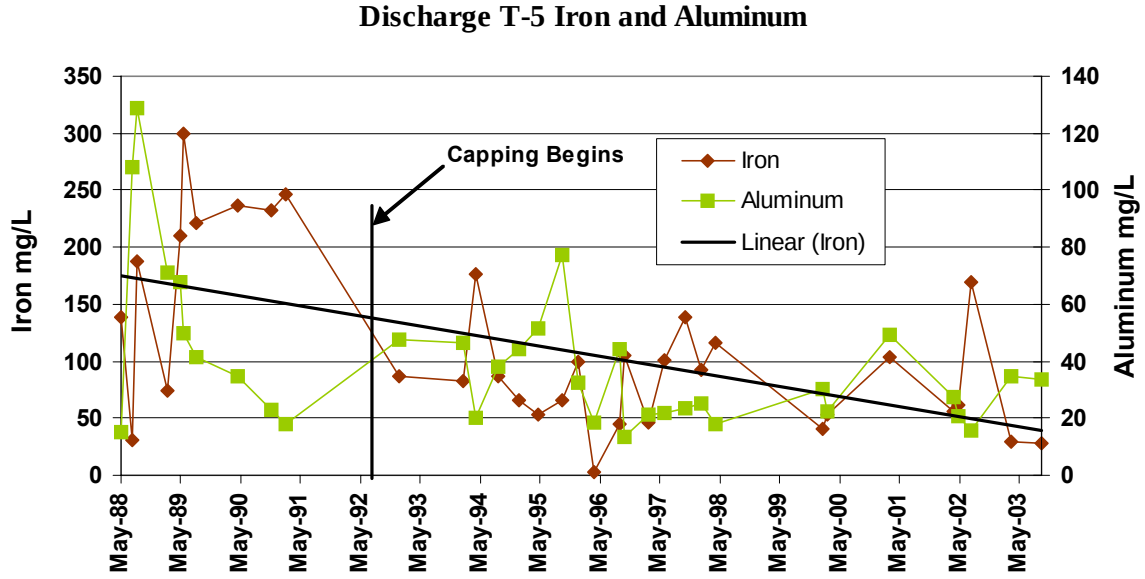


Figure 6.18. Historical quality of the T-5 discharge for aluminum and iron. Although not included, manganese follows a similar trend. The trend line for iron is included.

Being a rather conservative ion in mine drainage, the reduction of sulfate ions clearly suggests that AMD production has been reduced because of the influence of the cap. Acidity also shows a similar decrease in concentration over time. Figure 6.18 shows the historical concentrations of iron and aluminum over time. Similar to sulfate, concentrations of iron and aluminum in the discharge also reflect about a 50% reduction since the beginning of the ash cap.

A secondary objective of the project was to prevent additional pollution as a result of the beneficial use of ash. Evidence of success here includes the chemical quality of the discharge as well as macroinvertebrate and fish sampling in the receiving stream, Upper Three Runs. The results given in Table 6.7 show the absence of EPA priority pollutants from the discharge, which is being mitigated by the fly ash cap. The high concentrations for the parameters commonly associated with AMD, including alkalinity, acidity, iron, aluminum, manganese and sulfates, are attributable to the AMD and not the FBC ash cap.

Table 6.7. Mine drainage discharge quality sampled in 1997. Concentration of AMD parameters for 9/2003 are shown in parenthesis followed by an *.

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Total Dissolved Solids	5024	Cd	<0.0002
Alkalinity as $CaCO_3$	2 (8.4)*	Ca	326
Acidity as $CaCO_3$	706 (404.8)*	Cr	<0.004
Cl^-	8	Cu	<0.010
F^+	1.7	Pb	<0.001
Fe total	122 (27.6)*	Mg	547
Na	19.3	Hg	<0.001
NH_3 as N	<0.04	Se	<0.007
NO_3 as N	0.43	Zn	2.31
Al	23.7 (33.4)*	Mn	127 (85.5)*
As	<0.004	SO_4^{2-}	3386 (2875)*
Ba	<0.010	pH	(4.2)*

The Pennsylvania Fish and Boat Commission conducted both benthic macroinvertebrate and electrofishing surveys on at least four occasions on Upper Three Runs both upstream and downstream of the fly ash capping project. The results given in Figure 6.19 are for the macroinvertebrates and the electrofishing results are given in Figure 6.20. The water quality and aquatic life in Upper Three Runs has improved significantly since the fly ash cap was placed at the site. No detectable pollution from other EPA priority pollutants has been found in Upper Three Runs.

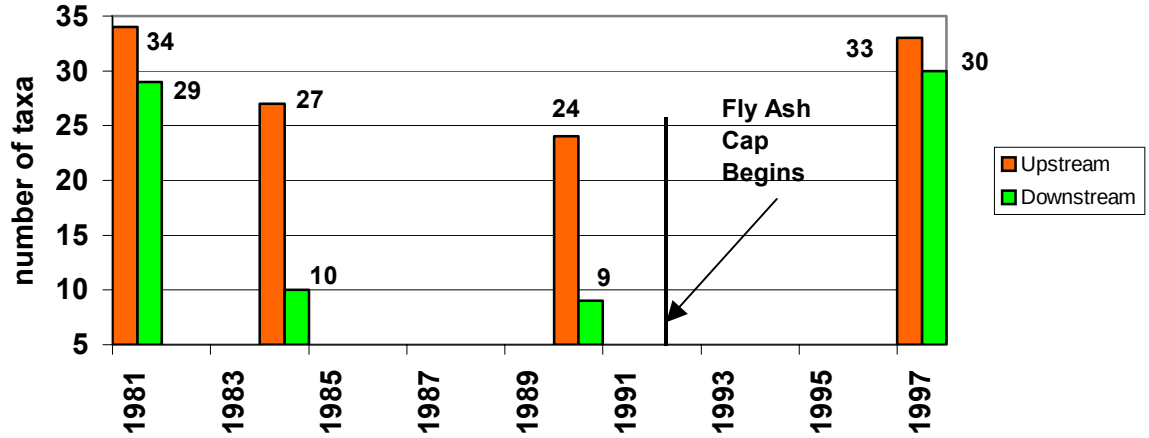


Figure 6.19. Qualitative benthic macroinvertebrate comparison upstream and downstream of discharge

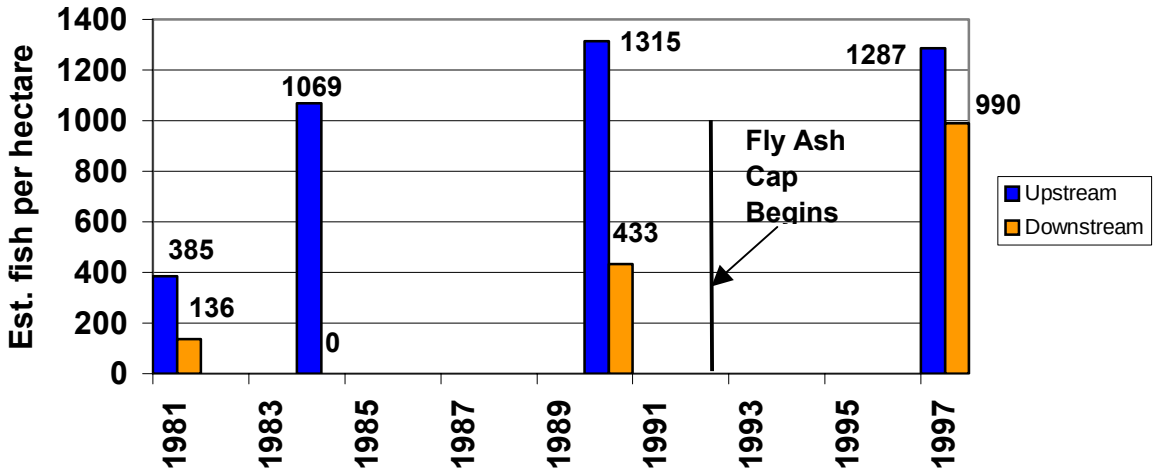


Figure 6.20. Electrofishing results upstream and downstream of discharge.

6.4.1.5 Conclusions

- The fly ash cap at the McCloskey site has enhanced reclamation, abated water pollution, and enhanced the aquatic life in the stream.

- The fly ash cap at the McCloskey site formed an effective barrier that prevents the infiltration of rainwater from entering the groundwater flow regime. Since the horizontal contribution to groundwater flow to the reclaimed spoils being negligible, the fly ash cap has substantially abated the formerly polluted post-mining discharge.

- The fly ash cap at the McCloskey site has not generated secondary problems in the form of EPA priority pollutants in the receiving stream.

This abatement and reclamation project demonstrated the environmentally safe and beneficial use of what otherwise would be considered a waste product. The project clearly demonstrates that a fly ash cap to retard vertical flow would be successful in cases of mine drainage pollution where vertical infiltration of precipitation is the primary source of recharge to a site.

However, if the inflow to a given mine site has a significant horizontal component, retarding the vertical flow from rainfall on the site itself might not be as successful as it has been at the McCloskey site. Insufficient time has elapsed to determine whether, at sites where the natural succession includes plants whose roots might penetrate the cap, a fly ash cap would lose its effectiveness over time or simply limit root zone development.

6.4.2 FBC Ash Grouting of Buried Piles of Pyritic Materials on a Surface Mine – Fran Site.

Effective in-situ abatement technology requires that the source(s) of the AMD production first be located. AMD source location can be done with little difficulty on many surface coal mines using geophysical mapping techniques (Schueck, 1988, 1990) (Schueck et al. 1994). Pyritic materials such as tipple refuse or pit cleanings are often placed in discrete piles and buried. When placed in discrete piles or pods and not properly isolated from infiltrating precipitation or groundwater, severe localized AMD production may result. Under these conditions, geophysical testing method can detect the pods and the resultant AMD plume.

Abatement technology can be applied once the precise locations of the acid producing materials buried within the backfill are determined. The contact of pyrite with oxygen and water is needed to produce AMD. In-situ AMD abatement will result if the pyrite can be isolated from the water and/or oxygen. FBC ash grout was used to isolate pyrite from oxygen and water in this project.

6.4.2.1 Site description

The project site is located in north-central Pennsylvania in the Sproul State Forest, East Keating Township, Clinton County, PA. This 37-acre surface coal mine was mined by the mountain top removal method and reclaimed between 1974 and 1977 under Fran Contracting. The Lower Kittanning coal seam was present in two splits separated by 10 to 20 ft. of clay. Only the upper split was mined, leaving a thick underclay as pavement. The coal was overlain by black shale capped by a sandstone unit. The black shale is pyritic and acid producing. Infiltrating precipitation is the only source of groundwater. Acidic discharges developed soon after reclamation and were first noted after a fish kill in 1978. The discharges (surface and underground), estimated to average 35 gal/min, destroyed five miles of native trout streams. The operator was unable to maintain treatment facilities and forfeited the reclamation bonds.

Buried pyrite-rich pit cleanings and some tipple refuse were found to be producing severe AMD at this site. The pyritic material is located in discrete piles or pods in the backfill, Figure 6.21. The pods and the resulting contaminant plumes were initially defined using geophysical techniques and confirmed by drilling. As demonstrated at the McCloskey site in the previous discussion, isolating the pyritic material from water and oxygen will prevent AMD production.

The AMD discharges from this site are among the worst quality discharges from any surface coal mine in the state. Monitoring wells have been sampled since 1990 to monitor changes in the water quality resulting from grouting efforts. Grouting occurred during the summers of 1992 and 1993.

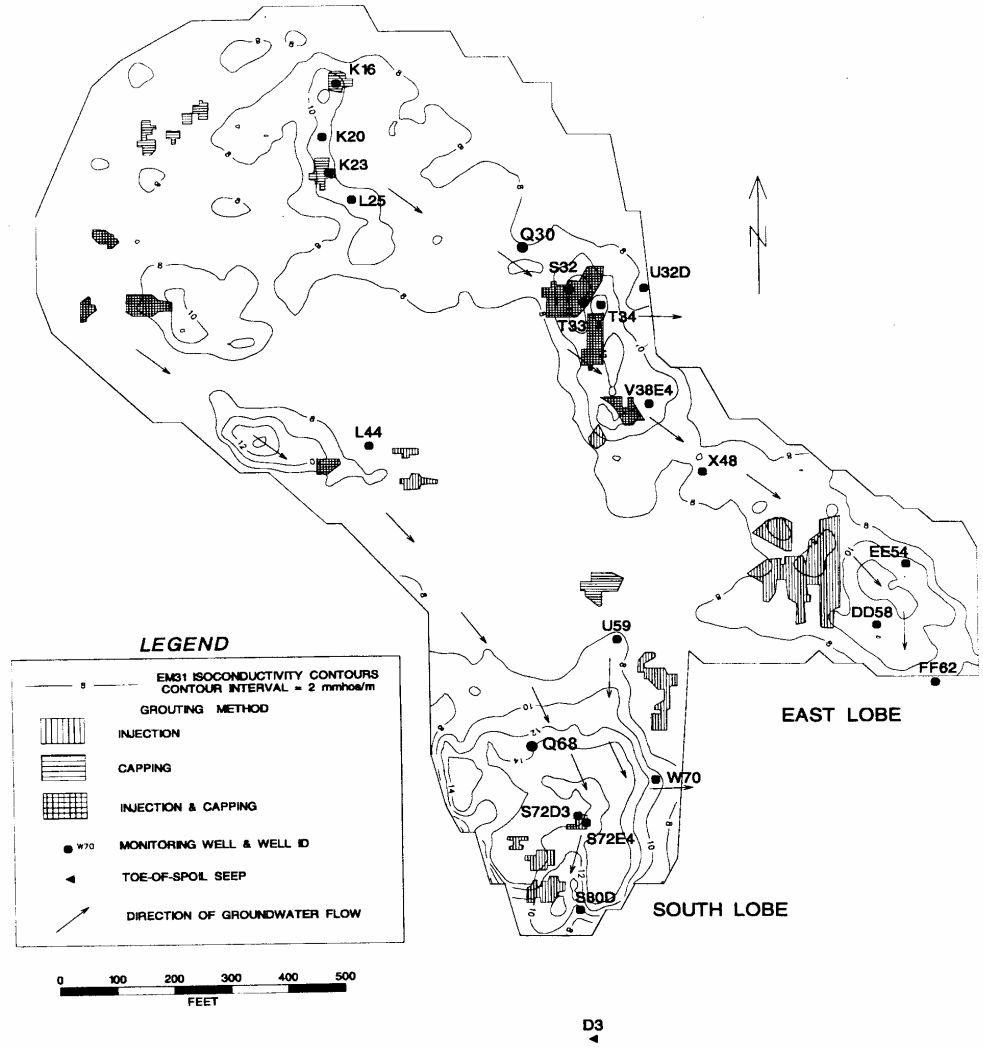


Figure 6.21. Location of buried pods of pyritic materials, sites and types of grout applications and ground monitoring points at the Fran Site, Clinton County.

6.4.2.2 Geophysical investigation and pre-grouting groundwater quality

Several geophysical mapping techniques were used for site characterization. These techniques included electromagnetic terrain conductivity (EM), magnetometry, and very low frequency (VLF). EM was used to map the location of the AMD plumes throughout and off the

site. The piles of buried refuse and pit cleanings were located with magnetometry. VLF was used to map bedrock fracture zones beneath and adjacent to the site (Schueck et al., 1994).

EM mapping and drilling data indicated the general groundwater flow path through the site. This is the down-dip direction. The pollutional plumes and groundwater flow direction is indicated in Figure 6.21. EM mapping also indicated pooling of pit water in the down-dip portions of the site behind the low wall. The EM mapping further indicated groundwater pollution plumes leaving the site at three locations where toe-of-spoil (surface) discharges were not present. VLF mapping indicated the presence of fractures in the pit floor, which coincide with the pollution plumes. These fractures apparently channel AMD from the mine spoil to a major joint system beneath the site. The joint system conveys the AMD to Rock Run as base flow, some 250 feet lower in elevation and northeast of the site. A toe-of-spoil discharge, D3, is present beyond the south lobe. The discharge rate of D3 varies from 2 to 85 gal/min and appears as a diffuse seep over a rather large area of about 2 acres. It is at an elevation equal to the lower, unmined split of coal. This discharge flows to the southwest into Camp Run, a tributary of Cooks Run.

Magnetometer mapping was used to determine the locations and configurations of concentrated pods or piles of pyritic materials such as tipple refuse. Magnetic anomalies indicate the aerial extent of the pods of pyritic material buried beneath the surface. In Figure 6.21, polygons are used to indicate the location and extent of the pods of pyritic material and to show the extent and type of grouting applied.

When the magnetic anomaly map was overlain with the EM map, it was observed that conductivity values were highest at or adjacent to the magnetic anomalies, Figure 6.21. The conductivity values gradually decreased in the direction of groundwater flow but showed an increase where the AMD was pooled behind the low wall. This observation is consistent with severe AMD production within the buried pods of pyritic material, followed by dilution as the AMD migrates further away from the pods.

Forty-two monitoring wells were drilled on and adjacent to the site. The wells were located using the results of the combined geophysical mapping. Wells located on the site were drilled through spoil to the pit floor, with depths ranging from 10 to 40 ft. Monitoring wells located adjacent to the site were drilled into the unmined lower split of the Lower Kittanning coal seam. This initial drilling effort confirmed the locations of the pods of refuse and pit cleanings identified with magnetometry. Water quality monitoring was initiated in 1990 and continued through 2001. The grouting occurred during the summers of 1992 and 1993. Sampling of the monitoring wells was done on approximately a bi-monthly schedule from 1990 through 1996, then semi-annually until the present. Water sampling was also performed at the only surface discharge, D3, which is the toe-of-spoil seep located 200 feet south of the site.

Table 6.8 lists pre-grouting water quality for the toe-of-spoil seep and selected monitoring wells, which are considered to be representative of the site (Fig. 6.21). Maximum, minimum, and mean pH values and metals concentrations are presented. These data are based on 13 to 21 sampling events.

The toe-of-spoil seep, labeled D3, and well FF62 represent the pre-grouting water quality which exits the site from the south and east lobes, respectively. Well FF62, located off site and adjacent to the east lobe, intercepts a subsurface discharge plume (as identified by EM survey) suspected to enter Rock Run as base flow. Also, well FF62 samples water in the lower, unmined split of coal. The poor water quality demonstrates fracture communication between the pit floor and lower coal seam. D3 also appears to be coming from the lower coal seam. Comparison of the mean concentrations indicates that the water discharging from the east lobe (FF62) is of poorer quality than that discharging from the south lobe (D3). Drainage from the majority of the pods of pyritic material flows towards the east lobe.

Table 6.8. Pre-grouting water quality from selected groundwater monitoring points. Note the wide variety in concentrations from one monitoring point to the next, especially Well K23.

Monitoring Point D3 – Toe-of-spoil seep area combination of all drainage N=16

	Lab	TDS	SO_4	Acid	FeTot	Fe^{3+}	Al	Mn	Cd	Cu	Cr	As	Zn
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Max	2.7	8828	3749	3520	543	385	348	62.3	66	852	269	40	4.2
Min	2.4	4540	1245	2220	183	149	205	28.4	1.9	399	125	4	2.5
Mean	2.49	6475	2751	2995	321	254	268	48.3	25.5	612	200	20.2	3.4

Monitoring Well FF62 – East Lobe – Groundwater discharge zone combination of all drainage N=15

	Lab	TDS	SO_4	Acid	FeTot	Fe^{3+}	Al	Mn	Cd	Cu	Cr	As	Zn
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Max	2.6	12706	5773	6440	1500	1294	562	67.3	167	1110	301	148	7.5
Min	2.2	3404	1272	1940	386	246	114	14.8	29	611	142	25	2.1
Mean	2.32	7970	3477	4088	876	737	256	39.2	83	806	221	69	4.3

Monitoring Well Q30 – AMD production from Lower Kittanning spoil w/ little influence from buried pods N=17

	Lab	TDS	SO_4	Acid	FeTot	Fe^{3+}	Al	Mn	Cd	Cu	Cr	As	Zn
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Max	2.3	26130	11060	10260	2180	1604	789	141	363	2560	778	208	15.5
Min	2.1	13096	3817	7220	300	25	281	34.2	64	2070	501	4	7.5
Mean	2.05	17000	6804	8492	1559	852	628	85.7	172	2336	633	139	11

Monitoring Well K23 – Severe AMD production in pods N=13

	Lab	TDS	SO_4	Acid	FeTot	Fe^{3+}	Al	Mn	Cd	Cu	Cr	As	Zn
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Max	2.2	128205	25110	23900	5690	2320	2440	79	1190	7410	1816	2890	39
Min	2.0	33706	9868	18280	3320	120	281	30.3	128	3360	593	684	10.8
Mean	2.1	46352	15639	21315	5437	1200	1515	60.5	610	5950	1108	1676	27.6

Monitoring Well X48 – Combined spoil and pyritic pods N=14

	Lab	TDS	SO_4	Acid	FeTot	Fe^{3+}	Al	Mn	Cd	Cu	Cr	As	Zn
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Max	2.8	25372	9950	9760	2210	1816	690	125	368	3370	687	493	10.5
Min	2.2	947	4763	3780	342	0	299	7.8	11	1680	492	169	6.2
Mean	2.37	14085	6991	7470	1707	439	492	72.8	227	2543	559	320	8.7

Monitoring well Q30 represents the pre-grouting water quality resulting from the Lower Kittanning spoil with little influence from buried pyritic pods. Q30 is not located directly downgradient of buried refuse or pit cleanings. Monitoring well Q30 is considered a suitable control well to monitor normal water quality variations on the site because it was not influenced by the grouting activities. Flow from Q30 would be toward the south lobe and eventually to the toe-of-spoil seep.

Monitoring well K23 demonstrates that the pods of refuse or pit cleanings can be sources of severe, localized AMD production. K23 is located within a pile of buried tipple refuse. It is located on the up dip portion of the mine site and is also at the upper end of a pollutional plume as defined by EM. The mean concentrations of the AMD parameters at K23 are two to three times greater than the concentrations of the same parameters in Q30 and X48, which represent AMD generated primarily by the spoil alone. This implies that enhanced AMD production from the pyritic material at K23 and similar locations significantly contribute to the degradation of the final discharge quality. The isolation of these subsurface pods of pyritic material from water and/or oxygen was expected to improve the final discharge quality (see Fig. 6.21)..

Monitoring well X48 is located several hundred feet downgradient of piles of pyritic material, but is within the flow path of mine drainage as it migrates through the site towards the east lobe. The water quality sampled from this well would be influenced primarily by the Lower Kittanning spoil as well as some AMD formed in the buried pods of pyritic materials. X48 indicates dilution of the severe AMD as it migrates and mixes with less severe mine drainage.

Certain trace metals also contribute to the pollution from this site. Elevated concentrations of zinc, copper, chromium, cadmium, and arsenic were common in the drainage from this site. The concentrations of other trace metals, such as lead, nickel, and selenium were generally below detection limits.

6.4.2.3 FBC ash grout injection project concept

The primary objective of this AMD abatement approach was to isolate pyritic material from water and oxygen. In sharp contrast to the McCloskey site where the isolation was achieved by capping the entire site, only those piles of buried pit cleanings suspected of causing the most severe AMD were targeted for isolation. FBC ash was the material selected to be used in this isolation approach. FBC ash was chosen primarily because of its pozzolanic (or cementitious) properties as well as for economic reasons.

A grout, composed of FBC ash and water, was used in two different approaches that attempted pyrite isolation. Pressure injecting grout directly into the buried pods to fill the void spaces within the pods and coat the pyritic materials with a cementitious layer was the first approach. In the second approach, pods that would not accept grout because of a clay matrix were capped with the grout to isolate the pyrite from percolating water.

A low viscosity grout was pressure injected into the geophysically identified zones (pods) as a means of encapsulating the pyritic materials with a cementitious coating. Diversion grouting was also used. This approach included capping of some of the pods and limited pit

floor paving. The grouting should generate zones of low permeability and redirect groundwater flow, significantly reducing water contact with the pyrite. Although the spoil, particularly the black shale, across the entire site was thought to be acid producing, the grouting effort was limited to only 5% of the site.

Statistically significant water quality improvements have been noted as a result of the grouting, although results are varied. Any water quality improvements resulting from the grouting are expected to be permanent because of the nature of the cementitious grout.

6.4.2.4 FBC ash characterization and grouting operations

The quality of the coal combustion ash is extremely important, particularly when it is being placed into an acidic environment. The characterization of the FBC ash used at the site was completed at the Penn State Materials Research Institute (Zhao,1995). Chemical analysis of the ash is as follows: $A1_2O_3$ - 12.51%, CaO - 38.03%, SiO_2 - 23.91%, SO_3 - 16.02%. The ash was tested using the EPA's Toxicity Characteristic Leaching Procedure (TCLP). All elemental contents of the ash fell within the established guidelines of the TCLP.

Mixed with only water, the FBC ash forms a low strength cement. After 20 days, at a water to solids ratio of 0.5, an unconfined compressive strength of 1920 psi is developed. The compressive strength continues to increase slowly to slightly over 2000 psi in 90 days (Zhao, 1995).

Only those pods of pyritic material identified with magnetometry were targeted for grouting. The grout injection wells were installed on 10 ft centers using 2 1/2 in. perforated, schedule 40 PVC casing. The injection wells were installed in August 1992. Grouting operations began September 1, 1992 and continued through the end of October 1992. The grouting operation resumed in June 1993 and was completed in August 1993. Grout injection wells were located within the polygons indicated in Figure 6.21. The grout was injected using a 650 psi positive displacement pump. The amount of grout accepted by the wells ranged from less than 0.3 to 83 yd^3 . Approximately 4500 yd^3 of grout were used on this project.

Originally, only pressure injection directly into the pods was planned for the isolation of the pyritic materials. However, soon after the grouting operations began, it became evident that this method would not work for all the pods within the site. Several of the piles refused to accept grout. Excavation within these pods showed the pyritic material was within a clayey matrix. These piles were capped with grout to divert infiltrating precipitation. The spoil above the piles was excavated. The excavated area was then pooled with fly ash grout. After the grout hardened, the excavated area was backfilled and regraded. However, the capping alone would not be effective in preventing lateral flow along the pit floor from coming into contact with the pyritic materials. Several of the pods were both capped and grouted. This combined application occurred where several of the wells within the pod accepted little or no grout, Figure 6.21.

Aluminum concentrations in excess of 1000 mg/L at various locations within the spoil suggested that the clay pit floor is a primary source of Al. Therefore, paving areas of the pit floor with a grout slurry was another water diversion technique applied at this site. The purpose

was to isolate the pit floor clays from contact with the AMD within the spoil. Success in this approach depends upon a high permeability of the spoil materials covering the pit floor. Well L25 shows the results of the paving activity and is discussed later in this report. The planned pit floor grouting activities were curtailed due to time constraints, ash supply and project funding.

6.4.2.5 Post-grouting water quality monitoring

Grouting occurred during the summers of 1992 and 1993. Water quality was monitored on approximately a monthly basis, April through November, from 1990 through 1995. Then the water quality was monitored on an annual or semiannual basis until 2001. In order to test the effectiveness of fly ash injection on water quality improvement, a series of one-tailed t-tests were computed for the water quality variables sampled from the monitoring wells. A t-test represents a test of significance that compares the mean and standard deviation of one group of samples to that of another to test if both groups came from the same population. The one-tailed t-test further compares not only if there is a significant difference between the two groups but if one group mean is significantly greater than the other. The $p <= 0.05$ level of significance was used as the rejection level of the null hypothesis for all tests. Davis (1986) and Krumbein and Graybill (1965) provide additional information regarding the t-test in geophysical applications.

For the tests, the water quality data for the respective monitoring wells were divided into two groups: the data sampled before fly ash injection occurred and the data sampled after fly ash injection was completed. It was obvious in some of the wells that the grout supernatant was impacting the water quality during and shortly after the grouting effort. These water samples were excluded from the data analysis.

During the summer of 1995, drought conditions existed at the site. The water quality in one of the control wells, L44, changed dramatically. Mean SO_4 values increased four-fold during the summer of 1995 and concentrations of TDS, acidity, Al, and Fe more than doubled. Moderate increases in concentrations of the mine drainage parameters were noted in most of the monitoring wells across the site during 1995. However, the increases were not nearly as drastic as were observed in L44. There were 7 sampling events in 1995, which represents about 25% of the post-grouting sampling events. There were only 8 sampling events since 1995. Because of this strong bias, the sampling events for 1995 were averaged and the average values were considered as a single sampling event. The conclusions within this paper are based on the averaging of the 1995 samples.

Table 6.9 lists the percentage reduction in mean concentrations for several of the mine drainage parameters for the three different applications. The applications included (a) injection only, (b) capping only and (c) a combination of injection and capping. Data are included for wells located both within the pod (IP) and for wells located downgradient (DG) of the pod. The percentage change in concentrations for two control wells, Q30 and Q68, is included for comparison.

Data for the first four wells in Table 6.9 reflect water quality changes resulting from only injection grouting directly into the pod (Table 6.9(a)). There is within-pod water quality data for only one pod that was subjected to grout injection only. There are two wells located within this

pod, S72D3 and S72E4 (Fig. 6.21). Both wells exhibited modest reductions in the mean concentrations of the common mine drainage parameters ranging from 29 to 51%. These reductions are all statistically significant. Significant reductions in trace metal concentrations from 36 to 86% were observed as well. This suggests that AMD production was reduced within the pod as a result of the grout injection. Wells EE54 and DD58 are located downgradient of a pod that was only pressure injected. These wells exhibited 22 to 38% statistically significant reductions in mean concentrations of the common AMD parameters with the exception of a non-significant decrease in sulfate concentrations in one of the wells. Significant trace metal reductions were also noted, although percent reductions were less than observed in the within-pod wells. Wells EE54 and DD58 are situated where the flow of AMD from the site created by the Lower Kittanning spoil can influence them, however.

Table 6.9. Percent reductions in mean concentrations as a result of the three grouting applications.

(a) Application: Injection Grouting Only												
Well	Loc*	TDS	SO_4	Acid	Fe	Al	Mn	Cd	Cu	Cr	Zn	As
S72D3	IP	**39%**	**51%**	**41%**	**36%**	**40%**	**47%**	**86%**	**50%**	**44%**	**43%**	**72%**
S72E4	IP	**39%**	**51%**	**38%**	**38%**	**29%**	**44%**	**84%**	**48%**	**45%**	**38%**	**81%**
EE54	DG	**26%**	**38%**	**23%**	**28%**	**24%**	**33%**	**81%**	**25%**	*16%*	**28%**	**62%**
DD58	DG	**22%**	*23%*	**25%**	**28%**	**26%**	**34%**	**84%**	**27%**	**30%**	**30%**	**51%**
(b)Application: Capped Only												
Well	Loc*	TDS	SO_4	Acid	Fe	Al	Mn	Cd	Cu	Cr	Zn	As
K23	IP	**32%**	**33%**	**26%**	*12%*	**34%**	**9%**	**77%**	*20%*	**33%**	**36%**	**59%**
K20	IP	**61%**	**70%**	**66%**	**64%**	**60%**	**48%**	**93%**	**61%**	**65%**	**62%**	**81%**
U59	DG	**31%**	**46%**	**35%**	**28%**	**38%**	**34%**	**85%**	**43%**	**43%**	**33%**	*49%*
L25	DG	**51%**	**54%**	**61%**	**61%**	**52%**	**64%**	**82%**	**54%**	**60%**	**60%**	**75%**
(c) Application: Grouted and Capped												
Well	Loc*	TDS	SO_4	Acid	Fe	Al	Mn	Cd	Cu	Cr	Zn	As
T33	IP	**67%**	**68%**	**70%**	**79%**	**73%**	**66%**	**92%**	**79%**	**79%**	**70%**	**90%**
T34	DG	**92%**	**92%**	**93%**	**90%**	**93%**	*19%*	**95%**	**96%**	**96%**	**92%**	**91%**
V38E4	DG	**37%**	**44%**	**47%**	**42%**	**47%**	**43%**	**88%**	**50%**	**51%**	**42%**	*10%*

Application: Control Wells – Far or indirectly downgradient from grouting activities												
Well	Loc*	TDS	SO_4	Acid	Fe	Al	Mn	Cd	Cu	Cr	Zn	As
Q30	Far	*11%*	*16%*	**14%**	*7%*	*2%*	*-9%*	**56%**	*9%*	**27%**	*-55%*	*33%*
Q68	Ind	*-5%*	*-17%*	*-1%*	*7%*	*10%*	*20%*	*74%*	*5%*	*8%*	*0%*	*-61%*

Negative values indicate a percent increase in mean concentration. Statistically significant changes where P <=0.05 are indicated in bold. Changes that were not statistically significant are shown in normal italics print. Control wells Q30 and S68 are included for comparison.

*Location IP = In-pod; DG = Downgradient; UG=Upgradient; Far=Far From; Ind=Indirectly Downgradient

Table 6.9(b) represents those pods that would not accept the pressure injected grout and were therefore capped. Wells K20 and K23 are located within a pod that was only capped. The worst quality found on the entire site before grouting operations was at well K23, Table 6.8. Despite the poor water quality, statistically significant decreases in the common mine drainage parameters, ranging from 9 to 66%, were observed. Statistically significant reductions in the concentrations of most of the trace metals, ranging from 33 to 93%, were also observed. A

downgradient monitoring well, L25, displayed similar reductions. On another area of the site a well downgradient from a pod that was only capped, U59, exhibited reductions in the mine drainage parameters from 34 to 46% and trace metal reductions from 33 to 85%.

Table 6.9(c) represents the situation where pods were both injection grouted and capped. Well T33 is located within a pod that accepted grout quite well, but was capped as an assurance measure. Significant decreases in mean concentrations range from 66 to 79% for the mine drainage parameters and from 70 to 92% for trace metals. Well T34 is immediately downgradient of this pod. Except for manganese, all parameters exhibited reductions in concentration in excess of 90%. The data suggest a reduction in AMD production within the pod and minimal migration of mine drainage from the pod toward the discharge points. Well V38E4 is situated downgradient of another pod which was both grouted and capped. Improvements noted here are less dramatic than in well T34. In well V38E4 significant reductions in concentrations of 37 to 43% were noted for the mine drainage parameters and from 42 to 88% for the trace metals. Grouting of this pod was somewhat less successful than the grouting of the pod at the T33 well location. However, the results are similar to the downgradient well observations for the grouted only situation, wells DD58 and EE54.

For the first year or so after the grouting was completed there were few observed decreases in SO_4 concentrations and there were even increases in some of the wells. However, most of the wells show a decrease in the concentrations of the other mine drainage parameters. The lack of reduction in SO_4 concentrations is not consistent with the premise that AMD production was reduced as evidenced by the reductions of the other mine drainage parameters. Dissolution of sulfate salts across the site is believed to be the reason for the lack of change in sulfate concentrations. Precipitates on the black shales found both on the above and below the ground surface were abundant on the site. Other studies indicate these are likely sulfate salts, most commonly pickeringite, $MgA1_2(SO_4)_4\ 22H_2O$, and halotrichite, $Fe^{+2}A1_2(SO_4)_4\ 22H_2O$ (Cravotta, 1994) and Nordstrom (1982). Re-dissolving of these salts would explain the observations. The continued, longer term monitoring appears to support this hypothesis. For all but one of the wells shown in Table 6.10 statistically significant reductions in SO_4 concentrations ranging from 33 to 92% over time demonstrates a reduction in AMD production as a direct result of the grouting when compared to the two control wells shown in the same table.

Using either total dissolved solids (TDS) or SO_4 as a surrogate measure for comparing the three grouting techniques, Table 6.9, it is quite evident that a combination of both injection grouting and capping of the pods produced the best results. The capping of the piles was the second most successful technique and the injection grouting alone was the least successful. The operator's inability to control grout placement with pressure injection likely reduces the effectiveness of this technique. With the pressure injection directly into the pods, the number and spacing of the injection wells can be controlled, but the path that the grout follows cannot. Pseudokarst conditions exist within mine spoil and the grout will follow the path of least resistance. During the grouting operations, it was not unusual for grout to be injected into one injection well only to surface two or three injection wells away, skipping the intermediate wells. The exceptionally wide variation in the amount of grout each well would accept was further testimony to this phenomenon.

The location of the pod with respect to the location of any perched water tables within the backfill likely influences the result that the combination of techniques works best. Capping only provides protection from infiltrating precipitation. If the pod that is only capped is in contact with water moving across the pit floor, AMD production will likely continue. Conversely, pods that are only injected with grout may not effectively be shielded from infiltrating precipitation.

There has been concern over the use of FBC ash because of the possibility of trace metals leaching from the ash once it is in place. The monitoring of this site should lay these concerns to rest. Trace metals concentrations are not normally determined in routine mine drainage analysis. However, they were determined on this project and their concentrations are presented in Table 6.10 for several of the wells. It should be noted that the concentrations of these metals produced on the site prior to FBC ash introduction are often orders of magnitude higher than the concentrations of the same metals, which leached from the ash in the TCLP. Of perhaps greater significance is the fact that the grouting reduced the trace metal concentrations more that it did the concentrations of the common mine drainage parameters. Cadmium concentrations were reduced most of all, universally. Even where mine drainage parameter reductions were modest at best, Cd reductions were major (wells EE54 and DD58, Table 6.9). Arsenic concentration reductions were generally only 5 to 10% less than that of Cd. This was followed by nearly equal reductions of Cu and Cr at about 30% less than that of Cd. The smallest reductions were noted for that of Zn, being about 5% less than that of Cu and Cr, but still significant.

Opponents of the use of FBC ash for AMD remediation argue that As will leach from the ash and pollute the groundwater and receiving streams. The monitoring data from this site refute those allegations. Just the opposite appears to be the actual case. What is also necessary to bear in mind in this case is that the ash injected into this site for over 10 years has been in daily contact with AMD with a pH ranging from 2.4 to 2.7, an exceptionally strong acid solution not normally found on mine sites. If the ash can prevail under field conditions this severe and rigorous, it is unlikely that the ash will create problems under much milder conditions found elsewhere.

Those metals found to be present at below detection limits were deleted from further testing at the request of the laboratory for economic reasons. It cannot be stated with certainty that trace metals are not leaching from the FBC ash, but it can be stated that there has been a significant decrease in the trace metal concentrations found at the site as a result of using the ash. In this case, the benefits of using the FBC ash far outweigh the concerns with respect to metals leaching from the ash.

It has been questioned whether post-grouting reductions in concentrations of the AMD parameters are a result of AMD abatement or a neutralization of the AMD by the alkaline ash grout. The noted reductions in SO_4 concentrations strongly suggest that AMD abatement is the dominate mechanism occurring here. During the grouting operation it was common to note spikes in calcium concentrations along with significant rises in pH and dramatic reductions in concentrations of other mine drainage parameters due to neutralization reactions. If the supernatant was still present and was responsible for the changes, then it would be expected that there would be statistically significant increases in calcium concentrations wherever there was a significant decrease in the concentrations of the other parameters. That is not the case. The data

in Table 6.9 show significant reductions in concentrations of the mine drainage parameters regardless of whether the calcium increased or decreased. Also, the noted spikes in pH usually disappeared within a few months to two years after grouting, indicating a flushing of the supernatant. Subsequent increases in calcium concentrations are thought to result from leaching of the grout.

The concentrations of ferric iron generated from the pods of pyritic material must also be considered when considering the effect that severe AMD generated within the pods has on the rest of the site. Garrels and Thompson (1960) have shown that pyrite is rapidly oxidized by ferric iron in the absence of oxygen and at low pH values.

According to the monitoring well data, Fe^{3+} concentrations from these pods commonly exceeded 1000 mg/L with pH values close to 2.0. Once the water exits the pod, such as the K23 location, it must migrate through 1500 ft of spoil before discharging from the site. The Fe^{+3} is available to rapidly oxidize pyrite located along its flow path to the discharge point. Reduction in Fe^{+3} formation should thus result in reduced pyrite oxidation. Although not shown in Table 6.9, reductions in Fe^{3+} concentrations closely paralleled those of total Fe.

Considering that the overburden on the site is acid producing, as demonstrated by the control wells such as Q30 and Q68, it is necessary to examine the changes in the water quality that discharges from the site to evaluate the overall effectiveness of the grouting effort. When reviewing the data, it is important to keep in mind that only 2 of the 37 acres (5% of the site) were directly affected by the grouting effort. Table 6.10 presents the pre- and post-grouting mean concentrations for several of the parameters tested, along with the percent reductions. A negative value indicates the concentrations increased rather than decreased.

There are three monitoring wells and a toe-of-spoil discharge which intercept AMD discharge plumes, as identified by the EM mapping, Figure 6.21. All of these wells are located along down-dip portions of the mine site and reflect the quality of water leaving the site from the lower split of the Kittanning seam. However, all three wells indicated a wide range in water quality, both before and after grouting. During the spring, the water quality is historically much better than during the summer and fall months. The lower split of the Lower Kittanning seam extends beyond the limits of the mining on the north and west sides. The winter snow pack is normally up to five feet thick. It appears that as the snow pack melts water infiltrates to this lower split of coal and migrates down dip, diluting the AMD intercepted by the monitoring wells. Even with this scatter, statistically significant reductions in mine drainage parameters of greater than 45% were noted for these wells. These improvements are notable considering that the total area affected by the grouting was only 5% of the surface mined area. The improvement in the quality of the discharge D3 is not nearly as dramatic as the monitoring wells. However, as can be seen in Figure 6.21, there was little actual grouting completed upgradient of this discharge. Additional work upgradient of the D3 discharge was planned, but was terminated due to time, ash supply and funding constraints.

Table 6.10. Pre- and post-grouting mean concentrations of mine drainage constituents and percent reduction in mean concentration for wells and toe of spoil seep located in discharge plumes. For locations refer to Figure 6.21.

Monitoring Well FF62												
Condition	Lab	TDS	SO_4	Acid	Fe tot	Al	Mn	Cd	Cu	Cr	Zn	As
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Pre-grout	2.3	7970	3477	4088	876	256	39.2	83.6	806	221	4270	69
Post-grout	2.6	4235	1749	2151	411	132	18	25	610	133	2321	27
Reduction	**-13%**	**46%**	**50%**	**47%**	**53%**	**48%**	**53%**	**69%**	*24%*	**39%**	**45%**	**60%**
Monitoring Well S80D												
Condition	Lab	TDS	SO_4	Acid	Fe tot	Al	Mn	Cd	Cu	Cr	Zn	As
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Pre-grout	2.4	9951	3500	5096	937	394	45.5	108.5	1542	394	4754	56
Post-grout	2.9	4914	1825	2148	343	193	22.4	18	576	156	2139	14.8
Reduction	**-23%**	**51%**	**47%**	**58%**	**63%**	**51%**	**51%**	**83%**	**63%**	**60%**	**55%**	**74%**
Monitoring Well W70												
Condition	Lab	TDS	SO_4	Acid	Fe tot	Al	Mn	Cd	Cu	Cr	Zn	As
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Pre-grout	2.6	9689	3695	4611	735	397	49.4	60.2	985	221	4931	19.5
Post-grout	3.0	3000	1630	1657	165	133	15.8	83	395	102	1559	17.8
Reduction	**-16%**	**69%**	**56%**	**64%**	**77%**	**66%**	**68%**	**80%**	**60%**	**54%**	**68%**	8%
Toe of Spoil Discharge D3												
Condition	Lab	TDS	SO_4	Acid	Fe tot	Al	Mn	Cd	Cu	Cr	Zn	As
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Pre-grout	2.5	6451	2451	3022	326	289	48.6	37.6	743	200	3455	20.2
Post-grout	2.53	5351	1815	2445	276	240	39.9	18	654	186	3062	17
Reduction	-1%	17%	**28%**	**19%**	15%	**16%**	**17%**	**52%**	**11%**	7%	**11%**	11%

Statistically significant % reductions are indicated in bold. A negative value indicates a % increase.

6.4.2.6 Chemical interactions between AMD and FBC ash grout

Monitoring well L25 provides a fairly clear picture of the chemical changes that occurred as a result of the ash injection into an acidic environment. L25 is located in the AMD plume downgradient of the pod of pyritic material at the K23 location. Pre-grouting water quality indicated the presence of severe AMD. Three injection wells were drilled within 50 feet of well L25 to accommodate a pit floor paving experiment. Only the bottom of the casing was open so that all of the injected grout would be directed to the pit floor. The two adjacent wells accepted a total of 90 yd^3 of grout and a third located 50 ft downgradient accepted 20 yd^3. In addition to the grouting, a "dry" ash cap was placed at the end of September 1993 within 30 feet of well L25. During the two grouting seasons, ash that had gotten wet and formed large clumps was cast to the side of the mixing bin. During final site cleanup, this ash was buried in its dry state adjacent to the cap placed over the pod intercepted by well K23 (Fig. 6.21). This ash would be subject to leaching by infiltrating precipitation.

The following graphs illustrate the chemical changes that occurred when the grout interacted with the AMD. The first graph, Figure 6.22, depicts the changes that occurred to pH. Prior to the grouting, the mean pH was 2.3. Grouting occurred during June 1993. The pH increased immediately to 8.9 because of the highly alkaline supernatant. Over the next several months, the pH value gradually dropped. In 1994, the mean pH was 2.8. The pH was back to pre-grouting levels by 1996.

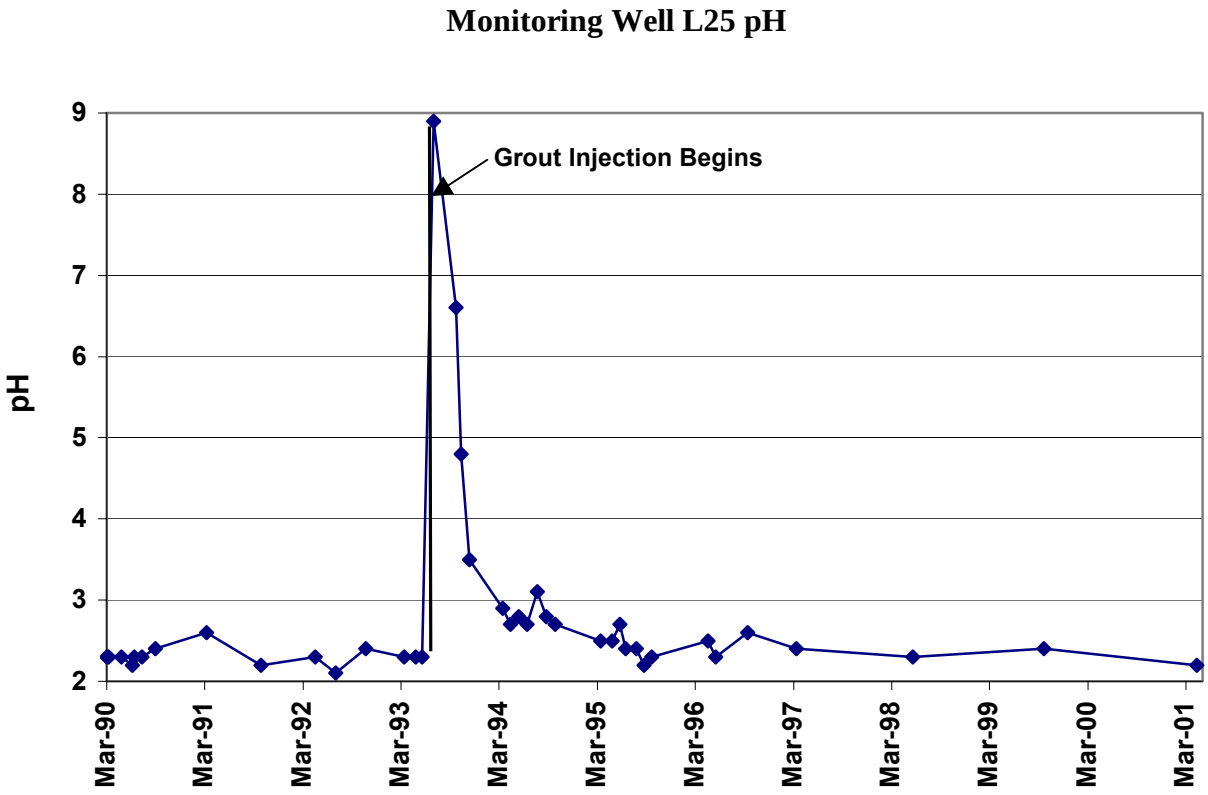


Figure 6.22. Response in pH monitoring well L25 to pit floor grouting effort.

Figure 6.23 is a graph of SO_4 and acidity concentrations over time. These two variables likewise show a response to the grout supernatent. Sulfate concentrations averaged 6496 mg/L prior to grouting. After grouting, the concentrations were close to 1500 mg/L for the next four months. Since that time, the SO_4 concentrations have risen, but are presently 2900 mg/L, much lower than the pre-grouting levels. The effect of the drought conditions in 1995 are clearly evident in the graph, where concentrations of virtually all constituents increased dramatically for all wells. Acidity levels also dropped dramatically as a result of the supernatent. In fact, the alkalinity concentration 90 days after the grouting was 766 mg/L. Similar to sulfate, the acidity concentrations spiked during the 1995 drought, but returned to and remain at below pre-grouting levels. Overall, there have been reductions in concentrations of 54% and 61% for sulfate and acidity, respectively, as a result of the grouting effort.

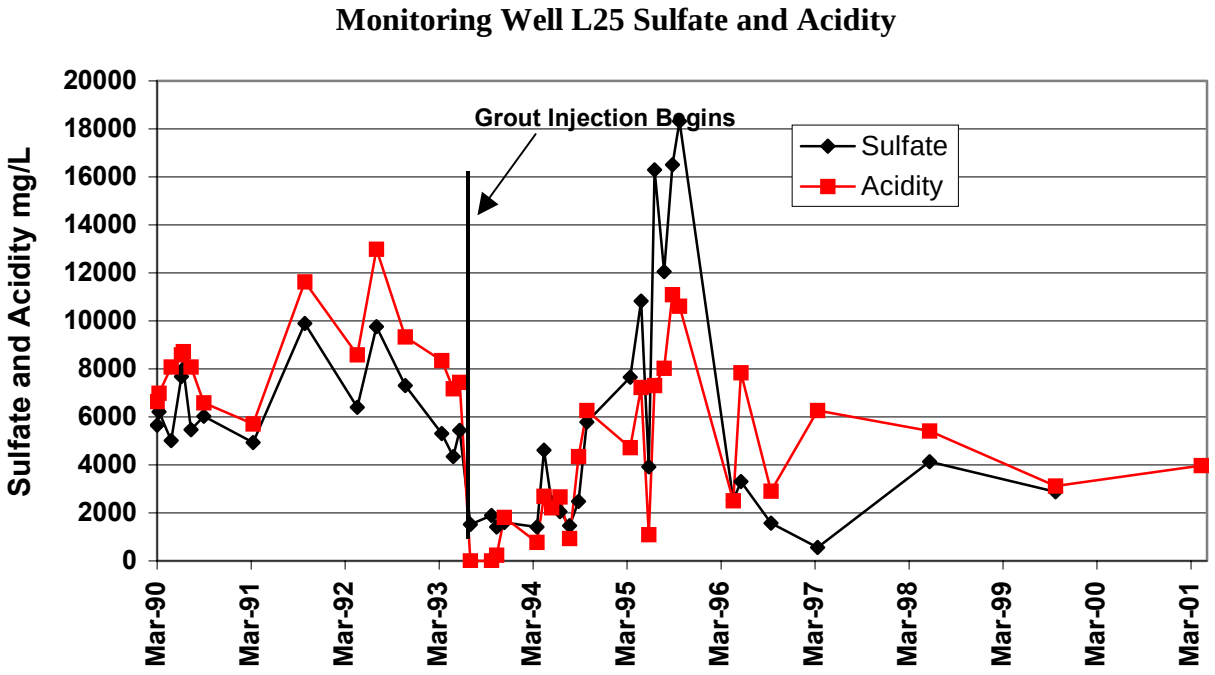


Figure 6.23. Sulfate and acidity response to pit floor grouting effort. Note the temporary effect of the drought during 1995.

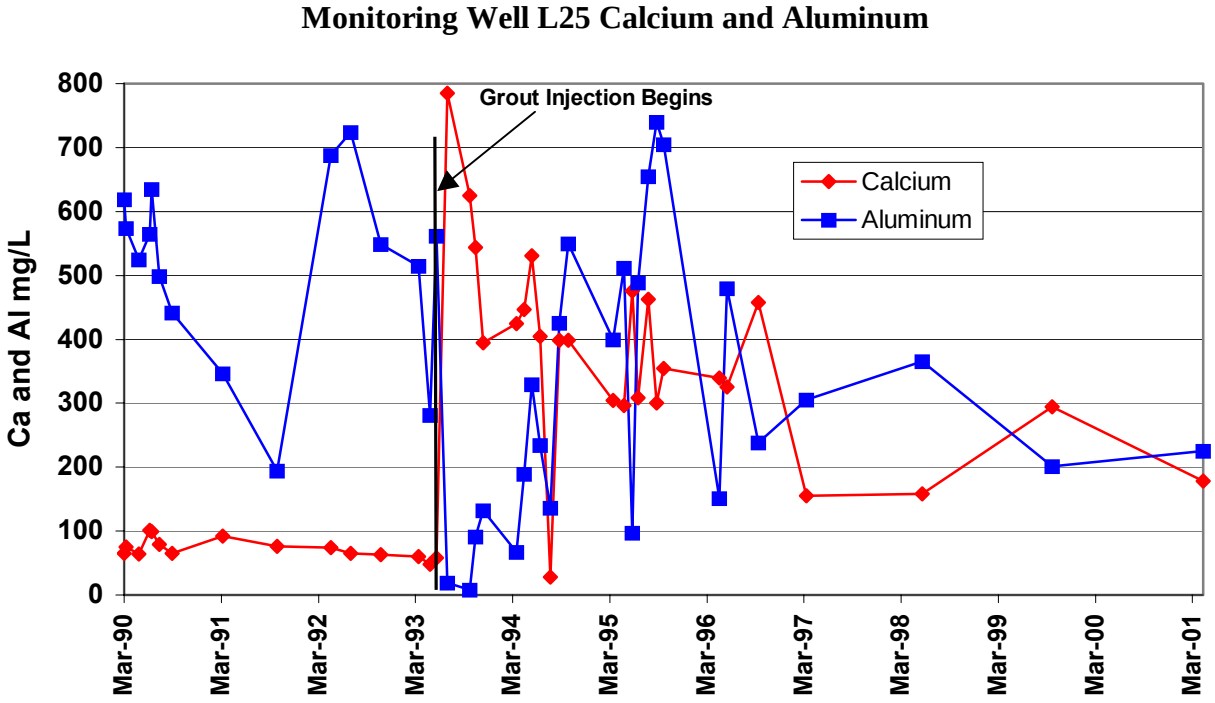


Figure 6.24. Calcium and aluminum response to the pit floor grouting effort. Note the general inverse relationship between Al from AMD and Ca, primarily from the grout.

The long-term response by aluminum suggests that pit floor paving may be effective in reducing leaching of the clays. Calcium and aluminum concentrations are included in the graph shown in Figure 6.24.. Shortly after grouting, A1 concentrations dropped to a low of 8 mg/L and have since rebounded, but are less than half of the pre-grouting concentrations. Although not shown on the graph, concentrations of iron and manganese closely paralleled that of Al. Calcium shows a rather different behavior. The mean Ca concentration prior to grouting was 72 mg/L for well L25. After injection, the concentration rose sharply to over 700 mg/L as a result of the supernatant. Since then, the mean concentration has returned to about 200 mg/L, above the pre-grouting value.

Based upon testing performed in the laboratory by the Penn State Materials Research Institute, there is an explanation for the increase in calcium. Within the grout, the calcium is normally present in three chemical phases. These include, in the order of decreasing solubilities, calcium hydroxide (log K=-5.05), calcium aluminum silicate hydrate (log K=-8.16 to -22.54), and calcium aluminum sulfate or ettringite (log K= -111.2). The high calcium concentrations are most likely a result of the dissolution of the calcium hydroxide. The calcium aluminum sulfate and the calcium aluminum silicate hydrate are likely to leach over time, but at a much slower rate than the calcium hydroxide. These reactions are similar to what would be expected if Portland cement had been injected instead of the fly ash .

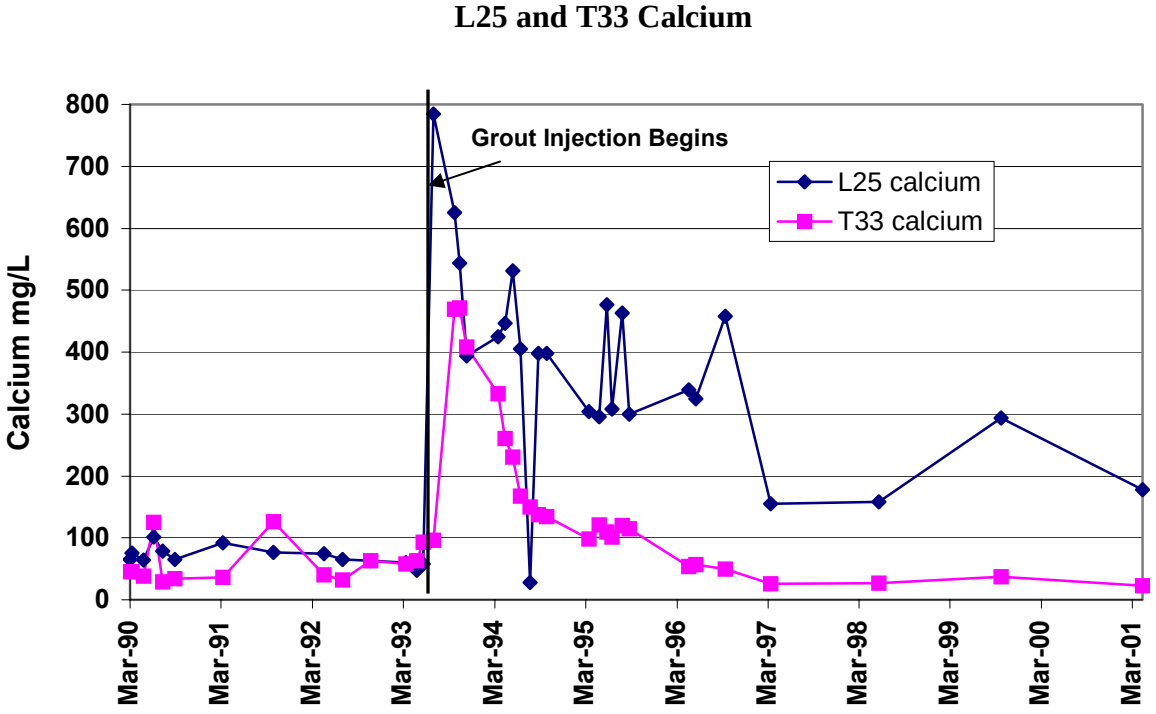


Figure 6.25. Long-term calcium concentrations in two monitoring wells.

The long-term increase in calcium that was noted in well L25 is not a universal occurrence at this site. The opposite was observed in monitoring well T33, an in-pod well where the pod was both grouted and capped, as shown in Figure 6.25. For both wells, the grouting

occurred during the summer of 1993. An immediate increase in calcium from the supernatent was noted in both wells. The increased levels of calcium were noted for three to four years after the grouting. After that, the concentrations leveled off. The post-grouting calcium concentration in T33 is less than that observed during the pre-grouting period, the opposite of what occurred in L25. As a whole, there have been both increases and decreases in calcium concentrations and there is no consistent pattern that has been established with respect to grouting technique.

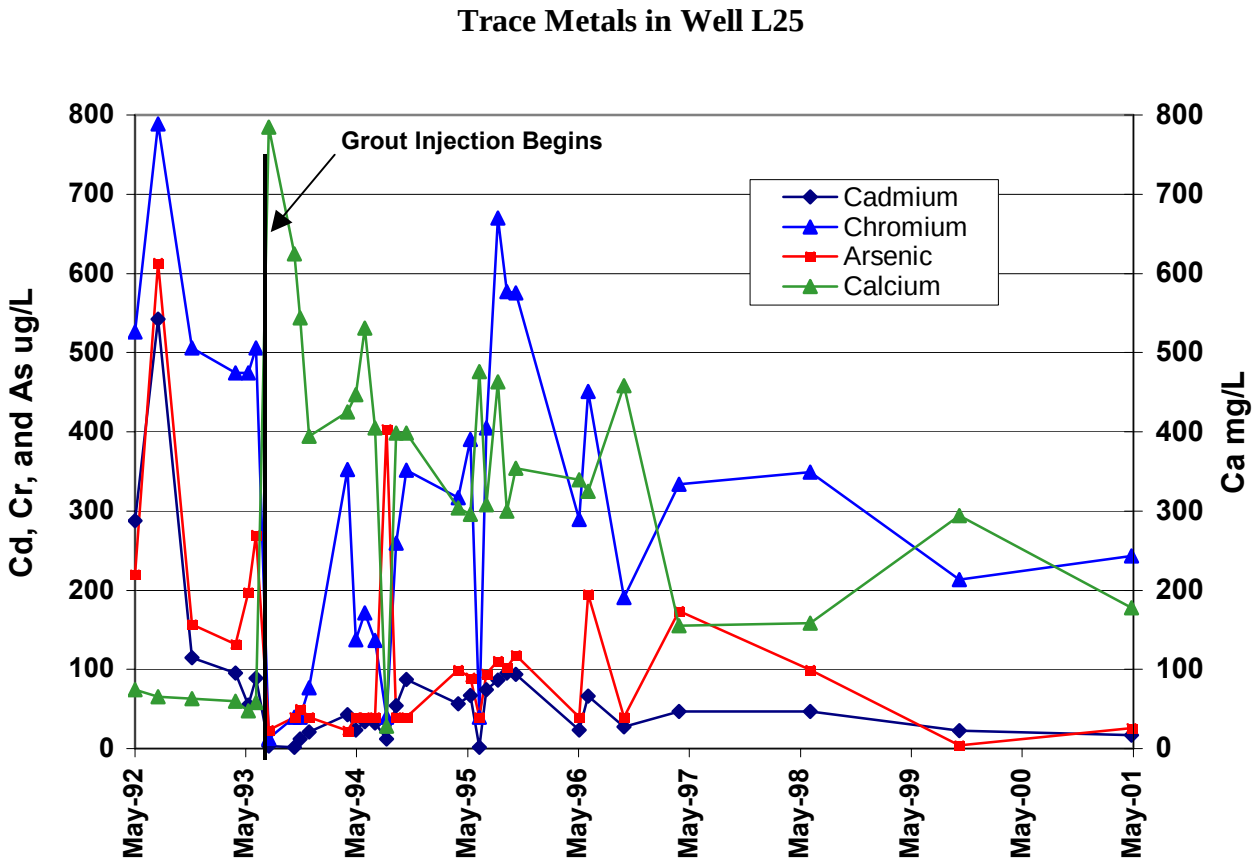


Figure 6.26. Long-term behavior of Cd, Cr, and As in well L25.

The final graph, Figure 6.26, illustrates the behavior of the trace metals cadmium, chromium and arsenic over time and provides evidence that the source of the trace metals is the spoil, not the FBC ash. Throughout the history of sampling on this site, arsenic, chromium and cadmium behaved in similar fashion. Following the injection of the grout in June 1993, the concentrations of these metals decreased dramatically because of the neutralizing effect of the supernatent. As the supernatent was flushed from the area, the concentrations of the trace metals rose somewhat, but remain well below pre-grouting levels. Note that, before grouting, trace metal concentrations fluctuated while calcium concentrations remained relatively constant. As stated earlier, calcium concentrations are more than twice as high post-grouting as they were pre-grouting. Post-grouting fluctuations in calcium concentrations are also quite noticeable. Note that, especially since 1997, there is an inverse relationship between the trace metals and calcium. If the FBC ash was the source of the trace metals, one would expect a direct relationship, i.e.

trace metal concentrations would rise when calcium concentrations rose. This is not happening and suggests that the leaching of the calcium from the FBC ash suppresses the dissolution of trace metals from the spoil

6.4.2.7 Summary of In Situ Grouting of the Fran Site

The pods of pyritic material were treated with FBC ash grout in three ways: 1) injection only, 2) capping only, and 3) both injection and grouting. Based on the water chemistry, the combination of injection grouting and capping produced the most favorable results, followed by capping only. Injection grouting produced the least favorable results. The combined approach inhibits contact between water, oxygen and pyrite by limiting infiltration as well as diverting lateral flow around the pods. Injection limits contact via lateral flow, but may not inhibit vertical infiltration. Capping is most applicable in situations where the pods are located high in the spoil and above the level of water table fluctuations within the backfill.

The inability to control final grout placement is a major drawback of the injection process. Pseudokarst conditions became established during backfilling operations (Hawkins, 1998). Because the gout is a viscous fluid, it will tend to flow into high permeability zones when pumped into spoil under pressure. If the permeability within the pod is low, the injected grout may flow away from the pod instead of filling the voids within the pod as intended or the well will accept very little grout. When this happens, AMD abatement will be limited or will not occur at all.

The placement of the grout in the capping operation is controlled by the operator and is a direct approach. The ability to control infiltration zones is dependent upon the area of excavation and grouting. This approach is appropriate where the pyritic material does not come into contact with water moving along the pit floor.

Use of the FBC ash grouting techniques on this site resulted in an overall improvement in water quality. Although the percent reduction in mean concentrations varies, concentrations of the common AMD parameters generally decreased by 45 to 65% and reduction of trace metals were usually higher. This is significant because the grout application occurred on only 5% of the site. The research effort was to designed demonstrate that FBC ash grout could effectively reduce the severe AMD production within the pods of pyritic material buried within the spoil. The noted water quality improvements indicated this goal has been met; however, the degree of improvement is somewhat less than what the researchers had hoped for. Any changes in water quality, which resulted from the grouting, are expected to be permanent because of the pozzolanic nature of the grout. It was known that the entire site generated AMD and there was no pretense of eliminating all AMD production. Despite less than total success at AMD abatement, the authors view injection grouting as a viable AMD abatement technique is worthy of application on sites which meet certain criteria. This technology is perhaps best indicated for those sites which would normally produce net alkaline drainage but improper placement of refuse or pit cleanings has resulted in an acidic discharge. The use of FBC ash is also recommended on active surface mines and refuse disposal sites as a preventative measure. FBC ash grout can be used in a controlled approach on active sites. The ash grout can be applied

directly to or mixed with refuse and pit cleanings to create monolithic structures capable of diverting water away from the pyritic materials.

6.5 CONCLUSIONS

1. Coal ash has been used in many abandoned mine hazard abatement projects in Pennsylvania in the past 35 years by state and federal government agencies. Most of these projects involved the use of pulverized coal powerplant ashes (PC ash), mixed with Portland cement (and sand or other aggregate material in some cases) to form grout mixtures that were pneumatically injected through boreholes into abandoned underground mines. In the Centralia Mine Fire in the Anthracite Region, starting in 1969, and numerous other anthracite and bituminous mine fires, many thousands of tons of the ash/cement grouts were injected to form barriers to attempt to control the mine fires. While these noncombustible ash barriers may have been effective in controlling the spread of the fires, they have not been successful in completely extinguishing the mine fire in most cases. However, the use of coal ash in these cases has not been shown to cause pollution of the mine pool or other groundwater degradation.

2. Coal ash cement grout mixtures have been used in numerous mine subsidence control projects in the anthracite and Bituminous Region. Most of these subsidence control projects used PC ashes that were injected through boreholes into abandoned underground mines, where the ash cement grout was either in direct contact with the minepool or in a groundwater flow path hydrologically connected to the minepool and/or mine drainage discharge points from the underground mines. Although many of these projects were completed with PC ash prior to the regulatory requirement to adjust the pH to a range between 7.0 and 12.0 for mine reclamation purposes, no cases of groundwater pollution related to this coal ash use have been reported. The widespread use of these coal ash cement grout mixtures has been effective in controlling mine subsidence and protecting homes and other structures on the land surface.

3. Coal ash, particularly FBC ash, has been used successfully in the Sharp Mountain Reclamation Project to make a cement-like grout that has structural properties suitable for plugging or bridging mine voids and cropfalls. The strength of the grout mixture is enhanced with the addition of Portland cement, cement kiln dust or other similar materials. Grout strengths are variable depending on the calcium content in the ash. Additional reinforcing materials such as rebar can be added to provide structural support (tensile strength) and the grout mixture can be adjusted to a consistency that allows it to flow freely these materials.

4. Coal ash can be used successfully as a bulk fill material for backfilling cropfalls and other mine subsidence features where little on-site material is available. Coal ash is available in abundance in the Anthracite and Bituminous Regions and it can be an economically viable alternative to importing other materials.

5. The use of coal ash in AMD abatement at the McCloskey site in Clearfield County, through the construction of a coal ash capping layer on the surface of the backfilled

surface mine, has significantly reduced infiltration of groundwater through the backfill and thereby substantially abated the post-mining AMD discharge. The improvement in water chemistry demonstrates abatement and the reduction in flows demonstrates the ability of an ash cap to serve as an infiltration barrier.

6. The coal ash cap at the McCloskey surface mine site has not generated secondary pollution problems in the receiving stream, and has allowed the population of a stream by fish which otherwise wouldn't support fish.

7. The use of an FBC ash cement grouting techniques to encapsulate the buried pods of pyritic refuse material at the reclaimed Fran surface mine site resulted in an overall improvement of the water quality of post-mining discharges. Generally, the mean concentrations of acid mine drainage parameters decreased by 45-65%, which represents a significant reduction in the pollution load to receiving streams. This project showed that there is a potential future for in situ grouting which requires more development.

CHAPTER 7. THE ELLENGOWAN AND SHEN PENN DEMONSTRATION PROJECTS

Barry E. Scheetz, Caroline M. Loop, William B. White

7.1 OBJECTIVES

The Ellengowan demonstration was initiated to provide an independent review of the potential environmental consequences of placing fluidized bed combustor ash directly into standing waters contaminated with acid mine drainage. Dry-to-wet and wet-to-wet placement techniques were evaluated. The scope of the study included field examination of the emplaced ash, the emplacement method, SPLP evaluation of the leachability of potentially hazardous elements from the ash. The Ellengowan demonstration project was a necessary precursor to the other demonstrations to develop tangible data on a small-scale before embarking on the full-scale demonstrations. The objective of the Shen Penn demonstration was to show that ash could be transported in the form of a slurry and placed in the deep standing waters of the Shen Penn mine pit. This demonstration permit site was never acted upon.

7.2 BACKGROUND FOR THE WESTERN MIDDLE FIELD

7.2.1 Local Geology

The following description of the geology of the Western Middle anthracite coal field is taken entirely from Danilchik, et al., 1955 "Geology of Anthracite in the Western Part of the Shenandoah Quadrangle, Pennsylvania." The eastern section of the Western Middle Anthracite Field is discussed in the aforementioned report, covers the section C-19 in figure 7.1, and contains the Ellengowan, Knickerbocker, and Shen Penn sites.

The Western Middle Anthracite Field is one of four coal fields containing anthracite in eastern Pennsylvania. The boundary of the Western Middle field is considered to be the outcrop of the oldest of the Lykens Valley Coal beds (Rothrock et al., 1951). Rocks of the Mississippian, Pennsylvanian, and Quaternary systems crop out in the field. The oldest exposed rocks belong to the upper part of the Mauch Chunk Formation of Mississippian age, which is overlain by the Pottsville and Llewellyn Formations of Pennsylvanian age (Fig. 7.2). Unconsolidated alluvial clay, silt, sand, and gravel of Quaternary age have been deposited on the Carboniferous rocks in the stream valleys but were not mapped. Stream transported mine waste, some of which contains valuable deposits of detrital coal, has also been deposited along many streams.

7.2.1.1 Stratigraphy

The Mauch Chunk Formation crops out in the northern part of the area north of Locust Mountain Basin and in a small area immediately north of Reservoir No. 3. In the southern part of the area, the formation crops out on the crest of the Eisenhuth Run anticline, in the valley occupied by Mill Creek, and in the Locust Creek Valley. Only the upper 1,000 feet of the formation is exposed in the mapped area.

The rocks in the Mauch Chunk Formation are mainly red claystone, shale, siltstone, and fine-grained sandstone, but green siltstone and fine-grained sandstone, red or green medium to coarse-grained sandstone, and scattered lenses of gray or green conglomerate are also present. All the beds are lenticular. The contact between the Mauch Chunk and the overlying Pottsville Formation is gradational and is mapped at the horizon below which the beds are predominantly red and above which they are predominantly gray, green, or brown.

Rocks of Pennsylvanian age consist of lenticular beds of conglomerate, sandstone, siltstone, claystone, and shale, interbedded with 12 persistent coal beds and several local coal beds. The lower part of the Pennsylvanian in the mapped area is predominantly conglomeratic, and the upper part is chiefly fine-grained. The coal beds are the most persistent of the lithologic units. The other rock units exhibit so many changes in lithology that they have little value as reference or key beds.

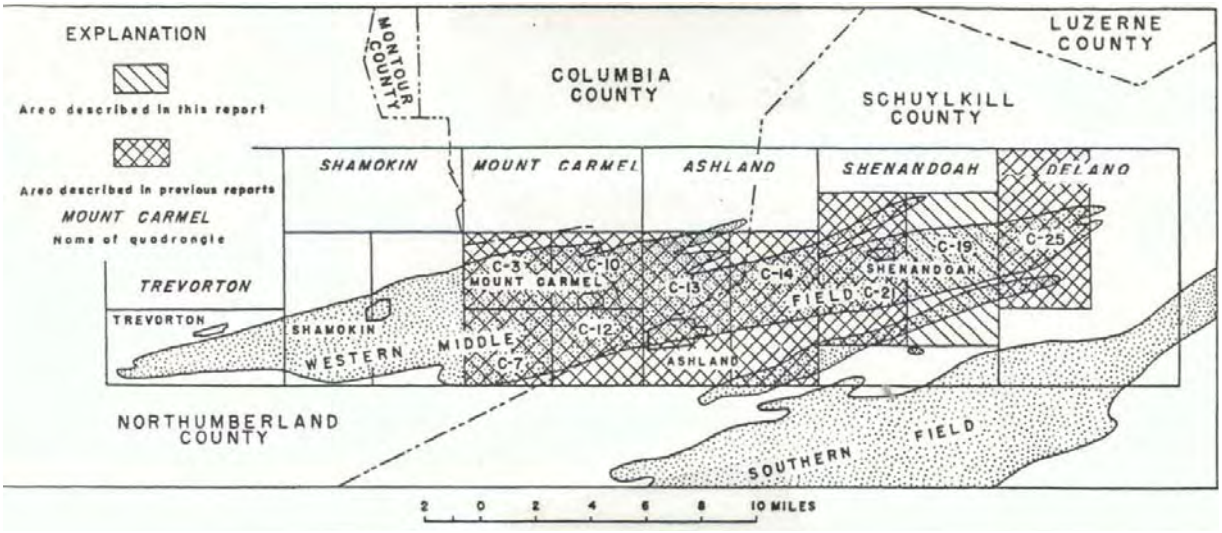


Figure 7.1. The eastern end of the Western Middle Anthracite Field, containing the Ellengowan, Knickerbocker, and Shen Penn mines (Danilchik et al., 1955).

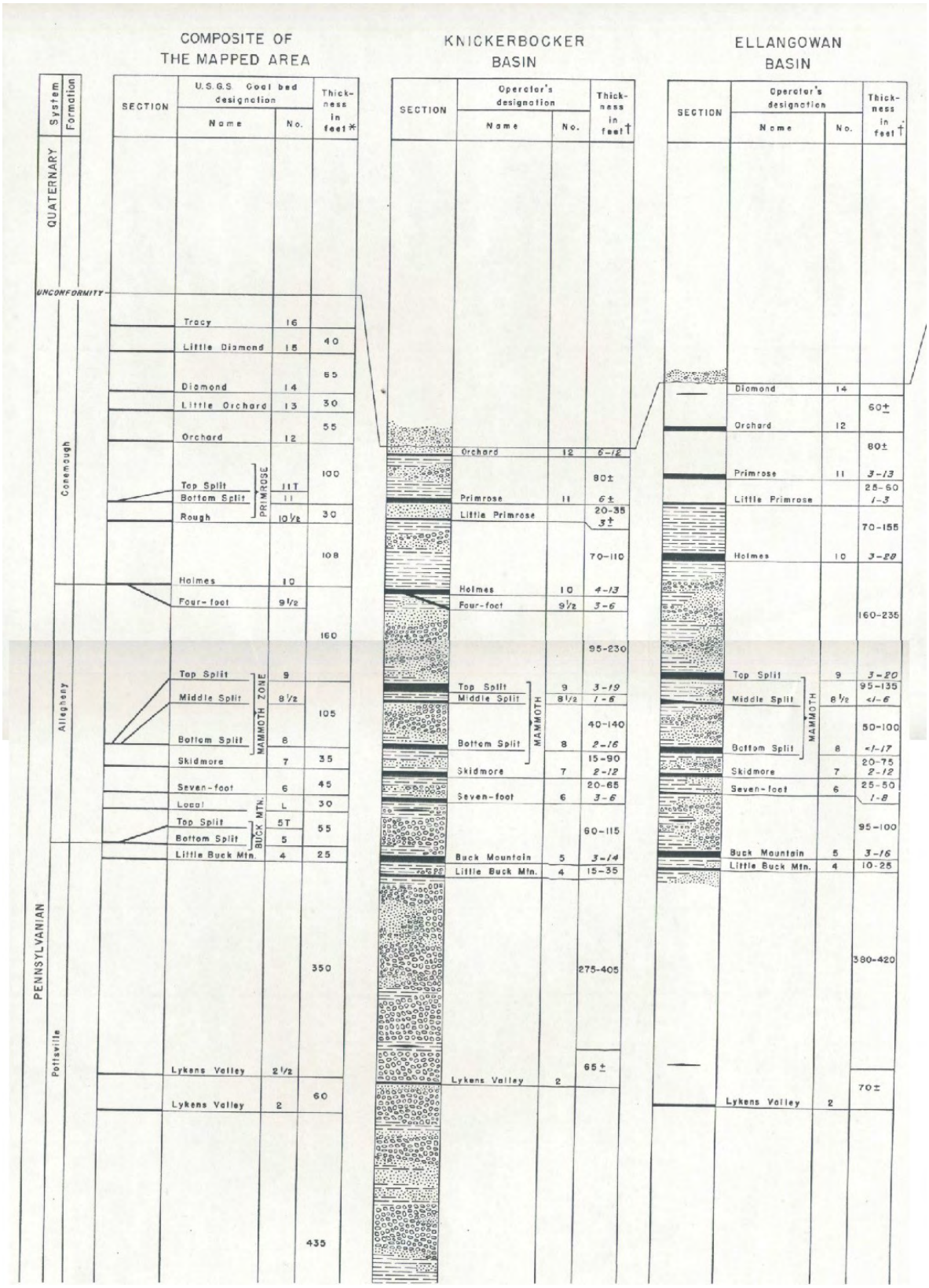


Figure 7.2. Lithologic sections of the Ellengowan and Knickerbocker Basins (Danilchik et al., 1955)

The Pottsville Formation, which includes the oldest rocks of Pennsylvanian age in the area, overlies the Mauch Chunk Formation and underlies the Llewellyn Formation. The Pottsville Formation is composed of beds of gray conglomerate, gray, green, brown, and red sandstone or siltstone and scattered lenses of gray or red claystone. The rest of the formation consists mainly of gray conglomerate, conglomeratic sandstone, coarse- to fine-grained sandstone, and scattered lenses of siltstone and claystone. The Lykens Valley (No. 2 and No. 2 ½) coalbeds are near the middle of the formation. The Little Buck Mountain (No. 4) coal bed is in the upper part of the formation.

The Llewellyn Formation, the base of which is the Buck Mountain (No. 5) coal bed (White, 1900), overlies the Pottsville Formation. The thickness of the Llewellyn Formation ranges from 350 feet in the north to a maximum of 530 feet in the south in this area. The formation is composed of conglomerate, sandstone, siltstone, claystone, and coal. The coal beds are the only laterally persistent lithologic units. In general, conglomerate and sandstone are more abundant in the lower part of the formation. Yellow to light-brown sandstone and siltstone are more abundant in the upper part.

The Llewellyn Formation is the source of most of the coal mined in the area. Six persistent coal beds: the Buck Mountain (No. 5); Seven-foot (No. 6); Skidmore (No. 7); and three beds in the Mammoth coal Zone (No. 8, No. 8 ½, and No. 9) are present in the Llewellyn Formation. The Buck Mountain and Mammoth zone coal beds are economically the most important.

7.2.1.2 Structure

Each of the Pennsylvania Anthracite Fields is a northeast-trending synclinorium composed of several overlapping folds, some of which have been faulted (Fig. 7.3). The area covered by this report is in the eastern part of the synclinorium that constitutes the Western Middle Anthracite Field. The coal-bearing area of the principal component synclines and some of the truncated limbs of these synclines in this field are called basins by the miners and the term is also used in this report. The miners' term "undersheet," which refers to the truncated limb of a syncline that extends beneath an adjacent overlying structure, is also used in this report.

The major basins in the area of discussion are, from north to south, the Knickerbocker, Delano, Maple Hill, Mahanoy City, and Mahanoy Basins. Anticlines separating these basins have been broken by thrust faults, resulting in partial overlaps of the basins (Fig. 7.3). Two small basins, the Locust Mountain Basin in the northern part of the area and the New Boston Basin in the southern part of the area, are separated from the main trunk of the Western Middle Field by the large, unfaulted Locust Mountain and Frackville Anticlines.

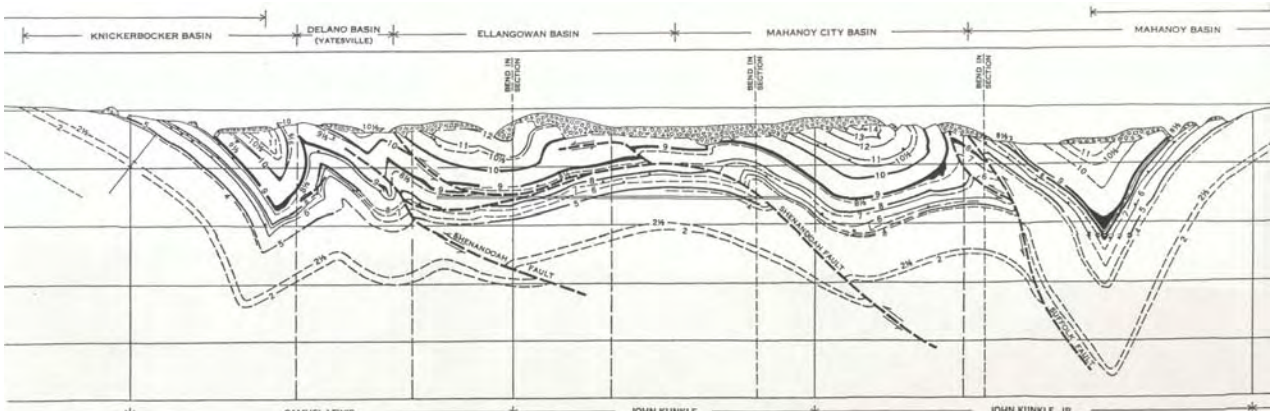


Figure 7.3. Cross section through the basins mapped on the eastern edge of the Shenandoah quadrangle (Danilchik et al., 1955).

The Knickerbocker Basin begins in the northwest as a faulted segment of the north limb of the Maple Hill Basin. It ends on the north limb of the Delano Basin. The Delano Basin is a relatively narrow structure that extends to the northeast. This basin lies beneath the Shenandoah thrust fault. A complex shallow syncline, known as the Ellengowan Basin in the thrust plate above the Shenandoah Fault, is present along the south side of the Delano Basin. At the western edge of the area, the westward-plunging Maple Hill Basin is about a mile wide and is one of the broadest basins in the Shenandoah quadrangle. This basin terminates or "spoons" abruptly.

The western end of the Mahanoy City Basin is about a fourth of a mile south of the eastern end of the Maple Hill Basin. The Mahanoy City Basin plunges northeastward. Its southeastern limb is truncated by the Suffolk thrust fault. North of Mahanoy City, this basin is offset by a transverse fault. The Mahanoy Basin is one of the largest and most continuous structures in the Western Middle Field. This basin originates near the center of the field and then extends across the mapped area and eastward to the end of the field. It is the most acutely folded of the major basins. The lowest coal beds in this basin are more than 700 feet below sea level.

The Locust Mountain Basin extends from the west. Only the Lykens Valley (No. 2) and the Little Buck Mountain (No. 4) coal beds are present in this basin in the eastern section of the Shenandoah quadrangle. The New Boston Basin extends diagonally in the south. The basin becomes broader and shallower toward the east. The lower coals of the Llewellyn Formation "spoon out" at the eastern margin of the quadrangle.

The major folds of the eastern part of the Western Middle Anthracite Field trend about N 70° E. In the southern part of the area, the axial planes are inclined approximately 80° to the north. In the northern part of the area, which is more deformed, the axial planes dip 50° to 75° to the south. In the Knickerbocker Basin, however, the axial plane has a north dip at depth and a south dip nearer the surface. The degree of folding, as measured by the least angle between tangents to the limbs of the fold, ranges from 35° to 130°.

Most faults in the eastern section of the Western Middle Anthracite Field are thrust faults that dip southward and are the result of compression. They trend at angles generally less than 60° except where drag has affected the beds. The principal faults, from north to south, are the Delano, Shenandoah, and Suffolk Faults.

The Delano Fault begins in the northeastern part of the area and extends into the adjacent area to the east. This fault is present east of a sharp salient in the Shenandoah Fault north of Mahanoy City, and its development may have been related to a change in amount or direction of displacement on the Shenandoah Fault. The Shenandoah Fault extends into the area from the west, and it terminates in the northeastern part of the area. This is a very irregular fault, as shown on the cross sections. It truncates the southeast limb of the Knickerbocker and Delano Basins.

The Suffolk Fault begins west of the mapped area and extends into the adjoining area on the east. The fault surface, which dips 60° south, truncates the north limb of the Mahanoy Basin. The displacement along the fault ranges from 1,000 feet in the west to 750 feet in the eastern part of the area, with a dip-slip displacement of approximately 450 feet. This displacement brings the Buck Mountain (No. 5) coal bed above the Mammoth Top Split (No. 9) coal bed. Coal beds along this fault have been intensely deformed with the result that, in some places, the coal has been squeezed into relatively thick, irregular pockets and, in other places, coal has been dragged out along the fault into thin sheets of shelly coal.

Several faults in the mapped area cut obliquely across the folds, making angles that range from 40° to 90° with the fold axes. These faults have relatively small displacements that range from a few feet to a few tens of feet. Some of the oblique faults are associated with shear zones in the coal beds. Some of the shear zones may represent transverse faulting in an early stage of development.

Mining is adversely affected by: (1) faults with displacements greater than the thickness of the respective coal bed (called rock faults by the miners); (2) areas in which the coal has been squeezed from between the roof and floor rock (called pinches); (3) small folds that have sheared, thinned, or thickened the coal (called rolls); and (4) shear zones-areas in which the coal is so fractured by differential movement and extreme pressure that it cannot be profitably mined.

7.2.1.3 Coal

In the Western Middle Anthracite Field, the coal beds of the different mines are designated by a number, a name, or both. This nomenclature has not been standardized between the different mines because: 1) coal beds in isolated mines were named before they could be correlated; (2) gaps exist between adjoining workings; (3) the structure and lithology are complex; (4) outcrops are scarce; and (5) once names have been established they tend to be locked into the mining records.

In this chapter, a coal bed is described as persistent, nonpersistent, local, or as a leader. A persistent coal bed can be traced throughout a basin and can be correlated with a bed in the same

stratigraphic position in adjoining basins in the Western Middle field. A nonpersistent coal bed is one that can be recognized and correlated in several of the basins, but is not continuous throughout the basin. A local coal bed is one that cannot be correlated across a basin or between adjoining basins, and generally cannot be traced within a basin for more than 3 or 4 miles. A leader coal bed is one that is: (1) present in only a small area; and (2) where first named it is so near a well-known or economically important coal bed that it serves as a guide or marker for that bed. It may or may not merge into the persistent coal bed and may be separated in some places from the persistent bed by a stratigraphic interval of as much as 40 feet.

Coal beds are rarely exposed in natural outcrops owing to the cover of soil. Listed below are the average thickness and range in thickness of coal beds in the eastern section of the Western Middle Anthracite Field (Table 7.1). Figures on the right half of the table show the thickness of all coal in each bed. Figures on the left half of the table show the thickness of all coal and all shale partings in each bed.

Table 7.1. Average thickness and range in thickness of coal beds mined in the eastern part of the Shenandoah quadrangle (Kehn and Wagner, 1955).

Bed #	**Thickness** Average		Range				Average		Range				% of refuse
	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In	Ft	In	
16	4	11	4	6	5	2	3	10	3	10	3	10	22.0
15	6	0	2	2	10	0	5	4	2	2	8	10	11.1
14	7	4	1	0	9	6	7	1	1	0	9	0	3.4
13	8	8	4	10	13	0	7	2	4	4	10	0	17.3
12	10	4	5	6	14	10	9	1	5	6	14	4	12.1
11	8	10	2	8	13	11	7	11	2	8	13	11	10.4
10½	3	1	1	0	5	6	2	10	0	11	4	7	8.1
10	11	4	2	0	28	0	10	2	2	0	28	0	10.3
9½	3	10	1	8	7	11	3	2	0	7	6	5	17.4
9	14	1	3	0	41	0	11	1	1	4	32	1	21.3
8½	6	5	1	0	27	0	5	2	0	2	21	6	19.5
8	10	6	1	0	40	0	9	0	0	6	40	0	14.3
7	7	1	1	0	17	11	5	5	1	0	15	2	23.5
6	6	4	1	0	15	8	5	5	0	7	13	0	14.5
5T			2	6	5	0			0	2	5	0	
5	12	0	2	10	23	11	9	11	2	7	20	0	17.4
44	4	6	1	11	9	7	3	4	1	7	5	7	25.9
2½	3	5	1	2	9	7	3	1	1	2	4	8	9.7
2	4	11	1	2	11	4	3	4	1	2	11	4	32.2

Most of the coal and bed thickness were obtained from mine company data and were chosen to show an average of many underground observations. Measurements of beds that may have been abnormally affected by deformation were not recorded. The maximum and minimum thicknesses shown in this table and in the columnar sections are from all observed measurements along tunnels, mined-coal measurements, drill cores, or sections measured by U.S. Geological

Survey personnel (Kehn and Wagner, 1955). Thickness figures have been omitted from the table where few reliable data are available.

Eighteen coal beds have been mined in the mapped area. Of these, Buck Mountain (No. 5), Seven-foot (No. 6) Skidmore (No. 7), the three splits of the Mammoth coal zone (No. 8, No. 8 ½, and No. 9), and Holmes (No. 10) coal beds are economically the most important.

The Buck Mountain (No. 5) coal bed, basal unit of the Llewellyn Formation, overlies the more resistant rocks of the Pottsville Formation and underlies the remaining beds of the Llewellyn, which are less resistant. As the result of differential resistance to erosion, a topographic bench forms in some areas making it possible to map the outcrop of the Buck Mountain coal bed rather accurately. The persistence, quality, and thickness of this coal bed make it one of the most economically important coals in the area. The Buck Mountain, which is extensively mined, has an average thickness of the coal in each of these beds of 5 feet 5 inches.

The Mammoth coal zone is economically the most important group of coal beds in the Llewellyn Formation. Throughout most of the mapped area, this zone consists of three coal beds or "splits." These are the Bottom Split (No. 8), Middle Split (No. 8 ½), and Top Split (No. 9). In the southwestern part of the New Boston Basin, the three splits merge and are mined as one bed. The Mammoth coal zone is persistent and is easily identified by its thickness. The Bottom Split (No. 8) coal bed attains a minimum thickness of 40 feet in some parts of the area.

The Holmes (No. 10) coal bed is economically important because of its greater than average thickness (11 feet 4 inches) and its smaller than average percentage of refuse (10.3%). Extensive mine-workings and a uniform interval from the Mammoth coal zone are factors that make the Holmes coal bed useful as a stratigraphic marker. The No. 10 coal bed ranges from 2 feet to 28 feet in thickness in the mapped area.

Several coal beds listed in the table on coal thickness are not described here. These coals are generally of poor quality or of such local occurrence that they were of little economic importance at the time of writing. This, however, does not presuppose that they may not be of greater economic importance as mining practices improve or if the market for coal improves.

7.2.2 Mining

A series of 11 mine maps from the Kehley Run, Indian Ridge, and Shen City colleries covering the stratigraphic interval from the Holmes coal vein down to the Buck Mountain coal (i.e. Holmes, Top Split Mammoth, Bottom Split Mammoth, Skidmore, Seven Foot, and Buck Mountain veins) were obtained from Reading Anthracite Company archives. These maps show the synclinal geologic structure of the Shen Penn Pit and the surrounding area, which plunges to the west and "spoons upward" several hundred feet east of the Shen Penn impoundment. These maps also show that the Buck Mountain coal was only deep mined on the flanks of the syncline (i.e. northern and southern edges of the impoundment), and that the coal is still intact under the center of the Shen Penn Pit near the axis of the syncline. Additional Reading Anthracite Company archives indicate that the Bottom Split Mammoth was the stratigraphically lowest seam removed by surface mining methods in the eastern section of the Shen Penn Pit. Therefore,

the Mammoth vein gangways at the eastern end of the Shen Penn Pit are the most likely outlets for minepool water to flow to adjacent abandoned underground mines to the east.

Figure 7.4 is a cross-section through the Shen Penn with dated intervals showing the location of post-World War II surface mining. The tan line cutting across the blocks represents the current bottom of the surface minepool after surface mining by Reading Anthracite and the extinguishing of the Kehley Run mine fire by the Bureau of Abandoned Mine Reclamation (BAMR).

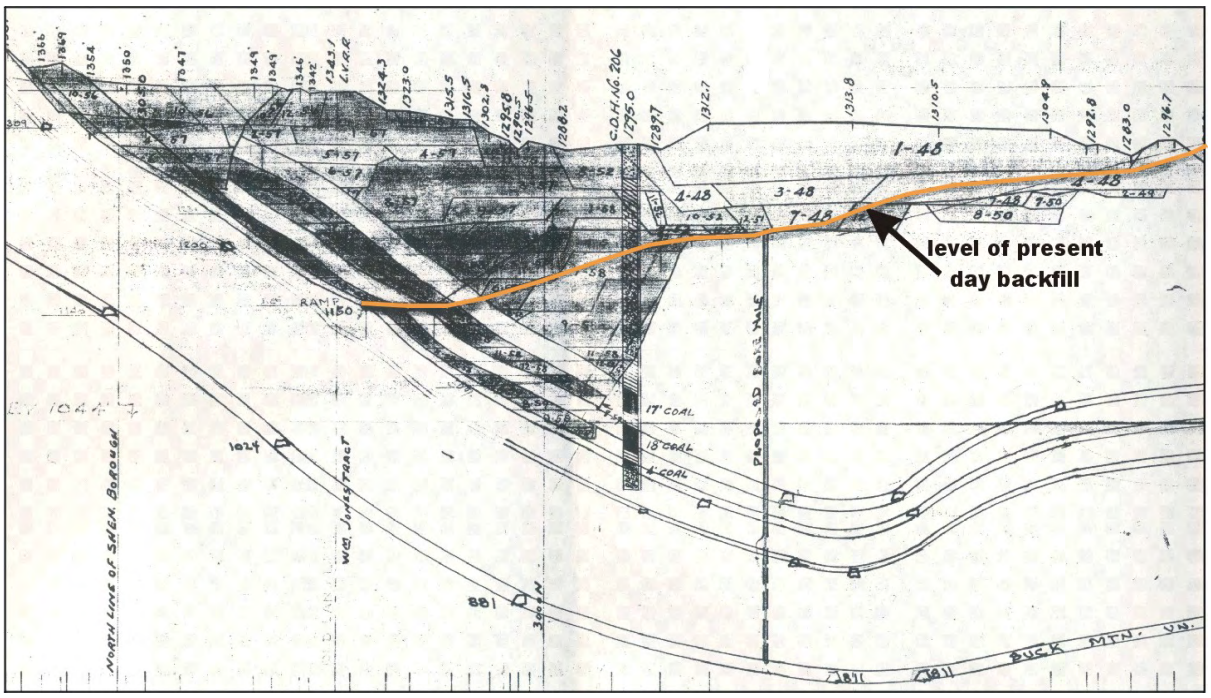


Figure 7.4. Cross-section through Shen Penn Pit (48+00E) showing surface mining locations and dates.

7.2.3 Subsurface Hydrology

The flow path of the minepool waters from the Shen Penn demonstration project intercepts roughly ten abandoned minepool complexes. The minepool flow path, as determined by the Pennsylvania Department of Environmental Protection (DEP), flows east from the pit underground through abandoned mine workings from the Kehley Run Colliery to the Shenandoah City Colliery, then to the Knickerbocker Colliery. At this point, the pool water flows south through barrier pillar breaches to the Maple Hill Colliery. Whereas, the Shenandoah City mine and Knickerbocker mine pillars have been breached, the flow pattern suggests that the Maple Hill/Mahanoy City pillar may be largely intact, directing the water across the synclinal structure and then westward (Fig. 7.5). The water flows west through the Packer #2, #3, #4, and Hammond Collieries. The minepool flow path continues in the same direction through the Packer 5 Colliery. It discharges to the surface at the Packer 5 airway located at the western end of the town of Girardville and approximately five miles from the Shen Penn Pit. The Packer 5 Mammoth pool discharge point represents the final (and primary) minepool discharge from the Shen Penn, Shenandoah City, Knickerbocker, Maple Hill, Packer 2, 3, 4, Hammond minepool

complexes, and the Shen Penn Pit. The final monitoring point for this water is the Shenandoah Creek (Mp 18) below the confluence with the Packer 5 discharge flow.

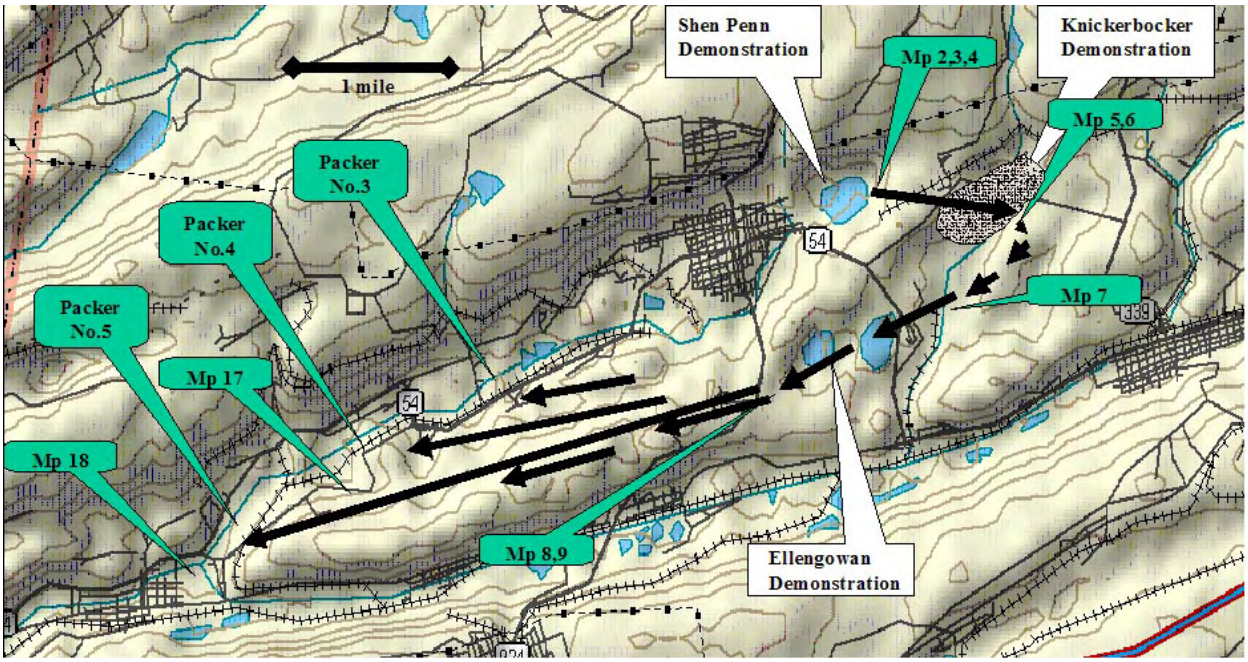


Figure 7.5. Projected flow path from minepool water discharging from the vicinity of the Shen Penn demonstration site (Laslow, pers. Communication, 2004). (Mp's are relevant DEP monitoring points utilized to establish mine pool flow pattern.)

A small amount of minepool water in this flow system discharges at a large diameter borehole drilled approximately 2500 feet east of Girardville by the Bureau of Abandoned Mine Reclamation (BAMR) in 1973 to eliminate basement flooding in Girardville from rising mine pools, and from the five Lost Creek relief boreholes drilled by BAMR in 1987 (not shown in Fig. 7.5)..

A depth survey conducted across the Shen Penn surface minepool established that the deepest section is approximately 230 feet below the water surface. As typically occurs in anthracite minepools, the minepool is chemically stratified (Fig. 7.6 and Table 7.2). However, the top water does not have a pH as high, and the bottom water does not have sulfate and metal concentrations as high as some minepools in the area. These water chemistry results may reflect the inflow and outflow configuration of the Shen Penn Pit, where the bottom water is higher in sulfate concentration than the top water. However, the outflow allows for some circulation not occurring in other deep minepools. Walter Manhart (Reading Anthracite) and Keith Laslow (DEP) determined that the outlet for minepool flow from the Shen Penn Pit into adjacent abandoned mine workings is at the eastern end of the pit, probably in the Mammoth vein and/or Buck Mountain vein gangways.

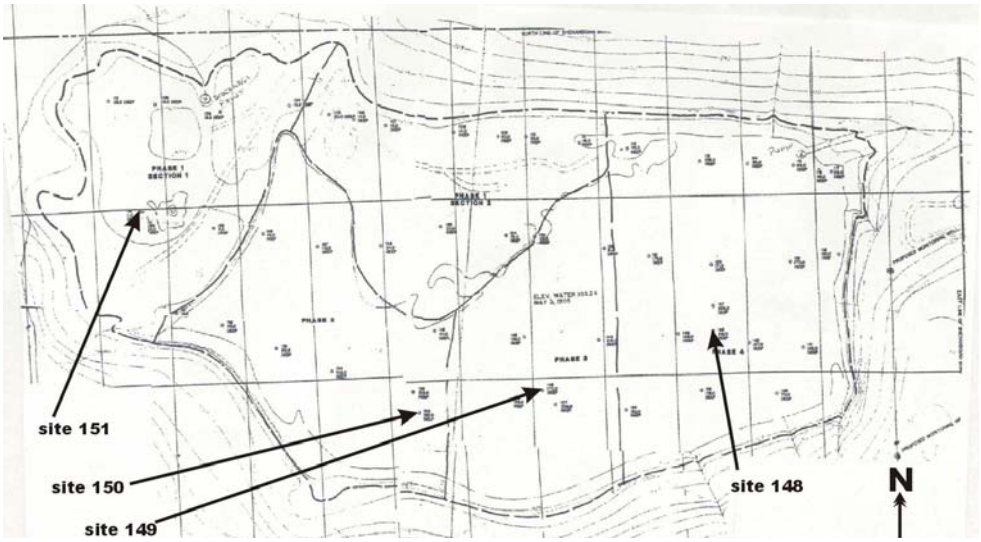


Figure 7.6. Shen Penn site map with locations of chemical sampling. The area of open connection to the deep underground mine is to the southeast.

Original minepool data indicated the surface elevation in the Shen Penn impoundment was at 1,103 feet msl prior to the breach in a channel that allowed the Kehley Run water to drain to the pit. A 1994 survey by Walter Manhart showed a surface minepool elevation of 1,132 feet. Given more time, the minepool may eventually return to a level of approximately 1,100 feet msl. Walter Manhart calculated that approximately eight million cubic yards of ash is needed to backfill the Shen Penn Pit to an elevation of 1,140 feet msl.

The significance of the Shen Penn Pit to mineland reclamation in the Commonwealth cannot be over stated. The sheer volume of the pit limits direct funding to backfill it. It is estimated that for just backfilling with rock, the cost would be between $20 and $28 million, comparable to the Pennsylvania Bureau of Abandoned Mine Reclamation's annual budget. One way to address such mammoth environmental projects would be to work jointly with industry where there would be sufficient materials available to meet the required volumes of fill.

7.3 THE ELLENGOWAN DEMONSTRATION PROJECT

7.3.1 Objectives

This study was initiated to provide an independent review of the potential environmental consequences of placing fluidized bed combustor ash directly into standing waters contaminated with acid mine drainage. Two placement techniques were evaluated in the study; direct dry-to-wet and slurry delivered, wet-to-wet placement. The scope of the study included field examination of the emplaced ash, the emplacement method, SPLP evaluation of the leachability of potentially hazardous elements from the ash. The Ellengowan demonstration project was a necessary precursor to the other demonstrations to develop tangible data on a small-scale before embarking on the full-scale demonstrations.

Table 7.2. Analytical results for depth sampling of the Shen Penn Pit. Samples collected on 3 May 1995. LD = less than detection. Values for As, Cd, Cr, and Hg were less than the detection level for all samples. Data from DEP*.

	Cond.	pH	alk/acid	Ca	Mg	Na	Cl	SO_4	Fe	Mn	Zn	Al
site 148												
surface	312	4.5	6.8/38	20.0	-	-	4	124	0.023	1.35	0.436	1.24
50’	371	4.6	7.4/-	26.7	20.8	4.41	3	162	0.012	1.46	0.452	1.32
100’	836	4.4	7.0/64	72.8	63.6	4.86	2	473	0.100	5.41	0.945	4.40
150’	979	4.2	5.8/68	96.8	65.7	5.73	2	588	0.389	7.39	1.060	4.06
200’	1047	4.6	9.6/100	105.0	73.9	5.40	2	525	17.7	9.87	1.410	4.86
site 149												
surface	312	4.5	6.6/22	20.6	15.6	4.02	4	119	0.021	1.34	0.686	1.14
50’	370	4.6	7.0/20	25.9	19.7	3.92	4	155	0.011	1.50	0.392	1.22
100’	869	4.3	6.8/48	77.8	53.2	4.60	2	456	0.087	5.61	0.950	4.41
150’	1004	4.1	4.6/52	90.8	60.9	4.85	2	546	0.342	6.72	0.936	3.91
200’	1091	4.6	9.0/82	99.0	64.6	4.66	2	589	20.9	9.35	1.300	5.27
site 150												
surface	315	4.5	6.4/20	19.1	15.5	4.05	4	121	0.024	1.39	0.330	1.18
50’	370	4.6	6.8/20	24.4	20.1	3.97	3	155	LD	1.57	0.410	1.21
100’	864	4.3	6.6/48	70.0	52.1	4.75	2	465	0.073	5.75	0.948	4.58
site 151												
surface	312	4.5	6.4/20	19.8	15.8	4.26	4	120	0.028	1.43	0.342	1.22

* conductivity is in µS/cm; alkalinity and acidity are in mg/L $CaCO_3$ equivalents, and all other concentrations are in mg/L.

7.3.2 Description of the Ellengowan Site

The Ellengowan demonstration was located near what was the small hamlet of Ellengowan just south of the town of Shenandoah and is now included as part of the ash placement site for Schuylkill Energy Resources on the west side of PA route 53. A large silt settling basin was present at this location, which had a 14 acre section along its eastern edge isolated by the construction of a rip-rap dam for this study. The depth of the water in this demonstration cell was approximately 10 feet with the bottom composed of fine coal silt locally referred to as “liver.”

7.3.3 Ash Characterization

Fly ash and bottom ash were collected at the Schuylkill Energy Resources (SER) facility as individual grab samples before the ash was wetted for transportation to the disposal site. The samples were recovered by an SER employee on 4 December 1994. Since at the facility, the fly and bottom ash are mixed in the relative proportion of 60% fly ash and 40% bottom ash (by volume), all testing was conducted with this ratio.

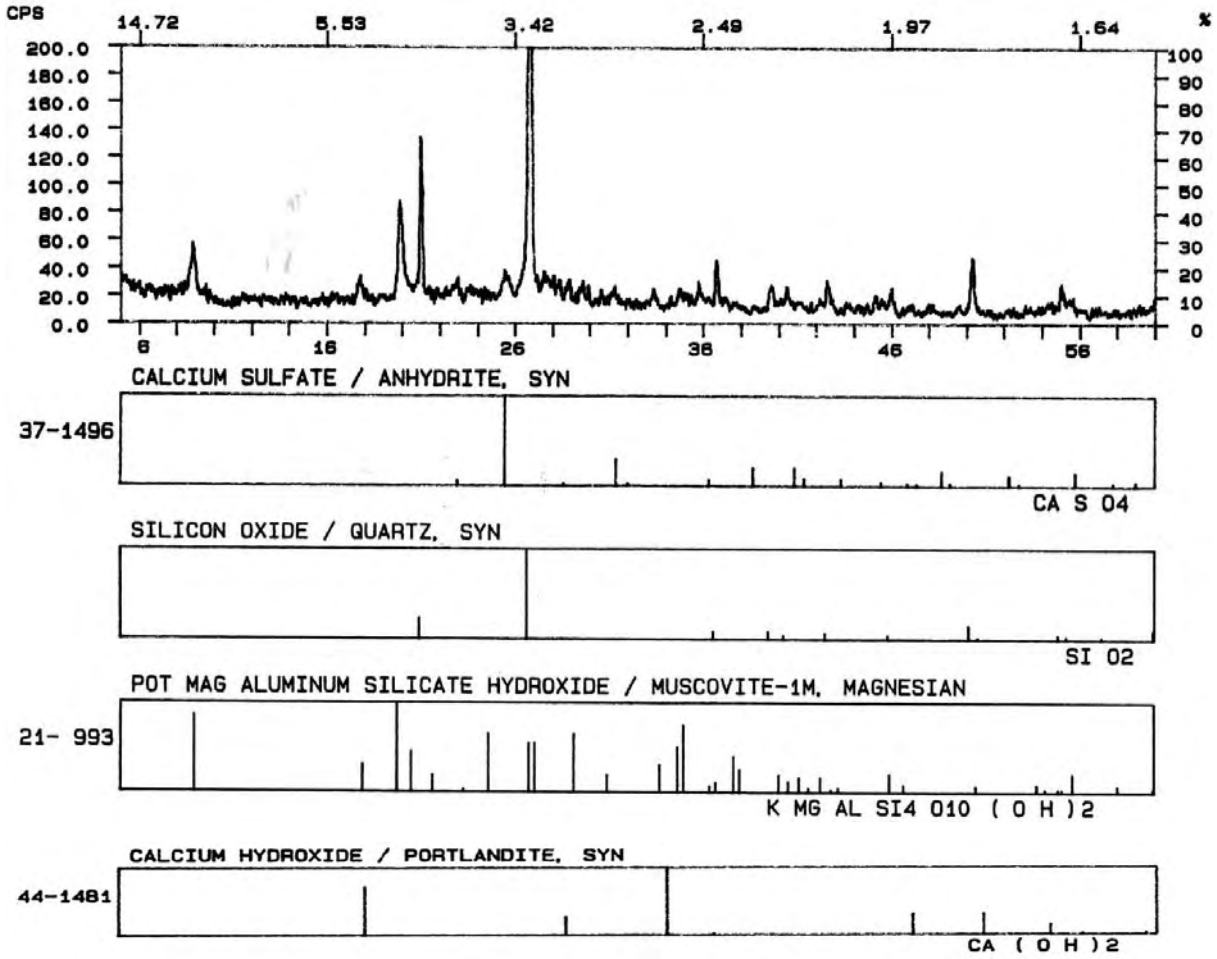


Figure 7.7. X-ray diffraction pattern and identified crystalline phases present in SER bottom ash.

X-ray diffraction data collected on the mixed samples of ash indicate that it is a mixture of: 1) predominantly quartz, derived from the anthracite refuse that SER is burning, 2) a clay, also derived from the refuse, 3) portlandite, derived from the hydration of calcined calcite, an added constituent of the fluidized bed, and 4) anhydrite, formed as the result of sulfur reacting with the calcium oxide in the fluidized bed. Figure 7.7 details the raw diffraction data and references it to the ICDD reference patterns for these four phases. The phase identification is consistent with other culm burning facilities with the exception of the clay content that would contribute to some cementitious behavior.

The ash was subjected to testing under the synthetic precipitation leaching procedure (SPLP) (EPA SW-846) protocol required by Module 25 of the DEP to evaluate its potential to release hazardous elements. Table 7.3 summarizes the results of these tests, which show that the ash mixture does indeed pass the regulatory leach test.

The mixture of fly and bottom ash was characterized with regard to its particle size distribution by passing a known mass through a set of sieves. These data are presented in table 7.4. The authors have developed the optimization of particle packing in order to achieve

maximum density with dry concrete mixes with the purpose of enhancing durability of the concrete. As part of this research activity, a PC-based computer code has been developed and utilized which accurately predicts the maximum packing density that may be anticipated from a material based on the sieve analysis. From these data in table 7.4, the model predicted that the maximum dry particle packing that may be anticipated for the SER ash mixture is about 60 to 62 percent of theoretical density. The theory underestimated the observed densities that routinely approached 90% for both the slurry placed and vehicle compacted ash.

Table 7.3. Chemical Analysis of SPLP Leach Test.

Element	mg/L	element	mg/L	element	mg/L
Ag	<0.02	Hg	<0.002	Sr	1.55
Al	0.37	K	8.0	Ti	<0.02
As	<0.01	Mg	0.05	Tl	0.06
B	0.02	Mn	<0.02	V	0.06
Ba	0.11	Mo	0.12	Zn	<0.02
Be	<0.02	Na	3.74	Zr	0.05
Ca	420	Ni	0.05	CN	<0.1
Cd	<0.02	Pb	<0.01	Cl	0.6
Co	0.06	Sb	0.01	NO_3	1.2
Cr	0.15	Se	0.02	SO_4	1080
Cu	<0.02	Si	4.5	pH (init.)	4.22
Fe	0.02	Sr	1.55	pH (final)	12.07

Table 7.4. Sieve Analysis 60:40 Mix Schuylkill Energy Resources Ash.

Sieve size	% retained	Sieve opening
¼ inch	0	2540µm
#4	2.08	4760µm
#8	13.74	2360µm
#16	14.75	1180µm
#30	5.02	600µm
#40	1.13	425µm
#60	1.53	250µm
#100	24.40	150µm
#140	20.78	105µm
#200	7.31	74µm
#270	3.97	51µm
#325	2.36	45µm
Pan	1.00	

7.3.4 Field Observations

The mixture of ashes was slurry pumped into 7 feet of standing water in a silt pond, as well as end-dumped into the standing water. The results of these observations were very encouraging, and are as follows.

7.3.4.1 End-dumped ash

Ash was placed into the standing water while still hot. The surface level of the ash was approximately 3 feet above the current water level. The ash compacts well under the normal operation of the heavy equipment. Two test pits were dug into the ash that had been in place for approximately 1 month (SER personnel). One pit was at the deepest portion of the silt pond and approximately 30 to 40 feet from the water's edge, while the other pit was placed about 10 to 15 feet from the water's edge. Both pits were dug to the silt "liner" interface and were found to be dry. The walls possessed sufficient strength that they held their form without any evidence of collapse. Figure 7.8 is a photograph taken at the time the pit was dug showing the competent structure of the pit walls. These observations suggest that the ash has successfully displaced the water and that, within the time frame of the observations, the water had not infiltrated back into the ash pile.

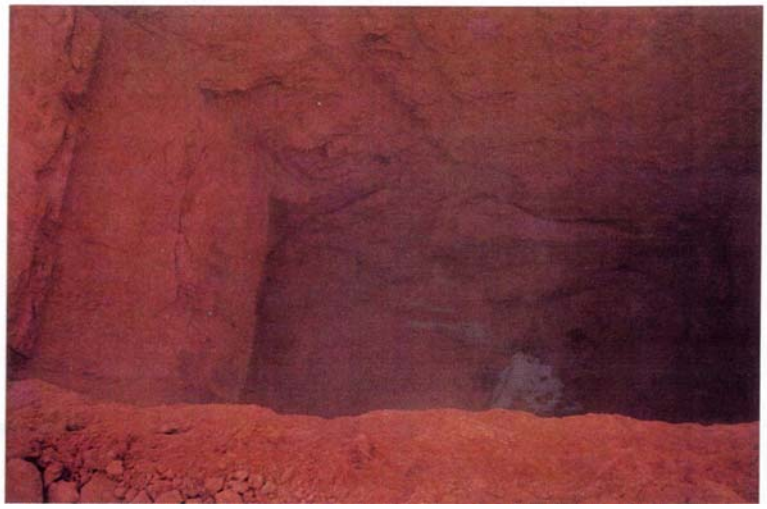


Figure 7.8. Photograph of test pit dug into end dumped ash. Note the wall structure and the presence of water at the silt/ash interface.

7.3.4.2 Pumped ash slurry

The photograph in figure 7.9 presents an overview of the slurry activities into the test pond. Two observation points were examined, one on the initial pumping site and the other near the site of the test pits. At the initial site, the level of the placed ash was less than a foot above the water level of the pond. A shovel test (dug by hand) revealed the saturation level at a depth of about 2 feet and, just like the beach, this hole gradually collapsed upon itself. This observation had prompted the request from DEP to dig the two test pits discussed above.

The second site had significantly more ash placed during our observation. Very limited turbidity was observed in the pond water, and only occurred in the shallow waters where the ash entered the pond after running over the previously placed material. It is important to prevent the fines from mixing with the pond water and forming a "mud puddle." Hence, slurryed ash should be placed in a non-turbulent manner as was practiced and observed in this demonstration. The

ash slurry should not be dropped into the water, especially deep minepool impoundments like Shen Penn.

A second visit was made to the site on 20 August 1995 to examine the portion of the pond that had been completed by slurrying ash into the standing water. The surface appeared competent and had supported the weight of large equipment. Figure 7.10 is a photograph of a D8 driving on the slurryed surface. As in our previous visit, a test pit was dug into the ash to examine the compaction of the ash. During this exercise, the operator of the GradeAll experienced difficulty in digging through compacted ash. The resulting hole was similar in appearance to those observed previously, showing no slumping of the side walls and containing water only at the contact between the underlying "liner" and the deposited ash. Because the conditions of the slurried ash were similar to those previously observed, no additional holes were dug. A portion of the hardened slurried ash was a prominent white effervescent deposit which was determined by XRD to be a mixture of gypsum [$CaSO_4 \cdot 2H_2O$] and syngenite [$K_2Ca(SO_4)_2 \cdot H_2O$].



Figure 7.9. Photograph of the slurry placement facility.

7.3.5 Fly Ash- Grout Development

The field experiments with placement of the unconsolidated fly ash have been very promising, but as a fall-back position, a cementitious grout based on the alkali activation of the SER ash was pursued. In contrast to what was observed in the field, preliminary scooping studies in the laboratory have shown that the mixture of fly and bottom ash by itself does not possess enough pozzolanic activity to effectively consolidate. The difference in these two observations can be traced to the placement of "hot" ash in the field, which accelerates the hydration reactions when contrasted to cooled ash in the laboratory. Studies have shown that activation can be achieved with the use of both a waste baghouse lime dust (LKD) or a waste baghouse cement kiln dust (CKD).

Laboratory data for the lime dust are very promising at early hydration times, yielding an unconfined compressive strength of 1153 psi, but as the hydration process continues, strength begins to decrease to a value of 400 psi at 90 days, (Fig. 7.11 and Table 7.5). The grout was prepared with a water to cement ratio of 0.21, which is quite a bit lower than 0.5, the ratio that is being used in the slurrying operation. The lime dust loading is 3.76 %wt. The addition of the lime dust obviously assisted in the relatively high early strength of this formulation, but it is believed that there was insufficient lime to maintain the chemical reactions associated with the hydration that was initiated. X-ray diffraction characterization of the 90-day cured grout and the ash recovered from the slurry demonstration show very little difference in bulk mineralogy, with the latter sample appearing to contain more amorphous materials than the grout (Figs. 7.12 panel a and panel b). The ability of the grout to transmit water was measured on the 56 day specimen and found to be 1.19 x 10^{-4} darcys (1.16 x 10^{-7} cm/sec), a value comparable to that of compacted clay.



Figure 7.10. A D8 operating on the surface of the slurry-placed ash after closure of the demonstration pond.

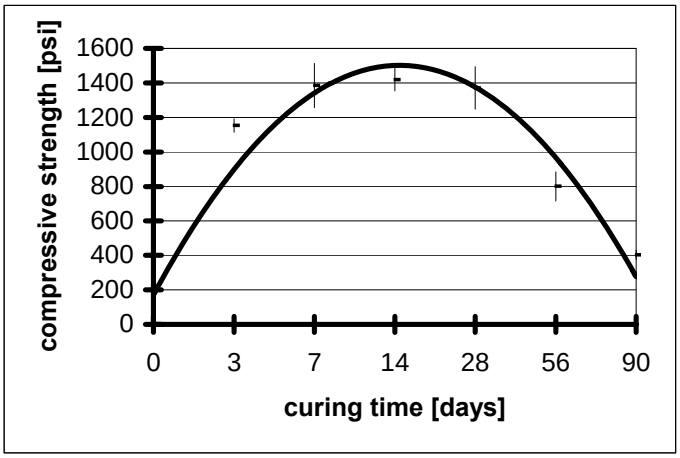


Figure 7.11. Strength development in lime kiln dust (LKD) activated fly ash grout as a function of curing time.

Table 7.5. Unconfined compressive strength of LKD activated fly ash grouts as a function of time.

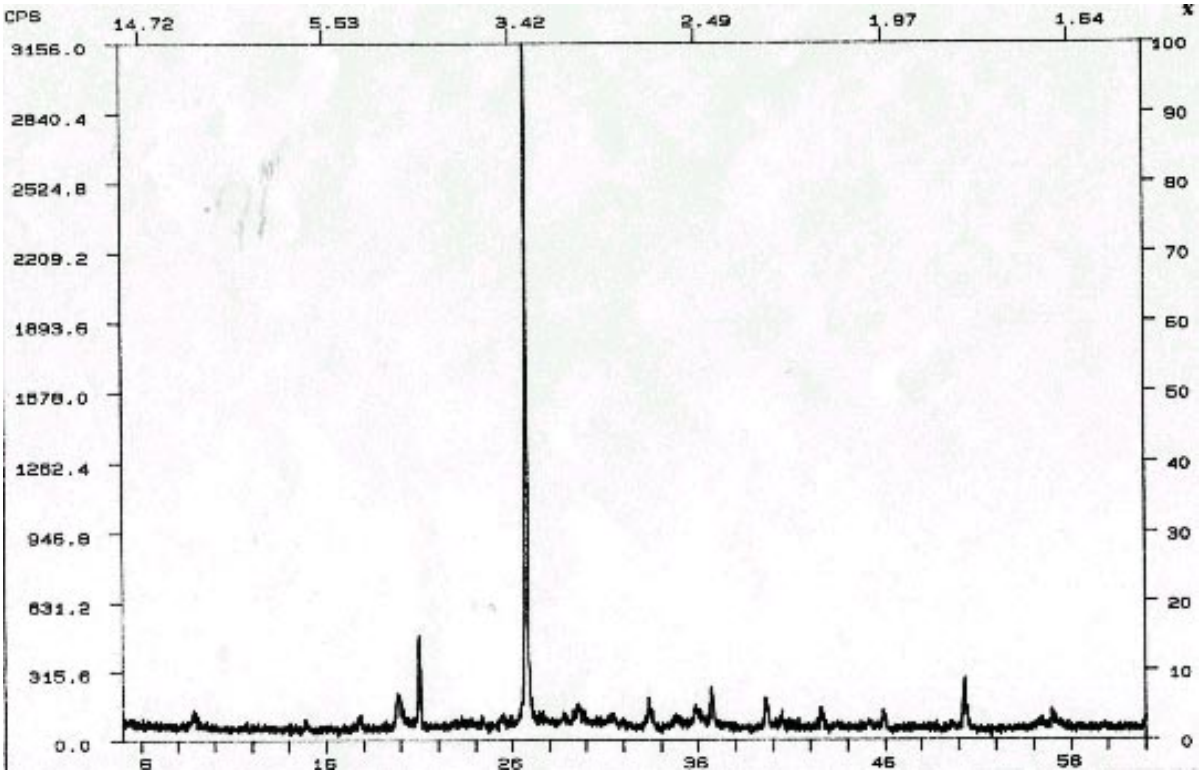
Curing Time (days)	Compressive Strength (psi)	Standard Deviation
3	1153	39.6
7	1385	128.4
14	1419	65.3
28	1371	122.7
56	800	83.8
90	403	27.5

Two samples of cement kiln dust were received from a cement manufacturer near Nazareth, PA. One sample was wet and the other was dry. Experience at PSU has been that wet CKD samples have little or no activation potential for fly ash grout formulations, therefore it was eliminated for further consideration. A formulation was chosen which utilized 14.8 %wt CKD with a water to solids ratio of 0.26. Preliminary mix design data were not very encouraging. Strength development with this mixture was limited to less than 200 psi in 28 days of curing (Fig. 7.13 and Table 7.6). Although CKD could be utilized, larger amounts of materials would be needed and the resulting quality of the grout would need additional evaluation for the cost effectiveness of its use. Another lime source that has potential for use as an activator with this class of fly ash is lime kiln dust (LKD). Lime kiln dust has the advantage of containing free lime which offers a significant benefit from its enhanced chemical reactivity. However LKD has the same drawback as CKD in that it must be obtained 'fresh' to take advantage of its benefits. Upon exposure to weathering, it too will adsorb carbon dioxide from the air and greatly reduce its function as an activator.

7.3.6 Ash Strength

With the slurry placement of the SER ash, a concern has been raised about the required minimum bearing strength for this ash. There are two reasons: 1) operations logistics require that it support heavy vehicles and 2) post placement usage for ultimate load, not quick sand. Clearly from Figure 7.10 the ash slurried into the demonstration pond was compacted enough to support the mass of this heavy tracked vehicle. Quantification of compaction of soils in general assumes that a wheeled vehicle would contact the uncompacted soil in circular pattern of diameter, D, and a load from the vehicle, L. The simple mass per unit area relationship can then be used to describe the compaction force on the soil once the buoyant effects of contacting soil particles are factored into the calculation. The buoyant effects act as a proportionality constant, which varies as a function of soil depth. Figure 7.14 includes a schematic drawing detailing these relationships. Table 7.7 and Figure 7.14 summarize calculated data for the example of a 10 inch wide tire on a vehicle with a load of 4,710 pounds per wheel. This simple calculation suggests that for a wheeled vehicle to traverse a freshly placed soil a minimum bearing strength of 36 psi would be necessary to allow the vehicle to pass. Following similar reasoning, the alleviation of soils compaction in agriculture application has been studied as a function of the tire width and diameter, ply structure, tire inflation pressure, and gross vehicle weight. The variation of surface pressures for these varying parameters, presented for the range of conventional construction vehicles, also suggests that a minimum of 30 psi is necessary to support the mass of a conventional vehicle, in agreement with the data calculated in the previous analysis.

a)



b)

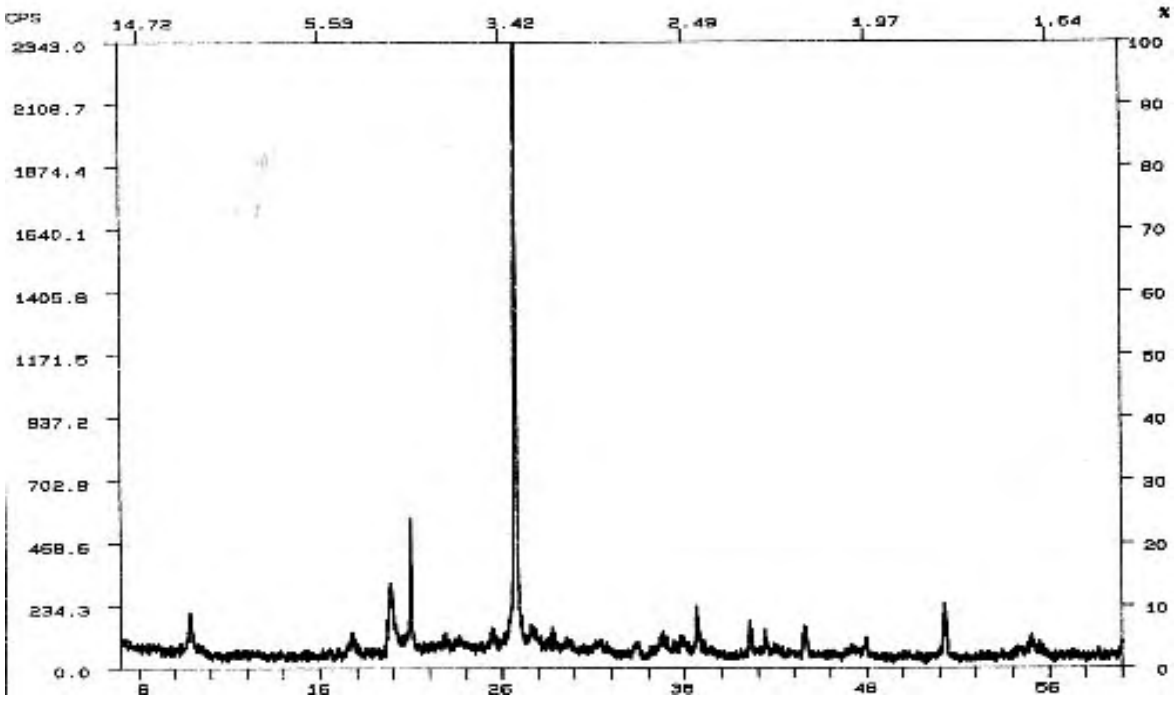


Figure 7.12. X-ray diffraction pattern for a) fly ash grout cured for 90 days and b) slurry placed fly ash.

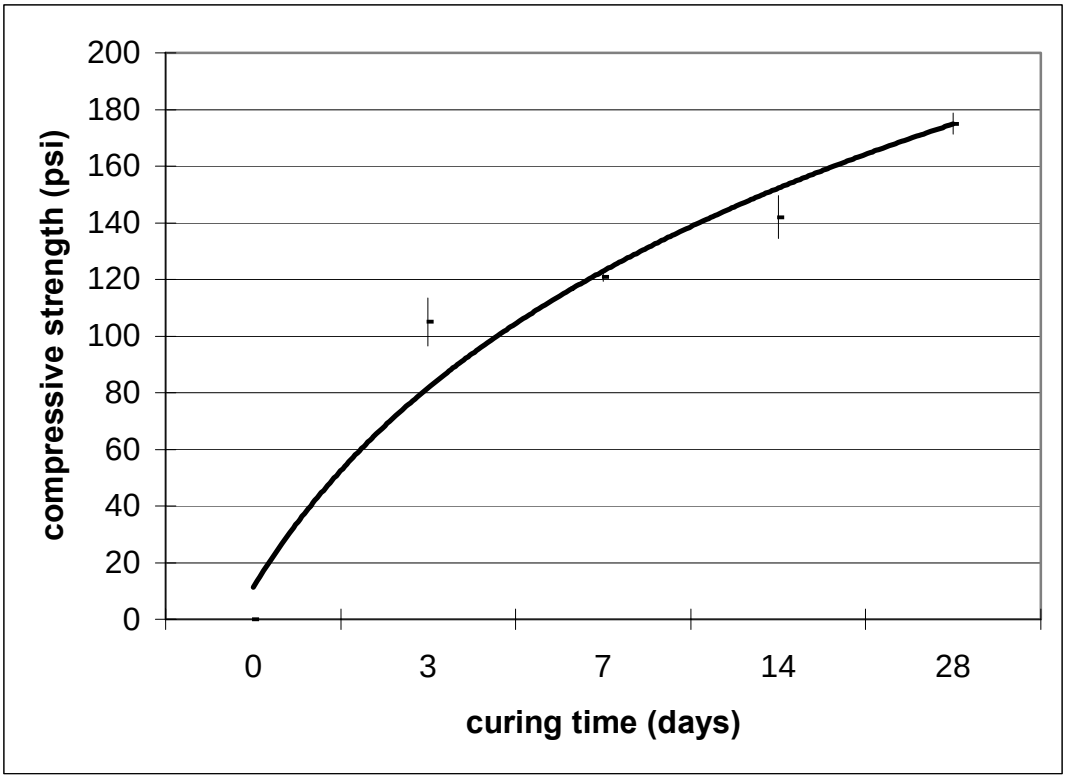


Figure 7.13. Strength development in CKD activated fly ash grout as a function of curing time.

Table 7.6. Unconfined compressive strength of CKD activated fly ash grouts as a function of time.

Curing Time (days)	Compressive Strength (psi)	Standard Deviation
3	105	8.5
7	121	1.7
14	142	7.6
28	175	3.8

Table 7.7. Variation in compaction pressure with depth under a load.

Example: **D = 10 in**
L = 4,710 pounds
A = 78.5 in^2
P = 4,710/78.5 = 60 psi

Distance under surface (inches)	Proportionality Factor	Soil Pressure (psi)
0	1.00	60.0
5	0.60	36.0
10	0.30	30.0
15	0.15	9.0
20	0.09	5.4

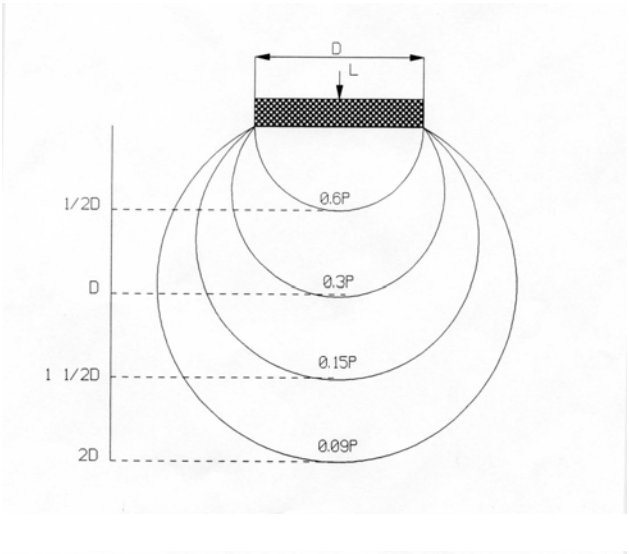


Figure 7.14. Variation in compaction pressure with depth under a load.

7.3.7 Recommendations

Slurry placement appears, by all observations in this demonstration, to be an adequate approach, if the slurry is allowed to flow into the standing water in a slow delta-like spreading flow. That is to say, the slurry should be allowed to flow as gently as possible into the water. This placement approach is recommended to best minimize turbulent mixing and the formation of turbidity. Under no circumstances should the slurry be "dropped" into the standing waters.

The behavior in deep waters approaching 50 to 250 feet of water can only be speculated from this demonstration. The advancing front of ash in the deep water would establish a subaqueous angle that may contribute to fine particle segregation resulting in high turbidity water. The possibility of subsurface placement of the ash near the bottom of the pit should be considered. Should segregation of the ash occur, resulting in excessive turbidity (a muddy appearance), the placement should be temporarily halted and the process re-evaluated and an alternative placement approach considered.

The slurried ash appears to be compacted enough to support the mass of heavy construction tracked vehicles. Quantitatively, the strength needed in the placed ash appears to be a minimum of 30 to 35 psi in order to support vehicular traffic.

If at some future point, it becomes necessary to further stabilize the FBC ash for placement, the preliminary studies support the observations that cementitious grouts can be formulated by the addition of lime kiln dust. The long-term strength performance of the formulation, chosen in this study, does however point out the necessity for additional detailed studies. Grouts formulated with cement kiln dust may also provide an alternative activation source but at the expense of lower strength and larger amounts of activator additions and

enhanced materials handling. The hydraulic conductivity (10^{-7} cm/sec) of the grout appears to be well within the range of clay sealants and in agreement with the field observations from the test pits.

7.4 THE SHEN PENN DEMONSTRATION PROJECT

7.4.1 Objectives

The Shen Penn Pit represents a significant public health and safety problem directly to the city of Shenandoah and surrounding communities because it is often used as a recreational swimming hole and is the site of multiple drowning fatalities. The most recent being an 11 year boy triggered a renewed interest in eliminating the safety problem with the water-filled pit. The objective of the demonstration was to show that ash could be transported in the form of a slurry and placed in the deep standing waters of the Shen Penn Pit.

7.4.2 Description of the Shen Penn Site

The Shen Penn Demonstration represents the one of three demonstration permits issued by the DEP for the purpose of establishing the efficacy of ash placement into mine waters. This permit was intended to evaluate the so-called wet-to-wet placement in which ash from the Schuylkill Energy Resources Cogeneration facility would be placed as a slurry into the mine pit water. The permit was issued to Reading Anthracite Company as DEP Waste Demonstration Permit # 301289 on the 22nd October 1995 to include a project area of 49 acres.

The Shen Penn Pit is located within the town of Shenandoah on the eastern end of town and encompasses approximately 39 water filled acres with a measured depth of 240 feet. Associated with the pit is an exposed highwall approaching 600 feet. Figure 7.15 is an aerial overview of the pit and its relationship to the cogeneration facility and the town of Shanendoah.

7.4.3 Proposed Ash Placement

The ash is generated from Schuylkill Energy Resources Cogeneration Plant at the rate of approximately 100 tons per hour. The ash is a mixture of bottom ash and fly ash of approximately 60/40%, respectively. The ash would be slurried from the plant at a 20:80 solid to water ratio. The water required for the slurry system would be pumped from the Shen Penn Pit, however, current plant mine water, and/or cooling tower blowdown water would be utilized when maintenance on the pipeline is required. The arrangement would consist of a mixing tank and (2) 10 inch diameter polyethylene pipelines approximately 7,000 feet in length. It is anticipated that provisions would be made for the installation of a slurry pump adjacent to the mixing tank, if necessary. If in the event of a slurry pipeline blockage or repairs, the ash would be disposed at the present ash disposal site.



Figure 7.15. Aerial photograph of the Shen Penn Pit in relation to the Schuylkill Energy Resources Cogeneration facility and to the town of Shenandoah to the west of the pit.

The pipeline would be fed by a mixing tank located on the ash silo operating floor. Future consideration on collecting the ash within the cogeneration plant would likely be the preferred choice. This would eliminate the transfer of ash from the ash coolers to the silo. Water would be fed to the mixing tank at a rate of 1,600 gallons per minute (gpm). The slurry flow rate would be approximately 1,850 gpm. A float valve would be used to maintain the water level in the mixing tank. One pipeline would be used for conveying ash and the second pipeline would be used for return water from the Shen Penn Pit to the power plant.

The pipeline may contain only three or four elbows. Connections would be fused together to eliminate the potential for ash leakage. The elevation change in the first 3,000 feet of pipeline would be approximately 62 feet. This may allow the slurry to be conveyed by gravity, however, provisions would be made for the possible installation of a slurry pump adjacent to the mixing tank. No unmanageable problems with leaks are expected, since the pipeline would be operated under low pressures (typically less than 15 psi). The last 4,000 feet of pipe would have adequate head to transport the slurry. The final 4000 feet of pipeline would operate under vacuum and be equipped with vacuum breakers. Any leaks that develop would draw air into the pipeline and not result in ash leaks. A booster pump would be operated to clean the pipeline if it starts to plug. Ash would be disposed at the existing permitted ash disposal area if the slurry pipeline is unavailable.

The first phase of ash placement would be located at the northwest corner of the Shen Penn Pit. The water is approximately 20 feet deep at this location. The slurry pipeline discharge point would be approximately 10 feet back from the shoreline at the current water elevation. The discharge pipe elevation and distance from the shoreline may require adjustments in order to

maintain proper flow characteristics. Proper flow regime would enable the ash to settle on a gentle slope under the water and assure greater stability as the ash placement progresses.

Ash placement would proceed in each phase to an elevation above the water that would support heavy equipment, which is required to extend and/or move the pipeline. The mechanism to extend the pipeline is essentially an iron to heat fuse additional lengths of pipe and elbows. Since the pipe is flexible, a crawler dozer may be required to move the discharge point a short distance. If the pipeline needs to be raised, a dozer would be utilized to lift the pipe and support would be placed underneath.

It was agreed that the ash was not required to set up in water like concrete, but must have some reasonable expectation for stability in order to proceed with work on the final ash surface and to drive heavy equipment on that surface. Therefore, the bearing capacity at the ash surface is a more significant measurement than to what extent the ash exhibits pozzolanic properties. William Pounds of the Bureau of Land Recycling and Waste Management developed the following operational definition: "The fly ash must solidify by a chemical or physical process concurrently with addition to the pit, or within the shortest period of time technologically practicable. The fly ash must solidify prior to filling the pit above the water level, and tests should be conducted to demonstrate that the fly ash is stable. The fly ash in the pit, after meeting this requirement, must be capable of withstanding a minimum bearing capacity of 1.5 tons per square foot." Another condition is that subaqueous ash must not leach or migrate from the Shen Penn Pit into adjacent abandoned underground mines.

The ash would be chemically and physically analyzed as per Module 25 requirements. Additional physical analysis would be conducted periodically regarding saturation and compaction. This testing would be conducted by augering, drilling (split spoon), and/or excavation, whichever is most efficient. Water monitoring would be conducted within the pit (in advance of the ash placement), the proposed monitoring wells, existing wells, and surface flows. The monitoring frequencies and parameters would be further defined once the project has commenced.

Upon successful completion of the entire project, the ash would be covered with three feet of intermediate cover and one foot of final cover and graded to blend with the existing topography. Once final cover grading is completed for the final land use, planting of trees and grasses would finish the reclamation at the Shen Penn Pit. Final completion of the reclamation would result in 40 acres of developable land.

CHAPTER 8. THE KNICKERBOCKER DEMONSTRATION PROJECT

Caroline M. Loop, William B. White, Barry E. Scheetz

8.1 OBJECTIVE

The objective of the Knickerbocker wet-to-dry demonstration was to establish the technology and economics of placement of ash via a water/solids slurry without impacting the environment in an inverse manner.

8.2 DESCRIPTION OF THE KNICKERBOCKER SITE

The Knickerbocker demonstration represented a wet-to-dry mine pit placement strategy not previously used in eastern ash handling. This method of moving mine tailings is used in metal mines in the western US and is proven to be efficient and very cost competitive. The Knickerbocker project was implemented in 1997 and completed in 2002 with the placement of approximately 4 million cubic yards of ash and the recovery of a stripping pit reclaimed back to its approximate original contour. The Knickerbocker Slurry Pit demonstration permit was issued to Reading Anthracite Company on the 21st July 1998 as DEP Waste Demonstration Permit # 301301 for a project area of 44 acres.

8.2.1 Local Geology

The Knickerbocker Pit is contained within the Knickerbocker Basin, part of the northeast-trending synclinorium in the eastern side of the Western Middle Anthracite Field. Description of the Western Middle Anthracite Field is contained in the previous chapter describing the Ellengowan and Shen Penn demonstration projects (section 7.2.1). Figure 7.2 shows the lithologic section through the Knickerbocker Basin. The Knickerbocker Pit is approximately one half-mile east of the Shen Penn Pit. The structural and lithological context is essentially the same. In the Knickerbocker Basin, the axial plane of the fold dips north at depth and south nearer to the surface (see Fig. 7.3). The geologic description is contained in Kehn and Wagner's 1955 "Geology of Anthracite in the Eastern Part of the Shenandoah Quadrangle, Pennsylvania."

The stripping operation and the former mining operations are located geologically in a series of coal basins, the Shenandoah, Ellengowan, Yatesville, and Middle Mahanoy, of the Western Middle Anthracite Field. The property of the Reading Anthracite Company in this area is bounded on the east by mining operations on lands controlled by Lehigh Valley Coal Company, on the north by lands controlled by the Cox and Girard Estates on the North Mahanoy Mountain, and on the south by the Reading Anthracite Company, Blaschak Coal Company and Read Realty Company properties and the Mahanoy anticlines and on the west by property controlled by the Girard Estate and Sheafer Estate. The property owned by Reading Anthracite Company in the overall area consists of ten tracts of land totaling 2300 acres. It extends a distance from its eastern boundary to the western boundary of 18,000 feet and from north to south approximately 6000 feet. It is in this overall area they operated deep mine operations at Mahanoy City, North Mahanoy, Knickerbocker and Turkey Run Collieries. Deep mine

operations were discontinued between 1932 and 1954. These deep mine operations were and are all interconnected underground on various levels and are all presently flooded.

Deep mining at these operations involved the mining in the Little Buck Mountain, Buck Mountain, Seven Foot, Skidmore, the Top, Middle and Bottom Splits of the Mammoth, the Holmes, Little Primrose, Primrose, Orchard, Little Orchard, Diamond, Tracy and Little Tracy Veins on both the North and South Dips of the various basins and anticlines in the area.

Mining at these deep mine operations began via water level drifts in the various veins about 1850. In subsequent years, as mining progressed, slopes were sunk from the surface on both North and South Dip measures of the various basins and later shafts were sunk at various locations with depths of 300 to 1000 feet. In some instances, underground slopes were sunk and developed coal reserves below sea level. The entire superficial acreage involved in mining at these former operations of Reading Anthracite Company comprised approximately 2300 acres.

During the operating years of these collieries, mining extended to the east on lands of Lehigh Valley Coal Company as far east as Delano, approximately 4 miles, where collieries were developed via water level drifts, slopes and shafts beginning in 1850 and continuing until 1960. Some of these collieries were the Primrose, Copley, Springdale, Malvean, Mayersville, Trenton and West Lehigh. These operations are all interconnected by underground mining and are all flooded. The water enters the property of Reading Anthracite Company on its eastern extremity at the Springdale Shaft, West Lehigh Colliery.

During the same period of time, mining operations were developed westward of Reading Anthracite Company's property on lands of the Girard Estate and Sheafer Estate, beginning development via Water Level Tunnels, slopes and shafts starting around 1850 and continuing until 1961. The collieries were William Penn, Packer Nos. 2, 3 and 4, Weston, Girard Mammoth, Packer No. 5, and Hammond. The operations had their western terminus in the vicinity of Girardville Borough. All of these mining operations are interconnected underground in the various veins and are all flooded.

All of the mining operations, beginning at Delano and Lehigh Valley Coal Company property, continuing through Reading Anthracite Company property and thoughout the Girard Estate and Sheafer Estate property, mined the same veins of coal from the Little Buck to the Tracy Veins. It is noted here that stripping operations have been conducted on some of these properties as far back as 1880. With the discontinuance of mining and pumping facilities in the 1950's and 1960's at collieries in the overall area, the operating collieries assumed high pumping loads because all of these operations were interconnected at various levels in the entire area. In 1961, with the abandonment of Packer No. 5, the last operating colliery, the impounded mine water rose to the surface in the vicinity of the eastern end of Girardville Borough at a location within a few feet of Mahanoy Creek at its junction with Shenandoah Creek in an area known as Connerton Village. This impounded mine water flowed to the surface through a backfilled Holmes Vein stripping pit, formerly a Packer No. 5 Colliery operation and through strata cracks caused by deep mine operations. In August 1963, it was estimated that the flow was 15,840,000 gallons per day from all of these abandoned operations. In June 1966, the flow was estimated at 21,600,000 gallons per day. The quantity of water is subject to fluctuations due to precipitation

in the area. The area drained by this discharge is estimated at 11 miles in an east to west direction by 4000 to 6000 feet in width representing approximately 8000 acres. There are two major streams which drain most of this area, Mahanoy Creek paralleling the southern boundary from Delano to Girardville and the Shenandoah Creek with headwaters north of Shenandoah Borough which joins Mahanoy Creek at Girardville.

The subsurface hydrology is described in section 7.2.3. The flow path is one of movement between the large interconnected minepools from Shen Penn, Shenandoah City, through Knickerbocker and Maple Hill. The water flows from the west from Shen Penn out of the abandoned mine workings from the Kehley Run Colliery to the Shenandoah City Colliery to Knickerbocker. From there, the water turns south, traveling through barrier pillar breaches to the Maple Hill Colliery and turning to the west. The ultimate discharge point for this system is suspected to be the Packer 5 outfall. The Packer 5 discharge flows to Shenandoah Creek. See figure 7.5 for the map of the flow path.

8.2.2 Mining History

The initial coal removal operation began in 1965 with the issuance of the Knickerbocker Stripping permit No. M-112A. An estimate of approximately 560,000 net raw tons of coal was recovered from former deep and strip mining operations on the site at a rate of 500 tons per day. The operations consisted of the extension of old stripping pits existing in the Bottom, Middle and Top Splits of the Mammoth Vein, the Holmes, Little Primrose, Primrose, Orchard, Diamond and Big and Little Tracy Veins. The various veins have a strike North 75^{o} East and have dips to the North and South from 30^{o} to 80^{o}. Figure 8.1 is a cross section mine map which run N-S through the demonstration site showing individual stripping sections. In all cases, the recoverable coal was from that remaining in the pillars left from previous deep mine operations and the stripping operations are all above the body of the impounded mine water.

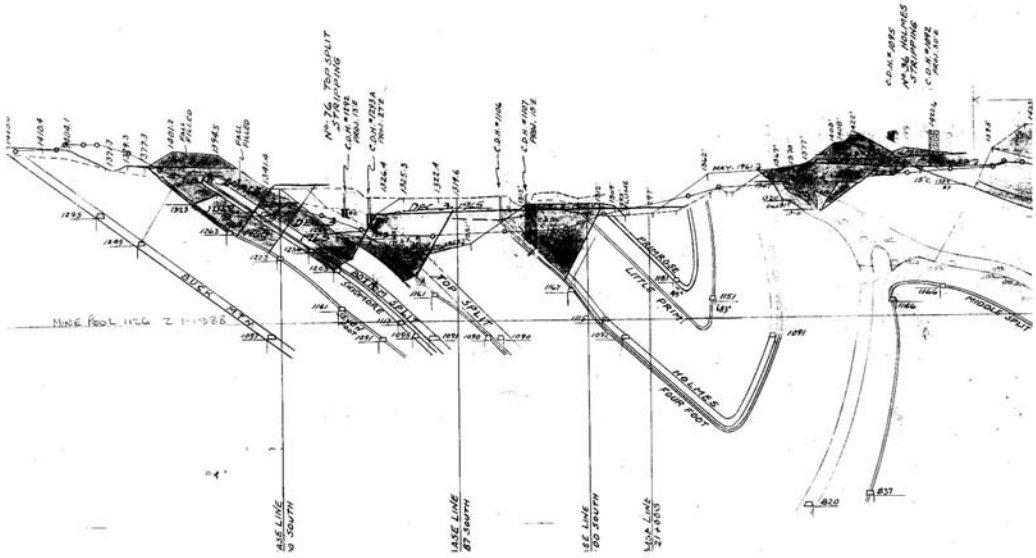


Figure 8.1. Cross-section through the Knickerbocker Pit (34+00).

The stripping operation was developed from east to west on the various veins where recoverable coal was assumed to be present. The overall length of the combined stripping pits in the various veins was approximately 3600 feet, with widths from 400 to 1800 feet. The elevation of the surface over the stripping operations ranged from 1300 feet to 1450 feet. The normal elevation of the impounded mine water in the flooded underground mine workings of Reading Anthracite Company's property is at 1060 feet msl before it overflows through penetrated barrier pillars to the west into the Packer No. 2,3 and 4 operations. All pits reached a depth of 150 or more feet. The overall area stripped was 173 acres.

Raw coal removed from the stripping location was transported by truck approximately three quarters of a mile to the adjacent Reading Anthracite Company's Maple Hill Cleaning Plant where the raw coal was pre-cleaned by removing the extraneous rock and the pre-cleaned product transported by rail to the company's new St. Nicholas Breaker and Fine Coal Plant approximately 55 rail miles away. The extraneous vein material removed in the course of pre-cleaning at Maple Hill Cleaning Plant was returned to the stripping pits where it was covered by backfilling operations.

There are no surface streams involved within the Knickerbocker stripping operation. All drainage is in the form of precipitation falling directly into the pits and flows by gravity into the existing minepool.

8.3 ASH PLACEMENT

8.3.1 Source of Ash

A water/ash slurry consisting of a mixture of 60% (by volume) deep minepool water pumped from the Maple Hill shaft and 40% ash was delivered to the placement site, a distance of approximately 1 km, in a 10 inch diameter high-density polyethylene pipe (Fig. 8.2). Discharge of the slurry into the pit was controlled so that laminar flow conditions were maintained. As observed in the Ellengowan demonstration, turbulent mixing of the slurry would result in unnecessary turbidity in the transporting water, which could percolate into the minepool or be recycled back to the ash slurrying operation. Neither outcome was desirable.

The ash slurry system began operation in September of 1998, with an average monthly deposition rate of approximately 52,000 tons of dry ash. Based on an ash density of 90 pounds per cubic foot, the estimated volume of the Knickerbocker Pit was initially 2,400,000 cubic yards.

8.3.2 CKD Test Cells

A subset of the principal wet-to-dry demonstration was a study intended to evaluate the potential for the enhancement of the mechanical properties of the cogeneration ash by the additions of cement kiln dust (CKD). CKD, depending upon its storage history, can contribute significant alkalinity to an ash/CKD mixture to enhance the cementitious reactions and/or it can serve as a fine filler to enhance packing within structural fills. The sub-study of placement of cogeneration derived ash and cement kiln dust (CKD) mixture into the Knickerbocker Pit began

on February 3, 2000. Schuylkill Energy slurried both bottom and fly ash approximately 2900 feet to a blending tank beside four test cells. Keystone Cement Company delivered 20 ton truckloads of CKD to the test cell area, which were then stockpiled. A front end loader was used to transfer the CKD into the hopper for mixing with the fly ash slurry at the outlet end of the delivery line, which was then piped into the test cells. The four test cells were at the northwest end of the Knickerbocker Pit. They were carved from ash originally slurried into the pit over the past 2 years. The cells can be seen in the foreground of the demonstration pit in Figure 8.2. The first cell measured 180'x180'x10' and was designed to remain undecanted. The three others were approximately 100'x100'x10'. Test cells 1 and 2 contained a mix of 20% CKD and 80% ash. Cells 3 and 4 contained 10% and 5% CKD, respectively, with ash as the remainder (Fig. 8.3).



Figure 8.2. Aerial photograph of the Schuylkill Energy plant and the Knickerbocker Pit.

As the mixture flowed into each cell, the heavier particles would settle out and form a delta-type deposit, with standing water covering the farthest ¾ of the cell (Figs. 8.3 and 8.4). Cells 1 and 2 were filled on the 3rd to 5th of February 2000 and cells 3 and 4 were filled the 15th to 17th of February 2000. Because the pump was not working properly, cells 1 and 2 stood for

approximately 12 days and cells 3 and 4 contained water for approximately 20 days before they were pumped.

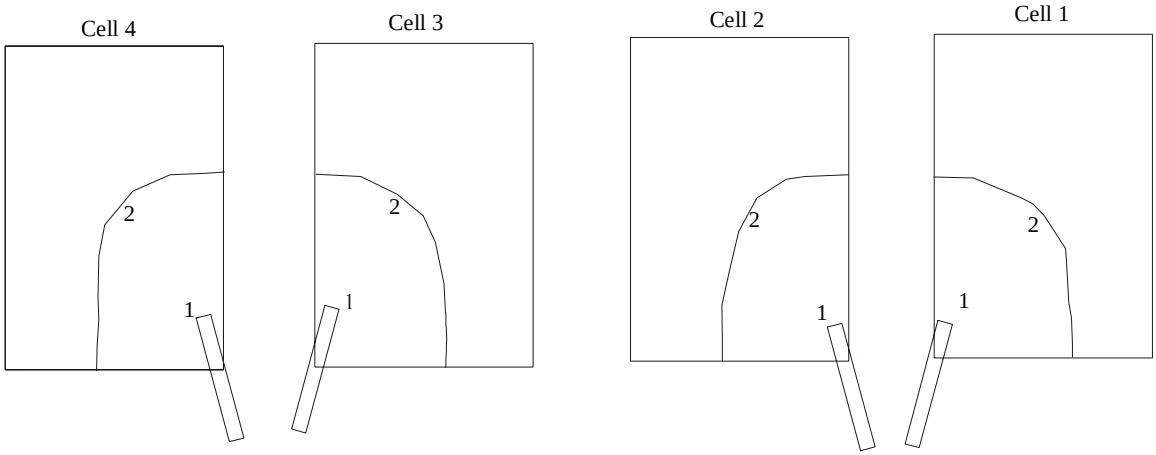


Figure 8.3. Schematic of cells and locations of sampling.

a.



b.



Figure 8.4. a) Inlet pipe to cell 1, February 2000. b) Locations of borings in cell 2, the first group of people is near the inlet pipe location, and the farther group is at the boring location

closer to the center of the cell. Delta formation is evident, with mudcracks in the remainder of the cell.

Water and sediment samples were collected when each cell was 1/3 full, 2/3 full, and completely filled. Soil borings were collected by the Borings, Soils, and Testing Company of Harrisburg, PA on the four cells in both August and November, 2000. At this time, the necessary blow counts were recorded. In August, dry density, wet density, and moisture measurements were collected by the DEP with a Troxler nuclear density moisture gauge. Weight bearing capacity measurements were collected with a penetrometer. Wet chemical, fertility, x-ray diffraction (XRD), moisture loss, grain size, and scanning electron microscope (SEM) analyses have been performed on the ash/CKD mixture from the Knickerbocker test cells in addition to blow count and densitometer measurements.

8.4 RESULTS

8.4.1 Ash Properties

8.4.1.1 Density analysis

When placed in a manner that allowed the transport water to flow in a slow and laminar fashion, the ash dropped out of suspension rapidly and resulted in a dense, strong compacted fill onto which mining equipment could immediately drive (Fig. 8.5). Semi-annual characterization of the proctor densities of the ash and size distributions are reported in Appendix 8.A. These data show that compaction of the ash was routinely above 90% with enough structural strength to support wheeled vehicles.



Figure 8.5. Truck parked on recently placed ash.

Density measurements in cells 2-4 were made by DEP using a Cs-137 densitometer on July 31, 2000 (Table 8.1). Moisture in the samples ranged from 9.8% to 14.9%. Excess water from slurrying may have seeped through the sediment, evaporated, and/or been incorporated into

minerals re-hydrating or forming within the sediment. The moisture content of the area away from the inlet pipe (hole 2), as measured in July 2000, consistently increased as CKD content decreased. Conversely, in the area close to where the inlet pipe was located (hole 1), there was a small decrease in the moisture content with decreasing CKD content. This difference may be due to the particle sizes in each location, which would be expected to be different based on the delta-type deposit, extending from the slurry pipe. The gradation in grain size with distance from the pipe is not supported by the grain size distribution measured in the laboratory, where there was no significant difference between samples (Table 8.2). However, packing density most likely plays a role in the increased strength and more consistent blow count values recorded in the center of the cells.

Table 8.1. Troxler nuclear density moisture gauge results collected by DEP, July, 2000.

cell/hole	%CKD, location	dry density (lbs/ft3)	moisture (%)	wet density (lbs/ft3)
2/1	20%, inlet	97.5	10.9	108.2
2/2	20%, center	98.5	9.8	108.1
3/1	10%, inlet	97.1	10.6	107.4
3/2	10%, center	99.2	10.5	109.6
4/1	5%, inlet	102.9	10.3	113.6
4/2	5%, center	95.5	14.9	107.9

Table 8.2. Percent grain size distribution (μm).

Cell	Hole	Depth	>160	160-74	74-45	45-38
2	1	4-6'	85.8	11.5	2.6	0.1
2	2	4-6'	85.3	11.4	3.2	0.1
4	1	4-6'	82.8	13.8	3.3	0.1
4	2	4-6'	79.0	18.4	2.5	0.1
1	2	12-14'	80.6	13.2	5.8	0.4
2	2	12-14'	83.8	10.2	5.6	0.5
3	1	12-14'	83.0	10.6	6.0	0.4
3	2	12-14'	81.6	12.1	5.8	0.5
5	2	12-14'	76.8	15.5	7.3	0.4

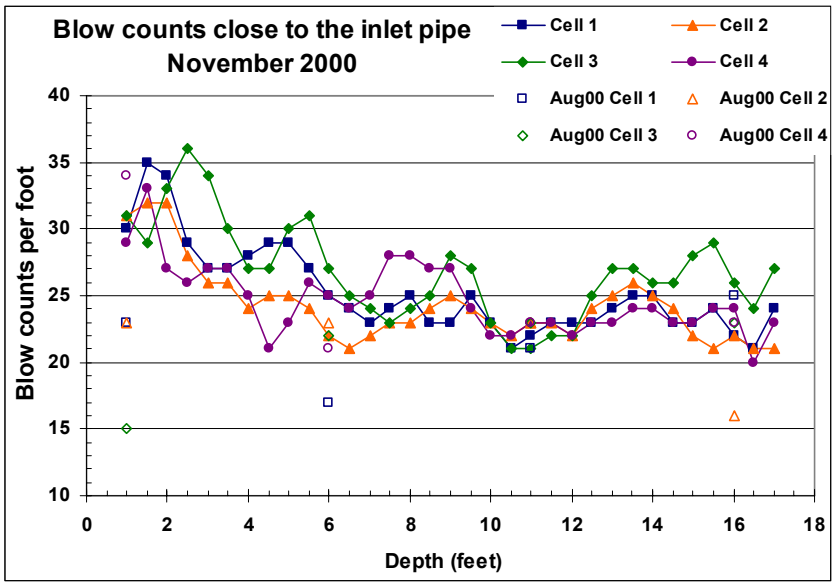
Penetrometer values ranged from 0.5 to greater than 5 tons per square foot at different locations in cell 2. The values were not consistent. Below the initial 1 cm of material, the hardness was generally increasing.

8.4.1.2 Split-spoon sampling

The number of blows per 6 inches of depth were noted by the Borings, Soils, and Testing Company as they drilled into the test cells and a control area in August and November. In each cell, one boring was drilled close to the inlet pipe location and another drilled toward the center of the cell, but on the ash platform. The control borings were drilled in the same fashion, in the portion of the Knickerbocker Pit that does not contain CKD.

In August, there was some indication of hardening (relative to the control boring) in the upper two feet of the borings close to the center of each cell, for all of the test cells. The borings close to the inlet pipe showed no such distinction. In November, a more complete set of blow counts was collected, and trends were more apparent (Fig. 8.6). The data are presented as blow counts per foot and in the appendices are also presented in normalized form relative to cell 4, with 5% wt. CKD addition (Appendix 8.B).

a)



b)

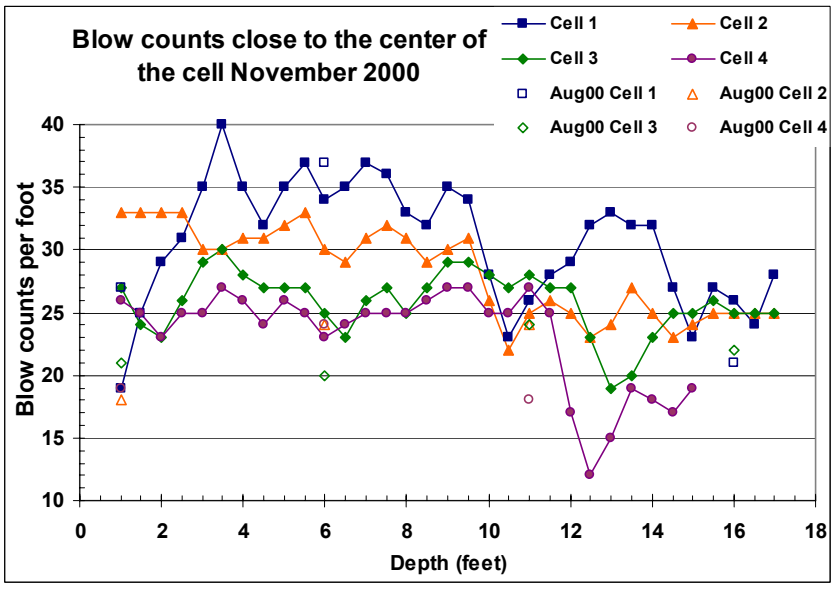


Figure 8.6. Blow count plots for samples taken in November 2000.

The number of blows needed to penetrate every half foot of ash/CKD was recorded through the proposed 10 feet of the test cells and into the cell floors, which was non-augmented ash. Two points were sampled in each test cell, one at a distance mid-way across the cell from

the injection point and one located at the injection point. The results of sampling at the injection point show blow count values that less clearly differentiate between the varying CKD loading, however, an increase in blows per foot above the background (as recorded below 10 feet) is observed for all cells. In fact, the initial two feet of the sample exhibits a resistance to penetration nearly 40% larger than background.

At sample point 2, from a depth of approximately 3 to 10 feet, there is a systematic effect of CKD content observed, generally grading from highest blow count with highest CKD loading to the lowest blow count with the lowest loading. In this set of samples, an increase in blow counts of approximately 15% was observed. The continuation of the pattern of blow counts versus CKD loading continues into the base of each cell, which suggests bias in the data collection methodology. Why this pattern is sometimes apparent at a depth of 17 feet is of interest, since the cells were only approximately 10 feet in depth. This differentiation could be due to an alteration in the underlying material with infiltration of fine particles from the ash/CKD slurry. The mean and standard deviations of the blow count values from cells 1 through 4 are presented in Table 8.3.

Table 8.3. Mean and standard deviation data for blow counts per foot recorded at the center of cells 1 – 4 in November 2000.

	Cell 1	Cell 2	Cell 3	Cell 4
Mean	12.07	7.93	4.67	2.87
Standard Deviation	1.94	1.53	2.29	1.96

The borings close to the inlet pipe locations for each of the cells show very different results. The most significant finding is the large increase in hardness in the initial 0-2 feet of material. This was followed by a moderate increase in hardness, and below 10 feet, no significant change in hardness relative to the cell containing no CKD. The results from the borings close to the inlet pipe were not differentiated with respect to the CKD composition, yet in the shallow depths the material was distinctly more difficult to penetrate than that containing no CKD. This indicates that the hardening reactions are aided by <5% of the CKD material. In comparison, the reactions taking place closer to the center of the test cells seem more dependent on the CKD content.

One way to assess the concentration of CKD in the cells is to analyze the ash for calcium oxide (Fig. 8.7). Ash was collected when cells were 1/3 filled, 2/3 filled, and filled. The full bulk analysis of these ash portions are presented in Appendix 8.D. In Figure 8.7, it is apparent that the calcium oxide concentrations are not consistent with depth or with what is expected for each cell. This suggests that greater consideration of the ability to form a consistent product be undertaken in the future. The variation in bulk chemistry of the fly and bottom ash, as well as the CKD, used in the study should be closely monitored in order to do a mass balance on the material and better understand the processes taking place.

8.4.1.3. Wet chemical analysis and leaching

Semi-annual fly ash bulk analyses and leach data are contained in Appendix 8.C. This is a routine test required by the Pennsylvania's Module 25. Data may be compared to those given in Chapter 9 for the NEPCO facility.

Water and sediment samples collected in February 2000 from the filling of the test cells underwent wet chemical analysis. Sediment samples were collected from recently placed ash three times during the filling of each cell. Water samples were collected at the same time from water at the edge of the ash bank. All aqueous samples were filtered with 0.20µm disposable filters and the samples were analyzed at the Materials Characterization Laboratory at The Pennsylvania State University (PSU). Sediment samples underwent microwave digestion with a combination of HCl and HF. Major and minor cations were analyzed by DC plasma emission spectroscopy and trace metals by atomic absorption graphite furnace. Anions were analyzed with an ion chromatograph. Appendix 8.D contains complete results from the chemical analysis performed by MRI.

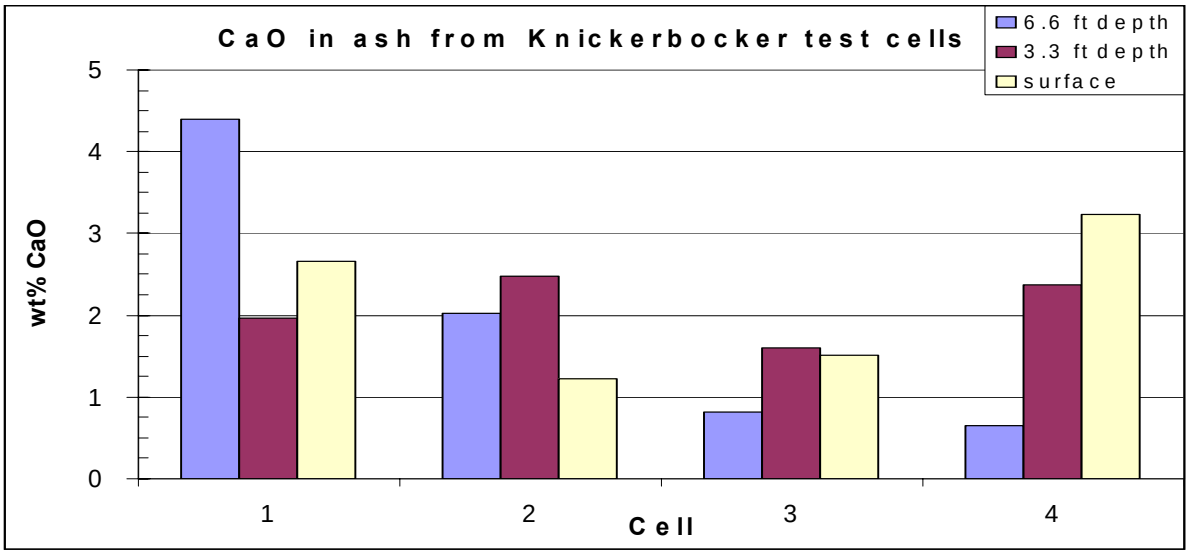


Figure 8.7. CaO concentration in test cells.

Of all the sediment and water analyses collected during the placement of the ash/CKD mixture, 9 samples of water exceeded the drinking water limits for fluoride, and all 12 water samples exceed the drinking water limits for sulfate (Table 8.4). The drinking water limits were not exceeded for any other analytes in the solid or water samples. Because the PA Module 25 limits that are applicable to mine waste, none of the samples exceed the Module 25 limits for sulfate. The pH values of the ash/CKD mixture were between 11.8 and 13.1, probably due to CaO in both the ash and the CKD.

Table 8.4. Range of concentrations in sediment (using the SPLP test) and in water from the Knickerbocker test cells, February 2000. For comparison, the maximum contaminant levels (MCL) for drinking water as of 2002 are given.

	water (mg/L)	sediment (mg/L)	MCL (mg/L)
Cations			
Ag	<0.02-0.09	<0.02-0.06	0.1*
Al	0.44-1.50	0.89-2.75	0.05 to 0.2*
As	<0.005-0.05	<0.005-0.01	0.01
B	0.19-0.27	<0.02-0.05	
Ba	0.24-0.46	<0.02-0.05	2
Be	<0.02	<0.02	0.004
Ca	760-1300	64-155	
Cd	<0.005	<0.005	0.005
Co	<0.02	<0.02-0.06	
Cr	<0.02	<0.02-0.04	0.1
Cu	<0.02-0.03	<0.02	1*
Fe	<0.02	<0.02-0.04	0.3*
Hg	<0.002	<0.002	0.002
K	295-1950	6.6-80	
Mg	0.05-0.14	0.03-0.18	
Mn	<0.02	<0.02	0.05*
Mo	<0.02	<0.02-0.06	
Na	110-330	2.87-11.6	
Ni	<0.02	<0.02	
Pb	0.01	0.01	0.015
Sb	<0.005-0.01	<0.005-0.01	
Se	0.01-0.02	<0.005	0.05
Si	4.2-8.2	5.5-11.9	
Sr	4.0-22.1	0.48-1.03	
Ti	<0.01	0.02-0.1	
Tl	<0.005	<0.005	0.002
V	<0.02	<0.02-0.05	
Zn	<0.02	<0.02	5*
Anions			
Br	2.3-12.6	<0.01-0.53	
Cl	52-230	0.28-9.0	250*
F	3.1-6.3	0.40-0.56	2*
NO2	<0.05	<0.01	1
NO3	19.2-32	0.03-0.12	10
PO4	0.2-0.3	<0.01	
SO4	1350-3100	61-270	250*

* = secondary drinking water standard

By weight, the ash is mostly composed of SiO_2, Al_2O_3, CaO, Fe_2O_3, K_2O, SO_3, TiO_2, MgO, Na_2O and water (Table 8.5). The authors expect that the bulk chemical composition of the

ash and CKD used should be relatively consistent with time. The raw data show that CaO can vary significantly with depth in the cells (Appendix 8.D). For example, in cell 4 at the 3.3 foot, 6.7 foot, and 10 foot intervals, CaO concentrations were 0.65, 2.37, and 3.23% wt., respectively. The other cells do not show the same consistent variation of CaO with depth, but also show less variability. The variation in CaO with depth indicates that the mixing of the ash and CKD in the test cells was not as consistent as would be desired, and in another application, these procedures should be improved. The bulk chemical inconsistencies within the cells most likely cloud the blow count results, tying them less directly to the proposed percentages of CKD within each cell.

Table 8.5. Average bulk chemical concentrations from the four test cells.

Wt %	Cell 1	Cell 2	Cell 3	Cell 4
Al_2O_3	13.9	12.5	13.5	11.3
CaO	3.01	1.90	1.31	2.08
Fe_2O_3	2.57	2.18	2.63	2.47
K_2O	2.36	1.98	2.35	2.22
MgO	0.52	0.38	0.34	0.28
Na_2O	0.28	0.25	0.27	0.27
SiO_2	45.3	49.3	51.7	50.3
TiO_2	0.90	1.25	1.01	0.95
SO_3	1.17	0.90	0.87	0.92
H_2O	30.1	28.4	25.4	28.3

Based on geochemical modeling using PHREEQC, a thermodynamic equilibrium model developed by the U.S. Geological Survey (Parkhurst, 1995), the solutions in each of the cells were found to be supersaturated with respect to calcium-containing minerals such as aragonite, calcite, dolomite, hydroxyapatite, and fluorite (Appendix 8.E). The solutions are also supersaturated with respect to barite and some clay minerals. Because PHREEQC does not incorporate kinetic factors, not all of the named minerals would be expected to precipitate (e.g. dolomite). Calcite, however, will almost certainly form in this environment with time.

8.4.1.4 Moisture loss

The moisture loss values for November 2000 samples at 4-6 feet and 12-14 feet depth almost all fall within 11-15% (Table 8.6). The exceptions are cell 4, hole 2 at a 12-14 foot depth, which had a large amount of black material (most likely from CKD addition) with, consequently a low moisture loss value (7.99%), and cell 4, hole 1 at a 4-6 foot depth, which had an anomalously high moisture loss value. Cell 5 samples had higher moisture loss values (15-17%) and there was no noticeable difference between the 12-14 foot and 4-6 foot sections in the cells. Thus, the moisture loss tests were not found to be very useful in determining the effects of ash/CKD placement.

8.4.1.5 X-ray diffraction

X-ray diffraction patterns collected from ash/CKD mixtures from all of the cells were consistent with respect to time, depth, percent CKD, and location with in the cell (Appendix 8.F). They were all primarily composed of quartz. Peaks at 4.49A, 2.59A, 9.64A, and 3.31A indicate that the second mineral is a muscovite or a type of clay. For some samples, a calcite peak at

3.02A is found. The XRD patterns show that between February and November 2000, no other mineral phases were formed at concentrations greater than 5% within the ash/CKD mixture. Ettringite may have been forming at lower concentrations.

Table 8.6. Test cell moisture loss values of samples collected November 2000.

Cell	Hole	Depth (ft)	Crucible mass (g)	Cruc+ wet ash (g)	Cruc+ dry ash (g)	Δ ash
1	2	12/14	31.696	50.16	47.94	12.02%
2	2	12/14	17.011	28.556	27.26	11.23%
3	2	12/14	23.243	34.001	32.6	13.02%
4	2	12/14	16.728	30.283	29.2	7.99%
3	1	12/14	16.67	28.294	26.66	14.06%
4	1	12/14	17.214	30.757	28.92	13.56%
2	2	4/6	25.252	35.38	33.93	14.32%
4	2	4/6	22.175	33.587	32.2	12.15%
2	1	4/6	15.894	26.885	25.46	12.97%
4	1	4/6	28.871	40.595	37.87	23.24%
5	1	4/6	18.194	33.713	31.06	17.10%
5	2	12/14	16.708	28.062	26.26	15.87%

* - major portions of CKD in sample 4-2 12/14'

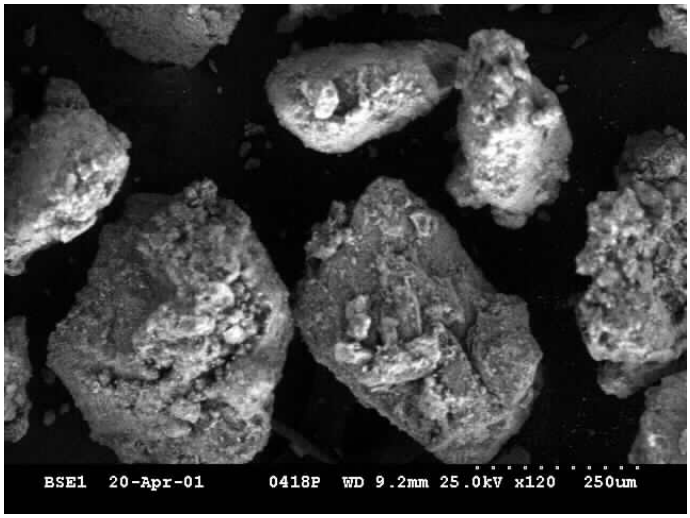
8.4.1.6 Scanning electron microscopy (SEM)

SEM images were generated for samples from cell 1 hole 2 at depths of 0-2 feet, 8-10 feet, and 16-18 feet, in addition to images collected from cell 5 hole 2 at depths of 0-2 feet and 58-60 feet. The grains observed were approximately 100-300μm in diameter. Each lower magnification (80x-250x) image showed rounded, non-spherical grains, with smaller grains on the surface. Higher magnification images (3000x-3500x) identified angular material mixed with rod-like shapes, an indication of the growth of cementitious phases, in all the samples. The ash and ash/CKD material looked similar at all levels of magnification, with no discernable additional crystal growth. Figure 8.8 shows the SEM images from cell 1 hole 2 at 8-10 feet depth.

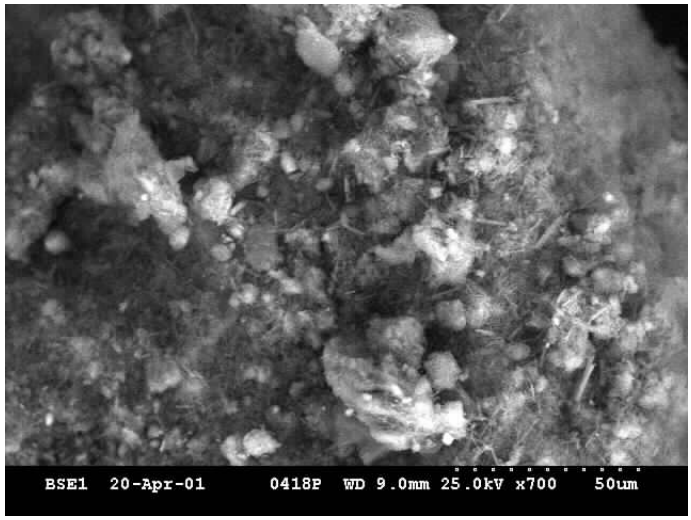
8.4.1.7 Fertility analysis

Samples of the ash/CKD mixtures from each of the four cells were sent for fertility analysis at the Agricultural Analytical Services Laboratory at PSU. The pH values for the solid samples (9.5-9.9) are much too high to support crops (Appendix 8.G). In every case the pH, and in two of the cells (2 and 4) the potash (K_2O), was deemed excessive. Phosphate levels decreased significantly with increasing cell number, from 225 lb/A, an optimum level, to 5 lbs/A, which is considered low for soil nutrients. Magnesium levels were high in every cell. Because the predominant feel is gritty and one cannot form a ball from the ash/CKD mixture, it has a sandy texture, as determined by the McRae finger assessment method (McRae, 1988).

a)



b)



c)

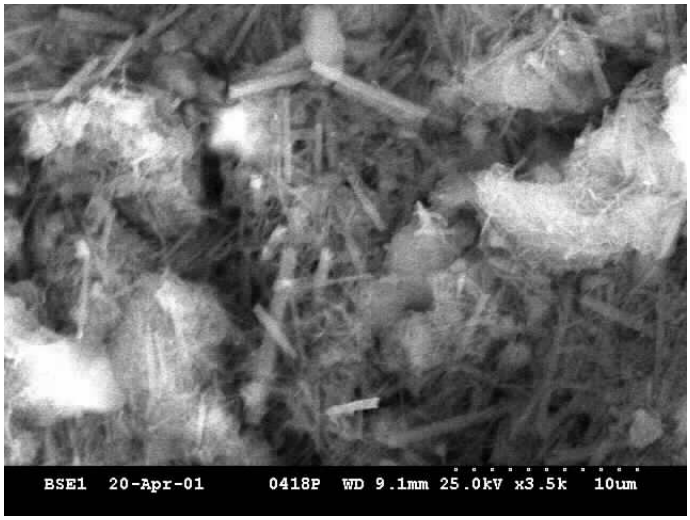


Figure 8.8 SEM images from cell 1-2 at 8-10 feet depth and a magnification of a) 120μm, b) 700μm, and c) 3500μm.

In order to support plants, the ash/CKD mixture would have to be mixed with a material to decrease the pH value and to keep the ash and CKD from hardening. The most obvious option would be to use compost. In Pennsylvania, after reclamation using ash is complete, the area is covered with 4 feet of clean fill, and then revegetated. This would be an appropriate method for revegetating above the ash/CKD mixture as well.

8.4.2 Groundwater Monitoring

The deposition of 52,000 cubic yards of ash per month was also accompanied by approximately 83,000 cubic yards of acid water from the minepool or approximately 18.5 million gallons of water per month. A portion of the water was retained in the ash as pore fluid or consumed in the hydration reactions. The excess water either percolated into the minepool or was recycled back to the power plant and reused.

To monitor the potential impact of the demonstration on the minepool waters, one up gradient well and four down gradient wells were installed to monitor the demonstration. One of the down gradient wells, the Packer V, was selected at the Packer V Mine discharge to represent a regional drainage profile for the entire coal field discharge (see section 7.2.3). These data are summarized in Appendix 8.H. The data show no significant trends, either increasing or decreasing.

8.5 CONCLUSIONS

The remediation approach described above has both environmental and economical benefits. The surface and ground water systems were not adversely affected, and the abandoned mine lands can be reclaimed and will no longer pose a public safety problem. The surface water that enters into the minepool system during the remediation operations may experience an increase in pH due to the chemistry of the ash, thus potentially impacting the microbial activity within the deep mine, and the pH conditions of the minepool discharge. Since the pipeline is a fully enclosed wet system, the potential for spillage and dusting are virtually eliminated, as opposed to the conveyor belt or truck transport alternatives, which require the moisture content to be substantially less. In addition, vehicle emissions are eliminated. Additional environmental benefits include the establishment of vegetation, support of wildlife, and prevention of surface waters entering the minepool.

The economic benefit to the Commonwealth is that abandoned mine lands are reclaimed at no cost to the Commonwealth. The company benefits due to the reduction of materials handling costs, from the minimal amount of maintenance and labor requirements. Previous disposal costs of utilizing truck transport were calculated at $2.50 to $3.00 per ton, and $1.11 per ton for the conveyor system. The slurry system costs are approximately $0.06 per ton, representing an enormous 97.6% cost saving, in 2003 dollars.

Use of CKD as a material to augment the mechanical properties of an ash/water slurry does appear to make a beneficial contribution to material strength. However, both mixing techniques and initial solids characterization need to be improved in further studies. More efficient mixing of the ash/CKD slurry may contribute to greater uniformity in results between

the cell inlet and center. Some cementitious behavior was observed in the placed ash/CKD slurry but the authors feel that it was insufficient to contribute to the observed gain in mechanical properties; rather it is believed that the presence of CKD contributed by enhancing the packing efficiencies of the slurry, specifically in the area farther from the pipe outlet. Long-term development of cementitious binding minerals is strongly suggested in the SEM observations of this study. The bearing strengths and compaction of the slurry (both with and without amendment) appear to be adequate for structural fill applications. The water that was used as a vehicle to transport the ash contained metals concentrations below any regulatory limit, however, sulfate and occasionally fluoride exceed drinking water standards, although sulfate did not exceed reclamation standards. It is clear from this study that the ash is not a fertile substrate for plant growth directly, based on the high lime content (and pH). For vegetative growth, the surface would either need to have soils added or the surface layer of placed ash amended specifically for plant growth.

CHAPTER 9. THE BIG GORILLA DEMONSTRATION PROJECT

Caroline M. Loop, Barry E. Scheetz, William B. White

9.1 OBJECTIVES

The Big Gorilla demonstration project involved dry-to-wet ash placement into standing mine water. Using the small-scale testing conducted at the Ellengowan demonstration as a starting point, the objectives of this demonstration were a) to show that large-scale placement of ash into mine water is possible with minimal turbidity generation, b) to develop the methodology for large-scale ash placement, and c) to demonstrate that ash in contact with mine water will not result in adverse environmental releases. Cogeneration ash was first placed in contact with the surface mine pool in August 1997, which was entirely filled by 2004. Over 3 million tons of ash was placed from two platforms, and will eventually be brought to pre-mining contour and re-seeded.

9.2 THE SILVERBROOK BASIN

9.2.1 Location and Local Geology

The Silverbrook Basin is located between the Eastern Middle and Southern Anthracite Fields, 6 miles south of Hazleton, Pennsylvania (Fig. 9.1). The basin is approximately five miles long and one mile wide at its broadest point (Fig. 9.2). The Silverbrook outfall drains the entire basin and forms the headwaters of the Little Schuylkill River under low flow conditions (Gannett, Fleming, Corddry, and Carpenter, Inc., 1972). The river received approximately 16,400 lb of acid daily from various sources in the Little Schuylkill River Basin (A.W. Martin, 1973). The upper reaches of the river have little to no aquatic life due to mine drainage (US EPA, 1991).

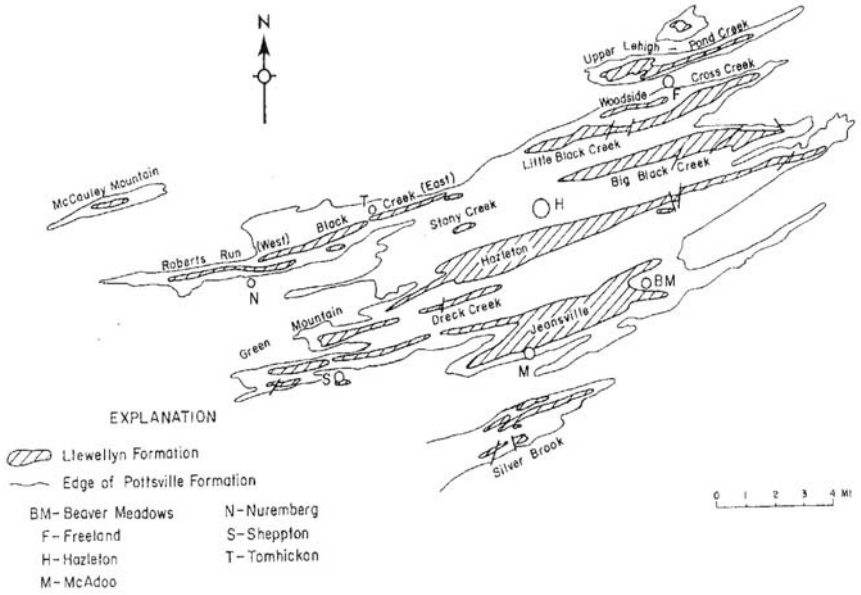


Figure 9.1. Anthracite basins of the Eastern Middle Field (Inners, 1988).

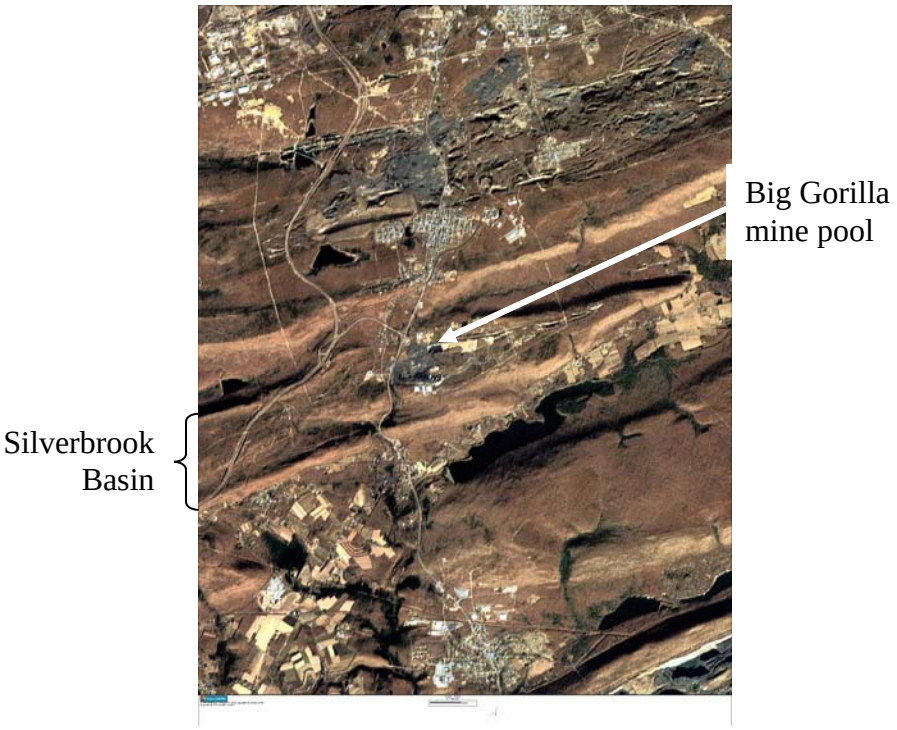


Figure 9.2. Aerial photo of the Silverbrook Basin.

The Silverbrook Basin contained two abandoned strip mined pits, one of which remains a surface mine pool, both of which resembled large ponds. They are locally known as the "Big Gorilla" and the "Little Gorilla." The Big Gorilla had an estimated volume of approximately 120 million gallons when the water level was at 1570 feet msl. It was approximately 1,400 feet long, 400 feet wide, and about 90 feet deep before ash placement began. It was significantly affected by AMD, but the Little Gorilla, which is approximately one quarter the size, is unaffected by AMD to the extent that it can support fish. The Little Gorilla is, most likely, a strip pit that was not fully developed (J. Wetzel, personal communication, 1997). It is fed by a surface stream and runoff, and is perched at a higher elevation than the Big Gorilla. The basin also contains acidic, seasonally wet areas that are linearly aligned between the Big Gorilla and the Silverbrook outfall. Termed silt ponds, they have the same elevation as the Big Gorilla. These shallow ponds are dry during the summer months.

NEPCO is located within the Silverbrook Basin, southeast of the intersection of State Route 309 and the on-ramp from McAdoo to Interstate 81 (Figs. 9.2 and 9.3). NEPCO's main operations are the production and sales of electricity by burning culm as fuel and secondarily, providing steam for the production of hothouse plants. The Silverbrook Basin also contains a 1 ½ acre site formerly owned by McAdoo Associates. This site is referred to as the McAdoo-Kline Township (MKT) location, and together with another local site received a Hazard Ranking System (HRS) score of 60.03 and was placed on the National Priorities List (NPL) in September 1983 (US EPA, 1991). The 1991 Record of Decision for the McAdoo Associates properties reports that there are few, if any MKT location-related inorganic or organic contaminants in the surface water or sediments in the Silverbrook outflow (US EPA, 1991).

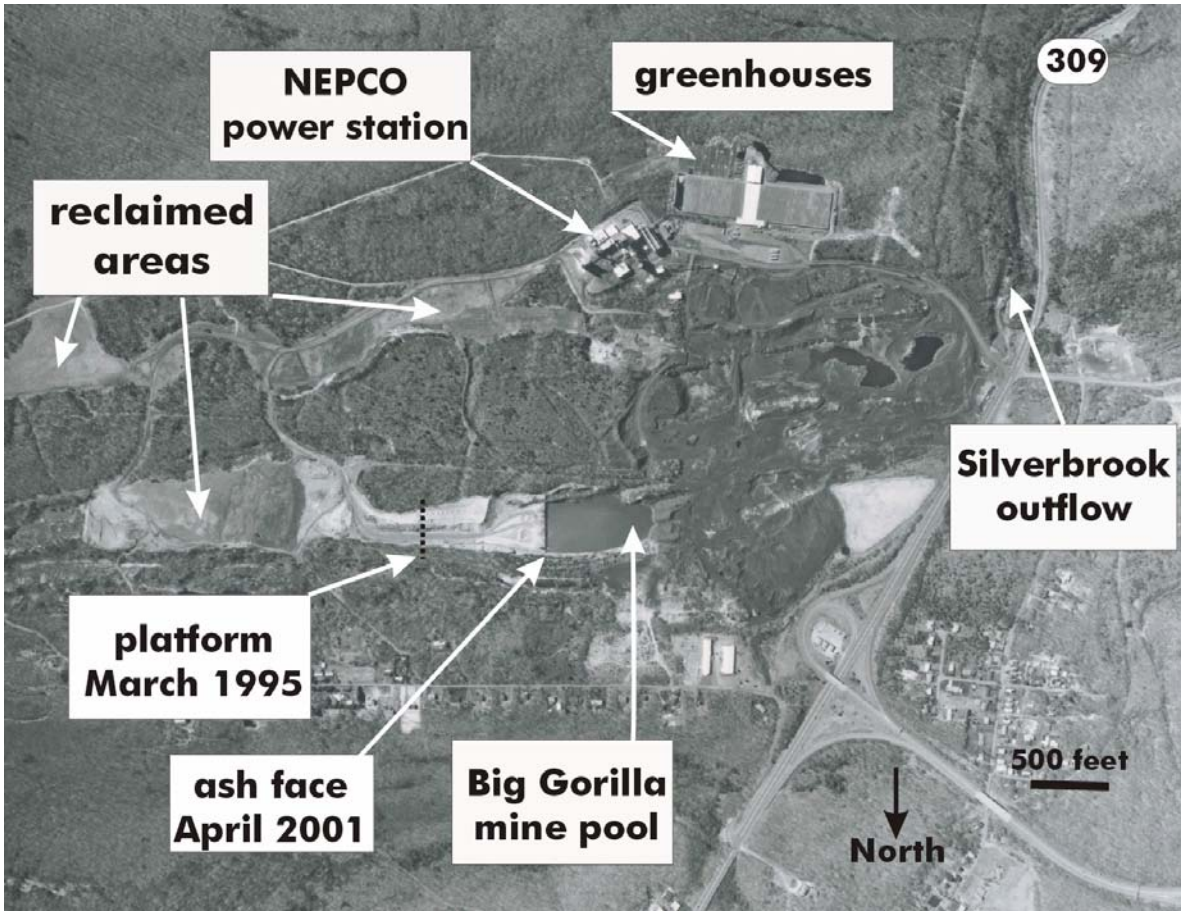


Figure 9.3. Location map for the Big Gorilla mine pool and the Silverbrook outflow within the Silverbrook Basin.

Folding and faulting trends to the northeast-southwest in the Anthracite Region. The Mauch Chunk, Pottsville, and Llewellyn Formations were deformed during the Allegheny Orogeny of the Early to Middle Permian, possibly Triassic time (Brady et al., 1998). As a result, the region surrounding the Silverbrook Basin contains several tight thrust-faulted synclines, such as the Silverbrook Syncline. The Silverbrook Syncline is divided by the Centralia thrust fault, which surfaces at the southern bank of the Big Gorilla mine pool (Fig. 9.4) (US EPA, 1991).

9.2.2 Mining and Reclamation

At this location, the Buck Mountain Vein was deep mined at the turn of the 19th Century. In the Silverbrook Basin, surface mining of the Mammoth Vein ceased before WWII, when there was an increased need for fuel, and hence, an increased interest in surface mining. Currently, NEPCO burns culm from this location and others nearby.

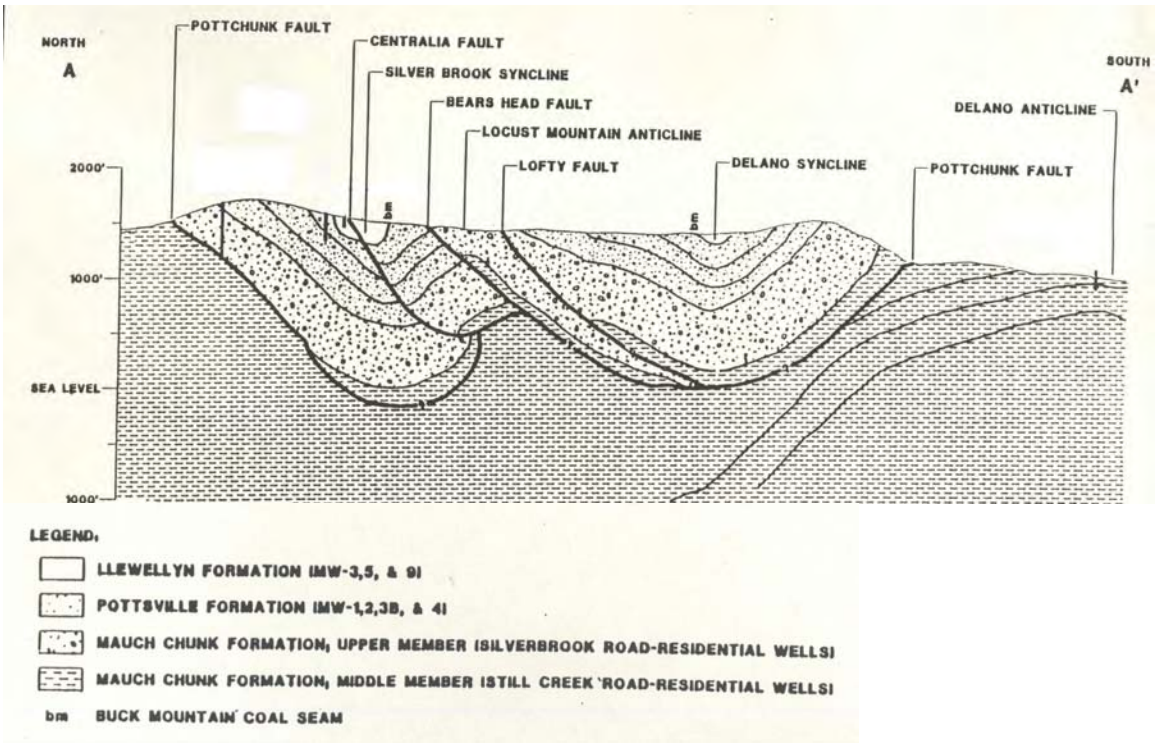


Figure 9.4. Regional geologic cross-section, McAdoo area, Pennsylvania (US EPA, 1991).

The schematic shown in Figure 9.5 is an adaptation of a mine map most likely made in the late 1940s when the basins created by mining the Mammoth Vein were filled with coal silt. This silt was later reclaimed, and the present day Big Gorilla occupies the #1 Basin. The water level is commonly at approximately 1570 feet msl, but can fluctuate by about $\pm$ 20 feet, depending on the season. The surface mine pool was about 90 feet deep under normal conditions. The Silverbrook outflow is at an elevation of 1537 feet msl, and is at the location where the southern arm of the Buck Mountain Vein intersects the land surface. Hence, water from the Big Gorilla would be required to travel through the #1 Tunnel, then down and up the #2 Basin Buck Mountain Vein to emerge at the Silverbrook outflow. The degree to which the #1 Tunnel is blocked by coal silt is unknown, thus the full extent of mixing between mine pool and deep mine waters is unclear.

NEPCO has been distributing its fly and bottom ash onsite to reclaim spoil since 1989. The ash is placed in layers, attempting to approximate the pre-mining grade. Clean fill is placed on top in 4 foot layers and the areas are seeded with crown vetch, native grasses, hardwoods, and conifers. Wild game has begun to populate the reclaimed areas, and reclamation has been and is considered successful by social, economic, and environmental standards.

The Big Gorilla project has an expected lifetime of 5 to 7 years, with monitoring continuing indefinitely. In 1994, clean fill was put into the eastern end of the pit in order to build a terrace above the maximum high water level. The terrace was built in preparation for dry land disposal of fly ash in accordance with existing permits and DEP regulations at that time, and was discontinued once the demonstration permit for direct water disposal was issued (NEPCO Big

Gorilla Pit, 6/16/97, #301304, 16.6 acres). Filling the entire pit with clean fill was cost prohibitive, whereas using fly and bottom ash from onsite avoided purchase and transportation cost in addition to having beneficial alkaline properties. Preliminary studies conducted for the Ellengowan Demonstration Project explored methods for ash placement that would minimize turbidity and maximize consolidation (see Section 7.3).

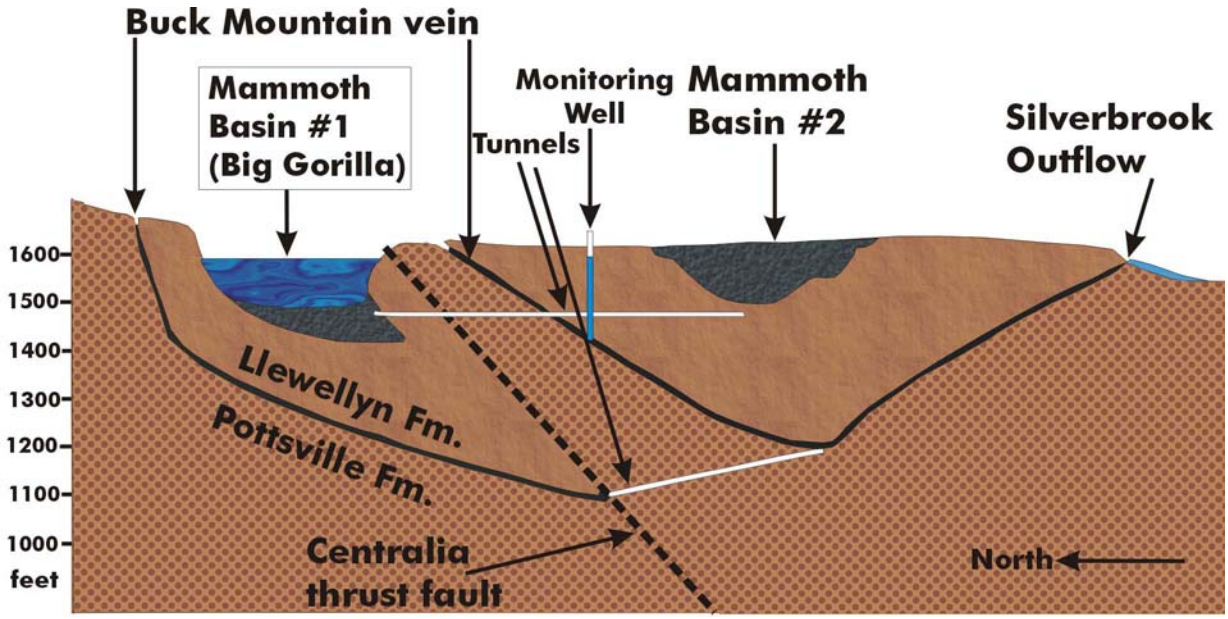


Figure 9.5. Mining cross-section of Silverbrook Basin. The #1 Basin contains the Big Gorilla (original draftsperson unknown). The two Mammoth basins show the former location of the removed Mammoth seam.

9.2.3 Regional Acid Mine Drainage Chemistry

The Silverbrook Basin is sometimes included in the Eastern Middle Anthracite Field (Gannett Fleming Corddry and Carpenter, Inc., 1972; Inners, 1988, Brady et al., 1998) and in other publications it is incorporated into the Southern Anthracite Field (Wood, 1996; Growitz et al., 1985). The DEP considers the Silverbrook Basin to be present in the Eastern Middle Anthracite Field, and that including the basin within the Southern field is incorrect. While the coal beds at the NEPCO are in the Eastern Middle Field, the drainage from this site is in the headwaters of the Little Schuylkill River, which flows to the Southern Anthracite Field and commingles with other mine drainage from that field.

Mine discharge quality data have been collected since the 1940s in all four fields of the anthracite basin (Felegy et al., 1948; Ash et al., 1951). Since then, production has declined and many of the mines that were dewatered have ceased activity, which has resulted in a water level rise within the mines and a potentially greater flow from the mines during storm pulses. In 1941, water discharge was 141 cfs in the Southern Field, of which 86% was pumped. In 1975, discharge was 206 cfs, 30% greater than in 1941 (Growitz et al., 1985). Over this same period, acid discharge decreased from 150 tons/day to 55 tons/day in the Southern Field.

Of the four fields, the Southern Field has the lowest coal production per square mile of coal measures (Table 9.1). The low production is the most likely reason for the relatively lower yields of water, sulfate, acid, and iron. Less space and surface area are available for storing water and oxidizing minerals, respectively. The Silverbrook Basin contributes to the Little Schuylkill River, and together with the other streams in the Little Schuylkill River Basin, is one of the most significant sources of sulfate, per square mile of coal measures, in the Southern Field (Table 9.2). In 1975, the Little Schuylkill River Basin received roughly 19% of the sulfate released from the Southern Field (Growitz et al., 1985).

Table 9.1. Summary of coal production, water, sulfate, acid, and iron yields from the four Anthracite Fields in eastern Pennsylvania (from Growitz et al., 1985).

Field	Coal production up to 1944 (10^9 tons)	Area of coal measures (mi^2)	Coal production (10^6tons/mi^2)	Water Yield (cfs/mi^2)	Sulfate Yield (tons/d)/mi^2	Acid Yield (tons/d)/mi^2	Iron Yield (tons/d)/mi^2
Northern	3.5	160	21.9	2.1	4.6	1.5	0.32
Eastern Middle	0.50	32	15.6	5.5	3.6	1.6	0.066
Western Middle	1.6	75	21.3	2.6	5.4	1.2	0.25
Southern	1.3	141	0.93	1.5	1.4	0.38	0.051

Table 9.2. Summary of water and sulfate discharge from mine drainage sites in the Southern Field (from Growitz et al., 1985).

Basin of receiving stream	Drainage area underlain by coal measures (mi^2)	Number of mine drainage sites	Yields of water (cfs/mi^2)	Yields of sulfate (tons/d)/mi^2
Lehigh	2.3	1	4.8	7.2
Little Schuylkill	13	12	1.3	2.9
Main Stem Schuylkill River	36	57	1.8	1.6
West Branch Schuylkill River	34	15	1.3	1.4
Swatara Creek	33	43	1.0	0.4
Mahantango Creek	10	10	1.6	1.4
Wisconisco	11	9	1.8	1.0
Stony Creek above Dauphin	2 (est.)	5	3.1	0.09
Total	141	152	1.5	1.4

When the Little Schuylkill River was sampled below Tamaqua, the pH was 5.4, and the sulfate concentration was 240 mg/L (Growitz et al., 1985). The water discharged from the 13 outflow sites contributing to the river was 18 cfs, approximately 23% of the flow at the sampled site below Tamaqua. The difference in sulfate load between the outflow sites and the sampled location below Tamaqua (13 tons/day) may be due to unsampled discharges in the coal field, or

less likely, the areas outside the coal field (Growitz et al., 1985). Acidity values in 1975 (Growitz et al., 1985) and 1991 (Wood, 1996) were determined in the field on an ambient temperature sample to the end points of both pH 7.0 and 8.3, and the values for the Silverbroook mine outflow increased from 80 to 234 mg/L $CaCO_3$ and from 90 to 252 mg/L $CaCO_3$, respectively (Wood, 1996). The discharge at the time of sampling at the Silverbrook outflow in 1991 was 31% of that in 1975.

Thirty-eight samples of iron and sulfate concentrations between 1970 and 1993 were included in the report by Wood (1996). While the average concentration of iron in the Silverbrook discharge shows no apparent trend, the sulfate values have been decreasing, most notably between the 1970-1972 period and 1975, where the mean concentration decreased by over one hundred mg/L. It is difficult to identify long-term trends in data from the coal mine discharge locations due to variation in flow at the time of sampling and the evolution of sampling methodology. Although these factors make comparisons a challenge, it appears that AMD production has decreased from previous years. This may be due to: (1) flooding of the mines which limits oxidation, (2) coating of sulfide minerals, (3) the lack of new culm piles derived from active mining and (4) the removal of culm piles by culm-burning power plants.

9.3 ASH GENERATION AND PLACEMENT

9.3.1 Ash Placement

Ash was first deposited into the Big Gorilla mine pool in August of 1997. The ability of the commingled ash to support heavy machinery on a large scale was initially unclear. Test studies were previously conducted during the Ellengowan Demonstration Project, which had indicated that the by-product would form a stable platform. DEP's Office of Surface Mining used a Cs-137 densitometer to ensure that the initial ash platform was compacted enough for heavy machines, before subaqueous ash placement (Fig. 9.6).

Fly ash from one silo and bottom ash from another were loaded into trucks in 45 ton loads and sprayed with water to prevent dust (Fig. 9.7). They were then taken to the Big Gorilla mine pool ash platform and piled on the bank. Bulldozers were used to push the ash piles into the water from the lower platform, with the exception of the winter months, when ash was only placed from the edge of the upper platform (Fig. 9.8). However, towards the end of the project no distinction was made, as both platforms were found to be safe during the winter.



Figure 9.6. Mike Menghini, Tom Owen, and Mike Wehr using Troxler nuclear density moisture gauge on the lower ash terrace.



Figure 9.7. Fly and bottom ash silos for storage until placement on the NEPCO site.



Figure 9.8. A truck and bulldozer used to transport and place ash in the Big Gorilla mine pool.

When ash was pushed into the water, turbidity boils could be seen approximately 300 feet from the ash face (Fig. 9.9). This indicated that at least the fine portion of the ash was flowing outward from the face, in a manner similar to that of a turbidity current. When post-placement ash samples were taken from the bottom of the Big Gorilla, only fine material was recovered, most likely that which moved to the mine pool center by such a turbidity current.

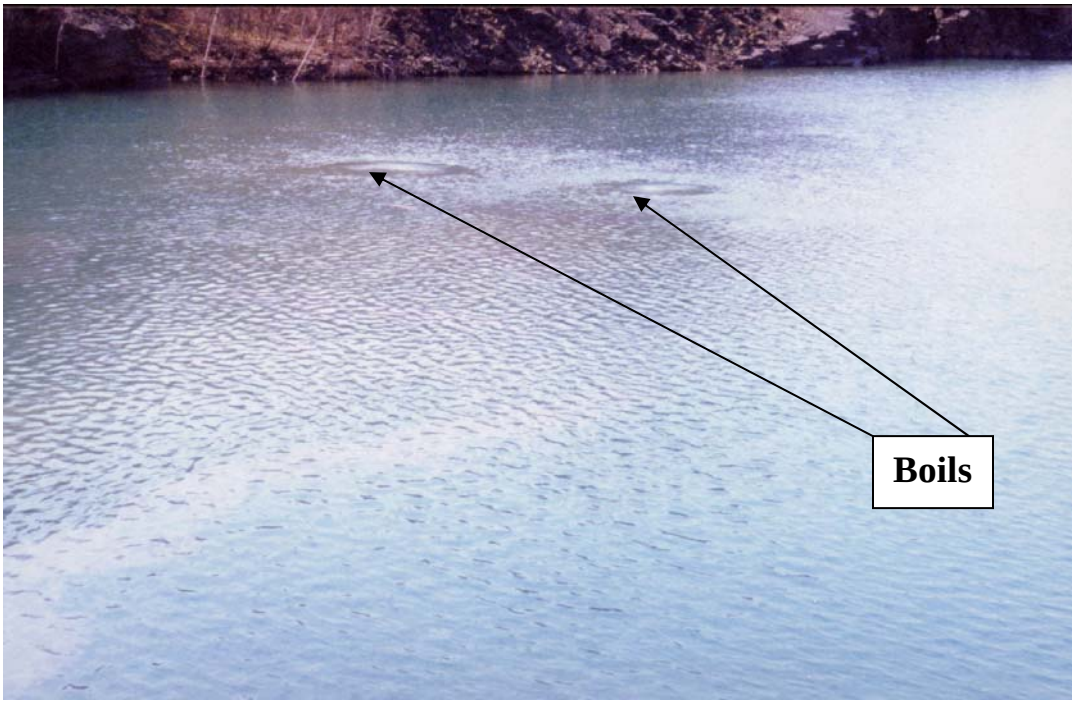


Figure 9.9. Turbidity boils present approximately 300 feet from the Big Gorilla ash face.

To monitor the subaqueous flow of ash, profiles of the bottom of the mine pool were taken from a small boat with a sonar unit. Multiple traverses on each of four days were collected for processing. The locations of the traverses accounted for an ash face movement of approximately 1 foot per 2000 tons of ash placed in the mine pool. Traverses from 9 July 1998, 25 September 1998, 11 August 1999, and 22 October 1999, as well as those included in the original permit for ash disposal, were converted into three-dimensional coordinates. The water level reference elevation used was based on a yellow marker painted on the north wall of the Big Gorilla mine pool and surveyed at 1570 feet msl in 1997. The edges of the mine pool were considered fixed, with the exception of the westward moving ash face. Two of the mine pool banks are approximately vertical, but because the other two are not, there is some error associated with the volume estimates. The greatest fluctuation in water level is 20 feet below the reference water level. The ash face migration calculation was drawn from the difference between the locations in the September 1996 permit application and a site map update from aerial photographs taken in March of 2000. By that time, approximately 600,700 tons of ash had been placed in the Big Gorilla mine pool, accounting for an ash face movement of 300 feet. The ash front has been assumed straight, and at all times parallel to the original. The three-dimensional coordinates were loaded into a computer graphing program, Surfer, which uses statistics to interpolate between points and calculate a volume for the mine pool. In this case, the multiquadric radial basis function was used for gridding.

Initially, the mine pool depth was greater than 90 feet. A saddle in the mine pool floor was evident both before and after the August 1999 depth profile. One possible explanation is that because the August profile was taken after a period of relative inactivity (no ash was placed between 1/24/99 and 7/23/99), scouring from ash placement ceased, and ash on the bottom of the mine pool was able to settle from the still water. If this was the case, either more material (>2500 tons) or a longer continuous ash placement period (longer than two weeks) was needed to reshape the bottom of the mine pool to show a saddle point. A seasonal effect is not thought to be the cause because of the dissimilar profiles in September 1998 and August 1999.

Volume calculations were performed by the Surfer program, using the Trapezoidal Rule, Simpson's Rule, Simpson's 3/8 Rule, and a cut minus fill approach. The volume calculations for individual traverses were within 1%, regardless of method. The cut minus fill values will be used in this text. The volume of the Big Gorilla decreased by 32% between the time that ash placement began and 22 October 1999 (Table 9.3). Based on the volume calculations from Surfer, approximately 76 gallons of water are displaced in the Big Gorilla mine pool per ton of ash placed beneath the surface. From the density of quartz (one of the major components of fly ash) one may obtain 90.5 gallons/ton of ash. There is a 16% difference in the estimates of the tons of ash needed to fill the mine pool to the 1570 foot mark, which may be due to the error in calculating the volume of the mine pool or ash input. Approximately 1.5 million tons of ash have been placed in the surface mine pool to bring it to the 1570 foot mark.

Prior to ash placement, there was concern about the displacement of water in the Big Gorilla mine pool. It was hypothesized that the mine pool water level would rise if tunnels that drained the system were blocked by ash. There has never been any indication that this was occurring. Water levels fell and rose, not with ash placement, but with the season, at levels seen in past years. There has yet to be any consistent change in the water level in the mine pool. The

ash is now blocking the entrance to the tunnel leading to the deep mines, therefore, no significant deep water loss is thought to be occurring. Well 3, 100-150 feet away from the south wall of the Big Gorilla, showed a chemical change occurring between the middle of 1999 and the middle of 2000. The chemical change was delayed by over a year in the well relative to that in the Big Gorilla. Alkalinity and pH increased, while sulfate and calcium decreased. After June 2000, iron, aluminum, calcium, and sulfate values stabilized at lower concentrations. This most likely represents the sealing off of the hydrological connection between well 3 and the Big Gorilla. Thus, little water is thought to be lost to the surrounding mine workings. Aerial photos of the filling of the Big Gorilla can be seen in Appendix 9.A.

Table 9.3 Placement and volume estimates for the Big Gorilla calculated from depth traverses.

	Ash Placed (cumulative tons)	**Volume (million gallons)**
March 1996	0	116.1
9 July 1998	125,640	112.0
25 September 1998	238,356	107.0
11 August 1999	400,200	94.9
22 October 1999	491,270	78.7

9.3.2 Ash Characterization

In NEPCO's case, ash is the by-product of burning culm and limestone to produce electricity and capture unwanted airborne emissions, respectively. Approximately 1700 tons of culm and 60 tons of limestone are burned daily. Therefore, the ash is expected to chemically resemble parent rock, with additional $CaCO_3$ and $CaSO_4$.

Ash from the NEPCO cogeneration facility is reddish brown when wet and pinkish grey when dry. A greater variety of colors are observable in the bottom ash when compared to the fly ash (Fig. 9.10). Fly ash particle sizes can be described as very fine, lower (4.0-3.5ϕ) with a diameter in the 62-88μm range. Bottom ash particles range from approximately 100μm to 1cm in diameter, and are angular.

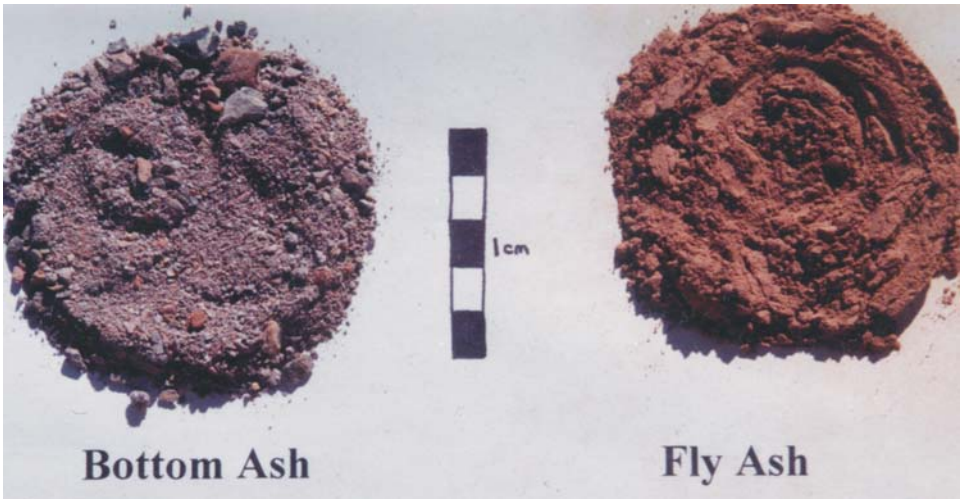


Figure 9.10. Photograph of bottom and fly ash from the NEPCO site.

9.3.2.1 Initial bulk chemistry

Both the bottom and the fly ash were subjected to testing under Pennsylvania DEP's Module 25. These regulations require the ash to be totally digested and analyzed, in addition to leachate tests. Leachate tests followed EPA Method 1311, the toxicity characteristic leaching procedure (TCLP) and later the synthetic precipitation leaching procedure (SPLP), EPA Method 1312. These procedures can be found in EPA publication SW-846 (US EPA, 1998). When the TCLP method was used, the pH values of the leachate were approximately 4 units lower than those of the bulk material. While the SPLP method was used, they were within one pH unit. Pottsville Environmental Testing Laboratory, Inc. (PETL) was contracted by NEPCO to perform these tests. Results can be found in Appendix 9.B. Table 9.4 provides an average of the results from ten years of testing the fly and bottom ash from NEPCO. Another test that can be used, but was not preformed for the demonstration projects is the synthetic groundwater leaching procedure (SGLP), which was modeled after the TCLP, and has a long-term leaching component (Hassett, 1998).

In comparing the fly and bottom ash, the bulk fly ash contains higher concentrations of the parameters of concern than the bottom ash. The higher concentrations may be due to the increased surface area of the fly ash, which would allow for greater sorption of the elements associated with the coal during processing. Similar to conventional pulverized coal combustion, volatile elements are released from the coal during combustion and adsorbed onto the fly ash as it travels up the stack. The differences in leachate concentrations are not as distinct as those of the bulk chemistry. For sulfate, antimony, molybdenum, and selenium, there is a significantly greater concentration in the leachate from the fly ash. Barium, boron, iron, chloride, zinc, and nitrate are all present in higher concentrations in the bottom ash leachate. As shown in the table, the maximum lechate concentrations are well above the average values for both the bottom and the fly ash leachate concentrations.

Wet chemical analyses performed at the Materials Research Institute (MRI) at The Pennsylvania State University confirmed the total amounts of silica and calcium in a fly ash sample. The sample underwent microwave digestion in hydrofluoric acid at 200º C and 200 psi; the liquid was analyzed using a direct current plasma spectrometer. The bulk chemical composition of the ash produced by NEPCO is similar to that of other local cogeneration facilities (Table 9.5).

Table 9.4. Average of values above detection from analyses performed on NEPCO fly and bottom ash for Module 25 regulations from 1992-2002. Maximum allowable leachate concentration values provided for comparison.

	Bulk Analysis	**(mg/kg)**	**Leachate Analysis**	**(mg/L)***	**Max. Leachate**
	Fly Ash	Bottom Ash	Fly Ash	Bottom Ash	**Conc. (mg/L)**
pH	10.67	11.47			
Sulfate	4901	3073	440	169	2500
Aluminum	26440	13993	2.53	2.77	5
Antimony	2.24	LF	0.05	0.01	0.15
Arsenic	17.79	3.55	LF	LF	1.25
Barium	211	116	0.16	0.21	50
Boron	44.07	8.49	0.30	0.37	31.5
Cadmium	1.22	0.68	LD	LD	0.13
Chromium	27.25	11.49	0.09	LF	2.5
Cobalt	3.62	1.11	LF	LF	
Copper	28.13	8.18	0.09	0.07	32.5
Iron	8713	4399	0.14	0.24	7.5
Lead	29.99	12.17	LF	LF	1.25
Manganese	161.04	272.65	0.20	0.21	1.25
Mercury	0.6400	LF	LF	LF	0.05
Molybdenum	9.28	3.29	0.13	0.02	4.38
Nickel	11.75	5.08	LF	LF	2.5
Potassium	6737	4400	9.88	7.75	
Selenium	14.38	5.47	0.17	0.03	1
Silver	3.56	LF	LF	LF	
Zinc	18.96	9.78	0.18	0.26	125
Nitrate-N			1.27	2.92	
Chloride			15.75	54.67	2500
Sodium			10.73	6.14	
Total organic carbon			LF	2.11	
Acid neutralizing potential	847400	1258625			

LD = always less than detection
LF = less than 5 measurements above detection (of 22)
* Leachate analyses were performed by TCLP before January 1995, and SPLP after.

Table 9.5. Comparison of bulk chemical analyses versus average composition of five culm-derived ash analyses. Values were calculated from aqueous chemistry by S. Atkinson.

Oxide	NEPCO ash composition [wt %]	Average composition of 5 culm-derived ash analyses
SiO_2	64.47	60.69
Al_2O_3	18.82	23.11
Fe_2O_3	5.74	5.08
CaO	5.45	5.44
MgO	1.48	1.15
K_2O	3.77	2.90
SO_3	0.26	1.60

9.3.2.2 Mineralogy

Quantitative x-ray diffraction (QXRD) was used to analyze the composition of fly ash. Thermal gravimetric analysis (TGA) was used to determine that roughly 6.8% of the fly ash sample was composed of portlandite ($Ca(OH)_2$). Combining QXRD results with chemical digestions and TGA, a more complete assessment was attained. As shown in table 9.6, the fraction of metaclays is significant, but quartz makes up the largest single mineral component.

Table 9.6. Mineralogical analysis of culm-derived fly ash used in the "Big Gorilla" project.

Mineral	*Formula*	*Analytical method*	*Wt. %*
Quartz	SiO_2	QXRD, wet chem	20.0
Mullite	$Al_6Si_2O_{13}$	QXRD	7.0
Hematite	Fe_2O_3	QXRD	2.0
Portlandite	$Ca(OH)_2$	DTA, QXRD, wet chem	6.5
Calcite	$CaCO_3$	QXRD, wet chem	0.4
Gypsum	$CaSO_4 \cdot 2H_2O$	QXRD	0.5
Meta-clays		QXRD	63.6
Total			100

The ash composition was confirmed by x-ray diffraction (XRD) of the pre-placement ash. The sample was placed on a zero background silicon metal slide that showed no interference until after 80° 2θ. The fly ash sample was scanned from 5° to 55° 2 θ , with a scan rate of 3° per minute and a step size of 0.020°. The data were then analyzed and materials compared using the DMSNT 1.37 software, which is based on the Hanawalt Search database and allowed visual comparison among minerals. The fly ash was found to contain significant amounts of quartz, in addition to a clay phase, possibly illite, or muscovite (Fig. 9.11).

On October 22, 1999, samples were collected from the bottom of the Big Gorilla mine pool. A 5 foot length of PVC pipe, with a septic system valve as a sediment catcher was used to collect samples of the pool bottom at three locations (Fig. 9.12). Each of the samples was fine-grained, more representative of fly ash than bottom ash. Sub-samples were analyzed by XRD,

and the patterns of each were nearly identical to that of the pre-placement fly ash (Fig. 9.13). Thus, the mineralogy of the ash before and within months of placement appears very similar.

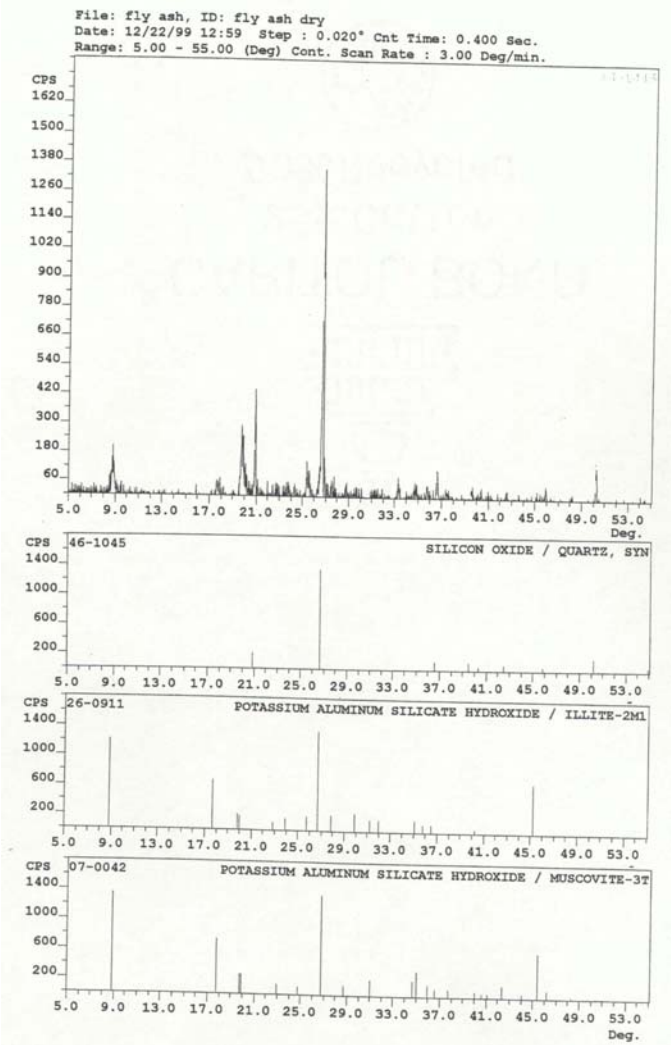


Figure 9.11. X-ray diffraction trace from a fly ash sample (pre-placement) and quartz, illite, and muscovite patterns for comparison.

A Hitachi S-3500N scanning electron microscope (SEM) with an energy dispersive x-ray spectroscopy (EDS) system was used to evaluate whether metal hydroxide coatings had formed on the ash since deposition into the mine pool, or if there had been significant morphological change in the ash since placement. The samples were each scattered across carbon tape, and gold sputtered for analysis. The samples of ash both before and after placement had the same EDS pattern of O, Si, Al, K, C, Fe, Ca, and Cu in the EDS scan of post-placement samples (Fig. 9.14). In this case, EDS was only used for a qualitative survey of the elements present in the ash

samples. Indeed, spectrochemical analysis showed CuO and Fe_2O_3 to compose 0.01 and 4.40% (by weight) of the post-placement ash, respectively. Values were also very similar to pre-placement ash.

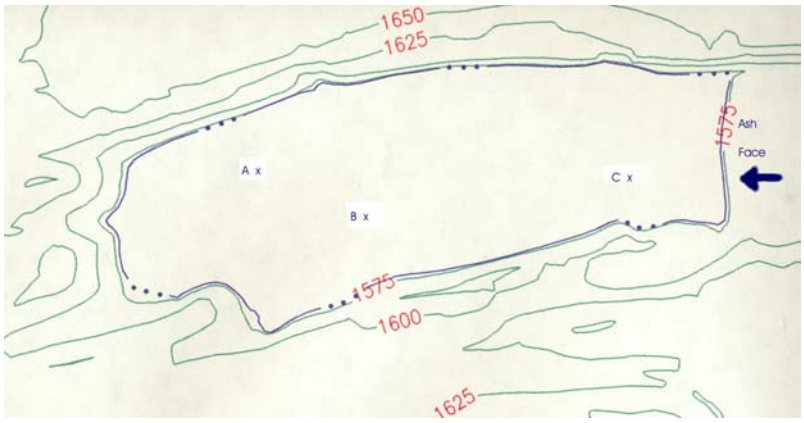


Figure 9.12. Three locations where the surface mine pool bottom was sampled on 22 October 1999.

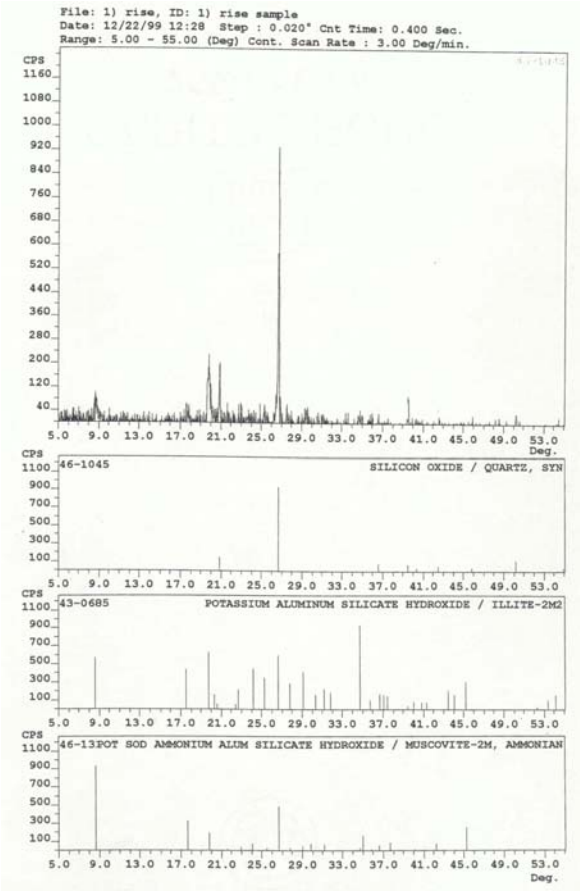


Figure 9.13. X-ray diffraction trace from a post-placement mine pool sample and quartz, illite, and muscovite patterns for comparison.

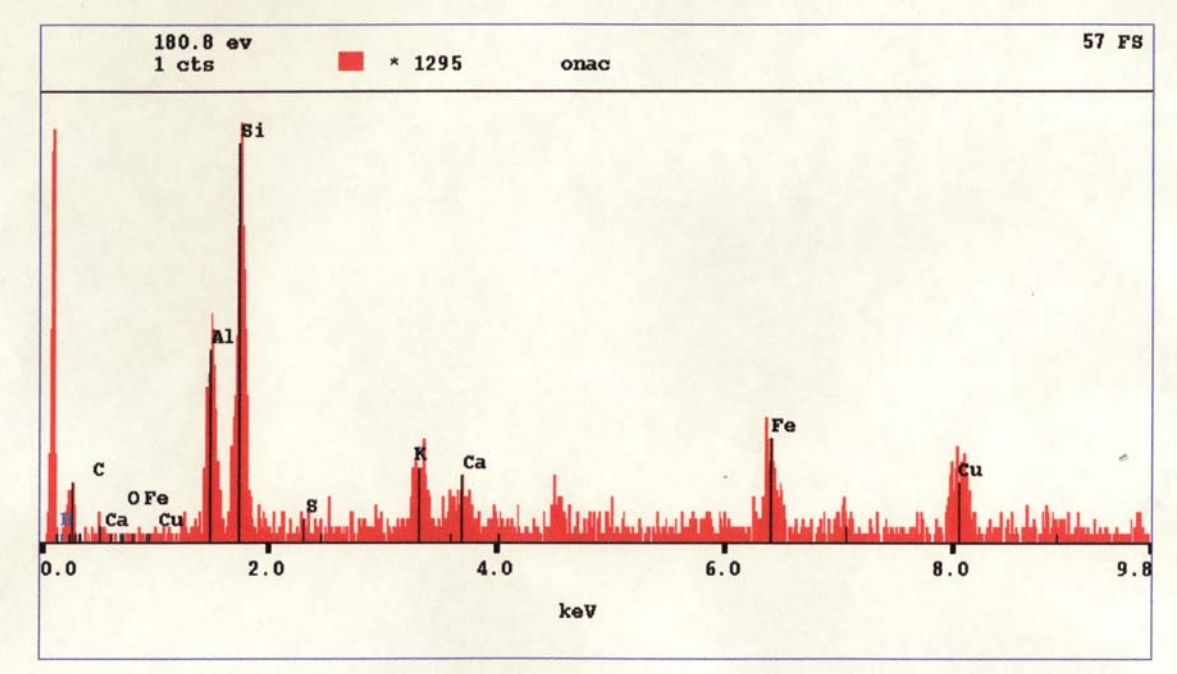


Figure 9.14. Sample EDS scan from post-placement ash.

In analyzing specific grains, there was no evidence of metal hydroxide or oxide coatings. The images of agglomerated grains and grain morphology also showed no apparent differences between pre-placement and post-placement ash (Figs. 9.15-9.17).

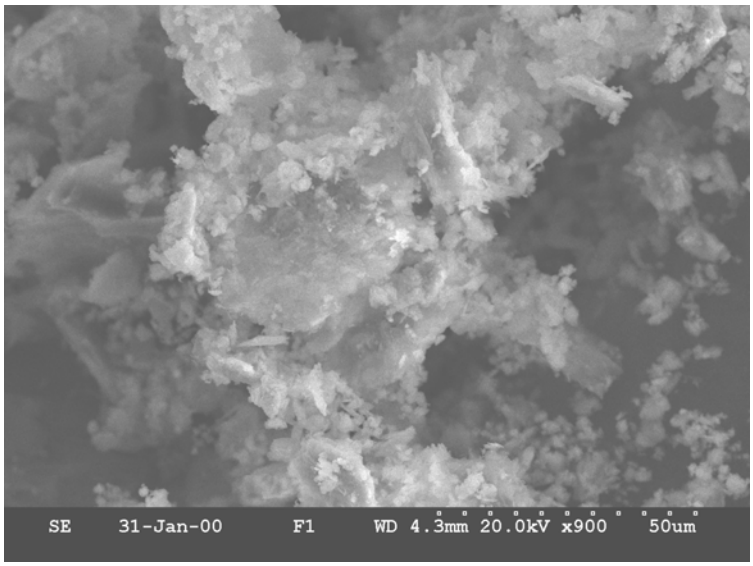


Figure 9.15. SEM image of fly ash before placement in the Big Gorilla mine pool.

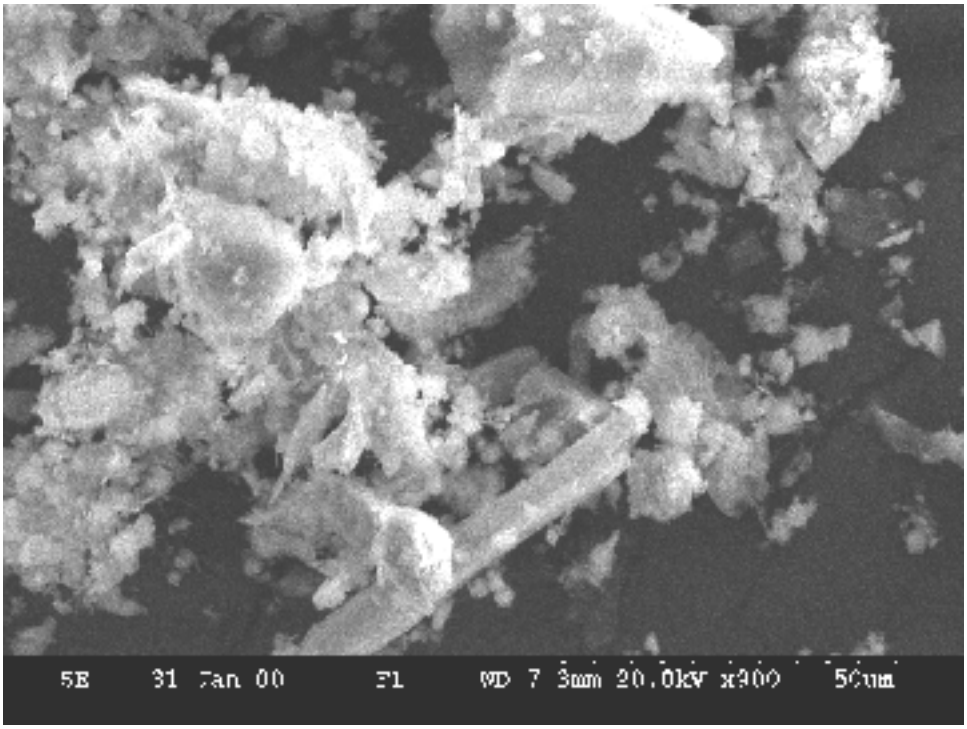


Figure 9.16. SEM image of post-placement ash collected from the Big Gorilla mine pool.

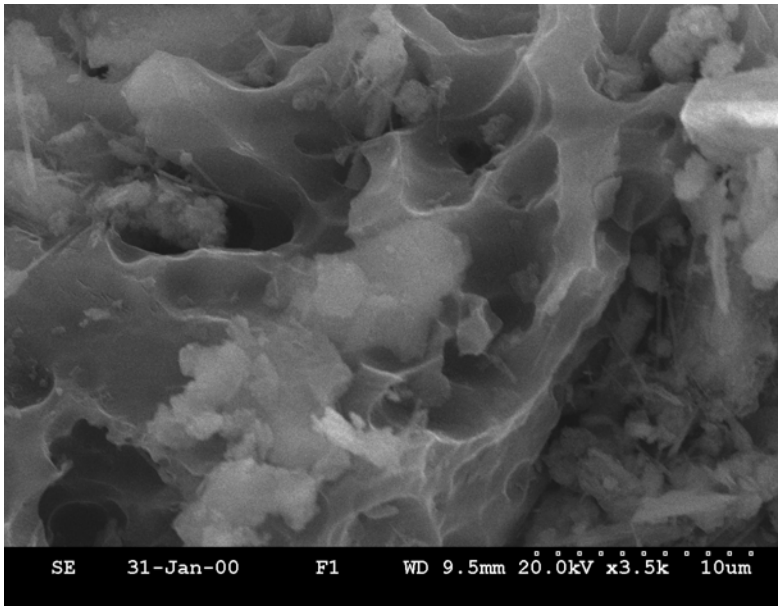


Figure 9.17. SEM image of post-placement ash collected from the Big Gorilla mine pool.

9.3.2.3 Radioassay of NEPCO fly and bottom ash.

Samples of both ash and waters in contact with the ash, and water in contact with native culm, were collected for determination of the radioactive content. The gamma spec results were provided by Pace Analytical Services, Waltz Mill Laboratory.

Water samples were MDA (minimum detectable analyte) for all isotopes except some lead in surface samples. The ash sample showed uranium decay series isotopes at approximately 1.5 pCi/g and thorium decay series at approximately 2 pCi/g. This compares to the USGS database samples for Pennsylvania coal ash results (inferred from coal activity and ash fraction) of 4.0 pCi/g uranium series and 2.6 pCi/g thorium series. Coal ash is specifically exempted from CERCLA controls, but even if it were not, the radium-226 concentration is well below the CERCLA limits of 5.0 pCi/g (surface) and 15 pCi/g (sub-surface).

The radon emanation rate was measured by DEP, Radon Division at 0.22 pCi/(m^2-sec). The radon emanation rate for soil in the United States has been estimated at 0.2 - 4.2 pCi/(m^2-sec) by the US EPA and the average value was estimated at approximately 0.6 pCi/(m^2-sec) by others (BEIR VI, 1999). The limiting radon emanation rate allowed in US EPA regulation for inactive phosphogypsum stacks (40CFR61.202) and for operating uranium mill tailings (40CFR61.252) is 20 pCi/g. The measured radon emanation rate is below regulatory controls for other materials. A residual radiation analysis was not performed because the radon emanation normally drives the dose in this type analysis, and the emanation rate is similar to native soil Therefore the risk from living on the ash fill is similar to the risk from living on native soil.

Dose rates measured during the visit are as follows:
1) ash pit ~20 µR/hr
2) culm area ~15 µR/hr
3) ash pit access road ~15 µR/hr
4) site access road at entrance ~12 µR/hr

9.3.3 Physical Properties of Emplaced Ash

The use of trucks and bulldozers in regular placement activities provided the only mechanical compaction of the ash platforms. When driving or walking on the ash, there is no indication of soft areas or water accumulation. NEPCO is required to submit ash samples to undergo a Proctor test (ASTM, 2001) every six months. The results from the Proctor test provide a theoretical maximum density, as well as an optimum moisture content. Also, the DEP's Pottsville office regularly monitors the density and moisture content of the ash platform using a Troxler nuclear moisture density gauge, following the guidelines outlined in the Troxler product manual. Based on both procedures, within three months, the density of the ash placed on the platform is consistently 90-100% of the theoretical maximum. The weight bearing capacity is measured in the field with a penetrometer by DEP, and is routinely over 69 MPa (5 tons per square foot). The bearing capacity was also measured by the S&F Drilling Company, who measured a bearing capacity of greater than 27 MPa (2 tons per square foot).

Two test borings were drilled into the lower ash platform on July 16-18, 2001, almost four years after ash placement began. Test boring 2 was drilled in ash less than 6 months old, while test boring 1 was drilled in ash approximately 3 years old. Split spoon testing was conducted, with both borings showing increased blow counts in the first 1.5m (5 ft.) of ash, approaching rejection. Test boring 1 showed a much greater hardness between the 15 and 23 m (50 – 75 ft.) depth, with an average of 25 blow counts per foot. Test boring 2 had less than 5 blow counts per foot in the 15 – 23 m (50 – 75 ft.) interval. Increased blow counts per foot reflect greater chemical reaction in a stronger sediment pile. Similar testing was conducted at the Knickerbocker mine pit, also with positive results.

Samples from the test borings underwent x-ray diffraction analysis using a Scintag Pad V diffractometer, and were mounted with Vaseline on a silicon metal zero background slide. The samples showed no marked mineralogical difference from the pre-placement fly ash. Both contain quartz and a clay phase, which most nearly matches muscovite. Scanning electron microscopy (SEM) was used to determine visually whether new, possibly cementitious, minerals were forming in the ash. Indeed, the cementitious phases ettringite and C-S-H were observed with the SEM in test boring 1, at the 15-16m (50 – 52 ft.) interval.

9.3.4 Hydraulic Properties of Emplaced Ash

Before drilling the two test borings discussed above, a boring was drilled to 5 m (17 ft.), cased, and abandoned. The abandoned boring was used to conduct a falling head test by filling the pipe with water and recording the water level with time. Data were analyzed using the Cooper, Bredehoeft, and Papadopolous curve matching method to obtain estimates of transmissivity (Batu, 1998). However, this test did not take place in the saturated portion of the aquifer, rather it was right above the water level, so transmissivity and storativity values calculated should be regarded as rough estimates. The transmissivity was approximately 0.3 m^2/day, which is similar to that measured for ashes in the laboratory.

9.4 CHEMICAL EVOLUTION OF THE BIG GORILLA MINE LAKE

Samples were taken at depth from four locations in the Big Gorilla when possible. Michael Wehr from DEP and James Wetzel from NEPCO used a bomb sampler that could be shut at a discrete depth to recover subaqueous samples. On 9 July 1998, the entire mine pool was both horizontally and vertically homogeneous, with a pH of approximately 11.1. Results of field pH measurements were confirmed within the hour at the facility's laboratory.

Data for the Silverbrook Basin were collected by both Pottsville Environmental Testing Laboratory (PETL) and DEP. Initially, only analyses required for the Module 25 were conducted, however, in August 1998 silica and potassium were added in order to better characterize the water for input into geochemical models. In this section, the influence of ash placement in the Big Gorilla surface mine pool will be discussed. Changes in the pH, acidity, alkalinity, and sulfate will be addressed in addition to iron, aluminum, and manganese, which are often concerns at mine-impacted sites. The ability of ash to leach metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Ba from coal ash has been monitored closely and concentrations of these

metals will be addressed. Ca, Na, Si, Mg, K, and Zn will not be discussed in detail, but the average, maximum, and minimum above detection limit concentrations for these elements, as well as the others mentioned, can be found in table 9.7.

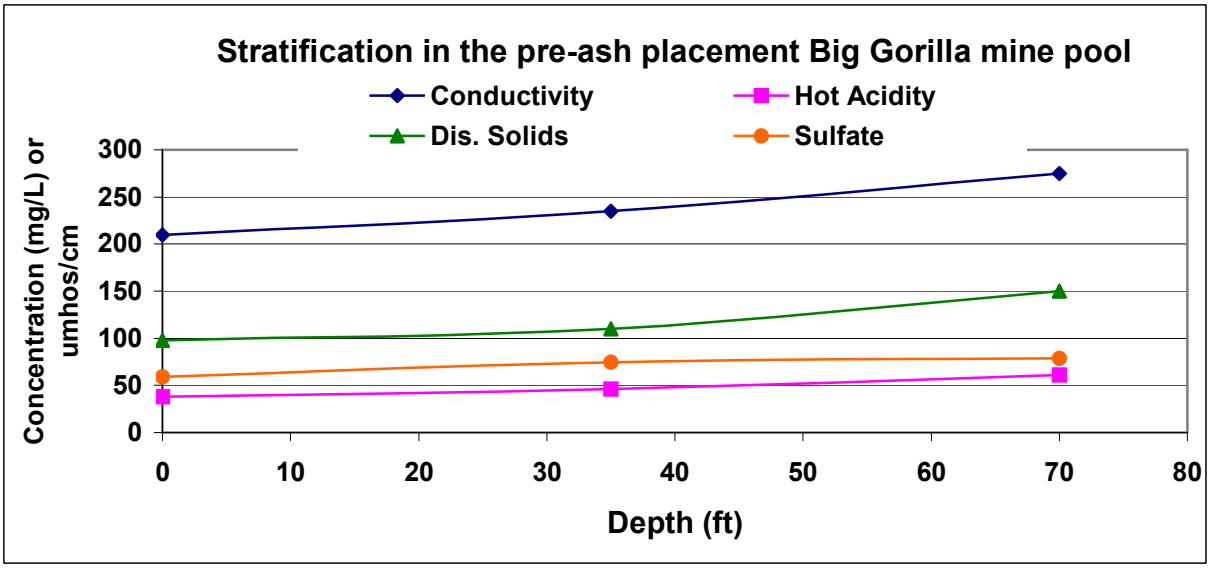
Table 9.7. Average, maximum, and minimum concentrations for analytes above detection limits in the Big Gorilla mine pool 1993-2002. Count is the number of above detection limit values used for the calculations. Note that true averages and minimums would be less if the concentrations below the detection limits were included. All units are in mg/L.

analyte	average	max.	min.	count	analyte	average	max.	min.	count
lab pH	10.99	12.10	3.20	109	arsenic	0.007	0.022	0.002	18
alkalinity	240	626	7	106	cadmium	0.007	0.018	0.001	6
sulfate	404	1021	55	106	chromium	0.092	0.260	0.005	79
fluoride	1.219	1.800	0.323	86	copper	0.033	0.132	0.010	72
chloride	5.197	22.00	1.00	100	lead	0.004	0.027	0.001	50
nitrate (N)	0.129	0.260	0.080	83	mercury	0.002	0.003	0.001	6
calcium	270	614	3.95	96	nickel	0.093	0.284	0.007	4
sodium	17.5	56.8	1.06	104	selenium	0.041	0.101	0.010	70
silica	12.9	39.0	4.3	72	barium	0.027	0.150	0.012	80
magnesium	0.765	10.80	0.051	96	iron	0.180	0.188	0.020	74
potassium	19.5	58.2	0.88	77	aluminum	1.154	9.00	0.208	101
zinc	0.070	1.250	0.008	82	manganese	0.076	0.970	0.002	67

9.4.1 Pre-placement Chemistry

Four samples were collected for aqueous analysis from the Big Gorilla mine pool prior to ash placement. A surface sample was collected in June 1993, and three variable depth samples were collected in July 1993. While the surface samples from June and July have very similar chemistry, there is very distinct stratification with depth (Fig. 9.18). Conductivity, total dissolved solids, turbidity and acidity all increased with depth. Aluminum, sulfate, iron, manganese, calcium, and magnesium concentrations all increased with depth as well. The pH values from the samples taken at depth were measured in the laboratory, and showed no consistent variation.

When quarterly sampling results of the Silverbrook outflow from 1993 and 1994 are compared to the pre-ash placement chemistry of the Big Gorilla mine pool, the Silverbrook outflow had a higher pH, in addition to higher values for acidity, iron, manganese, sodium, chloride, calcium, magnesium, and total dissolved solids. Although some of these values can be flow dependent, it is unlikely that flow from the deep mine pool alone could account for the higher values. In Figures 9.19 – 9.21, the values for iron, sulfate, and acidity from the deepest portion of the Big Gorilla mine pool appear most comparable to those from the Silverbrook outflow, indicating that the two areas may be influenced by similar acid producing processes in the interconnected mine workings.



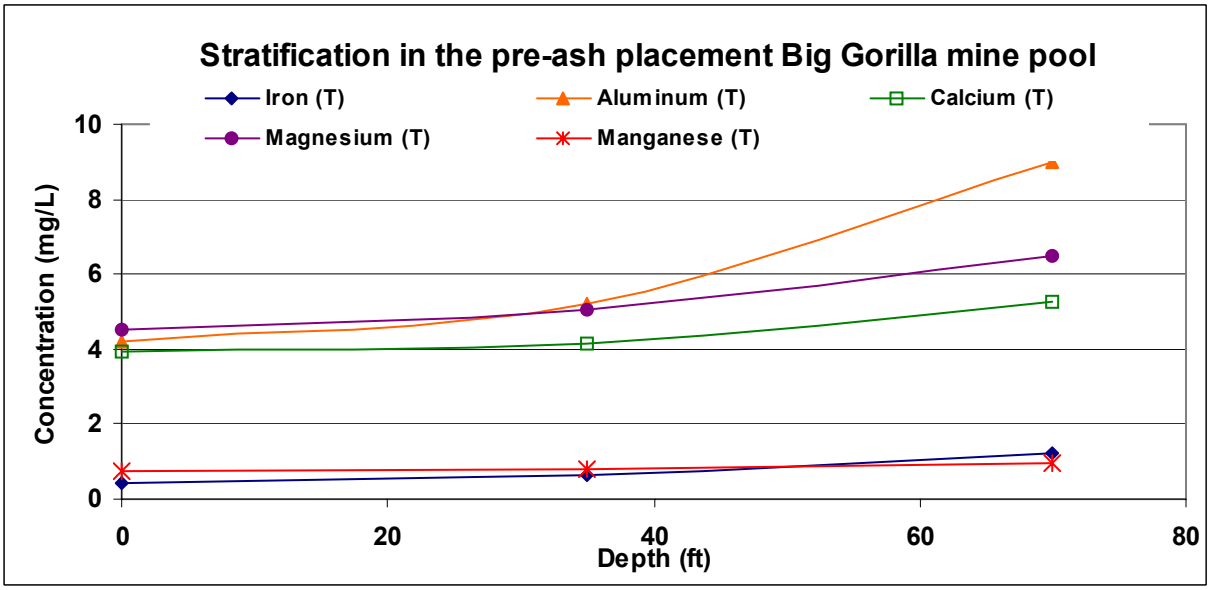


Figure 9.18. Two plots showing increasing concentrations of chemical constituents in the Big Gorilla mine pool with increasing depth 7/2/93. Conductivity in the first plot is measured in umhos/cm.

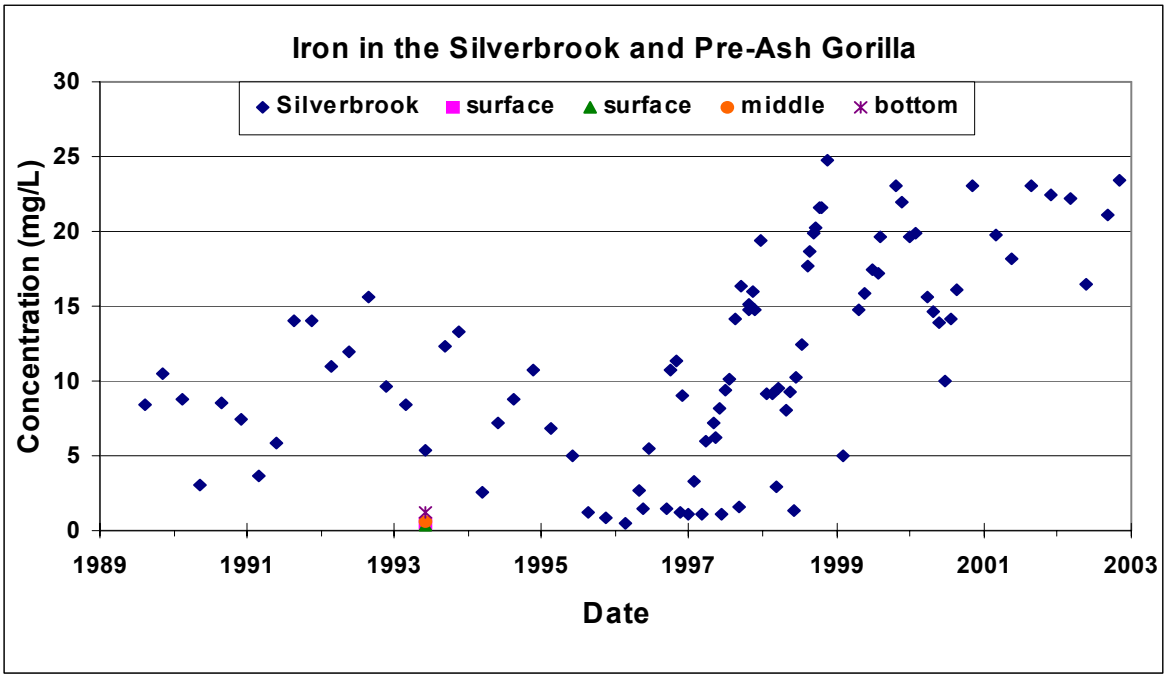


Figure 9.19. Plot of iron concentration in the Silverbrook outflow compared with the pre-ash placement concentration values from the Big Gorilla mine pool.

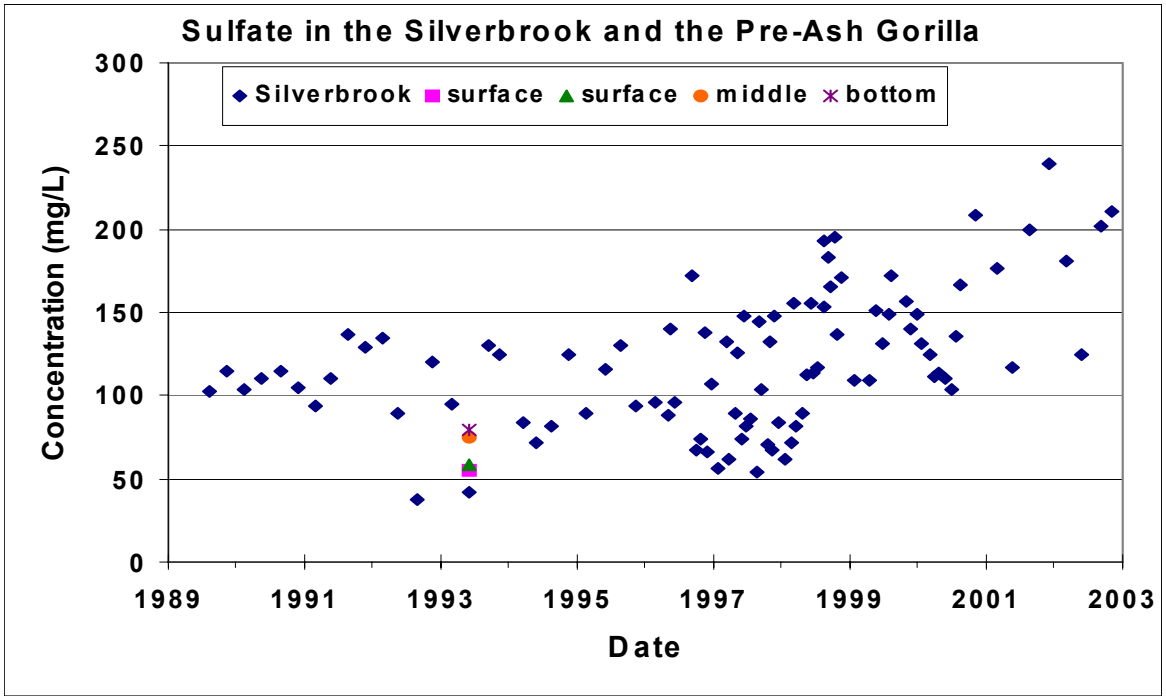


Figure 9.20. Plot of sulfate concentration in the Silverbrook outflow compared with the pre-ash placement concentration values from the Big Gorilla mine pool.

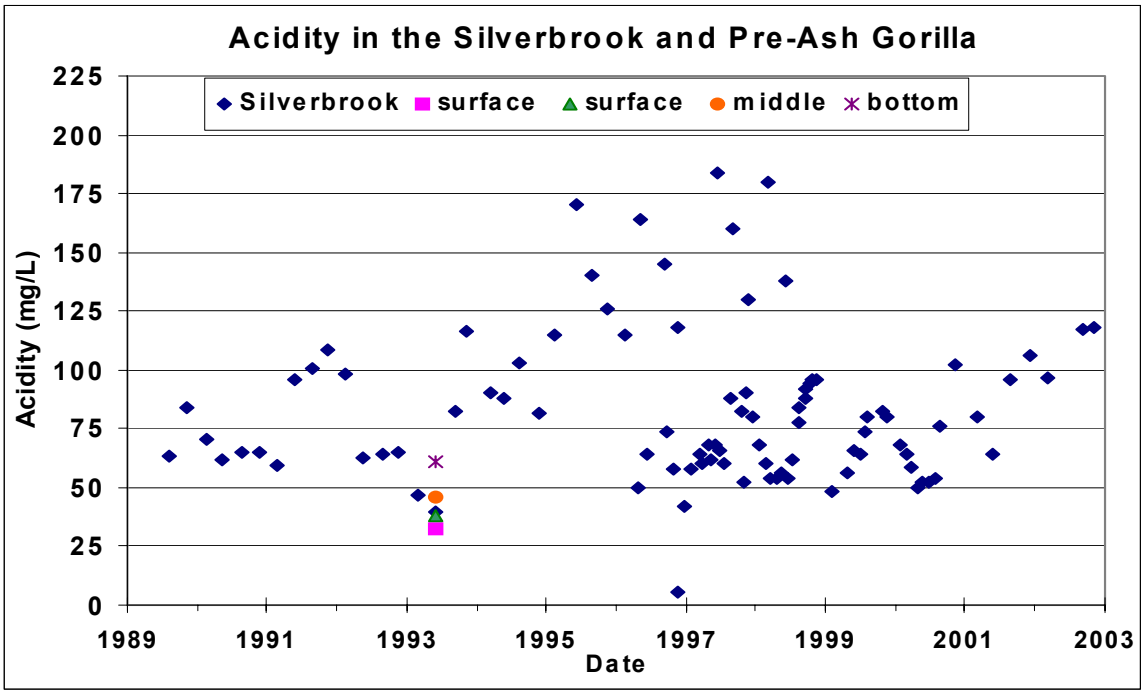


Figure 9.21. Plot of acidity concentration in the Silverbrook outflow compared with the pre-ash placement concentration values from the Big Gorilla mine pool.

As previously discussed, land reclamation on NEPCO property began in 1989. Calcium data from the Silverbrook outfall show a trend of increasing concentration beginning around January 1992 (Fig. 9.22). The pre-ash placement Big Gorilla mine pool calcium concentration values are most likely related to the pre-land reclamation values for the Silverbrook, rather than the trend of increasing calcium concentrations thought to be a result of land reclamation. It is unlikely that land reclamation would affect the Big Gorilla mine pool since it is upgradient of the majority of the land reclamation activities. If calcium derived from reclamation was being added to the Big Gorilla mine pool, one might expect a greater variation in the concentrations with depth than was measured in 1993.

Whereas sodium concentration values in the Silverbrook outflow show an increasing trend in concentration, the Big Gorilla mine pool samples from 1993 are lower than even the Silverbrook outflow's approximate baseline (Fig. 9.23). Chloride concentrations in the Silverbrook outflow are also higher than those measured in the Big Gorilla in 1993, and show seasonal influences with the highest concentrations in the December through April period. Thus, it is likely that the sodium in the outflow is from local salting of roads, and possibly from land reclamation using fly and bottom ash. The Big Gorilla mine pool is significantly farther from any public roads than the Silverbrook outflow and is upgradient of major land reclamation. This would explain the low concentrations of sodium and chloride in all of the Big Gorilla samples taken in 1993.

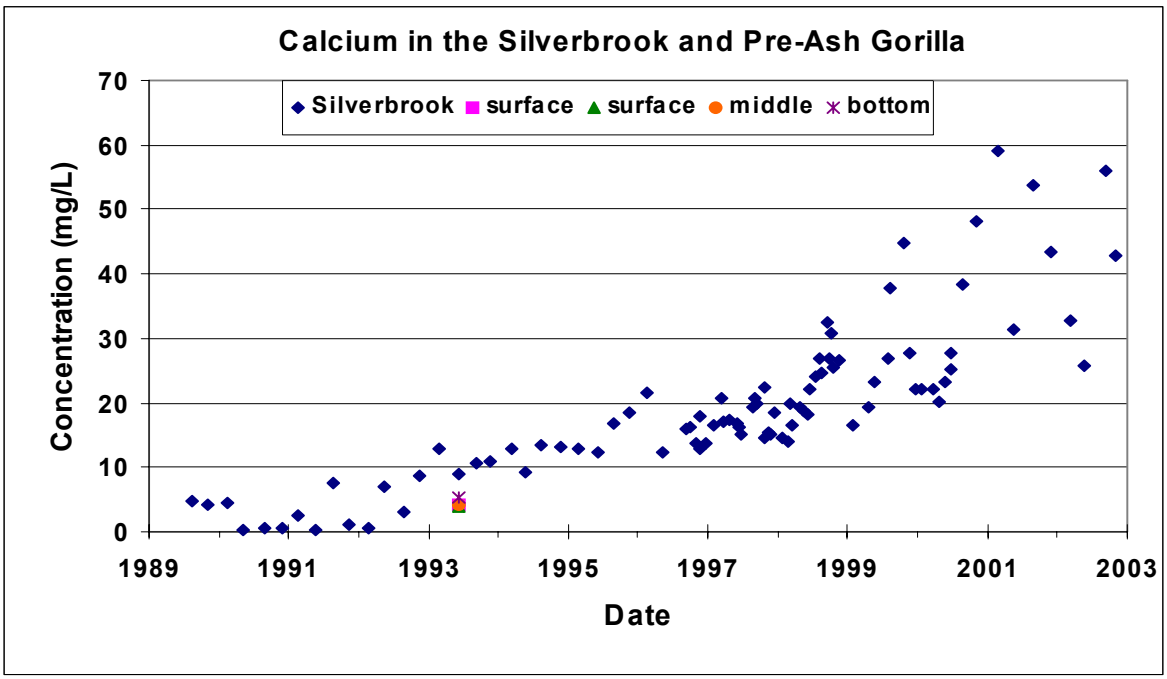


Figure 9.22. Plot of calcium concentration in the Silverbrook outflow compared with the pre-ash placement concentration values from the Big Gorilla mine pool.

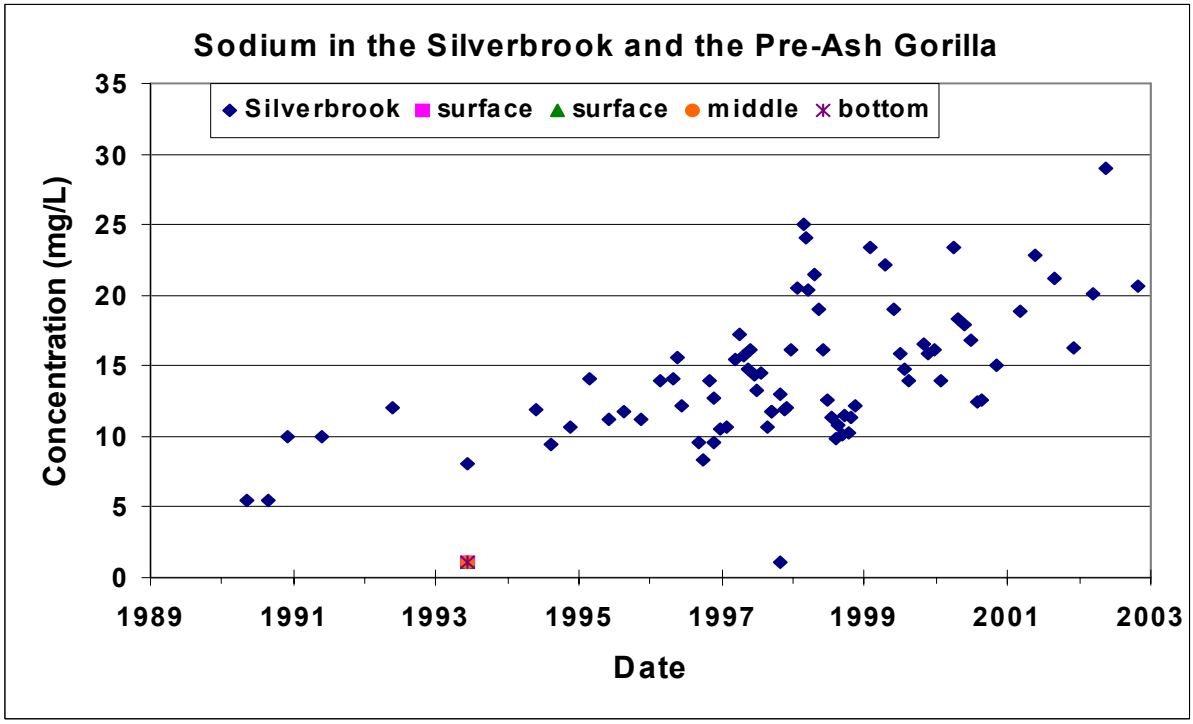


Figure 9.23. Plot of sodium concentration in the Silverbrook outflow compared with the pre-ash placement concentration values from the Big Gorilla mine pool.

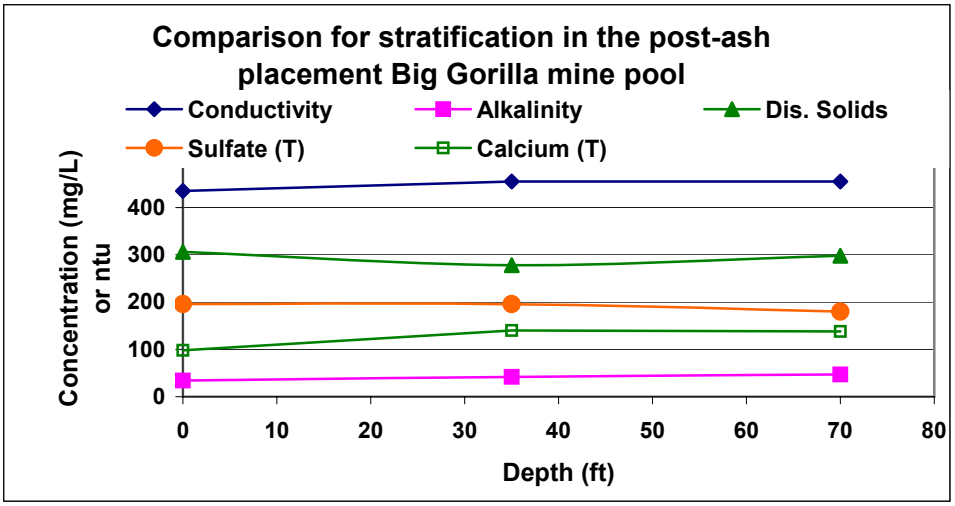
To conclude, the dominant characteristics of the pre-ash placement Big Gorilla aqueous chemistry are the presence of stratification and the similarity to the concurrent chemistry in the Silverbrook outflow with regard to iron, sulfate, and acidity. Calcium, sodium, and chloride contents in the Big Gorilla were not similar to those in the Silverbrook at the time of sampling, and this can be attributed to the mine pool's location upgradient from most of the land reclamation activities, and the distance to public roads.

9.4.2 pH, acidity, and alkalinity

Ash placement began in August 1997, and by the first two months, over 25,000 tons of fly and bottom ash had been placed in the Big Gorilla mine pool. At the first post-placement monitoring event, the consistent chemical stratification previously detected in the pool was for the most part absent, and significant chemical change had already occurred (Fig. 9.24). Response to the ash input was rapid and dramatic. The waters became alkaline, and the pH value increased by approximately six pH units.

The measured pH values increased as ash was placed in the mine pool (Fig. 9.25a). The first winter when placement was suspended, the pH value decreased by approximately 4 pH units, indicating that the system was not buffered. During the second and third major suspensions of ash input, however, the pH value decreased by at most 2 pH units. Because the mine pool was covered with ice during part of that time, it was difficult to obtain values representative of the entire pool. Between March 2000 and May 2002 the Big Gorilla mine pool water did not fall below a pH value of 11.0.

Since October of 1997, two months after ash placement began, the mine pool water has been alkaline. The water increased in alkalinity with increased ash input (Fig. 9.26). Before the first winter, there was not a significant amount of alkalinity present, and values remained below 50 mg/L $CaCO_3$ until June 1998. After June, there was a consistent increase in alkalinity, averaging 80 mg/L $CaCO_3$ per month for the next 5 months. This trend ended when ash placement ceased for the winter. At that point there was a dramatic decrease in alkalinity that was not reversed until ash placement resumed in July 1999. In early 1999, 2000, 2001 and 2002, alkalinity dropped dramatically, following significant suspensions in ash placement, indicating that the buffering capacity of the water was strongly tied to ash placement. The decreasing alkalinity values during the time of non-deposition indicate that the supply of minerals contributing to alkalinity is either consumed quickly or is only available in the very top layers of ash.



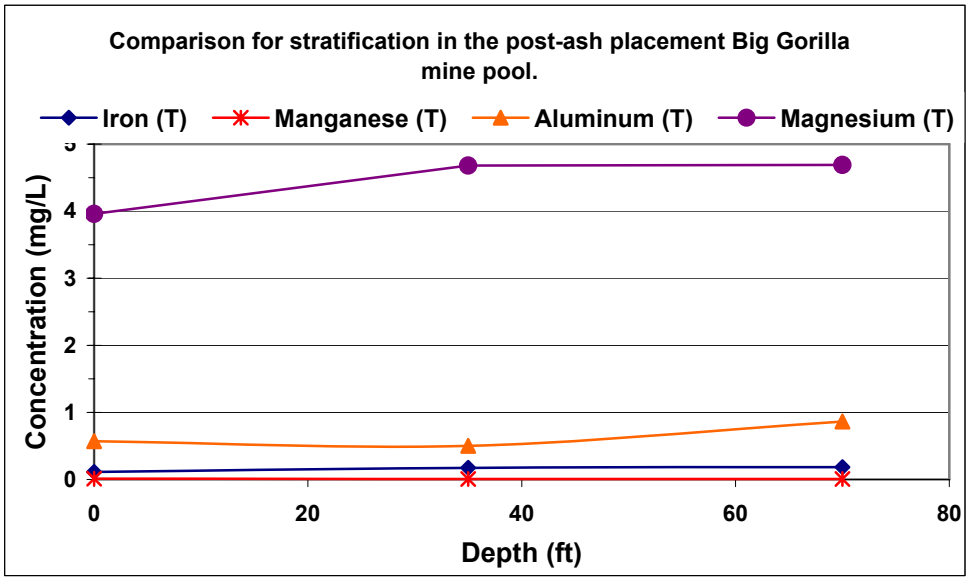


Figure 9.24. Plots showing lack of stratification in concentrations of chemical constituents in the Big Gorilla mine pool with depth 10/28/97.

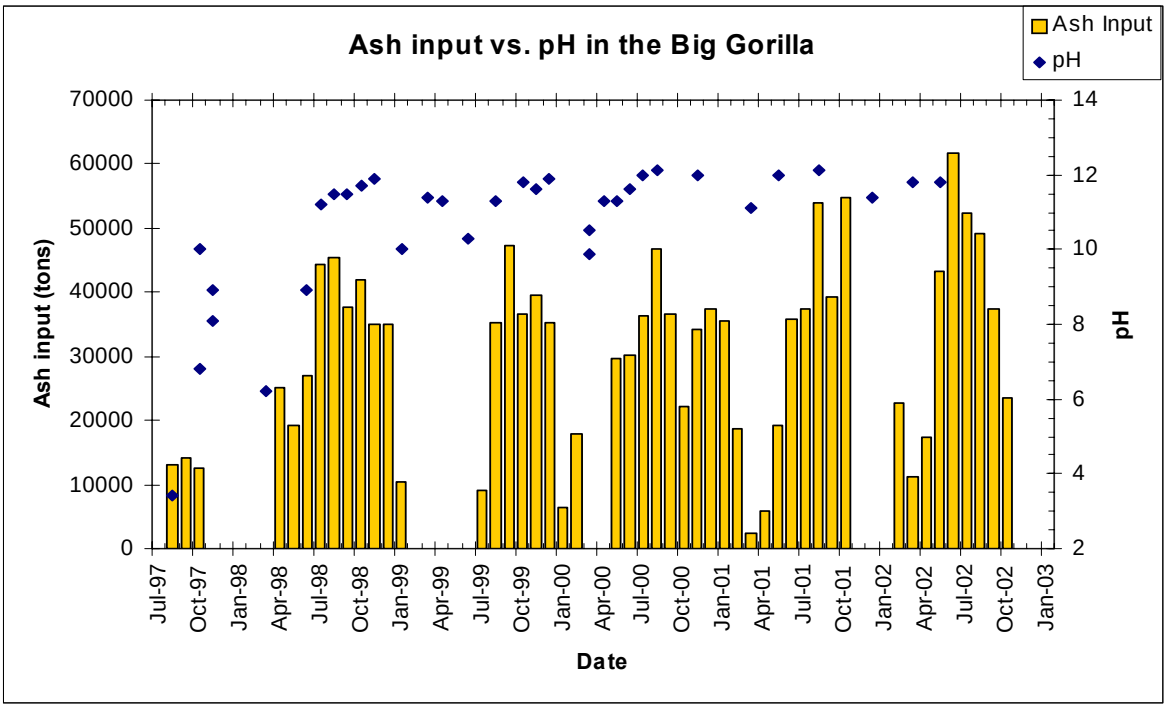


Figure 9.25. The response of pH to monthly ash input in the Big Gorilla mine pool.

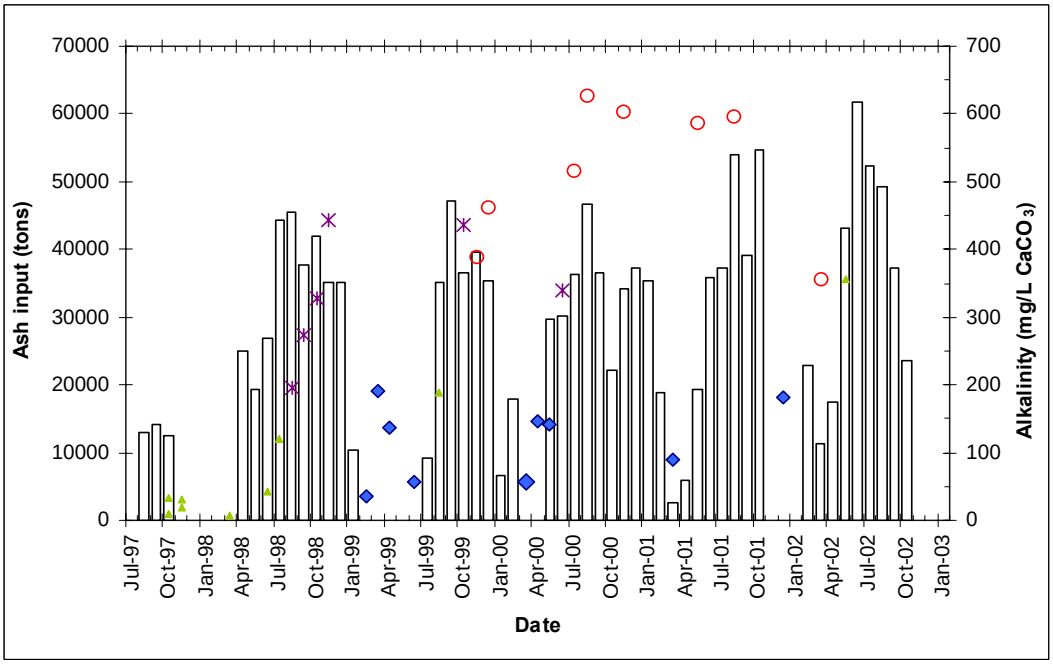


Figure 9.26. Ash input (bars) versus alkalinity (points) in the Big Gorilla. Open circles are points where surface samples were collected at the western end of the lake during periods of prolonged ash input. Asterisks represent monthly samples collected at depth, during periods of increasing ash input. Solid diamonds represent samples collected during hiatuses in ash input, and triangles represent samples for which no silica data are available.

The alkalinity in the Big Gorilla mine pool has three components: carbonate, hydroxide, and silicate. Total alkalinity in mg/L can be described as:

$$Alk = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] + [H_3SiO_4^-] \quad (1)$$

The alkalinity of natural waters is determined by the presence of carbonate minerals; however, at the pH values found in the Big Gorilla, hydroxide and silicate concentrations are crucial to understanding the impact of the ash on the pit water. The governing equations are:

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+ \quad (2)$$
$$Ca(OH)_2(s) \leftrightarrow Ca^{2+} + 2OH^- \quad (3)$$
$$H_4SiO_4 \leftrightarrow H_3SiO_4^- + H^+ \quad (4)$$

When ash is placed in the Big Gorilla, CaO hydrates to $Ca(OH)_2$ and dissociates, thereby increasing the pH. The quick reaction of the initially acidic mine water was due to the input of CaO. Soon after, a pattern emerged of high alkalinity during ash placement and low alkalinity when no ash was placed. To better understand the importance of the reactions taking place to produce alkalinity, and the long term impact of ash placement, it is useful to plot alkalinity against silica concentration (Fig. 9.27). Points on Figure 9.27 are coded to show the three different processes taking place. They are also matched to the points in figure 9.26 where both alkalinity and silica concentrations are known. The data shows that the caustic alkalinity is temporary and will be neutralized with carbon dioxide with time (pH will decrease to the range of 8 to 9).

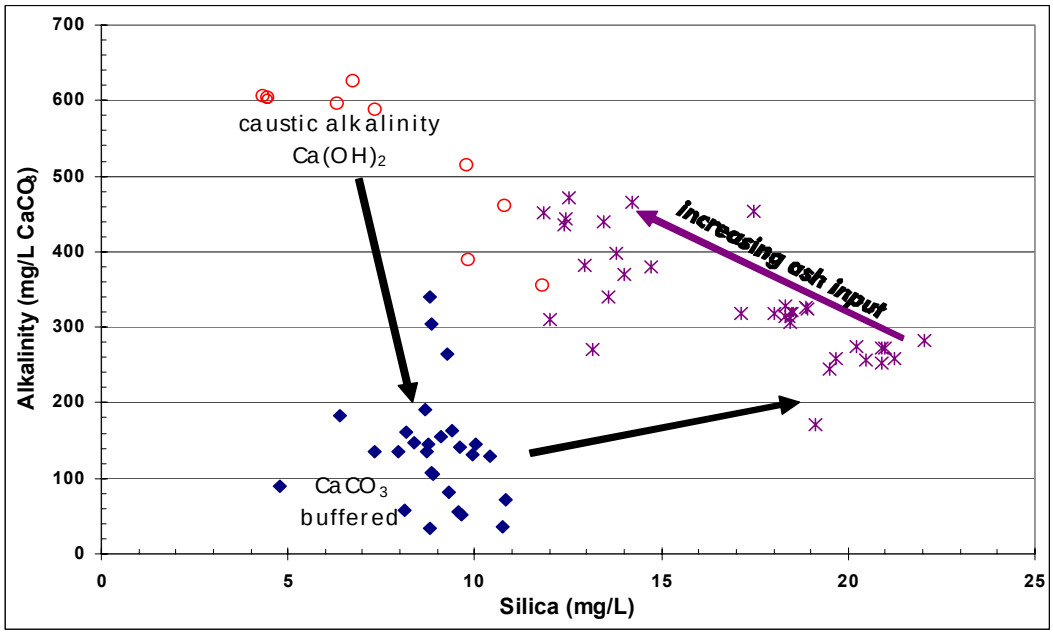


Figure 9.27. Plot of alkalinity versus silica in the Big Gorilla mine lake. Open circles are points where surface samples were collected at the western end of the lake during periods of prolonged ash input. Asterisks represent monthly samples collected at depth, during periods of increasing ash input. Solid diamonds represent samples collected during hiatuses in ash input. Data collected by DEP.

As will be discussed later, calcite began to visibly precipitate on the walls of the mine pool. The buffering capacity of the calcite in both the ash and the precipitated rim prevents the pit lake from returning to acidic conditions. When ash input is interrupted, alkalinity decreases, and calcite dissolves, which then adds bicarbonate to the water.

These relatively low alkalinity and low silica waters are highly influenced by carbonate reactions in this system. For example, in June 1999, at a depth of 20 ft and close to the ash face, the alkalinity was 52 mg/L as $CaCO_3$. $H_3SiO_4^-$ accounted for 13.6% of the alkalinity, OH^- accounted for 24.2% of the alkalinity, and HCO_3^- and CO_3^{2-} accounted for 62.2%.

The silica concentration increased as the ash came in contact with the pit lake water, due to the dissolution of dehydroxylated clays. As determined from the chemistry in late April 2000, when only a small amount of ash had been put into the lake, carbonate and silicate reactions were more important in the upper portion of the water column, and hydroxide had a greater influence on the alkalinity at depth. The alkalinity concentration began to increase as more ash was placed in the water, and the contribution of carbonate species and silicic acid to alkalinity decreased. Hydroxide generated by the dissociation of portlandite increased the pH and further increased the alkalinity. As ash input increased, samples collected at depths between 20 and 60 ft became chemically similar.

The very highest alkalinities were measured in waters with a pH value between 11.6 and 12.1 after prolonged ash input. These samples were taken across the mine lake from the ash face and at the surface of the water. Silica concentrations were lower than when ash first came in contact with the water, and the dissociation of portlandite produced the caustic alkalinity.

When ash placement was halted, the source of CaO to the water was limited to existing ash particles in the water column, or settled particles on the bottom and sides of the lake. Carbonate reactions began to play a larger role in the alkalinity, as atmospheric CO_2 diffused into the water. At pH above 10.3:

$$CO_2 + OH^- \leftrightarrow CO_3^{2-} + H^+ \quad (5)$$

and below 10.3:

$$CO_2 + OH^- \leftrightarrow HCO_3^- \quad (6)$$

The influence of silicic acid also increases as long as the pH stays above 9.5, because the total alkalinity is decreasing due to the precipitation of calcite. Calcite precipitation is described in the following reaction:

$$Ca^{2+} + 2HCO_3^- \leftrightarrow CaCO_3\,(s) + CO_2 + H_2O \quad (7)$$

By 2004, the surface mine pool was entirely filled with ash. As conventional ash placement continues, the land will be returned to approximate original contour and fully reclaimed. Reclamation will remove the surface hazard, but in order for continued alkalinity production to occur, the ash must retain a significant portion of alkaline minerals in the form of portlandite or calcite. The previous discussion described how portlandite will dissociate to

calcium and hydroxide ions, and how the presence of CO_2 will decrease the alkalinity and cause the precipitation of calcite. This will happen in the pore water of the ash platform as CO_2 migrates through the pores with time, as long as a sufficient reservoir of alkaline materials is present. Thus, it is crucial to understand what percentage of the ash is controlling the pH and alkalinity upon contact with the Big Gorilla water. This can be calculated from dissolved calcium concentrations.

Because the values for the weight percent of CaO in fly ash, the tons of ash input per month, the change in volume of the Big Gorilla with ash input, and the monthly calcium concentrations are all known, an average percent of available calcium from monthly additions of fly and bottom ash in the mine pool can be calculated (Table 9.8). Based on the June through November 1998 data, which were taken during ash placement, an average of 1.24% of the calcium in the ash is available. It is apparent that very little of the total CaO placed in the Big Gorilla mine pool is responsible for the large change in alkalinity in the Big Gorilla mine pool, even if water carrying dissolved calcium concentrations is being lost through the bottom of the mine pool. These calculations do not take into account the possibility of water flowing into the Big Gorilla mine pool, either carrying calcium or acidity, but this is thought to be insignificant. A large reservoir of excess CaO is present in the ash. This reservoir might contribute to the hardening of the ash into the platform that the trucks drive on to deposit the ash into the Big Gorilla.

Table 9.8. Calculation of calcium June-November 1998 showing that approximately 1.24% of the calcium is available in the water.

Date	Ash Input (million kg)	Mine pool volume (million L)	Calcium (mg/L)	Calcium in pool (kg)	Ca pool monthly change (kg)	Monthly Ca in ash (million kg)	Ca soluble
Jun. 98	24.4	408	101	41000		0.95	
Jul. 98	40.1	395	172	68000	26700	1.56	1.71%
Aug. 98	41.2	382	212	81000	13100	1.61	0.81%
Sept. 98	34.2	371	265	98000	17300	1.33	1.30%
Oct. 98	48.4	355	292	104000	5500	1.88	0.29%
Nov. 98	31.8	346	375	130000	25800	1.24	2.08%
					Average percent available:		1.24%

On October 22, 1999, samples of a white precipitate forming a ring around the Big Gorilla mine pool were collected. Figure 9.28 shows a 2 foot wide ring (from the variation in water level during precipitation) that extends upward from approximately 2 feet above the water level. Also present was a sub-aqueous ring that was sampled. A faint trace of a white precipitate was present in July 1998, but by October of 1999 there was a clear, continuous rim around the pool. Between the dates, the pH value rarely dropped below 11 for the Big Gorilla. XRD and SEM/EDS were used to determine the mineralogy and form of the precipitate forming on the walls of the Big Gorilla.



Figure 9.28. Photo of Big Gorilla mine pool with rim of calcite on 22 October 1999.

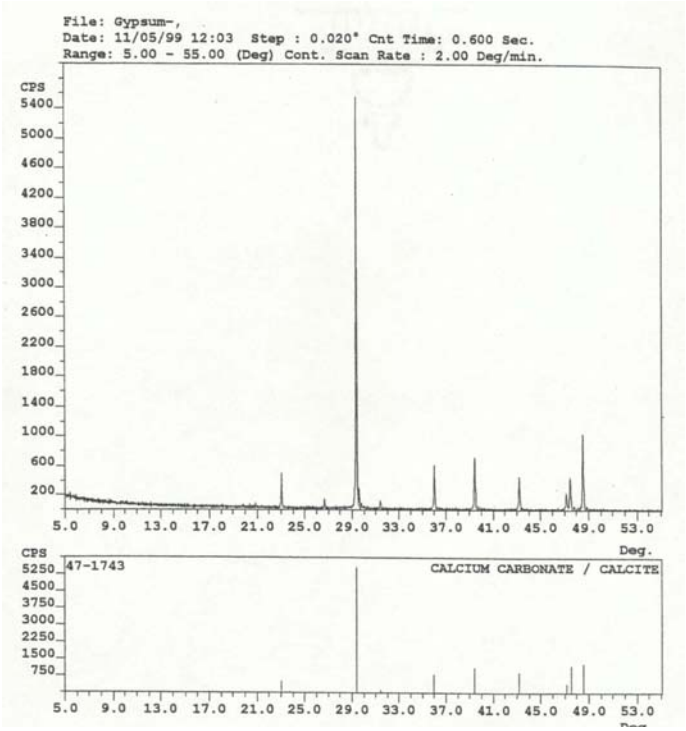


Figure 9.29 X-ray diffraction trace of calcite rim above the water surface. Collected 22 October 1999.

The chemical precipitate samples were analyzed at a continuous scan rate of 3° per minute and a step size of 0.020°. Both the above and below water samples were determined to be almost entirely composed of calcite (Figs. 9.29 and 9.30).

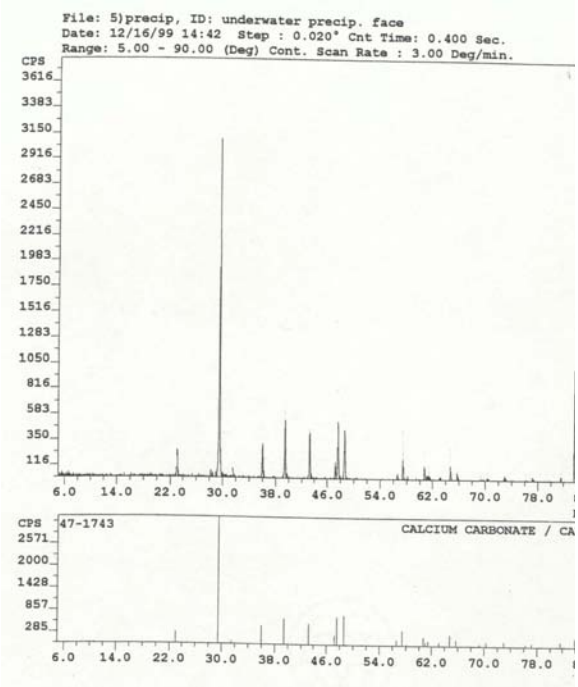


Figure 9.30. X-ray diffraction trace of calcite rim below the water surface. Collected 22 October 1999**.**

The SEM/EDS system used for ash analysis was also employed to investigate the character of the white precipitate scraped from the highwall of the Big Gorilla mine pool. At first, the sample looked like flat plates on one side and spheres on the other (Fig. 9.31). Upon closer inspection, the spheres appeared to have a pinecone texture with packed together rectangular-ended wedges (Fig. 9.32). Each rectangular end faced the same direction. This form had a distinct $CaCO_3$ chemistry when an EDS scan was made in the spot mode. Also present in the sample were spheres with pointed ends, which looked distinctly different from those previously described (Fig. 9.33). In this case, the form appeared to grow outward with points in all directions. Using the spot mode, this form had a $CaSO_4$ signature, which did not show up in XRD scans. Scott Atkinson analyzed the sample and found it to contain 2.11% (by weight) sulfate as SO_3 . As the sample was collected wet and later dried, there existed the potential for gypsum growth from solution in the sample while being heated.

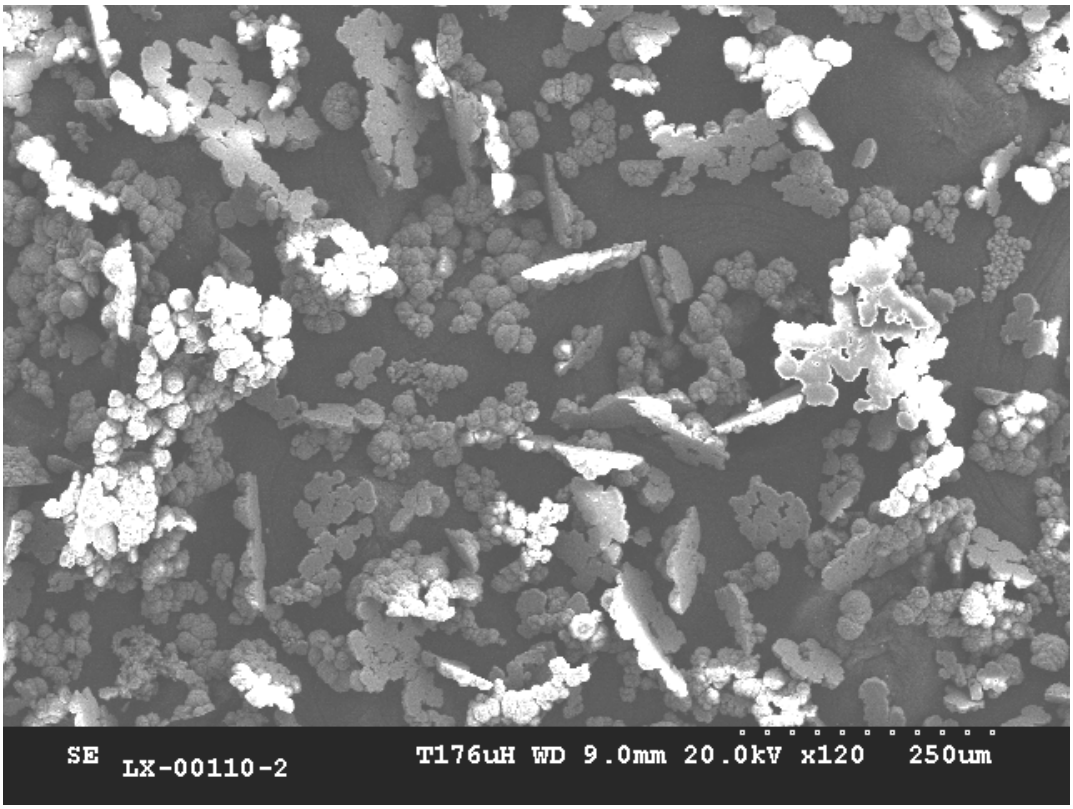


Figure 9.31. SEM image of white precipitate from the Big Gorilla mine pool (250um).

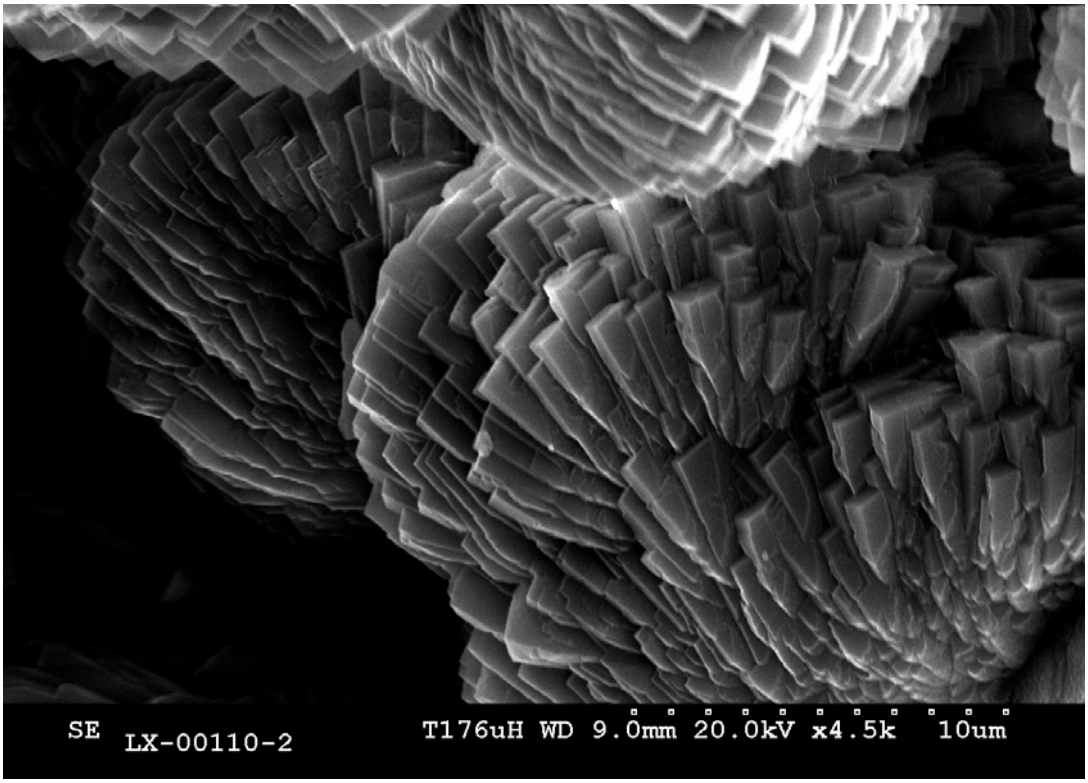


Figure 9.32. SEM image of white precipitate from the Big Gorilla mine pool (10um).

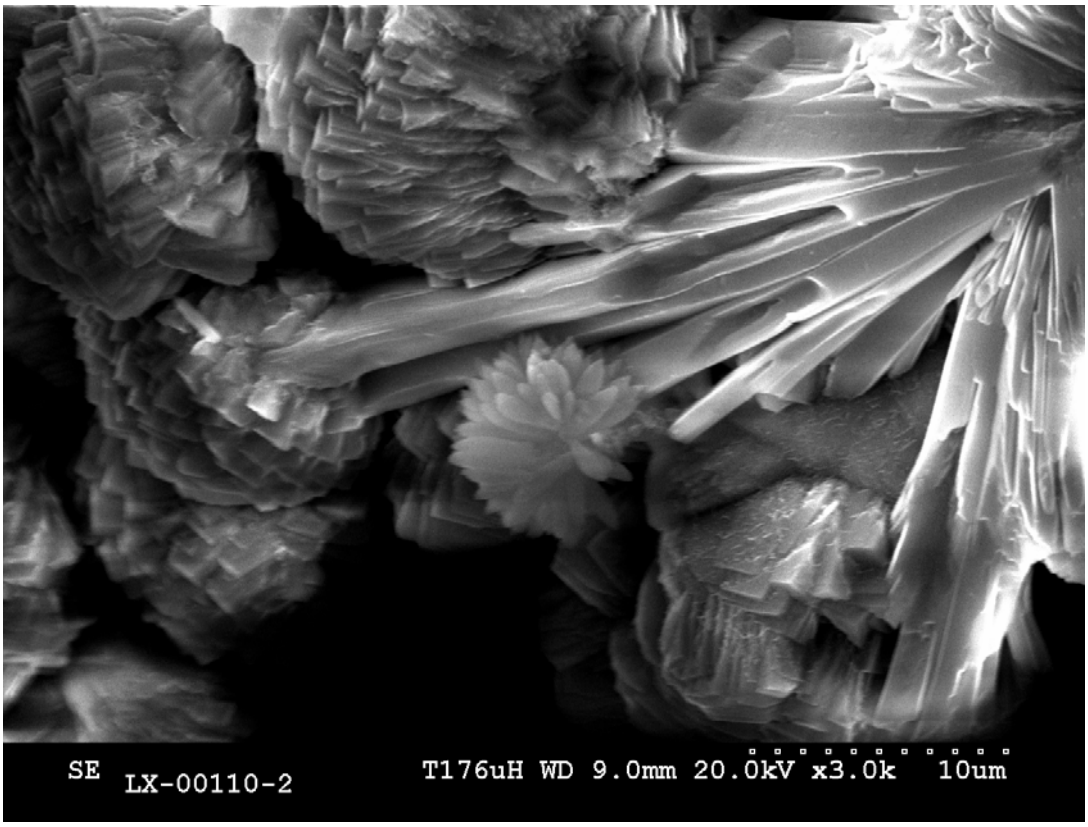


Figure 9.33. SEM image of white precipitate from the Big Gorilla mine pool (10um).

9.4.3 Sulfate

High sulfate concentrations are one of the key features of AMD impacted streams. As described previously, sulfur from pyrite (FeS_2) is oxidized, leached, and becomes sulfate. Median sulfate concentrations in ground water from the Llewellyn and Pottsville Formations were 6.3 mg/L and 6.0 mg/L, respectively (Becher, 1991). Of the 27 samples in the two formations, none exceeded 44 mg/L. Figure 9.34 shows the Eh-pH diagram for sulfur species at standard conditions with total dissolved sulfur activity of 96 mg/L. Eh was measured in November 1998, and plotted on the diagram, showing that sulfur was indeed most stable in the sulfate species. Total sulfate concentrations in the Big Gorilla mine pool at that time were approximately 147 mg/L.

Sulfate is present in the ash due in part to the pyrite and other sulfide minerals contained in coal as well as the trapping of SOx emissions from the stack by the fluidized bed of limestone. Sulfur has been measured as 0.104 weight % of the NEPCO ash. This value would certainly be higher in regions with high-sulfur coals.

Initially, the Big Gorilla mine pool water had sulfate concentrations ranging from 55 to 79 mg/L. Since July 1998, sulfate concentrations have risen in response to ash input (Fig. 9.35). The sulfate concentration in the Big Gorilla has been as high as 1021 mg/L, measured in August 2001. In four months, however, it had decreased to 800 mg/L, and within the year it was less than 600 mg/L.

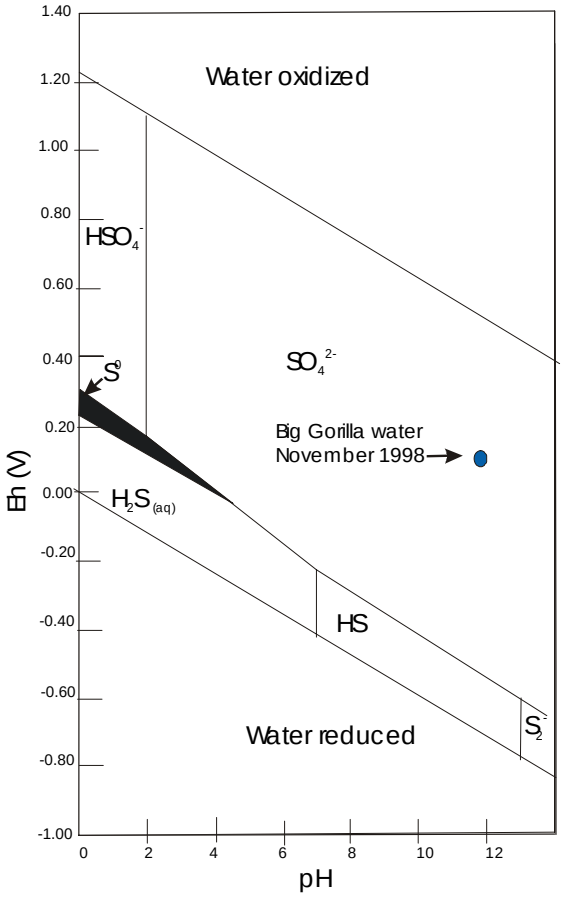


Figure 9.34. Eh-pH diagram for sulfur species at standard conditions with total dissolved sulfur activity of 96 mg/L (adapted from Hem, 1985).

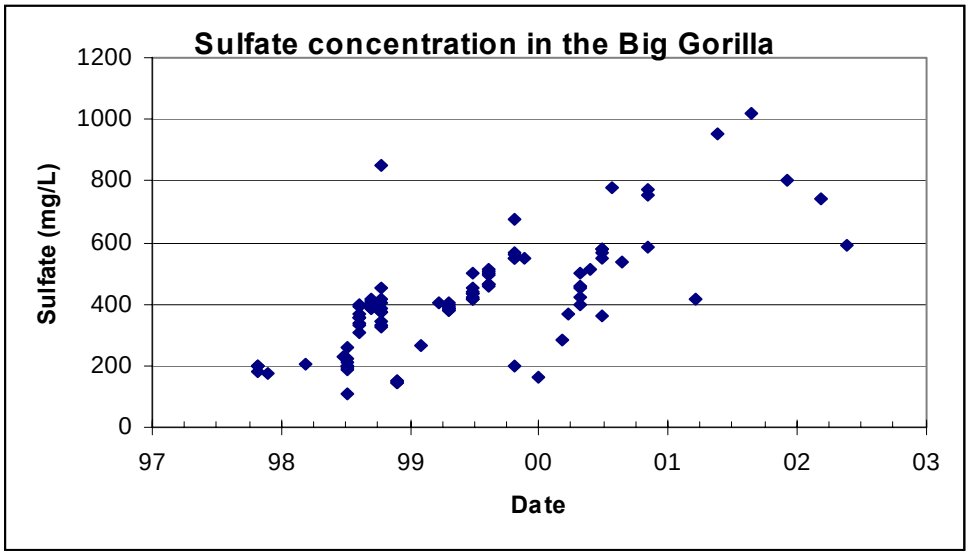


Figure 9.35. Sulfate concentrations in the Big Gorilla mine pool.

9.4.4 Iron, Aluminum, and Manganese

Orange iron oxide precipitates are another primary indication of acid mine drainage. Ground water from undisturbed portions of the Llewellyn and Pottsville Formations have median iron concentrations of 2 mg/L and 3.8 mg/L, respectively (Becher, 1991). The pre-ash placement Big Gorilla mine pool had an average iron concentration of 0.70 mg/L, masking the fact that the water filled a former strip mine.

Since ash placement began in 1997, total iron concentrations have dropped significantly and are often below 0.2 mg/L (Table 9.9). Iron concentrations respond to ash input in the Big Gorilla, mostly in the form of increased variability of iron concentrations, despite having lower values of iron in the water. Lower iron aqueous concentrations are most likely due to the high pH, which causes the precipitation of $Fe(OH)_3$, or $Fe(OH)_4^-$ the presence of which is supported by the Eh measurement taken in November 1998, and is shown on the stability diagram in Figure 9.36. The variation of iron concentrations may be due to the formation of colloidal sized iron oxide particles that are in the process of settling out of the water. No physical proof of iron precipitation has yet been collected.

The ash deposited into the Big Gorilla mine pool is approximately 9.97 wt.% aluminum. Aluminum is present in almost all clays, including illites and vermiculites. It is also a common oxide mineral. Like iron, high aluminum concentrations are one of the primary characteristics of acid mine drainage. Aluminum concentrations in the undisturbed portions of the Llewellyn and Pottsville Formations do not reach over 1 mg/L (Becher, 1991).

Table 9.9. Selected chemical analyses from the Big Gorilla mine pool, analyzed by DEP. All concentrations are total and for a surface sample, except for 10/27/99, which was taken at a depth of 6m (20ft.).

Concentration (mg/L)	6/7/93	7/2/93	10/28/97	10/27/99	8/28/01
Al	3.5	4.2	0.57	0.38	0.41
Fe	0.52	0.40	0.11	<0.020	0.15
Mn	0.71	0.72	0.011	0.010	0.014
Zn	0.22	0.20	0.008	0.052	<0.010

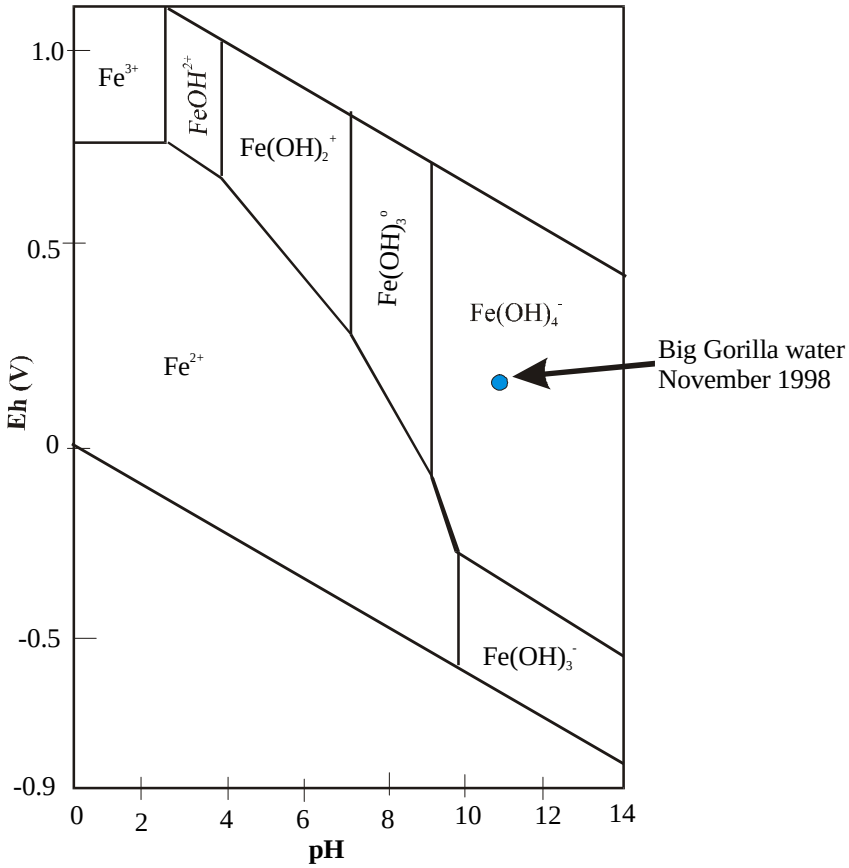


Figure 9.36. Eh-pH diagram at 25°C for aqueous species in the Fe-O_2-H_2O system at 10^{-5} mg/kg (Langmuir, 1997).

Pre-ash placement aluminum concentrations in the Big Gorilla mine pool ranged from 3.5 mg/L to 9.0 mg/L. The concentration of aluminum has been above 2.5 mg/L only once since ash placement began, and that value appears anomalously high. Aluminum concentrations measured in the mine pool can be related to ash input, and decrease shortly after each time ash placement was suspended. The correlation between ash input and aluminum concentration is not as clear as that for the other lithophillic elements. This may be due to the settling of recently formed oxides to the bottom of the pool.

Manganese is present in coal in the form of carbonate minerals, in which it replaces iron (Swaine, 1990, Finkelman, 1995). Less significant amounts may be associated with clays and pyrite in higher rank coals (Finkelman, 1995). The median concentration of manganese in ground water from the Llewellyn and Pottsville Formations are 0.14 mg/L and 0.08 mg/L, respectively (Becher, 1991). None of the 22 samples from these two formations had a concentration above 0.6 mg/L (Becher, 1991).

Pre-ash placement concentrations of manganese in the Big Gorilla ranged from 0.71 mg/L to 0.97 mg/L. With two apparently anomalous exceptions, manganese concentrations in the mine pool have been below 0.1 mg/L since October 1997, and have often been less than the

10 ug/L detection limit. Due to these low concentrations, it is difficult to determine the relationship of manganese to ash input. Most likely, manganese is removed from the water by the precipitation of manganese oxides to the bottom of the mine pool.

9.4.5 Toxic Metals

Toxic metals are present in coal, and are often associated with either pyrite or organic matter. The amount of toxic metals in a coal sample varies worldwide. When coal is burned, metals may become concentrated in the residual fly and bottom ash. An important question in the Anthracite Region of Pennsylvania is whether the continuous leaching of metals from acidic culm piles is more or less favorable than the isolation of the metals in the ash once it is placed in a manner that allows cementitious reactions to take place. Figure 9.37 presents a conceptual understanding of the mobility of certain metals at high and low pH values. The following discussion details the reaction of fly and bottom ash with acidic then alkaline water of the Big Gorilla mine pool.

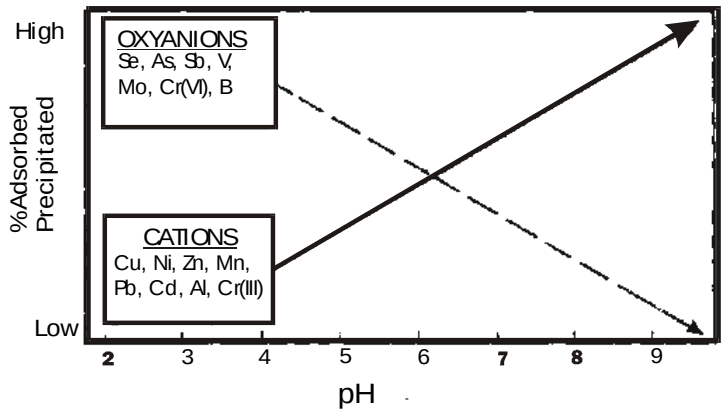


Figure 9.37. Schematic illustration of the effects of pH on the precipitation of trace elements occurring in the form of cations or oxyanions (Jones, 1995).

9.4.5.1 Arsenic and selenium

Arsenic and selenium both occur as oxyanions, and as such might be expected to be present in higher concentrations with increasing pH. Arsenic in coal is associated almost exclusively with pyrite (Finkelman, 1995), while there is extensive evidence that selenium is present in organics, pyrite, and clausthalite (PbSe), in addition to other forms (Swaine, 1990; Finkelman, 1995; Davidson and Clarke, 1996). Both elements can be emitted from the stack, although concentrations are usually minor compared to natural sources (Swaine, 1990). Arsenic and selenium are also considered to be concentrated on the surface of fly ash particles rather than in the matrix (Hansen and Fisher, 1980; Hansen et al., 1984; Eary et al., 1990; Jones, 1995).

The highest value given by Becher (1991) for arsenic in the Llewellyn and Pottsville Formations is 0.005 mg/L, which is above any concentrations measured in the pre-ash placement Big Gorilla mine pool. No values for background concentrations of selenium were given by Becher (1991), and all measurements of selenium for the pre-ash placement mine pool were less than the detection limit of 0.002 mg/L. The federal standard for drinking water is 0.050 mg/L for both arsenic and selenium. The maximum concentration for these elements was 0.101 mg/L for Se and 0.022 mg/L for As between August 1997 and May 2002 in the Big Gorilla mine pool. There is no apparent trend in the Big Gorilla data for either arsenic or selenium, with respect to ash input or otherwise.

9.4.5.2 Cadmium, mercury, and nickel

All three of these chalcophile elements can be toxic in low quantities and have been thought to occur with pyrite. The most widely agreed upon association is that of cadmium, which replaces zinc in sphalerite (ZnS) (Finkelman, 1995). Mercury, the most likely of these elements to be lost through the stack, is most commonly found in solid solution with pyrite, but there is evidence of the presence of metallic mercury and mercury associated with organic material in coal (Davidson and Clarke, 1996). Nickel may be organically bound or associated with sulfides (most likely pyrite). Finkelman (1995) cites both the lack of direct evidence for the mode of occurrence for nickel as well as the contradictory indirect evidence, to explain his lack of confidence in the association of nickel with coal.

Maximum concentrations of cadmium and nickel measured by Becher (1991) in ground water of the Llewellyn and Pottsville Formations were 0.002 mg/L and 0.440 mg/L, respectively. No values were given for mercury. There was no detectable change in or influence on the cadmium, mercury, or nickel concentrations in the Big Gorilla mine pool between August 1997 and June 2000. The values during that period were comparable to those measured for the pre-ash placement mine pool. The highest concentrations measured in the Big Gorilla mine pool for cadmium, mercury, and nickel were 0.018 mg/L, 0.003 mg/L, and 0.284 mg/L, respectively. The value for nickel appears anomalously high. Because the values are so low in each of the cases, it would be difficult to accurately estimate the impact of ash placement in the surface mine pool.

9.4.5.3 Barium

Barium, like calcium, magnesium, sodium, boron, and strontium decreases in concentration with increasing coal rank (Lindahl and Finkelman, 1986). In the high-rank coals such as anthracite, barium is predominantly associated with the inorganic component (Finkelman, 1995). Barium is more evenly distributed throughout fly ash particles, as compared to those elements concentrated on the surface (Hansen and Fisher, 1980; Hansen et al., 1984; Eary et al., 1990; Finkelman, 1995). Thus, it is less likely to be a water quality problem in subaqueous ash placement due to this distribution as well as the ash's ability to sequester elements by cementation.

There was no barium detectable (<0.1 mg/L) in the pre-ash placement Big Gorilla mine pool. Of the post-ash placement samples collected, only one sampling date had barium concentrations above 0.1 mg/L, and it appeared anomalously high. The majority of the detectable values ranged between 0.01 mg/L (by definition) and 0.04 mg/L. The concentrations appear to respond to ash input, increasing when the ash loads are increased, but the resolution between such small values is poor, thus making an accurate assessment difficult.

9.4.5.4 Chromium

Like barium, chromium is also an element that is evenly distributed throughout the fly ash particle, rather than being surface enriched (Hansen and Fisher, 1980; Hansen et al., 1984; Eary et al., 1990; Finkelman, 1995). There are more concerns about the toxicity of chromium than barium, especially in the hexavalent state. However, a study using x-ray absorption fine structure (XAFS) of about 30 coals from the United States found that nearly all the chromium was present in the +3 oxidation state (Huggins et al., 1993). Mode of occurrence studies for chromium have been inconclusive (Finkelman, 1995).

Chromium concentrations measured in the Llewellyn and Pottsville Formations by Becher (1991) were no higher than 0.02 mg/L; samples from the pre-ash placement Big Gorilla had chromium concentrations no higher than 0.05 mg/L. Chromium concentrations in the post-ash placement Big Gorilla mine pool were never above 0.260 mg/L. Chromium concentrations in the mine pool appear to increase with ash input and decrease during the suspension of ash placement. The chromium may be co-precipitating with an oxide or carbonate phase.

9.4.5.5 Lead

Lead is very toxic even in low concentrations. Like zinc, it forms a sulfide mineral, galena (PbS), that is common in coals (Finkelman, 1985). Although the bulk of lead in coals is thought to be associated with galena, there is some evidence that additional lead may be present in the form of lead selenide (PbSe), or replaces barium in silicates and phosphates (Finkelman, 1985; Dale et al., 1993; Goodarzi and Swaine, 1993). Ground water concentrations of lead in undisturbed portions of the Llewellyn and Pottsville Formations range from 0.001 mg/L to 0.065 mg/L (Becher, 1991).

Of the four analyses taken in 1993, the highest lead concentration was 0.002 mg/L. The highest post ash placement concentration of lead in the Big Gorilla was measured in August 1999 and had a value of 0.0274 mg/L. Only 3 samples from the Big Gorilla mine pool between August 1997 and May 2002 exceeded the drinking water limit for lead. Due to low concentrations of lead in the Big Gorilla, it is difficult to determine a relationship between ash input and lead in the Big Gorilla. However, the effect of ash placement in the Big Gorilla on lead concentration seems inconsequential.

9.4.5.6 Copper

Chalcopyrite ($CuFeS_2$) is the primary copper mineral in most coals, although some copper associated with organic matter may be present in low rank coals (Swaine, 1990; Finkelman, 1995). The highest concentration of copper measured in ground water of the Llewellyn and Pottsville Formations was 0.047 mg/L (Becher, 1991). The highest value for copper in the pre-ash Big Gorilla mine pool was 0.030 mg/L. Since ash placement began, it appears that there may be greater variation in the copper content of the mine water, although this is most likely a function of an increase in the number of samples taken. The federal secondary MCL for copper in water is 1.0 mg/L, but the maximum concentration of copper detected in the Big Gorilla is 0.132 mg/L. There are no discernable trends in the copper data for the Big Gorilla.

9.5 CHEMICAL EVOLUTION OF THE SILVERBROOK BASIN

9.5.1 Chemistry of the Silverbrook Outfall

The Silverbrook outfall's chemistry is key to understanding the net chemical result of the reclamation processes in the Silverbrook Basin, but it also deserves careful study for its role outside the basin. During dry conditions, the Silverbrook outfall forms the headwaters of the Little Schuylkill River (Gannett, Fleming, Corddry, and Carpenter, 1972). Figure 9.5 shows that the outfall is the emergence point for water contained by the deep mines carved in the Buck Mountain Vein. The hydraulic conductivity of the connection between the Big Gorilla mine pool, where the Mammoth Vein was mined, and the outflow is undetermined. It is thought to be filled to some extent by the coal silt that was present in the surface mine pool in the 1940s. The fine-grained silt could block nearly all the flow of water from the Big Gorilla through the tunnel and into the Buck Mountain seam. The coal silt may also act to acidify the water from the Big Gorilla entering the tunnel. Evidence for blockage of this tunnel between the Big Gorilla and Well 3 is provided by the delay in the change in the pH value of the well water, taking place over 2 years after ash placement in the Big Gorilla.

Because the Big Gorilla mine pool has not been filling with water as ash was placed inside, and rain causes some fluctuation in the water level, it is thought that the tunnel beneath the surface mine pool is acting as a slow drain. NEPCO has worked to prevent overland flow into the Big Gorilla surface mine pool. Cumulative monthly precipitation onto the surface of the Big Gorilla mine pool (not accounting for evaporation from the surface) accounts for no more than 2% of the average monthly flow at the Silverbrook outflow.

One way to assess the origin of the water emerging from the Silverbrook outflow is to measure the chemistry and determine how the chemical parameters change in response to climate and regional activities. There are four main types of data for this evaluation: 1) water chemistry analyses of the Silverbrook outfall since 1989, 2) climate statistics for Hazleton, Pennsylvania, 3) flow and major chemical parameter analyses in and near the Silverbrook outflow, and 4) timing of reclamation progress in the Silverbrook Basin.

Plots of individual chemical analyses and flow of the Silverbrook outfall water as well as regional precipitation and ash input to the Big Gorilla can be found in Loop, 2000. In looking at the data from 1989-1996, a major trend is seen in the calcium plot where there seems to be a definite change in slope in early 1992 (Fig. 9.22). Because the samples were taken upgradient from the limestone drains, the primary explanation for the increased calcium content is the influence of nearby land reclamation with FBC ash.

Plots of chemical analyses between 1989 and 2000 show generally increasing concentrations and an increase in the variability of the chemistry for iron, sulfate, acidity, calcium, and sodium (Figs. 9.19 – 9.21). The most distinct change in trend for that period is shown in the plot of conductivity, where the slope seems to change at around January of 1997, still before ash placement in the Big Gorilla began.

Land reclamation activities using ash in the Silverbrook Basin could have an effect on the chemistry of the water emerging from the Silverbrook outflow. This is especially true if there exist fractures or old tunnels to the subsurface. In 1992, an area to the east of the current ash silos was being reclaimed, and in early 1997 an area to the east of the Big Gorilla mine pool was the site of land reclamation activities. When calcium concentrations from the Silverbrook outflow are separated based on these apparent changes in slope, there appear to be four distinct groups of data, implying that there was a significant change in the chemistry (Fig. 9.38).

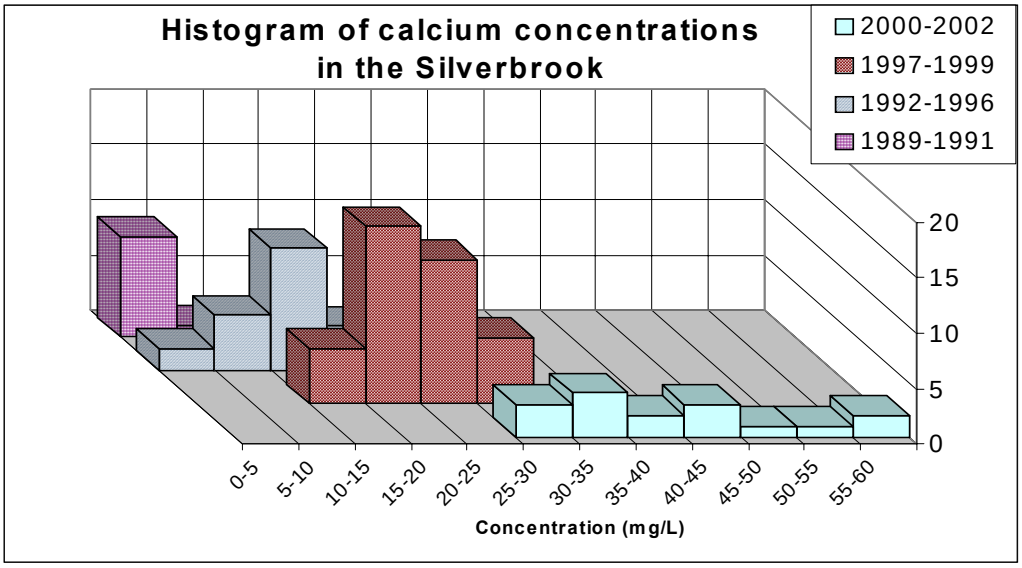


Figure 9.38. Calcium concentrations in the Silverbrook outflow 1989-2002.

Increases in Fe and SO_4 concentrations in the Silverbrook Basin cannot be attributed to changes in the Big Gorilla, because Fe concentrations in the Big Gorilla mine lake decreased with ash placement. Also, the positive trends began prior to ash placement (Figs. 9.19 and 9.20). The most likely source of the increase in Fe and SO_4 concentrations in the Silverbrook outflow is the redistribution of culm piles within the basin. Culm piles must be moved in order to burn the waste anthracite and remove it permanently, and as will be further discussed (section 9.5.3), the water chemistry of these piles is high in Fe and SO_4 due to the oxidation of pyrite. Hence, these increases are unfortunate, negative side effects of the complete and permanent removal of acidity generating spoil.

Chemical data collected between 1997 and 2000 from the Silverbrook outflow seem to show a cyclical, perhaps seasonal, change. While TDS, conductivity, aluminum, sulfate, and calcium are highest around October, chloride, and sodium are at their lowest. It may be noted that October has typically been a peak month for ash deposition into the Big Gorilla mine pool and by January less ash was usually placed.

The flow data measured by the Bureau of Abandoned Mine Reclamation (BAMR) between a site upstream and just downstream of the Silverbrook outfall along the Little Schuylkill River shows an approximately 15% higher flow than that measured by NEPCO at the mouth of the Silverbrook. Additional seeps along the side of the river, which have been seen during high flow periods, appear to account for the extra 15% of flow. The BAMR data are proportional to the cumulative monthly precipitation as measured at Penn State Hazleton Campus. The precipitation, and hence the flow, is lower in October and higher in April, similar to the trend shown in sodium and chloride and opposite to that for the other chemical constituents plotted. It is possible that the rains in April dilute most of the chemical constituents, but carry with them dissolved sodium and chloride from the salting of roads as they percolate through the land surface. In October, any mineral salts that may have formed from the oxidation of minerals will be washed from the system with only small amounts of water, therefore appearing concentrated.

The chemistry of waters above and below the Silverbrook outflow was also measured by BAMR. A major influence on the chemistry between the two points are two limestone diversion wells located directly above where the Silverbrook joins the Little Schuylkill River. The concentrations of some parameters appear to have become more variable (sulfate, iron, manganese, and aluminum), but this may be due to the change in sampling interval from weekly to monthly.

Thus, it appears that land reclamation may be responsible for three increases in chemical concentration trends (such as calcium) at the Silverbrook outfall, once in 1992, and another time in early 1997, prior to ash placement in the Big Gorilla surface mine pool. The third change in the trend of Ca concentration in the Silverbrook outfall occurs in early 2000. The variation in chemical concentrations at the Silverbrook between 1997 and 2002 may be due to precipitation throughout the basin moving through reclaimed areas and the Big Gorilla to emerge at the Silverbrook, or it may be a factor of waters traveling from either the Big Gorilla (impacted by ash placement) or the land reclamation sites. There is no definitive evidence that the change in

chemistry in the Big Gorilla mine pool has affected the chemistry of the Silverbrook outflow.

9.5.2 Monitoring Well Chemistry

Five monitoring wells and three test borings on and near the NEPCO property have been sampled for water quality (Fig. 9.39). Wells 1 and 2 are to the east of the Big Gorilla mine pool. Well 3 is within 100 feet of the southern boundary of the mine lake. Well 9 is to the west of the Big Gorilla, and is associated with a Superfund site that is between Route 309 and the NEPCO property. Well 4 was drilled in July 2001, to intersect the Buck Mountain Vein.

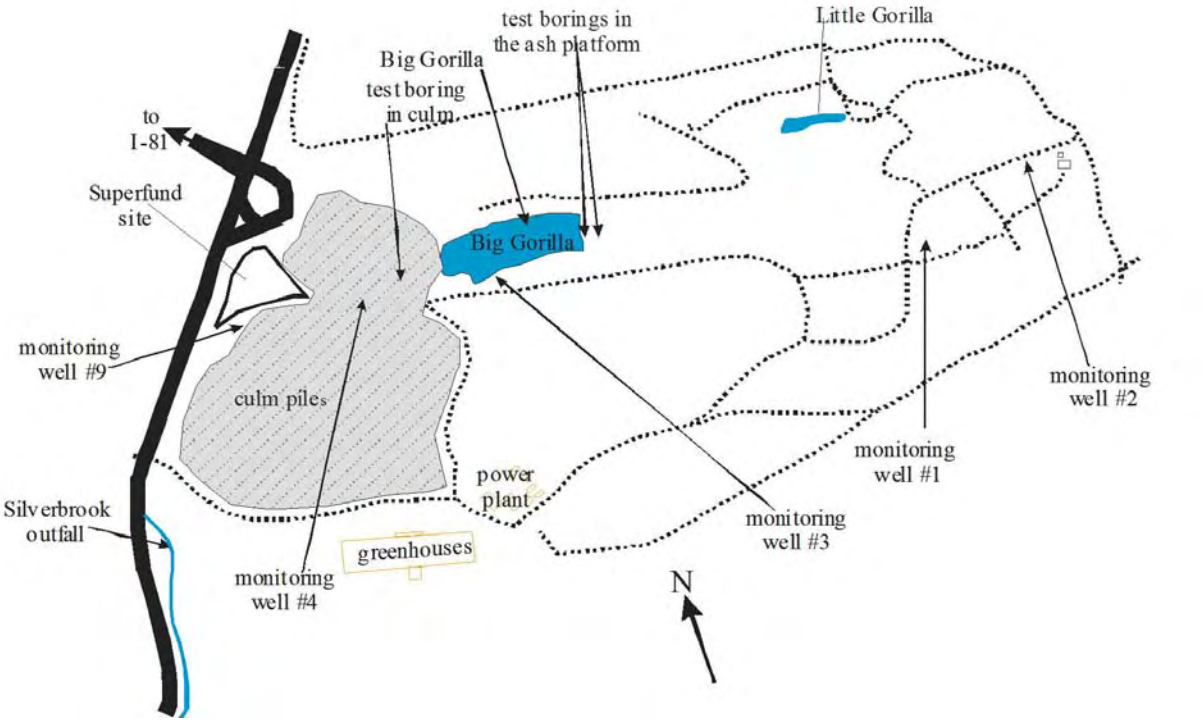


Figure 9.39. Location of the monitoring wells, Silverbrook outflow, Big Gorilla, and power plant on the NEPCO property.

Average concentrations for the wells show that each has a distinct chemical signature (Table 9.10). Only 8 samples were collected from well 1, but the iron concentration is significantly higher than that found in well 2. Well 2 has higher concentrations of sodium and chloride than does well 1. Both wells 1 and 2 have much lower concentrations of sulfate and aluminum than do wells 4 and 9. Wells 4 and 9 are more heavily impacted by AMD than wells 1 and 2. Well 4 intersects the Buck Mountain seam, and well 9 is downgradient of surface culm piles and subaqueous coal refuse.

The Al concentrations measured appear to be limited by the solubility of basaluminite and then jurbanite. Sulfate is present in culm and coal on the site, and to a lesser degree, sulfate is present in the FBC ash used for reclamation in the basin. With this in mind, it is understandable that the aluminosulfates control the Al solubility at low pH values. The solubility of gibbsite plots close to that of basaluminite, and some of the wells with lower

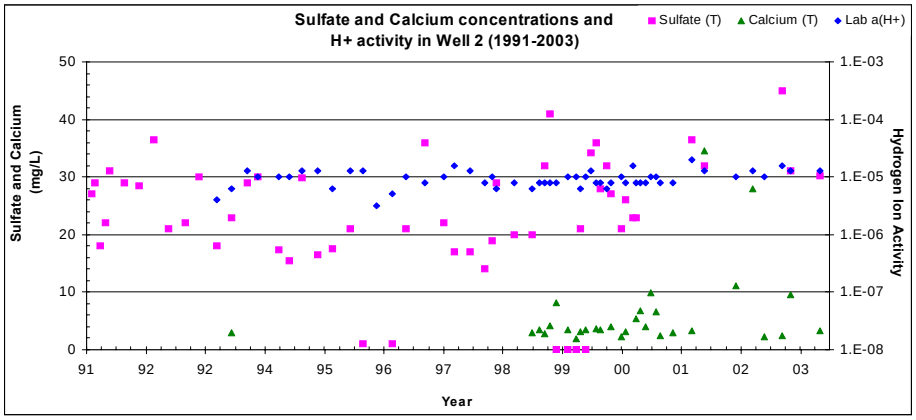
concentrations of sulfate (wells 1, 2, and possibly 3) would be more likely to have the maximum concentration of Al determined by the gibbsite solubility.

Table 9.10. Average of water chemistry of wells sampled 4 times a year on or near the NEPCO property. All concentrations reported in mg/L except for conductivity (µS/cm), turbidity (ntu), and pH. Average values are calculated from concentrations above the detection limit, and (T) indicates total (dissolved and suspended) concentration. Samples analyzed by DEP.

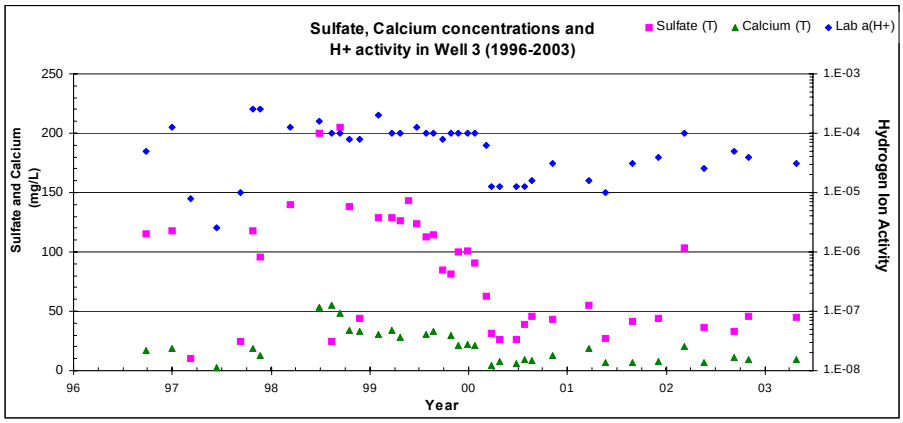
location	Well 1	Well 2	Well 3	Well 4	Well 9
	5/89 - 2/91	12/90 – 11/02	9/96 – 11/02	12/01- 11/02	9/96 – 11/02
# of samples	8	58	40	4	39
pH	4.30	5.04	4.30	3.75	3.7
Conductivity	89.13	68.88	249.28	528.25	455.0
Alkalinity	1.20	8.16	3.30		
Hot Acidity	37.56	47.79	47.49	114.95	147.1
Iron (T)	3.77	0.60	1.74	18.22	0.6
Manganese (T)	0.33	0.43	0.65	8.69	1.7
Sulfate (T)	33.50	30.81	82.82	191.75	182.7
Chloride	0.95	1.89	2.26		6.6
Sodium	0.25	4.66	9.38	4.47	16.0
Dis. Solids	75.25	69.40	161.54	436.00	368.6
Sus. Solids	2.86	7.15	9.48	5.33	29.2
Nitrate N		1.49	0.07		0.2
Silica (T)		7.38	10.26	28.61	57.7
Aluminum (T)	0.66	0.45	2.65	10.09	18.0
Barium (T)		0.03	0.03		0.0
Calcium (T)		6.26	20.65	32.03	18.8
Magnesium (T)	2.70	3.79	5.84	14.23	8.9
Zinc (T)	0.12	0.33	0.31	0.68	0.4
Potassium (T)		1.68	1.84	2.34	3.9

As mentioned previously, well 3 is close to the south wall of the Big Gorilla mine lake. In previous reports, no change was noted in the water quality of well 3 as a result of ash placement in the Big Gorilla. When plotting the data over a longer period of time, however, it appears that the water in well 3 more closely approximates the concentrations found in well 2 (Fig. 9.40). The largest change in water quality in well 3 occurred between mid-1999 and mid-2000. The pH value increased from 4 to 4.5-5. Sulfate and calcium concentrations dropped from about 125 mg/L to 50 mg/L and from 30 mg/L to 10 mg/L, respectively (Fig. 9.40 and 9.41). As one would expect with a pH change, iron and aluminum concentrations dropped significantly (Fig. 9.40c).

a)



b)



c)

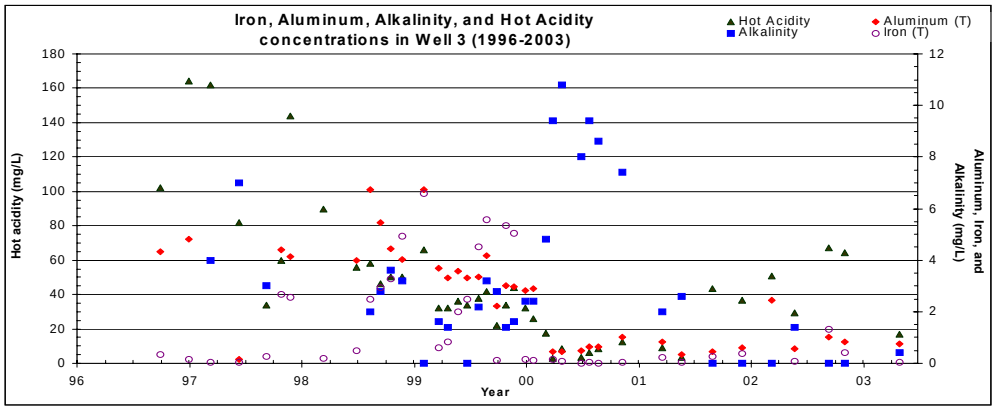


Figure 9.40. Sulfate, calcium, and hydrogen ion activity in wells 2 (a) and 3 (b). Corresponding aluminum, iron, hot acidity, and alkalinity concentrations for well 3 (c). Samples analyzed by DEP.

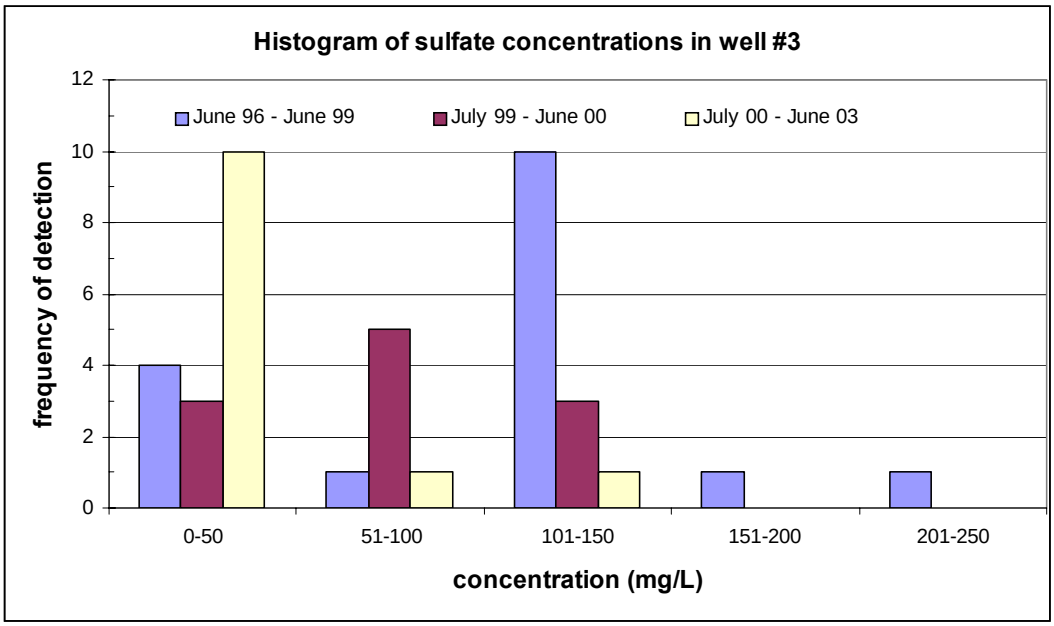


Figure 9.41. Histogram of sulfate concentrations in well 3. Data collected by the DEP.

The relative concentrations of alkalinity and hot acidity seem to be driving these changes. From the beginning of ash input to the Big Gorilla surface mine pool, the concentrations of acidity were being reduced. In January 2000, acidity was less than 10, while the alkalinity concentration in well 3 was 4.8 mg/L $CaCO_3$. For the next 14 months, acidity was below 15 mg/L $CaCO_3$, and alkalinity was 2.0 mg/L $CaCO_3$ or above. During this time, iron and aluminum concentrations remained consistently low. After May 2001, despite high rates of ash placement in the Big Gorilla, acidity again began to rise, and alkalinity remained low. However, in April 2003, with no recent ash placement, acidity again decreased and alkalinity increased slightly.

The obvious source of alkalinity to well 3 is the Big Gorilla surface mine pool. At times, the alkalinity concentration in the Big Gorilla has been over 600 mg/L $CaCO_3$. Aluminum decreased consistently from its initial concentration, in response to the increase in pH and alkalinity. However, iron concentrations were initially below 0.5 mg/L, but rose to a maximum of 6.6 mg/L with the additional input of Big Gorilla water. After November 1999, iron concentrations again generally remained low (<0.5 m/L). Iron concentrations were below 0.2 mg/L in the mine lake after ash placement began, with some exceptions, therefore it is unlikely that the increase in iron derived from inflow of water from the Big Gorilla. Formerly precipitated iron may have been remobilized, or re-dissolved with mixing of waters. It is also unlikely that an increase in pH and alkalinity would cause pyrite to contribute iron to solution.

Just as iron and alkalinity values were increasing in well 3, sulfate and calcium began decreasing. This is unexpected, because in the Big Gorilla water, alkalinity, sulfate, and calcium all increase in response to ash input. As will be discussed in the next section, the result of land reclamation and stock piling culm (in order to burn it) in the Silverbrook Basin has been an

increase in calcium, iron, and sulfate concentrations at the Silverbrook outflow. Yet, no increase in alkalinity values has been detected. It appears that the reactions taking place between the Big Gorilla and well 3 are the opposite of those taking place within the basin as a whole.

Because chemical change in well 3 did not occur sooner after ash placement in the Big Gorilla, and older maps show that coal silt once filled the Big Gorilla (and possibly the tunnel intersecting well 3), it is likely that there is a fine-grained material acting as a reactive barrier between the Big Gorilla and well 3. Coal silt, a mix of carbon, pyrite, and clays, is the likely composition. Because calcite only precipitated at the top few feet of the mine lake water, it is unlikely that calcite is present within the silt material, however, it may precipitate in the well itself, depending on the extent of CO_2 mixing.

9.5.3 Test Boring Chemistry

Two test borings were drilled into the lower ash platform, and one boring was drilled into the culm filling the Mammoth Basin #1 to the west of the Big Gorilla. PVC pipe was placed in each hole so that water samples could be collected. The water samples from the borings in the ash platform are very similar in chemistry to the Big Gorilla, as would be expected (Table 9.11). All of the borings in the ash platform have consistently high pH and calcium values. The CaO component of the ash has raised the pH value, and some of the dehydroxylated clays remain very reactive. It is important to note that with increased CO_2 mixing, calcite will precipitate, and the pH will decrease.

Because Al is amphoteric, at high pH values it can become more mobile than at neutral pH values. If the solubility of gibbsite is controlling the Al concentration in the Big Gorilla and the test borings in the ash platform, the equilibrium concentration of Al would be approximately 200 mg/L at pH 12 (Fig. 9.42). If amorphous $Al(OH)_3$ controls the solubility of Al at pH 12, the aqueous concentration would be substantially higher at equilibrium. This could obviously be a major problem considering the pH of the mine lake and test borings. However, as shown in Tables 9.9 and 9.11, no such levels are found.

The Al initially present in the Big Gorilla water most likely formed hydroxides, which precipitated on the bottom of the mine lake when the neutral pH was reached. When the ash is placed, a certain portion flows downslope and across the mine pool. Evidence for the transport of ash in this manner is found in both turbidity boils and fine ash particles present on the opposite bank of ash placement. The layers of ash would cover the initial precipitates and isolate them from further dissolution at higher pH values.

Al may still be leached from clays and mullite, which make up a combined 70.6 wt% of the ash, in contact with the mine water at a pH of 12. But, as seen in Figure 9.42, the Al concentration in the Big Gorilla appears to be limited in three different pH regions. The Al concentration between pH 8.5 and 11 seems relatively constant with pH. It is likely that at these pH values, significant Al had not yet been leached from the clays in the ash, and thus, the Al is undersaturated with respect to amorphous $Al(OH)_3$, which could be most important phase in this pH range.

Table 9.11. Water analyses for NEPCO test borings. Analyzed by Scott Atkinson at MRI, PSU. All concentrations are for dissolved constituents and are reported in mg/L. V was <0.02 mg/L, and As was <0.005 mg/L.

sample date	8/29/01	9/18/01	8/29/01	9/18/01	9/18/01	8/29/02
well location	culm	culm	platform-east	platform-east	platform-west	platform-west
Field pH	3.09	2.78	11.42	11.37	11.86	11.38
Al	40	45	0.38	0.97	0.53	0.38
B	<0.02	<0.02	<0.02	<0.02	<0.02	0.01
Ba	0.03	0.04	0.08	0.1	0.09	0.09
Ca	28.1	16.5	330	230	330	320
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	0.03
Co	0.07	<0.02	<0.02	<0.02	<0.02	0.05
Cr	0.19	0.24	0.18	0.2	0.18	0.14
Cu	0.21	0.27	<0.02	<0.02	<0.02	<0.02
Fe	26.2	24.8	0.06	0.04	0.06	0.03
K	9.3	6.7	57	57	48	51
Mg	13.4	12.6	0.03	<0.02	<0.02	0.05
Mn	2.07	2.06	0.02	<0.02	0.04	<0.02
Mo	<0.02	<0.02	0.7	0.59	0.7	0.21
Na	3.11	3.36	48	46	43	45
Ni	0.31	0.27	<0.02	<0.02	<0.02	<0.02
Pb	0.011	0.011	<0.005	<0.005	<0.005	<0.02
Se	<0.005	<0.005	0.033	0.034	0.025	
Si	75	41	3.22	10.7	2.79	3.66
Sr	0.15	0.15	1.88	1.78	1.75	1.58
Ti	0.05	<0.02	<0.02	0.05	<0.02	<0.02
Zn	0.34	0.34	0.06	0.07	0.1	0.21
F	0.05	0.06	1.62	0.59	1.55	0.06
Cl	1.61	0.39	16.6	11.3	11.3	14
NO2	0.01	0.01	1.63	0.23	0.13	1.15
NO3	0.02	0.02	0.11	0.03	0.04	0.9
PO4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
SO4	460	520	680	610	650	700

Between pH values of 11.0 and 11.5, the water is at saturation or undersaturated with respect to kaolinite, which can play a larger role in the Al concentration, because H_4SiO_4 is more soluble in this pH range. Between pH 11.5 and 12.2, there appears to be another phase limiting the aqueous Al concentration. The slope of the ettringite [$Ca_6Al_2(SO_4)_3\ (OH)_{12}\cdot 26H_2O$] solubility limit plotted by Dr. Cravotta at USGS is close to the apparent boundary in the data. Myneni et al. (1998) support a value of -111.6 for the solubility product, which was used to construct figure 9.42. It appears that either ettringite, or a phase metastable with respect to ettringite, controls the Al solubility at the highest pH values in the Big Gorilla mine lake. The red asterisks among the Big Gorilla data points represent the waters collected from test borings in the ash platform. As one would expect, the ash platform waters plot in the same region as the water collected from the mine pool itself. Thus, Al concentrations are not controlled by gibbsite

and amorphous $Al(OH)_3$ at the highest pH values in this system. The presence of silica, which is necessary to form kaolinite, and the presence of sulfate and calcium, which combine with Al to form ettringite, are key to limiting the concentration of Al in the surface mine lake.

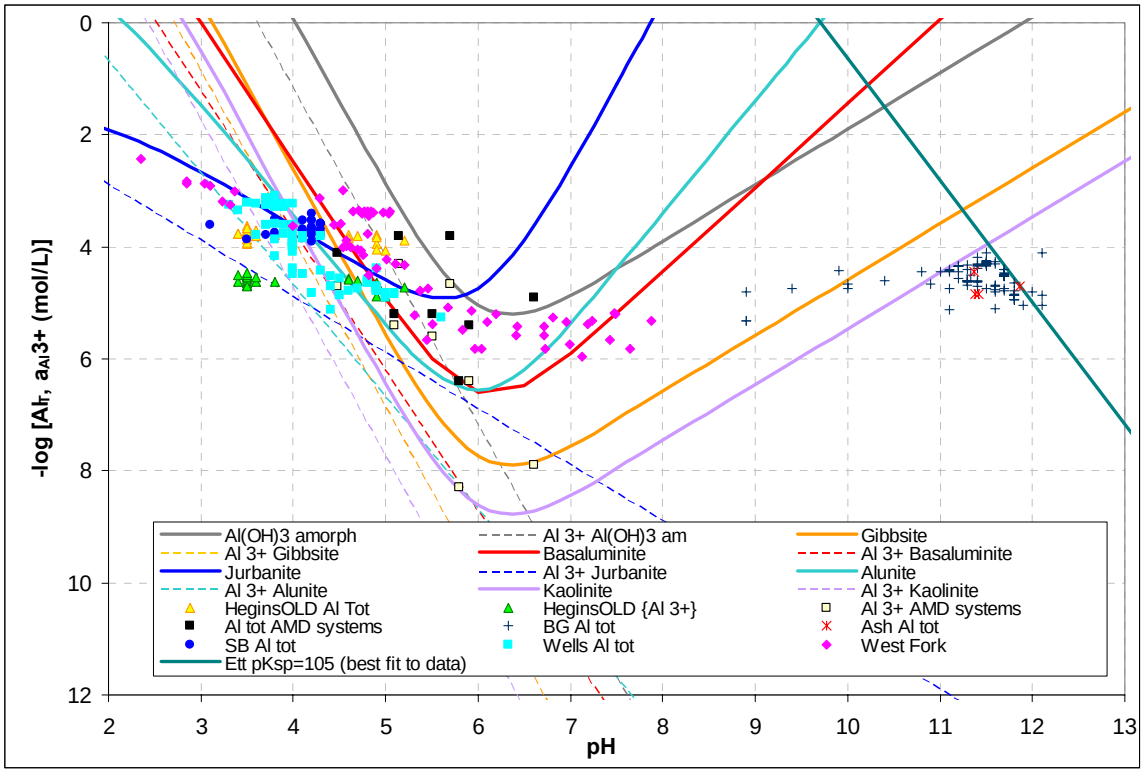


Figure 9.42. Solubility plot constructed by Dr. Charles Cravotta, USGS, with data from the Silverbrook Basin, provided by the DEP. All Al values represent dissolved and suspended constituents combined (total). Red asterisks show data from the test borings.

The water chemistry of the test boring in the ash platform sampled on 29 August 2001 was put into PHREEQC, which used the Lawrence Livermore National Laboratory database to calculate saturation indices for a variety of minerals. This database was chosen because it contains more of the minerals commonly found in Portland cements than do the other databases available. PHREEQC for Windows 2.5 (Parkhurst and Appelo, 2001) and PHREEQC Interactive RC1 version 2.5.0.2021 were downloaded from a U.S. Geological Survey webpage. PHREEQC was written in the C programming language, and uses a modified Newton-Raphson method to solve the simultaneous non-linear equations. The interactive shell facilitates the construction of input files to run the program. Although there are additional features, the basic operation of the program is the same as described by Parkhurst (1995). Alkalinity was not measured for this sample, but alkalinity for the surface mine pool is well known. Alkalinity was used to balance the charge of the solution within 1% error. Redox potential was calculated using the NO_3/NO_2 pair.

As would be expected at thermodynamic equilibrium, metals such as Fe, Mn, and Mg are supersaturated, and should form hydroxides and precipitate. The water from the test boring was

undersaturated with respect to gibbsite, and the Al present was instead more likely to be incorporated into silicate minerals under thermodynamic equilibrium conditions. The water was also undersaturated with respect to ettringite and kaolinite, which are most likely controlling the concentration of Al in the test boring water. The platform water is also shown to be significantly supersaturated with respect to saponite and nontranite, two smectite group clays. Along with calcite, which will precipitate with increased mixing of CO_2 with the water, these two clay minerals may in time form in the pore space of the ash platform below the water table.

The supersaturation of the ash platform water with respect to 14Å and 11Å tobermorite is encouraging, because tobermorite is a mineral with pozzolanic properties, and is commonly found in concretes. Processes taking place in a FBC boiler can be likened to the production of Portland cement, which is commonly made by heating a mixture of limestone and clay. In fact, the bulk chemical analysis of NEPCO and regional fly ashes is quite similar to Santorin Earth, a natural poorly-consolidated pozzolana from Italy. Figure 9.43 illustrates the composition of both tobermorites with respect to CaO, SiO_2, and H_2O (C, S, H, respectively). Calcium silicate hydrates play an essential role in the hydration reactions of most cements, and are nearly insoluble in water (Taylor, 1964). They include well-defined crystalline compounds as well as poorly crystallized minerals of indefinite composition. The 14Å tobermorite has a layered structure, which when heated to about 60ºC, loses interlayer water and shrinks to 11Å (Taylor, 1997). 14Å tobermorite occurs as a natural mineral and forms smaller and more elongated crystals than its 11Å counterpart (Fig. 9.43). The formation of 14Å tobermorite at thermodynamic equilibrium is further evidence for the long-term structural and chemical stability of the ash platform. Samples from the eastern test boring in the ash platform show elongated crystals with SEM analysis (Fig. 9.44).

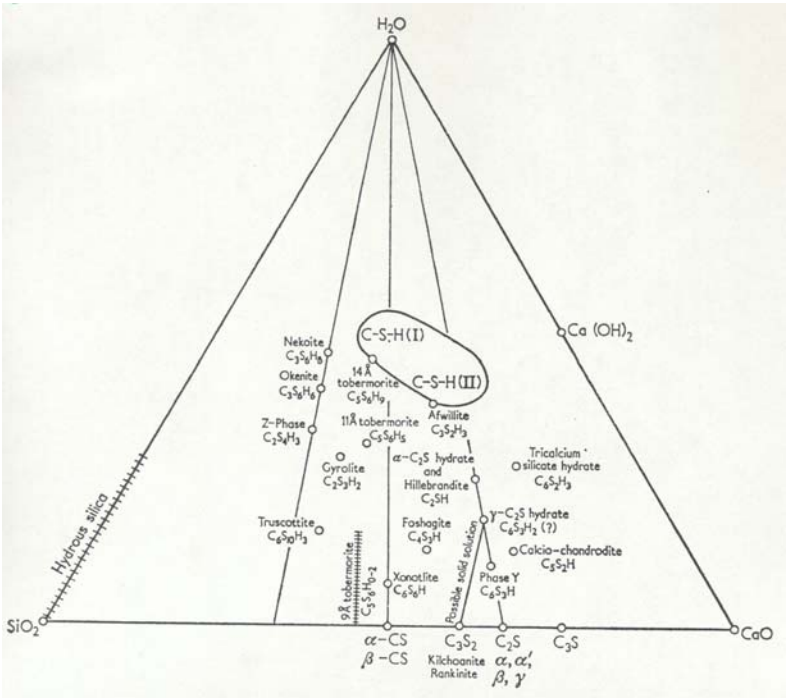


Figure 9.43. Compounds in the system CaO-SiO_2-H_2O (Taylor, 1964).



Figure 9.44. SEM image of ash from the eastern test boring in the ash platform at a depth of 50 to 52 feet. Long, thin particles are visible, and show evidence of cementitious phases forming.

The test boring within the culm bank was drilled to see if water from the Big Gorilla surface mine pool was migrating to the portion of the Mammoth Basin #1 that is filled with culm. In fact, with the exception of higher sulfate values, which are expected for water in contact with culm, the aqueous concentrations look very unlike those in the surface mine lake. The low pH values and high Fe, Al, Cu, and Pb concentrations make a good case for the reclamation of waste anthracite, as it can be a significant source of AMD within a basin (Table 9.11). All alkalinity that can be added to such waters is beneficial. Like the silt that was present in the Big Gorilla, the culm in this portion of the Mammoth Basin may be reclaimed and burned at the NEPCO plant, provided that permits are available, and the material can be dried properly.

9.5.4 Thermodynamic Equilibrium Models

PHREEQC may be used for speciation, reaction-path, advective-transport, and inverse geochemical calculations (Parkhurst, 1995). PHREEQC was also used for saturation index calculations and for mixing of waters. A saturation index (SI) is used to describe the state of saturation of a mineral, and may be defined as:

$$SI = \log (\text{ion activity product}/K_{eq})$$

When SI=0, the system is at thermodynamic equilibrium; when SI<0 and SI>0 the system is under- or oversaturated, respectively. The extent of over- or undersaturation may affect the kinetics of the reaction, but the kinetics will not be discussed further here.

SI values can be useful, but must be interpreted with caution. The thermodynamic data for the fluid and minerals of study must be accurate, complete, and gathered under conditions similar to those for which the SI calculation is being made (Langmuir, 1997). Slow nucleation, inhibition of precipitation, and precipitation of very small (submicron) particles may lead to errors in gathering data and/or interpreting SI data in practice. Also, the quantity of mineral produced is not predicted by the SI, only the relationship to thermodynamic equilibrium. If SI values are being calculated from solutions containing only very small concentrations of necessary species, it might be very easy for SI values to have large variations with continued sampling, due to error in aqueous chemical analyses. Therefore, they may not adequately describe the system. Also, because common ion effects link many mineral precipitation reactions, the reactions do not occur independently (Bethke, 1996). Despite these warnings, it still remains useful and common to calculate SI values for the characterization of an aqueous system.

Two waters were used to study the effects of mixing between the Big Gorilla mine pool and the Silverbrook outflow. The Big Gorilla mine pool chemical concentrations from 27 June 2000 at the west end of the pool and a depth of 40 feet were mixed with chemical concentrations of the Silverbrook outflow from 13 June 1997, two months before ash placement in the Big Gorilla began. It was hoped that the models would aid in pointing out changes that could be expected at the Silverbrook outflow from ash placement in the Big Gorilla. Both PHREEQC and The Geochemist's Workbench were used for mixing the two waters.

The saturation indices for over 50 minerals were calculated and the SI values for 12 key minerals were plotted with increasing concentration of Big Gorilla water (Fig. 9.45). Although some minerals for which SI values were calculated may never precipitate (ex. anorthite), calcite is readily observable. Supersaturation of water with respect to alunite appears to be an early indication of mixing of the two waters, whereas precipitation of calcite may not occur in the Silverbrook outfall until at least half of the flow is composed of Big Gorilla derived water. At a Silverbrook outfall water content of between 60 and 80%, manganite becomes significantly supersaturated and with goethite, appears the most likely mineral to form at increasing concentrations of Big Gorilla water. Thus, with an initial mixing of the two waters, the potential exists for a variety of minerals to precipitate, but with increasing concentrations of Big Gorilla water, the iron and manganese oxides and phyllosilicates again become the minerals that are most supersaturated in the water.

Results from The Geochemist's Workbench are similar to those found using PHREEQC. Alunite is also shown to be the first mineral to precipitate, followed by gibbsite and brucite, with increasing dissolution of ash. These minerals may serve as a sink for sulfates, aluminum, and magnesium in the Big Gorilla mine pool.

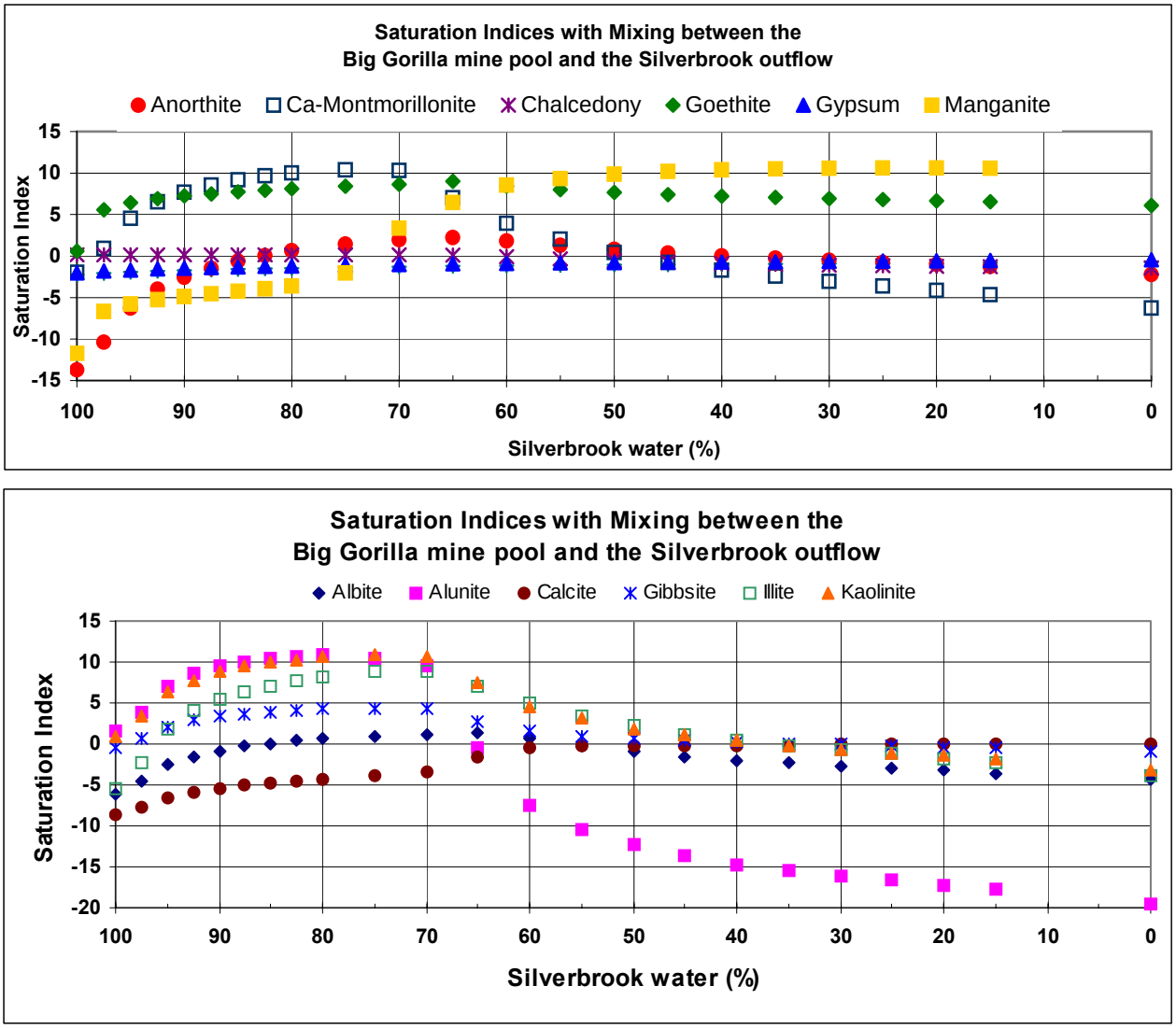


Figure 9.45. Saturation index values for 12 key minerals with mixing of the Silverbrook outflow and Big Gorilla waters.

9.6 CONCLUSIONS

The major findings of this investigation are:

1. the minepool chemistry homogenized instantly.
2. dry to wet placement provides a stable surface for the operation of heavy equipment .
3. the pore water chemistry can be modeled on Portland cement.
4. SEM and calculations showed the formation of ettringite.
5. ettringite formed as a result of sulfate in the mine water and ash and can act to sequestered heavy metals by crystal chemical substitution into its structure.
6. the elevated pH values measured during the transient phase of the project was shown not to mobilize aluminum because of the formation of ettringite.

The Big Gorilla mine pool project has been considered a success by both NEPCO and the DEP in terms of the stability and compaction of the ash terraces, the efficiency of the ash input process, and the chemistry of the surface mine pool water. The ash is being placed in an efficient manner and trace metal concentrations above the drinking water maximum allowable concentrations are not common. Meanwhile, a location for over three million tons of fly ash has been found on the site, and the formerly acidic surface mine pool will no longer present a potential safety hazard to nearby residents or allow the channeling of AMD water. In addition, abandoned culm piles are removed from local communities resulting in a further decrease in acid mine drainage production.

While the Silverbrook outflow chemistry has changed since 1989, most likely in response to land reclamation in the basin, it has been difficult to isolate the effects of ash input in the Big Gorilla on the chemistry of the outflow. To date, the change in the chemistry of the Silverbrook has not been in the form of increasing heavy metal content or other toxic parameters. However, the Silverbrook outflow should continue to be closely monitored.

When ash placement was suspended for the first significant length of time, many chemical parameters and constituents varied dramatically. With additional suspensions over the past five years, the extent of the variability has decreased. The Big Gorilla water maintained a consistently high pH value (11 to 12). Alkalinity varied with ash deposition, although the effect of sampling the mine pool at the boat ramp when the mine pool is inaccessible by boat in the winter may have some effect. A small amount of the calcium oxide (<2%) derived from the limestone added in the fluidized bed reactor appears to have been controlling the pH in the Big Gorilla mine pool. Therefore, the maximum possible pH is 12.4.

Iron, manganese, magnesium, aluminum, and zinc have all decreased significantly since ash placement began. Based on the PHREEQC and The Geochemist's Workbench models used, it is likely that the formerly acidic waters became supersaturated with metal oxides, following the beginning of ash placement, and the oxides began to precipitate. The models also predict the formation of clays derived from the chemical constituents present in the fly ash. Despite these predictions, the only physical evidence of mineral precipitation in the Big Gorilla mine pool has been the rim of calcite on the walls of the mine pool.

With current information on the response of the Big Gorilla mine pool to the ash input, it appears that the pH value of the pore water has a maximum of 12.4, which will decrease slowly as CO_2 migrates through available pores. Based on the chemistry of Well 3, it appears that there were only low levels of drainage from and/or flow to the Big Gorilla, which is offset by evaporation. Once the area above the mine pool is returned to the approximate pre-mining grade, very little water will flow through the ash plug in the former Big Gorilla mine pool, and the pH values of the measured subsurface waters will not be as high as seen in the surface mine lake. The hardening of the ash and sealing of pores will continue to make the elemental constituents of the ash immobile. Thus, one long-term effect of ash placement in the former Big Gorilla mine pool will be the prevention of acidic water production through the surface mine pool and interconnected passages.

CHAPTER 10. SOIL ADDITIVES AND SOIL AMENDMENTS

G. Nevin Strock, Richard C. Stehouwer

10.1 INTRODUCTION

The use of coal ash and clean coal combustion by-products as soil additives or soil amendments to enhance establishment and growth of vegetation on coal mined lands as well as agricultural soils has been extensively studied (Adams et al., 1972; Capp, 1978; Plass and Capp, 1974; Jastrow et al., 1981; Stehouwer et al., 1995b). Collectively, conventional coal combustion ash (fly ash and bottom ash) and clean coal combustion by-products (flue gas desulfurization sludges and fluidized bed combustion ash) are referred to as coal combustion by-products (CCB) (Pflughoeft-Hassett et al., 1996).

Certain physical and chemical characteristics of CCBs make them potentially useful in mine land reclamation for ameliorating the adverse chemical and physical conditions often associated with coal mine soils. Coal combustion by-products also have characteristics that could adversely affect plant growth or environmental quality if improperly used. Soil amendment materials, including those commonly used in agricultural production, can have both positive and negative effects on soil and environmental quality. Thus, as with other soil amendments, the use of coal combustion by-products for mine reclamation must be managed to maximize their beneficial effects while minimizing any potential for negative effects on soil and environmental quality. Such effective management requires an understanding of the physical, chemical, and biological constraints for plant growth presented by the mine soil or spoil, an assessment of the physical and chemical properties of the coal combustion by-product, and a determination if the ash (either alone or combined with other amendments) can ameliorate conditions sufficiently to allow establishment and growth of sustained vegetative cover.

10.2 NATURE AND PROPERTIES OF MINE SPOILS AND SOILS

Mining activities result in severe disturbance of surface soils, even with modern mining practices where soil materials are segregated and replaced on the surface during post-mining reclamation. Often native topsoils and subsoils in mined areas are very thin layers that become commingled during excavation and replacement. Because the original soil material was so limited there is insufficient soil to allow successful revegetation. At abandoned or “pre-act” mine sites, or at remining areas, there is often no soil material available and vegetation must be established in mine spoil material. Many mine spoils and other mining wastes contain pyrite (FeS_2) which oxidizes to generate acidity. These spoil materials can be extremely acidic ($pH<3.5$). In extreme cases, the generation of acidity results in accumulation of aluminum and iron sulfates and other salts resulting in material with high soluble salts. Textural properties of mine spoils and soils can range from very coarse with a large amount of rock fragments to very fine textured high clay material. Coarse material has very low water holding capacity and is extremely droughty, while fine textured materials may have high bulk density and low permeability. Excavation and replacement activities frequently result in highly compacted soil or spoil layers. All of these physical properties limit water and root penetration and plant available water reserves. Finally, because mine spoils and soils often originate from subsurface

layers they are typically very low in organic matter and microbially available carbon (energy). This together with chemical and physical constraints limits the diversity and activity of the microbial community they can support.

10.3 NATURE AND PROPERTIES OF COAL ASH

Combustion ash from coal-fired boilers is separated into bottom ash, which remains in the combustion chamber and fly ash which rises with flue gases. Bag filters or electrostatic precipitators remove slightly more than 99% of the fly ash particulates from the flue gases (Adriano et al., 1980). The physical, mineralogical, and chemical properties of coal ash depend on the composition of the coal burned, conditions during coal combustion, efficiency of emission control devices and the storage and handling of the by-products (Adriano et al., 1980). The American Society of Testing Materials (ASTM C 618, 2000) recognizes two classifications of pulverized coal fly ash based upon the relative concentrations of silica, aluminum, and iron oxide that correspond to a high-lime and low-lime content fly ash, Class C and F, respectively.

Fly ash generally has a silt loam texture with 65-90% of the particles having diameters of less than 0.010 mm (Chang et al., 1977; Roy and Griffin., 1982). In a study of fly ashes from various U.S. power plants, Theis and Wirth (1977) found that the major components were aluminum, iron and silicon, with smaller concentrations of calcium, potassium, titanium and sulfur. Silicon content of fly ashes ranged from 2-68% while aluminum content was 3-39% and iron content was from 3-29% (Haering and Daniels, 1991). Most naturally existing elements can be found in fly ash and a number of investigators agree that many of the trace elements in fly ash show a definite concentration trend with decreasing particle size. Concentrations of arsenic, cadmium, copper, gallium, molybdenum, lead, sulfur, antimony, selenium, thallium and zinc have been reported to increase with decreasing particle size (Davison et al., 1974; Kaakinen et al., 1975; Klein et al., 1975). Chemical compositions of 9 Class C and 49 Class F fly ashes are given in Table 10.1.

The alkalinity of coal fly ash attains 60% calcium carbonate equivalence (CCE) (Korcak, 1996). Class C coal fly ashes are high in calcium and magnesium oxides and typically have neutralizing capacities of around 50% (CCE) (Ritchey et al., 1998). (The neutralizing capacity of pure limestone is 100% CCE.) In contrast, the neutralizing capacity of Class F coal fly ash is normally less than 10% CCE, and these ashes have relatively low amounts of calcium and magnesium.

Clean coal combustion technology refers to any of several coal combustion and scrubber systems designed to reduce sulfur and nitrous oxide emissions. These technologies generate by-products with chemical and physical characteristics that differ considerably from conventional fly ash. Flue gas desulfurization (FGD) scrubbers produce relatively pure $CaSO_3$ sludges, that in some cases may be further oxidized to $CaSO_4$. In most configurations, FGD scrubbers are downstream from particulate removal so the FGD sludge contains no fly ash. Another common clean coal combustion technology is the fluidized-bed combustion (FBC) process in which coal is burned together with crushed limestone. The limestone reacts with sulfur dioxide gas in the combustion chamber to form $CaSO_4$. Bottom ash and fly ash from FBC systems are mixtures of conventional coal ash, $CaSO_4$, and unreacted limestone, some of which has been calcined to

oxide forms. Mineral composition of some fluidized bed ashes are given in Table 10.2. Chemical characteristics of FGD and FBC by-products are given in Table 10.3. The alkalinity of residues from clean coal combustion technologies varies widely. Pure FGD scrubber sludges have almost no CCE because they consist almost entirely of $CaSO_3$ or $CaSO_4$. Because alkaline reactants used in fluidized bed combustion or other clean coal combustion processes are not completely consumed, the by-products contain significant alkalinity with CCEs ranging from 20 to 80% (Terman et al., 1978; Korcak, 1980; Fowler et al., 1992).

Table 10.1. Chemical analysis (total digestion) of 9 Class C and 49 Class F fly ashes (from Miller et al., 2000).

	Class C ashes (9)			Class F ashes (49)		
Major elements (%)	Mean	Min	Max	Mean	Min	Max
Aluminum	6.8	5.1	10.4	11.0	6.3	14.4
Iron	5.1	2.9	9.5	8.0	1.7	17.4
Silicon	13.7	9.3	17.7	23.1	19.8	28.2
Phosphorus	0.36	0.10	0.63	0.14	0.08	0.26
Potassium	0.63	0.27	1.16	1.54	0.31	2.53
Calcium	17.2	10.1	22.5	3.2	0.2	11.5
Magnesium	2.19	0.44	4.18	0.89	0.30	2.70
Trace elements (mg kg^{-1})						
Arsenic	39.9	8.0	96.0	93	8	391
Boron	nd†	nd	nd	425	55.0	1108
Cadmium	nd	nd	nd	1.0	0.1	3.2
Cobalt	nd	nd	nd	47	14	120
Chromium	66.9	40.0	123.0	171	25	651
Copper	116.4	45.0	223.0	133	48	242
Lead	45.6	19.0	92.0	63	13.0	273
Molybdenum	14.6	5.3	32.0	29.8	3.7	139
Nickel	54.0	34.0	78.0	121	14.0	309
Selenium	11.4	6.0	14.2	11.4	1.0	47
Vanadium	nd	nd	nd	259	58	470
Zinc	266.0	25.0	658.0	270	27	2050

Table 10.2. Mineral composition of fluidized bed boiler ashes (Stehouwer et al., 1995a)

Mineral	Amount (weight %)
Fly ash	10-40
Calcite ($CaCO_3$)	1-29
Lime (CaO)	4-21
Portlandite ($Ca(OH)_2$)	1-3
Anhydrite ($CaSO_4$)	20-51
Dolomite ($CaMg(CO_3)_2$)†	17-31
Periclase (MgO) †	4-27

†High magnesium content samples were from a facility that used dolomite rather than limestone as the sorbent.

Table 10.3. Chemical composition of gypsum-containing clean coal combustion by-products (Miller et al., 2000)

	Fluidized bed combustion by-products	Flue gas desulfurization scrubber sludge
Major Elements	% dry weight	
Phosphorus	0.01-0.05	<0.1-0.2
Potassium	0.05-0.8	0.10
Calcium	24.0-46.0	21.0-23.5
Magnesium	0.1-1.6	0.02-0.2
Sulfur	7.2-14.0	16.6-18.6
Silicon	2.5-30.0†	0.07
Aluminum	0.3-2.0	0.03-0.2
Minor Elements	mg kg^{-1} dry weight	
Boron	95-170	75
Molybdenum	0.1-0.3	1.3
Copper	12-20	8.0
Zinc	12-20	36
Nickel	13-20	9.7
Lead	1.5-7.5	<0.1
Cadmium	0.5	0.01
Chromium	9-23	10
Selenium	0.2-0.6	0.3
Mercury	nd	0.01-0.4
Arsenic	nd	3.1

†from Stehouwer et al., 1995a

10.4 EFFECTS OF COAL ASH APPLICATIONS ON MINE SPOILS AND SOILS

According to literature reviews by Carlson and Adriano (1993), the main benefits of using fly ash on mined lands are increased alkalinity and improved water holding capacity (Stewart and Daniels, 1995). Dhaliwal et al., 1995 revisited a study site of Capp and Gillmore (1974) that used fly ash as a topsoil material on pyritic mine spoil. Even after 22 years, the fly ash treated site had higher soil pH than an adjacent area of reclaimed pyritic mine spoil not treated with fly ash. In addition, the fly ash treated area had more development of an A soil horizon and more prolific and deeper root development than the adjacent area. Spoil containing pyritic materials can have extremely high potential acidity and consequently very high ash application rates (up to 797 tons/acre) may be needed for complete acid neutralization (Capp, 1978). However, much lower applications (30 tons/acre) have been shown to increase pH on a 2.7 pH spoil (Taylor et al., 1988).

The use of such high application rates can significantly alter the textural properties of the mine spoil since fly ash will constitute over 50% of the resulting spoil-ash mixture. Capp (1978) reported that these high rates resulted in improvement in spoil texture and increased water holding capacity. Such effects are the result of adding predominantly silt-sized ash to coarse

textured spoil and would be expected with either Class C or Class F ashes. Some studies have shown improved plant growth with much lower alkaline fly ash application rates (31 tons/acre) (Fail, 1987). Spoil pH was increased by only 0.1 pH unit but the ash improved spoil texture which increased soil moisture. Determining application rates of alkaline fly ash on acidic spoils needed to increase pH requires matching total spoil acidity with ash CCE.

While fly ash amendments can clearly improve spoil quality, the extent to which pH and textural improvements will occur varies depending upon the initial quality of the spoil and the type of fly ash used. The neutralizing capacity of conventional pulverized coal fly ash is normally less than 10% CCE in contrast with some residues of clean coal technology that contain large amounts of alkaline material. In a laboratory incubation study, Seoane and Leiros (2001) reported that additions of non-alkaline fly ash (4.8% CCE) to an acidic spoil at rates of 20-40% was able to gradually increase pH to 3.0 due to weathering of silicate minerals. However, addition of both limestone and fly ash was required to achieve rapid increases in pH. Textural and water holding capacity benefits will be most likely to occur on very coarse textured spoils with a high content of rock fragments.

In several studies, addition of sufficient fly ash to neutralize spoil acidity has resulted in other constraints on plant growth. High rates of fly ash addition can increase soluble salts in mine spoils; thus an initial planting of salt tolerant species has been recommended (Capp et al., 1975; Capp, 1978). Jastrow et al. (1981) found that lime application produced better growth on an acid spoil than did alkaline fly ash amendment. The difference was attributed to boron toxicity or high soluble salts with the fly ash. Problems with high boron in fly ashes can often be minimized by using weathered fly ash rather than fresh fly ash. Because boron is relatively soluble, it is readily leached from fly ash during the weathering process. Seoane and Leiros (2001) reported that addition of sufficient fly ash to sustain a pH increase in acidic spoil resulted in production of large amounts of soluble salts that would likely have inhibited plant growth.

Another problem with large applications of fly ash is increases in erodibility. Silt-sized soil particles are highly erosive and erosivity with fly ash is even greater due to the largely spherical shape of the ash particles. Silt sized materials are also susceptible to surface crust formation which reduces infiltration rates, leading to increased runoff and consequently increased erosion. Gorman et al. (2000) found that fly ash amended spoil had much greater erosivity than unamended spoil. The high erosivity was attributed to silt grain size, spherical particles, and lack of initial aggregation. This work also demonstrated that covering with a wood chip mulch reduced erosion by about one half. In addition to surface protection, the mulch stimulated growth of fungi and mosses which stabilized aggregates and appeared to be more effective than cover crops at reducing erosion. These authors caution that while large fly ash applications may improve pH and water holding capacity, special precautions to reduce erosion potential are required (reduced slope gradient and length) and also recommend combining ash with organic amendments.

Pure FGD sludges have limited value as an amendment for acidic mine spoils. These are wet, paste-like materials that are difficult to handle and provide no alkalinity or textural benefits. Because these materials are almost pure $CaSO_3 \cdot 2H_2O$ or $CaSO_4 \cdot 2H_2O$ (gypsum), they can be used as a source of soluble calcium. Pietz et al. (1989) found no beneficial effects from addition

of gypsum for revegetation of acidic coal refuse. At some power plants, FGD sludges are mixed with fly ash and small amounts of lime to improve physical properties for landfilling. In a greenhouse study, Stehouwer (1997) found that such a FGD/fly ash/lime mixture was able to reduce acidity and permit plant growth. However, growth was much better with combined application of the FGD mix with yard waste compost.

Due to their generally high alkalinity, FBC ashes have been shown to be effective lime substitutes for neutralization of acidity in soils and mine spoils (Terman et al., 1978; Holmes et al., 1979; Korcak, 1980; Stehouwer et al., 1995a; Stehouwer et al., 1995b). The neutralizing capacity of FBC ash has been reported to range from 36 to 81% CCE (Carlson and Adriano, 1993). These materials are also effective sources of soluble calcium due to their gypsum content (Korcak, 1980). However, they can have extremely high pH (10 – 12) and high soluble salts, thus application in excess of what is needed to neutralize acidity can result in excessively high spoil pH and salt problems.

Large applications of fly ash or FBC by-products to acidic spoils can lead to mobilization of metals in the ash. This is most likely to occur if spoil acidity is not neutralized by the amendments since solubility of most metals increases rapidly as pH decreases below about 5.0. Stewart et al. (2001) found large quantities of manganese, iron, and copper were readily leached in a strongly acidic coal refuse amended with 5 – 20% of moderately alkaline fly ash. Leaching of these metals was controlled if alkalinity and potential acidity were balanced with fly ash and lime amendment.

10.5 COAL ASH RELATIONSHIP TO PLANT GROWTH

Plant growth is dependant upon a favorable combination of environmental factors to including nutrients, water, heat and air, and the absence of detrimental factors such as extreme acidity or alkalinity, salinity, or high availability of potentially toxic metals. The factor that is least optimum will determine the extent of plant growth (i.e. plant growth can be no greater than that allowed by the most limiting factor) (Brady and Weil, 2002). Seventeen elements have been demonstrated to be essential for plant growth. In addition to the elements carbon, hydrogen and oxygen that plants obtain primarily from air and water, there are six elements needed in relatively large amounts and referred to as macronutrients and eight elements needed in smaller amounts and referred to as micronutrients. The macronutrients are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. The micronutrients include iron, manganese, boron, molybdenum, copper, zinc, chlorine, and cobalt. Except for iron and manganese, these micronutrients are found sparingly in most soils and their availability to plants is often very low (Brady and Weil, 2002). Many of the micronutrients, however, can become phytotoxic if their availability in soil is increased.

Another potential benefit of fly ash as a soil or spoil amendment is as a source of nutrient elements for plant growth (Bennett et al., 1976; Chang et al., 1977; Taylor and Schuman, 1988). Of the macronutrients, fly ash can supply sulfur (Elseewi et al., 1978; Hill and Lamp, 1980) and alkaline fly ash can serve as a source of plant available calcium and magnesium (Martens and Beahm, 1976; Wallace et al., 1980; Hill and Lamp, 1980). However, fly ash is not a source of nitrogen or plant available phosphorus, and can only occasionally supply plant available

potassium. Fly ash may be a source of plant micronutrients. Selected fly ashes at controlled rates of application increased boron uptake in alfalfa (Medicago sativa) increased alfalfa yields by the addition of soluble molybdenum and corrected zinc deficiencies in corn (Martens, 1971). Increases in alfalfa yields have been attributed to an alleviation of boron deficiency by application of fly ash (Plank and Martens, 1974). FGD sludges and FBC by-products can serve as major sources of base cations, calcium and magnesium (Stehouwer et al., 1998).

Rather than a direct source of plant nutrients, the major benefit of fly ash and FBC amendment for plant nutrition is the indirect effect of pH adjustment on nutrient availability. Figure 10.1 shows how the availability of plant nutrients (and aluminum) is affected by changes in soil pH (Pennsylvania State University, College of Agricultural Sciences). Knowing the neutralizing potential and element content of these coal ash materials and the characteristics of the land application site is extremely important for effective revegetation of coal mine lands. Application rates of alkaline coal ash need to be established based on the amount needed to adjust the mine soil pH to the optimum level for the vegetation to be established. Some coal surface mine operations involve the remining of coal waste piles or coal refuse banks and coal siltation basins. Coal refuse with low pH and associated toxic levels of aluminum, iron and manganese are found to be factors most limiting plant growth (Stewart and Daniels, 1992). The detrimental effects of low pH on plant growth have been identified and addressed in detail by many authors (Thomas and Hargrove, 1974; Bohn et. al., 1985; Brady and Weil, 2002). Aluminum toxicity is a growth limiting factor for plants in many acid soils below pH 5.0 and manganese is a problem in some strongly acid soils and mine soils below pH 5.5 whose parent materials are sufficiently high in total manganese (Foy et al., 1978). As soil pH decreases below 5.5, the availability of aluminum and manganese to plants increases and may reach a point of toxicity to the plant. Figure 10.1 shows how the availability of aluminum and manganese is affected by changes in soil pH.

Iron, aluminum and manganese have been identified as the main phytotoxic elements on acid mine spoils (Berg and Vogel, 1973; Bennett, 1971). As the pH of acid soils increases, aluminum, iron, and manganese become less available to plants and at a pH somewhat above 7.0, certain plants may suffer from a lack of available iron and manganese. Extremely acid soils suddenly brought to neutral or alkaline conditions by excessive applications of lime may result in lack of plant available iron and manganese. If soil pH is increased too much above 7.0, phosphate nutrition of higher plants is affected whereby complex insoluble calcium phosphates are formed causing indigenous and applied phosphorus fertilizers to become insoluble and unavailable to plants (Brady and Weil, 2002). Applications of fly ash to soil may cause phosphorus deficiency even when the ash contains adequate amounts of phosphorus because soil phosphorus forms insoluble complexes with iron and aluminum in ash (Martens, 1971; Adriano et al., 1978; Adriano et al., 1980).

The amount of alkaline material needed to ameliorate highly acid mine spoil can be 5 to 10 times greater than is needed when applied to agricultural soils that are typically only slightly acidic. Applying coal ash as the alkaline material to acid mine soils at rates necessary for adjusting pHs in ranges favorable for plant establishment and growth may result in high levels of soluble salts and loadings of certain trace elements detrimental to plants (Stehouwer et al., 1995b).

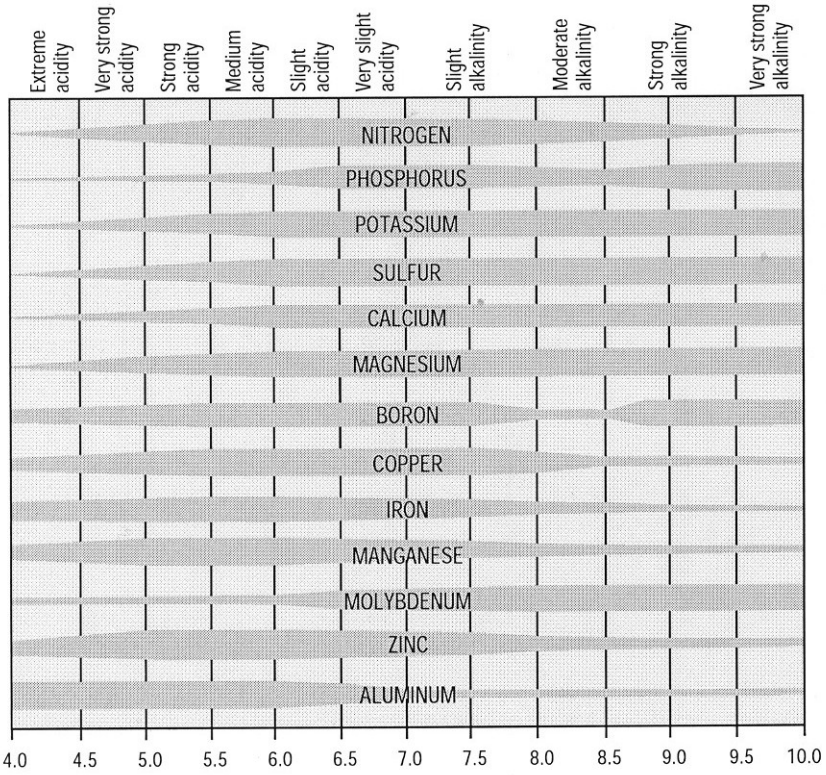


Figure 10.1. How soil pH affects availability of plant nutrients and aluminum.

When soluble salt levels measured by electrical conductivity exceed 2.0 mmhos/cm, yields of very salt sensitive plants are reduced (Rhoades, 1982). Electrical conductivity may affect seed germination at 1.0 mmhos/cm, reduce growth of some salt sensitive plants at 2 mmhos/cm, and result in severe injury to many plant species at 4.0 mmhos/cm (Jackson, 1958). Dry FGD by-products may contain high concentrations of soluble salts and some trace elements of environmental concern (Fowler et al., 1992). Plants differ markedly in their tolerance to salt levels.

Boron is a constituent of coal ash and is an essential plant nutrient. Coal ash may be applied to mine soils deficient in boron. However, boron applied in excessive amounts may be toxic to vegetation (Darmody, 1996). Boron concentrations greater than 1.0 mg/L in soil solutions may be toxic to sensitve plants (Bohn et al., 1979). Boron becomes toxic to most agricultural crops when hot water extractable boron exceeds 20 mg/kg (Hodgson and Townsend, 1969). Some agricultural crops such as alfalfa (Medicago sativa) require yearly applications of about 2.0 lb/acre of boron for maximum yields. Some sensitive agricultural crops have exhibited boron toxicities and decreased yields when boron was applied from 0.50 to 4.50 lb/acre (Stout et al., 1988). Normally, most soils contain sufficient molybdenum to supply needs for plant growth but molybdenum becomes less available to plants as spoil acidity increases or pH mixtures on coal mine spoils when legumes such as clovers (Trifolium species) and crownvetch (Coronilla varia) are grown (Bennett, et al., 1976). Molybdenum along with manganese are essential for certain nitrogen transformation in plants. Molybdenum is thought to be essential for nitrogen fixation (Brady and Weil, 2002). Increases in soil pH increase the availability of soil

molybdenum. Increases in soil pH from application of alkaline fly ash would therefore likely increase the availability of molybdenum indigenous to the soil (Doran and Martens, 1972). Excess molybdenum has induced molybdenosis (a copper deficiency) in grazing cattle when present in forages at levels of 5 ppm or higher (Suttle, 1991). If fly ash is applied in moderation (from 25 to 50 tons/acre), forages can benefit from the nutrients. However, at extremely high application rates (100 to 600 tons/acre), phytotoxicities develop with most all forage species (Bennett et al., 1976). Studies of trace metal behavior in soils found trace metal solubility and mobility decrease as soil pH increases from the acid range (Chaney et al., 1987; Woodbury, 1992). It appears that if FGD by-products are applied in amounts that will not cause excessively high pH or phytotoxic salt concentrations, there is little potential for adverse effects on soil quality from trace elements (Stehouwer et al., 1995c).

10.6 CO-APPLICATION OF CCB AND ORGANIC RESIDUALS

While coal combustion by-products can alleviate plant growth limiting factors in mine spoils such as low pH and coarse texture, plant growth may still be limited by other factors. CCBs are poor sources of nitrogen and phosphorus (Carlson and Adriano, 1993; Bradshaw and Chadwick, 1980). Mine spoils are also typically low energy environments and CCBs provide no microbially available carbon sources. As has previously been noted, spoils amended with CCBs may have poor structure, have slow water infiltration rates, and be highly erosive. Several studies have indicated that these limitations can often be overcome with combined application of CCB and organic residuals such as composts, manures, or biosolids. Conceptually, blending large amounts of CCBs and organic residuals with mine spoils is a reclamation approach that approaches in-situ manufacture of a topsoil-like material. The objectives of this approach are not only to alter the adverse spoil properties, but also to build a soil-like matrix that is capable of supporting sustained vegetative growth.

Schumann and Sumner (1999) evaluated nutrient availability in mixtures of fly ash and biosolids or poultry manure. Maximum maize (*Zea mays*, L.) growth with fly ash amendment alone was just 50% of a fertilized control soil, and maximum growth with organic amendments alone was 49 – 71% of control. Combined fly ash and organic amendments, however, achieved up to 94% of growth on the control. The ability of a fly ash and biosolids mixture to allow establishment and growth of vegetative cover under extreme conditions has been demonstrated at a Palmerton, PA zinc smelter site (Oyler, 1988). A 1:1 blend of ash and biosolids plus lime and potash was used to coat an acidic, eroded mountainside with extreme zinc and cadmium contamination. The blend was able to supply nitrogen, phosphorus, and potassium as well as water to allow vegetation to become well established and sustained for over 10 years. Stehouwer et al. (1998) reviewed four greenhouse and four field experiments in which highly acidic mine spoils or coal refuse were amended with alkaline FGD or FBC materials alone or combined with biosolids or yard waste compost. In all but one experiment, application of either the CCBs or organic amendments separately allowed plant growth to occur. One experiment with hyper acidic coal refuse amended with only compost remained phytotoxic. Co-application of FGD or FBC with biosolids or compost gave varied results. In three experiments, co-application increased plant growth over either amendment alone (Fig. 10.2). In one experiment, yield was suppressed with compost application due to nitrogen immobilization. Addition of nitrogen

fertilizer overcame this problem. In the remaining experiments, there was not a clear plant yield advantage to co-application.

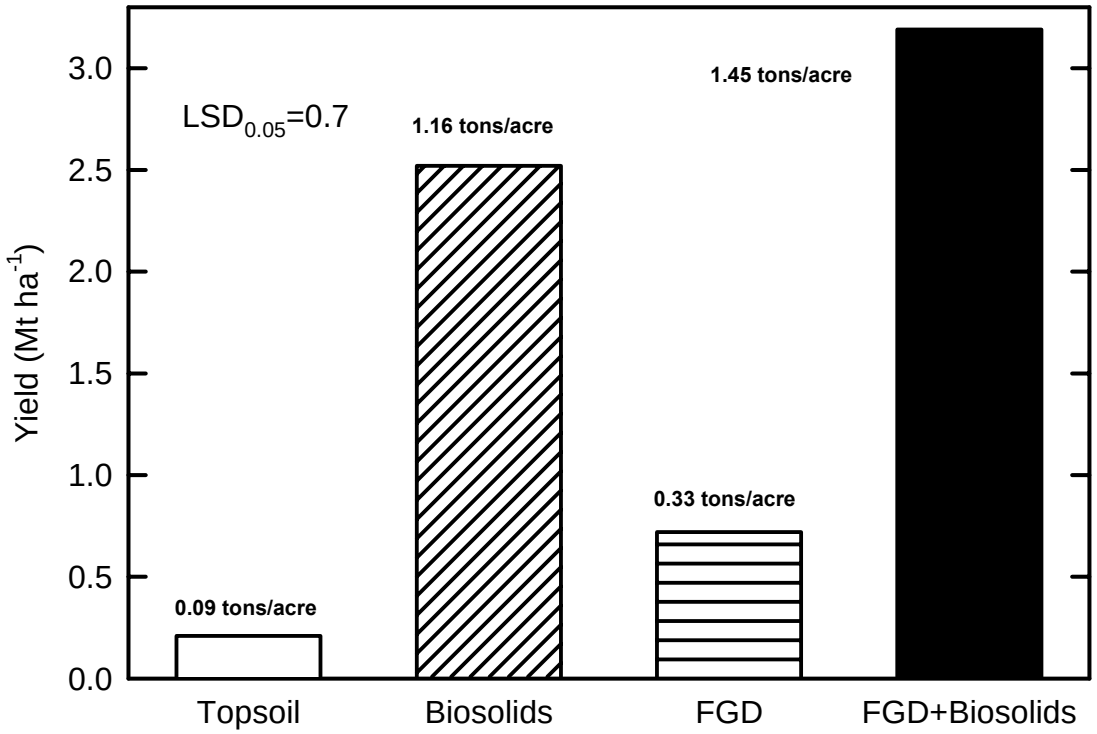


Figure 10.2. Plant yields on acidic mines spoil covered with 20 cm depth of borrow topsoil or amended with biosolids (100 Mt ha^{-1}) (45 tons/acre), FGD (670 Mt ha^{-1}) (299 tons/acre), or FGD+biosolids (Stehouwer et al., 1998). [note: 1Metric tonne/hectar = 0.445 English tons/acre].

Shumann and Sumner (1999) reported that fly ash did not supply nitrogen, phosphorus, and potassium. In fact alkaline fly ash alone exacerbated phosphorus and magnesium nutrition due to precipitation of phosphorus and cation imbalance from excess calcium. However, these macronutrients were provided by biosolids (nitrogen and phosphorus) or by poultry manure (phosphorus). These researchers also noted boron toxicity from fly ash reduced plant growth and that co-application did little to reduce boron availability. Stehouwer et al. (1998) reported that while organic amendments did little to increase spoil pH, they caused large reductions in soluble and exchangeable aluminum and iron, likely due to complexation of these metals by organic ligands. Stehouwer et al. (1998) found some evidence that co-application affected spoil chemistry below the depth of amendment mixing. One experiment showed clear evidence that co-application of alkaline FGD and biosolids increased transport of calcium into subjacent mine spoil and reduced exchangeable aluminum and iron (Fig. 10.3).

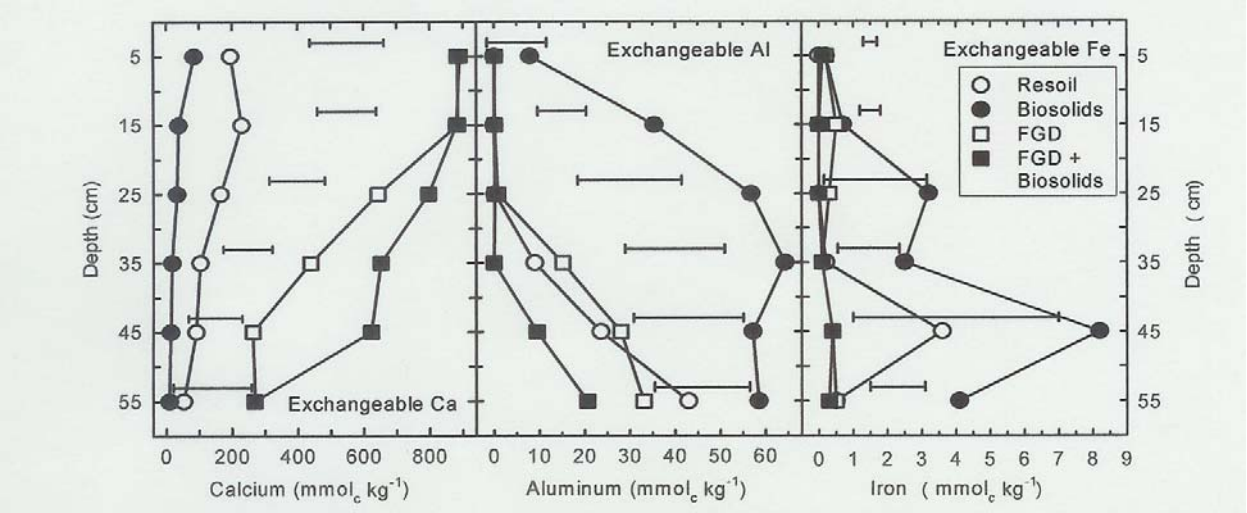


Figure 10.3. Distribution of exchangeable calcium, aluminum, and iron in the acidic mine spoil profile nine months after treatment application. (Error bars indicate the width of the $LSD_{0.1}$ value for comparison of treatment means at each depth.) (Stehouwer et al., 1998).

10.7 PLANT SPECIES RESPONSE TO DIFFERENT MINE SPOIL AND SOIL CONDITIONS

Plant species vary as to their optimum range of soil pH, needs for plant nutrients and tolerances to high levels of metals. Most plants grow best within a defined soil pH range. Table 10.4. shows ranges of soil pH for best growth of selected plants (Lyle, 1987; USDA Natural Resources Conservation Service, 2004).

Table 10.4. Soil pH ranges for selected plants

Plant Species	Soil pH Range
Birdsfoot trefoil (Lotus corniculatus)	5.0 – 7.5
Alsike clover (Trifolium hybridum)	5.2 – 7.0
Orchardgrass (Dactylis glomerata)	5.0 – 7.5
Redtop (Agrostis alba)	4.0 – 7.6
Perennial rye (Lolium perenne)	5.5 – 8.0
Switchgrass (Panicum virgatum)	4.5 – 7.5
Timothy (Phleum pretense)	4.5 – 8.0
Black locust (Robinia pseudoacacia)	4.8 – 7.5
Northern red oak (Quercus rubra)	4.3 – 6.5
Red pine (Pinus resinosa)	4.5 – 6.0
Eastern white pine (Pinus strobes)	4.0 – 6.5

Woody species vary greatly in tolerance to aluminum toxicity. In laboratory studies using hydroponic systems, hybrid poplar (Populus maximowiczii X trichocarpa) were very sensitive to concentrations of aluminum as low as 10 ppm while red oak (Quercus rubra) and pin

oak (Quercus palustris) were most tolerant of aluminum at 120-160 ppm. Yellow birch (Betula alleghaniensis), gray birch (Betula populifolia), paper birch (Betula papyrifora), Virginia pine (pinus virginiana), pitch pine (Pinus rigida) and scotch pine (Pinus sylvestris) were intermediate in tolerance to aluminum at 80-120 ppm (McCormick and Steiner, 1978).

Manganese toxicity to legumes in acid soils is well documented (Hewitt, 1946; Morris, 1948; Jackson, 1967). Manganese toxicity was observed on sericea lespedeza (Lespedeza cuneata) growing in mine spoils with a pH of 5.0 or lower. Species more tolerant of manganese like birdsfoot trefoil (Lotus corniculatus) and black locust (Robina pseudoacacia) seldom developed manganese toxicity symptoms on mine spoils with a pH greater than 4.4 (Berg and Vogel 1973; National Academy of Science, 1973).

As has been previously discussed, alkaline fly ashes and FBC by-products are effective limestone substitutes and can be effectively used to adjust spoil pH and reduce aluminum, iron, and manganese toxicity. Thus, these materials can be used to aid establishment of a variety of species on acidic soils and spoils. Furthermore, species selection should be done to match the pH range achievable with whatever alkaline amendments are used.

10.8 MANAGEMENT PRACTICES FOR LAND APPLICATION OF COAL COMBUSTION BY-PRODUCTS

Strongly acidic mine spoils often contain pyrite that continues to generate acidity as it oxidizes. For this reason application rates of alkaline materials to mine spoil must be much higher than for acid agricultural soils to neutralize both active and potential acidity (Dick et al., 1994). However, when alkaline CCBs are used for neutralizing mine soil acidity, the large application rates needed must be balanced against potential negative effects on soil quality such as potentially increased loadings of trace elements, the possibility of increased soluble salt levels causing phytotoxicity problems, excessively high pH, decreased infiltration rates and increased erosivity. Factors that may preclude the use of some CCBs are high heavy metals concentrations, high boron content, high soluble salts and low neutralization potential (Carlson and Adriano, 1993; Clark et al., 1995; Stehouwer et al., 1995a). Use of some FBC by-products could lead to conditions of high pH, high calcium and sulfate concentrations. With adequate moisture, these conditions could lead to the formation of ettringite. Ettringite is highly expansive and cementitious and would severely restrict water movement and root development (Stehouwer et al., 1995a,b).

Coal combustion by-products with high soluble salts may cause problems with seed germination and plant establishment. Surface applications of coal combustion by-products followed by incorporation of the ash into the mine spoil would decrease the potential negative impacts of high soluble salts on seed germination. Timing of the ash application plays a significant role in avoiding problems of high soluble salts on seed germination. Ash used as a soil additive or soil amendment should be applied as far in advance of plant establishment as possible to allow time for the salts to leach out of the root zone (Korcak, 1996). If applying coal combustion by-products as a soil additive or amendment after vegetation is established, application rates should be adjusted accordingly considering incorporation of the materials would not be feasible without destroying some of the existing vegetation. Under these

circumstances, applying the coal combustion by-products when the vegetation is dormant would be beneficial in avoiding problems of adverse effects to plants due to soluble salts. Use of weathered ash can alleviate problems of soluble salts. Martens and Beahm (1976) reported use of weathered ash at rates of 58 tons/acre was successful while fresh ash caused salt related problems at 29 tons/acre.

Studies of the effects of using fly ash applied to coal refuse found that bulk blends of fly ash and coal refuse had higher plant yields than surface applied ash treatments. These higher yields were attributed to the lower levels of soluble salts. Some blends of the fly ash and coal refuse had higher water holding capacities than the native sandstone derived soils (Stewart and Daniels, 1995).

Selection of equipment for applying and mixing fly ash with mine spoil or coal refuse depends primarily upon the relative roughness of the surface and the grades of slopes. On gentle slopes, contour plowing or ripping deep furrows along contours was more effective for controlling erosion. Survival of seeded grasses was more successful in the furrows and particularly during dry weather (Adams et al., 1972). Germination and growth of seeded grasses on coal refuse amended with fly ash was reported to result in poor vegetative growth partly due to dry weather but mostly due to the variable pH conditions from uneven fly ash application.

The physical and handling characteristics of CCBs can also present challenges for hauling, stockpiling, spreading and incorporating. Material can range from fine, extremely dusty dry fly ash to coarse granular bed ash. Ash may be conditioned with water to reduce dust but then may stick or bridge in trucks and spreaders. FGD sludges can be very sticky and paste-like. Wetting and drying of alkaline materials can result in formation of extremely hard clumps due to pozzolanic reactions. Conventional agricultural limestone and fertilizer application equipment may not be able to spread material with these characteristics, or may not be able to spread them uniformly or at high enough rates. When desired application rates become extremely large (223 tons/acre) it becomes difficult to uniformly incorporate such a large volume of material into the soil or spoil. In such cases, spreading in multiple lifts, with tillage after each application may be necessary.

10.9 CONCLUSIONS

Coal combustion by-products have the potential to improve mine spoil and soil quality for establishment of sustained vegetative cover. The major benefits are improved physical properties and neutralization of acidity. Most fly ashes and FBC ashes will increase the water holding capacity of coarse textured, high rock fragment spoils. Alkaline fly ash and FBC ashes contain significant alkalinity and are effective liming materials for acid soils and spoils. While CCBs can supply some plant micronutrients, notably boron, they generally are not good sources of macronutrients with the exception of calcium. The major benefit of alkaline CCBs with respect to plant nutrition is the indirect effect of pH increases on increased nutrient availability and decreased availability of phytotoxic metals, especially aluminum, iron, and manganese. Some of the shortcomings of CCBs as amendments for mine spoil revegetation can be overcome by combined application with organic amendments. Materials such as biosolids, manures, and composts can be good sources of nitrogen, phosphorus, and potassium, increase plant available

water, reduce erosivity, promote structural development and stability, and stimulate microbial activity. CCBs can also have negative effects on mine soil and spoil quality such as decreased water infiltration, increased erosivity, decreased phosphorus availability, high soluble salts, and potentially phytotoxic amounts of boron. Amending of mine spoils and soils with CCBs requires balancing both the positive and negative effects on soil quality. Application rates, timing, and methods, use of other amendments, and selection of plant species to maximize positive effects, minimize negative effects and insure that the overall result is an increase in the ability and capacity of the mine soil or spoil to support a sustained vegetative community.

CHAPTER 11. INTERPRETATION, APPLICATIONS AND CONCLUSIONS

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11.1 PURPOSE FOR EVALUATING COAL ASH BENEFICIAL USE IN MINE RECLAMATION

In recent years the beneficial use of coal ash on mine sites has become a controversial topic on a national level. As a result, the U. S. EPA has been tasked to review the adequacy of coal ash beneficial use programs nationwide, to determine if federal regulation, guidelines or other requirements are needed to help insure that the beneficial use of ash on mine sites does not cause groundwater contamination. Recently, the commissioning of a National Academy of Sciences study to evaluate the results of coal ash beneficial use was announced.

Some of the sites identified as "damage cases" by critics of coal ash beneficial use are Pennsylvania sites. In reviewing the concerns over the Pennsylvania sites, it becomes apparent that many of them were generated by misinterpretation of data and a lack of in-depth analysis of the sites. For example, coal ash has been cited as a source of contamination where background sampling shows that the contamination predated coal ash use. In other cases alkaline coal ash has been identified as the cause of acid mine drainage contamination, when the technical data demonstrate that rock strata native to the sites caused the contamination, and that the alkaline coal ash was not chemically capable of generating acid mine drainage. Cause-effect relationships have been assumed without consideration of critical factors such as the timing of events, site hydrogeology, site background conditions, and site history. Individuals and organizations with interests only tangentially related to the beneficial use of coal ash and groundwater protection have weighed in on the debate, further complicating the issue.

The U.S. EPA's review of this issue has not documented any damage cases related to the use of coal ash at coal mine sites. However, EPA has documented at least five coal ash damage cases related to utilization of coal ash at sand and gravel mine sites. These sites are noted by some critics as coal ash damage cases, but in reality, there were other waste materials deposited at each site with the coal ash, and therefore, a clear cause of any "damage" is not easily defined. The actual history of these sites is also vague or not available, which further complicates the determination of the actual cause of any "damage".

Against this background, PA DEP and the Penn State Materials Research Institute decided to develop this book, to take an in-depth look at Pennsylvania's coal ash beneficial use program. The goal was not to examine every site; such broad-based evaluations tend toward the superficial. Rather this effort was designed to evaluate in detail sites representative of various beneficial use practices. Some of the sites selected are ones that have been identified by other investigators as coal ash "damage" cases. In addition, another central goal of this effort was to investigate in detail the demonstration sites Pennsylvania has permitted in recent years to advance the science of the beneficial use of coal ash.

The following sections of this chapter summarize the information and findings of this endeavor. Section 11.2 presents a synopsis of the key findings from the previous ten chapters. Sections 11.3 and 11.4 present some of the more important scientific findings concerning ash fill integrity and chemical effects from the three Anthracite Region demonstration projects discussed in chapters 7 through 9. The remaining sections provide some thoughts for consideration by those involved in the beneficial use of coal ash in mine site reclamation.

11.2 KEY FINDINGS AND PRINCIPLES FROM PREVIOUS CHAPTERS

Approximately 52% of the electrical power produced in Pennsylvania is from coal burning power plants, and these plants produce about 10 million tons of coal ash annually. During the past five years, an average of 6.3 million tons of coal ash per year has been beneficially used at mine sites. Fifteen fluidized bed combustor (FBC) power plants operating in Pennsylvania have reclaimed more than 3,400 acres of abandoned mine lands within the past 15 years. These 15 FBC plants have consumed 88,551,078 tons of coal refuse and produced 58,188,180 tons of alkaline coal ash from 1988 to 2002.

There are 21 pulverized coal (PC) power plants operated by major utilities in Pennsylvania. These PC power plants burn about 45 million tons of coal and produce about 5 million tons of ash annually. The FBC plants produce more ash per ton of fuel burned than PC plants because the coal refuse contains more inorganic mineral matter than the coal. About 80% of the coal ash beneficially used for mine reclamation in Pennsylvania is from the FBC power plants.

The geologic setting of the Anthracite and Bituminous Coal Fields of Pennsylvania provides a foundation for much of the subject matter in this book. Pennsylvania was blessed with abundant coal reserves. Along with this blessing of abundant coal reserves, Pennsylvania was also bestowed with somewhat of a curse of abundant abandoned mine land problems----including greater than 189,000 acres of abandoned, unreclaimed surface mines, more than 3,100 miles of stream polluted by acid mine drainage, and thousands of mine subsidence features, mine fires and other mine hazards. The physiography, geologic structure, stratigraphy and hydrogeology of the anthracite and bituminous coal regions are significantly different, but there are substantial similarities in the beneficial use of coal ash in these regions to reclaim abandoned mine lands and remediate acid mine drainage problems. The anthracite coal fields have the most significant abandoned mine land reclamation problems due to the complexity of the geologic structure, the thickness of these coals, and the hydrology of the minepool systems. The bituminous coal fields have the greatest number of acid mine drainage discharge problems and the most severe concentrations of acidity, iron and other parameters of the acidic drainage, due to the stratigraphy and depositional environments (i.e. greater sulfur contents) of these coals and overburden strata.

The physical properties of the coal ash make it an ideal material for backfilling abandoned mines, and its chemical characteristics promote further usefulness of coal ash as a stabilized product and component in cementitious grouts for abatement of mine subsidence features and other mine hazards. Coal ash generally contains approximately 60 to 70% silt-size particles, and 30 to 40% sand-size particles, which classifies it as a silt loam in a soils

engineering context. Standard laboratory and field tests used in soils engineering practices are specified in DEP regulations and permit conditions to determine the strength or bearing capacity of the coal ash. There are established interrelationships among the laboratory Proctor Density Test, the theoretical Maximum Dry Density and the Optimum Moisture Content (Fig. 3.2), which are evaluated to ensure that field compaction results achieve 90% of the standard laboratory maximum density. Monitoring data from more than 10 years of test data in DEP files for four FBC ash sites showed that maximum dry densities varied from approximately 70 to 105 lbs/cu.ft. (mean = 85 pcf), the optimum moisture content varied from 16 to 38% (mean = 25%), and field compaction tests were almost always 90% or higher. The engineering and monitoring data on the physical properties of the coal ash placement at mine sites document that the compacted ash backfills have sufficient bearing capacity to support a variety of structures and other post mining land uses.

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, such as the 209 acres reclaimed at the Mt. Carmel cogeneration plant site and the 113 acres reclaimed at the Wheelabrator site. The evaluation of more than 15 years worth of groundwater monitoring data for the case study sites presented in Chapter 4, and other permitted sites throughout the anthracite region, has not resulted in any significant findings of environmentally damaging groundwater pollution cases, as measured at key downgradient minepool monitoring points. For example, the placement of more than 15 million tons of coal ash from the Gilberton Power and Schuylkill Energy Resources FBC plants in the Mahanoy Creek watershed did not result in significant median aluminum increases in any of the downgradient monitoring wells, and the median aluminum concentration of the Gilberton shaft and Packer V minepool discharges have been relatively constant at less than 1.0 mg/L from 1986 to 2003, despite the relatively high aluminum (and iron) concentrations in the ash. At least two sites discussed in Chapter 4 produced a significant increase in alkalinity concentrations, or reduction in acidity or other analytes that is attributable to the beneficial use of coal ash on these sites.

The development of realistic groundwater monitoring plans for anthracite coal ash sites should include some combination of monitoring wells and shafts or minepool overflow discharges, because each of these groundwater monitoring tools was shown to have advantages and disadvantages, and there is no guarantee that any of these tools alone, is sufficient. The groundwater monitoring data for some of the case study sites and the hydrologic budget discussion in Chapter 4 demonstrate that the “high and dry” concept of placing relatively dry (optimum moisture content) ash into a relatively dry mine environment is working well.

The beneficial use of coal ash in mine reclamation and mine drainage remediation in the Bituminous Coal Region of western Pennsylvania includes: a) remining of large coal refuse piles, b) the use of coal ash as an alkaline addition material, and c) use as a pit floor and/or final backfill capping material as shown in Chapter 5.

The use of FBC ash in the remining 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. A downgradient

monitoring well (MW-1) that was severely degraded by AMD, showed a steady trend of declining concentrations of acidity, iron, manganese and sulfate throughout the remining and reclamation period (1988 to 2004). In addition, pollution loads and flows have decreased at the four largest seeps from the Revloc site. The major mechanism for the decrease of mine drainage pollution at the Revloc site 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.

Remining and partial reclamation of the McDermott active surface mining permit area caused an increase in AMD degradation. Overburden analysis data in the permit application identified strata with the potential for AMD production and the applicant formulated an alkaline addition plan, using FBC ash, to address this deficiency in neutralizing material in the overburden. Water quality data indicate that the large quantity of coal 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. Water quality data at the McDermott site show that, while the ash did not prevent AMD formation, is also did not cause pollution in terms of increased non-AMD toxic metals in downgradient monitoring points.

The Abel-Dreshman site is an abandoned bond forfeiture surface mine site in Clarion County, Pennsylvania, where the use of FBC ash in the reclamation of the site resulted in an improvement in downgradient water quality. Overburden analysis data for this site show that the site overburden had significant potential to generate AMD. The use of ash on the site, including the addition of a layer of compacted ash on the surface of the backfill, appears to be generating alkalinity, whereas the overburden on site did not have the capability to do so.

Coal ash has been used in mine subsidence control and mine fire control in Pennsylvania since at least 1965, when the Bureau of Mines of the U.S. Dept. of the Interior and the PA Dept. of Mines and Mineral Industries cooperated in a project to build subsurface barriers with coal ash to control the Centralia Mine Fire. These state and federal agencies developed specifications for various mixtures of coal ash, Portland cement, sand, and other materials for use in mine subsidence “flushing” projects and mine fire control projects. The Office of Surface Mining Reclamation and Enforcement (OSMRE) of the U.S. Department of the Interior and the DEP Bureau of Abandoned Mine Reclamation (BAMR) are continuing to use similar ash cement grout mixtures in specifications for mine subsidence control and mine fire control projects in the anthracite and bituminous regions of Pennsylvania.

The cropfall type of mine subsidence features, that are prevalent in the Southern Anthracite Field, present a significant challenge in abandoned mine reclamation efforts because of the general lack of adjacent backfill materials. Conventional backfill materials, or concrete, have resubsided shortly after completion of previous reclamation projects. The Sharp Mountain cropfall project described in Chapter 6 is an innovative approach to abating the mine subsidence problems, utilizing FBC ash in formulating ash cement grout mixtures, and using PC ash as a bulk fill material. Various mixtures of FBC ash and Portland cement or cement kiln dust (CKD) were evaluated to determine their relative strengths, bearing capacities, and cost-effectiveness.

Coal ash cement grout mixtures have also been effectively used in acid mine drainage remediation projects in the Bituminous Coal Region of Pennsylvania. At the Fran site in Clinton County, a FBC ash grout was pressure injected in boreholes drilled on a backfilled surface mine directly into buried pods of acid-producing materials to fill void spaces and encapsulate the pyritic materials with the cementitious mixture. An overall improvement in water quality of the post-mining discharges occurred at the Fran site, and the mean concentrations of AMD parameters decreased by 30 to 40% in some of the discharges. FBC coal ash was also used to form an impermeable cap at the reclaimed McCloskey surface mine site in Clearfield County, in order to promote a reduction in the flow of post-mining AMD discharges from the site. The coal ash cap at the McCloskey site has not generated any secondary pollution problems in the receiving stream, and has allowed the stream to support a population of fish, which would not previously survive there.

The Ellengowan and Shen Penn demonstration projects described in Chapter 7 are related to the first of three one-of-a-kind Waste Demonstration Permits issued to evaluate alternative ash placement methodology in the anthracite region (i.e. alternatives to the conventional coal ash beneficial use requirements of placing relatively dry (optimum moisture content) ash in a relatively dry mine environment, at least 8 ft. above groundwater levels). The Ellengowan demonstration project was a necessary precursor to the three Waste Demonstration Permits in order to develop tangible data on a small scale before embarking on the full-scale demonstration projects. The Ellengowan silt dam was within the approved ash disposal area on the Reading Anthracite surface mining permit, and it contained about 9 ft. of water wherein two ash placement techniques were evaluated: direct dry-to-wet end dumping of ash into the water, and slurry delivered, wet-to-wet placement. Both placement techniques were successful in the shallow water impoundment. Slurry placement of the ash was found to be an adequate approach if the slurry is allowed to flow into shallow standing water in a slow delta-like spreading flow of material. Unfortunately, the Shen Penn Waste Demonstration Permit was never activated after issuance, due to the ash tax imposed on the project. The water-filled mine hazard remains unchanged.

The Knickerbocker demonstration project described in Chapter 8 is the second Waste Demonstration Permit issued to evaluate the alternative ash placement technology of using an ash slurry pipeline to fill a dry abandoned surface mine pit (i.e. wet-to-dry placement). A water/ash slurry consisting of a mixture of 60% (by volume) minepool water pumped from the Maple Hill shaft and 40% coal ash from the SER cogeneration plant was delivered to the Knickerbocker pit in a 10 inch diameter high-density polyethylene pipe, extending for a distance of about 1 km from the power plant. Discharge of the slurry into the abandoned surface mine pit was controlled so that laminar flow conditions were maintained, because turbulent mixing of the slurry would result in excessive turbidity in the transporting water or the water infiltrating back into the minepool. When placed in a manner that allowed the transport water to flow in a slow and laminar fashion, the ash dropped out of suspension rapidly and resulted in a dense, strong compacted fill onto which mining equipment could immediately drive (compaction of the ash was routinely above 90%). The use of cement kiln dust (CKD) as a material to augment the properties of the slurry appears to make a beneficial contribution to material strength, but it is believed that this is partly due to enhancement of the packing efficiencies of the slurry material.

The Big Gorilla demonstration project described in Chapter 9 is the third Waste Demonstration Permit issued to evaluate alternative ash placement technology of placing relatively dry (optimum moisture content) ash into a water-filled abandoned surface mine pit (i.e. dry-to-wet placement). Early in the process of filling the pit with FBC ash from the NEPCO power plant, two significant findings were recognized: a) the pH of the 80 ft. deep mine water impoundment had changed from a background water quality of pH 3.6 to a pH of approximately 11, homogeneously throughout the impoundment, due to the unreacted calcium hydroxide in the FBC ash, and b) the physical properties of the completed ash terrace, resulting from the placement technique of end-dumping the ash into the standing water, had adequate stability and bearing capacity to support heavy equipment, meet the DEP compaction requirements, and allow an orderly advancement of the dumping face from east to west, without causing turbidity in the western portion of the impoundment. Detailed scientific research produced three additional significant conclusions: c) the pore water chemistry within the completed coal ash fill closely resembles the chemistry of pore water solutions in conventional Portland cement and concrete products, d) the mineral ettringite has formed and is abundant in the completed ash fill, which is an important component in the cement formulation process, and e) the relatively high sulfate concentrations of the mine pool chemistry were necessary to promote the formation of the ettringite, and then the ettringite provides an additional environmental benefit by sequestering heavy metals.

Some physical and chemical characteristics of coal ash make it useful in mine land reclamation for ameliorating the adverse conditions associated with many coal mine soils. The major benefits are improved physical properties and neutralization of acidity. Most PC ashes and FBC ashes will increase water holding capacity of coarse-textured, high-rock-fragment soils and reduce compaction in heavier textured soils. The use of coal ash as a soil additive or soil amendment reduces mine soil acidity and provides plant nutrients. Seventeen elements have been demonstrated to be essential for plant growth, of which the macronutrients include nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur; while the micronutrients include iron, manganese, boron, molybdenum, copper, zinc, chlorine, and cobalt. Boron and molybdenum are examples of constituents in coal ash that are essential plant nutrients. Amendment of mine soils and spoils with coal ash requires managing application rates, and selection of plant species to maximize positive effects, minimize negative effects and insure that the overall result is an increase in the ability and capacity of the mine soil or spoil to support a sustained vegetative community.

11.3 ASH FILL INGEGRITY AND STABILITY

11.3.1 Mechanical Properties

The mechanical properties of structural fills for restoration of minelands can be reduced to three categories:

- density
- bearing capacity
- permeability

All of these mechanical properties relate to potential end uses of the restored minelands such that industrial development could occur on the land. Compaction is related to end use through the optimum moisture content of fly ashes, usually between 8 and 20% (Fig. 11.1), and in turn relates through Proctor density measurements to a requirement of 90% or greater as determined with a Troxler nuclear density moisture gauge.

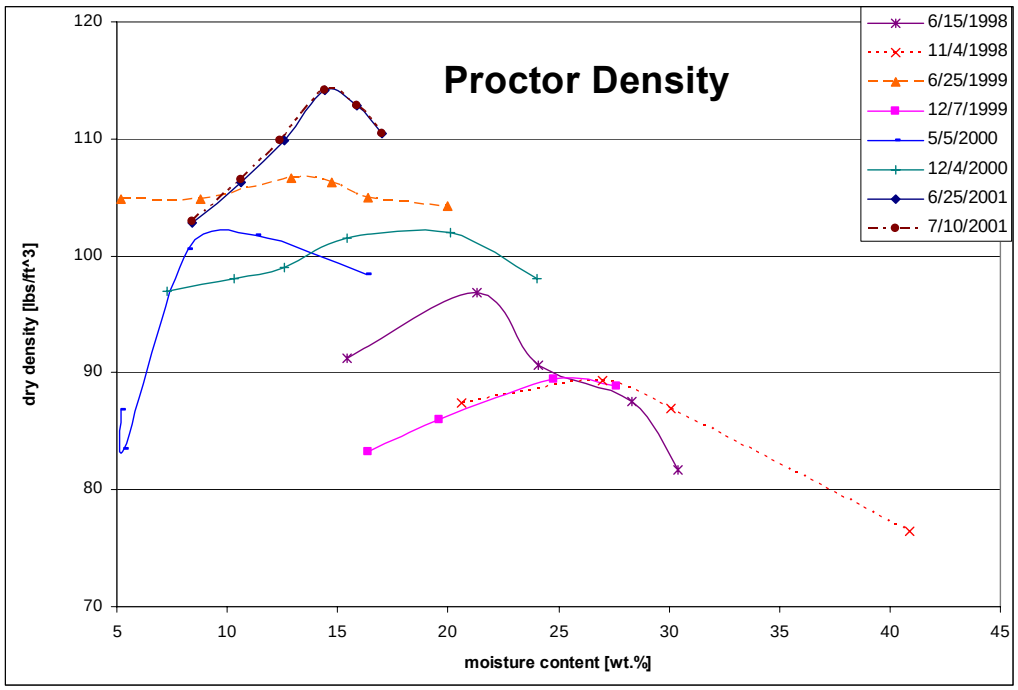


Figure 11.1 Range in proctor density measurements for a single FBC facility.

At these densities, bearing capacities are typically in excess of 4000 pounds per square foot. Split spoon sampling following ASTM D 1586 is used to provide additional indication of the structural stability of the fill. For most mineland projects, 50 blow counts per foot with a standard pound is considered the point of rejection and further attempts to penetration stopped. Structural fills meeting these minimum geotechnical requirements are more than adequate for the construction of foundation walls for industrial construction. A hydraulic conductivity between 10^{-5} to 10^{-6} cm/sec, comparable to requirements for closures of hazardous landfills, limits ingress of fluids, which under heavy traffic load or earthquake could become unstable and fluidize. Since the vast majority of reclamation projects represent a fill scenario, no requirements for the angle of repose are presented.

The primary reason for attempting a wet-to-dry ash remediation project is the elimination of dangerous conditions that have been recognized as threats to public health and safety. The technical and economic issues addressed by this approach of reclamation are: 1) materials handling, 2) reliability of delivery, 3) disposition of delivery water, 4) mechanical stability of the placed ash, and 5) economics of the methodology.

Delivery in the form of a dense slurry to the deposition area eliminates all issues of dusting from the ash handling and truck traffic on the access roads; it further eliminates the need for watering trucks and the associated atmospheric emission from delivery and water vehicles. The experience gained from this demonstration support the conclusions that down time from failure of the delivery piping and clogging of delivery piping was minimal. It was necessary to pump the slurry and not rely upon gravity feed. The water used to carry the ash through the delivery piping was re-circulated back to the combustion facility and reused. Monitoring of the waters in the flooded deep mines beneath the demonstration site did not detect any influence from the surface activities. The practice of recycling the delivery water was discontinued later in the demonstration and the water allowed to re-enter the deep mine from which it was drawn, with no observed impact. The placed ash was shown to possess a bearing capacity sufficient for trucks to drive on the surfaces immediately adjacent to the incoming ash. A sub-study conducted to evaluate the impact of CKD additions to the ash slurry suggested that a recognizable benefit from enhanced particle packing could be gained by its use and the researchers speculated that enhanced cementitious behavior would also occur if 1) the CKD was adequately mixed during placement and 2) of sufficient quality to improve the alkalinity of the pore fluids in the placed ash. Finally, an economic evaluation by the company comparing the delivery of ash for placement by truck, to belt delivery, and to a dense slurry demonstrated a remarkable 97% reduction in cost by using the dense slurry compared to the truck delivery approach. This approach has the potential to significantly extend the amount of mine lands that could be recovered per unit cost.

The structural and chemical stability of wet or dry ash placement into standing water, in our opinion, is not limited in any scientific way to the size of the reclamation project, nor to the geometry of the pit. However, consideration should be given to the size as it relates to the projected scope in terms of the available ash. A project should not be started that cannot be completed in a reasonable time frame or that cannot be completed with the projected volume of ash generated by the permit holder of the project.

11.3.2 Chemical Integrity

The following sections will examine the anticipated changes in the ash fill as it undergoes chemical reaction resulting in the hydration of the mineralogical constituents of the ash and will attempt to provide bounding calculations on the anticipated durability of the ash fill based upon the most soluble component of the phase assemblage. The sections will also provide some insight into mechanisms for the sequestration of metals associated with the mix.

11.3.2.1 Paragenesis of mineralogical assemblage in the ash

The mineralogy of the NEPCO ash was quantified and reported in table 9.6. Some of the mineralogical constituents of the ash remain inert with respect to the chemical reactions that take place within the ash fill. Quartz, mullite, and hematite from the NEPCO ash fall into this category. The pore fluids were sampled and determined to have a pH of 12. Loop et al. (2003) demonstrated that this pH was in part a result of the fluids striving to reach a pH of 12.45, the equilibrium value for portlandite, and the reactions with atmospheric carbon dioxide in an open system precipitating calcite. The high pH and the presence of both gypsum and sulfates in the

mine water are responsible for the reaction of the thermally altered clays to form ettringite and possibly gysmondine.

$$\underset{\text{Clay}}{\text{Alumino-silicate}} + \underset{\text{gypsum}}{CaSO_4 \cdot 2H_2O} \rightarrow \underset{\text{ettringite}}{Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 24H_2O}$$

Ettringite is an important component of the alteration of the ash since it has been demonstrated thermodynamically that it is not only responsible for limiting control of the solubility of aluminum in the mine-pit lake waters at high pH (Fig 11.2), but it is also an important component in the cementitious reactions that are taking place within the ash fill and an important control for arsenic sequestration. Scanning electron microscopic (SEM) characterization of placed ash has visually confirmed the development of ettringite (Fig. 11.3).

The high alkalinity also results in a large amount of meta-clay undergoing pozzolanic reactions with the formation of hydrous calcium silicate phases. Thermodynamic modeling has confirmed the existence of 14Å tobermorite. This phase is the crystalline equivalent of C-S-H, the glue in Portland cement. Although the thermodynamic calculations have been conducted for a phase that contains no aluminum, C-S-H that forms under real world cement hydration conditions always contains a finite amount of aluminum substitution that is at the maximum solubility limits (Barnes and Scheetz, 1989).

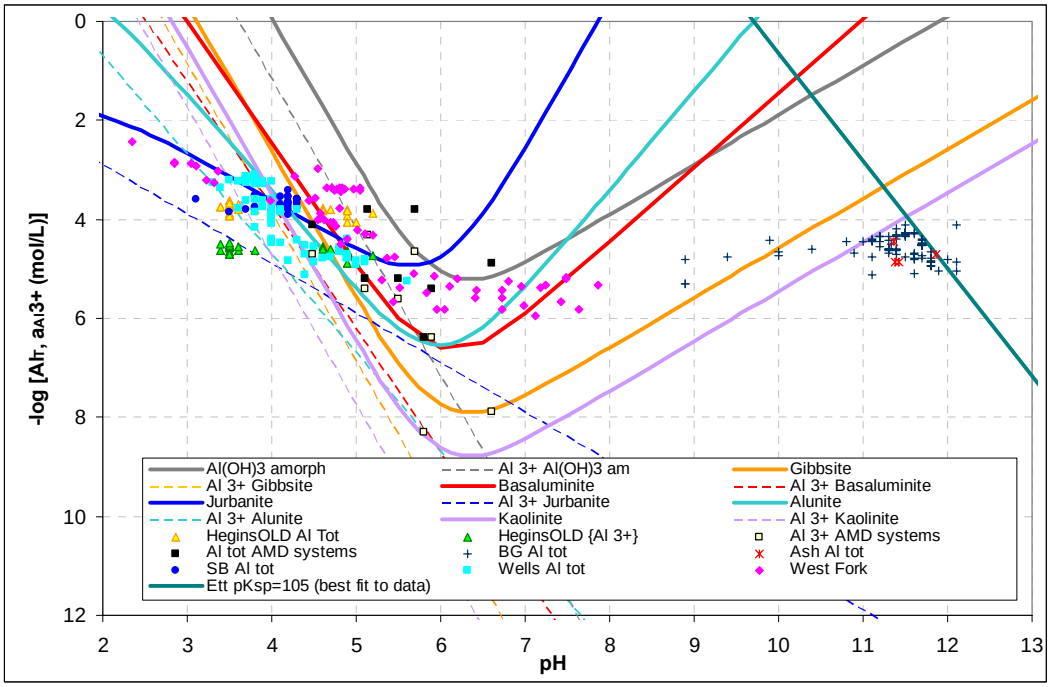


Figure 11.2. Thermodynamic control over the solubility of aluminum in AMD and the Gorilla mine-pit lake waters. Plot constructed by Dr. Charles Cravotta of the U.S. Geological Survey, with an ettringite solubility line altered by the authors to best fit the Big Gorilla data.

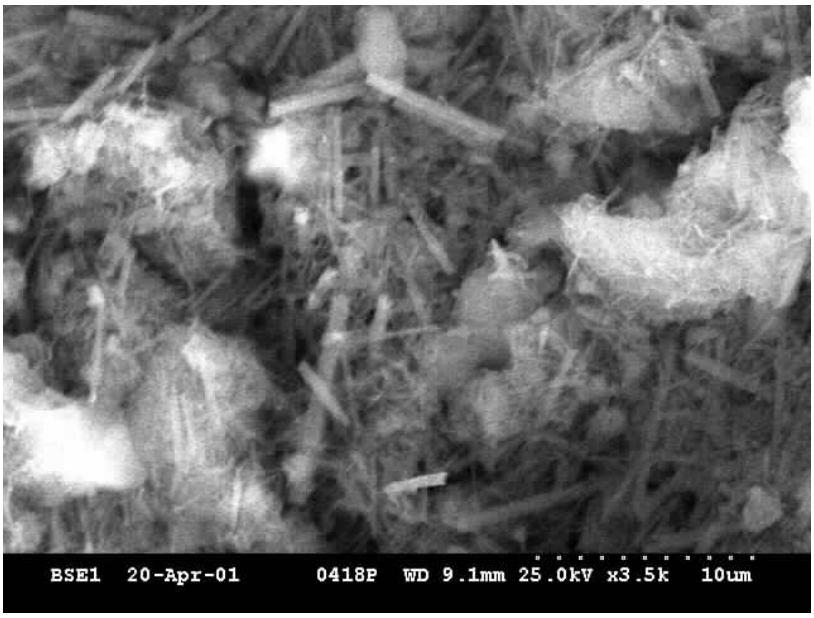


Figure 11.3. Scanning electron micrograph of ettringite growth in FBC ash.

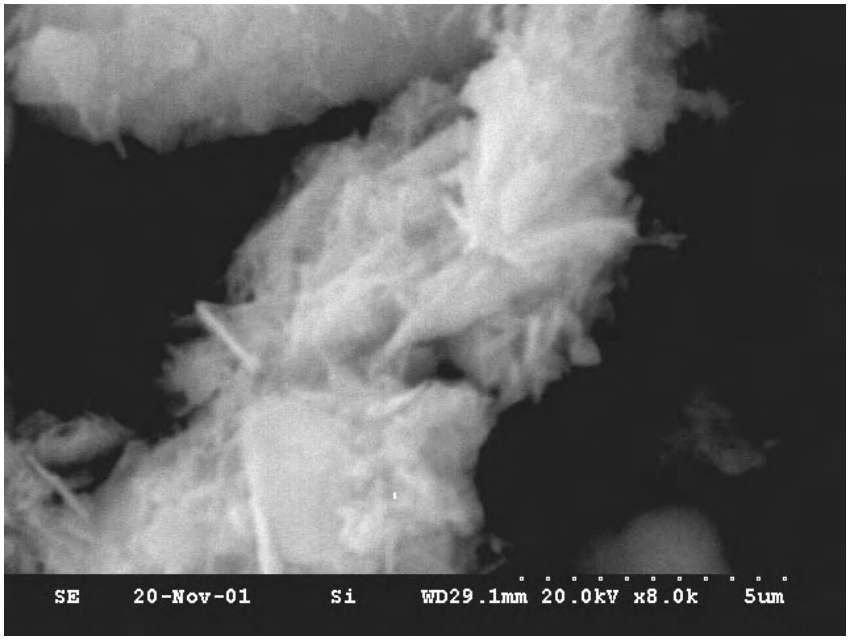


Figure 11.4. Development of C-S-H in ash.

Thermodynamic calculations also suggest the formation of gysmondine, a calcium zeolite in the assemblage of reaction products in the ash. Although this particular zeolite has not been identified in the ash via SEM characterization, the presence of zeolites in hydrating cementitious systems is well documented (Grutzeck et al., 1997, 1999, 2003). Finally, the thermodynamic calculations also suggest that in the presence of atmospheric carbon dioxide, common carbonate

minerals of the alkaline earth elements are forming, including calcite and to a lesser extent, whiterite.

Although these FBC ashes are not strongly pozzolanic, the presence of large amounts of thermally altered clays in the presence of an alkalinity source that will raise the pH in excess of 9.5 results in hydration products forming that are not unlike those which are formed in the Portland cement system. The similarities offer us an unprecedented opportunity to model the behavior of these structural ash fills

11.3.2.2 Longevity of the ash fill

The primary question that is most commonly asked of a structural fill like the Big Gorilla project is "How long will it be stable?" This is a fair question that can be addressed in several ways. Subsequent calculations will attempt to provide bounding calculations that will bracket anticipated longevity questions based upon several different approaches describing the ash fill.

During the course of the ash placement, both compaction measurements on the ash fill and hydraulic conductivity measurements were made. It was determined that the hydraulic conductivity of the ash was 1 x 10^{-6} cm/sec, a value not atypical of others reported for ash monofills (Ghosh and Subbarao, 1998). The structural fill can be represented as a homogeneous body in which water movement will remain in a laminar flow condition. With these assumptions, Darcy's law can be used to describe the time it would take for a given volume of water to flow through the mass.

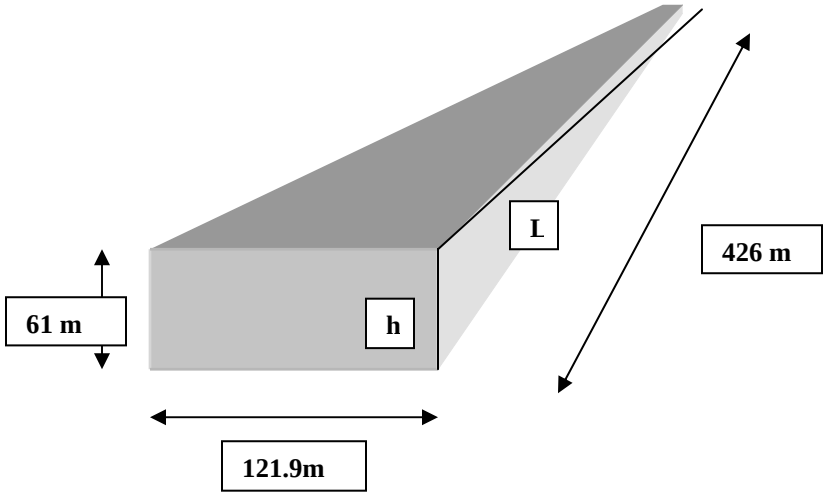


Figure 11.5. Model for calculation of hydraulic conductivity.

$$Q = KIA$$

Where:

Q = flow rate (vol/time)
K = hydraulic conductivity (1×10^{-6} cm/sec)
I = hydraulic head (h/L)
A = cross sectional area of the pile (cm)

The compacted mass of ash in the Gorilla represents approximately 60 million cubic feet of ash. If the porosity is approximately twenty percent, the volume of ash contains about 12 million cubic feet or about 51 million gallons of pore water. Using Darcy's Law, one can determine the time required for a single gallon of this 51 million gallons of pore water to flow through this modeled system based on the conservative assumptions that the hydraulic head is the complete thickness of the fill. Using the stated assumptions and the dimensions of the Big Gorilla pit and assuming a rectangular parallelepiped as shown in Figure 11.5, an estimated 3,000,000 years is calculated for that one gallon of pore water to move through the entire ash body. It must also be recognized that as this water moves through the fill, it will become alkaline with the fill acting as a large alkaline reservoir.

The initial calculations were conservative, based on a hydraulic head of ~15% compared to the more commonly encountered 1% head. The corresponding time interval for the smaller gradient is well in excess of 10,000,000 years.

The paragenesis of hydrated phases in the ash structure has the potential to form large quantities of C-S-H from the 63 wt% thermally altered clays. Using the model for the ash structure based upon a Portland cement model suggested by thermodynamic calculations of the pore fluids, a portrait of the long-term behavior of the ash structure can be constructed. Figure 11.6 is a schematic representation of the resulting phase assemblage and pH.

Stage I, [To – T1] represents a period when the pH of the ash structure is controlled by the buffer established by portlandite and C-S-H. The leachates will remain at a value of 12.45 until such time as all of the portlandite has been removed. Table 8.1 details the reported solubility product constants for the phase assemblage in the ash structure; as can be readily seen, portlandite is the most soluble component of the system.

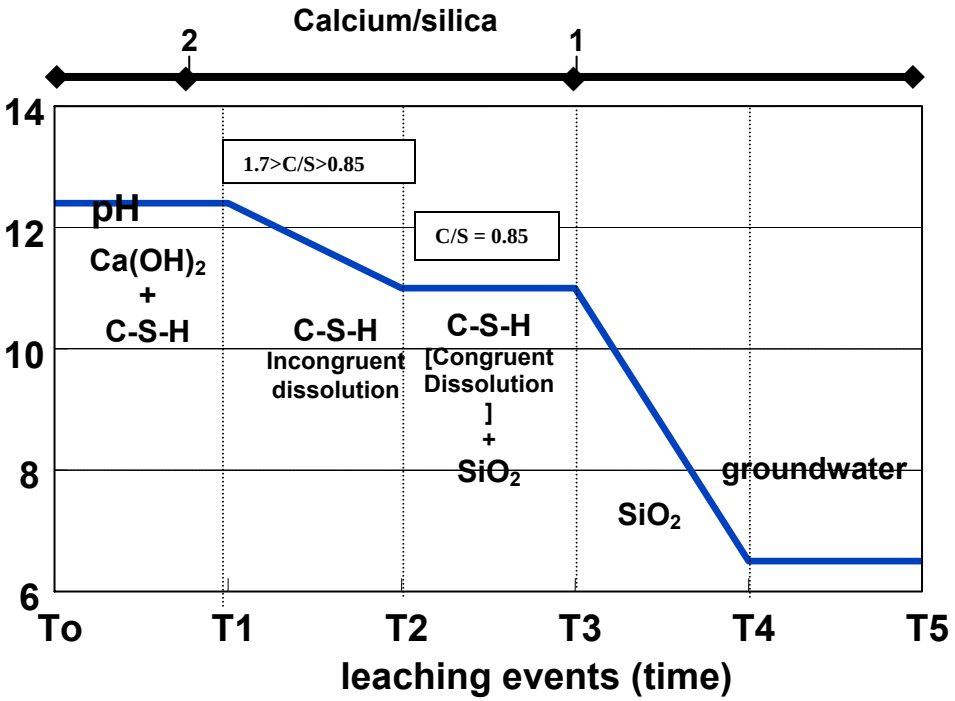


Figure 11.6 Effects of leaching on pH of C-S-H-portlandite-silica system as a function continued leaching. (after Atkinson, 1985)

Table 11.1. Summary of the solubility products of phases in the ash structure.

Name	***Formula***	***log K_{sp}***	***reference***
Portlandite	$Ca(OH)_2$	-5.31	Allison et al. (1992)
14Å tobermorite	$Ca_5Si_6O_{16}(OH)_2 \cdot 4H_2O$	-14.6	Geelhoed et al. (2002)
Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$	-111.6	Myneni et al. (1998)
Brucite	$Mg(OH)_2$	-16.79	Geelhoed et al (2002)
Calcite	$CaCO_3$	-8.48	Geelhoed et al (2002)
Gypsum	$CaSO_4$	-5.2	Rothstein et al. (2002)

Bounding calculations can be conducted for the leach interval To-T1 based upon a) ash structure control of the leaching and b) the contacting geologic control of the leaching.

The shrinking core model is based on the dissolution of portlandite in the cement:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$$

The flux is calculated from:

$$Flux = -D_i [(C_l - C_{gw})/X]$$

$$dX/dt = [D_i/X][C_l - C_{gw}/C_s]$$

Walton et al. (1990) have developed an approach for the depth of leaching of portlandite from a cementitious body that takes the form:

$$\mathbf{x=(2Di[Cp-Cgw]/Cst)^{0.5}}$$

Where:		
X	distance	Cm
Di	intrinsic diffusivity	cm^2/sec
Cp	concrete pore	$Moles/cm^3$
Cgw	groundwater	$Moles/cm^3$
Cs	solids	$Moles/cm^3$
T	time	Sec

The shrinking core model assumes that the removal of calcium from the exterior surface of the concrete is rapid relative to the movement through the concrete. This relationship takes the inventory of Ca-ions in the pore fluids of the ash structure minus the leaching water concentration and ratios it to the total available in the solids. By multiplying against the intrinsic diffusivity for calcium in the ash as a function of the square root of time (diffusion controls the leaching), a depth of penetration into the structure can be calculated. Because concrete is less permeable than the surrounding geology, the dominant flow direction will rarely be normal to the concrete (structural fill) surface.

Based on 61 m, the smallest dimension of the filled Gorilla pit and assuming diffusion through both sides toward the middle of the structure, a time (t) can be calculated when both diffusion surfaces meet. The results of this calculation, based on a conservative intrinsic diffusivity of 3×10^{-6} cm^2/sec, yielded a time frame for To-T1 on the order of 10,000,000 years (Fig. 11.7).

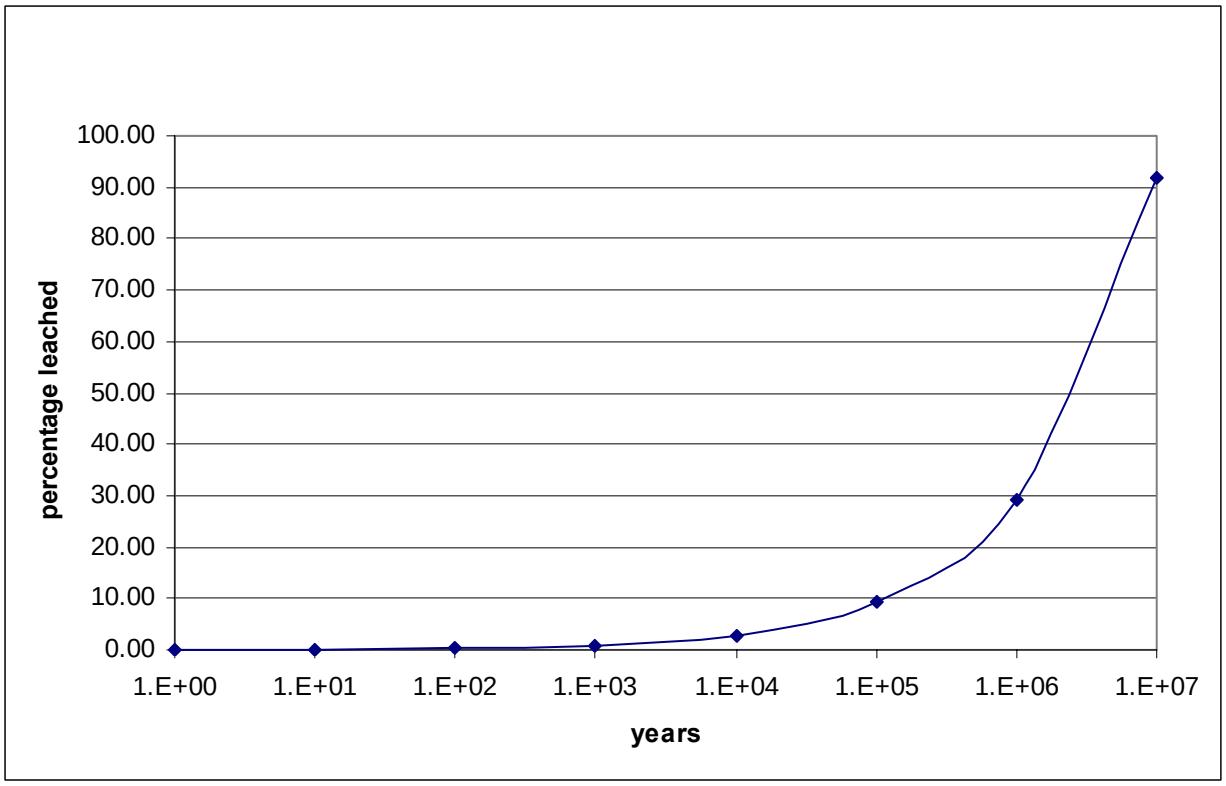


Figure 11.7 Percentage leached of the smallest dimension of the Gorilla ash fill as a function of time based on an ash structure-controlled leaching model.

The alternative approach suggested by Walton et al. (1990) (after Atkinson and Hearne, 1984) was to allow the surrounding geology to control the diffusion of calcium from portlandite in the ash fill to diffuse into the surrounding geology. In this approach, the concentrations are described by an error function:

$$[C\text{-}C_{gw}/C_l\text{-}C_{gw}] = \text{ercf}[X/(4D_e t/R_d)^{1/2}]$$

The total material leached in a given time period is obtained by integrating with respect to time:

$$M_t = \Phi C_l\text{-}C_{gw}(4R_d D_e t/\pi)^{1/2}$$

The total amount of calcium hydroxide removed can be related to the inventory in the fill as:

$$M_t = XC_{bulk}$$

Following a similar approach, Walton presented the following equation in which he calculated the depth of leaching in the ash fill:

$$x=2\Phi[Cp-Cgw/Cs](RdDeT/\pi)^{0.5}$$

where:

X	distance	cm
π	pi	
Cp	concrete pore	moles/cm^3
Cgw	ground water	moles/cm^3
Cs	solids	moles/cm^3
Rd	retardation	
De	effective diffusivity	cm^2/sec
Φ	porosity	
T	time	sec

In this analysis he also utilizes the percentage of the total inventory of calcium in the ash released but controlled by the effective diffusivity of the geologic media as well as the retardation of the geologic media. Assuming conservative values for Rd and De, the estimated time that the leaching process took to diffuse through parallel sides of the ash structure 61 m thick was on the order of 255,000 years (Fig. 11.8).

Although the spread of time to accomplish the total removal of portlandite from the ash structure in the Gorilla ranges over two-orders of magnitude, the bounding calculations suggest that for the leaching interval To-T1, times in excess of a quarter of a million years will transpire. It is noteworthy to point out that during this time interval a slow release of alkalinity in the form of calcium hydroxide will be taking place. Only after the total removal will the pH begin to drop.

Stage II [T1-T2] is represented by the stability of a single phase and described by the incongruent dissolution of C-S-H from a calcium to silica ratio of 1.7 to a value of 0.85 and will proceed until pH 10.7 is reached. All of the excess calcium in the structure is removed and C-S-H begins to undergo congruent dissolution. Estimates of the length of time involved in this stage of leaching of the fill are difficult to make since they depend on the amount of C-S-H formed during the hydration of the ash components. In Portland cement concrete as a point of reference, this stage typically is calculated to require approximately 1,000,000 years to reach the onset of congruent dissolution of the C-S-H (Atkinson, 1985).

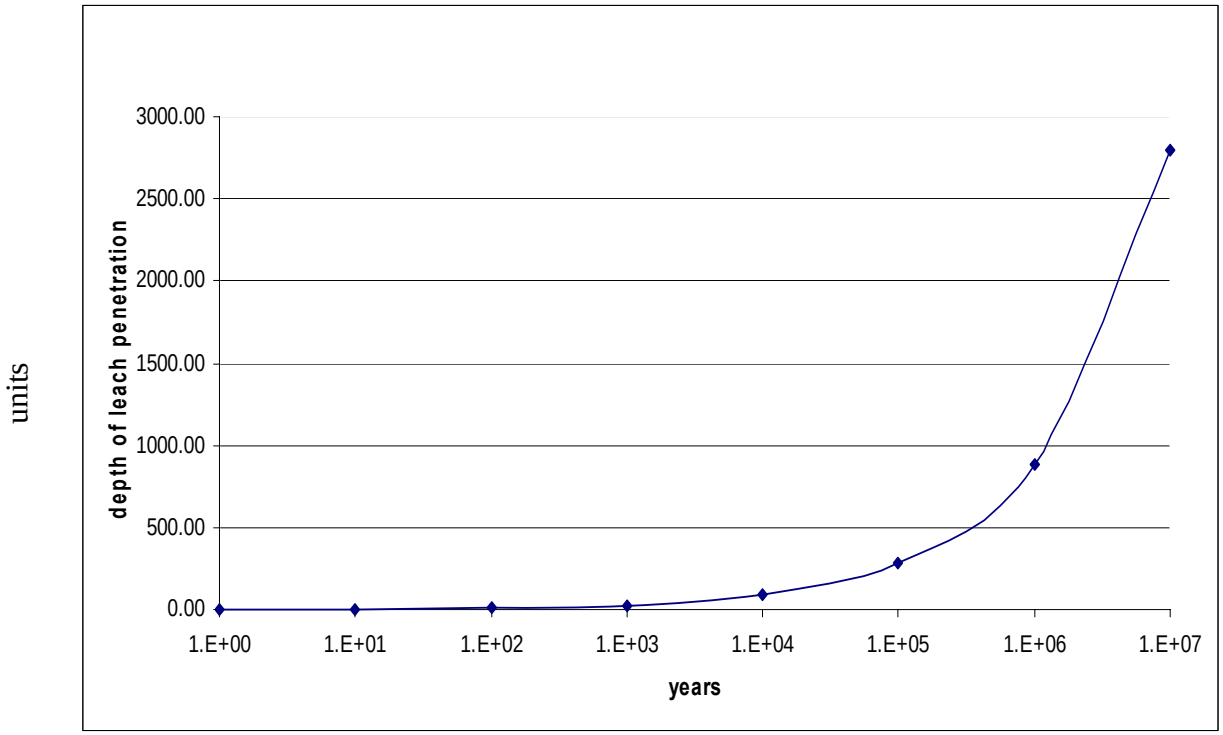


Figure 11.8 Percentage leached of the smallest dimension of the Gorilla ash fill as a function of time based on a geology-controlled leaching model.

The transition marks the onset of Stage III [T2-T3] in which the phase rule dictates the coexistence of two phases, C-S-H and SiO_2. Dissolution follows at a constant pH until all of the C-S-H is removed. Following a similar argument direct estimates of the durability are not possible to make but by analogy with concrete Atkinson (1985) calculates about 500,000 years to achieve complete dissolution of the C-S-H. Stage IV represents the stability of only a single phase, SiO_2, thus allowing by the Gibbs Phase Rule, the pH to drop to the controlling groundwater pH, Stage V.

The above exercises were conducted in order to provide some sense of the long-term stability that may be anticipated from the structural fill in the Big Gorilla Pit. The calculations were conducted based upon our recognition that the changing mineralogy of the fill materials could be modeled using Portland cement as an analog. Furthermore, the calculations were conducted with conservative input data to the model, that is to say that reasonable but aggressive parameters were chosen that would hasten the leaching of the fill and in this manner provide a more conservative interpretation of the data.

These results suggest that the structural fill will be stable for a period of time most probably in excess of 100,000 years and likely well in excess of 1,000,000 years. During the period of time in which it is altering, the pH of the leachates released from the fill will be above a value of 10.7 for the vast majority of that time. In an environment where the ground waters are impacted by acid mine drainage, the fill will act as a local reserve of alkalinity that will slowly be released over its service life.

11.3.3 Mechanisms of Controlling Heavy Metals

Sequestration of heavy metals in the hydration products in the ash fill takes on several forms. The metals can be precipitated as a result of the elevated pH levels in the pore fluids of this ash, they can be crystal chemically incorporated into the developing hydration products, they can form surface compounds on the grains of the ash, they can be chemisorbed onto ash grains and/or they can become incorporated as inclusions in the matrix of the hydrated compounds in the ash fill. Figure 11.9 from Gougar et al. (1996) graphically summarizes these options.

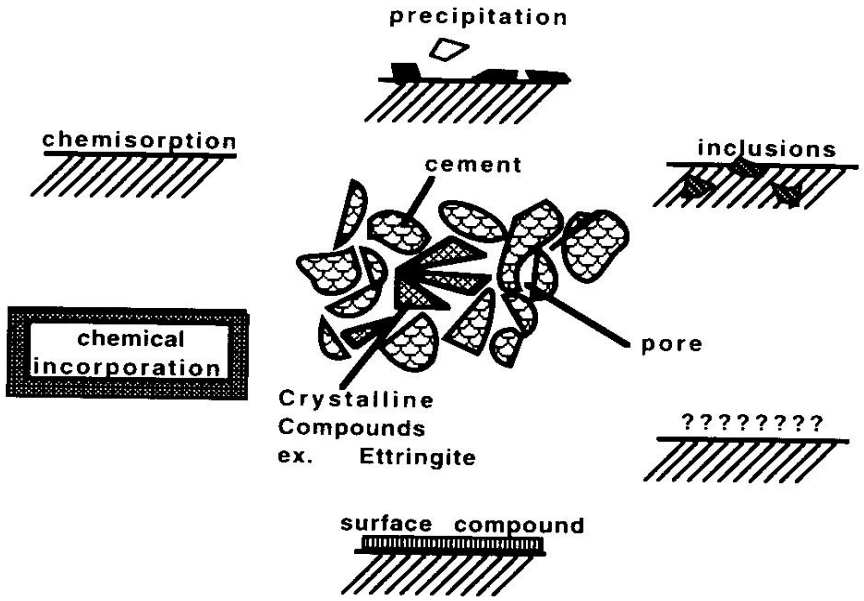


Figure 11.9 Various possibilities for the interaction of heavy metals in a cementitious matrix (after Gougar et al., 1996).

11.3.3.1 $Ca(OH)_2$

All of our experiences suggest that the presence of free lime ($Ca(OH)_2$) is necessary for placement of ash in standing mine water. Lime serves to immobilize labile heavy metals but more importantly, it is the activator that initiates chemical reactions among the fly ash phases. These hydration reactions not only contribute to the immobilization of metals but also to the development of cementitious chemical reactions that will influence the development of favorable mechanical and physical properties of the ash. As the hydration reactions mature with time, the resulting microstructure of the mass will continue to develop leading to a decrease in permeability to external fluids. Lime from the ash in contact with the pit waters will result in an elevated pH, the driving factor in the chemical reactions. The aluminosilicate structures of the glass or meta-clay phases are activated by elevated pH values to initiate the hydration reactions which begin to dissolve their structures. The presence of aluminum and silica in solution in the

presence of calcium results in the precipitation of tobermorite (a fiberous mineral that acts like the glue in Portland cement and the glue in the ash hydration). The formation of tobermorite has been predicted by thermodynamic calculations demonstrating the stability of this phase.

The exact amount of excess lime necessary to accomplish these favorable chemical reactions is dependent upon the mineralogy of the ash to be placed. Any ash that contains either a glassy phase or a dehydroxylated 'meta'-clay as the dominant phase will respond to the lime additions. Our best estimate at this point is that a minimum of 3 to 5% by mass of the ash should consist of lime. If the ash is predominantly crystalline quartz, it is likely that even the presence of large amounts of excess free lime will have little influence on the hydration reactions. Under these unique circumstances, the ash placement would be similar to the placement of sand as a structural fill material.

11.3.3.2 Calcium-silicate-hydrate

In Portland cement, calcium-silicate-hydrate (C-S-H) forms as an amorphous hydration product of both di- and tri-calcium silicate. It is the morphology of this phase that imparts the mechanical properties that are attributed to concrete. C-S-H is the 'glue' in Portland cement. In the ash fill, clays in the culm and coal are thermally altered to the point where the clays give off their water and dehydroxylate. It is the reaction of these meta-clays with Ca at elevated pH that forms C-S-H. C-S-H does not possess long-range crystalline structure. A general formula for it has been proposed in the form of the Richardson-Groves model:

$$Ca_xH_{(6n-2x)}(Si_{1-a}R_a^{[IV]})_{(3n-1)}O_{(9n-2)}\cdot A^{c+}_{a(3n-1)/c}\cdot zCa(OH)_2\cdot mH_2O$$

Where:

$x=0.5(6n-w)$
$z=0.5[w+n(y-2)]$
and for $0<y<2 \rightarrow n(2-y)<w<2n$
$2<y<4 \rightarrow 0<w<2n$
$4<y<6 \rightarrow 0<w<n(6-y)$
and $0<a<n-1/3n-1$
R is a trivalent cation in tetrahedral coordination
A is an interlayer ion

C-S-H has been identified with scanning electron microscopic studies and in thermodynamic calculations in the hydration products of ash.

Gougar et al. (1996) have reported in a review of relevant literature that the sequestration mechanism for mercury oxide and cadmium hydroxide is encapsulated within the matrix of hydrating C-S-H. Nickel, lead and uranium are immobilized by chemisorption on the hydrating C-S-H particles.

11.3.3.3 Ettringite

Ettringite is essential in the hydration of Portland cement for controlling the setting time of the hydration reaction. It also occurs as a predominant reaction product in FBC ashes derived from bituminous mining waste. Ettringite is a crystalline material composed of columnar units of:

$$\{Ca_6(Al(OH)_6)_2 \cdot 24H_2O\}^{+6}$$

with large channels containing:

$$\{(SO_4)_3 \cdot 2H_2O\}^{-6}$$

Extensive crystal chemical substitution has been reported in the ettringite structure. Table 11.2 summarizes the extent of this substitution. Of particular importance in this list of immobilized elements are arsenic and selenium, and to a lesser extent hexa-valent chromium, which substitute for sulfate in the structure.

The results of our studies have pointed out the importance of the formation of the mineral phase ettringite in the hydrating ash body and in the mine pit water in contact with the ash. At the elevated pH ranges established by the lime, the glass or meta-clays will release aluminum to the pit waters in excess of that amount precipitated into the hydrous calcium alumino silicate phase. The solubility levels of aluminum at the pH 12 range is in excess of 6 orders of magnitude higher than that encountered at pH 6.5 and as such could represent the formation of a potential environmental threat. The observation that ettringite formation limited the solubility of aluminum in the pit waters suggests that the sulfate content of the pit water/ash mass is also an important controlling component.

In the case of the Gorilla demonstration, sufficient sulfate from both the mine pit water and the gypsum formed in the ash were present to limit the solubilization of aluminum. The total sulfur content of the ash was 5000 ppm and the water concentration ~500 ppm. It is apparent that concerns of aluminum solubilization would only be an issue in non-FBC ashes without the addition of a sulfate source. For example, a lime stabilized PC ash would require the admixture of a calcium sulfate from FGD or another gypsum source.

The thermodynamic analysis of the Al-pH system also indicates that ettringite is not stable below a pH value of 10.5. This study of the Gorilla waters contains several data points for the pit water while it has been in transition from a dormant condition where ash was not actively being placed with a mildly alkaline condition (pH 8), to active ash placement with a pH values approaching 12. The aluminum solubility for these few points also remained low. We have not at this point identified the mineral phase that is responsible for the control of aluminum in the pit water but literature references also suggest the presence of a yet to be identified hydrous alumino sulfate compound. The reason for the scarcity of data is the unusual confluence of the chemical conditions that are represented and hence a lack of detailed study in the area.

Table 11.2. Reported substitutions in the ettringite structure

$(Ca^{2+})^{VIII}$	$(Al^{3+})^{VI}$	(SO_4^{2-})	(OH^{1-})
Sr	Cr	$B(OH)_4$	O
Ba	Si	CO_3	
Pb	Fe	Cl	
Cd	Mn	**CrO_4**	
Co	Ni	**AsO_4**	
Ni	Co	**SeO_4**	
Zn	Ti	VO_4	
		BrO_3	
		NO_3	
		MoO_4	
		ClO_3	
		SO_3	
		IO_3	
Elements designated in bold type are of concern in AMD waters.			

11.3.3.4 Metal hydroxides

Most metals exhibit a change in solubility as a function of pH that is marked by increased solubility at both acid and basic conditions with minimum solubility at varying pH values characteristic to the individual metal. Figure 11.10 is an example of several metals over a pH range extending to 14. As can be seen in this figure, the majority of metals exhibit a solubility minimum in the range of 9 to 12. Chemically, hydroxides are controlling the solubility behavior at pH values above 7.

Since no one pH value is ideal for 'all' elements, the immobilization is based solely on the idea that metal hydroxide precipitation is a trade off that nonetheless is an effective means of lowering metal concentrations.

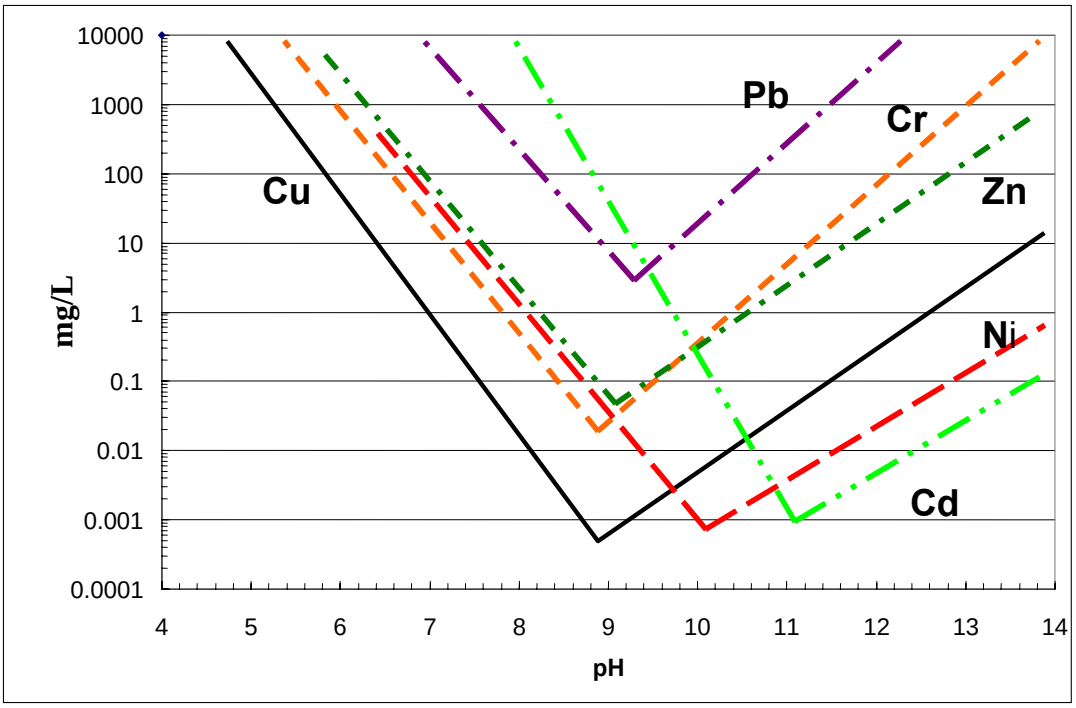


Figure 11.10 Solubility (mg/L) vs. pH plots for selected metallic elements in the system M-O-H showing minimum solubilities.

11.4 IMPACTS OF ASH PLACEMENT ON WATERS

11.4.1 Selected Properties

Modification of existing pit lakes by ash addition is expected to have both immediate and long term effects on the chemical quality of water. It is, of course, the water in the pit lake that will be dramatically modified in the short term but by the end of the project, the lake will no longer exist. The remnant of the pit water exists in the pore spaces of the ash pile, which now acts as a low permeability aquifer. In the case of the Big Gorilla demonstration site, the Silverbrook outfall serves as an overflow point for the entire basin and forms a tributary of the Little Schuylkill River. In a deep-mined synclinal valley such as the Silverbrook Basin, ground water is hard to define. The present state of the interconnecting tunnels of the deep mining operation is largely unknown. Some are definitely open; some may be clogged with silt. The locations of the outfalls from all of the demonstration sites are known, but the details of the flow paths are at best conjectural. There must be some exchange of ground water between the flooded mines and the permeable rock units. Ground water can be sampled from monitoring wells but the relationship between waters from monitoring wells and other ground waters is not always apparent.

With these limitations in mind, some interesting conclusions can be drawn from the water quality data collected during the closure of the Big Gorilla pit lake. The details from which these conclusions are drawn are found in Chapter 9.

11.4.1.1 Acidity

The initial pH of the Big Gorilla pit lake was in the range of 3.4 before ash addition commenced. With the first ash addition, the pH rose rapidly to values in the range of 11. The ash slid into the lake and along the bottom as a density current, causing rapid mixing of the lake water and destruction of the stratification that had been observed earlier. Ash addition was discontinued in the winter season and in the first year the pH of the undisturbed lake water dropped to the range of 6 but not back to the pre-addition acidity levels. When ash addition was resumed the following summer, pH rose quickly to 11.4 and afterwards only rarely dropped below 11.

The strongly alkaline water in the diminishing pit lake was due to the presence of CaO in the ash. CaO hydrates rapidly to $Ca(OH)_2$ which ionizes with the release of OH^- ions. The upper pH limit for water saturated with $Ca(OH)_2$ would be 12.45. These high pH waters are unstable. Over long time periods of time,the excess OH^- ions in the water will react with carbon dioxide from the atmosphere and result in the formation of bicarbonate ions precipitating $CaCO_3$. The pH value will eventually decrease to somewhere in the range of 8–9 depending on the effective CO_2 pressure in the ash pile. Some evidence for this mechanism is provided by the white band of calcite-containing deposit that formed around the water-line of the lake.

11.4.1.2 Iron

The concentration of iron in the pit lake was in the range of 1 mg/L before ash addition. As would be expected, the concentration fell even lower in the alkaline water created by the ash. Because the pit lake is exposed to atmospheric oxygen, iron is expected to be in the Fe^{3+} valence state. When the pH climbs into the neutral and alkaline regime, Fe^{3+}, which is soluble in acid solution, precipitates as the highly insoluble $Fe(OH)_3$. This material would be adsorbed on the ash particles and be incorporated as part of the ash pile.

11.4.1.3 Aluminum and sulfate

The behavior of aluminum is very interesting because it is the element for which the high pH of the pit lake could be expected to cause problems. Aluminum is amphoteric, meaning that its solubility increases at both low and high pH. Aluminum is extracted from rocks by acid mine waters to give a mean concentration in the pit lake of 1.2 mg/L (Table 9.7). One would expect high concentrations of aluminum in the alkaline lake water because of the dissolution of modified clays in the ash by the strongly alkaline water. This was not observed. The sulfate concentrations in the pit lake had typical values greater than 400 mg/L and these rose to near 1000 mg/L with ash emplacement. Leaching of gypsum, $CaSO_4.2H_2O$, from the ash is an additional source of sulfate. At these concentrations, aluminum becomes immobilized as insoluble alumino-sulfate compounds and the expected increase in aluminum in the strongly alkaline pit lake water did not take place. Ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$, is the likely immobilization phase. Mobilization of aluminum was seen as one of the largest risks to water quality from placing ash in an acid pit lake. If the sulfate concentrations are high, in excess of 400 mg/L, mobilization of aluminum is unlikely to take place.

11.4.1.4 Toxic metals

The water in the Big Gorilla pit lake contains quantities in the range of a few parts per billion to several hundred parts per billion of an array of toxic elements (Table 9.7). These include As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Ba. The question is what happens to these elements when the background chemistry of the lake water is changed by the addition of ash?

Arsenic and selenium both occur in the oxidized form as the AsO_4^{3-} and SeO_4^{2-} ions. Both ions readily substitute for sulfate, SO_4^{2-} and should be immobilized in any sulfate minerals that may form. During the period of ash addition, the maximum concentration observed in the pit lake was 101 ppb for Se and 22 ppb for As. There was no apparent trend in concentration of either element with respect to ash input.

The highest concentrations of Cd, Hg, and Ni in the pit lake were 18 ppb, 3 ppb, and 284 ppb respectively. The value for nickel seems anomalously high. The values measured during ash addition were comparable to those measured before ash placement was undertaken.

Barium is likely to track with calcium and to coprecipitate in calcite in the reactions of the alkaline lake with atmospheric CO_2. There was no barium detected in the pre-ash placement pit lake. After ash placement began, barium concentrations were in the range of 10 to 40 ppb. The concentrations appear to respond to ash input, increasing when ash loads are increased.

Chromium concentrations before ash placement were never higher than 50 ppb. The concentrations increased after ash placement began but never exceeded 260 ppb. The concentrations appeared to increase with ash input and decrease when ash placement was halted.

Lead is a very minor element in both pre- and post-placement lake water. The highest pre-placement concentration was 2 ppb. The highest post-placement concentration was 27 ppb. Only 3 samples in the post-placement period exceeded the drinking water standard for lead. The concentrations were so low that relationships between lead concentration and ash placement were difficult to distinguish.

Copper is present in the pit lake with a maximum concentration of 132 ppb. The measured concentrations varied erratically with no obvious relation to ash placement.

11.4.2 Zone of Influence

In spite of the dramatic increase of pH in the pit lake, the pH of the Silverbrook outfall had not changed as of the writing of this book. Water discharging from the Silverbrook remains near 4.0. Before any ash addition, the acidity of the Silverbrook was in the range of 75 mg/L compared with 40 mg/L in the Big Gorilla pit lake. There was an upward spike to about 175 mg/L acidity in the time period of 1995 – 1998, after which the acidity at the Silverbrook has dropped back to values in the range of 50 – 100 mg/L. The behavior of acidity and pH at the Silverbrook outfall suggests that it is mainly discharging water from the flooded deep mines and that the hydraulic connections between the pit lake and the outfall, if any, are very inefficient.

The Silverbrook outfall contains substantially more iron than does the pit lake (Fig. 9.19). Data collected before the beginning of ash placement show considerable scatter, but iron concentrations range from 5–15 mg/L. After 1997, the start of the project, the iron content of the Silverbrook water increased to the range of 15 – 25 mg/L.

Calcium, iron, and sulfate concentrations increased in the water flowing from the Silverbrook discharge. These data were first collected at the beginning of active remediation within the Silverbrook outfall, approximately eight years before ash was first placed in the Big Gorilla. A pattern of gradual increase in calcium, starting shortly after surface remediation began on the eastern flank of the Silverbrook basin, has been attributed to the early land remediation using CaO-rich ash. Surface reclamation of the exposed and mined Buck and Mammoth veins took place. These areas connect to deeper underground workings, and hence, directly to the Silverbrook discharge.

Concurrent with initial ash placement at the Big Gorilla, the operation activities at the power facility intensified, and a fuel (culm) storage area was activated and enlarged. Surface runoff from the access road to the facility and associated parking areas all drain through this freshly disturbed site and ultimately leave the basin at the Silverbrook discharge. Iron and sulfate concentrations in the Silverbrook discharge increased due to the newly exposed pyrite surfaces within the culm piles. Although the disturbance, transportation, and storage of waste coal piles is an unavoidable step in permanently removing them, in some cases future operations may need to consider interim measures to limit any temporary impacts that may occur from affecting long-dormant piles.

Finally, winter-time use of de-icing salt on the access road to the facility has been observed to correlate with a cyclical sodium and chloride signature in the Silverbrook outfall. Enhanced activity at the fuel storage area represented a significant increase in the amount of fuel that was being trucked to the site from locations outside the Silverbrook basin. Thus, there was an increased need to keep truck access open during inclement weather conditions.

11.4.3 Water Monitoring

The need to monitor the effluent from a demonstration site is predominantly regulatory, however, if sufficient additional control can be added, the long-term observations of the site chemistry can add valuable scientific data. Demonstration projects carry the burden to provide scientific data necessary to evaluate the effectiveness and value of the practice being demonstrated; the monitoring plans for those projects must take this extra burden into consideration. For non-demonstration mine reclamation projects, the monitoring plan must be adequate to meet the regulatory requirements that are in place to protect public health and safety. Good monitoring also provides the necessary data to evaluate damage claims and helps to build a track record of results, which can be helpful in public acceptance of future projects. In all cases monitoring plans must be adapted to project-specific considerations such as: duration of the project, scale of the project, hydrogeologic setting, intent of the project, surrounding resources, materials being used, and risk assessment.

It is recommended that the six-month pre-placement monitoring be maintained to establish a baseline information set. Beyond that the frequency should be adapted to the project. Projects that involve the use of large amounts of ash over relatively short periods, such as intensive backfilling or slurrying of ash into large pits may need to be monitored as frequently as monthly, while lesser frequencies would probably suffice in most active mining situations where the addition of ash is incidental to mining activity. Tiered monitoring plans are also an option to consider; under such plans the monitoring frequency could be increased if data showed results that warranted closer evaluation for a period of time and then could be scaled back again if the results that caused the concern proved to be temporary or anomolous. On most projects monitoring should be continued for a minimum of 5 years. On smaller projects where the monitoring data set has been stable, monitoring may not have to continue for the entire five years. On the other hand, in cases where evaluation of the data shows a changing condition or other reason for concern the monitoring may need to be extended beyond five years.

The current DEP requirement for both downgradient and upgradient wells should be maintained. (It is recognized that in some upland settings, establishment of a functional upgradient well may not be achievable.) In some cases, especially on larger projects or demonstration projects, at least one well in the interior of the ash fill may be required (more may be required if the geometry warrants) in order to track changes in the ash chemistry with time. Where downgradient ground water discharge points, clearly hydrologically connected to the ash placement area, are available these can be used to supplement or replace monitoring well data. The number of monitoring points should be commensurate with the size and complexity of the site. Large long-duration sites may require numerous monitoring points, while smaller, shorter-duration sites, such as small refuse-reclamation sites lasting only a few weeks, may require few monitoring points.

In addition to acidity, alkalinity, field and laboratory pH, iron, aluminum and sulfate taken on filtered and unfiltered samples the complete suite of rock forming elements should also be included in the routine analyses. These should include Si and K as well as the RCRA trace elements. The rationale for this recommendation is the need to obtain an electrical balance in the water chemistry. This is required for speciation and reactions path computer models that will make geochemical predictions.

11.5 IMPACTS AND BENEFITS OF THE CLOSURE PROJECTS

11.5.1 The Big Gorilla Demonstration

The ultimate benefit for the Gorilla has not yet been realized because the Silverbook reclamation project is still ongoing and is likely to take 5 to 10 years to totally reclaim the basin. The dry-to-wet demonstration represented only a Phase I of the overall Gorilla project, with Phase II consisting of conventional dry ash placement to bring the pit back to approximate original contour.

The Gorilla Demonstration Project succeeded in removing approximately 135,000,000 gallons of acid mine drainage impacted water from the 465,000,000 gallons in the Silverbrook inventory, about 30%. This observation means that all of the acid loading, the sulfate loading,

and metal loadings that were associated with the Gorilla waters are no longer available to the complex aquifer system of the Silverbrook Basin. From a human health and safety standpoint, the hazard of the water-filled pit and associated highwall from the strip mining has been eliminated for the small community of people living immediately adjacent to the mine property.

In total, for both phases of the project, approximately 7 million tons of fill will have been consumed to restore just the Gorilla site. The Bureau of Abandoned Mineland Reclamation of the Commonwealth's Department of Environmental Protection has saved approximately $4.5 million in deferred costs to the DEP through this cooperative partnership with NEPCO. Economically, the McAdoo community has also benefited, both directly through the continued employment of local people, and indirectly through the purchasing of products and services from the local community, the payment of local taxes by the utility and its employees. The intangible benefit to the community and the Commonwealth can be ascribed to the visual change that will occur at the completion of the project, transforming the site from a blighted wasteland to a restored meadow that will provide wildlife habitat.

11.5.2 The Knickerbocker Demonstration

The Knickerbocker coal ash slurry site demonstrated that an abandoned surface mine pit could be effectively reclaimed using an ash slurry from the SER cogeneration plant. The FBC ash from that plant was mixed with minewater pumped from the Maple Hill shaft and transported by the ash slurry pipeline to the Knickerbocker pit. The ash slurry technology has been successfully used at pulverized coal (PC) power plant sites for many years, but the mine site characteristics and the minewater/coal ash interactions in this demonstration project are different from the conventional ash slurry impoundment sites.

The Knickerbocker demonstration site proved at least two significant aspects of this type of slurry project: 1) the water to solids ratio in the slurry was not a big issue in the ash placement procedures on the site, as the excess water from the slurry rapidly infiltrated into the underlying minepool and was recycled back to the Maple Hill shaft pumping location, and 2) the dewatered ash slurry material in the Knickerbocker pit solidified into a deposit that had sufficient bearing capacity to support large rubber-tired equipment, almost immediately after placement. The success of this demonstration permit project is indicative of the results that could be achieved at the Shen Penn site.

11.5.3 The Shen Penn Demonstration

The Shen Penn demonstration project showed significant potential to abate and reclaim a significant mine hazard (i.e.$20 to 28 million) at no cost to the taxpayers. The success of the Knickerbocker demonstration project in refining the ash slurry technology, as adapted to the surface mine environment , provides a measure of confidence that the technology proposed will work at the Shen Penn site. The coal ash/minewaer interactions described in Chapter 9 and this chapter, show that the minepool chemistry, helps rather than impedes the process of getting a stable surface. Therefore, the unknowns of the Shen Penn project have been substantially reduced by the success of the other two demonstration projects, and the most significant remaining unknown is the interactions of the deep minepool chemistry and the coal ash slurry.

However, the greater sulfate concentrations of the minepool at 230 foot depth should improve ash solidification.

11.6 MINE SITE EVALUATION CRITERIA FOR COAL ASH PLACEMENT

The first step associated with any coal ash placement scenario should be the testing of the proposed coal ash to be utilized at the site. If the coal ash does not meet the regulatory guidelines or limits, the project cannot proceed. Should the coal ash meet the regulatory guidelines or limits, the next step is to review the proposed site information. The site information reviewed should include, but is not limited to the following: depth to groundwater, geologic/hydrologic site characterization, site volume calculations, proposed site reclamation plan, water uses in and around the proposed site (both surface and groundwater), location of any adjacent public or private buildings, any suitable or unsuitable site characteristics related to the proposed placement, and the potential to mitigate any safety or pollution issues once the site is reclaimed. Some of these items may limit the type of coal ash that should be proposed for utilization at the site. This item was discussed earlier in the book, and one must not forget that not all types of coal ash are suitable for all proposed placement scenarios.

If the coal ash and the proposed site appear to meet the regulatory requirements and/or guidelines, the project design phase should begin. The project design or operational plans should include a number of basic requirements or specifications related to fugitive dust control, coal ash placement criteria, final grading, erosion and sedimentation controls, and final cover and revegetation. The proposed site monitoring plan should also be included in these plans, and a thorough review of the adequacy of the plan should be conducted. Once the coal ash and site design or operational plan are reviewed and deemed adequate, the overall site and risk assessment of the proposed coal ash placement can be conducted. This assessment considers all the pertinent site factors and the characteristics or properties of the coal ash itself. The assessment is also based on known historical or scientific information, or data related to the coal ash and sites with similar geologic and hydrologic site characteristics, and other pertinent site information.

Some basic site evaluation factors that have been established by the approximately 20 years of coal ash placement and site monitoring, as well as scientific research and modeling are:

A. Is the tested and approved ash being placed in or above groundwater?
B. Is the tested and approved ash going to be conditioned to the optimum moisture content and compacted to 90% Modified Proctor Density if the use requires such compaction?
C. Is the groundwater degraded or impacted by acid mine drainage?
D. Is the final cover or capping designed to promote positive drainage and the development of vegetation?
E. What type of coal ash is planned to be utilized: FBC or PC?
F. What are the chemical and physical characteristics of the coal ash to be utilized?
G. Are the site's operational and monitoring plans adequate and practical?
H. What resources exist in or around the site that could possibly be impacted if something unplanned occurs?

I. What is the nature and the scale of the abandoned mine features to be reclaimed, and what is the value of that reclamation in terms of dollars and public safety.

These are only a few of the questions that are entertained in a site risk assessment or selection, but they represent the core of what a decision to approve or deny an application is usually based on by a reviewer for the following reasons:

A. If the proposed coal ash placement is above groundwater, and if the coal ash meets all regulatory beneficial use requirements, and the ash is going to be placed in accordance with generally accepted practices, the likelihood of any adverse impact from the ash placement is very low.
B. If the coal ash is FBC ash or alkaline PC ash, the likelihood of degradation from any coal ash leachate should be minimal; as the metals within the ash are less likely to be leached by any water that may come in contact with the coal ash.

These conclusions or generalizations are based on data, testing, and scientific information that has been developed over the past 20 years from actual coal ash placement sites, coal ash demonstration projects, scientific testing and a host of other measures. However, each proposed coal ash placement site or project must be reviewed individually, and if necessary, additional testing or permit required actions should be implemented for any potential issues that may arise from the proposed coal ash placement. In fact, we have determined that there are specific coal ash types and mine site scenarios that should not be approved for various chemical, geological or other scientific reasons, even though the sites may represent significant abandoned mine land hazards. The risk of the potential solution creating a bigger problem should never be dismissed. For example, in the Bituminous Region, where coal ash has been used as an alkaline addition agent on surface mine sites to offset large deficiencies in overburden quality, the results have generally not been favorable and additional AMD was produced. The coal ash itself caused no damage, but it did not prevent AMD, just as limestone addition has often failed to prevent AMD on sites with clearly bad overburden. Based on these results, using alkaline ash to offset large deficiencies in site overburden is in most cases not an advisable practice.

11.7 CLOSING THOUGHTS

This book has presented descriptions of a variety of permit and project sites in Pennsylvania where coal ash has been beneficially used in mine reclamation and mine drainage remediation. Most of these sites have been clear success stories: abandoned mine lands and their associated safety and environmental hazards have been reclaimed at no cost to the taxpayer; water quality has been improved; a waste material has been recycled to a useful end rather than being landfilled. None of these sites represent environmental damage groundwater pollution cases attributable to the coal ash quality. However, a few of the mine sites cannot be counted as successes, because existing mine drainage worsened as a result of the re-mining of the sites. The production of AMD on these sites occurred because the ability of the alkaline ash to remediate and prevent the AMD was overestimated; on at least one site, poor mining and reclamation techniques were also a factor.

Are the sites where AMD worsened "coal ash damage cases?" Some investigators, particularly those associated with various advocacy groups, have argued "yes," but the correct answer to this important question is clearly "no." To be meaningful and useful the term "coal ash damage case" must be reserved for sites where the application of coal ash has caused some deleterious effect. The cause-effect relationship is critical to the integrity of the term. Where other site activities, such as additional mining has caused problems, it is important those problems be identified and understood so that the conditions that led to them are not repeated. However, incorrectly labeling such sites as "coal ash damage cases," serves to obscure the causes and potential remedies for the production of AMD on those sites, and only muddies the discussion over when and how coal ash may be beneficially used at mine sites. The determination of whether a site represents a damage case should be based on science, not semantics.

Much attention has been given to the potential effects of coal ash placement on groundwater quality in this book and in the many criticisms of coal ash use on mine sites. That attention is well founded, because land reclamation benefits should not be achieved at the cost of water quality degradation. That principle has been a centerpiece of Pennsylvania's coal ash beneficial use program form the beginning and will continue to be so.

In addition to the general lack of water quality impacts and the contrasting demonstrations of water quality improvements in the chapters of this book, the favorable physical characteristics of compacted coal ash have been described in an engineering context chapters of this book. The reams of monitoring data on these physical properties of coal ash often go unnoticed by the public in DEP file searches, so they were explained in an easy to read format in the book. The natural pozzolonic properties of some coal ash types were featured in several chapters of the book, and the use of ash grout cements in abating mine hazards was described.

Finally, this book contains some significant new information on the interactions between coal ash and minewater that has not been previously published. These findings were set forth in the chapters on the waste demonstration sites, where the coal ash was placed directly into the minewater, or mixed with the minewater in the ash slurry application (and are further described in the preceding sections of this chapter). The presence of significant sulfate concentrations in the minewater, which is characteristically the dominant anion in acid mine drainage and neutralized AMD, fortuitously promotes the formation of ettringite and other similar mineral phases. These minerals enhance the cementitous behavior of the coal ash and also sequester arsenic and other constituents of concern found in the ash and in coal refuse. These findings suggest that, while the traditional practice of maintaining a separation distance between the coal ash and the groundwater table was a prudent practice, there may be applications beyond these waste demonstration permit sites where some types of coal ash should be permitted to be in contact with minewaters, in order to reclaim abandoned pits, abate mine hazards or remediate mine drainage problems. This is not to suggest the wholesale application of the techniques employed at the waste demonstration sites, but rather to provide alternatives for consideration by those engaged in defining the range of acceptable practices in the beneficial use of coal ash.

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Tim Kania – has over twenty years experience in working with coal mine drainage prediction and the investigation of water quality issues related to mining. He is currently managing the technical section of the Cambria District Mining Office which is responsible for the technical evaluation of proposed and existing mining operations in a seven county area of southwestern PA. Tim holds a BA in journalism 1976 and a BS in earth sciences 1980 both from Pennsylvania State University.

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Kenneth J. Levitz – works for the consulting company, Eco Maintenance Organization, Inc. in Jim Thorpe, PA. He has had extensive experience in the reprocessing of waste coal and coal ash placement with Panther Creek Partners from 1994 to 2000. He has served as the lead consultant and project manager of the Sharp Mountain Growing Greener project in Pottsville. Ken holds a B.S. degree in Mining Engineering from the Pennsylvania State University.

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Scott E. Walters – received a B.S. in Chemistry from The Ohio State University and a Ph.D. in Analytical Chemistry from the University of Tennessee. He has been employed as an Environmental Chemist for PA DEP's Division of Municipal and Residual Waste since 1988. Prior to that, he was an Assistant Professor of Chemistry at Penn State University's Capital College. He has been a member of the American Chemical Society for 25 years and a Registered Environmental Professional since 1990. Scott's professional interests include beneficial use of nonhazardous waste, waste oil regulation, and analytical characterization of wastes.

William B. (Will) White – was trained as a chemist and geochemist. He has spent most of his professional career at Penn State from graduate school in 1958 to his retirement as Professor Emeritus of Geochemistry in 2002. His research has covered many topics in geosciences and materials science. Among his principal interests has been ground water in carbonate rock aquifers and in environmental geochemistry. He holds a B.S. from Juniata College and a Ph.D. from The Pennsylvania State University.

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Appendix for Preface:

Joint Legislative Committee Report

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**

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.

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

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…*"

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;

- 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

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.

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 5.A

Pre-permitting Testing Requirements

Appendix 5.A—Pre-permitting Testing Requirements

III. COAL ASH AND LEACHATE ANALYSES

Coal Ash Generation Facility Name _____

RESULTS OF ANALYSES ☐ No pH adjustment ☐ After pH Adjustment

Constituents	Acceptable Methods of Analysis Indicate Method Used: EPA SW-846	Acceptable Methods of Analysis Indicate Method Used: Other Acceptable	Ash Dry Wt. Concentration. (mg/kg)	EPA's SW-846 Method 1312, SPLP Leachate Concentration (mg/L)	Maximum Acceptable Leachate Concentration (mg/L)
pH Solid	9045				
Aluminum	6010A, 7020				5.0
Antimony	6010A, 7040, 7041				0.15
Arsenic	6010A, 7060A, 7061A				1.25
Barium	6010A, 7080A, 7081				50
Boron		EPA 600/4-79-020			31.50
Cadmium	6010A, 7130, 7131A				0.13
Chromium	6010A, 7190, 7191				2.5
Copper	6010A, 7210, 7211				32.5
Iron	6010A, 7380,7381				7.5
Lead	6010A, 7420, 7421				1.25
Manganese	6010A, 7460, 7461				1.25
Mercury	7470, 7471A				0.05
Molybdenum	6010A, 7480, 7481				4.38
Nickel	6010A, 7250				2.5
Selenium	6010A, 7740, 7741				1.00
Zinc	6010A, 7950, 7951				125
Sulfate	9035A, 9036A, 38A				2500
Chloride	9250, 9251A, 9252				2500
Sodium	6010A, 7770				

	Method of Analysis	Calcium Carbonate Equivalence	
Acid Neutralizing Potential*	☐ Neutralization Potential Test, DEP's Overburden Sampling and Testing Manual, Noll *et al.* ☐ Other indicate method _____	Tons of $CaCO_3$ per 1,000 tons of ash _____	% $CaCO_3$ Dry Wt._____
Hydraulic Conductivity**	☐ ASTM D 5084-90 ☐ Other indicate method _____	Permeability (cm/sec)	

* Provide only when the requested beneficial use is alkaline addition.

** Provide only when the requested beneficial use is as a low-permeability material.

Analytical Laboratory Name, Address _____ Analyst(s) Name _____

_____ _____

_____ Telephone No.

Laboratory reports must be attached

Appendix 5.B

Water Monitoring Results for the Revloc Sites

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	3.6	3.70	3.70	540	0.0	216.0	3.13	7.56	31.90	319	486	
08/28/90	0.9	3.60	3.60	580	0.0	270.0	7.16	10.30	32.90	389	554	
09/26/90	4.1	3.70	3.60	600	0.0	240.0	1.05	7.98	25.80	407	622	
10/25/90	7.0	3.90	3.60	500	0.0	200.0	0.53	5.33	29.40	324	450	
11/20/90	2.8	4.10	3.40	620	0.0	240.0	4.22	7.42	36.20	406	572	
12/20/90	13.9	4.00	3.90	500	4.0	148.0	0.22	3.76	17.30	286	396	
01/15/91	4.5	4.00	4.00	600	4.0	166.0	0.22	5.23	14.50	314	640	
02/22/91	5.9	4.90	4.00	260	4.0	116.0	0.16	3.59	14.40	210	262	
03/25/91	7.4	4.00	3.80	340	4.0	102.0	0.15	3.33	10.20	217	298	
04/18/91	2.5	4.00	3.80	560	2.0	158.0	0.19	4.34	19.80	253	332	
05/14/91	3.0	3.80	3.80	680	2.0	112.0	0.18	4.78	14.60	308	454	
06/17/91	0.5	3.70	3.70	600	0.0	230.0	2.20	6.81	34.20	402	798	
07/24/91	0.0											
08/23/91	1.0	3.80	3.70	660	0.0	250.0	0.97	10.20	34.60	412	556	
09/27/91	0.0											
10/29/91	0.0											
11/27/91	8.7	3.90	3.80	560	4.0	156.0	0.54	10.60	31.20	320	530	6.0
12/12/91	0.3	4.00	4.00	500	6.0	144.0	0.25	9.97	16.70	257	336	36.0
01/23/92	0.8	4.00	3.90	400	2.0	448.0	0.19	6.43	11.80	196	348	
02/11/92	0.8	4.10	4.00	560	6.0	110.0	0.15	6.34	13.50	250	620	
03/25/92	2.8	4.20	3.90	560	6.0	94.0	0.15	3.97	13.00	236	384	
04/29/92	1.9	4.10	4.00	520	4.0	78.0	0.15	3.44	10.40	182	342	4.0
05/20/92	1.3	4.10	4.10	520	4.0	14.0	0.40	3.23	9.00	157	336	
06/18/92	0.0	3.80	3.70	600	0.0	144.0	3.84	7.44	12.40	265	506	28.0
07/29/92	0.5	3.60	3.60	680	0.0	120.0	9.60	11.30	9.70	310	388	
08/24/92	0.0											
09/22/92	0.5	3.90	3.60	640	0.0	170.0	12.60	8.20	11.60	291	528	48.0
10/21/92	0.0											
11/20/92	0.1	4.80	3.30	620	0.0	280.0	23.90	9.90	20.80	465	610	
12/21/92	0.5	3.40	3.40	560	0.0	200.0	5.90	8.00	21.80	368	518	
01/18/93	4.4	3.50	3.50	620	0.0	200.0	15.70	8.80	18.40	443	554	4.0
02/25/93	0.3	3.90	3.70	780	0.0	240.0	6.10	11.40	21.20	559	840	
03/04/93	1.0	3.90	3.80	600	0.0	162.0	5.80	10.20	24.00	350	536	4.4
03/24/93	1.5	3.90	3.80	520	4.0	126.0	4.32	6.20	15.20	310	396	
04/21/93	1.3	3.70	3.50	600	0.0	180.0	7.20	6.50	17.90	205	560	
06/28/93	0.1	3.80	3.80	1200	10.0	270.0	45.70	14.70	17.80	682	986	6.0
07/29/93	0.9	3.50	3.40	380	0.0	258.0	7.90	6.60	17.00	603	698	
08/18/93	0.2	4.00	3.70	680	0.0	300.0	22.80	8.30	23.50	551	884	
09/30/93	2.0	4.30	3.50	540	0.0	180.0	4.80	5.80	18.00	365	622	
10/27/93	0.2	3.70	3.50	780	0.0	1510.0	14.00	9.40	25.30	608	966	
11/15/93	0.7	4.00	3.70	540	0.0	284.0	10.30	9.20	19.60	435	586	
12/15/93	0.4	4.80	3.40	620	0.0	242.0	10.60	8.30	23.40	495	836	
01/26/94	0.7	4.50	3.80	580	2.0	208.0	6.20	7.30	22.30	483	686	
02/28/94	0.6	4.60	3.80	620	2.0	224.0	6.50	6.30	22.50	560	852	
03/30/94	0.7	3.70	3.70	640	0.0	182.0	8.90	7.50	21.10	530	810	0.4
04/26/94	0.4	3.80	3.40	1400	0.0	280.0	14.50	9.20	23.50	949	1336	2.8
05/31/94	0.3	4.20	4.00	1200	8.0	272.0	30.40	9.10	25.50	889	1366	
06/22/94	0.2	4.60	3.90	1400	4.0	320.0	65.10	10.70	12.20	977	1532	50.0
10/31/94	0.0	4.00										
11/22/94	0.3	4.00	4.00	1400	4.0	200.0	13.60	10.30	20.00	575	844	
12/27/94	0.3	4.00	4.00	1800	10.0	110.0	6.80	8.00	27.00	668	992	4.0
01/31/95	0.4	4.00	3.60	1800	0.0	220.0	5.90	8.40	28.00	604	922	
02/27/95	0.5	4.00	3.90	1400	4.0	200.0	5.70	8.20	24.00	554	786	
03/30/95	0.4	4.00	3.80	2000	4.0	228.0	7.50	96.00	3.00	880	1258	
04/27/95	0.3	4.00	3.60	1800	0.0	220.0	7.30	9.60	31.00	793	1228	
05/31/95	0.3	3.90	3.60	1800	0.0	280.0	12.90	8.10	29.00	819	1244	
06/21/95	0.2	3.80	3.60	2000	0.0	270.0	36.50	7.70	19.00	887	1798	
07/25/95	0.1	3.40	3.70	1800	0.0	220.0	35.10	7.30	22.00	966	746	
08/28/95	0.0											
09/20/95	0.0											
10/24/95	0.3	3.90	3.70	2000	0.0	190.0	8.30	8.20	27.00	855	960	
11/22/95	0.3	4.20	3.60	1800	0.0	185.0	7.20	7.80	25.00	820	875	
12/21/95	0.4	4.50	3.60	1400	0.0	146.0	6.70	8.30	21.00	545	884	
01/29/96	0.3	4.70	3.70	1400	0.0	160.0	4.80	13.70	17.00	466	784	
02/09/96	0.0											

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
03/14/96	0.6	4.20	3.60	1400	0.0	180.0	9.80	13.20	22.00	581	858	
04/22/96	0.5	4.20	3.60	1600	0.0	20.0	2.70	15.10	27.00	719	1270	
05/20/96	0.4	4.30	3.50	1094	0.0	38.0	1.70	13.70	9.00	705	1094	
06/21/96	0.2	4.20	3.60	1400	0.0	180.0	20.30	14.10	13.00	668	1106	
07/31/96	0.1	3.50	3.50	1800	0.0	160.0	38.70	13.90	18.00	827	1714	
08/26/96	0.0											
09/30/96	0.2	4.60	3.80	1400	4.0	126.0	15.00	13.40	26.00	654	1076	
10/25/96	0.2	4.00	3.90	1800	4.0	204.0	11.40	12.80	2.00	631	946	
11/22/96	0.4	4.00	3.80	1800	2.0	148.0	13.40	17.40	18.00	834	1174	
12/18/96	0.4	3.40	3.20	1600	0.0	70.0	9.90	13.90	25.00	786	842	
01/16/97	0.5	4.00	3.80	2000	4.0	496.0	10.60	22.10	41.00	995	1426	
02/24/97	0.4	3.50	3.80	1800	1.0	179.0	7.10	17.20	26.00	812	1496	
03/12/97	0.4	3.50	3.80	1800	2.0	160.0	6.40	12.50	19.00	784	1120	
04/16/97	0.0											
05/28/97	0.3	3.30	3.50	1800	0.0	190.0	9.20	14.40	23.00	792	1390	4.0
06/16/97	0.3	3.40	3.70	2000	0.0	328.0	19.10	22.80	31.00	1000	1850	
07/25/97	0.2	3.40	3.50	1800	0.0	300.0	27.70	21.30	34.00	1066	1460	
08/22/97	0.3	3.50	3.40	1800	0.0	180.0	3.80	15.60	27.00	745	1328	4.0
09/25/97	0.1	4.10	3.90	2000	8.0	252.0	22.20	15.80	16.00	959	1694	
10/29/97	0.2	4.00	3.90	2000	6.0	256.0	16.20	15.10	28.00	1013	1338	
11/21/97	0.6	3.90	3.60	1600	0.0	200.0	4.70	12.20	22.00	867	1312	
12/18/97	0.4	4.20	3.60	1800	0.0	150.0	7.30	13.80	20.00	916	1392	
01/19/98	0.5	4.40	3.80	1800	2.0	268.0	2.10	14.20	21.00	966	1048	
02/23/98	0.6	4.30	3.60	2000	0.0	200.0	6.30	11.90	19.00	835	1252	
03/26/98	0.4	4.30	3.60	2000	0.0	210.0	4.40	13.30	24.00	985	1496	
04/29/98	0.5	4.30	3.70	1800	0.0	200.0	7.90	12.10	17.00	856	1310	
05/28/98	0.3	4.80	3.60	2200	0.0	260.0	2.00	13.80	21.00	1189	1552	
06/16/98	0.5	5.10	3.40	2000	0.0	260.0	2.50	15.20	22.00	851	1746	
07/24/98	0.3	5.40	3.10	2200	0.0	400.0	5.40	17.20	24.00	997	1622	80.0
08/31/98	0.0											
09/21/98	0.2	3.50	3.50	1700	0.0	260.0	27.30	16.50	17.00	1016	1664	8.0
10/21/98	0.6	3.70	3.60	2000	0.0	700.0	24.00	18.00	15.00	1141	1460	
11/18/98	0.0											
12/16/98	0.0											
01/13/99	1.0	3.80	3.70	1400	0.0	190.0	1.00	12.80	17.00	654	918	
02/10/99	0.9	4.00										
03/17/99	1.4	3.70	4.10	1400	8.0	152.0	1.30	11.80	16.00	682	1060	16.0
04/14/99	0.5	3.70	3.50	1800	0.0	300.0	4.80	16.40	16.00	864	1296	153.0
05/26/99	0.3	3.50	3.80	1800	3.0	317.0	2.10	18.70	26.00	1175	1716	
06/22/99	0.0											
07/14/99	1.2	3.50	3.20	1400	0.0	160.0	5.20	19.10	22.00	1007	2196	
08/11/99	0.0											
09/22/99	0.0											
10/27/99	0.0											
11/17/99	0.0											
12/15/99	0.0											
01/27/00	0.0											
02/16/00	0.4	3.80	3.90	1400	4.0	196.0	4.30	18.80	20.00	1300	1256	8.0
03/15/00	0.0											
04/19/00	0.0											
05/17/00	0.0											
06/14/00	0.0											
07/31/00	0.0											
08/30/00	0.1	3.70	4.70	1600	2.0	260.0	4.40	23.70	21.00	1272	1572	16.0
09/29/00	0.8	3.60	3.60	1600	0.0	240.0	6.60	19.50	13.00	976	1270	94.0
10/25/00	0.3	3.70	3.60	1800		310.0	15.80	21.30	19.00	931	1400	
11/15/00	0.7	3.90	3.70	1810	0.0	200.0	11.50	24.00	20.00	933	1320	
12/13/00	0.4	3.90	3.70	1871	0.0	190.0	2.50	24.00	19.00	767	1298	
01/17/01	0.4	3.60	3.60	1830	0.0	160.0	3.70	20.00	19.00	909	1410	17.0
02/08/01	0.5	3.80	3.60	1709	0.0	48.0	3.70	20.50	20.00	844	736	
03/14/01	1.0	3.90	3.50	1340	0.0	200.0	1.90	15.10	17.00	639	922	
04/11/01	0.9	3.60	3.10	1576	0.0	200.0	3.90	16.40	14.00	703	1098	
05/17/01	0.3	3.50	3.60	2060	0.0	200.0	8.70	25.00	25.00	1316	1500	68.0
06/11/01	0.0											
07/11/01	0.4	3.50	3.00	2020	0.0	200.0	2.50	19.30	19.00	918	884	66.0

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
08/08/01	0.0											
09/13/01	0.0											
10/10/01	0.0											
11/06/01	0.1	3.60	3.90	2090	6.0	231.0	6.50	26.00	24.00	1069	1772	
12/05/01	0.2	3.70	3.80	1885	4.0	31.0	4.40	25.00	25.00	920	1440	
01/10/02	1.2	3.60	3.60	1726	0.0	146.0	3.20	19.50	20.00	881	1272	18.0
02/06/02	0.4	3.70	3.80	1813	1.0	177.0	1.70	25.00	23.00	931	1370	8.0
03/08/02	0.4	3.70	3.90	1928	4.0	126.0	1.70	23.00	22.00	984	1558	
04/02/02	0.5	3.70	3.80	1772	2.0	198.0	2.00	19.90	21.00	932	1440	
05/10/02	0.5	3.50	3.80	1667	2.0	148.0	4.40	17.80	18.00	803	1180	
06/03/02	0.3	3.60	3.60	1935	0.0	190.0	2.80	20.90	22.00	1004	1474	16.0
07/03/02	0.2	3.60	3.30	2190	0.0	200.0	24.00	23.00	25.00	1073	1532	10.0
08/06/02	0.2	3.60	3.30	2120	0.0	100.0	4.40	23.00	18.00	1063	1651	14.0
09/03/02	0.0											
10/04/02	0.2	3.10	3.50	2140	0.0	160.0	36.00	23.00	22.00	1103	1614	
11/06/02	0.0											
12/10/02	0.3	3.60	3.50	1966	0.0	10.0	6.90	24.00	25.00	306	1168	8.0
01/10/03	0.7	3.70	3.60	1700	0.0	144.0	3.60	17.10	17.00	834	1156	
02/06/03	0.5	3.80	3.20	1862	0.0	200.0	1.20	18.60	22.00	1117	1364	114.0
03/07/03	0.6	3.90	3.90	1694	6.0	148.0	1.70	17.70	19.00	856	1308	
04/02/03	0.8	3.10	3.70	1758	0.0	160.0	3.60	19.00	24.00	876	1338	
05/07/03	0.6	3.60	3.40	1932	0.0	200.0	1.80	22.00	18.00	937	1444	
06/10/03	0.5	3.70	3.30	1739	0.0	200.0	7.70	19.80	18.00	902	1378	
06/10/03	0.1		3.50	1756	0.0	185.2	6.49	18.90	17.80	930	1638	6.0

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

23 SP
Inorganics

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	0.5	4.50	4.50	180	0.0	38.0	3.56	1.26	1.00	23.9				117	
08/28/90	0.2	4.50	4.50	160	0.0	26.0	6.69	1.05	1.00	30.5				68	
09/26/90	5.9	4.20	4.40	140	10.0	26.0	0.72	0.80	1.00	40.3				110	6.0
10/25/90	3.2	4.50	4.30	140	10.0	26.0	0.86	1.37	1.00	34.6				112	
11/20/90	1.9	4.50	4.30	180	8.0	26.0	2.05	1.55	1.55	49.4				73	38.0
12/20/90	6.0	5.60	5.90	220	6.0	14.0	0.81	0.66	1.87	89.7				90	14.8
01/15/91	2.8	4.40	4.70	160	1.0	13.0	0.21	1.47	1.00	46.9				42	
02/22/91	8.2	5.70	4.60	86	1.0	11.0	0.58	1.18	1.00	38.7				34	12.0
03/25/91	5.2	4.50	4.50	120	0.0	8.0	0.16	1.11	1.00	37.0				120	
04/18/91	1.2	4.50	4.30	220	8.0	22.0	0.42	1.24	1.00	43.6				88	
05/14/91	0.6	4.00	4.00	260	4.0	26.0	1.64	1.38	1.00	37.8				132	
06/17/91	0.3	4.50	4.50	220	8.0	22.0	0.35	1.67	1.14	52.7				158	24.0
07/24/91	0.0														
08/23/91	0.0														
09/27/91	0.0														
10/29/91	0.0														
11/27/91	0.0														
12/12/91	0.5	4.40	4.30	260	8.0	22.0	0.15	1.12	1.41	76.5				336	20.0
01/23/92	0.6	4.50	4.50	200	0.0	14.0	0.25	1.58	1.29	51.0				146	
02/11/92	0.3	4.80	4.60	260	2.0	16.0	0.15	1.71	1.46	70.0				336	
03/25/92	2.2	4.60	4.50	240	0.0	12.0	1.75	1.75	1.00	74.0				150	
04/29/92	0.4	4.50	4.50	240	0.0	18.0	0.15	1.66	1.00	85.6				104	8.0
05/20/92	0.0														
06/18/92	0.0														
07/29/92	0.0														
08/24/92	0.0														
09/22/92	1.9	4.20	4.00	300	6.0	46.0	0.15	2.30	3.47	113				310	
10/21/92	0.0														
11/20/92	0.1	4.20	4.10	340	6.0	10.0	0.15	2.05	2.08	86				206	
12/21/92	3.9	4.00	4.00	320	4.0	26.0	0.15	2.64	2.56	125				184	
01/18/93	1.0	4.40	4.40	280	4.0	36.0	0.15	2.47	2.62	116				218	
02/25/93	0.3	4.50	4.60	300	2.0	26.0	0.15	2.34	2.42	144				216	
03/04/93	4.6	4.50	5.00	280	2.0	18.0	0.15	3.14	2.60	137				190	
03/24/93	11.3	4.50	4.70	420	2.0	40.0	0.18	2.51	4.02	235				342	
04/21/93	11.1	4.50	4.30	420	10.0	36.0	0.19	2.29	3.37	188				340	
05/21/93	0.6	4.40	4.30	140	12.0	0.0	0.19	2.72	6.30	236				468	
06/28/93	0.0														
07/29/93	4.4	3.90	4.20	340	8.0	38.0	0.23	2.76	3.50	207				334	
08/18/93	0.0														
09/30/93	16.0	4.70	4.30	360	10.0	38.0	0.22	2.18	2.50	139				240	
10/27/93	0.4	4.30	4.40	380	2.0	60.0	0.30	3.00	3.74	174				340	20.0
11/15/93	4.2	4.50	4.30	340	10.0	202.0	0.16	3.25	4.61	170				286	
12/15/93	1.7	4.80	4.30	420	6.0	210.0	0.23	3.79	7.76	324				484	
01/26/94	4.1	5.10	4.30	360	8.0	58.0	0.25	3.08	5.27	226				326	
02/28/94	3.6	5.00	4.30	320	10.0	44.0	0.15	2.25	4.13	166				278	

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
03/30/94	4.6	4.40	4.40	260	8.0	26.0	0.15	6.14	1.00	115				260	
04/26/94	0.4	4.40	4.10	420	8.0	44.0	0.15	3.23	3.67	168				306	
05/31/94	0.0														
06/22/94	0.2	4.90	4.10	380	6.0	40.0	1.11	3.41	3.27	175				450	
10/31/94	6.3	4.10	4.10	480	4.0	62.0	0.20	3.80	6.00	169				120	
11/22/94	1.4	4.20	4.10	520	6.0	70.0	1.20	4.00	8.00	217				338	
12/27/94	0.7	4.30	4.30	560	12.0	72.0	0.20	3.60	7.00	221				312	
01/31/95	1.0	4.30	3.90	560	4.0	66.0	0.20	3.70	7.00	202				312	
02/27/95	1.2	4.30	4.20	540	6.0	60.0	0.20	2.00	7.00	184				260	
03/30/95	0.8	4.40	4.20	740	14.0	66.0	0.20	4.60	10.00	296				500	
04/27/95	0.5	4.30	4.10	660	4.0	76.0	0.20	4.20	10.00	268				434	
05/31/95	0.0														
06/21/95	0.0														
07/25/95	0.0														
08/28/95	0.0														
09/20/95	0.0														
10/24/95	0.6	4.30	4.30	480	4.0	65.0	0.20	3.60	6.00	218				380	
11/22/95	1.6	4.40	4.30	490	5.0	72.0	0.20	3.40	7.00	196				410	
12/21/95	1.0	4.70	4.40	510	4.0	66.0	0.20	3.90	8.00	228				420	
01/29/96	0.8	4.90	4.20	600	6.0	72.0	0.20	3.30	8.00	274				416	
02/09/96	0.6	4.60	4.40	420	6.0	52.0	0.20	2.40	5.00	186				334	
03/14/96	2.8	4.60	4.30	460	5.0	5.0	0.20	2.40	5.00	154				186	
04/22/96	2.3	4.60	4.00	620	6.0	44.0	***0.15***	4.60	10.00	281				340	
05/20/96	1.5	4.80	4.20	480	4.0	56.0	***0.15***	2.50	***1.00***	151				246	
06/21/96	0.5	4.80	4.10	360	6.0	40.0	0.20	2.40	3.00	145				232	
07/31/96	0.0														
08/26/96	0.1	3.70	4.00	500	4.0	0.0	0.30	2.80	5.00	157				210	
09/30/96	1.3	5.30	4.10	380	8.0	50.0	0.20	2.30	5.00	160				242	
10/25/96	1.2	3.50	4.10	420	6.0	46.0	***0.15***	2.30	4.00	142				200	
11/22/96	0.9	4.20	4.20	500	4.0	70.0	***0.15***	2.90	5.00	240				382	
12/18/96	1.7	3.50	3.50	420	0.0	40.0	0.20	2.40	5.00	165				268	
01/16/97	1.1	4.10	4.20	600	8.0	22.0	***0.15***	3.40	8.00	340				490	
02/24/97	1.9	3.90	4.40	400	9.0	45.0	***0.15***	2.00	4.00	175				344	
03/12/97	2.2	3.80	4.30	420	6.0	44.0	***0.15***	2.10	4.00	188				200	
04/16/97	0.5	3.90	4.20	640	4.0	68.0	***0.15***	3.20	6.00	269				452	
05/28/97	1.2	3.70	4.10	440	6.0	0.0	***0.15***	2.30	4.00	142				296	
06/16/97	0.2	3.50	4.10	500	6.0	42.0	0.30	3.20	5.00	197				498	
07/25/97	0.2	3.50	3.80	600	2.0	8.0	0.20	4.10	9.00	275				460	
08/22/97	0.3	3.90	4.10	480	8.0	44.0	0.20	2.30	4.00	168				312	
09/25/97	0.0														
10/29/97	0.4	4.20	4.20	620	6.0	58.0	0.30	3.90	9.00	280				448	
11/21/97	1.8	4.30	4.10	520	4.0	74.0	***0.15***	2.20	6.00	272				396	
12/18/97	1.0	4.60	4.40	580	8.0	106.0	0.20	3.20	7.00	249				426	
01/19/98	1.5	4.70	4.40	540	10.0	70.0	0.20	2.60	5.00	244				332	10.0
02/23/98	1.8	4.80	4.20	560	8.0	62.0	***0.15***	2.20	4.00	181				362	

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

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Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
03/26/98	1.1	4.80	4.40	620	6.0	82.0	***0.15***	2.80	5.00	242				476	4.0
04/29/98	1.1	4.60	4.20	440	6.0	44.0	***0.15***	2.40	4.00	165				220	
05/28/98	0.0														
06/16/98	2.1	4.50	4.00	740	4.0	10.0	0.40	3.10	8.00	286				732	
07/24/98	0.0														
08/31/98	0.0														
09/21/98	0.0														
10/21/98	0.0														
11/18/98	0.0														
12/16/98	0.0														
01/13/99	4.5	4.00	4.10	640	8.0	10.0	***0.15***	4.10	10.00	354				502	18.0
02/10/99	2.0	4.00													
03/17/99	2.3	4.10	4.10	660	6.0	154.0	***0.15***	3.20	8.00	359				496	
04/14/99	1.6	4.10	4.00	480	2.0	198.0	***0.15***	2.10	3.00	177				344	
05/26/99	0.4	3.90	4.20	660	7.0	9.0	0.30	4.10	7.00	378				608	16.0
06/22/99	0.0														
07/14/99	0.0														
08/11/99	0.0														
09/22/99	0.0														
10/27/99	0.0														
11/17/99	0.0														
12/15/99	2.5	4.40	4.40	460	8.0	104.0	***0.15***	2.30	5.00	262				396	
01/27/00	0.0														
02/16/00	1.8	4.10	4.30	440	8.0	88.0	***0.15***	2.80	5.00	222				358	
03/15/00	5.2	4.20	4.30	480	8.0	2.0	***0.15***	2.90	4.00	193				370	
04/19/00	10.1	4.10	4.30	360	6.0	78.0	***0.15***	2.50	3.00	184				282	28.0
05/17/00	0.1	3.90	4.10	600	4.0	96.0	0.40	4.20	8.00	226				1524	
06/14/00	0.0														
07/31/00	8.1	3.90	4.00	720	4.0	126.0	0.50	3.60	8.00	240				474	108.0
08/30/00	0.2	4.00	5.10	740	14.0	86.0	0.30	3.70	7.00	272				476	
09/29/00	5.3	4.00	3.90	840	6.0	64.0	0.30	2.70	4.00	259				390	
10/25/00	0.6	4.10	3.80	760	2.0	86.0	0.20	3.30	5.00	203				346	
11/15/00	0.7	3.90	4.10	631	4.0	0.0	0.20	3.30	6.00	219				348	
12/13/00	1.2	4.30	4.10	736	4.0	106.0	***0.15***	3.20	5.00	247				388	
01/17/01	1.1	4.20	4.10	879	6.0	74.0	***0.15***	3.90	8.00	386				600	
02/08/01	1.4	4.10	4.00	700	2.0	88.0	***0.15***	3.00	5.00	247				450	
03/14/01	6.3	4.20	6.70	513	12.0	6.0	***0.15***	1.80	3.00	144				284	
04/11/01	4.1	4.00	3.60	680	0.0	100.0	0.20	2.30	3.00	173				360	
05/17/01	0.0														
06/11/01	0.0														
07/11/01	1.0	3.90	3.60	832	0.0	100.0	0.30	3.60	5.00	249				262	
08/08/01	0.0														
09/13/01	0.0														
10/10/01	0.0														
11/06/01	0.0	3.90	4.30	948	13.0	89.0	***0.15***	5.90	9.00	358				728	

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

23 SP
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
12/05/01	0.5	6.10	4.10	742	8.0	3.0	***0.15***	4.40	6.00	247				464	
01/10/02	3.5	4.00	4.10	856	10.0	42.0	***0.15***	4.20	8.00	315				570	2.0
02/06/02	0.7	4.10	4.20	748	7.0	49.0	0.20	3.90	6.00	292					
03/08/02	0.7	4.20	4.50	812	0.0	41.0	***0.15***	3.90	7.00	305				546	
04/02/02	1.7	4.10	4.30	614	10.0	40.0	***0.15***	2.50	3.00	205				424	
05/10/02	2.0	4.00	5.30	527	14.0	0.0	0.20	2.00	3.00	173				360	
06/03/02	0.3	4.10	4.20	586	8.0	42.0	0.20	3.00	3.00	186				304	12.0
07/03/02	0.0														
08/06/02	0.9	3.90	4.20	947	10.0	90.0	0.30	4.50	7.00	303				580	
09/03/02	0.0														
10/04/02	0.4	4.00	4.30	932	10.0	40.0	0.20	4.90	8.00	305				606	
11/06/02	0.0														
12/10/02	0.7	4.10	4.00	788	1.0	499.0	***0.15***	3.80	7.00	289				404	
01/10/03	2.6	4.10	4.30	611	4.0	40.0	***0.15***	2.20	3.00	234				476	
02/06/03	6.8	4.10	3.40	805	0.0	100.0	***0.15***	3.30	5.00	365				452	
03/07/03	2.3	4.20	4.40	678	14.0	38.0	***0.15***	2.70	4.00	252				436	
04/02/03	3.8	4.20	4.20	723	6.0	6.0	***0.15***	2.70	4.00	193				446	
05/07/03	3.1	4.10	4.80	914	2.0	20.0	***0.15***	3.50	5.00	336				688	
06/10/03	1.7	4.10	4.10	623	4.0	40.0	***0.20***	2.60	3.00	209				410	
06/10/03	1.6		4.10	624	0.0	55.6	0.21	2.36	2.97	190	61.50	38.10	7.07	394	2.0

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc
Site

4 SP
Inorganics
Page 1

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	36.2	3.20	3.20	2400	0.0	2570.0	2.16	11.10	391.30	3122	4873	
08/28/90	26.9	3.10	3.10	2400	0.0	3050.0	2.30	11.80	443.00	3738	5310	
09/26/90	31.3	3.10	3.10	2600	0.0	3110.0	2.32	11.20	449.40	4016	6462	
10/25/90	36.6	3.30	3.10	2600	0.0	2930.0	2.33	9.39	426.50	3662	5410	
11/20/90	33.9	3.30	3.20	2400	0.0	2340.0	2.23	11.80	413.80	3448	4943	
12/20/90	38.6	3.20	3.20	2200	0.0	2400.0	2.15	10.20	405.50	3497	4890	
01/15/91	30.0	3.00	3.10	2800	0.0	2790.0	2.23	11.10	409.60	3903	5172	
02/22/91	45.5	3.40	3.20	2000	0.0	2500.0	2.18	8.42	444.40	3296	5382	8.0
03/25/91	50.9	3.20	3.20	2200	0.0	2480.0	1.89	7.27	333.30	3378	4740	
04/18/91	48.2	3.10	3.00	3000	0.0	2570.0	1.98	8.96	333.30	3346	5038	
05/14/91	43.0	3.00	3.00	3400	0.0	2600.0	2.16	9.12	512.20	3524	4824	
06/17/91	31.8	3.00	3.10	2800	0.0	3140.0	2.38	9.28	531.70	4045	6644	
07/24/91	20.4	3.10	3.10	4200	0.0	2672.0	2.40	11.80	521.70	4499	7148	14.0
08/23/91	15.9	3.10	3.00	3800	0.0	3530.0	2.22	10.30	480.00	4788	7608	24.0
09/27/91	13.1	3.10	3.10	4200	0.0	3600.0	2.87	16.00	591.60	4743	7078	2.0
10/29/91	10.3	3.20	3.20	3800	0.0	3400.0	2.11	15.60	623.40	4732	6686	0.8
11/27/91	11.0	3.10	3.10	3600	0.0	3280.0	2.34	14.90	417.70	4425	6988	36.0
12/12/91	16.1	3.20	3.20	2800	0.0	2980.0	2.54	13.90	307.70	4005	5796	26.0
01/23/92	18.7	3.00	2.80	2600	0.0	2510.0	2.39	12.00	323.00	3296	4656	
02/11/92	24.3	3.10	3.30	2800	0.0	2400.0	1.64	10.70	198.00	2931	4658	
03/25/92	35.8	3.10	3.20	2800	0.0	2040.0	1.70	7.00	164.00	3023	4330	4.0
04/29/92	38.1	3.20	3.20	2800	0.0	2330.0	1.35	9.90	174.00	2831	4098	6.0
05/20/92	29.3	3.20	3.20	2600	0.0	2090.0	1.58	8.50	196.00	2635	4130	
06/18/92	20.8	3.00	3.20	2800	0.0	2840.0	1.49	9.30	237.00	2953	4940	26.0
07/29/92	19.8	3.10	3.20	2800	0.0	2640.0	2.00	8.60	289.00	3505	5270	20.0
08/24/92	19.1	3.10	3.10	2800	0.0	2800.0	1.98	11.00	202.00	3085	5310	
09/22/92	19.3	3.20	3.20	2600	0.0	2660.0	1.80	8.70	210.00	2684	4706	12.0
10/21/92	18.3	3.30	3.20	2800	0.0	2400.0	1.75	8.90	295.00	3227	4656	
11/20/92	17.7	3.50	3.00	2600	0.0	2530.0	1.78	8.20	247.00	3766	4586	
12/21/92	25.9	3.10	3.10	2600	0.0	2510.0	2.13	8.10	242.00	3684	3774	1.2
01/18/93	44.1	3.20	3.20	2600	0.0	2830.0	2.27	10.20	252.00	3709	5244	
02/25/93	28.1	3.60	3.20	2400	0.0	1870.0	1.80	7.60	152.00	3208	4848	
03/24/93	32.1	3.60	3.30	2400	0.0	1390.0	1.90	8.00	207.00	3352	3962	
04/21/93	58.4	3.20	3.20	2200	0.0	3870.0	2.57	8.90	295.00	3592	5418	
05/21/93	37.3	3.30	3.40	1800	0.0	2238.0	2.12	5.80	200.00	2557	4318	
06/28/93	29.5	3.40	3.40	2000	0.0	2450.0	2.30	11.90	168.00	3885	5148	
07/29/93	24.3	3.00	3.30	2200	0.0	2520.0	2.37	7.60	280.00	3542	5702	
08/18/93	23.0	3.40	3.20	1800	0.0	2500.0	2.55	8.80	265.00	3796	4482	
09/30/93	21.4	3.90	3.20	2200	0.0	2750.0	2.42	8.00	190.00	3172	4548	
10/27/93	21.5	3.20	3.20	2200	0.0	1660.0	2.45	8.40	222.00	3436	4970	
11/15/93	21.5	3.50	3.30	1800	0.0	2650.0	2.21	11.00	235.00	3065	4554	
12/15/93	37.9	3.50	3.10	1600	0.0	2242.0	2.14	7.60	206.00	3141	4408	
01/26/94	27.2	3.50	3.20	1600	0.0	2410.0	2.08	8.10	196.00	3160	4226	16.0
02/28/94	26.5	3.40	3.20	1600	0.0	2200.0	2.54	7.80	200.00	3358	4134	
03/30/94	25.8	3.30	3.30	2000	0.0	2820.0	2.26	10.10	256.00	3662	5116	
04/26/94	43.5	3.40	3.00	2200	0.0	2590.0	2.85	8.10	265.00	3864	5768	
05/31/94	31.3	3.40	3.20	1600	0.0	2390.0	2.71	7.30	214.00	3974	4408	
06/22/94	23.8	3.50	3.10	2000	0.0	2432.0	2.56	7.80	102.00	3192	5168	
10/31/94	18.30	3.30	3.20	3000	0.0	2212.0	2.59	7.30	245.00	3148	3830	
11/22/94	Flooded											
12/27/94	25.10	3.40	3.40	3200	0.0	1724.0	1.98	7.05	192.00	2344	3766	
01/31/95	Flooded											
02/27/95	21.20	3.50	3.30	2800	0.0	1590.0	1.92	5.52	153.00	2072	2774	
03/30/95	29.70	3.50	3.30	2800	0.0	1230.0	1.81	5.53	152.00	2139	3112	
04/27/95	Flooded											
05/31/95	Flooded											
06/21/95	Flooded											
07/25/95	Flooded											
08/28/95	Flooded											
09/20/95	Flooded											
10/24/95	Flooded											
11/22/95	Flooded											
12/21/95	Flooded											
01/29/96	Flooded											
02/09/96	21.80	3.20	3.30	2800	0.0	1960.0	1.93	7.10	290.00	2667	3852	

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
03/14/96	39.60	3.50	3.20	2600	0.0	2002.0	1.76	11.00	333.00	2565	4740	
04/22/96	31.1	3.70	3.30	2400	0.0	1904.0	1.72	9.60	333.00	2475	4346	
05/20/96	Flooded											
06/21/96	23.00	4.00	3.20	2400	0.0	1740.0	1.41	9.60	218.00	2500	3596	
07/31/96	22.80	3.20	3.10	2800	0.0	1330.0	1.53	9.70	282.00	2463	4242	
08/26/96	17.00	3.00	3.20	2400	0.0	2000.0	1.77	9.30	287.00	2471	3340	
09/30/96	23.60	3.20	3.30	2600	0.0	1150.0	1.54	8.70	272.00	2470	3169	
10/25/96	24.70	3.10	3.20	2600	0.0	1070.0	1.27	7.50	224.00	2233	2934	
11/22/96	28.70	3.20	3.20	2400	0.0	1150.0	1.22	8.70	198.00	2258	2820	
12/18/96	32.90	2.70	2.30	2400	0.0	1270.0	1.64	7.50	231.00	2003	2832	
01/16/97	28.10	3.00	3.30	2600	0.0	1382.0	1.41	7.30	309.00	2261	2856	
02/24/97	27.10	3.00	3.30	2600	0.0	1410.0	1.91	8.90	236.00	2296	3336	
03/12/97	37.00	2.90	3.20	2600	0.0	1290.0	2.04	7.20	199.00	2175	2172	
04/16/97	29.20	2.70	3.30	2600	0.0	1000.0	1.39	5.90	205.00	2208	3316	
05/28/97	23.50	3.00	3.30	3000	0.0	1940.0	1.86	15.30	279.00	2816	4490	
06/16/97	15.80	2.60	3.30	2600	0.0	1600.0	1.50	11.20	220.00	2340	4595	
07/25/97	13.00	3.40	2.90	2400	0.0	1700.0	1.56	11.10	415.00	2475	3452	
08/22/97	13.90	2.80	3.30	2800	0.0	1890.0	1.68	13.70	304.00	2269	4132	
09/25/97	9.50	2.90	3.30	2600	0.0	1540.0	1.43	9.20	146.00	2374	3222	2.0
10/29/97	8.58	3.00	3.30	2600	0.0	1620.0	1.53	10.10	179.00	2363	3250	
11/21/97	23.40	3.10	3.60	2600	0.0	1600.0	1.61	8.00	150.00	2530	3382	
12/18/97	25.80	3.50	3.30	2800	0.0	1720.0	2.26	8.60	182.00	2481	3586	
01/19/98	3.90	3.40	3.70	2800	0.0	2220.0	2.90	8.90	152.00	2898	3526	
02/23/98	7.08	3.50	3.30	3000	0.0	1840.0	3.60	8.30	244.00	2482	3478	
03/26/98	34.2	3.50	3.50	3200	0.0	3000.0	4.30	10.30	363.00	3769	5150	8.0
04/29/98	30.02	3.60	3.20	2600	0.0	2180.0	4.10	9.00	201.00	2832	3908	
05/28/98	28.51	4.00	3.20	3000	0.0	3040.0	4.20	8.30	218.00	3152	4124	
06/16/98	20.06	4.50	3.20	3200	0.0	2490.0	4.40	9.20	281.00	2927	5842	
07/24/98	14.84	4.10	3.10	3000	0.0	1900.0	2.10	9.60	269.00	2823	4526	
08/31/98	9.30	3.00	3.20	2200	0.0	1730.0	1.80	10.10	230.00	2394	3536	10.0
09/21/98	7.33	3.00	3.40	2000	0.0	1010.0	1.70	10.10	216.00	2422	3100	
10/21/98	4.80	3.20	3.20	2600	0.0	264.0	1.60	10.00	205.00	2248	3300	
11/18/98	2.14	3.00	2.80	2600	0.0	1400.0	1.60	9.50	167.00	2449	3604	
12/16/98	0.75	3.10	3.30	2400	0.0	2130.0	1.40	10.60	175.00	2510	3202	
01/13/99	3.20	3.20	3.30	2000	0.0	1420.0	1.40	8.60	182.00	2062	2896	
02/10/99	3.00	3.10										
03/17/99	17.20	3.10	3.20	2400	0.0	1630.0	1.50	8.30	162.00	2137	3118	
04/14/99	28.50	3.00	3.10	2200	0.0	1658.0	1.40	8.10	137.00	2179	2728	
05/26/99	16.90	3.20	3.30	1600	0.0	1940.0	1.60	9.00	179.00	2349	2928	
06/22/99	8.60	3.00	3.20	2600	0.0	1770.0	1.40	8.20	201.00	2607	3198	
07/14/99	5.20	3.20	3.30	2000	0.0	1200.0	1.30	9.20	178.00	40	3928	
08/11/99	3.20	3.10	3.30	540	0.0	1468.0	1.40	10.20	167.00	1847	3064	
09/22/99	3.30	3.00	3.30	1200	0.0	680.0	1.30	8.60	174.00	1744	2886	
10/27/99	4.05	3.20	2.90	1800	0.0	1910.0	1.20	10.50	134.00	5529	2696	
11/17/99	3.37	3.00	3.40	1800	0.0	442.0	1.20	10.70	122.00	2055	2536	6.0
12/15/99	8.29	3.10	3.30	2000	0.0	508.0	1.20	8.30	188.00	2196	2902	
01/27/00	7.18	3.40	3.80	1600	0.0	1480.0	1.20	9.60	167.00	1856	2454	
02/16/00	Flooded											
03/15/00	18.70	3.10	3.30	2200	0.0	111.0	1.10	10.30	220.00	1874	2580	
04/19/00	18.52	3.20	3.40	1400	0.0	700.0	0.90	7.60	134.00	1493	1778	6.0
05/17/00	16.31	3.40	3.30	1400	0.0	1000.0	1.00	7.70	104.00	1524	3604	
06/14/00	16.90	3.30	2.60	1800	0.0	940.0	0.90	8.00	108.00	1505	2174	
07/31/00	7.98	3.60	3.50	1800	0.0	900.0	0.90	7.80	119.00	1419	2254	
08/30/00	8.01	3.30	4.70	1800	0.0	970.0	0.90	8.60	117.00	1826	696	
09/29/00	6.89	3.30	3.40	2400	0.0	1250.0	1.00	9.70	183.00	1988	2350	
10/25/00	6.86	3.30	3.10	2600	0.0	1300.0	1.00	9.70	163.00	1713	2612	
11/15/00	6.86	3.30	3.20	2320	0.0	1100.0	1.00	9.10	129.00	1666	2322	
12/13/00	8.59	3.30	3.30	2160	0.0	940.0	0.90	8.90	128.00	1417	1968	
01/17/01	8.79	3.20	3.40	2500	0.0	800.0	0.90	7.50	75.00	1461	2148	5.0
02/08/01	10.93	3.10	3.10	2660	0.0	870.0	0.80	8.00	126.00	1281	1836	
03/14/01	22.75	3.20	3.00	2700	0.0	1200.0	1.20	7.30	187.00	1709	2310	
04/11/01	22.62	3.20	3.00	2220	0.0	1200.0	1.10	6.40	147.00	1649	2384	4.0
05/17/01	16.24	3.20	3.60	2110	0.0	1450.0	1.20	6.40	157.00	1714	2106	
06/11/01	10.90	3.20	3.40	2180	0.0	1130.0	0.90	6.50	181.00	1389	1490	
07/11/01	9.88	3.30	3.00	2180	0.0	1800.0	0.90	7.80	124.00	1461	2044	

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc
Site

4 SP
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
08/08/01	5.43	3.30	3.20	2140	0.0	1000.0	0.90	7.80	154.00	1632	2104	
09/13/01	4.18	3.20	3.20	2210	0.0	590.0	1.00	8.60	114.00	1565	2254	
10/10/01	2.89	3.30	3.30	2090	0.0	1000.0	3.00	7.80	122.00	1396	2938	
11/06/01	1.38	3.20	3.70	2150	0.0	800.0	0.90	9.10	118.00	1445	2144	
12/05/01	3.10	3.30	3.40	2030	0.0	537.0	0.80	9.30	122.00	1434	1948	
01/10/02	8.87	3.10	3.30	2200	0.0	782.0	1.00	8.40	156.00	1551	2080	
02/06/02	10.95	3.20	3.50	1947	0.0	689.0	1.00	6.70	103.00	1249	1784	
03/08/02	12.59	3.10	3.50	1860	0.0	543.0	0.80	6.00	85.00	1129	1592	
04/02/02	19.13	3.20	3.40	1775	0.0	600.0	0.70	6.10	74.00	1039	1514	
05/10/02	22.22	3.20	3.40	1948	0.0	660.0	0.80	5.70	100.00	1221	1870	
06/03/02	24.07	3.20	3.30	2100	0.0	870.0	0.90	5.50	138.00	1492	1932	
07/03/02	19.19	3.30	3.30	2030	0.0	700.0	0.80	4.90	156.00	1293	1844	
08/06/02	9.69	3.30	3.40	1825	0.0	500.0	0.70	5.10	79.00	1121	1780	
09/03/02	6.16	3.20	3.60	1923	0.0	600.0	0.60	6.50	71.00	1126	1594	
10/04/02	4.83	3.30	3.50	2020	0.0	700.0	0.60	7.50	85.00	1249	1794	
11/06/02	0.00											
12/10/02	12.37	3.20	3.20	2090	0.0	800.0	0.90	6.80	116.00	1799	1820	
01/10/03	24.46	3.30	3.30	2050	0.0	544.0	0.80	6.00	98.00	1260	1802	
02/06/03	19.55	3.30	3.10	2100	0.0	21.0	0.90	4.10	83.00	1100	1650	
03/07/03	19.44	3.30	3.40	2080	0.0	480.0	0.60	5.10	78.00	1116	1670	
04/02/03	28.96	3.50	3.30	2210	0.0	660.0	0.80	4.50	93.00	1261	1894	
05/07/03	21.1	3.40	3.30	2020	0.0	558.0	0.70	3.70	63.00	1058	1706	
06/10/03	24.09	3.50	3.20	2000	0.0	600.0	0.70	5.30	74.00	1162	2038	

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

4 SPA
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Al (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	17.1	3.00	3.00	2400	0.0	3370.0	2.67	10.60	4135	507.20	6116	
08/28/90	10.2	3.10	3.10	3000	0.0	3470.0	2.70	13.30	4335	519.00	6104	
09/26/90	11.8	3.00	3.00	3200	0.0	4050.0	2.69	14.00	4505	550.60	7898	
10/25/90	14.1	3.20	3.10	3000	0.0	3600.0	2.94	11.70	4517	573.50	7024	
11/20/90	15.5	3.20	3.10	2800	0.0	3120.0	2.73	14.00	4273	534.50	5946	
12/20/90	17.6	3.10	3.10	2600	0.0	3250.0	2.35	12.80	4253	516.60	5827	
01/15/91	15.3	3.00	3.10	3200	0.0	3380.0	2.76	12.40	4531	506.00	6452	2.0
02/22/91	20.4	3.30	3.00	2000	0.0	3300.0	2.89	10.20	4442	522.20	6544	
03/25/91	21.7	3.00	3.00	2600	0.0	3200.0	2.66	7.72	4303	448.70	5872	
04/18/91	20.0	3.00	3.00	3600	0.0	3280.0	2.71	9.73	4161	432.10	6166	
05/14/91	19.0	3.00	3.00	4000	0.0	3570.0	2.83	9.65	4566	329.30	6198	
06/17/91	11.8	2.90	3.00	3200	0.0	3820.0	2.82	10.50	4817	632.90	9126	
07/24/91	7.8	3.00	3.00	4800	0.0	4100.0	2.73	11.00	5078	586.90	8040	7.0
08/23/91	6.2	3.10	3.00	4200	0.0	4160.0	2.67	10.70	5272	453.00	8150	
09/27/91	4.2	3.00	3.00	4800	0.0	4200.0	3.36	17.30	5372	704.20	8160	2.0
10/29/91	3.0	3.10	3.10	4200	0.0	3900.0	2.43	15.00	5527	558.40	8288	
11/27/91	2.8	3.10	3.10	4000	0.0	3980.0	2.75	15.30	5303	558.40	7872	24.0
12/12/91	6.1	3.10	3.10	4200	0.0	3740.0	2.97	13.90	4284	461.70	6642	26.0
01/23/92	7.5	2.90	2.70	1300	0.0	2900.0	2.30	12.90	3759	344.00	5632	
02/11/92	8.8	3.00	3.20	3200	0.0	2600.0	1.87	10.50	3477	229.00	5134	
03/25/92	15.1	3.10	3.10	3200	0.0	2530.0	1.92	7.10	3430	164.00	4846	
04/29/92	20.7	3.20	3.10	2800	0.0	2050.0	1.34	9.90	2859	203.00	4198	12.0
05/20/92	12.8	3.10	3.20	3000	0.0	2880.0	1.92	8.10	3526	239.00	5266	0.8
06/18/92	7.7	2.90	3.00	3000	0.0	3270.0	1.74	9.40	3310	340.00	5876	26.0
07/29/92	7.7	3.00	3.10	3200	0.0	2700.0	2.30	10.00	4105	299.00	5644	12.0
08/24/92	8.2	3.00	3.00	3000	0.0	3200.0	2.19	10.30	4006	236.00	6384	10.0
09/22/92	8.6	3.10	3.00	3000	0.0	2820.0	2.14	9.80	4474	284.00	5674	
10/21/92	7.7	3.10	3.00	3200	0.0	2900.0	2.11	10.50	4422	366.00	5292	
11/20/92	7.4	3.30	3.10	2800	0.0	3300.0	2.14	9.00	3998	286.00	5314	
12/21/92	10.9	3.10	3.00	2800	0.0	2730.0	2.48	9.60	4104	295.00	4732	
01/18/93	18.4	3.10	3.10	3000	0.0	3350.0	2.61	10.90	4230	301.00	5878	
02/25/93	11.5	3.90	3.20	2800	0.0	2540.0	2.00	8.70	3574	202.00	5116	
03/24/93	Flooded											
04/21/93	32.0	3.00	3.20	1800	0.0	3370.0	3.52	8.90	4368	358.00	7006	
05/21/93	18.8	3.10	3.20	2000	0.0	2560.0	3.06	6.00	3091	250.00	5104	0.8
06/28/93	13.9	3.20	3.30	2000	0.0	3560.0	2.95	10.80	4140	218.00	7188	
07/29/93	11.4	2.80	3.20	2200	0.0	3540.0	2.83	9.00	4491	360.00	6736	
08/18/93	10.1	3.30	3.10	2600	0.0	3170.0	2.96	9.70	4488	294.00	5662	
09/30/93	8.4	3.60	3.10	2600	0.0	3700.0	3.05	9.70	4235	230.00	7024	
10/27/93	3.3	3.10	3.10	2200	0.0	3230.0	3.01	8.80	3942	283.00	5974	
11/15/93	10.2	3.30	3.10	1800	0.0	3000.0	2.26	11.50	4263	275.00	5562	
12/15/93	15.6	3.30	3.10	2000	0.0	2560.0	2.48	8.30	3465	243.00	5138	10.0
01/26/94	8.0	3.40	3.10	1800	0.0	3110.0	2.44	8.30	3868	250.00	5486	
02/28/94	7.3	3.20	3.00	2000	0.0	3030.0	3.20	9.90	3798	250.00	5772	
03/30/94	10.4	3.10	3.10	2200	0.0	2860.0	2.79	9.70	4030	278.00	5452	
04/26/94	18.9	3.30	2.80	2400	0.0	3250.0	3.63	7.70	4200	286.00	6338	
05/31/94	12.3	3.80	3.10	1800	0.0	2850.0	3.36	8.60	3916	276.00	5540	
06/22/94	7.8	3.20	3.20	2000	0.0	3090.0	3.29	11.80	3952	112.00	5776	
10/31/94	18.3	3.30	3.20	3000	0.0	2212.0	2.59	7.30	3148	245.00	3830	
11/22/94	Flooded											
12/27/94	25.1	3.40	3.40	3200	0.0	1724.0	1.98	7.05	2344	182.00	3766	
01/31/95	Flooded											
02/27/95	21.2	3.50	3.30	2800	0.0	1590.0	1.90	5.52	2072	153.00	2774	
03/30/95	29.7	3.50	3.30	2800	0.0	1230.0	1.81	5.53	2139	152.00	3112	
04/27/95	Flooded											
05/31/95	Flooded											
06/21/95	Flooded											
07/25/95	Flooded											
08/28/95	Flooded											
09/20/95	Flooded											
10/24/95	Flooded											
11/22/95	Flooded											
12/21/95	Flooded											

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Al (mg/L)	TDS (mg/L)	TSS (mg/L)
01/29/96	Flooded											
02/09/96	Flooded											
03/14/96	9.1	3.40	3.10	3000	0.0	2460.0	1.97	12.10	2945	381.00	5166	
04/22/96	6.8	3.60	3.10	2800	0.0	2270.0			2908	404.00	4662	
05/20/96	Flooded											
06/21/96	2.4	3.90	3.10	2800	0.0	2230.0	1.60	10.60	3054	285.00	4724	
07/31/96		3.00	3.00	3000	0.0	1520.0	1.80	10.50	2966	361.00	5430	
08/26/96		3.00	3.10									
09/30/96	3.4	3.00	3.20	2800	0.0	1480.0	1.90	9.80	2864	365.00	3754	
10/25/96	11.9	3.00	3.10	3000	0.0	1350.0	1.40	9.20	2679	235.00	3268	
11/22/96	11.7	3.30	3.10	2600	0.0	1240.0	1.50	8.90	2423	233.00	3096	
12/18/96	14.6	2.80	2.30	2600	0.0	1290.0	1.80	7.90	2423	252.00	3460	
01/16/97	10.5	3.00	3.20	2800	0.0	5100.0	1.50	8.10	2598	375.00	3320	
02/24/97	10.2	2.90	3.20	3000	0.0	1810.0	2.30	14.30	2914	298.00	3912	
03/12/97	11.5	2.80	3.10	2800	0.0	1670.0	2.30	7.90	2583	222.00		
04/16/97	1.5	2.60	3.20	3000	0.0	1000.0	1.50	6.30	2500	244.00	3716	
05/28/97	3.7	2.90	3.20	3400	0.0	2520.0	2.30	12.30	3384	346.00	5070	
06/16/97	0.5	2.60	3.20	2800	0.0	1800.0	1.80	9.80	2749	269.00	5196	4.0
07/27/97	0.0											
08/22/97	0.4	2.70	3.20	3200	0.0	2000.0	2.20	11.80	2823	395.00	4816	
09/25/97	0.0											
10/29/97		2.90	3.70	2800	0.0	2160.0	2.00	11.90	3006	180.00	3812	
11/21/97	0.0											
12/18/97	0.0											
01/19/98	29.9	3.50	3.30	2600	0.0	1880.0	2.50	8.00	2617	150.00	3066	
02/23/98	29.4	3.40	3.20	3200	0.0	2210.0	4.10	8.80	2992	226.00	3916	
03/26/98	6.9	3.40	3.20	3800	0.0	2870.0	5.00	9.80	3921	384.00	5976	2.0
04/29/98	7.9	3.40	3.10	3000	0.0	2500.0	4.60	10.10	3563	275.00	4264	
05/28/98	3.1	3.90	3.00	3200	0.0	2800.0	4.90	8.10	3310	258.00	4488	
06/16/98	2.7	4.50	3.10	3600	0.0	2830.0	4.30	10.10	3828	412.00	7024	
07/24/98	0.2	4.00	2.90	3200	0.0	2400.0	2.60	10.10	3150	279.00	5272	
08/31/98	0.0											
09/21/98	0.0											
10/21/98	0.0											
11/18/98	0.0											
12/16/98	0.0											
01/13/99	0.0											
02/10/99	0.0											
03/17/99	2.0	2.90	3.10	2600	0.0	2400.0	2.20	8.40	2932	225.00	3824	
04/14/99	7.9	2.90	3.00	2600	0.0	1900.0	1.80	9.70	2762	164.00	3306	
05/26/99	1.1	3.00	3.30	2400	0.0	2650.0	2.00	9.80	3034	220.00	3701	
06/22/99	0.0											
07/14/99	0.0											
08/11/99	0.0											
09/22/99	0.0											
10/27/99	0.0											
11/17/99	0.0											
12/15/99	0.0											
01/27/00	0.0											
02/16/00	0.0											
03/15/00	1.1	3.00	3.30	2400	0.0	1270.0	1.60	11.20	2184	267.00	2974	
04/19/00	4.6	3.10	3.00	1800	0.0	1200.0	1.30	8.40	1763	197.00	2348	
05/17/00	0.8	3.20	3.20	1800	0.0	1200.0	1.30	7.90	1868	143.00	4202	
06/14/00	1.5	3.20	2.50	2000	0.0	1270.0	1.20	8.60	1807	129.00	2702	
07/31/00	0.0											
08/30/00	0.0											
09/29/00	0.0											
10/25/00	0.0											
11/15/00	0.0											
12/13/00	0.3	3.10	3.20	2390	0.0	1260.0	1.20	10.10	1609	167.00	2222	
01/17/01	0.3	3.00	3.20	2740	0.0	800.0	1.20	8.30	1775	87.00	2482	9.0
02/08/01	0.7	3.00	3.00	2700	0.0	1170.0	1.20	9.10	1532	191.00	2300	
03/14/01	Flooded											

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Al (mg/L)	TDS (mg/L)	TSS (mg/L)
04/11/01	5.0	3.00	2.90	2480	0.0	1400.0	1.30	6.50	1907	218.00	2656	
05/17/01	2.4	3.10	3.50	2310	0.0	1750.0	1.30	6.20	1896	201.00	2370	
06/11/01	1.3	3.10	3.30	2000	0.0	1100.0	1.10	7.10	1603	208.00	2238	
07/11/01	1.5	3.20	3.00	2320	0.0	1200.0	1.10	8.20	1692	171.00	2110	
08/08/01	0.0	3.10	3.20	2310	0.0	1200.0	1.10	8.10	1945	180.00	2362	
09/13/01	0.0											
10/10/01	0.0											
11/07/01	0.0											
12/05/01	0.0											
01/10/02	0.0											
02/06/02	0.4	2.50	3.20	2270	0.0	868.0	1.40	7.60	1570	169.00	2450	
03/08/02	0.6	3.00	3.30	2130	0.0	811.0	1.20	6.60	1342	115.00	2036	
04/02/02	2.2	3.00	3.30	2060	0.0	300.0	1.20	7.00	1392	140.00	348	
05/10/02	4.7	3.00	3.20	2200	0.0	1020.0	1.30	6.20	1592	161.00	2448	
06/03/02	3.1	3.00	3.20	2380	0.0	1160.0	1.20	6.00	1784	191.00	2374	
07/03/02	3.7	3.20	3.20	2250	0.0	800.0	1.10	5.40	1603	224.00	2370	
08/06/02	1.6	3.20	3.30	2090	0.0	800.0	0.90	5.90	1279	88.00	2028	
09/03/02	0.1	3.10	3.40	2010	0.0	700.0	0.70	7.40	1259	102.00	1724	
10/04/02	0.0											
11/06/02	0.0											
12/10/02	1.4	3.00	3.00	2440	0.0	1200.0	1.60	7.40	1149	191.00	2388	
01/10/03	6.4	3.10	3.10	2450	0.0	1038.0	1.60	6.50	1719	168.00	2514	
02/06/03	4.5	3.10	2.90	2430	0.0	900.0	1.50	4.60	1465	136.00	1978	
03/07/03	5.1	3.10	3.30	2480	0.0	920.0	1.40	5.60	1598	161.00	2838	
04/02/03	8.2	3.20	3.20	2490	0.0	870.0	1.50	4.70	1466	171.00	2470	
05/07/03	6.2	3.20	3.20	2200	0.0	616.0	1.20	4.00	1321	97.00	1802	
06/10/03	4.8	3.20	3.00	2240	0.0	900.0	1.30	5.30	1504	113.00	2846	
06/10/03			3.20	2240	0.0	847.8	0.95	4.79	1525	129.00	2850	6.0

Appendix 5.B
Ebensburg Power Company
Revloc Site

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Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	19.5	3.20	3.20	2200	0.0	2060.0	2.22	10.50	333.30	2760				4134	
08/28/90	12.3	3.20	3.20	2200	0.0	2240.0	2.16	9.98	278.50	2907				4060	
09/26/90	14.5	3.30	3.20	2400	0.0	2200.0	2.04	11.40	292.10	2951				5056	
10/25/90	23.0	3.40	3.30	2200	0.0	2300.0	2.23	9.95	352.90	2852				4958	
11/20/90	19.8	3.40	3.30	2200	0.0	2010.0	2.12	10.50	344.80	2814				4000	
12/20/90	22.6	3.20	3.30	2000	0.0	2090.0	1.85	9.41	333.30	2857				3872	
01/15/91	19.6	3.20	3.20	2600	0.0	2270.0	2.07	8.46	313.30	3021				4274	
02/22/91	35.1	3.40	3.20	1400	0.0	1740.0	1.93	6.45	288.90	2498				3722	
03/25/91	37.8	3.40	3.20	1800	0.0	1740.0	1.70	5.68	230.80	2435				3466	
04/18/91	28.7	3.20	3.10	2400	0.0	1730.0	1.74	6.61	246.90	2277				3370	
05/14/91	24.1	3.20	3.20	2600	0.0	1910.0	2.10	7.52	182.90	2620				3664	
06/17/91	12.0	3.10	3.20	2400	0.0	2500.0	2.20	7.71	329.10	3054				4570	
07/24/91	5.9	3.20	3.20	3600	0.0	2630.0	2.18	11.30	304.30	3528				5865	5.0
08/23/91	3.1	3.20	3.20	3000	0.0	2380.0	1.82	8.56	253.00	3218				5742	
09/27/91	1.0	3.30	3.30	3200	0.0	2200.0	1.76	15.60	338.00	2995				4580	
10/29/91	0.3	3.40	3.40	2800	0.0	2100.0	1.31	13.10	285.70	2976				4432	6.4
11/27/91	0.1	3.20	3.30	2400	0.0	1600.0	1.68	12.00	233.80	2308				3970	22.0
12/12/91	5.4	3.40	3.40	2600	0.0	1540.0	1.23	11.20	217.90	2270				2974	20.0
01/23/92	6.2	3.10	3.20	2200	0.0	1800.0	1.46	9.71	226.00	2333				3684	
02/11/92	11.5	3.20	3.40	2400	0.0	1600.0	1.25	7.64	198.00	2175				3546	
03/25/92	20.4	3.30	3.30	2400	0.0	1520.0	1.28	6.22	146.00	2324				3478	
04/29/92	26.3	3.30	3.20	2400	0.0	1680.0	1.22	6.94	145.00	2342				3370	2.0
05/20/92	17.0	3.30	3.40	2200	0.0	1490.0	1.38	5.42	141.00	2011				3250	
06/18/92	8.3	3.20	3.20	2400	0.0	2400.0	1.29	7.54	196.00	2737				3948	26.0
07/29/92	7.2	3.30	3.40	2200	0.0	2200.0	1.40	7.08	124.00	2263				3334	4.0
08/24/92	7.4	3.30	3.30	2400	0.0	1700.0	1.45	7.23	135.00	2912				4138	
09/22/92	7.1	3.40	3.30	2200	0.0	1650.0	1.27	6.57	137.00	2178				3336	
10/21/92	6.6	3.40	3.40	2400	0.0	1830.0	1.27	6.36	169.00	2324				3356	
11/20/92	5.7	3.60	3.30	2000	0.0	1500.0	1.10	5.16	130.00	1880				2586	
12/21/92	8.9	3.00	2.90	2000	0.0	1410.0	1.24	5.65	128.00	2282				2862	
01/18/93	28.5	3.30	3.30	2600	0.0	2470.0	1.92	7.25	272.00	3282				4984	
02/25/93	14.2	3.60	3.40	2200	0.0	1510.0	1.60	7.12	101.00	2628				3474	
03/24/93	20.6	3.60	3.60	2000	0.0	1690.0	1.62	6.37	217.00	2336				3048	
04/21/93	40.1	3.30	3.30	2000	0.0	2190.0	2.45	6.92	221.00	2634				4384	
05/21/93	26.2	3.40	3.40	1600	0.0	1440.0	2.16	4.15	150.00	1877				3162	0.4
06/28/93	16.5	3.50	3.50	2000	0.0	1910.0	2.45	9.73	149.00	2575				3676	
7/29/1993	11.1	3.50	3.10	1400	0.0	1660.0	2.14	6.29	220.00	2654				3932	
8/18/1993	9.9	3.70	3.30	1800	0.0	1870.0	2.03	6.56	167.00	2599				3444	
9/30/1993	7.2	3.90	3.40	2000	0.0	1360.0	1.71	5.91	120.00	2128				3496	
10/27/1993	8.7	3.30	3.40	1600	0.0	1550.0	1.96	6.86	141.00	2297				3238	
11/15/1993	9.7	3.60	3.40	1600	0.0	1590.0	1.66	8.66	167.00	2367				3186	
12/15/1993	25.4	3.60	3.30	1600	0.0	1900.0	1.98	5.81	168.00	2538				3626	
1/26/1994	15.1	3.70	3.40	1600	0.0	1710.0	1.85	5.84	143.00	2377				3332	
2/28/1994	11.3	3.50	3.40	1600	0.0	1470.0	2.03	6.07	138.00	2444				3044	
3/30/1994	16.8	3.40	3.40	1800	0.0	1900.0	2.49	6.98	167.00	2793				4108	

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
4/26/1994	30.9	3.60	3.10	2000	0.0	1790.0	2.75	5.32	153.00	2379				3322	
5/31/1994	18.1	3.60	3.30	1600	0.0	1500.0	2.73	5.76	143.00	2433				3498	
6/22/1994	11.5	3.60	3.30	1800	0.0	1490.0	2.38	7.21	102.00	2591				3942	
10/31/1994	6.1	3.40	3.40	2400	0.0	1280.0	1.60	5.40	122.00	2200				2754	
11/22/1994	6.7	3.60	3.70	2200	0.0	1040.0	1.40	6.40	116.00	1841				2322	
12/27/1994	18.2	3.50	3.60	2600	0.0	1150.0	1.50	5.50	138.00	1980				2890	
1/31/1995	17.5	3.60	3.20	2400	0.0	880.0	1.30	5.10	88.00	1474				2352	
2/27/1995	16.1	3.60	3.50	2600	0.0	1120.0	1.30	5.00	91.00	1569				2112	
3/30/1995	18.7	3.60	3.40	2600	0.0	920.0	1.40	4.90	111.00	1698				2452	
4/27/1995	13.4	3.60	3.40	2200	0.0	940.0	1.30	5.80	122.00	1671				2452	
5/31/1995	13.3	3.50	3.40	2200	0.0	920.0	1.30	4.80	107.00	1724				2766	
6/21/1995	12.9	3.50	3.40	2400	0.0	990.0	1.30	5.80	88.00	1725				3022	
7/25/1995	13.1	3.50	3.60	2200	0.0	1050.0	1.20	5.30	92.00	2079				1594	
8/28/1995	9.9	3.30	3.50	2600	0.0	1300.0	1.50	5.70	113.00	2133				3364	
9/20/1995	7.1	3.50	3.20	2600	0.0	1210.0	1.30	5.70	125.00	2105				2970	
10/24/1995	Flooded						Flooded								
11/22/1995	Flooded						Flooded								
12/21/1995	Flooded						Flooded								
1/29/1996	Flooded						Flooded								
2/9/1996	Flooded						Flooded								
3/14/1996	11.0	3.30	3.30	2400	0.0	1400.0	1.50	8.20	210.00	1997				3268	
4/22/1996	11.2	3.70	3.30	2200	0.0	1300.0	1.60	6.60	246.00	1811				2956	
5/20/1996	Flooded						Flooded								
6/21/1996	13.5	4.10	3.30	2200	0.0	1050.0	1.20	8.40	131.00	1849				2576	
7/31/1996	13.2	3.00	3.20	2400	0.0	730.0	1.30	7.40	170.00	1812				3258	
8/26/1996	9.3	3.30	3.30	2200	0.0	800.0	1.40	7.00	168.00	1936				3672	
9/30/1996	15.4	3.20	3.40	2400	0.0	840.0	1.30	7.00	199.00	2040				3218	
10/25/1996	18.0	3.10	3.30	2400	0.0	650.0	1.00	6.20	145.00	1686				2166	
11/22/1996	22.1	2.90	3.30	2200	0.0	600.0	1.10	6.20	120.00	1707				2358	
12/18/1996	25.0	3.00	2.50	2200	0.0	130.0	1.30	5.90	117.00	1609				1934	
1/16/1997	18.8	3.10	3.40	2400	0.0	700.0	1.10	6.00	141.00	1613				2156	
2/24/1997	16.6	3.20	3.40	2200	0.0	700.0	1.40	7.90	124.00	1658				2428	
3/12/1997	24.5	3.10	3.30	2400	0.0	770.0	1.60	6.00	105.00	1621				2442	
4/16/1997	18.9	2.70	3.40	2400	0.0	1600.0	1.10	5.30	124.00	1685				2410	
5/28/1997	13.8	3.10	3.40	2400	0.0	970.0	1.20	7.50	146.00	1786				2936	
6/16/1997	16.6	2.80	3.40	2200	0.0	900.0	1.10	9.70	148.00	1749				3236	
7/25/1997	6.4	3.20	3.10	2000	0.0	900.0	0.90	7.50	197.00	1546				2524	
8/22/1997	7.1	3.20	3.50	2000	0.0	300.0	0.80	7.30	119.00	1351				2310	
9/25/1997	4.4	3.50	3.50	2000	0.0	690.0	0.70	5.30	97.00	1519				2154	
10/29/1997	3.6	3.30	3.30	2000	0.0	610.0	0.70	5.30	92.00	1339				1760	
11/21/1997	12.7	3.30	3.60	2400	0.0	1300.0	1.00	6.70	97.00	2061				3188	
12/18/1997	13.3	3.70	3.20	2400	0.0	1110.0	1.40	5.80	92.00	1799				2498	
1/19/1998	15.8	3.70	3.60	2400	0.0	1120.0	1.40	5.60	98.00	1779				2682	
2/23/1998	14.9	3.70	3.50	2400	0.0	990.0	1.80	5.60	115.00	1677				2342	
3/26/1998	18.8	3.70	3.40	2600	0.0	1510.0	2.30	7.70	130.00	2457				3504	

Bold Italic= less than detection limits

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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
4/29/1998	16.4	3.70	3.40	2200	0.0	1140.0	1.90	5.90	93.00	1916				2516	
5/28/1998	14.3	4.10	3.30	2400	0.0	1130.0	2.00	6.60	87.00	2077				2788	
6/16/1998	6.8	4.70	3.40	2800	0.0	1550.0	2.70	7.80	205.00	2457				4040	
7/24/1998	4.4	4.30	3.30	2600	0.0	1100.0	1.00	7.40	131.00	1984				3160	
8/31/1998	1.8	3.30	3.40	2400	0.0	800.0	0.90	8.60	107.00	2231				3078	
9/21/1998	2.3	3.30	3.40	1800	0.0	1050.0	0.80	8.10	114.00	2018				2524	
10/21/1998	4.6	3.50	3.40	2200	0.0	922.0	0.60	6.70	115.00	1963				2794	
11/18/1998	0.0						Flooded								
12/16/1998	0.0						Flooded								
1/13/1999	0.0						Flooded								
2/10/1999	0.0						Flooded								
3/17/1999	10.8	3.30	3.50	2000	0.0	830.0	0.50	5.70	100.00	1838				2170	
4/14/1999	21.0	3.40	3.40	2000	0.0	800.0	0.50	5.80	43.00	1552				1918	
5/26/1999	11.0	3.40	3.40	1800	0.0	790.0	0.60	5.60	74.00	1492				2018	
6/22/1999	4.2	3.30	3.50	2400	0.0	890.0	0.60	6.40	107.00	1640				2582	
7/14/1999	1.8	3.50	3.60	2212	0.0	650.0	0.60	8.10	124.00	2212				3392	
8/11/1999	0.5	3.40	3.60	570	0.0	500.0	0.60	9.10	108.00	1656				3070	
9/22/1999	0.4	3.40	3.70	480	0.0	64.0	0.50	8.00	135.00	1518				2114	
10/27/1999	1.1	3.50	3.40	1800	0.0	82.0	0.50	8.00	7.00	6148				2316	
11/17/1999	0.8	3.50	3.60	2000	0.0	990.0	0.40	8.40	81.00	1535				2832	
12/15/1999	3.1	3.50	3.60	1900	0.0	510.0	0.50	7.60	93.00	1497				3148	
1/27/2000	3.6	3.50	3.70	1600	0.0	1140.0	0.40	7.10	72.00	1306				1766	
2/16/2000	2.5	3.50	3.60	1600	0.0	430.0	0.30	7.30	81.00	1376				2300	
3/15/2000	14.4	2.40	3.70	2000	0.0	730.0	0.50	8.50	122.00	1521				2194	70.0
4/19/2000	15.4	3.40	3.70	1400	0.0	600.0	0.40	6.90	81.00	1194				1550	28.0
5/17/2000	12.9	3.50	3.60	1400	0.0	600.0	0.40	6.50	44.00	1172				2918	
6/14/2000	12.4	3.50	2.90	2800	0.0	570.0	0.40	7.00	57.00	1268				1726	
7/31/2000	4.3	3.60	3.60	1800	0.0	600.0	0.40	8.00	76.00	1389				1812	
8/30/2000	4.6	3.60	4.80	1800	0.0	680.0	0.50	7.90	82.00	1525				2132	
9/29/2000	2.7	3.60	3.70	2600	0.0	950.0	0.50	8.70	133.00	1804				2364	
10/25/2000	3.4	3.60	3.50	2600	0.0	700.0	0.50	8.40	110.00	1695				2448	
11/15/2000	3.6	3.50	3.50	2220	0.0	700.0	0.40	7.80	50.00	1494				2102	
12/13/2000	4.4	3.60	3.60	2120	0.0	580.0	0.50	7.40	74.00	1281				1920	
1/17/2001	4.9	3.50	3.60	2020	0.0	500.0	0.40	6.90	56.00	1194				1810	
2/8/2001	6.9	3.40	3.40	1983	0.0	500.0	0.40	7.00	60.00	1148				1838	
3/14/2001	Flooded						Flooded								
4/11/2001	Flooded						Flooded								
5/17/2001	12.7	3.30	3.50	2180	0.0	700.0	0.60	6.30	79.00	1576				1930	
6/11/2001	7.4	3.40	3.60	2000	0.0	700.0	0.60	7.40	100.00	1414				1624	
7/11/2001	6.8	3.50	3.20	2180	0.0	600.0	0.50	8.00	82.00	1473				2054	
8/8/2001	4.0	3.50	3.50	2190	0.0	700.0	0.50	8.00	97.00	1450				2072	
9/13/2001	2.3	3.50	3.70	2140	0.0	400.0	0.50	8.20	88.00	1441				2058	
10/10/2001	1.0	3.50	3.60	2120	0.0	600.0	0.40	7.60	84.00	1398				2848	
11/6/2001	0.3	3.50	4.00	2130	13.0	462.0	0.40	8.50	86.00	1411				2042	
12/5/2001	1.0	3.60	3.70	2090	0.0	90.0	0.40	8.70	86.00	1330				1928	

Bold Italic= less than detection limits

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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)
1/10/2002	5.3	3.50	3.60	1906	0.0	373.0	0.40	6.80	60.00	1038				4084	
2/6/2002	6.9	3.50	3.70	1766	0.0	333.0	0.40	6.00	50.00	968				1492	
3/8/2002	12.7	3.50	3.80	1834	0.0	284.0	0.30	5.90	41.00	1030				1512	
4/2/2002	14.3	3.50	4.30	1845	0.0	280.0	0.30	6.10	40.00	970				1804	
5/10/2002	18.4	3.50	3.70	1805	0.0	310.0	0.30	5.40	42.00	983				1574	
6/3/2002	22.4	3.50	3.60	1917	0.0	430.0	0.30	5.40	65.00	1134				1668	
7/3/2002	17.8	3.60	3.70	1913	0.0	500.0	0.40	4.90	59.00	1091				1626	
8/6/2002	6.9	3.60	3.70	2010	0.0	500.0	0.30	5.80	48.00	1157				1788	
9/3/2002	3.9	3.50	3.80	2150	2.0	300.0	0.30	7.10	51.00	1238				1762	
10/4/2002	2.5	3.70	3.80	2170	2.0	188.0	0.20	7.70	63.00	1290				1976	
11/6/2002	0.0						Flooded								
12/10/2002	9.7	3.60	3.50	2030	15.0	400.0	0.30	6.30	52.00	107				1790	
1/10/2003	21.7	3.60	3.70	1953	15.0	400.0	0.20	5.40	44.00	1044				1668	
2/6/2003	16.3	3.60	3.40	2090	14.0	400.0	0.30	4.70	44.00	1239				1652	
3/7/2003	16.3	3.60	3.80	1896	2.0	1760.0	0.30	5.40	44.00	1086				2090	
4/2/2003	25.3	3.70	3.70	2120	0.0	300.0	0.30	5.20	48.00	6925				9532	
5/7/2003	17.7	3.70	3.70	2090	0.0	400.0	0.40	4.40	40.00	1157				1768	
6/10/2003	21.8	3.70	3.60	2090	0.0	432.0	0.30	5.50	49.00	1171				2050	
6/10/2003			3.70	2090	0.0	350.2	0.24	5.09	51.90	1159	98.00	55.30	37.80	2400	4.0

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
07/31/90	3.6	3.20	3.20	2000	0.0	1700.0	3.61	10.80	362.30	2488	3737	
08/28/90	2.1	3.20	3.20	2200	0.0	2070.0	3.73	11.80	265.80	2795	3984	
09/26/90	2.9	3.20	3.10	2200	0.0	1880.0	4.00	12.00	236.00	2627	4398	
10/25/90	2.8	3.30	3.20	2200	0.0	2090.0	6.14	10.10	323.50	2795	4092	
11/20/90	3.0	3.20	3.10	2000	0.0	1590.0	3.64	10.90	275.90	2495	3489	
12/20/90	3.4	3.40	3.30	1800	0.0	1560.0	2.66	9.07	226.70	2133	3246	
01/15/91	2.6	3.10	3.10	2400	0.0	2210.0	3.35	8.28	204.80	2775	3694	
02/22/91	6.4	3.60	3.10	1200	0.0	1600.0	2.93	6.54	222.20	2156	3044	
03/25/91	9.0	3.40	3.20	1800	0.0	1550.0	2.44	5.45	192.30	2156	2974	
04/18/91	6.7	3.10	3.00	2200	0.0	1670.0	2.96	7.15	209.90	2184	3060	
05/14/91	4.0	3.20	3.20	2600	0.0	1800.0	3.56	8.32	158.50	2515	3476	
06/17/91	2.1	3.00	3.10	2400	0.0	2400.0	6.46	11.10	253.20	2903	5408	
07/24/91	1.0	3.10	3.10	3400	0.0	2280.0	3.58	12.10	315.20	3058	5027	10.0
08/23/91	0.5	3.10	3.10	2600	0.0	1680.0	2.62	8.77	253.00	2236	3970	
09/27/91	0.7	3.10	3.10	18	0.0	760.0	2.53	9.72	98.60	1098	1922	
10/29/91	0.0											
11/27/91	0.0											
12/12/91	0.6	3.40	3.40	2000	0.0	840.0	2.42	11.50	88.50	1386	1850	28.0
01/23/92	2.3	3.00	3.10	2000	0.0	1380.0	3.19	8.85	161.00	1948	2624	
02/11/92	2.0	3.10	3.20	2200	0.0	1500.0	3.21	9.69	146.00	1966	2980	
03/25/92	3.7	3.20	3.20	2400	0.0	1410.0	2.92	6.54	130.00	2156	3172	
04/29/92	3.0	3.30	3.30	2200	0.0	1530.0	2.44	7.15	130.00	2099	2990	10.0
05/20/92	3.2	3.20	3.40	2200	0.0	1530.0	2.79	6.62	141.00	1970	3180	
06/18/92	1.6	3.00	3.10	2400	0.0	2040.0	2.43	7.79	165.00	2371	3468	30.0
07/29/92	1.3	3.20	3.20	2200	0.0	1000.0	3.15	8.09	113.00	1509	2406	
08/24/92	1.2	3.20	3.20	2200	0.0	1100.0	2.66	8.53	112.00	2577	3484	
09/22/92	0.9	3.30	3.20	2000	0.0	1310.0	2.36	7.01	116.00	1735	2834	
10/21/92	1.1	3.30	3.20	2200	0.0	1470.0	2.84	7.24	141.00	2286	3090	4.0
11/20/92	0.7	3.50	3.10	1800	0.0	1060.0	3.05	5.79	117.00	1568	2158	
12/21/92	1.3	3.00	2.80	2000	0.0	940.0	2.44	6.16	97.00	1993	2118	
01/18/93	6.2	3.20	3.20	2400	0.0	2080.0	3.48	6.11	184.00	3017	3594	
02/25/93	2.5	3.60	3.20	2200	0.0	1380.0	3.36	6.66	121.00	2272	3302	
03/24/93	Flooded											
04/21/93	Flooded											
05/21/93	5.6	3.40	3.30	1200	0.0	1310.0	3.17	4.25	140.00	1877	2898	
06/28/93	3.0	3.40	3.40	2000	0.0	1840.0	3.94	10.10	119.00	2472	3436	
7/29/1993	1.7	3.10	3.20	2000	0.0	1550.0	3.88	7.30	150.00	2204	3588	
8/18/1993	1.5	3.50	3.20	1400	0.0	1410.0	3.89	9.10	137.00	2182	3186	
9/30/1993	1.4	3.90	3.30	1400	0.0	770.0	2.34	4.10	59.00	1328	1568	
10/27/1993	1.4	3.30	3.30	1600	0.0	1320.0	3.78	8.00	121.00	2252	3116	
11/15/1993	1.3	3.50	3.20	1400	0.0	1260.0	3.04	7.30	128.00	1896	2666	
12/15/1993	5.3	3.60	3.20	1440	0.0	1440.0	3.13	5.40	122.00	2124	3168	
1/26/1994	2.3	3.80	3.30	1600	0.0	1440.0	3.24	6.10	107.00	2169	3246	
2/28/1994	2.1	3.50	3.30	1400	0.0	1080.0	3.41	5.40	88.00	1597	2326	
3/30/1994	2.2	3.30	3.30	1800	0.0	1630.0	3.43	6.70	144.00	2504	3324	
4/26/1994	7.1	3.50	3.10	1800	0.0	1330.0	3.69	4.70	122.00	2281	3326	
5/31/1994	1.0	3.50	3.20	1400	0.0	1400.0	4.04	5.60	112.00	2320	3118	
6/22/1994	1.7	3.50	3.10	1600	0.0	1240.0	4.11	6.50	99.00	2235	3692	
10/31/1994	0.6	3.30	3.20	2400	0.0	980.0	2.93	5.30	96.00	1988	2272	
11/22/1994	0.7	3.40	3.50	2000	0.0	700.0	2.42	5.80	81.00	1306	1768	
12/27/1994	2.7	3.40	3.50	2400	0.0	900.0	3.02	5.50	100.00	1631	2228	
1/31/1995	Flooded											
2/27/1995	2.3	3.60	3.40	2200	0.0	840.0	2.63	5.17	70.00	1342	1862	
3/30/1995	2.5	3.60	3.30	2400	0.0	820.0	2.77	5.64	81.00	1439	2300	
4/27/1995	1.7	3.60	3.30	2200	0.0	750.0	2.79	5.60	97.00	1480	2148	
5/31/1995	1.8	3.40	3.30	2000	0.0	710.0	2.77	4.73	80.00	1432	2604	
6/21/1995	1.6	3.40	3.30	2400	0.0	820.0	2.62	5.00	64.00	1414	2614	
7/25/1995	1.6	3.30	3.40	2000	0.0	680.0	2.98	5.39	72.00	1862	1242	
8/28/1995	0.9	3.30	3.30	2400	0.0	1040.0	2.48	5.82	104.00	1872	3362	
9/20/1995	0.4	3.40	3.10	2400	0.0	970.0	1.56	5.53	98.00	1766	2478	
10/24/1995	0.8	3.30	3.20	2200	0.0	960.0	2.75	4.90	96.00	1977	2175	
11/22/1995	1.4	3.40	3.40	2400	0.0	800.0	2.62	5.10	85.00	1426	1780	
12/21/1995	2.4	3.70	3.10	2000	0.0	1030.0	2.77	5.20	100.00	1781	2590	

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
1/29/1996	1.1	3.80	3.30	2200	0.0	890.0	2.56	7.50	135.00	1506	2418	
2/9/1996	1.3	3.50	3.40	2000	0.0	900.0	2.30	11.50	160.00	1502	2188	
3/14/1996	6.0	3.60	3.20	2200	0.0	1080.0	2.21	8.10	162.00	1613	2746	
4/22/1996	2.7	3.70	3.20	2200	0.0	1050.0	2.55	6.80	184.00	1562	2814	
5/20/1996	2.2	3.90	3.30	2200	0.0	680.0	2.26	7.60	49.00	1524	2142	
6/21/1996	1.8	4.00	3.20	2000	0.0	760.0	2.41	8.40	97.00	1527	2122	
7/31/1996	1.7	3.10	3.10	2200	0.0	580.0	2.55	7.60	117.00	1491	2498	
8/26/1996	1.0	3.00	3.20	2000	0.0	900.0	2.96	7.10	121.00	1854	2404	
9/30/1996	2.0	3.10	3.30	2200	0.0	600.0	2.50	6.55	129.00	1597	2430	
10/25/1996	2.2	3.00	3.20	2200	0.0	450.0	2.23	5.90	91.00	1330	1798	
11/22/1996	3.2	3.00	3.30	2000	0.0	480.0	2.23	5.80	87.00	1370	1986	
12/18/1996	5.3	2.90	2.30	2000	0.0	600.0	2.32	5.80	97.00	1355	1544	
1/16/1997	2.9	3.10	3.30	2200	0.0	700.0	2.43	6.70	165.00	1496	2216	
2/24/1997	2.4	3.00	3.30	2000	0.0	430.0	2.76	7.90	75.00	1158	1834	
3/12/1997	4.6	3.10	3.20	2000	0.0	600.0	2.75	5.40	88.00	1335	1808	
4/16/1997	2.8	2.70	3.30	2200	0.0	1000.0	2.14	5.60	92.00	1400	2064	
5/28/1997	1.6	3.10	3.30	2200	0.0	710.0	2.30	9.70	110.00	1486	2116	
6/16/1997	2.1	2.70	3.30	2000	0.0	300.0	2.27	9.10	104.00	1437	2540	2.0
7/25/1997	0.6	3.00	3.00	2000	0.0	200.0	2.14	8.30	131.00	1343	1920	
8/22/1997	0.7	3.00	3.40	1800	0.0	490.0	1.59	6.20	79.00	949	1598	
9/25/1997	0.2	3.40	3.30	2000	0.0	590.0	2.63	5.00	74.00	1288	1330	6.0
10/29/1997	0.1	3.30	3.20	1600	0.0	430.0	2.00	4.60	52.00	868	1216	
11/21/1997	Flooded											
12/18/1997	0.1	3.50	3.40	2400	0.0	950.0	11.50	8.10	76.00	1735	2670	
1/19/1998	0.0											
2/23/1998	0.0											
3/26/1998	0.0											
4/29/1998	0.0											
5/28/1998	0.0											
6/16/1998	0.0											
7/24/1998	0.0											
8/31/1998	0.0											
9/21/1998	0.0											
10/21/1998	0.0											
11/18/1998	0.0											
12/16/1998	0.0											
1/13/1999	0.0											
2/10/1999	0.0											
3/17/1999	0.0											
4/14/1999	0.0											
5/26/1999	0.0											
6/22/1999	0.0											
7/14/1999	0.0											
8/11/1999	0.0											
9/22/1999	0.0											
10/27/1999	0.0											
11/17/1999	0.0											
12/15/1999	0.0											
1/27/2000	0.0											
2/16/2000	0.0											
3/15/2000	0.0											
4/19/2000	0.0											
5/17/2000	0.0											
6/14/2000	0.0											
7/31/2000	0.0											
8/30/2000	0.0											
9/29/2000	0.0											
10/25/2000	0.0											
11/15/2000	0.0											
12/13/2000	0.0											
1/17/2001	0.0											
2/8/2001	0.0											
3/14/2001	0.0											

Bold Italic= less than detection limits

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)
4/11/2001	0.0											
5/17/2001	0.0											
6/11/2001	0.0											
7/11/2001	0.0											
8/8/2001	0.0											
9/13/2001	0.0											
10/10/2001	0.0											
11/6/2001	0.0											
12/5/2001	0.0											
1/10/2002	0.0											
2/6/2002	0.0											
3/8/2002	0.0											
4/2/2002	0.0											
5/10/2002	0.0											
6/3/2002	0.0											
7/3/2002	0.0											
8/6/2002	0.0											
9/3/2002	0.0											
10/4/2002	0.0											
11/6/2002	0.0											
12/10/2002	0.0											
1/10/2003	0.0											
2/6/2003	0.0											
3/7/2003	0.0											
4/2/2003	0.0											
5/7/2003	0.0											

Appendix 5.2
Ebensburg Power Company
Revloc Site

MW-1
Inorganics

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)
09/21/88		4.20	4.10	1400	9.0	127.0	269.00	22.00	1111					1895	15.0		
12/06/88		4.60	4.40	1200	18.0	148.0	210.00	15.00	1148					1873	11.6		
03/29/89		4.21	4.00	1400	8.0	165.0	249.00	15.10	1091					1610	26.0		
06/02/89		5.31	3.20	1400	0.0	600.0	164.00	14.30	1082					2346	268.0		
09/21/89		4.60	4.10	1400	10.0	570.0	235.00	18.60	1053					1600	152.0		
12/21/89		4.20	3.60	1200	0.0	570.0	183.00	19.80	976					1590	14.4		
03/21/90		4.40	4.10	1200	10.0	560.0	206.00	19.00	902					1454	42.8		
09/26/90	1907.0	4.20	4.30	1200	14.0	520.0	211.40	15.90	888					1756	86.0		
12/20/90	1907.0	4.30	3.90	1000	6.0	494.0	393.90	42.40	866	1.00	8.10	8.33	4.89	1300	16.0		***0.10***
03/25/91	1909.0	4.20	4.20	920	12.0	488.0	174.00	13.20	869					1326	60.0		
06/17/91	1905.0	4.30	4.30	1200	12.0	468.0	150.30	28.10	838	1.00	8.80	7.84	6.05	1360	354.0		0.10
09/27/91	1903.0	4.40	4.40	1800	8.0	400.0	161.10	16.90	867					1464			
12/12/91	1903.0	3.20	3.20	2000	0.0	470.0	134.50	13.60	882	***0.92***	4.80	7.12	4.90	1442	154.0		***0.10***
03/25/92	1904.0	4.50	4.10	1400	4.0	436.0	164.60	7.60	800					1100	134.0		
06/18/92	1903.0	3.30	3.30	1600	0.0	410.0	65.70	11.00	788	2.00	2.50	9.60	7.25	1316			3.50
09/22/92	1906.0	4.70	3.90	1400	0.0	480.0	99.00	11.70	785					1312	14.0		
12/21/92	1906.0	3.60	3.60	1400	0.0	420.0	93.80	10.20	853	1.10	3.00	7.48	6.80	1192			0.10
03/24/93	1908.0	4.50	3.90	1400	6.0	424.0	164.10	9.27	735					1034			
06/28/93	1909.0	4.70	4.20	1200	12.0	364.0	117.60	13.70	772	1.60	0.24	7.38	6.90	1164	50.0		0.10
09/30/93	1907.0	5.40	3.20	1200	0.0	390.0	69.20	7.60	696					1086			
12/15/93	1910.0	4.80	3.00	620	0.0	366.0	158.00	7.20	593	2.20	8.40	8.35	6.98	1054		***1.00***	***0.10***
03/30/94	1908.0	4.70	4.10	700	8.0	322.0	214.00	8.40	658					956			
06/24/94	1908.0	4.60	4.10	620	6.0	344.0	140.00	8.20	640	2.00	3.00	6.36	6.41	956			8.40
09/28/94	1909.0	4.80	4.30	460	8.0	302.0	89.00	9.80	603					918	8.0		
12/27/94	1908.0	4.70	4.40	1600	18.0	414.0	66.00	7.40	578	2.00	3.40	6.78	6.13	786			2.50
03/30/95	1908.0	4.60	4.20	1400	18.0	260.0	72.00	7.50	508					752			
06/21/95	1909.0	4.40	4.00	1200	6.0	54.0	77.00	5.60	481	0.72	8.30	6.99	6.40	858	0.8	3.36	10.00
09/21/95	1908.0	4.80	4.20	1200	8.0	252.0	66.00	6.40	464					770	4.0		
12/21/95	1908.0	4.80	3.00	700	0.0	180.0	87.00	5.70	476	0.66	6.60	6.61	7.45	600		3.36	1.90
03/14/96	1908.0	4.60	3.20	1400	0.0	220.0	218.00	9.40	465					564			
06/24/96	1909.0	5.00	4.20	1000	6.0	252.0	80.00	10.00	476	0.74	0.56	5.46	0.50	828		***0.10***	***0.10***
09/30/96	1908.0	4.30	4.40	700	10.0	22.0	91.00	7.80	428					560			
12/18/96	1911.0	3.70	3.70	700	0.0	200.0	207.00	7.40	379	0.75	6.00	5.28	4.13	514		1.40	***0.10***
03/12/97	1911.0	3.60	3.90	700	4.0	366.0	112.00	5.90	359					672			
06/16/97	1910.0	4.00	4.50	660	0.0	1300.0	92.00	8.90	385	0.70	2.70	5.07	3.77	654	126.0	1.14	***0.10***
09/25/97	1908.0	4.50	4.40	600	12.0	138.0	62.00	5.90	387					570	8.0		
12/18/97	1909.0	4.90	2.70	1400	0.0	160.0	73.00	5.30	347	0.68	9.80	8.10	3.58	512	14.0	2.24	***0.10***
03/26/98	1911.0	5.90	3.10	760	0.0	510.0	48.00	6.30	381					504	12.0		
06/23/98	1909.0	5.50	3.10	660	0.0	220.0	95.00	5.90	325	0.64	16.00	5.29	3.60	508	14.0	2.24	0.22
09/21/98	1908.0	4.40	3.60	540	0.0	180.0	44.00	6.50	364					158			
12/16/98	1906.0	4.50	4.00	600	8.0	262.0	18.00	6.20	336	0.50	3.70	5.60	3.81	502	4.0	2.24	***0.10***
03/17/99	1909.0	4.10	3.00	1200	0.0	140.0	23.00	6.50	342					400	42.0		
06/22/99	1908.0	4.20	2.90	1400	0.0	300.0	53.00	6.40	394	0.58	11.00	10.90	3.61	458	32.0	3.36	***0.10***
09/22/99	1907.0	4.70	3.40	300	0.0	40.0	43.00	6.50	328					432			
12/15/99	1909.0	4.39	3.00	760	0.0	170.0	15.00	5.40	327	0.64	22.00	5.00	3.63	468		1.12	***0.10***

Bold Italic= less than detection limits

Appendix 5.2
Ebensburg Power Company
Revloc Site

MW-1
Inorganics
Page 2

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)
03/15/00	1909.0	4.33	3.70	600	0.0	170.0	63.00	6.20	278					460			
06/14/00	1910.0	4.76	3.60	680	0.0	150.0	30.90	6.40	293	0.62	3.53	10.70	3.45	602	12.0		***0.10***
09/29/00	1907.9	4.90	4.50	760	0.0	190.0	71.00	5.90	291					446			
12/13/00	1908.0	4.40	4.50	1112	0.0	160.0	54.00	5.80	279		14.50	15.50	3.53	376			
03/14/01	1908.0	3.23	3.20	735	0.0	170.0	21.50	6.00	240					332			
06/11/01	1910.0	3.50	2.90	853	0.0	100.0	3.72	6.70	241					388			
09/13/01	1908.0	3.82	3.70	815	0.0	230.0	53.00	6.10	292					422			
11/06/01	1907.0	4.74	4.20	809	10.0	68.7	49.00	6.30	109		22.50	11.80	3.28	142			
03/08/02	1909.0	3.65	3.30	874	0.0	97.3	6.10	5.90	247					376			
06/17/02	1911.0	4.50	3.50	789	0.0	70.0	69.00	6.50	257					392			
09/03/02	1908.3	4.80	3.00	1048	0.0	200.0	20.60	6.80	286					244			
11/06/02	1907.8	5.00	2.70	933	0.0	130.0	23.30	6.10	284		19.90	5.25	3.43	484			
03/07/03	1908.9	3.70	4.00	743	4.0	106.0	12.70	5.90	239					320			
6/10/2003	1911.0	3.60	3.00	729	0.0	600.0	82.00	7.20	296					270			
6/10/2003			3.30	720	0.0	110.2	77.80	6.97	219		23.40	5.90	2.92	1690	68.0		

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

MW-2
Metals
Page 1

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
09/21/88		1.00																										
12/06/88		6.70																										
03/29/89		1.30																										
06/02/89		2.80																										
09/21/89		2.20																										
12/21/89		1.00																										
03/21/90		1.00																										
09/26/90		1.23																										
12/20/90		1.00		0.0088		***0.200***		***0.0500***		3.64		***0.1000***		0.060		***0.1000***		0.83		0.0023				***0.0020***		***0.060***		0.060
03/25/91		1.00																										
06/17/91		1.00		0.0020		0.200		0.0500		2.13		0.1000		0.040		0.1000		6.19		0.0005				0.0020		0.060		0.040
12/12/91		1.00		0.0087		0.200		***0.0500***		0.99		***0.1000***		0.080		0.1400		4.81		***0.0005***				***0.0020***		***0.100***		0.060
06/18/92		1.00		0.0088		***0.200***		***0.0500***		4.37		***0.1000***		0.040		***0.1000***		3.95		***0.0005***				0.0049		***0.100***		0.040
09/22/92		1.00																										
12/21/92		10.20		0.0032		***0.200***		***0.0500***		5.78		***0.1000***		0.040		***0.1000***		5.13		***0.0005***				0.0186		***0.060***		0.120
03/24/93		1.00																										
06/28/93		1.88		0.0215		***0.200***		***0.0500***		3.66		***0.1000***		***0.040***		***0.2300***		4.40		***0.0005***				0.0097		***0.060***		0.080
09/30/93		3.10																										
12/15/93		1.12		0.0137		***0.200***		***0.0500***		4.94		***0.1000***		***0.040***		***0.1000***		4.41		***0.0005***				0.0220		***0.060***		0.100
03/30/94		1.00																										
06/22/94		1.00		0.0029		***0.200***		***0.0500***		4.14		***0.1000***		***0.040***		***0.1000***		4.40		***0.0005***				0.0026		***0.060***		0.110
09/28/94		2.61																										
12/27/94		1.17		0.0049		***0.200***		***0.0500***		5.17		***0.1000***		***0.040***		***0.1000***		4.81		***0.0005***				0.0020		***0.060***		0.050
03/30/95		1.01																										
06/21/95		1.30		0.0073		***0.200***		***0.0500***		3.80		***0.1000***		***0.040***		***0.1000***		4.75		***0.0005***				0.0055		***0.060***		0.110
09/21/95		1.98																										
12/21/95		1.00		0.0074		***0.200***		***0.0500***		5.26		***0.1000***		***0.040***		***0.1000***		3.19		***0.0005***				0.0020		***0.060***		0.080
03/14/96		1.00																										
06/24/96		1.00		***0.0010***		***0.200***		***0.0500***		5.40		***0.1000***		***0.040***		***0.1000***		7.80		***0.0005***				***0.0010***		***0.100***		***0.030***
09/30/96		1.00																										
12/18/96		***1.00***		***0.0020***		***0.200***		***0.0500***		4.74		***0.1000***		***0.040***		0.1500		6.85		***0.0005***				***0.0020***		***0.060***		0.070
03/12/97		***1.00***																										
06/16/97		***1.00***		***0.0020***		***0.200***		***0.0500***		5.30		***0.1000***		***0.040***		***0.1000***		8.60		***0.0005***				***0.0020***		***0.060***		0.060
09/25/97		1.00																										
12/18/97		***1.00***		***0.0020***		***0.200***		***0.0500***		3.90		***0.1000***		***0.040***		0.1400		7.10		***0.0005***				***0.0020***		***0.060***		0.060
03/26/98		***1.00***																										
06/23/98		***1.00***		***0.0020***		***0.200***		***0.0500***		3.50		***0.1000***		***0.040***		***0.1000***		6.20		***0.0005***				***0.0020***		***0.060***		***0.030***
09/21/98		2.00																										
03/17/99		***1.00***																										
06/22/99		***1.00***		***0.0020***		***0.200***		***0.0500***		4.10		***0.1000***		***0.040***		***0.1000***		7.00		***0.0005***				0.0030		***0.100***		0.100
09/22/99		7.00																										
12/15/99		6.00		0.0048		***0.200***		***0.0500***		2.99		***0.1000***		***0.040***		***0.1000***		108.00		***0.0005***				0.0081		***0.100***		***0.030***
03/15/00		4.00																										
06/14/00		***1.00***		***0.0020***				***0.0500***		7.00		***0.1000***		***0.040***		***0.1000***		8.00		***0.0005***				***0.0020***				0.700
09/29/00		***1.00***																										
12/13/00		***1.00***		***0.0020***				***0.0500***		6.00		***0.1000***		***0.040***		***0.1000***		8.00		***0.0005***		***0.100***		0.0080				***0.030***
03/14/01		***1.00***																										
06/11/01		***1.00***																										
09/13/01		***1.00***																										
11/06/01		2.00		0.0100				***0.0500***		5.00		***0.1000***		***0.040***		***0.1000***		5.00		***0.0005***		***0.100***		0.0000				0.060
03/08/02		***1.00***																										
06/17/02		***1.00***																										
09/03/02		***1.00***																										
11/06/02		***1.00***		0.0100				***0.0500***		***0.05***		***0.1000***		***0.040***		***0.1000***		8.00		***0.0005***		0.120		0.0000				***0.030***

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

MW-2
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
03/07/03		***1.00***																										
06/10/03		***1.00***																										
06/10/03		0.97		***0.0040***				***0.0100***		4.63		***0.0500***		***0.010***		0.0013		8.54		***0.0010***		0.069		***0.0070***				0.095

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

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Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
06/14/88		4.95	4.50	1100	0.0	200.0	6.41	3.00	342					515	474.0					
09/21/88		7.20	3.30	380	0.0	40.0	15.90	4.70	165					266	39.0					
12/06/88		5.40	4.60	200	1.0	21.0	6.30	1.26	105					143	57.0					
03/29/89		5.29	5.00	480	4.0	76.0	27.20	3.93	252					336	12.0					
06/02/89		4.33	3.00	820	0.0	210.0	57.00	8.39	458					762	15.6					
09/21/89		5.70	6.10	100	10.0	0.0	1.19	0.59	43					62	6.0					
12/21/89		5.10	6.10	120	8.0	0.0	0.17	0.72	49					94	4.8					
03/21/90		5.30	5.90	100	10.0	4.0	3.46	0.69	41					80	222.0					
09/26/90	1921.0	5.40	5.50	56	8.0	8.0	2.16	0.41	22					60	89.6					
12/20/90	1921.0	5.70	5.60	64	8.0	8.0	2.60	0.38	9	***0.10***	2.30	3.67	1.38	88	70.0		0.10			
03/25/91	1925.0	5.50	5.50	54	8.0	6.0	5.56	0.92	51					48	102.0					
06/17/91	1921.0	5.70	5.20	46	4.0	4.0	1.43	0.24	29	0.11	1.70	2.80	0.08	112	110.0		0.50			
09/27/91	1918.0	4.20	4.20	140	6.0	12.0	3.15	0.93	44					102	80.0					
12/12/91	1919.0	5.00	5.00	62	4.0	6.0	1.26	0.28	26	***0.10***	2.60	2.67	1.52	20	112.0		0.18			
03/25/92	1920.0	5.40	5.20	66	4.0	8.0	3.72	0.37	25					26	325.0					
06/18/92	1918.0	5.40	5.40	66	6.0	2.0	0.61	0.41	19	0.13	1.75	3.61	2.86	80	238.0		0.31			
09/22/92	1920.0	5.60	5.20	120	6.0	0.0	1.04	0.64	26					72	14.0					
12/21/92	1920.0	5.00	4.90	160	4.0	18.0	4.55	3.33	36	0.11	2.40	2.85	2.55	124			0.21			
03/24/93	1923.0	5.70	5.70	140	12.0	2.0	3.02	0.82	93					10	8.0					
06/28/93	1923.0	5.90	5.70	160	8.0	12.0	3.76	0.91	57	0.17	0.38	3.50	2.80	124	52.0		***0.10***			
09/30/93	1922.0	6.00	6.40	180	4.0	4.0	3.49	1.14	72					152	26.0					
12/15/93	1925.0	5.90	6.20	120	6.0	6.0	3.32	0.64	130	0.19	0.47	4.20	2.81	114	108.0	***1.00***	0.66			
03/30/94	1923.0	5.60	5.70	140	12.0	0.0	3.33	0.63	63					130	62.0					
06/24/94	1922.0	5.00	5.00	140	2.0	18.0	0.86	0.80	57	0.14	1.70	4.20	3.07	62			8.40			
09/28/94	1923.0	5.10	5.30	120	2.0	14.0	2.67	0.98	63					134	26.0					
12/27/94	1922.0	4.80	4.50	180	0.0	16.0	2.26	1.35	64	0.12	5.00	4.10	2.73	202	20.0		1.00			
03/30/95	1923.0	4.60	4.30	200	12.0	10.0	2.70	1.48	56					122	10.0					
06/21/95	1923.0	3.60	3.50	300	0.0	6.0	1.25	2.41	73	***0.10***	4.80	4.78	3.20	182	56.0	1.12	5.40			
09/21/95	1923.0	3.90	3.30	380	0.0	50.0	3.05	2.79	105					242	46.0					
12/21/95	1922.0	5.10	5.20	160	2.0	8.0	0.80	2.50	49	***0.10***	6.40	2.30	3.38	68	2.0	2.24	0.69			
03/14/96	1923.0	5.80	5.50	160	4.0	14.0	0.20	0.80	23											
06/24/96	1921.0	6.00	5.60	64	8.0	0.0	0.40	0.50	43	***0.10***	0.18	4.44	3.15	14	6.0		***0.10***			
09/30/96	1922.0	5.80	5.60	100	8.0	8.0	0.60	0.50	25					84	30.0					
12/18/96	1925.0	4.10	5.00	120	2.0	9.0	0.80	0.70	22	0.10	1.80	3.99	1.06	86		2.80	***0.10***			
03/12/97	1925.0	4.40	5.80	120	8.0	6.0	0.50	0.80	26					58	16.0					
06/16/97	1948.0	4.70	5.60	60	12.0	0.0	1.00	0.40	20	***0.10***	1.30	4.30	0.83	2	46.0	1.12	***0.10***			
09/25/97	1923.0	5.60	5.50	64	14.0	0.0	1.70	0.30	30					184	92.0					
12/18/97	1924.0	5.50	6.90	120	6.0	22.0	0.70	0.50	28	***0.10***	3.30	3.80	0.88	92	30.0	1.12	0.11			
03/26/98	1924.0	5.80	5.50	160	4.0	14.0	1.40	1.00	63					114	28.0					
06/23/98	1923.0	6.00	4.00	164	6.0	32.0	2.10	2.30	86	0.13	0.52	4.81	1.46	164	6.0	1.12	0.13			
09/21/98	1919.0	3.80	3.40	480	0.0	50.0	20.00	6.10	275					490	56.0					
12/16/98										0.15	5.20	7.04	2.66			2.24	***0.10***			
12/18/98	1918.0	3.60	3.60	760	0.0	220.0	17.80	9.00	437					670	26.0					
03/17/99	1922.0	3.90	3.00	1400	0.0	140.0	12.60	8.80	397					508	122.0					
06/22/99	1921.0	4.20	3.10	1600	0.0	200.0	81.00	13.00	602	0.18	26.00	19.20	2.85	782	94.0	1.12	0.25			

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

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Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
09/22/99	1919.0	3.90	3.20	380	0.0	90.0	32.90	14.50	549					752	192.0					
12/15/99	1921.0	4.50	2.90	140	0.0	200.0	23.50	13.90	582	0.15	42.00	9.00	2.71	510	186.0		***0.10***			
03/15/00	1921.0	4.30	3.80	1200	0.0	250.0	112.00	16.00	559					874	110.0					
06/14/00	1924.0	4.30	3.40	1000	0.0	270.0	75.00	17.90	647	0.26	24.80	21.90	2.83	1234	20.0		***0.10***			
09/29/00	1921.0	4.20	4.00	1200	6.0	324.0	142.00	18.60	761					1110						
12/13/00	1922.0	4.50	4.20	2080	6.0	354.0	110.00	19.00	731		38.70	25.70	2.81	778						
03/14/01	1923.0	4.20	4.20	1344	8.0	334.0	149.00	19.00	706					1074						
06/11/01	1923.0	3.30	2.60	1770	0.0	300.0	57.00	21.00	629					956						
09/13/01	1920.0	2.80	2.90	1537	0.0	150.0	36.10	17.80	581					766						
11/06/01	1920.0	3.10	3.30	1697	0.0	300.0	78.00	19.90	740		27.00	25.60	3.16	948	78.0					
03/08/02	1923.0	3.31	3.20	1572	0.0	219.0	33.00	17.50	608					864						
06/17/02	1924.7	3.40	3.00	1520	0.0	240.0	120.00	18.60	559					602	36.0					
09/03/02	1920.9	4.50	2.80	2080	0.0	246.0	67.00	27.00	868					914	170.0					
09/09/02		4.60	2.90	2100	0.0	600.0														
09/10/02		5.00	3.10	2280	0.0	500.0														
09/11/02		5.00	3.00	2300	0.0	600.0														
09/12/02		5.00	3.00	2320	0.0	600.0														
09/13/02		5.10	3.00	2490	0.0	500.0	220.00	31.00	1074					1428	860.0					
11/06/02	1920.3	4.50	2.70	1886	0.0	300.0	144.00	19.50	696		119.00	32.80	3.15	1190	64.0					
03/07/03	1920.0	5.20	4.80	1494	2.0	262.0	155.00	17.80	672					1092						
6/10/2003	1920.0	3.70	3.00	828	0.0	200.0	58.00	8.30	262					494	16.0					
6/10/2003			3.50	831	0.0	156.6	45.70	6.82	276		61.70	9.95	1.75	688	152.0					

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

Well 4
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
10/28/96	1945.0	6.60	7.30	400	76.0	0.0	0.50	1.10	156	0.15	42.00	7.55		162	20.0		0.15	90.40	60.0	480.00
11/22/96	1944.0	6.60	7.70	420	96.0	0.0	17.00	1.00	102	0.12	48.00	7.49		324	6158.0		0.14	106	70.0	440
12/18/96	1946.0	5.70	6.90	420	102.0	0.0	2.70	0.80	44	0.22	60.00	6.49		282	182.0		0.14	117	140.0	20
01/16/97	1957.0	5.40	6.90	460	114.0	0.0	1.80	***0.06***	76	0.12	50.00	8.64		292	4168.0		0.12	125	320.0	76
02/24/97	1945.0	6.50	7.30	47	106.0	0.0	0.40	0.50	47					408	2968.0					
03/12/97	1945.0	5.80	7.20	460	104.0	0.0	8.20	0.70	114					172	1976.0					
06/16/97	1945.0	4.50	7.00	400	102.0	0.0	7.40	0.60	69		130.00	6.49		252	1284.0					
09/25/97	1846.0	7.10	7.00	460	114.0	0.0	2.40	0.80	65					334	178.0					
12/18/97	2039.0	7.00	8.30	500	98.0	0.0	1.58	0.69	82		88.00	12.80	4.26	342	258.0					
03/26/98	1945.0	6.90	8.90	460	68.0	0.0	2.10	0.60	107					286	86.0					
06/23/98	1945.0	7.20	7.40	460	128.0	0.0	1.96	0.65	40		46.00	11.30	2.94	330	50.0					
09/21/98	1944.0	6.60	7.00	420	108.0	0.0	1.00	0.70	61					444	102.0					
12/18/98	1944.0	6.40	8.40	520	106.0	0.0	1.00	0.74	62		25.00	7.32	3.75	478	68.0					
03/17/99	1945.0	6.70	8.30	520	96.0	0.0	0.80	0.70	55					334	122.0					
06/22/99	1943.0	6.50	8.20	580	102.0	0.0	0.73	0.80	80		62.00	16.10	2.92	422	108.0					
09/22/99	1919.0	6.70	6.80	70	102.0	0.0	0.80	0.80	156					374	102.0					
12/15/99	1945.0	6.41	8.30	500	102.0	0.0	1.03	0.54	66		190.00	14.70	2.67	408	90.0					
03/15/00	1945.0	6.80	6.90	520	96.0	0.0	1.40	0.70	53						36.0					
06/14/00	1945.0	6.85	7.00	680	90.0	0.0	1.64	0.87	57		113.00	19.90	2.66	584	8.0					
09/29/00	1944.7	6.40	6.70	760	98.0	0.0	1.90	0.80	80					360	230.0					
12/13/00	1945.0	6.28	6.80	722	90.0	0.0	1.07	0.61	58		51.60	21.20	2.77	260	46.0					
03/14/01	1947.0	6.32	6.40	638	106.0	0.0	1.29	0.59	45					384	30.0					
06/11/01	1945.0	6.45	8.00	623	106.0	0.0	***0.15***	0.50	29					408	29.0					
09/13/01	1943.0	6.28	8.10	632	96.1	0.0	0.96	0.75	57					400	16.0					
11/06/01	1941.0	6.25	7.70	664	71.1	0.0	***0.15***	0.67	44		45.30	21.20	2.52	38	10.0					
03/08/02	1940.0	6.25	8.50	683	92.0	0.0	***0.15***	0.50	48					240	26.0					
06/17/02	1943.0	6.47	7.00	696	108.0	0.0	1.80	0.66	46					488	32.0					
09/03/02	1941.0	6.29	8.30	691	64.0	60.0	0.18	0.55	57					348	26.0					
11/06/02	1940.0	6.10	8.30	826	72.0	0.0	2.31	0.64	51					628	154.0					
03/07/03	1939.0	6.20	8.30	665	104.0	0.0	0.20	0.70	51					276						
06/10/03	1937.7	6.20	6.40	769	116.0	0.0	1.40	0.70	51					528	92.0					
06/10/03			7.10	812	109.8	0.0	2.41	0.65	32		175.20	17.10	2.31	918	50.0					

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

Well 4
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
10/28/96	1945.0	6.60	7.30	400	76.0	0.0	0.50	1.10	156	0.15	42.00	7.55		162	20.0		0.15	90.40	60.0	480.00
11/22/96	1944.0	6.60	7.70	420	96.0	0.0	17.00	1.00	102	0.12	48.00	7.49		324	6158.0		0.14	106	70.0	440
12/18/96	1946.0	5.70	6.90	420	102.0	0.0	2.70	0.80	44	0.22	60.00	6.49		282	182.0		0.14	117	140.0	20
01/16/97	1957.0	5.40	6.90	460	114.0	0.0	1.80	***0.06***	76	0.12	50.00	8.64		292	4168.0		0.12	125	320.0	76
02/24/97	1945.0	6.50	7.30	47	106.0	0.0	0.40	0.50	47					408	2968.0					
03/12/97	1945.0	5.80	7.20	460	104.0	0.0	8.20	0.70	114					172	1976.0					
06/16/97	1945.0	4.50	7.00	400	102.0	0.0	7.40	0.60	69		130.00	6.49		252	1284.0					
09/25/97	1846.0	7.10	7.00	460	114.0	0.0	2.40	0.80	65					334	178.0					
12/18/97	2039.0	7.00	8.30	500	98.0	0.0	1.58	0.69	82		88.00	12.80	4.26	342	258.0					
03/26/98	1945.0	6.90	8.90	460	68.0	0.0	2.10	0.60	107					286	86.0					
06/23/98	1945.0	7.20	7.40	460	128.0	0.0	1.96	0.65	40		46.00	11.30	2.94	330	50.0					
09/21/98	1944.0	6.60	7.00	420	108.0	0.0	1.00	0.70	61					444	102.0					
12/18/98	1944.0	6.40	8.40	520	106.0	0.0	1.00	0.74	62		25.00	7.32	3.75	478	68.0					
03/17/99	1945.0	6.70	8.30	520	96.0	0.0	0.80	0.70	55					334	122.0					
06/22/99	1943.0	6.50	8.20	580	102.0	0.0	0.73	0.80	80		62.00	16.10	2.92	422	108.0					
09/22/99	1919.0	6.70	6.80	70	102.0	0.0	0.80	0.80	156					374	102.0					
12/15/99	1945.0	6.41	8.30	500	102.0	0.0	1.03	0.54	66		190.00	14.70	2.67	408	90.0					
03/15/00	1945.0	6.80	6.90	520	96.0	0.0	1.40	0.70	53						36.0					
06/14/00	1945.0	6.85	7.00	680	90.0	0.0	1.64	0.87	57		113.00	19.90	2.66	584	8.0					
09/29/00	1944.7	6.40	6.70	760	98.0	0.0	1.90	0.80	80					360	230.0					
12/13/00	1945.0	6.28	6.80	722	90.0	0.0	1.07	0.61	58		51.60	21.20	2.77	260	46.0					
03/14/01	1947.0	6.32	6.40	638	106.0	0.0	1.29	0.59	45					384	30.0					
06/11/01	1945.0	6.45	8.00	623	106.0	0.0	***0.15***	0.50	29					408	29.0					
09/13/01	1943.0	6.28	8.10	632	96.1	0.0	0.96	0.75	57					400	16.0					
11/06/01	1941.0	6.25	7.70	664	71.1	0.0	***0.15***	0.67	44		45.30	21.20	2.52	38	10.0					
03/08/02	1940.0	6.25	8.50	683	92.0	0.0	***0.15***	0.50	48					240	26.0					
06/17/02	1943.0	6.47	7.00	696	108.0	0.0	1.80	0.66	46					488	32.0					
09/03/02	1941.0	6.29	8.30	691	64.0	60.0	0.18	0.55	57					348	26.0					
11/06/02	1940.0	6.10	8.30	826	72.0	0.0	2.31	0.64	51					628	154.0					
03/07/03	1939.0	6.20	8.30	665	104.0	0.0	0.20	0.70	51					276						
06/10/03	1937.7	6.20	6.40	769	116.0	0.0	1.40	0.70	51					528	92.0					
06/10/03			7.10	812	109.8	0.0	2.41	0.65	32		175.20	17.10	2.31	918	50.0					

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

Well 5
Metals
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Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
10/28/96		72.00	0.0138	0.0359	***0.200***	***0.200***	***0.0500***	***0.0500***	276.80	289.50	***0.1000***	***0.1000***	0.100	0.140	0.2400	0.3700	440.00	447.60	***0.0005***	***0.0005***	4.120	4.780	***0.0020***	***0.0020***	***0.060***	***0.060***	1.830	2.000
11/22/96		11.00	***0.0020***	***0.0020***	***0.200***	***0.200***	***0.0500***	***0.0500***	214.00	233.70	***0.1000***	***0.1000***	***0.040***	0.050	0.1300	0.2200	217.00	221.00	***0.0005***	***0.0005***	1.500	1.760	***0.0020***	***0.0020***	***0.060***	***0.060***	1.600	1.930
12/18/96		8.00	***0.0020***	***0.0020***	***0.200***	***0.200***	***0.0500***	***0.0500***	199.90	204.50	***0.1000***	***0.1000***	***0.040***	0.060	0.1600	0.2300	126.00	159.80	***0.0005***	***0.0005***	0.930	1.010	***0.0020***	***0.0020***	***0.060***	***0.060***	1.400	1.560
01/16/97		3.00	0.0311	0.0337	***0.200***	***0.200***	***0.0500***	***0.0500***	139.00	151.10	***0.1000***	***0.1000***	***0.040***	***0.040***	***0.1000***	***0.1000***	130.40	142.90	***0.0005***	***0.0005***	0.710	0.740	***0.0020***	***0.0020***	***0.060***	***0.060***	0.960	1.040
02/24/97		2.00																										
03/12/97		2.00																										
06/16/97		***1.00***		***0.0020***				***0.0500***		92.00		***0.1000***		***0.040***		***0.1000***		71.00		***0.0005***				0.0580				***0.030***
09/25/97		***1.00***																										
12/18/97		***1.00***		***0.0020***				***0.0500***		50.00		***0.1000***		***0.040***		0.2100		41.00		***0.0005***				0.0386				0.080
03/26/98		***1.00***																										
06/23/98		1.00		***0.0020***				***0.0500***		31.00		***0.1000***		***0.040***		***0.1000***		20.00		***0.0005***				***0.0020***				***0.030***
09/21/98		***1.00***																										
12/18/98		***1.00***		***0.0020***				***0.0500***		30.00		***0.1000***		***0.040***		***0.1000***		12.00		***0.0005***				0.0943				***0.030***
03/17/99		***1.00***																										
06/22/99		***1.00***		0.0000				***0.0500***		22.00		***0.1000***		***0.040***		***0.1000***		12.00		***0.0005***				0.0729				***0.030***
09/22/99		***1.00***																										
12/15/99		***1.00***		***0.0020***				***0.0500***		19.00		0.3000		***0.040***		***0.1000***		107.00		***0.0005***				0.0802				0.040
03/15/00		***1.00***																										
06/14/00		***1.00***		***0.0020***				***0.0500***		2.00		***0.1000***		***0.040***		***0.1000***		10.00		***0.0005***				***0.0020***				***0.030***
09/29/00		***1.00***																										
12/13/00		***1.00***		***0.0020***				***0.0500***		20.00		***0.1000***		***0.040***		***0.1000***		9.00		***0.0005***		***0.100***		0.0187				***0.030***
03/14/01		***1.00***																										
06/11/01		***1.00***																										
09/13/01		***1.00***																										
11/06/01		***1.00***		0.0100				***0.0500***		19.00		***0.1000***		***0.040***		***0.1000***		6.00		***0.0005***		***0.100***		0.0850				0.040
03/08/02		***1.00***																										
06/17/02		***1.00***																										
09/03/02		***1.00***																										
11/06/02		***1.00***		0.0100				***0.0500***		17.00		***0.1000***		***0.040***		***0.1000***		9.00		***0.0005***		***0.100***		0.0100				***0.030***
03/07/03		***1.00***																										
06/10/03		***1.00***																										
06/10/03		***2.00***		***0.0040***				***0.0100***		17.40		***0.0500***		***0.010***		***0.0010***		8.26		***0.0010***		***0.050***		***0.0070***				0.058

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

R2A
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
04/19/96	0.0	3.10	2.60	6400	0.0	4630.0	71.00	94.70	7543					9652						
05/17/96	12.4	3.30	2.80	5200	0.0	2930.0	35.00	55.60	5184					7238	8.0					
06/21/96	0.0	3.30	2.70	5200	0.0	3020.0	31.70	59.10	6087					8292	30.0					
07/26/96	0.0	2.00	2.50	6000	0.0	2580.0	34.80	61.60	5929					11104						
08/23/96	0.1	2.00	2.70	7200	0.0	5000.0	33.30	75.80	7900					10104						
09/30/96	12.4	2.50	2.80	4800	0.0	1950.0	26.90	43.90	5211					6760						
10/25/96	12.4	2.40	2.70	5200	0.0	1810.0	31.80	42.70	4711	***0.10***	0.28	7.33		8512		25.76	1.20	***2***	1.4	8
11/22/96	12.4	2.60	2.80	5000	0.0	480.0	47.40	46.40	5859	***0.10***	***0.10***	7.27		7434		32.48	0.72	***2***	1.4	16
12/18/96	16.7	2.80	2.10	5000	0.0	2550.0	57.90	47.90	4893	***0.10***	***0.10***	6.71		6884			1.20	***2***	1.0	20
01/16/97	12.4	2.60	2.90	6000	0.0	4200.0	98.00	110.00	6866	***0.10***	2.00	8.59		9632		30.80	0.76	***2***	2.2	20
02/24/97	16.7	2.60	2.70	4800	0.0	2200.0	86.00	80.00	5027					7470						
03/12/97	12.4	2.40	2.50	5000	0.0	2620.0	47.30	42.00	5473					8440						
04/16/97	6.1	2.60	2.80	6000	0.0	3700.0	43.50	60.10	6398					11034						
05/28/97	21.7	2.30	2.80	5000	0.0	2260.0	28.70	71.00	4397					6802						
06/16/97	8.9	3.00	2.80	5600	0.0	3700.0	50.20	83.00	6560		1.30	7.90		14104						
07/25/97	3.8	2.50	2.50	5200	0.0	5200.0	51.00	970.00	7353					11478						
08/22/97	8.9	2.30	2.90	5200	0.0	3200.0	42.30	71.00	5278					6748						
09/25/97	3.8	2.70	2.80	5600	0.0	3700.0	38.30	56.00	6872					9554	8.0					
10/29/97	3.8	2.60	2.80	5600	0.0	3480.0	33.10	49.30	7401					7160						
11/21/97	12.4	2.50	3.00	4200	0.0	3200.0	34.70	32.00	4997					7544						
12/18/97	12.4	3.14	2.70	5400	0.0	2930.0	33.10	35.00	5375		2.30	15.40	1.99	7170						
01/19/98	12.4	3.10	2.90	4800	0.0	820.0	36.30	35.70	5823					6328						
02/23/98	27.6	3.30	2.90	4400	0.0	2240.0	40.50	29.00	3851					5404						
03/26/98	12.4	3.10	3.20	5800	0.0	3700.0	54.00	52.00	6373					1422	10.0					
04/29/98	16.7	3.20	2.90	5756	0.0	2350.0	37.10	32.60	4246					5756						
05/28/98	6.1	3.60	2.80	5600	0.0	3490.0	58.00	34.00	7010					8428						
06/16/98	8.9	4.62	3.00	6000	0.0	1632.0	93.40	59.00	6134		6.00	24.60	10.40	8968	14.0					
07/24/98	6.1	4.30	2.90	5000	0.0	3400.0	29.70	46.00	5444					9392	800.0					
08/31/98	2.2	2.60	2.90	4600	0.0	4250.0	48.30	73.00	5890					11846	204.0					
09/21/98	2.2	2.74	2.80	3800	0.0	4030.0	42.50	60.00	7366					9850	14.0					
10/21/98	2.2	2.80	2.80	4600	0.0	3500.0	14.90	61.90	5296					8798						
11/18/98	2.2	2.70	3.00	5400	0.0	5300.0	32.30	70.40	7217					11114						
12/16/98	1.1	2.80	3.00	5000	0.0	4600.0	15.80	75.10	6771		***0.10***	7.80	1.38	11252						
01/13/99	0.0	3.50	3.70	1600	0.0	730.0	2.50	11.10	1432					1834	762.0					
03/17/99	0.0	2.95	3.00		0.0	3220.0	29.40	49.00	5107					7258	16.0					
04/14/99	12.4	2.70	2.90	3800	0.0	3000.0	18.00	37.00	5106					6244						
05/26/99	6.1	2.70	3.20	4200	0.0	4310.0	32.00	67.00	6989					9656						
06/22/99	2.2	2.66	2.90	6800	0.0	4900.0	57.00	116.00	7238		7.00	43.00	2.07	12454						
07/14/99	2.2	2.80	3.00	380	0.0	4980.0	44.00	93.00	1675					14068	6.0					
08/11/99	1.1	2.70	2.90	590	0.0	4980.0	49.00	110.00	7964					14112	14.0					
09/22/99	2.2	2.75	2.90	4200	0.0	4980.0	25.00	82.00	6952					10670						
10/27/99	2.2	2.80	2.80	3600	0.0	3420.0	39.00	66.00	8343					8924						
11/17/99	2.2	2.70	3.00	3500	0.0	3994.0	51.00	74.00	7681					10572	16.0					
12/15/99	3.8	2.64	3.10	3400	0.0	3050.0	20.00	33.00	4902		12.00	11.10	2.13	6488						
01/27/00	0.0																			

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

R2A
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
02/16/00	0.0																			
03/15/00	3.8	2.74	2.90	4600	0.0	3920.0	25.00	74.00	6209					7992						
04/19/00	6.1	2.80	2.90	2800	0.0	3300.0	20.00	64.00	5389					7312	6.0					
05/17/00	3.8	2.80	2.90	5200	0.0	4200.0	22.50	77.00	6908					12188						
06/14/00	6.1	2.90	2.10	5600	0.0	3400.0	20.50	71.00	5886		***0.10***	19.30	3.34	8724						
07/31/00	3.8	3.00	3.10	4800	0.0	2900.0	24.90	74.00	5925					8610						
08/30/00	3.8	2.90	4.20	5000	192.0	3094.0	21.00	73.00	6839					9430						
09/29/00	3.8	3.04	3.30	4200	0.0	2520.0	13.90	41.00	3495					5256						
10/25/00	3.8	2.90	3.10	6000	0.0	3500.0	17.90	65.00	5527					8794						
11/15/00	2.2	2.90	3.10	5180	0.0	3200.0	18.20	62.00	5248					7104						
12/13/00	2.2	2.85	3.00	5960	0.0	3440.0	17.10	64.00	5306		4.99	25.60	6.62	7354						
01/17/01	2.2	2.80	3.00	6390	0.0	4400.0	17.20	63.00	4059					7460	19.0					
02/08/01	3.8	2.70	2.80	7480	0.0	3820.0	15.10	81.00	6016					8416						
03/14/01	21.7	2.90	2.80	7770	0.0	3200.0	14.00	85.00	6119					8690						
04/11/01	12.4	2.80	2.70	5680	0.0	2500.0	11.50	6.40	4922					7270						
05/17/01	3.8	2.80	3.10	6630	0.0	4000.0	19.40	87.00	7654					9278						
06/11/01	3.8	2.18	2.60	6600	0.0	4200.0	20.00	97.00	6894					10946						
07/11/01	8.9	2.90	2.60	6500	0.0	3700.0	14.10	80.00	6331					8564						
08/08/01	2.2	2.80	2.90	7030	0.0	4500.0	23.50	92.00	7755					10340						
09/13/01	2.2	2.89	3.00	6800	0.0	2870.0	20.70	90.00	7226					9730						
10/10/01	2.2	2.80	3.10	7190	0.0	4400.0	25.20	91.00	7239					10118						
11/06/01	2.2	3.10	3.20	7270	0.0	4200.0	29.00	99.00	7188		16.70	32.80	12.70	9544	44.0					
12/05/01	3.8	2.87	3.00	6930	0.0	533.5	2.53	95.00	6735					10050						
01/10/02	6.1	3.00	3.10	3850	0.0	1224.0	10.90	41.00	3175					4386						
02/06/02	6.1	2.80	3.10	6330	0.0	2482.0	15.50	78.00	5661					8406						
03/08/02	3.8	2.80	3.10	5150	0.0	2205.9	12.80	57.00	4556					6664						
04/02/02	6.1	2.80	3.10	5350	0.0	2200.0	11.20	59.00	4936					7198						
05/10/02	12.4	2.80	3.10	4420	0.0	1690.0	6.70	43.00	3588					5856						
06/03/02	6.1	2.88	3.10	4670	0.0	1800.0	8.30	45.00	3871					6492						
07/03/02	3.8	3.00	3.00	4870	0.0	1900.0	9.80	49.00	4115					6350						
08/06/02	6.1	3.00	3.20	3070	0.0	1500.0	7.40	34.00	2998					4632						
09/03/02	2.2	2.84	3.10	5390	0.0	3070.0	19.90	68.00	5288					6588						
10/04/02	2.2	3.20	3.30	4460	0.0	1660.0	2.60	47.00	3938					6036						
11/06/02	12.4	3.04	2.90	3330	0.0	1270.0	5.80	30.00	52		16.30	26.00	30.50	102						
12/10/02	2.2	2.90	3.00	4930	0.0	2290.0	13.40	46.00	4466					5514						
01/10/03	8.9	2.90	3.00	4700	0.0	1900.0	7.10	41.00	3690					4618						
02/06/03	0.0																			
03/07/03	12.4	3.00	3.20	4020	0.0	1220.0	4.9	31.00	3241					4246						
04/02/03	8.9	3.20	3.10	3850	0.0	5244.0	6.4	33.00	3108					4388						
05/07/03	6.1	3.20	3.20	3590	0.0	1400.0	7.1	33.00	3011					3688						
06/10/03	6.1	3.08	2.80	4640	0.0	2400.0	11.6	45.00	4724					7700	22.0					
06/10/03			3.00	4560	0.0	2574.2	8.24	42.50	3740		3.70	8.91	3.91	8554	16.0					

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

R2B
Inorganics
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Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
04/19/96	0.4	3.50	3.00	3400	0.0	760.0	19.00	39.20	2460					3758						
05/17/96	2.2	3.70	3.10	3200	0.0	900.0	11.30	31.90	2368					3424	4.0					
06/21/96		3.50	2.90	3000	0.0	650.0	8.54	27.60	2154					2978						
07/26/96		2.50	2.70	4200	0.0	850.0	14.70	36.90	3395					6094	6.0					
08/23/96	0.4	2.30	2.90	3800	0.0	1200.0	15.80	38.60	3352					3972						
09/30/96	2.2	3.20	3.10	3000	0.0	580.0	11.60	26.50	2289					2922						
10/25/96	3.8	2.90	3.00	3200	0.0	600.0	8.70	25.90	2200	***0.10***	2.10	8.31		2906		30.24	4.40	***2***	1.8	12
11/22/96	2.2	3.30	3.10	3400	0.0	724.0	13.40	32.20	2762	***0.10***	2.70	8.92		3924	4.0	34.72	3.40	***2***	25.0	4
12/18/96	3.8	2.40	2.40	3200	0.0	850.0	11.20	28.60	2644	***0.10***	2.00	8.15		3702		21.28	4.00	***2***	1.8	24
01/16/97	0.0																			
02/24/97	3.8	3.20	3.10	2600	0.0	550.0	11.50	113.80	1757					2580						
03/12/97	2.2	3.00	2.70	3200	0.0	800.0	14.40	26.70	2462					4456	56.0					
04/16/97	2.2	3.30	3.10	4200	0.0	700.0	20.90	42.70	3837					6090	254.0					
05/28/97	3.8	2.60	2.90	3400	0.0	1020.0	9.10	34.00	2616					3572	4.0					
06/16/97	2.2	2.60	3.00	4000	0.0	1200.0	19.10	42.00	3644		5.80	9.29		8168	82.0					
07/25/97	0.4	2.90	2.80	3200	0.0	1200.0	14.20	660.00	3680					5264						
08/22/97	2.2	3.90	4.20	3000	16.0	366.0	3.80	14.30	2084					1664	28.0					
09/25/97	0.4	3.90	3.80	4000	6.0	994.0	104.00	17.00	3727					4794	34.0					
10/29/97	1.1	4.00	4.00	3600	14.0	916.0	9.30	18.20	3110					3860	26.0					
11/21/97	2.2	3.70	3.20	3000	0.0	800.0	8.40	14.90	2752					3742	2.0					
12/18/97	0.0																			
01/19/98	2.2	4.40	3.80	2800	8.0	442.0	4.60	10.10	2123					2606	10.0					
02/23/98	2.2	4.10	3.50	3000	0.0	480.0	11.60	12.00	1931					2700						
03/26/98	0.4	4.25	3.70	3600	0.0	680.0	7.10	18.40	2708					3808	14.0					
04/29/98	2.2	4.10	3.50	2600	0.0	700.0	22.10	17.00	2457					3250						
05/28/98	0.4	4.00	3.20	4600	0.0	2050.0	45.00	35.50	4529					6484						
06/16/98	2.2	4.49	3.50	3800	0.0	940.0	14.50	25.40	2784		19.00	26.70	25.80	4646	30.0					
07/24/98	2.2	5.10	3.70	3200	0.0	500.0	2.30	15.50	2193					3756						
08/31/98	0.0																			
09/21/98	0.4	3.47	3.60	2400	0.0	470.0	2.50	14.00	2259					3200	2.0					
10/21/98	0.0																			
11/18/98	0.0																			
12/16/98	0.0																			
01/13/99	0.0																			
02/10/99	0.0																			
03/17/99	0.0																			
04/14/99	2.2	3.30	3.40	2600	0.0	300.0	6.70	23.80	2551					3072						
05/26/99	0.0																			
06/22/99	0.0																			
07/14/99	0.0																			
08/11/99	0.0																			
09/22/99	0.4	3.51	3.60	64	0.0	186.0	3.20	26.00	2537					1900						
10/27/99	0.0																			
11/17/99	0.0																			
12/15/99	0.4	4.23	4.20	1600	12.0	138.0	0.41	18.40	1202		52.00	14.30	24.50	1946						

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

R2B
Inorganics
Page 2

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
01/27/00	0.0																			
02/16/00	0.0																			
03/15/00	0.0																			
04/19/00	0.4	4.60	5.10	2000	4.0	64.0	0.30	9.70	1879					3182	6.0					
05/17/00	0.0																			
06/14/00	1.1	4.41	5.10	4200	2.0	34.0	0.21	10.10	1899		586.00	275.00	616.00	1840	36.0					
07/31/00	0.0																			
08/30/00	0.0																			
09/29/00	1.1	4.33	4.10	1000	10.0	74.0	0.37	7.10	498					708						
10/25/00	0.0																			
11/15/00	0.0																			
12/13/00	0.0																			
01/17/01	0.0																			
02/08/01	0.0																			
03/14/01	3.8	4.24	4.50	2860	0.0	80.0	0.46	5.10	1299					2084						
04/11/01	3.8	4.30	4.40	2820	8.0	50.0	0.50	4.00	1476					2546						
05/17/01	0.0																			
06/11/01	0.0																			
07/11/01	1.1	4.40	4.70	3210	2.0	26.0	0.20	4.00	1764					2452	6.0					
08/08/01	0.0																			
09/13/01	0.0																			
10/10/01	0.0																			
11/06/01	0.0																			
12/05/01	0.0																			
01/10/02	6.1	4.60	4.80	1926	2.0	50.0	0.30	4.70	950						6.0					
02/06/02	0.0																			
03/08/02	2.2	4.60	4.90	2520	2.1	37.5	***0.15***	4.10	1296					1906	6.0					
04/02/02	2.2	4.20	4.70	2930	4.0	76.0	0.40	6.90	1579					2602						
05/10/02	2.2	4.50	5.20	2970	4.0	22.0	0.20	1.50	1870					2992						
06/03/02	0.4	5.50	7.00	3810	26.0	0.0	***0.15***	0.25	2086					3316	162.0					
07/03/02	0.0																			
08/06/02	0.0																			
09/03/02	0.0																			
10/04/02	1.1	5.40	7.70	2710	34.0	0.0	***0.15***	3.30	1468					2310						
11/06/02	3.8	4.26	4.50	2540	0.0	82.0	0.81	4.80	53		194.00	149.00	199.00	130						
12/10/02	0.0																			
01/10/03	2.2	4.70	4.80	2470	2.0	46.0	0.40	2.80	1338											
02/06/03	0.0													2088						
03/07/03	0.0																			
04/02/03	3.8	4.90	4.90	2570	2.0	52.0	0.30	3.40	1463					2178						
05/07/03	1.1	4.60	5.20	2740	6.0	24.0	1.50	3.90	1526					2318						
06/10/03	0.4	6.70	5.70	3040	38.0	10.0	***0.15***	0.20	1849					2718						
06/10/03			9.00	2960	36.2	0.0	0.13	0.22	1834		65.60	72.70	221.00	3400	36.0					

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

SP-1 (Downstream)
Inorganics
Page 1

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Sodium (mg/L)	TDS (mg/L)	TSS (mg/L)
07/14/88			3.50	1200		2480.0	7.64	10.18	120.00	3200		3878	1.0
07/14/88			3.20	2400		2060.0	7.80	13.20	241.70	2777		4438	1.0
09/21/88	5639		4.30	240	6.0	50.0	1.14	0.70	9.20	119		299	36.0
12/06/88	2374		4.30	360	16.0	166.0	1.12	0.92	22.40	258		363	2.8
09/02/89			4.00		3.0	466.0	3.09	3.27	85.80	564	10.00		12.0
12/03/89			4.50		10.0	102.0	1.57	1.14	19.70	103	10.00		3.0
10/17/90			4.50		8.0	62.0	1.07	0.77	11.70	125	10.00		37.0
03/25/91	22604		4.70	140	2.0	20.0	0.62	0.30	4.74	37		116	20.0
04/15/91			4.70		7.0	30.0	2.86	0.65	9.67	100	15.30		79.0
06/17/91	927		4.10	620	16.0	298.0	1.65	1.91	48.10	421		803	14.0
09/13/91			3.50		0.0	1960.0	5.33	13.40	344.00	2794	13.60		2.0
09/27/91	110		3.70	2200	0.0	284.0	2.75	8.34	183.00	1635		2528	0.0
12/12/91	3261		4.60	360	2.0	8.0	0.61	0.80	7.56	109		226	30.0
12/20/91	20263		4.90	140	2.0	16.0	0.42	0.28	2.80	52		34	35.6
03/25/92	3475		4.50	520	0.0	64.0	0.68	0.87	9.82	154		306	10.0
05/27/92			4.30		15.0	292.0	1.95	2.92	59.40	390	11.50		2.0
06/25/92	126		3.70	1400	0.0	690.0	1.81	3.92	84.50	854		1424	20.0
09/18/92			4.10		10.0	368.0	2.08	3.95	70.10	426	16.80		6.0
09/22/92	2075		4.60	320	2.0	52.0	2.50	1.24	11.60	147		288	80.0
12/18/92			6.30		14.0	1.0	0.69	0.34	2.32	44	27.40		22.0
12/21/92	9630		5.70	300	8.0	14.0	0.63	0.33	2.20	96		84	2.0
03/24/93	10111		6.10	2400	8.0	0.0	0.67	0.40	2.40	63		166	24.0
03/24/93			5.90		12.0	6.2	1.02	0.40	2.73	55	19.50		30.0
06/28/93	820		4.20	500	26.0	594.0	2.33	3.63	51.40	699		1178	0.0
09/30/93	8935		6.60	220	6.0	4.0	0.80	0.35	3.00	76		160	26.0
12/15/93	9374		4.50	220	0.0	62.0	1.02	0.70	9.81	139		188	18.0
12/30/93			4.50		7.2	50.0	1.87	1.81	30.40	73	13.60		4.0
03/30/94	14440		4.80	180	2.0	36.0	0.52	0.29	4.89	87		194	0.0
06/22/94	123		4.20	540	16.0	280.0	1.87	2.60	22.40	586		1250	0.0
09/28/94	3760	5.00	4.50	180	0.0	20.0	0.61	0.83	5.30	109		166	0.0
12/23/94			4.70		10.4	48.0	0.77	0.69	8.86	88	10.00		16.0
12/27/94	4621	5.20	4.70	320	1.0	51.0	1.00	0.78	8.70	117		258	18.0
03/30/95	4259	4.90	4.50	400	0.0	6.0	1.03	0.99	11.10	119		246	6.0
06/21/95	1497	4.60	4.40	460	12.0	82.0	0.80	1.69	13.00	170		412	0.0
06/21/95			4.40		9.0	86.0	0.94	1.93	14.80	161	11.70		22.0
09/21/95	328	3.90	3.60	1600	0.0	620.0	2.48	5.38	58.30	960		1342	0.0
09/26/95			3.90		0.0	392.0	3.39	4.87	60.20	573	15.30		3.0
12/21/95	3539	5.90	4.60	260	3.0	33.0	0.43	0.69	6.60	75		180	0.0
03/14/96	6330	5.40	4.60	320	1.0	58.0	0.61	0.59	7.10	86		6	0.0
03/29/96			4.60		7.6	62.0	0.50	0.46	5.97	77	12.70		3.0
06/22/96	1632	5.20	4.60	260	2.0	42.0	0.46	1.06	4.50	111		150	34.0
06/28/96			4.50		11.8	114.0	3.15	1.38	16.20	162	10.00		19.0
09/30/96	13628	6.30	5.40	108	4.0	12.0	0.68	0.41	4.80	65		108	20.0
12/18/96	993	4.50	4.20	240	2.0	30.0	1.07	0.49	5.30	68		124	0.0
03/12/97	349	7.60	5.10	240	2.0	12.0	0.52	0.30	2.90	61		8	0.0
03/31/97			5.30		11.8	12.2	0.91	0.34	3.58	58	12.80		16.0
06/16/97	96	3.40	4.60	320	1.0	107.0	1.62	1.11	13.10	162		400	46.0
06/24/97			4.30		8.0	130.0	2.07	1.79	22.50	243	10.50		16.0
09/25/97	24	4.20	4.20	1200	14.0	356.0	1.71	3.40	53.00	649		906	8.0
09/25/97			4.10		8.6	380.0	1.66	4.40	67.80	802	14.70		3.0
12/18/97	126	5.20	4.90	380	1.0	81.0	1.04	0.68	9.50	108		164	56.0
03/26/98	175	4.90	4.60	380	2.0	68.0	1.02	0.57	11.00	145		352	10.0
06/16/98	253	6.60	6.10	280	12.0	8.0	0.40	0.60	3.00	69		238	30.0
09/21/98	21	4.00	3.10	620	0.0	1510.0	1.20	3.40	30.00	496		568	
12/16/98	14	4.40	4.30	660	20.0	386.0	2.30	3.20	32.00	479		670	2.0
03/17/99	120	5.50	5.10	740	2.0	28.0	0.40	0.60	5.00	114		482	10.0
06/22/99	6	3.70	3.90	1600	2.0	656.0	1.70	4.90	62.00	846		1184	
09/22/99	14	4.50	4.50	300	0.0	44.0	0.40	1.80	9.00	170		460	4.0
12/15/99	421	6.40	6.60	200	12.0	10.0	0.40	0.20	1.00	78		98	2.0
03/15/00		5.30	4.60	320	1.0	29.0	0.50	0.60	3.00	68		208	6.0
06/14/00	60	4.90	4.10	340	2.0	28.0	1.20	1.20	4.00	104		236	8.0
09/29/00	13092	7.70	6.60	300	32.0	0.0	1.40	0.30	1.00	46		132	48.0
12/13/00	5454	5.40	5.80	643	8.0	0.0	0.60	0.50	***1.00***	64		260	

Bold Italic= less than detection limits

Appendix 5.B
Ebensburg Power Company
Revloc Site

SP-1 (Downstream)
Inorganics
Page 2

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Sodium (mg/L)	TDS (mg/L)	TSS (mg/L)
03/14/01	29925	6.20	5.90	366	6.0	14.0	0.60	0.30	2.00	13		178	
06/11/01	1543	4.70	4.40	511	10.0	118.0	0.50	1.40	9.00	184		224	8.0
09/13/01	115	3.80	3.70	1298	0.0	260.0	2.90	5.70	62.00	744		1044	
11/06/01	468	5.40	7.40	509	17.0	4.0	0.30	2.40	***1.00***	155		328	16.0
03/08/02	2887	5.40	7.00	334	6.0	17.0	0.30	0.50	***1.00***	62		192	
06/03/02	1967	4.70	4.80	379	2.0	38.0	0.40	0.90	10.00	165		182	32.0
09/03/02	124	3.40	4.10	1095	10.0	0.0	0.30	4.20	62.00	561		708	
11/06/02		5.00	6.70	242	28.0	0.0	0.80	0.20	1.00	47		1610	
03/07/03	10772	4.70	7.00	637	18.0	8.0	0.40	0.40	***1.00***	78		360	
06/10/03	9648	5.30	5.30	250	18.0	52.0	0.30	0.40	***1.00***	42		172	

Bold Italic= less than detection limits

Appendix 5.C

Water Monitoring Results for the McDermott Sites

Appendix 5.C
Laurel Land Development
McDermott Site

MD-1
Metals
Page 1

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
9/10/93		92.90																										
10/20/93		61.76																										
11/26/93		34.14																										
12/21/93		32.02																										
1/28/94		10.46																										
2/25/94		25.50																										
3/22/94																												
4/28/94		23.02																										
5/25/94		26.32																										
6/22/94		39.77																										
7/27/94		62.10																										
8/10/94		86.80																										
09/23/94		52.76																										
10/21/94		64.90																										
11/15/94		120.80																										
12/20/94		29.71																										
01/20/95		13.55																										
02/17/95		17.36																										
03/13/95		20.57																										
5/22/1995	38.40	40.40	**0.0040**	**0.0040**	0.022	0.024	**0.0100**	**0.0100**	28.70	30.20	**0.050**	**0.050**	0.057	0.057	0.0050	0.0051	28.10	29.30	**0.0010**	**0.0010**	0.389	0.403	**< 0.007**	**< 0.007**			0.544	0.562
6/16/1995	50.70	51.30	**0.0040**	**0.0040**	0.019	0.020	**0.0100**	**0.0100**	41.70	42.20	**0.050**	**0.050**	0.064	0.071	0.0060	0.0060	37.20	37.20	**0.0010**	**0.0010**	0.585	0.585	**< 0.007**	**< 0.007**			0.708	0.708
6/28/1995		50.73																										
9/22/1995		91.20																										
10/17/1995		104.70																										
10/17/95	107.00	107.00	***0.0040***	***0.0040***	0.012	0.012	***0.0100***	***0.0100***	68.40	66.30	***0.050***	0.066	0.137	0.138	0.0064	0.0064	68.20	66.50	***0.0010***	***0.0010***	1.050	1.010	***< 0.007***	***< 0.007***			1.400	1.360
11/29/95	27.90	28.60	***0.0040***	***0.0040***	0.029	0.033	***0.0100***	***0.0100***	31.10	31.70	***0.050***	***0.050***	0.044	0.050	0.0035	0.0034	4.66	4.76	***0.0010***	***0.0010***	0.311	0.315	***< 0.007***	***< 0.007***		***0.0100***	0.410	0.416
11/30/95		28.45																										
02/15/96		31.43																										
03/05/96		9.41																										
03/19/96		25.94																										
04/25/96		34.65																										
05/21/96		30.19																										
06/10/96		49.20																										
07/30/96		46.19																										
08/28/96	61.20	62.80	***0.0040***	***0.0040***	0.018	0.022	0.0200	0.0300	43.90	45.90	***0.050***	***0.050***	0.076	0.077	0.0056	0.0056	50.60	51.90	***0.0010***	***0.0010***	0.624	0.648	***< 0.007***	***< 0.007***		***0.0100***	0.848	0.886
08/30/96		70.50																										
09/27/96		25.18																										
10/03/96		26.60																										
10/15/96		44.39																										
11/20/96		29.25																										
12/12/96	5.40	5.70	***0.0040***	***0.0040***	0.026	0.026	***0.0100***	***0.0100***	11.40	11.60	***0.050***	***0.050***	0.020	0.013	0.0012	***0.0010***	5.46	5.59	***0.0010***	***0.0010***	0.064	0.064	***< 0.007***	***< 0.007***		***0.0100***	0.088	0.088
12/23/96		26.46																										
01/13/97		29.10																										
01/22/97		49.15																										
02/05/97		6.90																										
02/12/97		17.73																										
03/03/97		12.70																										
03/05/97	10.30	10.30	***0.0040***	***0.0040***	0.033	0.033	***0.0100***	***0.0100***	15.0.	15.00	***0.050***	***0.050***	0.036	0.036	0.0021	0.0021	8.56	8.59	***0.0010***	***0.0010***	0.117	0.117	***< 0.007***	***< 0.007***		***0.0100***	0.150	0.150

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development, Inc.
McDermott Site

MD-2
Inorganics
Page 1

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
09/10/93	0.0	4.60	2.60	2980		1296	206.80	12.00	1664						2.7					
10/20/93	0.0	4.50	2.50	2260		974	134.90	8.46	1230						1.3					
11/26/93	2.8	2.60	2.50	1430		918	135.90	6.53	1003						0.3					
12/21/93	0.0	4.50	2.60	1900		1064	190.80	7.34	1162						0.3					
01/28/94	0.0	4.70	2.90	1140		400	66.45	3.38	613						0.7					
02/25/94	3.5	4.60	2.70	1780		748	138.50	5.04	919						1.0					
03/22/94	2.0	4.50	3.00	1110		386	73.40	2.62	526						0.7					
01/20/95	2.2	4.70	2.90	1100	0	486	75.81	4.26	520						4.3					
05/22/95			2.70	1965	0	794	118.00	6.91	258	0.30	1.00	0.58		2294	***2.0***	0.13	0.15		***1.0***	
06/16/95			2.60	2461	0	1170	169.00	9.81	847	0.38	***1.00***	1.24		2974	12.0	0.17	0.11		***1.0***	
08/14/95			2.50	2938	0	1562	225.00	12.50	1192	0.58	***1.00***	0.84		4240	***2.0***	0.42	***0.40***		1.0	
10/17/95			2.50	2770	0	1566	242.00	15.70	1101	0.59	2.00	0.94		4134	***2.0***	0.35	***0.004***		***1.0***	
11/29/95			3.40	460	0	94	1.37	2.02	112	***0.20***	2.00	0.86		342	***2.0***	***0.02***	0.37		0.1	
11/30/95	23.0	4.70	3.30	478	0	100	1.41	1.93	141						0.3					

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MD-3
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
09/10/93		46.40																										
10/20/93		34.00																										
11/26/93		17.80																										
05/22/95	18.70	18.70	***0.0040***	***0.0040***			***0.0100***	***0.0100***	20.60	20.70	***0.0500***	***0.0500***	0.023	0.029	0.0015	0.0015	31.80	31.80	***0.0010***	***0.0010***	0.410	0.410	***0.0070***	***0.0070***		***0.010***	0.612	0.612
06/16/95	19.20	20.30	***0.0040***	***0.0040***			***0.0100***	***0.0100***	25.20	25.20	***0.0500***	***0.0500***	0.032	0.034	0.0037	0.0039	37.30	37.70	***0.0010***	***0.0010***	0.564	0.564	***0.0070***	***0.0070***		***0.010***	1.080	1.080
08/14/95	32.80	33.20	***0.0040***	***0.0040***			***0.0100***	***0.0100***	30.30	30.50	***0.0500***	***0.0500***	0.049	0.049	0.0024	0.0024	45.80	46.20	***0.0010***	***0.0010***	0.659	0.659	***0.0070***	***0.0070***		***0.010***	0.846	0.846
10/17/95	56.00	56.00	***0.0040***	***0.0040***			***0.0100***	***0.0100***	39.80	39.80	***0.0500***	***0.0500***	0.091	0.091	0.0028	0.0023	54.50	54.50	***0.0010***	***0.0010***	0.866	0.866	***0.0070***	***0.0070***			1.250	1.250
11/29/95	17.40	17.60	***0.0040***	***0.0040***			***0.0100***	***0.0100***	22.80	22.80	***0.0500***	***0.0500***	0.041	0.041	0.0011	0.0011	31.50	31.50	***0.0010***	***0.0010***	0.391	0.391	***0.0070***	***0.0070***		***0.010***	0.606	0.606
08/28/96	28.00	28.10	***0.0040***	***0.0040***	0.017	0.018	***0.0100***	***0.0100***	30.30	30.50	***0.0500***	***0.0500***	0.060	0.060	0.0025	0.0025	47.80	48.00	***0.0010***	***0.0010***	0.561	0.561	***0.0070***	***0.0070***		***0.010***	0.807	0.807
12/12/96	10.80	11.30	***0.0040***	***0.0040***	0.052	0.053	***0.0100***	***0.0100***	18.80	19.60	***0.0500***	***0.0500***	0.027	0.027	0.0017	0.0012	24.90	25.80	***0.0010***	***0.0010***	0.253	0.260	***0.0070***	***0.0070***		***0.010***	0.372	0.385
03/05/97	12.00	12.00	***0.0040***	***0.0040***	0.039	0.039	***0.0100***	***0.0100***	17.60	17.60	***0.0500***	***0.0500***	0.031	0.031	0.0026	0.0026	26.50	26.50	***0.0010***	***0.0010***	0.290	0.290	***0.0070***	***0.0070***		***0.010***	0.403	0.403
06/25/97	30.90	31.30	***0.0040***	***0.0040***	0.017	0.017	***0.0100***	***0.0100***	26.70	27.00	***0.0500***	***0.0500***	0.075	0.076	0.0020	0.0020	43.00	43.60	***0.0010***	***0.0010***	0.561	0.564	***0.0070***	***0.0070***		***0.010***	0.756	0.766
09/24/97	40.50	40.50	***0.0040***	***0.0040***	0.010	0.010	***0.0100***	***0.0100***	33.70	33.70	***0.0500***	***0.0500***	0.081	0.081	0.0038	0.0038	53.20	53.20	***0.0010***	***0.0010***	0.664	0.673	***0.0070***	***0.0070***		***0.010***	0.920	0.928
12/17/97	23.00	23.60	***0.0040***	***0.0040***	0.052	0.053	***0.0100***	***0.0100***	31.40	32.40	***0.0500***	***0.0500***	0.065	0.082	0.0025	0.0025	39.00	40.10	***0.0010***	***0.0010***	0.490	0.511	***0.0070***	***0.0070***		***0.010***	0.718	0.747
03/16/98	19.20	20.20	***0.0040***	***0.0040***	0.029	0.031	***0.0100***	***0.0100***	27.90	29.80	***0.0500***	***0.0500***	0.059	0.065	***0.0010***	***0.0010***	37.30	39.60	***0.0010***	***0.0010***	0.405	0.432	***0.0070***	***0.0070***			0.619	0.663
06/25/98	19.20	20.40	***0.0040***	***0.0040***	0.040	0.040	***0.0100***	***0.0100***	57.80	58.00	***0.0500***	***0.0500***	0.100	0.100	***0.0010***	***0.0010***	38.10	38.60	***0.0010***	***0.0010***	0.395	0.395	***0.0070***	***0.0070***		***0.010***	0.574	0.574
08/21/98	34.60	35.90	***0.0040***	***0.0040***	0.013	0.013	***0.0100***	***0.0100***	48.50	50.50	***0.0500***	***0.0500***	0.119	0.119	***0.0010***	***0.0010***	40.50	42.10	***0.0010***	***0.0010***	0.513	0.539	***0.0070***	***0.0070***		***0.010***	0.759	0.788
03/29/99	27.20	27.20	***0.0040***	***0.0040***	0.031	0.031	0.0120	0.0120	74.50	74.50	***0.0500***	***0.0500***	0.188	0.188	0.0078	0.0078	44.20	44.20	***0.0010***	***0.0010***	0.676	0.676	***0.0070***	***0.0070***		***0.010***	0.965	0.965
06/23/99	32.70	32.70	***0.0040***	***0.0040***	***0.010***	***0.010***	***0.0100***	***0.0100***	54.60	55.00	***0.0500***	***0.0500***	0.159	0.171	0.0038	0.0038	32.80	32.80	***0.0010***	***0.0010***	0.645	0.693	***0.0070***	***0.0070***		***0.010***	0.998	1.070
09/30/99	55.70	55.70	***0.0040***	***0.0040***	***0.010***	***0.010***	0.0190	0.0240	125.00	125.00	***0.0500***	***0.0500***	0.184	0.184	0.0032	0.0032	66.40	73.10	***0.0010***	***0.0010***	0.831	0.831	***0.0070***	***0.0070***		***0.010***	1.210	1.210
12/06/99	58.90	61.30	***0.0040***	***0.0040***	***0.010***	***0.010***	***0.0100***	***0.0100***	127.00	132.00	***0.0500***	***0.0500***	0.285	0.299	0.0031	0.0031	70.50	76.10	***0.0010***	***0.0010***	1.010	1.060	***0.0070***	***0.0070***		***0.010***	1.480	1.520
03/06/00	44.40	45.30	***0.0040***	0.0043	0.021	0.022	0.0120	0.0160	128.00	140.00	***0.0500***	***0.0500***	0.269	0.294	0.0042	0.0036	74.20	82.50	***0.0010***	***0.0010***	0.853	0.948	0.0095	0.0105	***0.010***	***0.010***	1.270	1.350
06/13/00		42.70	***0.0040***					***0.0100***		153.00		***0.0500***		0.204		0.0058		80.10		***0.0010***		0.906		***0.0070***				1.340
09/28/00		57.80		***0.0040***				***0.0100***		161.00		***0.0500***		0.261		0.0027		97.00		***0.0010***		1.040		***0.0070***				1.550
10/31/01		40.30								125.00								72.20										
12/27/01		42.00		***0.0040***				***0.0100***		197.00		***0.0500***		0.240		0.0022		126.00		***0.0010***		1.580		0.0089				2.100
03/23/02		46.00		***0.0040***				***0.0100***		248.00		***0.0500***		0.180		0.0028		153.00		***0.0010***		1.640		0.0097				2.080
06/11/02		44.90		0.0053				***0.0100***		289.00		***0.0500***		0.141		0.0026		192.00		***0.0010***		1.820		0.0250				2.120
09/24/02		42.10		***0.0040***				***0.0100***		176.00		***0.0500***		0.110		0.0019		119.00		***0.0010***		1.130		***0.0070***				1.350
12/18/02		42.60		***0.0040***				***0.0100***		238.00		***0.0500***		0.115		0.0018		166.00		***0.0001***		1.480		0.0092				1.860
03/25/03		42.80		***0.0040***				***0.0100***		288.00		***0.0500***		0.143		0.0026		220.00		***0.0001***		2.060		***0.0070***				2.600
05/28/03		33.00																										
06/09/03		39.00		0.0053				***0.0100***		293.00		***0.0500***		0.117		0.0022		233.00		***0.0010***		1.955		0.0276				2.643
07/24/03		34.30		0.0043				0.0160		300.00		***0.0500***		0.089		0.0022		231.00		***0.0010***		1.710		0.0250				1.940
08/05/03		31.20		***0.0040***				***0.0100***		278.00				0.075		0.0017		211.00		***0.0010***		1.590		0.0113				1.810
09/10/03		34.60		***0.0040***				0.0070		289.00		***0.0500***		0.085		0.0019		209.00		***0.0010***		1.620		0.0131				1.750
11/17/03		27.40																										

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MD-5
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
05/22/95	***0.01***	***0.14***	***0.0040***	***0.0040***	0.028	0.028	***0.0100***	***0.0100***	12.30	12.30	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	4.96	4.96	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	***0.010***	***0.010***
06/16/95		***0.14***	***0.0040***	***0.0040***		0.029		***0.0100***		14.10		***0.0500***		***0.010***	***0.0010***	***0.0010***		5.57	***0.0010***	***0.0010***		***0.025***	***0.0070***	***0.0070***		***0.010***		0.281
08/09/95		***0.14***	***0.0040***	***0.0040***		0.034		***0.0100***		18.30		***0.0500***		***0.010***	***0.0010***	***0.0010***		7.16	***0.0010***	***0.0010***		***0.025***	***0.0070***	***0.0070***		***0.010***		***0.010***
10/17/95	***0.14***	23.10	***0.0040***	***0.0040***	0.048	0.047	***0.0100***	***0.0100***	23.30	23.10	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	9.32	9.32	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***			***0.010***	***0.010***
11/29/95	***0.14***	***0.14***	***0.0040***	***0.0040***	0.053	0.540	***0.0100***	***0.0100***	30.80	31.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	10.20	10.20	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.013	0.013
08/28/96	***0.14***	***0.14***	***0.0040***	***0.0040***	0.033	0.034	***0.0100***	***0.0100***	20.40	20.90	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	7.00	7.30	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.027	0.027
12/12/96	***0.14***	***0.14***	***0.0040***	***0.0040***	0.055	0.057	***0.0100***	***0.0100***	33.10	33.70	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	9.20	9.40	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.010	0.011
03/05/97	***0.14***	***0.14***	***0.0040***	***0.0040***	0.067	0.069	***0.0100***	***0.0100***	37.20	37.70	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	10.50	10.70	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.012	0.014
06/25/97	***0.14***	***0.14***	***0.0040***	***0.0040***	0.039	0.039	***0.0100***	***0.0100***	22.30	22.30	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	7.90	7.90	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	***0.010***	***0.010***
09/24/97	***0.20***	***0.20***	***0.0040***	***0.0040***	0.039	0.039	***0.0100***	***0.0100***	22.80	22.80	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	0.0010	8.40	8.40	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	***0.010***	***0.010***
12/17/97	***0.20***	***0.20***	***0.0040***	***0.0040***	0.164	0.175	***0.0100***	***0.0100***	72.50	75.70	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	23.60	24.60	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	0.015	0.015
03/16/98	***0.20***	***0.20***	***0.0040***	***0.0040***	0.055	0.058	***0.0100***	***0.0100***	30.50	32.80	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	11.70	12.50	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***			0.012	0.012
06/25/98	***0.20***	***0.20***	***0.0040***	***0.0040***	0.035	0.035	***0.0100***	***0.0100***	17.80	17.80	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	6.40	6.40	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	***0.010***	***0.010***
08/21/98	***0.20***	***0.20***	***0.0040***	***0.0040***	0.046	0.050	***0.0100***	***0.0100***	26.00	26.20	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	9.11	9.37	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	***0.010***	***0.010***
12/14/98	***0.20***	***0.20***	***0.0400***	***0.0400***	0.046	0.046	***0.0100***	***0.0100***	27.40	29.10	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0100***	***0.0100***	11.90	12.70	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0700***	***0.0700***			0.010	0.010
03/29/99	***0.20***	***0.20***	***0.0400***	***0.0400***	0.064	0.076	***0.0100***	***0.0100***	34.60	34.70	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0100***	***0.0100***	15.50	15.50	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0700***	***0.0700***		***0.010***	0.014	0.014
06/23/99	***0.20***	0.48	***0.0040***	***0.0040***	0.110	0.112	***0.0100***	***0.0100***	428.00	430.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	0.0018	208.00	210.00	***0.0010***	***0.0010***	0.050	0.055	***0.0070***	***0.0070***		***0.010***	0.175	0.175
09/30/99	***0.20***	***0.20***	***0.0040***	***0.0040***	0.054	0.052	***0.0100***	***0.0100***	27.80	27.60	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	14.00	14.00	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	0.020	0.018
12/06/99	***0.20***	***0.20***	***0.0040***	***0.0040***	0.047	0.049	***0.0100***	***0.0100***	25.70	26.60	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	11.50	11.90	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	0.025	0.025
03/06/00	1.44	2.93	***0.0040***	***0.0040***	0.092	0.098	***0.0100***	***0.0100***	50.30	52.30	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	24.50	25.40	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***	***0.010***	***0.010***	0.024	0.024
06/13/00		0.31		***0.0040***				***0.0100***		44.70		***0.0500***		***0.010***		***0.0010***		35.90		***0.0010***		***0.050***		***0.0070***				0.064
09/28/00		***0.20***		***0.0040***				***0.0100***		33.30		***0.0500***		***0.010***		***0.0010***		20.00		***0.0010***		***0.050***		***0.0070***				0.016
10/31/01		0.14								38.90								22.60										
12/27/01		***0.20***		***0.0040***				***0.0100***		30.10		***0.0500***		***0.010***		***0.0010***		16.40		***0.0010***		***0.050***		***0.0070***				0.010
03/23/02		***0.20***		***0.0040***				***0.0100***		48.00		***0.0500***		***0.010***		***0.0010***		18.60		***0.0010***		***0.050***		***0.0070***				***0.010***
06/11/02		***0.20***		***0.0040***				***0.0100***		42.80		***0.0500***		***0.010***		0.0013		29.20		***0.0010***		***0.050***		***0.0070***				0.033
09/24/02		2.02		***0.0040***				***0.0100***		79.50		***0.0500***		***0.010***		0.0021		60.20		***0.0010***		0.095		***0.0070***				0.129
12/18/02		***0.20***		***0.0040***				***0.0100***		198.00		***0.0500***		***0.010***		***0.0010***		68.30		***0.0010***		***0.050***		***0.0070***				0.067
03/25/03		***0.20***		***0.0040***				***0.0100***		47.30		***0.0500***		***0.010***		0.0010		21.20		***0.0010***	.	***0.050***		***0.0070***				1.470
05/28/03		***0.50***																										
06/09/03		***0.20***		***0.0040***				***0.0100***		28.90		***0.0500***		***0.010***		***0.0010***		14.70		***0.0010***		***0.050***		***0.0070***				0.113
07/24/03		***0.20***		***0.0040***				***0.0100***		32.40		***0.0500***		***0.010***		***0.0010***		17.30		***0.0010***		***0.050***		***0.0070***				0.011
09/10/03		***0.20***		***0.0040***				***0.0100***		39.30		***0.0500***		***0.010***		0.0012		26.20		***0.0010***		***0.050***		***0.0070***				0.036

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MD-12
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
05/22/95	0.51	0.59	***0.0040***	***0.0040***	0.067	0.069	***0.0100***	***0.0100***	7.71	7.92	***0.0500***	***0.0500***	***0.0100***	***0.0100***	**0.0010**	**0.0010**	3.05	3.33	***0.0010***	***0.0010***	0.025	0.025	***0.0070***	***0.0070***		***0.010***	0.041	0.035
06/16/95	0.76	1.98	***0.0040***	***0.0040***	0.068	0.079	***0.0100***	***0.0100***	8.70	8.24	***0.0500***	***0.0500***	***0.0100***	***0.0100***	0.0138	0.0057	3.72	3.72	***0.0010***	***0.0010***	0.025	0.025	***0.0070***	***0.0070***		***0.010***	0.014	0.014
07/18/95	0.51	0.57	***0.0040***	***0.0040***	0.568	0.079	***0.0100***	***0.0100***	8.01	8.01	***0.0500***	***0.0500***	***0.0100***	***0.0100***	**0.0010**	**0.0010**	3.13	3.13	***0.0010***	***0.0010***	0.025	0.025	***0.0070***	***0.0070***		***0.010***	0.031	0.031
10/17/95	4.60	4.70	***0.0040***	***0.0040***	0.046	0.470	***0.0100***	***0.0100***	20.20	20.60	***0.0500***	***0.0500***	***0.0100***	***0.0150***	0.0015	0.0015	12.50	12.80	***0.0010***	***0.0010***	0.083	0.104	***0.0070***	***0.0070***		***0.010***	0.166	0.166
11/29/95	0.46	0.45	***0.0040***	***0.0040***	0.072	0.072	***0.0100***	***0.0100***	9.87	9.87	***0.0500***	***0.0500***	***0.0100***	***0.0100***	**0.0010**	**0.0010**	3.16	3.16	***0.0010***	***0.0010***	0.012	0.025	***0.0070***	***0.0070***		***0.010***	0.034	0.034
04/09/96		7.78	***0.0040***	***0.0040***		0.271	***0.0100***	***0.0100***		21.60	***0.0500***	***0.0500***	***0.0100***	***0.0160***	**0.0010**	0.0077		9.05	***0.0010***	***0.0010***	0.025	0.041	***0.0070***	***0.0070***		***0.010***		0.104
08/28/96	9.38	10.20	***0.0040***	***0.0040***	0.053	0.057	***0.0100***	***0.0100***	64.30	69.70	***0.0500***	***0.0500***	0.028	0.028	0.0201	0.0201	40.80	43.90	***0.0010***	***0.0010***	0.186	0.213	***0.0070***	***0.0070***		***0.010***	0.353	0.385
12/12/96	3.92	3.92	***0.0040***	***0.0040***	0.051	0.052	***0.0100***	***0.0100***	40.60	40.60	***0.0500***	***0.0500***	0.025	0.018	0.0070	0.0070	18.00	18.00	***0.0010***	***0.0010***	0.096	0.100	***0.0070***	***0.0070***		***0.010***	0.182	0.182
03/05/97	10.10	10.60	***0.0040***	***0.0040***	0.051	0.054	***0.0100***	***0.0100***	65.90	65.90	***0.0500***	***0.0500***	0.033	0.033	0.0167	0.0167	35.10	35.10	***0.0010***	***0.0010***	0.193	0.194	***0.0070***	***0.0070***		***0.010***	0.341	0.345
06/25/97	20.60	20.60	***0.0040***	***0.0040***	0.033	0.033	***0.0100***	***0.0100***	150.00	150.00	***0.0500***	***0.0500***	0.052	0.052	0.0412	0.0412	67.90	67.90	***0.0010***	***0.0010***	0.494	0.494	***0.0070***	***0.0070***		***0.010***	0.809	0.809
09/24/97	23.40	23.40	***0.0040***	***0.0040***	0.031	0.031	***0.0100***	***0.0100***	212.00	212.00	***0.0500***	***0.0500***	0.048	0.048	0.0629	0.0629	91.80	91.80	***0.0010***	***0.0010***	0.691	0.691	***0.0070***	***0.0070***		***0.010***	1.070	1.070
12/17/97	16.50	16.60	***0.0040***	***0.0040***	0.035	5.270	***0.0100***	***0.0100***	176.00	184.00	***0.0500***	***0.0500***	0.035	0.042	0.0289	0.0298	68.90	71.30	***0.0010***	***0.0010***	0.535	0.565	***0.0070***	***0.0070***		***0.010***	0.831	0.871
03/16/98	11.10	11.90	***0.0040***	***0.0040***	0.026	0.028	***0.0100***	***0.0100***	158.00	168.00	***0.0500***	***0.0500***	0.021	0.022	0.0225	0.0240	77.30	85.80	***0.0010***	***0.0010***	0.393	0.426	***0.0070***	***0.0070***			0.620	0.680
06/25/98	8.37	8.60	***0.0040***	***0.0040***	0.034	0.035	***0.0100***	***0.0100***	186.00	186.00	***0.0500***	***0.0500***	0.022	0.022	0.0223	0.0219	87.20	87.20	***0.0010***	***0.0010***	0.410	0.419	***0.0070***	***0.0070***		***0.010***	0.631	0.659
08/21/98	17.60	17.70	***0.0040***	***0.0040***	0.038	0.039	***0.0100***	***0.0100***	271.00	275.00	***0.0500***	***0.0500***	0.019	0.020	0.0240	0.0270	115.00	118.00	***0.0010***	***0.0010***	0.704	0.714	***0.0070***	***0.0070***		***0.010***	1.050	1.070
12/14/98	16.50	16.50	***0.0400***	***0.0400***	0.024	0.025	***0.0100***	***0.0100***	240.00	240.00	***0.0500***	***0.0500***	0.019	0.019	0.0230	0.0210	107.00	107.00	***0.0010***	***0.0010***	0.604	0.635	***0.0700***	***0.0700***			0.937	0.989
03/29/99	3.49	3.58	***0.0400***	***0.0400***	0.022	0.022	***0.0100***	***0.0100***	95.10	95.10	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0100***	***0.0100***	40.00	40.00	***0.0010***	***0.0010***	0.166	0.169	***0.0700***	***0.0700***		***0.010***	0.287	0.294
06/23/99	12.00	12.50	***0.0040***	***0.0040***	0.026	0.027	***0.0100***	***0.0100***	184.00	187.00	***0.0500***	***0.0500***	***0.010***	0.011	0.0093	0.0093	94.10	94.10	***0.0010***	***0.0010***	0.592	0.597	***0.0070***	***0.0070***		***0.010***	1.020	1.020
09/30/99	13.60	13.50	***0.0040***	***0.0040***	0.044	0.045	***0.0100***	0.0130	223.00	222.00	***0.0500***	***0.0500***	0.014	0.012	0.0053	0.0053	107.00	105.00	***0.0010***	***0.0010***	0.573	0.579	***0.0070***	***0.0070***		0.011	0.859	0.876
12/06/99	13.40	14.10	***0.0040***	***0.0040***	0.024	0.025	***0.0100***	***0.0100***	179.00	188.00	***0.0500***	***0.0500***	***0.010***	***0.010***	0.0036	0.0037	84.40	84.70	***0.0010***	***0.0010***	0.500	0.519	***0.0070***	***0.0070***		***0.010***	0.811	0.830
03/06/00	6.82	7.02	***0.0040***	***0.0040***	0.017	0.017	***0.0100***	***0.0100***	114.00	117.00	***0.0500***	***0.0500***	***0.010***	***0.010***	0.0023	0.0022	49.80	51.20	***0.0010***	***0.0010***	0.280	0.280	***0.0070***	***0.0070***	***0.010***	***0.010***	0.449	0.463
06/13/00		9.85		***0.0040***				***0.0100***		135.00		***0.0500***		***0.010***		***0.0010***		60.80		***0.0010***		0.386		***0.0070***				0.576
09/28/00		27.50		***0.0040***				***0.0100***		259.00		***0.0500***		***0.010***		0.0063		153.00		***0.0010***		0.797		***0.0070***				1.140
12/14/00																												
03/16/01																												
06/14/01		16.50		***0.0040***				***0.0100***		201.00		***0.0500***		***0.010***		0.0058		92.20		***0.0010***		0.459		***0.0070***				0.650
09/18/01		36.20		***0.0040***				***0.0100***		328.00		***0.0500***		0.012		0.0077		165.00		***0.0010***		0.914		***0.0070***				1.280
12/27/01		13.50		***0.0040***				***0.0100***		146.00		***0.0500***		***0.010***		0.0032		73.10		***0.0010***		0.470		***0.0070***				0.660
03/23/02		7.01		***0.0040***				***0.0100***		114.00		***0.0500***		***0.010***		0.0028		52.00		***0.0010***		0.240		***0.0070***				0.380
06/11/02		5.50		***0.0040***				***0.0100***		104.00		***0.0500***		0.010		0.0049		48.50		***0.0010***		0.257		***0.0070***				0.361
09/24/02		18.20		***0.0040***				***0.0100***		250.00		***0.0500***		0.016		0.0136		126.00		***0.0010***		0.509		***0.0070***		.		0.648
12/18/02		13.20		***0.0040***				***0.0100***		173.00		***0.0500***		***0.010***		0.0034		82.40		***0.0010***		0.373		***0.0070***				0.552
03/25/03		4.09		***0.0040***				***0.0100***		83.00		***0.0500***		***0.010***		0.0022		37.10		***0.0010***		0.186		***0.0070***				0.258
06/09/03		3.01		0.0072				***0.0100***		73.70		***0.0500***		0.012		0.0033		32.60		***0.0010***		0.162		***0.0070***				0.439
09/10/03		2.72		0.0063				0.0013		87.30		***0.0500***		0.010		0.0225		41.90		***0.0010***		0.173		***0.0070***				0.197

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MD-16
Inorganics
Page 1

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
05/22/95			3.90	727	0	136	0.23	10.70	254	0.45	1.00	1.06		396	22.0	***0.02***	0.11		***1.0***	
06/16/95	1.0		4.00	362	2	90	0.24	2.53	139	0.21	1.00	0.86		378	***2.0***	0.04	0.24		***1.0***	
08/14/95			6.50	386	38	0	0.51	0.02	226	***0.20***	2.00	0.96		374	8.0	***0.02***	0.11		1.7	
10/17/95			3.50	1215	0	300	20.02	28.30	568	0.60	2.00	1.68		1518	***2.0***	0.04	***0.04***		***1.0***	
11/29/95			4.10	309	5	54	0.19	4.40	85	0.27	1.00	0.69		242	***2.0***	***0.02***	0.07		0.2	
08/28/96	0.6	4.30	3.90	735	0	144	0.95	13.90	304	0.46	1.00	1.85		944	2.0	***0.02***	0.04		***1.0***	
12/12/96	35.0	4.50	4.20	199	6	42	0.12	2.32	57	***0.20***	1.00	0.12		192	***2.0***	***0.02***	0.20		***1.0***	
03/05/97	13.0	4.50	4.10	345	3	64	0.14	4.46	114	0.26	***1.00***	0.98		228	2.0	***0.02***	0.11		***1.0***	
06/25/97	1.0	4.70	4.10	576	6	104	0.29	9.30	259	0.43	1.00	1.36		664	14.0	***0.02***	0.10		***1.0***	
09/24/97	1.0	4.60	3.90	709	0	112	1.03	13.10	256	0.48	1.00	1.39		636	10.0	***0.02***	0.05		***1.0***	
12/17/97	4.0	4.40	4.20	456	7	80	0.20	8.88	126	0.33	8.00	1.45		372	***2.0***	0.07	0.16		***1.0***	
03/16/98	6.0	4.60	4.30	410	7	60	0.46	6.41	144	***0.20***	1.00	1.07		316	4.0	***0.02***	0.17		***1.0***	
06/25/98	9.5	4.30	4.00	419	3	66	0.27	5.96	179	0.32	1.00	1.19		434	***2.0***	***0.02***	***0.04***		***1.0***	
08/21/98	1.0	4.50	3.90	717	0	112	0.85	14.60	233	0.49	2.00	2.19		713	4.0	***0.02***	***0.04***		***1.0***	
03/29/99	30.0	4.60	4.10	270	4	42	0.29	3.00	85	0.22	1.00	0.86		224	***2.0***	***0.02***	***0.04***		***1.0***	
06/23/99	2.0	4.60	4.00	699	3	110	0.56	10.60	359	0.33	2.00	1.88		732	***2.0***	***0.02***	***0.04***		***1.0***	
09/30/99	1.0	4.50	3.80	653	0	106	0.80	13.60	316	0.38	2.00	1.92		534	***2.0***	***0.02***	***0.04***		***1.0***	
12/06/99	6.0	4.20	4.10	520	4	94	0.31	9.05	238	0.41	2.00	1.85		374	***2.0***	***0.02***	***0.04***		***1.0***	
03/06/00	6.0	4.30	4.20	435	5	66	0.13	6.92	161	0.32	2.00	1.52		414	6.0	***0.02***	***0.04***		***1.0***	
06/13/00	4.0	4.40	4.00	598	2	94	0.36	9.52	244		2.00	1.89		536	16.0					
09/28/00	2.0	4.20	3.90	701	0	112	0.76	13.20	321		3.00	2.45		762	18.0					
12/14/00	15.0	4.50	4.10	377	4	56	0.18	5.54	219					294	***2.0***					
03/16/01	13.0	4.30	4.20	255	0	38	0.14	3.43	96					180	16.0					
06/14/01	1.0	4.80	3.90	638	0	142	0.44	12.70	318		2.00	2.28		634	8.0					
09/18/01	1.0	4.50	3.70	902	0	165	2.13	19.10	220		3.00	3.17		974	***2.0***					
12/27/01	5.0	4.50	4.10	486	0	103	196.00	8.40	232		2.00	1.78		336	***2.0***					
03/23/02	8.0	4.50	4.20	335	0	89	110.00	4.80	129		2.00	1.35		262	6.0					
06/11/02	5.0	4.50	4.00	549	0	124	0.49	9.32	279		2.00	2.20		474	***2.0***					
09/24/02	0.1	4.00	3.60	907	0	183	1.95	17.80	425		3.30	3.35		1040	8.0					
12/18/02	4.5	4.00	4.10	477	0	112	0.21	7.34	239		2.40	1.97		440	***2.0***					
03/25/03	35.0	4.50	4.10	446	0	112	0.26	6.25	227		2.60	1.88		386	***2.0***					
05/28/03	2.4		4.00		1	96	<0.300	4.67	160											
06/09/03	11.1	4.20	4.10	241	0	66	0.12	3.04	88		1.70	1.12	***1.00***	240	2.0					
09/10/03	2.0	4.06	4.00	531	0	102	0.76	7.54	279		3.00	1.91	1.45	432	2.0					
11/17/03	5.0		3.60		0	174	3.55	14.50	476						10.0					

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MD-22
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
08/21/98	***0.20***	***0.20***	***0.0040***	***0.0040***	0.028	0.030	***0.0100***	***0.0100***	637.00	637.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	140.00	140.00	***0.0010***	***0.0010***	0.663	0.672	***0.0070***	***0.0070***		***0.010***	0.569	0.578
12/14/98	***0.20***	0.70	***0.0400***	***0.0400***	0.017	0.017	***0.0100***	***0.0100***	590.00	630.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0100***	***0.0100***	97.00	103.00	***0.0010***	***0.0010***	0.304	0.316	***0.0700***	***0.0700***			0.119	0.136
03/29/99	14.50	15.00	***0.0400***	***0.0400***	0.017	0.019	0.0180	0.0180	478.00	485.00	***0.0500***	***0.0500***	0.059	0.064	***0.0100***	***0.0100***	195.00	198.00	***0.0010***	***0.0010***	1.920	1.920	***0.0700***	***0.0700***		***0.010***	2.320	2.340
06/23/99	***0.20***	***0.20***	***0.0040***	***0.0040***	0.021	0.021	***0.0100***	***0.0100***	464.00	472.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	106.00	108.00	***0.0010***	***0.0010***	0.638	0.648	***0.0070***	***0.0070***		***0.010***	0.615	0.624
09/30/99	***0.20***	0.24	***0.0040***	***0.0040***	0.029	0.028	***0.0100***	***0.0100***	614.00	597.00	***0.0500***	***0.0500***	***0.010***	0.018	***0.0010***	***0.0010***	115.00	112.00	***0.0010***	***0.0010***	0.449	0.418	0.0080	0.0080	***0.010***	0.011	0.284	0.256
12/06/99	***0.20***	***0.20***	***0.0040***	***0.0040***	0.024	0.025	***0.0100***	***0.0100***	568.00	629.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	109.00	120.00	***0.0010***	***0.0010***	0.403	0.412	0.0090	0.0110		***0.010***	0.250	0.256
03/06/00	14.50	14.70	***0.0040***	***0.0040***	0.015	0.014	***0.0100***	0.0180	595.00	589.00	***0.0500***	***0.0500***	0.038	0.036	0.0040	0.0042	275.00	272.00	***0.0010***	***0.0010***	1.710	1.580	0.0080	0.0090	***0.010***	***0.010***	2.070	1.930
06/13/00		4.80		***0.0040***			.	***0.0100***		506.00		***0.0500***		***0.010***		0.0012		160.00		***0.0010***		1.220		***0.0070***				1.350
09/28/00		0.20		***0.0040***				***0.0100***		630.00		***0.0500***		***0.010***		***0.0010***		142.00		***0.0010***		0.579		***0.0070***				0.407
12/14/00																												
03/16/01																												
06/14/01		3.80		***0.0040***				***0.0100***		571.00		***0.0500***		***0.010***		***0.0010***		183.00		***0.0010***		0.913		***0.0070***				0.896
09/18/01		***0.20***		0.0053				***0.0100***		676.00		***0.0500***		***0.010***		***0.0010***		161.00		***0.0010***		0.528		0.0099				0.358
12/27/01		6.70		***0.0040***				***0.0100***		526.00		***0.0500***		0.010		0.0015		236.00		***0.0010***		1.450		0.0095				1.580
03/23/02		10.60		***0.0040***				***0.0100***		492.00		***0.0500***		0.020		0.0015		224.00		***0.0010***		1.370		***0.0070***				1.430
06/11/02		11.50		0.0043				***0.0100***		570.00		***0.0500***		***0.010***		0.0015		247.00		***0.0010***		1.310		0.0140				1.380
09/24/02		0.93		***0.0040***				***0.0100***		589.00		***0.0500***		***0.010***		***0.0010***		191.00		***0.0010***		0.639		***0.0070***				0.469
12/18/02		11.60		0.0062				***0.0100***		488.00		***0.0500***		***0.010***		0.0030		208.00		***0.0010***		1.050		0.0234				1.220
03/25/03		15.80		***0.0040***				***0.0100***		493.00		***0.0500***		0.013		0.0022		259.00		***0.0010***		1.520		***0.0070***				2.020
06/09/03		13.80		***0.0040***				***0.0100***		466.00		***0.0500***		0.011		0.0017		247.00		***0.0010***		1.443		***0.0070***				2.185
09/10/03		16.00		***0.0040***				0.0050		494.00		***0.0500***		***0.010***		0.0017		264.00		***0.0010***		1.450		***0.0070***				1.580

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MW-1
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
07/18/95	20.30	22.00	***0.0040***	***0.0040***	0.016	0.028	***0.0100***	***0.0100***	17.70	17.90	***0.0500***	***0.0500***	0.264	0.269	0.0593	0.0677	15.60	15.80	***0.0010***	***0.0010***	0.239	0.240	***0.0070***	***0.0070***		***0.010***	0.562	0.562
08/08/95	21.00	21.10	***0.0040***	***0.0040***	0.019	0.025	***0.0100***	***0.0100***	20.90	20.90	***0.0500***	***0.0500***	0.042	0.042	0.0151	0.0156	16.80	16.80	***0.0010***	***0.0010***	0.247	0.248	***0.0070***	***0.0070***		***0.010***	0.463	0.463
10/17/95	39.10	39.40	***0.0040***	***0.0040***	0.022	0.022	***0.0100***	***0.0100***	33.70	34.00	***0.0500***	***0.0500***	0.186	0.187	0.0228	0.0228	33.30	33.40	***0.0010***	***0.0010***	0.403	0.406	***0.0070***	***0.0070***		***0.010***	0.745	0.749
11/29/95	21.00	21.00	***0.0040***	***0.0040***	0.018	0.020	***0.0100***	***0.0100***	16.90	16.90	***0.0500***	***0.0500***	0.224	0.224	0.0186	0.0183	15.50	15.50	***0.0010***	***0.0010***	0.231	0.231	***0.0070***	***0.0070***		***0.010***	0.457	0.457
02/23/96		13.70		***0.0040***		0.022		***0.0100***				***0.0500***				0.0096				***0.0010***				***0.0070***		***0.010***		
05/17/96	27.00	28.30	***0.0040***	***0.0040***	0.023	0.023	***0.0100***	***0.0100***	30.50	31.60	***0.0500***	***0.0500***	0.105	0.109	0.0116	0.0111	22.00	22.80	***0.0010***	***0.0010***	0.221	0.232	***0.0070***	***0.0070***		***0.010***	0.401	0.417
08/28/96	24.70	24.70	***0.0040***	***0.0040***	***0.010***	***0.010***	***0.0100***	***0.0100***	36.50	36.50	***0.0500***	***0.0500***	0.177	0.189	0.0349	0.0350	30.60	30.60	***0.0010***	***0.0010***	0.238	0.262	***0.0070***	***0.0070***		***0.010***	0.581	0.616
12/12/96	25.30	24.60	***0.0040***	***0.0040***	0.017	0.019	***0.0100***	***0.0100***	69.00	69.00	***0.0500***	***0.0500***	0.179	0.183	0.0232	0.0240	30.00	30.00	***0.0010***	***0.0010***	0.300	0.300	***0.0070***	***0.0070***		***0.010***	0.554	0.554
03/05/97	27.10	27.10	***0.0040***	***0.0040***	0.027	0.027	***0.0100***	***0.0100***	75.60	75.60	***0.0500***	***0.0500***	0.086	0.086	0.0110	0.0110	36.80	36.80	***0.0010***	***0.0010***	0.270	0.274	***0.0070***	***0.0070***		***0.010***	0.581	0.581
06/26/97	32.50	33.80	***0.0040***	***0.0040***	0.021	0.023	***0.0100***	***0.0100***	115.00	115.00	***0.0500***	***0.0500***	0.132	0.144	0.0160	0.0166	54.80	54.80	***0.0010***	***0.0010***	0.347	0.347	***0.0070***	***0.0070***		***0.010***	0.772	0.815
09/29/97	26.50	26.70	***0.0040***	***0.0040***	0.017	0.098	***0.0100***	***0.0100***	118.00	118.00	***0.0500***	***0.0500***	0.110	0.111	0.0207	0.0194	50.00	50.00	***0.0010***	***0.0010***	0.367	0.367	***0.0070***	***0.0070***		***0.010***	0.616	0.618
12/17/97	34.10	36.70	***0.0040***	***0.0040***	0.023	0.025	***0.0100***	***0.0100***	146.00	156.00	***0.0500***	***0.0500***	0.100	0.121	0.0184	0.0184	60.10	63.70	***0.0010***	***0.0010***	0.407	0.418	***0.0070***	***0.0070***		***0.010***	0.778	0.815
03/16/98	38.70	42.40	***0.0040***	***0.0040***	0.019	0.019	***0.0100***	***0.0100***	193.00	209.00	***0.0500***	***0.0500***	0.094	0.099	0.0211	0.0205	86.70	95.60	***0.0010***	***0.0010***	0.405	0.425	***0.0070***	***0.0070***			0.740	0.786
06/25/98	35.60	35.80	***0.0040***	***0.0040***	0.020	0.020	***0.0100***	***0.0100***	180.00	182.00	***0.0500***	***0.0500***	0.109	0.113	0.0164	0.0165	81.50	82.30	***0.0010***	***0.0010***	0.361	0.361	***0.0070***	***0.0070***		***0.010***	0.732	0.732
08/21/98	43.70	45.00	***0.0040***	***0.0040***	0.019	0.020	***0.0100***	***0.0100***	179.00	182.00	***0.0500***	***0.0500***	0.165	0.167	0.0210	0.0240	96.50	96.50	***0.0010***	***0.0010***	0.436	0.436	***0.0070***	***0.0070***		***0.010***	0.834	0.834
12/14/98	40.10	40.10	***0.0400***	***0.0400***	0.016	0.016	***0.0100***	***0.0100***	143.00	143.00	***0.0500***	***0.0500***	0.260	0.272	***0.0100***	***0.0100***	78.00	85.00	***0.0010***	***0.0010***	0.418	0.420	***0.0700***	***0.0700***			0.790	0.790
03/29/99	29.40	30.10	***0.0400***	***0.0400***	0.017	0.018	***0.0100***	***0.0100***	170.00	173.00	***0.0500***	***0.0500***	0.157	0.157	0.0176	0.0176	60.50	67.50	***0.0010***	***0.0010***	0.388	0.390	***0.0770***	***0.0700***		***0.010***	0.683	0.692
06/23/99	40.30	40.30	***0.0040***	***0.0040***	0.016	0.017	***0.0100***	***0.0100***	186.00	187.00	***0.0500***	***0.0500***	0.180	0.190	0.0194	0.0194	84.50	87.00	***0.0010***	***0.0010***	0.459	0.468	***0.0070***	***0.0070***		***0.010***	1.000	1.040
09/30/99	27.10	26.60	***0.0040***	***0.0040***	0.016	0.017	***0.0100***	***0.0100***	154.00	155.00	***0.0500***	***0.0500***	0.159	0.177	0.0167	0.0167	72.50	73.40	***0.0010***	***0.0010***	0.351	0.345	***0.0070***	***0.0070***		***0.010***	0.631	0.622
12/06/99	30.30	31.90	***0.0040***	***0.0040***	0.018	0.020	***0.0100***	***0.0100***	147.00	155.00	***0.0500***	***0.0500***	0.163	0.187	0.0169	0.0169	65.90	69.30	***0.0010***	***0.0010***	0.368	0.420	***0.0070***	***0.0070***		***0.010***	0.724	0.831
03/06/00	27.40	28.20	***0.0040***	***0.0040***	0.018	0.018	***0.0100***	***0.0100***	173.00	177.00	***0.0500***	***0.0500***	0.083	0.086	0.0148	0.0142	75.10	83.60	***0.0010***	***0.0010***	0.309	0.324	***0.0070***	***0.0070***	***0.010***	***0.010***	0.664	0.677
06/13/00		32.60		***0.0040***				***0.0100***		211.00		***0.0500***		0.147		0.0315		82.40		***0.0010***		0.410		***0.0070***				0.817
09/28/00		32.20		***0.0040***				***0.0100***		177.00		***0.0500***		0.166		0.0153		8.30		***0.0010***		0.379		***0.0070***				0.772
12/14/00																												
03/16/01																												
06/14/01		29.20		***0.0040***				***0.0100***		205.00		***0.0500***		0.157		0.0199		87.90		***0.0010***		0.393		***0.0070***				0.806
09/18/01		35.40		***0.0040***				***0.0100***		236.00		***0.0500***		0.419		0.0239		108.00		***0.0010***		0.436		***0.0070***				0.866
12/27/01		22.00		***0.0040***				***0.0100***		161.00		***0.0500***		0.140		0.0134		71.50		***0.0010***		0.310		***0.0070***				0.680
03/23/02		24.20		***0.0040***				***0.0100***		193.00		***0.0500***		0.180		0.0197		74.00		***0.0010***		0.310		***0.0070***				0.620
06/11/02		29.80		***0.0040***				***0.0100***		291.00		***0.0500***		0.170		0.0200		117.00		***0.0010***		0.494		0.0075				0.904
09/24/02		33.00		***0.0040***		.		***0.0100***		245.00		***0.0500***		0.318		0.0221		105.00		***0.0010***		0.489		***0.0070***				0.907
12/18/02		27.90		***0.0040***				***0.0100***		242.00		***0.0500***		0.127		0.0166		104.00		***0.0010***		0.438		0.0120				0.850
03/25/03		22.30		***0.0040***				***0.0100***		218.00		***0.0500***		0.146		0.0165		89.80		***0.0010***		0.486		***0.0070***				1.120
06/09/03		23.80		***0.0040***				***0.0100***		250.00		***0.0500***		0.281		0.0203		98.90		***0.0010***		0.484		***0.0070***				0.966
09/10/03		25.10		***0.0040***				***0.0100***		291.00		***0.0500***		0.351		0.0255		115.00		***0.0010***		0.557		***0.0070***				0.938

Bold= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MW-2
Inorganics

Date	Flow (GPM) or Static Water Elevation (ft)	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)
07/18/95			5.60	96	12.2	120.0	2.12	0.22	28	***0.20***	2.00	0.55		74	96.0	0.05	0.96	0	59.5	
08/08/95			5.30	76	11.0	6.6	2.01	0.26	65	***0.20***	***1.00***	0.36		40	40.0	0.02	0.28	0	14.6	
10/17/95			5.30	94	10.8	32.0	3.75	0.53	32	***0.20***	1.00	0.47		94	***2.0***	0.06	0.11	0	***1.0***	
11/29/95			5.00	95	10.8	10.4	0.19	0.25	68	***0.20***	3.00	0.68		72	6.0	***0.02***	1.00	0	0.6	
05/17/96	2263.1	5.00	4.90	184	9.0	10.4	0.36	0.60	105	***0.20***	2.00	0.68		130	22.0	***0.02***	0.68		6.7	
08/28/96	2263.2	4.70	4.50	564	7.8	40.0	2.27	7.28	252	***0.20***	2.00	1.11		582	12.0	***0.02***	0.35		6.2	
12/12/96	2269.4	4.60	3.50	1212	0.0	150.0	16.80	14.40	427	0.23	4.00	2.61		1100	220.0	0.21	1.17		160.0	
03/05/97	2270.4	4.60	3.30	1316	0.0	210.0	40.80	29.70	538	0.27	5.00	3.56		1178	***2.0***	0.16	0.35		15.7	
06/26/97	2268.1	4.50	3.40	208	0.0	458.0	119.00	44.60	1080	0.44	8.00	6.28		2460	36.0	0.31	0.04		8.4	
09/29/97	2270.5	4.70	3.40	2140	0.0	344.0	81.80	34.80	656	0.31	10.00	9.23		2202	76.0	0.34	0.47		13.9	
12/17/97	2271.3	4.00	3.50	2480	0.0	392.0	99.20	42.80	1420	0.33	11.00	9.77		2802	6.0	0.47	0.17		3.0	
03/16/98	2271.8	4.40	3.30	2440	0.0	310.0	120.00	43.00	1440	0.44	10.00	7.57		2606	24.0	0.31	0.35		6.1	
06/25/98	2271.3	4.20	3.30	2580	0.0	402.0	164.00	50.50	1500	0.45	15.00	9.12		3042	20.0	0.28	0.14		3.4	
08/21/98	2269.2	4.70	3.60	2660	0.0	384.0			1300	0.45	20.00			3163	16.0	0.35	***0.04***		4.2	
12/14/98	2266.6	4.00	3.50	2310	0.0	310.0	121.00	38.90	1506	0.32	20.00	9.48		2280	4.0	0.55	***0.04***		4.9	
03/29/99	2271.8	4.20	3.20	2010	0.0	196.0	51.10	22.30	1150	0.23	10.00	6.08		1808	20.0	0.19	0.49		4.2	
06/23/99	2268.6	4.20	3.50	2720	0.0	350.0	158.00	42.60	1815	0.31	23.00	12.70		3090	***2.0***	0.33	***0.04***		1.8	
09/30/99	2268.5	4.20	3.40	2290	0.0	290.0	130.00	33.70	1280	0.23	20.00	11.70		2502	***2.0***	0.22	0.09		18.9	
12/06/99	2269.3	4.00	3.40	2360	0.0	326.0	117.00	30.10	1380	0.32	21.00	12.90		2114	10.0	0.43	***0.04***		2.4	
03/06/00	2267.1	4.00	3.40	2740	0.0	306.0	113.00	38.30	1370	0.38	22.00	15.30		2628	30.0	0.27	***0.04***		5.9	
06/13/00	2267.0	4.60	3.40	2840	0.0	384.0	147.00	40.30	1930		24.00	14.40		2982	36.0					
09/28/00	2266.9	4.00	3.70	2510	0.0	338.0	177.00	36.90	1520		23.00	13.10		2836	28.0					
12/14/00	2267.3	4.00	3.60	2470	0.0	336.0	143.00	33.40	1360					2344	10.0					
03/16/01	2269.5	4.30	3.40	2200	0.0	280.0	112.00	31.20	970					2224	46.0					
06/14/01	2267.2	4.70	3.50	2470	0.0	344.0	164.00	37.40	1548		25.00	12.30		2796	32.0					
09/18/01	2266.0	4.00	3.70	2700	0.0	419.2	164.00	37.80	1590		39.00	17.80		3188	***2.0***					
12/27/01	2269.0	4.50	3.70	2320	0.0	294.0	116.00	24.60	1610		20.00	11.00		2484	6.0					
03/23/02	2269.4	4.50	3.50	2050	0.0	325.4	112.00	25.70	1192		11.00	8.16		2034	48.0					
06/11/02	2268.6	4.70	3.70	2370	0.0	364.0	151.00	31.80	1548		15.00	10.60		2696	***2.0***					
09/24/02	2267.1	4.50	3.60	2890	0.0	380.0	143.00	37.40	1951		59.70	26.60		3478	18.0					
12/18/02	2268.4	4.00	3.70	2430	0.0	330.4	147.00	32.30	1689		19.60	13.50		3066	22.0					
03/25/03	2269.9	4.00	3.40	1869	0.0	262.4	78.00	21.20	1130		7.70	6.63		1824	4.0					
06/09/03	2269.8	3.50	3.50	2060	0.0	275.8	92.00	23.63	1244		10.20	24.10	11.00	2432	28.0					
09/10/03	2269.6	3.73	3.50	2280	0.0	264.0	102.00	29.00	1332		11.40	9.58	13.30	2714	38.0					

Bold Italic= less than detection limits

Appendix 5.C
Laurel Land Development
McDermott Site

MW-3
Metals

Date	Dissolved Al (mg/L)	Total Al (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved Zn (mg/L)	Total Zn (mg/L)
07/18/95	**0.14**	0.56	**0.0040**	**0.0040**	0.049	0.049	***0.0100***	***0.0100***	9.25	9.25	***0.0500***	***0.0500***	0.018	0.018	0.0138	0.0216	5.47	5.47	***0.0010***	***0.0010***	0.036	0.036	***0.0070***	***0.0070***			0.047	0.047
08/08/95	**0.14**	0.24	**0.0040**	**0.0040**	0.043	0.047	***0.0100***	***0.0100***	4.02	3.93	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	***0.0010***	1.65	1.70	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***			0.013	0.013
10/17/95	0.26	0.23	**0.0040**	**0.0040**	0.091	0.092	***0.0100***	***0.0100***	29.10	29.00	***0.0500***	***0.0500***	***0.010***	0.010	0.0122	0.0122	20.20	20.20	***0.0010***	***0.0010***	0.125	0.120	***0.0070***	***0.0070***			0.132	0.140
11/29/95	**0.14**	**0.14**	**0.0040**	**0.0040**	0.039	0.045	***0.0100***	***0.0100***	4.07	3.26	***0.0500***	***0.0500***	0.012	0.012	0.0035	0.0035	1.42	1.77	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***			0.010	0.016
05/17/96	0.14	5.54	***0.0040***	***0.0040***	***0.050***	***0.080***	***0.0100***	***0.0100***	4.31	4.50	***0.0100***	***0.0500***	***0.010***	***0.010***	***0.0010***	0.0039	1.49	1.77	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.128	0.143
08/28/96	***0.14***	6.89	***0.0040***	***0.0070***	0.053	0.075	***0.0100***	***0.0100***	4.79	4.88	***0.0500***	***0.0500***	***0.010***	***0.010***	0.0020	0.0057	1.72	2.06	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.014	0.017
12/12/96	***0.14***	3.71	***0.0040***	***0.0040***	0.040	0.047	***0.0100***	***0.0100***	4.47	4.47	***0.0500***	***0.0500***	***0.010***	***0.010***	0.0011	0.0044	1.08	1.17	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.021	0.027
03/05/97	***0.14***	7.14	***0.0040***	***0.0040***	0.058	0.084	***0.0100***	***0.0100***	4.29	4.29	***0.0500***	***0.0500***	***0.010***	0.016	***0.0010***	0.0044	1.34	1.56	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.019	0.063
06/26/97	***0.14***	2.91	***0.0040***	***0.0040***	0.060	0.069	***0.0100***	***0.0100***	4.22	4.22	***0.0500***	***0.0500***	***0.010***	0.013	***0.0010***	0.0042	1.62	1.68	***0.0010***	***0.0010***	***0.025***	***0.025***	***0.0070***	***0.0070***		***0.010***	0.021	0.034
09/29/97	1.46	9.71	***0.0040***	***0.0040***	0.124	0.124	***0.0100***	***0.0100***	22.20	22.80	***0.0500***	***0.0500***	0.017	0.017	0.0043	0.0044	14.40	14.60	***0.0010***	***0.0010***	0.078	0.078	***0.0070***	***0.0070***		***0.010***	0.143	0.156
12/17/97	***0.20***	7.31	***0.0040***	***0.0040***	0.074	0.117	***0.0100***	***0.0100***	5.63	5.95	***0.0500***	***0.0500***	0.017	0.136	0.0100	0.0122	2.12	2.52	***0.0010***	***0.0010***	***0.050***	***0.050***	***0.0070***	***0.0070***		***0.010***	0.017	0.041
03/16/98	1.78	7.02	***0.0040***	***0.0040***	0.054	0.103	***0.0100***	***0.0100***	53.60	59.50	***0.0500***	***0.0500***	0.019	0.063	***0.0010***	***0.0010***	40.30	44.40	***0.0010***	***0.0010***	0.177	0.209	***0.0070***	***0.0070***			0.334	0.383
06/25/98	0.50	2.82	***0.0040***	***0.0040***	0.023	0.053	0.0180	0.0220	114.00	114.00	***0.0500***	***0.0500***	***0.010***	0.044	***0.0010***	***0.0010***	67.60	67.60	***0.0010***	***0.0010***	0.156	0.160	***0.0070***	***0.0070***		***0.010***	0.239	0.244
08/21/98	0.42	7.86	***0.0040***	***0.0040***	0.020	0.083	0.0150	0.0150	95.10	95.40	***0.0500***	0.0950	***0.010***	0.039	***0.0010***	***0.0010***	52.50	55.50	***0.0010***	***0.0010***	0.142	0.188	***0.0070***	***0.0070***		***0.010***	0.217	0.242
12/14/98	0.33	5.64	***0.0400***	***0.0400***	0.013	0.049	***0.0100***	***0.0100***	96.80	100.00	***0.0500***	***0.0500***	***0.010***	0.011	***0.0100***	***0.0100***	62.50	65.00	***0.0010***	***0.0010***	0.163	0.181	***0.0700***	***0.0700***			0.221	0.242
03/29/99	0.41	0.88	***0.0400***	***0.0400***	0.018	0.023	0.0260	0.0290	125.00	125.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0100***	***0.0100***	66.50	67.70	***0.0010***	***0.0010***	0.262	0.262	***0.0700***	***0.0700***		***0.010***	0.254	0.254
06/23/99	0.31	0.46	***0.0040***	***0.0040***	0.018	0.019	***0.0100***	***0.0100***	117.00	120.00	***0.0500***	***0.0500***	0.013	0.013	0.0017	0.0018	75.00	77.90	***0.0010***	***0.0010***	0.380	0.380	***0.0070***	***0.0070***		***0.010***	0.576	0.576
09/30/99	0.32	0.92	***0.0040***	***0.0040***	0.026	0.028	0.0500	0.0520	183.00	189.00	***0.0500***	***0.0500***	***0.010***	***0.010***	0.0014	0.0028		94.70					***0.0070***	***0.0070***				
12/06/99	0.26	0.98	***0.0040***	***0.0040***	0.021	0.026	***0.0100***	0.0150	165.00	174.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	0.0016	81.30	91.10	***0.0010***	***0.0010***	0.395	0.430	***0.0070***	***0.0070***		***0.010***	0.559	0.609
03/06/00	***0.20***	0.48	***0.0040***	***0.0040***	0.016	0.021	0.0120	0.0190	139.00	142.00	***0.0500***	***0.0500***	***0.010***	***0.010***	***0.0010***	0.0012	80.80	88.70	***0.0010***	***0.0010***	0.340	0.346	***0.0070***	***0.0070***	***0.010***	***0.010***	0.503	0.522
06/13/00		0.73		***0.0040***				***0.0100***		135.00		***0.0500***		***0.010***		0.0067		72.50		***0.0010***		0.347		***0.0070***				0.508
09/28/00		0.73		***0.0040***				***0.0100***		171.00		***0.0500***		***0.010***		0.0010		87.50		***0.0010***		0.349		0.0070				0.469
12/14/00																												
03/16/01																												
06/14/01		0.40		***0.0040***				***0.0100***		177.00		***0.0500***		***0.010***		0.0014		88.10		***0.0010***		0.368		***0.0070***				0.480
09/18/01		0.37		***0.0040***				***0.0100***		188.00		***0.0500***		***0.010***		0.0012		91.60		***0.0010***		0.370		***0.0070***				0.476
12/27/01		0.40		***0.0040***				***0.0100***		162.00		***0.0500***		***0.010***		***0.0001***		81.80		***0.0010***		0.440		***0.0070***				0.530
03/23/02		0.53		0.0050				***0.0100***		167.00		***0.0500***		***0.010***		0.0010		80.90		***0.0010***		0.430		***0.0070***				0.520
06/11/02		0.83		0.0044				***0.0100***		165.00		***0.0500***		***0.010***		0.0110		92.50		***0.0010***		0.452		***0.0070***				0.567
09/24/02		0.98		***0.0040***				***0.0100***		207.00		***0.0500***		***0.010***		***0.0010***		101.00		***0.0010***		0.465		***0.0070***				0.624
12/18/02		1.74		***0.0040***				***0.0100***		182.00		***0.0500***		0.031		0.0085		91.00		***0.0010***		0.469		***0.0070***				0.680
03/25/03		1.02		***0.0040***				0.0680		212.00		***0.0500***		***0.010***		0.0014		101.00		***0.0010***		0.472		***0.0070***				2.110
06/09/03		0.77		0.0058				***0.0100***		185.00		***0.0500***		***0.010***		0.0011		98.30		***0.0010***		0.428		***0.0070***				1.035
09/10/03		0.72		0.0048				0.0007		205.00		***0.0500***		***0.010***		***0.0010***		100.00		***0.0010***		0.437		***0.0070***				0.587

Bold Italic= less than detection limits

Appendix 5.D

Water Monitoring Results for the Abel-Dreshman Sites

Appendix 5.D
Abel-Dreshman Site

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Inorganics
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DATE	Flow (GPM)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/l)	Acidity (mg/l)	Net Alkalinity (mg/l)	Iron (mg/l)	Total Mn (mg/l)	Dissolved Mn (mg/l)	Biochemical Oxygen Demand	SO4 (mg/l)	Fluoride (mg/l)	Chloride (mg/l)	Na (mg/l)	TDS (mg/l)	TSS (mg/l)	Ammonia (mg/l)	Total Nitrate (mg/l)	Total Nitrite (mg/l)	Total Kjeld Nitrogen (mg/l)	Phosphorous (mg/l)	Turbidity NTU
10/12/94		3.5		0	126	-126	1.6	53.1			760											
05/16/95		3.6		0	128	-128	1.4	39.5			556											
06/29/95		3.6		0	122	-122	1.7	47.6			633											
07/11/95		3.3		0	154	-154	2	44.1			710											
07/27/95		3.3		0	208	-208	2.3	68.6			1087											
09/12/95	8	3.4		0	234	-234	1.7	77.2			1373											
11/20/95		3.9		0	40	-40	0.4	18			336											
02/22/96		3.9		0	52	-52	0.6	23.1			354											
03/27/96		3.6		0	150	-150	1.5	49.7			849											
04/18/96		3.6		0	148	-148	1.3	47.4			908											
06/11/96	68	3.5		0	192	-192	1.9	72.2			894											
06/27/96	59	3.6		0	128	-128	1.3	42			720											
07/31/96	65	3.4		0	74	-74	1.79	76.4		<.20	826		5	7.73		<2		0.11	<.004	0.5	<.02	
08/29/96	25	3.6	1390	0	146	-146	1.03	54.3	51		640	0.31	5	5.83	1574	2	0.08	0.13				<1
09/18/96		3.6		0	72	-72	0.739	17.4			332			<10.00		<3						
10/24/96	70	3.7	1165	0	114	-114	1.37	48.6	47.6		288	0.3	5	6.12	1142	2	0.09	0.29				<1
11/26/96		3.9		0	86	-86	0.977	22			465			<10.00		<3						
01/06/97		3.8		0	94	-94	1.36	32.2			655			<10.00		<3						
03/21/97	130	3.6		0	150	-150	2.05	45.1			903			<10.00		<3						
06/10/97	20	3.5		0	138	-138	1.28	38.6			654			<10.00		<3						
07/10/97		3.4		0	186	-186	2.46	55			950			<10.00		4						
09/04/97		3.6	2120	0	248	-248	35.8	86			1100	0.32	6	16.4	2682	228	0.41	<.04				38
09/22/97		3.7		0	94	-94	0.959	27.6			586			<10.00		<3						
11/13/97		4.1	830	3.6	44	-40.4	0.477	25.4	25.4		208	0.38	4	4.93	706	<2	0.04	0.38				<1
12/29/97		3.9	938	0	86	-86	1.48	35.8	35.8		890	0.24	3	4.25	806		0.14	0.34				<1
02/03/98	84.4	3.8		0	102	-102	4.01	35			723			<10.00		<3						
02/20/98	139.4	3.9		0	82	-82	4.74	31.6			552			<10.00		4						
03/25/98	81	4.1	931	4	84	-80	5.09	31.9	31.1		444	0.27	3	4.48	790	84	0.12	0.35				1.6
06/03/98	56	3.8	1231	0	122	-122	3.99	44.4	44.4		496	0.36	3	4.8	1012	6	0.11	0.23				1.1
07/28/98	26	3.8		0	84	-84	0.656	27.4			625			<10.00		<3						
10/09/98	20	4.4		7.6	34	-26.4	0.581	16.3			461			<10.00		<3						
12/10/98	9	4.4		6.2	22	-15.8	0.143	15.3	14.8		311	0.29	18	6.79	602	26		1.07				<1
02/25/99	45	5.1		11	7.2	3.8	0.15	8.02			192			<10.00		14						
03/11/99	28	4.9	554	8.2	12.4	-4.2	0.072	10.9	10.3		247	<.2	7	4.9	352	1	0.17	1.46				<1
07/15/99		4.5		7.2	13.8	-6.6	0.444	10.4			276.5			<10.00		4						
08/20/99		4.4		7.2	12.2	-5	0.556	12.2			372			11.5		1.5						
11/12/99	8.1	4.7		8.4	11	-2.6	0.15	7.63			282.3			<10.00		1.5						
03/08/00	55	5		7.8	5.2	2.6	0.15	3.47			215.5			<10.00		1.5						
04/25/00	45	6.5		20	0	20	0.15	9.66			263.8			10.4		1.5						
08/31/00	4	4.8		7.6	6.2	1.4	0.15	4.91			290.6			11.4		1.5						
10/18/00	4	5		8.8	6.6	2.2	0.15	5.54			340.9			12.5		1.5						
01/24/01	19	5.1		10.2	9.2	1	0.15	4.36			255					6						

Appendix 5.D
Abel-Dreshman Site

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Inorganics
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DATE	Flow (GPM)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/l)	Acidity (mg/l)	Net Alkalinity (mg/l)	Iron (mg/l)	Total Mn (mg/l)	Dissolved Mn (mg/l)	Biochemical Oxygen Demand	SO4 (mg/l)	Fluoride (mg/l)	Chloride (mg/l)	Na (mg/l)	TDS (mg/l)	TSS (mg/l)	Ammonia (mg/l)	Total Nitrate (mg/l)	Total Nitrite (mg/l)	Total Kjeld Nitrogen (mg/l)	Phosphorous (mg/l)	Turbidity NTU
04/05/01	28.6	5.8		11	2.6	8.4	0.15	4.31			281.2					1.5						
05/08/01	22	6		12.4	0	12.4	0.15	5.81			363.8					4						
06/22/01		5.3		8.2	40.6	-32.4	0.463	7.02			367.7					1.5						
07/11/01		4.9		6.8	31	-24.2	0.15	6.16			402.2					12						
10/18/01		5.1		8.2	56.6	-48.4	0.15	10.2			383.2					1.5						
04/30/02		5.8		10	12.4	-2.4	0.15	2.35			94.4					6						
07/25/02		6		10.6	54.4	-43.8	0.15	23.7			544.5					10						
10/08/02		5.1		8.6	71.2	-62.6	0.15	11.7			390.8					4						
03/14/03		6.3		9	11.8	-2.8	0.796	0.785			43.7					22						

Appendix 5.D
Abel-Dreshman Site

29A
Inorganics
Page1

DATE	Flow (GPM)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/l)	Acidity (mg/l)	Net Alkalinity (mg/l)	Iron (mg/l)	Total Mn (mg/l)	Dissolved Mn (mg/l)	Biochemical Oxygen Demand	SO4 (mg/l)	Fluoride (mg/l)	Chloride (mg/l)	Na (mg/l)	TDS (mg/l)	TSS (mg/l)	Ammonia (mg/l)	Total Nitrate (mg/l)	Total Nitrite (mg/l)	Total Kjeld Nitrogen (mg/l)	Phosphorous (mg/l)	Turbidity NTU
05/16/95		3.3		0	220	-220	3.8	73.8			965											
07/17/95		3.3		0	184	-184	3.1	48.2			863											
09/12/95	5	3.2		0	320	-320	5.9	110			1532											
11/20/95		3.7		0	74	-74	1.9	33.3			557											
02/22/96		3.7		0	88	-88	1.2	34.7			645											
03/27/96		3.4		0	232	-232	3.1	82.1			1295											
04/18/96		3.4		0	236	-236	3.2	76.6			1465											
06/11/96	36	3.3		0	270	-270	4.1	96.5			1250											
06/27/96	38	3.3		0	42	-42	3.5	73.2			1236											
07/31/96	30	3.2		0	222	-222	0.236	18.3		0.4	998		1	2.91	<2			0.31	<.004	0.2	<.02	
08/29/96	15	3.3	642	0	242	-242	0.118	17.2	17.2		1110	0.34	1	2.07		722	<.02	0.31				<1
09/18/96	60	3.5		0	116	-116	1.65	28.6			655			<10.00	<3							
10/24/96	35	3.5	1735	0	188	-188	3.47	81.2	81.2		110			10.8	<2	1816	0.25	<.04				<1
11/26/96		3.7		0	112	-112	1.48	27.2			547			<10.00	<3							
01/06/97	25	3.6		0	138	-138	2.46	47.4			932			<10.00	<3							
03/21/97	60	3.5		0	206	-206	3.95	63.9			1053			<10.00	8							
06/10/97	25	3.2		0	258	-258	3.45	73.3			1279			<10.00	<3							
07/10/97	15	3.2		0	278	-278	5.23	84.1			1342			11.5	<3							
09/04/97		3.7	2120	0	254	-254	45.4	106			1120	0.32	19	17.2	<2	2658	0.46	<.04				35
09/22/97		3.4		0	216	-216	4.57	59.7			947			<10.00	<3							
11/13/97		3.7	1600	0	144	-144	2.16	63.5	58.9		436	0.43	9	9.77	18	1712	0.17	0.1				<1
12/29/97		3.6	1828	0	220	-220	7.13	96.3	96.3		637	0.35	5	8.02	<2	1838	0.38	0.07				6.2
02/03/98	20	3.7		0	204	-204	16.9	69.5			1287			<10.00	<3							
02/20/98	40	4		3.2	118	-114.8	10	43			797			<10.00	16							
03/25/98	41	4.1	1678	5	210	-205	24.6	76.2	73.4		918	0.46	5	8.19	16	1700	0.31	0.09				3.6
06/03/98	28	3.6	1928	0	230	-230	20.1	88.8	88.8		1000	0.46	4	7.94	12	1750	0.26	<.04				1.5
07/28/98	10	3.4		0	212	-212	3.6	73.6			1197			<10.00	<3							
10/09/98	8	4.3		7.4	90	-82.6	2.08	35.1			882			21.8	<3							
12/10/98	3	4	1834	2.2	134	-131.8	0.575	63	63		872	<.2		40.5	26	1164	0.48	0.11				70
03/11/99	12	4.7	554	9	66	-57	0.072	10.9	10.3		561	<.20	7	4.9	<2	352	0.17	1.46				<1
07/15/99	3	6.4		28	64	-36	0.15	40.7			1029			26.2	4							
08/20/99	10	6.1		30	3.2	26.8	0.15	22.8			901			47.9	1.5							
09/09/99	6	6.2		24	4.8	19.2	0.15	17.5			925			50.2	1.5							
11/12/99	2	5.3		10.4	17.4	-7					637											
03/08/00	5	6.1		13.8	3	10.8	0.082	14.5	15.7		542	<.2	40	32.4	8	1014	<.02	0.66				<1
04/25/00	15	6.9		56	0	56	0.15	25.3			696			23.1	1.5							
08/31/00	1	6.3		26	0	26	0.15	5.15			747			40.5	1.5							
10/18/00	1	6.3		22	0	22	0.38	9.01			689			49.2	1.5							
01/24/01	4	6.3		19.4	13.8	5.6	0.15	13.4			602				8							
04/05/01	7	6.7		36	0	36	0.15	15.1			692				1.5							
05/08/01	7	6.7		42	0	42	0.15	18.1			692				1.5							
05/31/01	3	6.5		28	0	28	0.302	20.7	20.7		870		11	13.2	18	1276						
07/11/01	4	6.4		17.4	29.2	-11.8	1.04	16			727				14							

Appendix 5.D
Abel-Dreshman Site

29A
Inorganics
Page2

DATE	Flow (GPM)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/l)	Acidity (mg/l)	Net Alkalinity (mg/l)	Iron (mg/l)	Total Mn (mg/l)	Dissolved Mn (mg/l)	Biochemical Oxygen Demand	SO4 (mg/l)	Fluoride (mg/l)	Chloride (mg/l)	Na (mg/l)	TDS (mg/l)	TSS (mg/l)	Ammonia (mg/l)	Total Nitrate (mg/l)	Total Nitrite (mg/l)	Total Kjeld Nitrogen (mg/l)	Phosphorous (mg/l)	Turbidity NTU
10/18/01	1	5.9		12.2	75.2	-63	0.15	21.1			708				6							
03/13/02	8	5.3		2.4	31.8	-29.4	0.07	7.56			584				6							
04/30/02	15	5.3		9	75	-66	0.15	18.4			494				1.5							
07/25/02	5	6.3		14.2	122.8	-108.6	1.02	53.2			1393				12							
10/08/02	2	5.9		11.4	112.6	-101.2	0.15	35.1			958				6							
03/14/03	20	6.1		9.8	10.6	-0.8	0.15	6.07			256											
06/17/03	5	4.9		2	90.8	-88.8					896				8							
09/11/03	5	5.8		10	93.4	-83.4	0.382	28.3			831				10							

Appendix 5.D
Abel-Dreshman Site

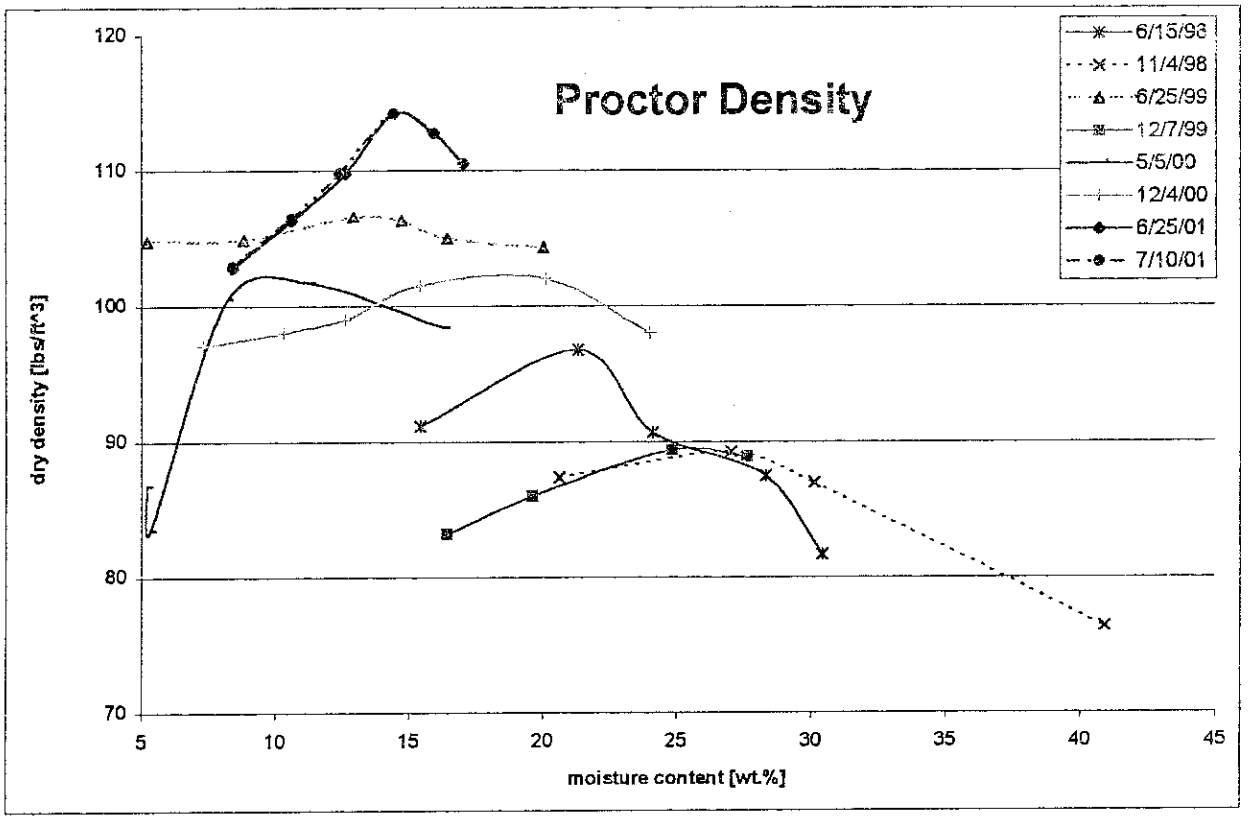
29B
Metals
Page1

DATE	Total Al (mg/l)	Dissolved Al (mg/l)	Total As (mg/l)	Dissolved As (mg/l)	Total Barium (mg/l)	Dissolved Barium (mg/l)	Total Cd (mg/l)	Dissolved Cd (mg/l)	Total Ca (mg/l)	Dissolved Ca (mg/l)	Total Cr (mg/l)	Dissolved Cr (mg/l)	Total Cu (mg/l)	Dissolved Cu (mg/l)	Total Pb (mg/l)	Dissolved Pb (mg/l)	Total Mg (mg/l)	Dissolved Mg (mg/l)	Total Hg (mg/l)	Dissolved Hg (mg/l)	Total Ni (mg/l)	Dissolved Ni (mg/l)	Total Se (mg/l)	Dissolved Se (mg/l)	Total Zn (mg/l)	Dissolved Zn (mg/l)
05/16/95	2.80																									
07/17/95	4.50																									
09/12/95	4.90																									
11/20/95	2.20																									
02/22/96	1.80																									
03/27/96	3.20																									
04/18/96	4.50																									
06/11/96	5.80																									
06/27/96	3.90																									
07/31/96	3.12		<.004		0.0300		<.010								0.0045				<.001				<.007			
08/29/96	1.91		<.004	<.004	0.0150	0.0150	<.010	<.010	223.0	208.0	<.050	<.050	<.010	<.010	0.0055	0.0055	132	126	<.001	<.001	0.5020	0.5020	<.007	<.007	0.3560	0.3560
09/18/96	1.57																									
10/24/96	3.23	3.23	<.004	<.004	0.0300	0.0300	<.010	<.010	46.3	44.3	<.050	<.050	<.010	<.010	<.001	<.001	40	38	<.001	<.001	0.1540	0.1540	<.007	<.007	0.2090	0.2090
11/26/96	2.74																									
01/06/97	2.77																									
03/21/97	2.25																									
06/10/97	2.36																									
07/10/97	3.03																									
09/04/97	3.11		<.004		0.0220		<.010		51.4		<.050		<.010		<.001		41		<.001		0.1820		<.007		0.3050	
09/22/97	2.03																									
11/13/97	2.16	2.16	<.004	<.004	0.0380	0.0380	<.010	<.010	43.0	43.0	<.050	<.050	<.010	<.010	0.0043	0.0043	33	32	<.001	<.001	0.1660	0.1660	<.007	<.007	0.2340	0.2340
12/29/97	1.34	1.34	<.004	<.004	0.0400	0.0370	<.010	<.010	36.5	36.5	<.050	<.050	<.010	<.010	<.001	<.001	31	31	<.001	<.001	0.1140	0.1080	<.007	<.007	0.1860	0.1860
02/03/98	1.22																									
02/20/98	1.07																									
03/25/98	1.15	1.15	<.004	<.004	0.0370	0.0370	<.010	<.010	30.0	30.0	<.050	<.050	<.010	<.010	<.001	<.001	26	26	<.001	<.001	0.0990	0.0990	<.007	<.007	0.1600	0.1600
06/03/98	1.50	1.48	<.004	<.004	0.0320	0.0320	<.010	<.010	42.9	40.9	<.050	<.050	<.010	0.0110	0.0012	0.0012	34	33	<.001	<.001	0.1220	0.1220	<.007	<.007	0.2030	0.2030
07/28/98	2.69																									
10/09/98	2.23																									
12/10/98	1.72	1.72	<.004	<.0040	0.0270	0.0270	<.010	<.010	50.2	47.3	<.050	<.050	<.010	<.010	<.001	<.001	35	32	<.001	<.001	0.1370	0.1370	<.007	<.007	0.1970	0.1970
03/11/99	0.62	0.56	<.0040	<.0040	0.0340	0.0310	<.010	<.010	27.8	27.8	<.050	<.050	<.010	<.010	<.001	<.001	15	14	<.001	<.001	0.0630	0.0570	<.007	<.007	0.0880	0.0810
07/15/99	1.20																									
08/20/99	1.19																									
09/09/99	1.09																									
11/12/99																										
03/08/00	0.70	1.15	<.0040	<.0040	0.0290	0.0310	<.010	<.010	31.1	32.9	<.050	<.050	<.010	<.010	<.001	<.001	20	21	<.001	<.001	0.0550	<.05	<.007	<.007	0.0790	0.1140
04/25/00	0.62																									
08/31/00	0.89																									
10/18/00	1.01																									
01/24/01	0.68																									
04/05/01	0.66																									
05/08/01	0.79																									
05/31/01		0.96		<.004				<.01	43.6	43.6		<.05		<.010		0.0013	27	27		<.001		0.0780		<.007		0.1040
07/11/01	0.99																									
10/18/01	0.94																									
03/13/02	0.77																									
04/30/02	0.74																									
07/25/02	1.07																									
10/08/02	0.99																									
03/14/03	0.25																									
06/17/03																										
09/11/03	0.25																									

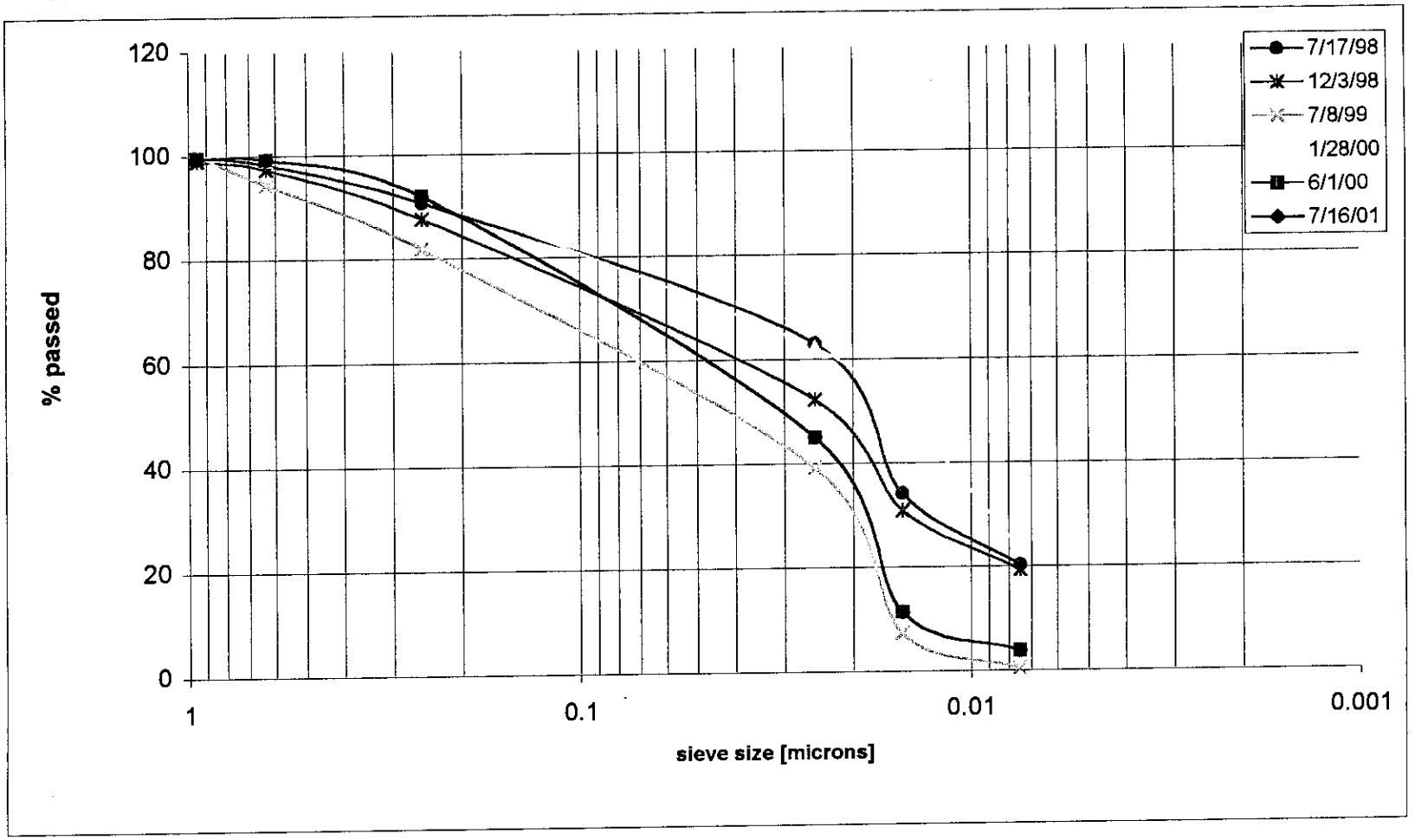
Appendix 8.A

Semi-annual characterization of the proctor densities of the Schuylkill Energy ash and size distribution

moisture	dry density	moisture	dry density
	6/15/98		5/5/00
15.4	91.2	5.2	86.8
21.3	96.8	5.3	83.5
24.1	90.7	8.2	100.5
28.3	87.5	11.3	101.7
30.4	81.7	16.3	98.4
	11/4/98		12/4/00
20.6	87.4	7.3	97
27	89.3	10.3	98
30.1	87	12.6	99
40.9	76.4	15.4	101.5
	6/25/99	20.1	102
5.2	104.8	24	98
8.8	104.9		6/25/01
12.9	106.6	8.4	102.8
14.7	106.3	10.6	106.3
16.4	105	12.6	109.8
20	104.3	14.4	114.2
	12/7/99	15.9	112.8
16.4	83.2	17	110.5
19.6	86		7/10/01
24.8	89.4	8.4	102.9
27.6	88.9	10.6	106.5
		12.4	109.8
		14.4	114.2
		15.9	112.8
		17	110.5



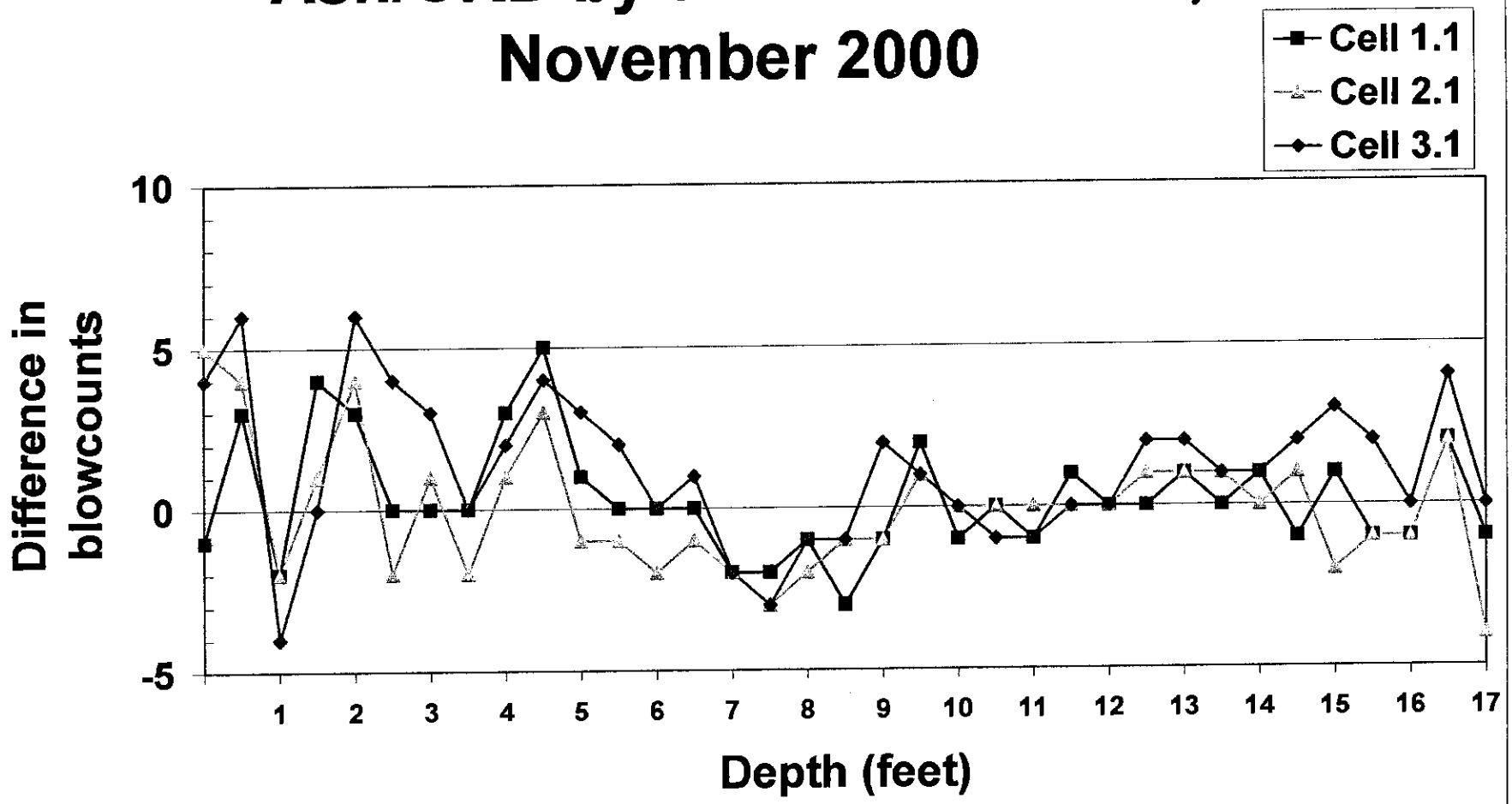
seive size	7/16/01	6/1/00	1/28/00	7/8/99	12/3/98	7/17/98
0.953	99.5	99.5	100	100	98.9	99.8
0.635	99.1	99.1	99	94.3	97.2	98.2
0.254	91.9	91.9	92.1	81.8	87.6	90.6
0.025	45	45	62.2	39.2	52.2	63
0.015	11.3	11.3	49.8	7.2	30.9	34.1
0.0075	3.7	3.7	23.3	0.4	19.3	20.2



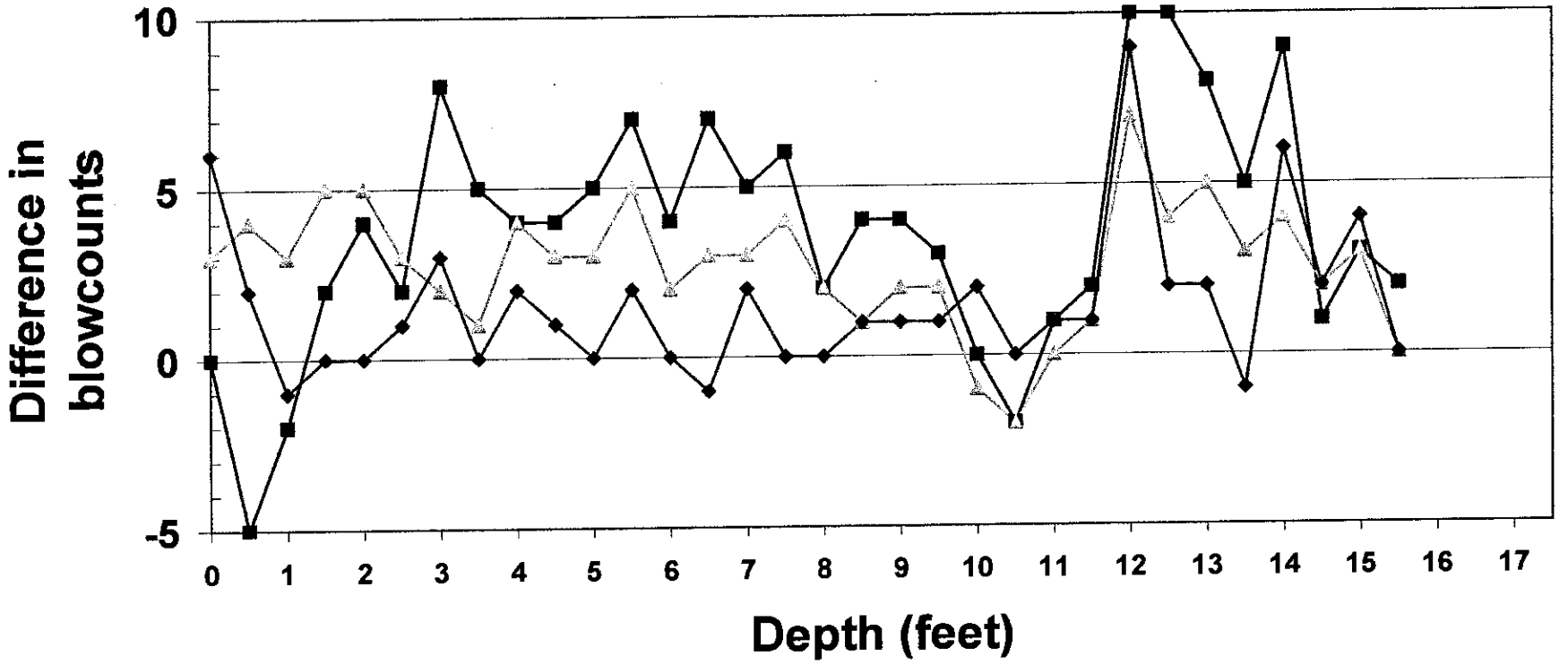
Appendix 8.B

Blow count data normalized to cell #4

Normalized (to cell 4) blowcounts for Ash/CKD by the inlet location, November 2000



Normalized (to cell 4) blowcounts for Ash/CKD in the center of the cell, November 2000



Appendix 8.C

Semi-annual fly ash analyses and leach data

HAWKMTN
LABS INC

201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 7/29/97

Material Tested: Fly Ash
Date Received: 5/28/1997
Date Sampled: 5/28/1997
Client ID: Schuylkill Energy, Semi Annual Fly Ash Analysis

HawkMtn #: 9705-00305-001
Sampler Client
Sample pt. ID: Schuylkill Energy

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	10.11	10.75	EPA SW846, METH. 9045
Aluminum	263000	1.5	SW-846 METH. 7020
Antimony	<20.0	0.003	SW-846 METH. 7040
Arsenic	29.0	<0.005	SW-846 METH. 7060
Barium	149	<0.10	SW-846 METH. 7080
Boron	<10.0	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	METH. 7131
Chromium	33	0.10	METH. 7191
Copper	18	0.03	EPA SW846 METH. 7210
Iron	53000	0.06	EPA SW846 METH. 7380
Lead	13	<0.10	METH. 7421
Manganese	82	0.02	EPA SW846 METH. 7460
Mercury	0.40	<0.0002	METH. 7471
Molybdenum	20	0.3	EPA SW846 METH. 7480
Nickel	19	<0.04	EPA SW846 METH. 7520
Selenium	<0.5	<0.005	EPA SW846 METH. 7740
Zinc	68.1	0.022	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

ISO 9001:2000
REGISTERED COMPANY

HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DER MODULE 25

SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 7/29/1997

Material Tested: Fly Ash
Date Received: 5/28/1997
Date Sampled: 5/28/1997
Client ID: Schuylkill Energy, Semi Annual Fly Ash Analysis

Hawk Mtn ID: 9705-00305-001
Permit No.:
Sample Pt. ID: Schuylkill Energy

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.75	su, ending	EPA SW846 METH. 1312	7/02/1997
Sulfate, Leachate	851	mg/l	EPA METH. 300 HPLC IC	7/16/1997
Nitrate, Leachate	<0.002	mg/l	EPA METH. 300 HPLC IC	7/16/1997
Chloride, Leachate	4.33	mg/l	EPA METH. 300 HPLC IC	7/16/1997
Sodium, Total, leachate	5.9	mg/l	EPA SW846 METH. 7770	7/14/1997
Acid Neutralization Potent	34.01	**	EPA 600/2-78-054	7/21/1997

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

ISO 9001:2000 REGISTERED COMPANY

HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 11/26/97

Material Tested: Fly Ash
Date Received: 10/17/1997
Date Sampled: 10/15/1997
Client ID: SER, Semi Annual Fly Ash Analysis

HawkMtn #: 9710-00243-001
Sampler Client
Sample pt. ID: SER

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	10.02	10.82	EPA SW846, METH. 9045
Aluminum	22000	4.26	SW-846 METH. 7020
Antimony	<20.0	<0.005	SW-846 METH. 7040
Arsenic	<0.5	0.010	EPA SW846 METH. 7060
Barium	180	<0.10	EPA SW846 METH. 7080
Boron	14.3	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	EPA SW846 METH. 7131
Chromium	35	0.07	EPA SW846 METH. 7191
Copper	18	<0.02	EPA SW846 METH. 7210
Iron	1200	0.08	EPA SW846 METH. 7380
Lead	10	<0.10	EPA SW846 METH. 7421
Manganese	43	0.04	EPA SW846 METH. 7460
Mercury	0.73	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	<0.1	EPA SW846 METH. 7480
Nickel	6.0	<0.04	EPA SW846 METH. 7520
Selenium	<0.5	<0.005	EPA SW846 METH. 7740
Zinc	23	<0.005	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-3011 • FAX (570) 455-6321

DER MODULE 25

SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 11/26/1997

Material Tested: Fly Ash
Date Received: 10/17/1997
Date Sampled: 10/15/1997
Client ID: SER, Semi Annual Fly Ash Analysis

Hawk Mtn ID: 9710-00243-001
Permit No.:
Sample Pt. ID: SER

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.89	su, ending	EPA SW846 METH. 1312	10/27/199
Sulfate, Leachate	686	mg/l	EPA METH. 300 HPLC IC	10/30/199
Nitrate, Leachate	0.04	mg/l	EPA METH. 300 HPLC IC	10/30/199
Chloride, Leachate	5.24	mg/l	EPA METH. 300 HPLC IC	10/30/199
Sodium, Total, leachate	17.0	mg/l	EPA SW846 METH. 7770	11/10/199
Acid Neutralization Potent	29.8	**	EPA 600/2-78-054	11/03/199

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

HAWKMTN
LABS INC

201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 7/17/98

Material Tested: Fly Ash
Date Received: 6/03/1998
Date Sampled: 6/02/1998
Client ID: Reading Anthracite Semi Annual Fly Ash Analysis

HawkMtn #: 9806-00072-001
Sampler Client
Sample pt. ID: Reading

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	10.16	10.40	EPA SW846 METH. 9045
Aluminum	26700	0.96	SW-846 METH. 7020
Antimony	<20.0	<0.001	SW-846 METH. 7040
Arsenic	19.5	0.035	EPA SW846 METH. 7060
Barium	290	0.24	EPA SW846 METH. 7080
Boron	40	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	EPA SW846 METH. 7131
Chromium	57	0.13	EPA SW846 METH. 7191
Copper	26	0.02	EPA SW846 METH. 7210
Iron	23800	0.09	EPA SW846 METH. 7380
Lead	<10.0	<0.10	EPA SW846 METH. 7421
Manganese	65	0.01	EPA SW846 METH. 7460
Mercury	0.61	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	0.15	EPA SW846 METH. 7480
Nickel	9.4	<0.04	EPA SW846 METH. 7520
Selenium	<0.5	<0.005	EPA SW846 METH. 7740
Zinc	25	0.06	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DER MODULE 25
SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 7/17/1998

Material Tested: Fly Ash
Date Received: 6/03/1998
Date Sampled: 6/02/1998
Client ID: Reading Anthracite Semi Annual Fly Ash Analysis

Hawk Mtn ID: 9806-00072-001
Permit No.:
Sample Pt. ID: Reading

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.63	su, ending	EPA SW846 METH. 1312	6/05/1998
Sulfate, Leachate	646.0	mg/l	EPA METH. 300 HPLC IC	6/29/1998
Nitrate, Leachate	<0.002	mg/l	EPA METH. 300 HPLC IC	6/29/1998
Chloride, Leachate	<0.02	mg/l	EPA METH. 300 HPLC IC	6/29/1998
Sodium, Total, leachate	5.90	mg/l	EPA SW846 METH. 7770	6/10/1998
Acid Neutralization Potent	13.3	**	EPA 600/2-78-054	6/17/1998

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 12/03/98

Material Tested: Fly Ash
Date Received: 10/28/1998
Date Sampled: 10/28/1998
Client ID: SER, Semi Annual Fly Ash Analysis

HawkMtn #: 9810-00265-001
Sampler Client
Sample pt. ID: SER

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	9.64	10.13	EPA SW846 METH. 9045
Aluminum	27900	1.72	SW-846 METH. 7020
Antimony	<20.0	<0.010	SW-846 METH. 7040
Arsenic	13.4	0.014	EPA SW846 METH. 7060
Barium	287	0.24	EPA SW846 METH. 7080
Boron	<10.0	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	0.010	EPA SW846 METH. 7131
Chromium	47	0.08	EPA SW846 METH. 7191
Copper	48	0.02	EPA SW846 METH. 7210
Iron	24500	<0.03	EPA SW846 METH. 7380
Lead	45	0.12	EPA SW846 METH. 7421
Manganese	62	0.03	EPA SW846 METH. 7460
Mercury	<0.02	<0.0002	EPA SW846 METH. 7471
Molybdenum	13	0.15	EPA SW846 METH. 7480
Nickel	15	0.04	EPA SW846 METH. 7520
Selenium	<0.5	0.077	EPA SW846 METH. 7740
Zinc	23.0	<0.005	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

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HAWK MTN
L A B S I N C
201 West Clay Avenue / West Hazleton, PA 18202
DER MODULE 25 PHONE (570) 455-6011 • FAX (570) 455-6321

PAGE NO.

SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 12/03/1998

Material Tested: Fly Ash
Date Received: 10/28/1998
Date Sampled: 10/28/1998
Client ID: SER, Semi Annual Fly Ash Analysis

Hawk Mtn ID: 9810-00265-001
Permit No.:
Sample Pt. ID: SER

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.42	su, ending	EPA SW846 METH. 1312	10/29/199
Sulfate, Leachate	360.0	mg/l	EPA METH. 300 HPLC IC	11/02/199
Nitrate, Leachate	<0.002	mg/l	EPA METH. 300 HPLC IC	11/02/199
Chloride, Leachate	4.47	mg/l	EPA METH. 300 HPLC IC	11/02/19°
Sodium, Total, leachate	4.80	mg/l	EPA SW846 METH. 7770	11/12/199
Acid Neutralization Potent	21.0	**	EPA 600/2-78-054	11/09/199

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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HAWK MTN
LABS INC

201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 7/08/99

Material Tested: Fly Ash
Date Received: 6/10/1999
Date Sampled: 6/09/1999
Client ID: Semi Annual Fly Ash Analysis, Reading, SER Ash

HawkMtn #: 9906-00161-001
Sampler Client
Sample pt. ID: SER Ash

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	9.42	9.24	EPA SW846 METH. 9045
Aluminum	27300	1.48	SW-846 METH. 7020
Antimony	<20.0	0.01	SW-846 METH. 7040
Arsenic	1.1	0.020	EPA SW846 METH. 7060
Barium	178	<0.10	EPA SW846 METH. 7080
Boron	22.6	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	EPA SW846 METH. 7131
Chromium	11	0.09	EPA SW846 METH. 7191
Copper	153	<0.02	EPA SW846 METH. 7210
Iron	10600	0.03	EPA SW846 METH. 7380
Lead	23	<0.10	EPA SW846 METH. 7421
Manganese	54.6	<0.01	EPA SW846 METH. 7460
Mercury	<0.02	<0.0002	EPA SW846 METH. 7471
Molybdenum	21	0.10	EPA SW846 METH. 7480
Nickel	<4.0	<0.04	EPA SW846 METH. 7250
Selenium	<0.5	<0.005	EPA SW846 METH. 7740
Zinc	19.2	<0.005	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

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PHONE (570) 455-6011 • FAX (570) 455-6321

DER MODULE 25
SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 7/08/1999

Material Tested: Fly Ash
Date Received: 6/10/1999
Date Sampled: 6/09/1999
Client ID: Semi Annual Fly Ash Analysis, Reading, SER Ash

Hawk Mtn ID: 9906-00161-001
Permit No.:
Sample Pt. ID: SER Ash

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	9.56	su, ending	EPA SW846 METH. 1312	6/21/1999
Sulfate, Leachate	255.0	mg/l	EPA METH. 300 HPLC IC	6/28/1999
Nitrate, Leachate	<0.002	mg/l	EPA METH. 300 HPLC IC	6/28/1999
Chloride, Leachate	8.88	mg/l	EPA METH. 300 HPLC IC	6/28/1999
Sodium, Total, leachate	1.97	mg/l	EPA SW846 METH. 7770	6/24/1999
Acid Neutralization Potent	17.8	**	EPA 600/2-78-054	7/02/1999

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 2/10/00

Material Tested: Fly Ash
Date Received: 11/30/1999
Date Sampled: 11/30/1999
Client ID: Reading Anthracite, Semi Annual Fly Ash Analysis

HawkMtn #: 9912-00016-001
Sampler Client
Sample pt. ID: SER Ash

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	10.22	8.83	EPA SW846 METH. 9045
Aluminum	13000	2.85	SW-846 METH. 7020
Antimony	<20.0	0.30	SW-846 METH. 7040
Arsenic	6.9	0.053	EPA SW846 METH. 7060
Barium	121.0	<0.10	EPA SW846 METH. 7080
Boron	<10.0	0.22	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	EPA SW846 METH. 7131
Chromium	16.0	0.069	EPA SW846 METH. 7191
Copper	9.60	0.032	EPA SW846 METH. 7210
Iron	8360	0.12	EPA SW846 METH. 7380
Lead	<L10.0	<0.10	EPA SW846 METH. 7421
Manganese	50.0	0.02	EPA SW846 METH. 7460
Mercury	0.41	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	0.45	EPA SW846 METH. 7480
Nickel	38.0	0.119	EPA SW846 METH. 7250
Selenium	<0.5	0.014	EPA SW846 METH. 7740
Zinc	8.07	<0.005	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

HAWK MTN
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DER MODULE 25
SEMI-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 2/10/2000

Material Tested: Fly Ash
Date Received: 11/30/1999
Date Sampled: 11/30/1999
Client ID: Reading Anthracite, Semi Annual Fly Ash Analysis

Hawk Mtn ID: 9912-00016-001
Permit No.:
Sample Pt. ID: SER Ash

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	9.53	su, ending	EPA SW846 METH. 1312	2/01/2000
Sulfate, Leachate	252.0	mg/l	EPA METH. 300 HPLC IC	2/04/2000
Nitrate, Leachate	0.27	mg/l	EPA METH. 300 HPLC IC	2/04/2000
Chloride, Leachate	1.75	mg/l	EPA METH. 300 HPLC IC	2/04/2000
Sodium, Leachate	2.92	mg/l	EPA SW846 METH. 7770	2/04/2000
Acid Neutralization Potent	20.8	**	EPA 600/2-78-054	2/08/2000

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 6/01/00

Material Tested: Fly Ash
Date Received: 4/13/2000
Date Sampled: 4/13/2000
Client ID: SER Semi Annual Fly Ash Analysis

HawkMtn #: 0004-00263-001
Sampler Client
Sample pt. ID: SER

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	11.91	11.62	EPA SW846 METH. 9045
Aluminum	25400	0.90	SW-846 METH. 7020
Antimony	<20.0	<0.010	SW-846 METH. 7040
Arsenic	11.2	<0.005	EPA SW846 METH. 7060
Barium	242	0.13	EPA SW846 METH. 7080
Boron	<10.0	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	1.3	0.021	EPA SW846 METH. 7131
Chromium	36	0.08	EPA SW846 METH. 7191
Copper	23.9	0.03	EPA SW846 METH. 7210
Iron	18800	0.24	EPA SW846 METH. 7380
Lead	12	<0.10	EPA SW846 METH. 7421
Manganese	53	0.01	EPA SW846 METH. 7460
Mercury	0.105	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	0.10	EPA SW846 METH. 7480
Nickel	28	0.05	EPA SW846 METH. 7250
Selenium	1.5	<0.005	EPA SW846 METH. 7740
Zinc	15.5	0.019	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

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DER MODULE 25
SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 6/01/2000

Material Tested: Fly Ash
Date Received: 4/13/2000
Date Sampled: 4/13/2000
Client ID: SER Semi Annual Fly Ash Analysis

Hawk Mtn ID: 0004-00263-001
Permit No.:
Sample Pt. ID: SER

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	11.72	su, ending	EPA SW846 METH. 1312	4/26/2000
Sulfate, Leachate	423.0	mg/l	EPA METH. 300 HPLC IC	5/02/2000
Nitrate, Leachate	0.00	mg/l	EPA METH. 300 HPLC IC	5/02/2000
Chloride, Leachate	0.00	mg/l	EPA METH. 300 HPLC IC	5/02/2000
Sodium, Leachate	3.82	mg/l	EPA SW846 METH. 7770	5/12/2000
Acid Neutralization Potent	12.03	**	EPA 600/2-78-054	5/02/2000

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
PO Box 1200
Pottsville, PA 17901

Report Date: 12/28/00

Material Tested: Fly Ash
Date Received: 11/13/2000
Date Sampled: 11/10/2000
Client ID: Schuylkill Energy Resources, Semi Annual Ash Analysis

HawkMtn #: 0011-00204-001
Sampler Client
Sample pt. ID: SER

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	10.42	10.3	EPA SW846 METH. 9045
Aluminum	45600	1.67	SW-846 METH. 7020
Antimony	<20.0	<0.010	EPA SW846 METH. 7040
Arsenic	42.4	<0.005	EPA SW846 METH. 7060
Barium	243	<0.10	EPA SW846 METH. 7080
Boron	17.2	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	0.023	EPA SW846 METH. 7131
Chromium	27	<0.05	EPA SW846 METH. 7191
Copper	17	0.02	EPA SW846 METH. 7210
Iron	26700	<0.03	EPA SW846 METH. 7380
Lead	<10.0	<0.10	EPA SW846 METH. 7421
Manganese	84	0.07	EPA SW846 METH. 7460
Mercury	<0.02	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	<0.1	EPA SW846 METH. 7480
Nickel	25	<0.04	EPA SW846 METH. 7250
Selenium	1.2	<0.005	EPA SW846 METH. 7740
Zinc	13.5	<0.005	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

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DER MODULE 25
SEMI-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 12/28/2000

Material Tested: Fly Ash
Date Received: 11/13/2000
Date Sampled: 11/10/2000
Client ID: Schuylkill Energy Resources, Semi Annual Ash Analysis

Hawk Mtn ID: 0011-00204-001
Permit No.:
Sample Pt. ID: SER

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.70	su, ending	EPA SW846 METH. 1312	11/15/200
Sulfate, Leachate	219.0	mg/l	EPA METH. 300 HPLC IC	11/17/200
Nitrate, Leachate	<0.002	mg/l	EPA METH. 300 HPLC IC	11/17/200
Chloride, Leachate	0.55	mg/l	EPA METH. 300 HPLC IC	11/17/200
Sodium, Leachate	1.91	mg/l	EPA SW846 METH. 7770	11/29/200
Acid Neutralization Potent	41.3	**	EPA 600/2-78-054	11/15/200

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
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DEP MODULE 25
SEMI--ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
200 Mahantongo Street
Pottsville, PA 17901

Report Date: 7/16/01

Material Tested: Fly Ash
Date Received: 6/01/2001
Date Sampled: 6/01/2001
Client ID: SER Semi Annual Fly Ash Analysis

HawkMtn #: 0106-00003-001
Sampler Client
Sample pt. ID: SER

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	9.61	10.1	EPA SW846 METH. 9045
Aluminum	27700	2.21	SW-846 METH. 7020
Antimony	1.0	<0.005	SW-846 METH. 7040
Arsenic	7.9	0.023	EPA SW846 METH. 7060
Barium	205	<0.10	EPA SW846 METH. 7080
Boron	23.5	<0.2	AGR. #9, PART 2, 2ND. ED
Cadmium	<0.5	<0.005	EPA SW846 METH. 7131
Chromium	30.9	<0.05	EPA SW846 METH. 7191
Copper	23	<0.02	EPA SW846 METH. 7210
Iron	24	0.07	EPA SW846 METH. 7380
Lead	<10.0	<0.10	EPA SW846 METH. 7421
Manganese	86	<0.01	EPA SW846 METH. 7460
Mercury	0.28	<0.0002	EPA SW846 METH. 7471
Molybdenum	<10.0	<0.1	EPA SW846 METH. 7480
Nickel	14	<0.04	EPA SW846 METH. 7250
Selenium	3.3	<0.005	EPA SW846 METH. 7740
Zinc	17.8	0.008	EPA SW846 METH. 7950

* pH values are represented by Standard pH units (su)

HAWK MTN
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DER MODULE 25
SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 7/16/2001

Material Tested: Fly Ash
Date Received: 6/01/2001
Date Sampled: 6/01/2001
Client ID: SER Semi Annual Fly Ash Analysis

Hawk Mtn ID: 0106-00003-001
Permit No.:
Sample Pt. ID: SER

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	6/5/2001	su, ending	EPA SW846 METH. 1312	6/05/2001
Sulfate, Leachate	328.0	mg/l	EPA METH. 300 HPLC IC	6/05/2001
Nitrate, Leachate	0.18	mg/l	EPA METH. 300 HPLC IC	6/05/2001
Chloride, Leachate	1.22	mg/l	EPA METH. 300 HPLC IC	6/05/2001
Sodium, Leachate	4.38	mg/l	EPA SW846 METH. 7770	6/12/2001
Acid Neutralization Potent	44.3	**	EPA 600/2-78-054	6/05/2001

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
PO Box 1200
Pottsville, PA 17901

Report Date: 1/07/02

Material Tested: Fly Ash
Date Received: 11/21/2001
Date Sampled: 11/21/2001
Client ID: Reading Anthracite, Semi Annual Ash Analysis

HawkMtn #: 0111-00357-001
Sampler Client
Sample pt. ID: Reading Anthracite

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	9.65	9.99	SW846-9045
Aluminum	23400	1.58	SW846-6010B
Antimony	<3.5	<0.04	SW846-6010B
Arsenic	6.16	0.032	SW846-7060A
Barium	226	0.015	SW846-6010B
Boron	24.0	<0.2	SW846-6010B
Cadmium	1.8	<0.005	SW846-6010B
Chromium	35.1	0.008	SW846-6010B
Copper	17.9	<0.005	SW846-6010B
Iron	15200	<0.01	SW846-6010B
Lead	<5.0	<0.025	SW846-6010B
Manganese	107	0.009	SW846-6010B
Mercury	0.10	<0.0002	SW846-7471A
Molybdenum	<1.00	0.016	SW846-6010B
Nickel	8.2	<0.010	SW846-6010B
Selenium	<0.50	<0.005	SW846-7740
Zinc	16.6	0.013	SW846-6010B

* pH values are represented by Standard pH units (su)

HAWK MTN
LABS INC
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PHONE (570) 455-6011 • FAX (570) 455-6321

DER MODULE 25 PAGE No. 2

SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 1/07/2002

Material Tested: Fly Ash
Date Received: 11/21/2001
Date Sampled: 11/21/2001
Client ID: Reading Anthracite, Semi Annual Ash Analysis

Hawk Mtn ID: 0111-00357-001
Permit No.:
Sample Pt. ID: Reading Anthracite

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.2	su, ending	EPA SW846 METH. 1312	11/29/200
Sulfate, Leachate	233.0	mg/l	EPA METH. 300 HPLC IC	11/30/200
Nitrate, Leachate	0.05	mg/l	EPA METH. 300 HPLC IC	11/30/200
Chloride, Leachate	0.68	mg/l	EPA METH. 300 HPLC IC	11/30/200
Sodium, Leachate	5.25	mg/l	SW846-6010B	12/18/200
Acid Neutralization Potent	34	**	EPA 600/2-78-054	12/05/200

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

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HAWKMTN LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DEP MODULE 25
SEMI-ANNUAL MONITORING REPORT

TO: Reading Anthracite
Engineering Department
PO Box 1200
Pottsville, PA 17901

Report Date: 5/03/02

Material Tested: Fly Ash
Date Received: 4/17/2002
Date Sampled: 4/17/2002
Client ID: Semi Annual Ash Analysis, Schuylkill Energy Resources

HawkMtn #: 0204-00267-001
Sampler Client
Sample pt. ID: SCR

TEST DESCRIPTION	TEST RESULTS Dry Wt. mg/kg	Test Results Leachate mg/l	TEST METHOD
*pH	9.07	9.63	SW846-9045
Aluminum	10300	1.64	SW846-6010B
Antimony	2	<0.04	SW846-6010B
Arsenic	9.87	0.057	SW846-7060A
Barium	108	0.03	SW846-6010B
Boron	44.5	0.07	SW846-6010B
Cadmium	2	<0.005	SW846-6010B
Chromium	25	<0.005	SW846-6010B
Copper	14	<0.005	SW846-6010B
Iron	13200	0.02	SW846-6010B
Lead	18	0.05	SW846-6010B
Manganese	87	0.01	SW846-6010B
Mercury	0.15	<0.0002	SW846-7471A
Molybdenum	<1.00	<0.005	SW846-6010B
Nickel	10	<0.010	SW846-6010B
Selenium	<0.5	<0.005	SW846-7060A
Zinc	17	0.06	SW846-6010B

* pH values are represented by Standard pH units (su)

ISO 9001:2000
REGISTERED COMPANY

HAWK MTN
LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

DER MODULE 25
SEM-ANNUAL FLY ASH/ SPLP LEACHATE ANALYSIS

TO: Reading Anthracite

Report Date: 5/03/2002

Material Tested: Fly Ash
Date Received: 4/17/2002
Date Sampled: 4/17/2002
Client ID: Semi Annual Ash Analysis, Schuylkill Energy Resources

Hawk Mtn ID: 0204-00267-001
Permit No.:
Sample Pt. ID: SCR

TEST DESCRIPTION	TEST RESULT	UNITS	TEST METHOD	DATE OF ANALYSIS
SPLP Fluid #3, Water	10.18	su, ending	EPA SW846 METH. 1312	4/19/2002
Sulfate, Leachate	315.0	mg/l	EPA METH. 300 HPLC IC	4/24/2002
Nitrate, Leachate	0.25	mg/l	EPA METH. 300 HPLC IC	4/24/2002
Chloride, Leachate	1.40	mg/l	EPA METH. 300 HPLC IC	4/24/2002
Sodium, Leachate	0.53	mg/l	SW846-6010B	4/30/2002
Acid Neutralization Potent	15.3	**	EPA 600/2-78-054	4/23/2002

** Tons Calcium Carbonate equivalent/ 1000 Tons of Material

Jeffrey Gittleman, Lab Director

ISO 9001:2000
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Appendix 8.D

Chemical analyses of ash and water samples collected Febuary 2000 [MRL]

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

Wt. %	1A-1	1B-1	1C-1	2A-1	2B-1	2C-1
Moist.	25.5	27.0	27.2	26.5	24.2	23.1
LOI-1000	30.2	29.8	30.4	30.0	27.4	27.9
AgO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Al2O3	12.3	15.4	13.9	12.2	15.90	9.41
As2O3	<0.001	0.002	0.002	0.002	0.002	0.001
B2O3	0.01	0.01	0.02	0.02	0.02	0.02
BaO	0.05	0.05	0.05	0.04	0.05	0.03
BeO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
CaO	4.40	1.97	2.66	2.02	2.47	1.22
CdO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CoO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr2O3	0.01	0.01	0.01	0.01	0.01	0.01
CuO	0.01	0.01	0.01	0.01	<0.005	0.01
Fe2O3	2.30	2.83	2.58	2.91	2.28	1.35
HgO	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K2O	2.31	2.44	2.34	2.10	2.44	1.41
MgO	0.54	0.50	0.52	0.36	0.51	0.28
MnO	0.02	0.02	0.02	0.02	0.01	0.01
MoO3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Na2O	0.29	0.28	0.27	0.24	0.30	0.20
NiO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
PbO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb2O3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SeO2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SiO2	46	44	46	47	46	55
SrO	0.03	0.01	0.02	0.02	0.02	0.01
TiO2	0.82	0.93	0.95	0.90	0.96	1.88
Tl2O	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V2O5	0.01	0.01	0.01	0.02	0.01	0.01
ZnO	0.01	0.01	0.01	0.01	0.01	<0.005
F	0.008	0.006	0.007	0.008	0.008	0.008
Cl	0.019	0.003	0.007	0.011	0.011	0.008
NO2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Br	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NO3	0.001	<0.001	0.001	<0.001	<0.001	<0.001
PO4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO3	1.02	1.53	0.97	0.98	0.84	0.87
TOTAL	100.4	99.8	100.8	98.9	99.3	99.6

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

Wt. %	3A-1	3B-1	3C-1	4A-1	4B-1	4C-1
Moist.	21.3	23.5	24.1	24.4	22.6	26.7
LOI-1000	23.8	26.2	26.2	27.3	25.8	31.8
AgO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Al2O3	13.5	13.2	13.7	11.7	11.2	11.1
As2O3	0.002	0.00	0.002	0.002	0.001	0.002
B2O3	0.02	0.02	0.02	0.02	0.01	0.02
BaO	0.04	0.05	0.04	0.04	0.04	0.05
BeO	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
CaO	0.82	1.60	1.51	0.65	2.37	3.23
CdO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CoO	0.01	<0.005	<0.005	0.01	0.01	0.03
Cr2O3	0.01	0.01	0.01	0.01	0.01	0.02
CuO	0.01	0.01	0.01	0.01	0.01	0.01
Fe2O3	2.67	2.32	2.89	2.62	2.50	2.30
HgO	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K2O	2.62	2.21	2.21	2.15	2.12	2.40
MgO	0.34	0.36	0.33	0.24	0.30	0.29
MnO	0.02	0.02	0.01	0.01	0.02	0.02
MoO3	<0.005	<0.005	<0.005	<0.005	0.01	0.01
Na2O	0.28	0.26	0.27	0.28	0.25	0.27
NiO	0.01	<0.005	<0.005	<0.005	0.01	0.01
PbO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb2O3	0.002	0.002	0.002	0.002	<0.001	<0.001
SeO2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SiO2	52	52	51	52	52	47
SrO	0.01	0.01	0.01	0.01	0.01	0.02
TiO2	1.02	1.06	0.94	1.01	0.92	0.92
Tl2O	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V2O5	0.02	0.02	0.01	0.02	0.02	0.03
ZnO	0.01	0.01	0.01	0.01	0.01	0.01
F	0.007	0.009	0.005	0.004	0.007	0.007
Cl	0.001	0.004	0.002	0.003	0.005	0.011
NO2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Br	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NO3	0.002	0.001	0.002	<0.001	<0.001	<0.001
PO4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO3	0.71	0.93	0.98	0.72	1.01	1.04
	97.9	100.3	100.2	98.8	98.6	100.6

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

mg/L	Blank-HCl	Cell-1A	Cell-1B	Cell-1C	Cell-2A	Cell-2B	Cell-2C
Temp.C		7.7	17.4	16.3	16.7	12.5	18.3
pH		12.40	11.79	12.14	12.80	13.10	12.80
Ag	<0.02	0.04	<0.02	<0.02	0.09	0.06	0.05
Al	0.18	0.85	1.10	1.04	1.50	1.42	1.35
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
B	<0.02	0.22	0.24	0.22	0.27	0.26	0.26
Ba	<0.02	0.24	0.31	0.44	0.31	0.33	0.30
Be	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ca	0.14	1050	810	980	1220	1210	1300
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	<0.02	<0.02	0.02	<0.02	0.03	0.02	<0.02
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Hg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
K	0.04	1950	410	750	1160	1210	1390
Mg	<0.02	0.05	0.07	0.06	0.06	0.07	0.06
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Na	0.02	300	130	175	215	220	330
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb	<0.005	0.01	0.01	0.01	0.01	0.01	0.01
Sb	<0.005	0.01	0.01	<0.005	0.01	0.01	0.01
Se	<0.005	0.01	0.02	0.02	0.01	0.02	0.02
Si	0.13	4.3	5.8	4.9	5.9	5.9	4.2
Sr	<0.02	22.1	5.0	10.6	13.4	14.1	16.9
Ti	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	<0.005	6.3	4.3	4.8	5.9	4.7	5.9
Cl	0.1	230	70	115	150	155	175
NO2	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Br	<0.01	12.6	2.7	5.6	7.7	8.3	9.6
NO3	0.02	21.5	21.9	24.0	20.5	19.8	19.2
PO4	<0.01	0.2	0.3	0.2	0.3	0.2	0.3
SO4	0.12	2930	1600	2040	2890	2850	3100

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

mg/L	Cell-3A	Cell-3B	Cell-3C	Cell-4A	Cell-4B	Cell-4C
Temp.	15.3	17.0	15.5	18.0	19.0	15.5
pH	12.61	12.52	12.69	12.51	12.44	12.94
Ag	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Al	0.93	0.97	0.45	0.44	0.74	0.88
As	<0.005	<0.005	0.02	0.05	<0.005	<0.005
B	0.26	0.26	0.19	0.22	0.23	0.20
Ba	0.38	0.26	0.32	0.25	0.32	0.46
Be	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ca	770	760	830	760	800	1120
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Hg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
K	490	350	410	295	350	1060
Mg	0.14	0.10	0.07	0.07	0.08	0.05
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Na	125	125	120	110	115	255
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb	0.01	0.01	0.01	0.01	0.01	0.01
Sb	0.01	0.01	0.01	0.01	0.01	<0.005
Se	0.02	0.02	0.02	0.02	0.02	0.01
Si	6.7	8.2	5.8	4.4	6.0	5.5
Sr	6.1	5.1	5.8	4.0	5.5	14.3
Ti	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	3.9	3.1	4.4	4.2	3.8	5.1
Cl	80	60	69	52	62	125
NO2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Br	3.5	2.6	3.2	2.3	2.9	8.1
NO3	32	22.3	31	22.1	21.5	24.3
PO4	0.3	0.2	0.2	0.2	0.2	0.2
SO4	1640	1400	1530	1350	1470	2460

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

mg/L	1A-S	1B-S	1C-S	2A-S	2B-S	2C-S
Ag	<0.02	0.06	<0.02	<0.02	<0.02	<0.02
Al	2.75	1.57	1.97	1.68	2.33	1.76
As	<0.005	0.01	0.01	0.01	<0.005	<0.005
B	0.03	<0.02	<0.02	0.03	<0.02	0.03
Ba	0.03	0.02	0.02	0.03	0.02	0.03
Be	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ca	64	110	85	90	75	110
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	<0.02	<0.02	<0.02	<0.02	0.03	<0.02
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	0.03
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe	0.02	<0.02	<0.02	0.02	<0.02	<0.02
Hg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
K	80.0	16.1	24.4	31	44	35
Mg	0.03	0.11	0.08	0.08	0.05	0.07
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	0.02	0.02	<0.02	0.02	<0.02	0.03
Na	11.6	5.0	6.0	6.2	7.6	6.6
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb	0.01	0.01	0.01	0.01	0.01	0.01
Sb	<0.005	0.01	0.01	0.01	0.01	0.01
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	6.3	7.6	7.0	6.9	6.4	6.7
Sr	0.85	0.97	0.79	0.90	0.81	0.87
Ti	0.04	0.1	0.02	0.06	0.06	0.07
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	0.52	0.47	0.5	0.51	0.54	0.50
Cl	9.0	1.45	3.30	3.51	5.6	3.76
NO2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Br	0.53	0.04	0.14	0.16	0.25	0.17
NO3	0.05	0.03	0.04	0.03	0.04	0.04
PO4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SO4	140	61	155	170	145	170

Date: March 8, 2000
To: Caroline Loop
From: Scott D. Atkinson
Subj: Spectrochemical Analysis

mg/L	3A-S	3B-S	3C-S	4A-S	4B-S	4C-S
Ag	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Al	1.52	0.89	1.49	2.21	2.55	1.94
As	0.01	<0.005	0.01	0.01	<0.005	<0.005
B	<0.02	<0.02	0.03	<0.02	0.03	0.05
Ba	<0.02	0.04	0.02	<0.02	0.03	0.05
Be	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ca	110	155	135	110	110	110
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	<0.02	<0.02	<0.02	<0.02	0.06	0.04
Cr	<0.02	<0.02	0.03	0.02	0.04	0.02
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe	0.03	0.03	0.03	<0.02	0.04	0.02
Hg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
K	6.6	17.7	9.6	12.6	25.3	43
Mg	0.18	0.06	0.15	0.11	0.08	0.13
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	0.04	0.05	0.06	0.03	0.05	0.05
Na	2.87	4.3	3.34	3.29	5.1	7.3
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb	0.01	0.01	0.01	0.01	0.01	0.01
Sb	0.01	<0.005	0.01	0.01	0.01	0.01
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	6.6	11.9	5.8	5.5	6.9	7.1
Sr	0.48	0.88	0.74	0.60	0.77	1.03
Ti	0.06	0.05	0.09	0.05	0.09	0.08
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	0.02	<0.02	0.03	0.02	0.05	0.02
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	0.48	0.49	0.40	0.47	0.49	0.56
Cl	0.28	0.55	0.51	0.96	2.31	5.1
NO2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Br	<0.01	0.08	0.02	0.05	0.11	0.26
NO3	0.12	0.05	0.05	0.06	0.05	0.05
PO4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SO4	185	195	270	205	165	165

Appendix 8.E

PHREEQC thermodynamic equilibrium results from water analyses in the test cells

```
------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      PHASES
      EXCHANGE_MASTER_SPECIES
      EXCHANGE_SPECIES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-------------------------------------
Reading input data for simulation 1.
-------------------------------------

      SOLUTION 1 Cell 1B
            temp  17.4
            pH    11.79
            pe    4.0
            redox pe
            units mg/l
            density     1.0
            Al    1.10
            B     0.24
            Ba    0.31
            Br    2.7
            C(4)  1279  charge
            Ca    810
            Cl    70
            Cu    0.02
            F     4.3
            K     410
            Mg    0.07
            N(5)  21.9
            Na    130
            P     .000000316  Mol/l
            Pb    0.01
            S(6)  1600
            Si    5.8
            Sr    5.0
-----------------------------------------
Beginning of initial solution calculations.
-----------------------------------------

Initial solution 1.     Cell 1B

-----------------------------Solution composition------------------------------

      Elements            Molality       Moles

      Al                  4.095e-05   4.095e-05
      B                   2.230e-05   2.230e-05
      Ba                  2.267e-06   2.267e-06
      Br                  3.394e-05   3.394e-05
      C(4)                7.352e-03   7.352e-03  Charge balance
      Ca                  2.030e-02   2.030e-02
```

Cl	1.983e-03	1.983e-03
Cu	3.161e-07	3.161e-07
F	2.273e-04	2.273e-04
K	1.053e-02	1.053e-02
Mg	2.892e-06	2.892e-06
N(5)	1.570e-03	1.570e-03
Na	5.679e-03	5.679e-03
P	3.174e-07	3.174e-07
Pb	4.848e-08	4.848e-08
S(6)	1.673e-02	1.673e-02
Si	9.695e-05	9.695e-05
Sr	5.731e-05	5.731e-05

----------Description of solution----------

pH	=	11.790
pe	=	4.000
Activity of water	=	0.999
Ionic strength	=	5.988e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	1.978e-02
Total CO2 (mol/kg)	=	7.352e-03
Temperature (deg C)	=	17.400
Electrical balance (eq)	=	-5.950e-16
Iterations	=	9
Total H	=	1.110178e+02
Total O	=	5.560535e+01

----------Distribution of species----------

	Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
	OH-	4.229e-03	3.389e-03	-2.374	-2.470	-0.096
	H+	1.912e-12	1.622e-12	-11.718	-11.790	-0.072
	H2O	5.551e+01	9.990e-01	0.000	0.000	0.000
Al		4.095e-05				
	Al(OH)4-	4.095e-05	3.329e-05	-4.388	-4.478	-0.090
	Al(OH)3	3.084e-11	3.127e-11	-10.511	-10.505	0.006
	Al(OH)2+	7.636e-16	6.209e-16	-15.117	-15.207	-0.090
	AlOH+2	5.892e-22	2.575e-22	-21.230	-21.589	-0.359
	AlF3	2.150e-23	2.180e-23	-22.668	-22.662	0.006
	AlF2+	1.219e-23	9.909e-24	-22.914	-23.004	-0.090
	AlF4-	1.876e-24	1.525e-24	-23.727	-23.817	-0.090
	AlF+2	2.675e-25	1.169e-25	-24.573	-24.932	-0.359
	AlF5-2	9.897e-27	4.326e-27	-26.005	-26.364	-0.359
	AlSO4+	1.287e-27	1.047e-27	-26.890	-26.980	-0.090
	Al+3	3.064e-28	6.957e-29	-27.514	-28.158	-0.644
	Al(SO4)2-	2.066e-28	1.680e-28	-27.685	-27.775	-0.090
	AlF6-3	5.726e-30	8.895e-31	-29.242	-30.051	-0.809
	AlHSO4+2	3.244e-40	1.418e-40	-39.489	-39.848	-0.359
B		2.230e-05				
	H2BO3-	2.224e-05	1.808e-05	-4.653	-4.743	-0.090
	H3BO3	5.796e-08	5.876e-08	-7.237	-7.231	0.006
	BF(OH)3-	4.670e-12	3.797e-12	-11.331	-11.421	-0.090
	BF2(OH)2-	1.445e-19	1.175e-19	-18.840	-18.930	-0.090
	BF3OH-	5.226e-29	4.249e-29	-28.282	-28.372	-0.090

	BF4-	6.149e-38	5.000e-38	-37.211	-37.301	-0.090
Ba		2.267e-06				
	BaSO4	1.127e-06	1.142e-06	-5.948	-5.942	0.006
	Ba+2	9.730e-07	4.330e-07	-6.012	-6.364	-0.352
	BaCO3	1.562e-07	1.583e-07	-6.806	-6.800	0.006
	BaOH+	1.112e-08	9.038e-09	-7.954	-8.044	-0.090
	BaHCO3+	1.357e-10	1.103e-10	-9.867	-9.957	-0.090
Br		3.394e-05				
	Br-	3.394e-05	2.700e-05	-4.469	-4.569	-0.099
C(4)		7.352e-03				
	CaCO3	5.425e-03	5.501e-03	-2.266	-2.260	0.006
	CO3-2	1.820e-03	8.245e-04	-2.740	-3.084	-0.344
	NaCO3-	5.678e-05	4.617e-05	-4.246	-4.336	-0.090
	HCO3-	4.115e-05	3.376e-05	-4.386	-4.472	-0.086
	SrCO3	6.675e-06	6.768e-06	-5.176	-5.170	0.006
	CaHCO3+	2.072e-06	1.700e-06	-5.684	-5.770	-0.086
	MgCO3	3.843e-07	3.896e-07	-6.415	-6.409	0.006
	BaCO3	1.562e-07	1.583e-07	-6.806	-6.800	0.006
	NaHCO3	8.345e-08	8.461e-08	-7.079	-7.073	0.006
	SrHCO3+	7.810e-09	6.408e-09	-8.107	-8.193	-0.086
	MgHCO3+	2.630e-10	2.139e-10	-9.580	-9.670	-0.090
	CO2	1.359e-10	1.377e-10	-9.867	-9.861	0.006
	BaHCO3+	1.357e-10	1.103e-10	-9.867	-9.957	-0.090
	Pb(CO3)2-2	3.513e-11	1.535e-11	-10.454	-10.814	-0.359
	PbCO3	7.312e-12	7.413e-12	-11.136	-11.130	0.006
	PbHCO3+	1.707e-17	1.388e-17	-16.768	-16.858	-0.090
Ca		2.030e-02				
	Ca+2	9.937e-03	4.524e-03	-2.003	-2.344	-0.342
	CaCO3	5.425e-03	5.501e-03	-2.266	-2.260	0.006
	CaSO4	4.357e-03	4.417e-03	-2.361	-2.355	0.006
	CaOH+	5.688e-04	4.625e-04	-3.245	-3.335	-0.090
	CaF+	7.115e-06	5.785e-06	-5.148	-5.238	-0.090
	CaHCO3+	2.072e-06	1.700e-06	-5.684	-5.770	-0.086
	CaPO4-	3.167e-07	2.575e-07	-6.499	-6.589	-0.090
	CaHPO4	2.017e-10	2.045e-10	-9.695	-9.689	0.006
	CaHSO4+	4.728e-14	3.845e-14	-13.325	-13.415	-0.090
	CaH2PO4+	3.189e-16	2.593e-16	-15.496	-15.586	-0.090
Cl		1.983e-03				
	Cl-	1.983e-03	1.593e-03	-2.703	-2.798	-0.095
	PbCl+	3.325e-17	2.704e-17	-16.478	-16.568	-0.090
	PbCl2	7.786e-20	7.894e-20	-19.109	-19.103	0.006
	PbCl3-	1.170e-22	9.516e-23	-21.932	-22.022	-0.090
	PbCl4-2	1.563e-25	6.831e-26	-24.806	-25.166	-0.359
Cu(1)		2.364e-18				
	Cu+	2.364e-18	1.867e-18	-17.626	-17.729	-0.103
Cu(2)		3.161e-07				
	Cu(OH)2	2.991e-07	3.032e-07	-6.524	-6.518	0.006
	Cu(OH)3-	1.384e-08	1.126e-08	-7.859	-7.949	-0.090
	Cu(OH)4-2	3.165e-09	1.383e-09	-8.500	-8.859	-0.359
	CuOH+	2.921e-13	2.356e-13	-12.535	-12.628	-0.093
	Cu+2	8.228e-17	3.825e-17	-16.085	-16.417	-0.333
	CuSO4	3.842e-17	3.895e-17	-16.415	-16.409	0.006
F		2.273e-04				
	F-	2.198e-04	1.761e-04	-3.658	-3.754	-0.096
	CaF+	7.115e-06	5.785e-06	-5.148	-5.238	-0.090
	NaF	4.454e-07	4.516e-07	-6.351	-6.345	0.006
	MgF+	6.914e-09	5.622e-09	-8.160	-8.250	-0.090

	BF(OH)3-	4.670e-12	3.797e-12	-11.331	-11.421	-0.090
	HF	3.693e-13	3.744e-13	-12.433	-12.427	0.006
	HF2-	2.912e-16	2.368e-16	-15.536	-15.626	-0.090
	BF2(OH)2-	1.445e-19	1.175e-19	-18.840	-18.930	-0.090
	AlF3	2.150e-23	2.180e-23	-22.668	-22.662	0.006
	AlF2+	1.219e-23	9.909e-24	-22.914	-23.004	-0.090
	AlF4-	1.876e-24	1.525e-24	-23.727	-23.817	-0.090
	AlF+2	2.675e-25	1.169e-25	-24.573	-24.932	-0.359
	AlF5-2	9.897e-27	4.326e-27	-26.005	-26.364	-0.359
	BF3OH-	5.226e-29	4.249e-29	-28.282	-28.372	-0.090
	AlF6-3	5.726e-30	8.895e-31	-29.242	-30.051	-0.809
	BF4-	6.149e-38	5.000e-38	-37.211	-37.301	-0.090
	SiF6-2	0.000e+00	0.000e+00	-44.798	-45.158	-0.359
H(0)		3.970e-35				
	H2	1.985e-35	2.012e-35	-34.702	-34.696	0.006
K		1.053e-02				
	K+	1.019e-02	8.182e-03	-1.992	-2.087	-0.095
	KSO4-	3.248e-04	2.641e-04	-3.488	-3.578	-0.090
	KOH	1.724e-05	1.748e-05	-4.764	-4.758	0.006
	KHPO4-	1.871e-12	1.522e-12	-11.728	-11.818	-0.090
Mg		2.892e-06				
	Mg+2	1.189e-06	5.565e-07	-5.925	-6.255	-0.330
	MgOH+	7.569e-07	6.154e-07	-6.121	-6.211	-0.090
	MgSO4	5.540e-07	5.617e-07	-6.257	-6.251	0.006
	MgCO3	3.843e-07	3.896e-07	-6.415	-6.409	0.006
	MgF+	6.914e-09	5.622e-09	-8.160	-8.250	-0.090
	MgHCO3+	2.630e-10	2.139e-10	-9.580	-9.670	-0.090
	MgPO4-	5.256e-11	4.273e-11	-10.279	-10.369	-0.090
	MgHPO4	3.355e-14	3.401e-14	-13.474	-13.468	0.006
	MgH2PO4+	4.995e-20	4.062e-20	-19.301	-19.391	-0.090
N(5)		1.570e-03				
	NO3-	1.570e-03	1.250e-03	-2.804	-2.903	-0.099
	PbNO3+	1.176e-17	9.563e-18	-16.930	-17.019	-0.090
Na		5.679e-03				
	Na+	5.467e-03	4.456e-03	-2.262	-2.351	-0.089
	NaSO4-	1.376e-04	1.119e-04	-3.861	-3.951	-0.090
	NaCO3-	5.678e-05	4.617e-05	-4.246	-4.336	-0.090
	NaOH	1.789e-05	1.814e-05	-4.747	-4.741	0.006
	NaF	4.454e-07	4.516e-07	-6.351	-6.345	0.006
	NaHCO3	8.345e-08	8.461e-08	-7.079	-7.073	0.006
	NaHPO4-	1.019e-12	8.287e-13	-11.992	-12.082	-0.090
O(0)		6.164e-26				
	O2	3.082e-26	3.125e-26	-25.511	-25.505	0.006
P		3.174e-07				
	CaPO4-	3.167e-07	2.575e-07	-6.499	-6.589	-0.090
	HPO4-2	2.251e-10	9.538e-11	-9.648	-10.021	-0.373
	CaHPO4	2.017e-10	2.045e-10	-9.695	-9.689	0.006
	PO4-3	1.566e-10	2.269e-11	-9.805	-10.644	-0.839
	MgPO4-	5.256e-11	4.273e-11	-10.279	-10.369	-0.090
	KHPO4-	1.871e-12	1.522e-12	-11.728	-11.818	-0.090
	NaHPO4-	1.019e-12	8.287e-13	-11.992	-12.082	-0.090
	MgHPO4	3.355e-14	3.401e-14	-13.474	-13.468	0.006
	H2PO4-	3.206e-15	2.603e-15	-14.494	-14.585	-0.090
	CaH2PO4+	3.189e-16	2.593e-16	-15.496	-15.586	-0.090
	MgH2PO4+	4.995e-20	4.062e-20	-19.301	-19.391	-0.090
Pb		4.848e-08				
	Pb(OH)4-2	3.400e-08	1.486e-08	-7.468	-7.828	-0.359

	Pb(OH)3-	1.295e-08	1.053e-08	-7.888	-7.977	-0.090
	Pb(OH)2	1.469e-09	1.489e-09	-8.833	-8.827	0.006
	Pb(CO3)2-2	3.513e-11	1.535e-11	-10.454	-10.814	-0.359
	PbOH+	7.643e-12	6.214e-12	-11.117	-11.207	-0.090
	PbCO3	7.312e-12	7.413e-12	-11.136	-11.130	0.006
	PbSO4	1.510e-15	1.531e-15	-14.821	-14.815	0.006
	Pb+2	1.184e-15	5.174e-16	-14.927	-15.286	-0.359
	Pb(SO4)2-2	9.677e-17	4.230e-17	-16.014	-16.374	-0.359
	PbCl+	3.325e-17	2.704e-17	-16.478	-16.568	-0.090
	PbHCO3+	1.707e-17	1.388e-17	-16.768	-16.858	-0.090
	PbNO3+	1.176e-17	9.563e-18	-16.930	-17.019	-0.090
	PbCl2	7.786e-20	7.894e-20	-19.109	-19.103	0.006
	PbCl3-	1.170e-22	9.516e-23	-21.932	-22.022	-0.090
	Pb2OH+3	4.634e-25	7.198e-26	-24.334	-25.143	-0.809
	PbCl4-2	1.563e-25	6.831e-26	-24.806	-25.166	-0.359
S(6)		1.673e-02				
	SO4-2	1.189e-02	5.263e-03	-1.925	-2.279	-0.354
	CaSO4	4.357e-03	4.417e-03	-2.361	-2.355	0.006
	KSO4-	3.248e-04	2.641e-04	-3.488	-3.578	-0.090
	NaSO4-	1.376e-04	1.119e-04	-3.861	-3.951	-0.090
	SrSO4	1.486e-05	1.507e-05	-4.828	-4.822	0.006
	BaSO4	1.127e-06	1.142e-06	-5.948	-5.942	0.006
	MgSO4	5.540e-07	5.617e-07	-6.257	-6.251	0.006
	HSO4-	8.693e-13	7.068e-13	-12.061	-12.151	-0.090
	CaHSO4+	4.728e-14	3.845e-14	-13.325	-13.415	-0.090
	PbSO4	1.510e-15	1.531e-15	-14.821	-14.815	0.006
	Pb(SO4)2-2	9.677e-17	4.230e-17	-16.014	-16.374	-0.359
	CuSO4	3.842e-17	3.895e-17	-16.415	-16.409	0.006
	AlSO4+	1.287e-27	1.047e-27	-26.890	-26.980	-0.090
	Al(SO4)2-	2.066e-28	1.680e-28	-27.685	-27.775	-0.090
	AlHSO4+2	3.244e-40	1.418e-40	-39.489	-39.848	-0.359
Si		9.695e-05				
	H3SiO4-	9.163e-05	7.450e-05	-4.038	-4.128	-0.090
	H2SiO4-2	4.259e-06	1.862e-06	-5.371	-5.730	-0.359
	H4SiO4	1.067e-06	1.082e-06	-5.972	-5.966	0.006
	SiF6-2	0.000e+00	0.000e+00	-44.798	-45.158	-0.359
Sr		5.731e-05				
	Sr+2	3.515e-05	1.609e-05	-4.454	-4.793	-0.339
	SrSO4	1.486e-05	1.507e-05	-4.828	-4.822	0.006
	SrCO3	6.675e-06	6.768e-06	-5.176	-5.170	0.006
	SrOH+	6.225e-07	5.084e-07	-6.206	-6.294	-0.088
	SrHCO3+	7.810e-09	6.408e-09	-8.107	-8.193	-0.086

----------Saturation indices----------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-4.10	7.21	11.31	Al(OH)3
Albite	-6.22	-1.24	4.98	NaAlSi3O8
Alunite	-19.94	-20.38	-0.44	KAl3(SO4)2(OH)6
Anglesite	-9.73	-17.56	-7.83	PbSO4
Anhydrite	-0.28	-4.62	-4.34	CaSO4
Anorthite	-3.29	23.73	27.02	CaAl2Si2O8
Aragonite	2.86	-5.43	-8.29	CaCO3
Barite	1.46	-8.64	-10.10	BaSO4
Ca-Montmorillonite	-10.14	-1.58	8.56	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	3.01	-5.43	-8.44	CaCO3

Celestite	-0.45	-7.07	-6.62	SrSO4
Cerrusite	-5.15	-18.37	-13.22	PbCO3
Chalcedony	-2.32	-5.96	-3.64	SiO2
Chlorite(14A)	11.87	83.15	71.28	Mg5Al2Si3O10(OH)8
Chrysotile	6.88	40.04	33.17	Mg3Si2O5(OH)4
CO2(g)	-8.49	-26.66	-18.18	CO2
Dolomite	2.14	-14.77	-16.91	CaMg(CO3)2
Fluorite	0.84	-9.85	-10.69	CaF2
Gibbsite	-1.34	7.21	8.55	Al(OH)3
Gypsum	-0.04	-4.62	-4.58	CaSO4:2H2O
H2(g)	-31.58	-31.58	0.00	H2
Hydroxyapatite	8.10	-31.87	-39.97	Ca5(PO4)3OH
Illite	-6.82	5.86	12.68	K0.6Mg0.25Al2.3Si3.5O10(OH)2
K-feldspar	-3.29	-0.98	2.31	KAlSi3O8
K-mica	-0.40	13.44	13.84	KAl3Si3O10(OH)2
Kaolinite	-5.62	2.49	8.11	Al2Si2O5(OH)4
O2(g)	-22.58	63.16	85.74	O2
Pb(OH)2	-0.13	8.29	8.42	Pb(OH)2
Quartz	-1.87	-5.96	-4.10	SiO2
Sepiolite	0.79	16.75	15.97	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-1.91	16.75	18.66	Mg2Si3O7.5OH:3H2O
SiO2(a)	-3.19	-5.96	-2.78	SiO2
Strontianite	1.39	-7.88	-9.27	SrCO3
Talc	5.83	28.11	22.29	Mg3Si4O10(OH)2
Witherite	-0.86	-9.45	-8.59	BaCO3

End of simulation.

Reading input data for simulation 2.

End of run.

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Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      PHASES
      EXCHANGE_MASTER_SPECIES
      EXCHANGE_SPECIES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      SOLUTION 1 Cell 2B
            temp  12.5
            pH    13.1
            pe    4
            redox pe
            units mg/l
            density     1
            Al    1.42
            B     0.26
            Ba    0.33
            Br    8.3
            C(4)  450
            Ca    1210
            Cl    155
            Cu    0.02
            F     4.7
            K     1210
            Mg    0.07
            N(5)  19.8
            Na    220   charge
            P     2.11e-07    Mol/l
            Pb    0.01
            S(6)  2850
            Si    5.9
            Sr    14.1
 ----------------------------------------
 Beginning of initial solution calculations.
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 Initial solution 1.     Cell 2B

 -----------------------------Solution composition------------------------------

       Elements           Molality       Moles

       Al                 5.295e-05   5.295e-05
       B                  2.420e-05   2.420e-05
       Ba                 2.418e-06   2.418e-06
       Br                 1.045e-04   1.045e-04
       C(4)               7.420e-03   7.420e-03
       Ca                 3.038e-02   3.038e-02
```

Cl	4.399e-03	4.399e-03	
Cu	3.167e-07	3.167e-07	
F	2.489e-04	2.489e-04	
K	3.114e-02	3.114e-02	
Mg	2.897e-06	2.897e-06	
N(5)	1.422e-03	1.422e-03	
Na	6.623e-02	6.623e-02	Charge balance
P	2.123e-07	2.123e-07	
Pb	4.856e-08	4.856e-08	
S(6)	2.985e-02	2.985e-02	
Si	9.880e-05	9.880e-05	
Sr	1.619e-04	1.619e-04	

----------Description of solution----------

pH	=	13.100
pe	=	4.000
Activity of water	=	0.996
Ionic strength	=	1.571e-01
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	9.274e-02
Total CO2 (mol/kg)	=	7.420e-03
Temperature (deg C)	=	12.500
Electrical balance (eq)	=	1.766e-13
Iterations	=	9
Total H	=	1.110905e+02
Total O	=	5.573035e+01

----------Distribution of species----------

	Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
	OH-	6.251e-02	4.568e-02	-1.204	-1.340	-0.136
	H+	9.805e-14	7.943e-14	-13.009	-13.100	-0.091
	H2O	5.551e+01	9.962e-01	-0.002	-0.002	0.000
Al		5.295e-05				
	Al(OH)4-	5.295e-05	4.034e-05	-4.276	-4.394	-0.118
	Al(OH)3	1.861e-12	1.930e-12	-11.730	-11.714	0.016
	Al(OH)2+	3.736e-18	2.846e-18	-17.428	-17.546	-0.118
	AlOH+2	2.790e-25	9.393e-26	-24.554	-25.027	-0.473
	AlF3	4.797e-28	4.973e-28	-27.319	-27.303	0.016
	AlF2+	3.011e-28	2.294e-28	-27.521	-27.639	-0.118
	AlF4-	4.524e-29	3.446e-29	-28.344	-28.463	-0.118
	AlF+2	8.335e-30	2.806e-30	-29.079	-29.552	-0.473
	AlF5-2	2.908e-31	9.790e-32	-30.536	-31.009	-0.473
	AlSO4+	4.375e-32	3.332e-32	-31.359	-31.477	-0.118
	Al+3	1.157e-32	1.738e-33	-31.937	-32.760	-0.823
	Al(SO4)2-	9.347e-33	7.119e-33	-32.029	-32.148	-0.118
	AlF6-3	2.565e-34	2.215e-35	-33.591	-34.655	-1.064
	AlHSO4+2	0.000e+00	0.000e+00	-45.195	-45.668	-0.473
B		2.420e-05				
	H2BO3-	2.420e-05	1.843e-05	-4.616	-4.734	-0.118
	H3BO3	3.114e-09	3.228e-09	-8.507	-8.491	0.016
	BF(OH)3-	2.569e-13	1.957e-13	-12.590	-12.708	-0.118
	BF2(OH)2-	3.897e-22	2.969e-22	-21.409	-21.527	-0.118
	BF3OH-	7.551e-33	5.752e-33	-32.122	-32.240	-0.118

	BF4-	0.000e+00	0.000e+00	-42.361	-42.479	-0.118
Ba		2.418e-06				
	BaSO4	1.136e-06	1.178e-06	-5.945	-5.929	0.016
	Ba+2	9.903e-07	3.274e-07	-6.004	-6.485	-0.481
	BaOH+	1.826e-07	1.391e-07	-6.738	-6.857	-0.118
	BaCO3	1.089e-07	1.129e-07	-6.963	-6.947	0.016
	BaHCO3+	5.430e-12	4.136e-12	-11.265	-11.383	-0.118
Br		1.045e-04				
	Br-	1.045e-04	7.527e-05	-3.981	-4.123	-0.143
C(4)		7.420e-03				
	CaCO3	4.400e-03	4.562e-03	-2.357	-2.341	0.016
	CO3-2	2.509e-03	8.580e-04	-2.600	-3.067	-0.466
	NaCO3-	4.966e-04	3.783e-04	-3.304	-3.422	-0.118
	SrCO3	1.136e-05	1.178e-05	-4.944	-4.929	0.016
	HCO3-	2.555e-06	1.953e-06	-5.593	-5.709	-0.117
	BaCO3	1.089e-07	1.129e-07	-6.963	-6.947	0.016
	CaHCO3+	9.685e-08	7.406e-08	-7.014	-7.130	-0.117
	MgCO3	8.236e-08	8.539e-08	-7.084	-7.069	0.016
	NaHCO3	4.844e-08	5.023e-08	-7.315	-7.299	0.016
	SrHCO3+	7.927e-10	6.061e-10	-9.101	-9.217	-0.117
	BaHCO3+	5.430e-12	4.136e-12	-11.265	-11.383	-0.118
	MgHCO3+	3.648e-12	2.779e-12	-11.438	-11.556	-0.118
	CO2	4.138e-13	4.290e-13	-12.383	-12.368	0.016
	Pb(CO3)2-2	3.113e-16	1.048e-16	-15.507	-15.980	-0.473
	PbCO3	4.690e-17	4.863e-17	-16.329	-16.313	0.016
	PbHCO3+	6.643e-24	5.060e-24	-23.178	-23.296	-0.118
Ca		3.038e-02				
	Ca+2	1.088e-02	3.816e-03	-1.964	-2.418	-0.455
	CaOH+	1.043e-02	7.943e-03	-1.982	-2.100	-0.118
	CaSO4	4.667e-03	4.839e-03	-2.331	-2.315	0.016
	CaCO3	4.400e-03	4.562e-03	-2.357	-2.341	0.016
	CaF+	5.619e-06	4.280e-06	-5.250	-5.369	-0.118
	CaPO4-	2.120e-07	1.615e-07	-6.674	-6.792	-0.118
	CaHCO3+	9.685e-08	7.406e-08	-7.014	-7.130	-0.117
	CaHPO4	6.687e-12	6.933e-12	-11.175	-11.159	0.016
	CaHSO4+	2.580e-15	1.965e-15	-14.588	-14.707	-0.118
	CaH2PO4+	5.804e-19	4.421e-19	-18.236	-18.355	-0.118
Cl		4.399e-03				
	Cl-	4.399e-03	3.232e-03	-2.357	-2.491	-0.134
	PbCl+	3.986e-22	3.036e-22	-21.399	-21.518	-0.118
	PbCl2	1.914e-24	1.985e-24	-23.718	-23.702	0.016
	PbCl3-	6.172e-27	4.701e-27	-26.210	-26.328	-0.118
	PbCl4-2	1.954e-29	6.577e-30	-28.709	-29.182	-0.473
Cu(1)		8.340e-22				
	Cu+	8.340e-22	5.911e-22	-21.079	-21.228	-0.150
Cu(2)		3.167e-07				
	Cu(OH)4-2	2.349e-07	7.907e-08	-6.629	-7.102	-0.473
	Cu(OH)3-	4.148e-08	3.160e-08	-7.382	-7.500	-0.118
	Cu(OH)2	4.032e-08	4.181e-08	-7.394	-7.379	0.016
	CuOH+	2.155e-15	1.596e-15	-14.667	-14.797	-0.130
	Cu+2	3.550e-20	1.272e-20	-19.450	-19.895	-0.446
	CuSO4	1.643e-20	1.704e-20	-19.784	-19.769	0.016
F		2.489e-04				
	F-	2.389e-04	1.746e-04	-3.622	-3.758	-0.136
	CaF+	5.619e-06	4.280e-06	-5.250	-5.369	-0.118
	NaF	4.429e-06	4.593e-06	-5.354	-5.338	0.016
	MgF+	1.511e-09	1.151e-09	-8.821	-8.939	-0.118

	BF(OH)3-	2.569e-13	1.957e-13	-12.590	-12.708	-0.118
	HF	1.611e-14	1.670e-14	-13.793	-13.777	0.016
	HF2-	1.307e-17	9.952e-18	-16.884	-17.002	-0.118
	BF2(OH)2-	3.897e-22	2.969e-22	-21.409	-21.527	-0.118
	AlF3	4.797e-28	4.973e-28	-27.319	-27.303	0.016
	AlF2+	3.011e-28	2.294e-28	-27.521	-27.639	-0.118
	AlF4-	4.524e-29	3.446e-29	-28.344	-28.463	-0.118
	AlF+2	8.335e-30	2.806e-30	-29.079	-29.552	-0.473
	AlF5-2	2.908e-31	9.790e-32	-30.536	-31.009	-0.473
	BF3OH-	7.551e-33	5.752e-33	-32.122	-32.240	-0.118
	AlF6-3	2.565e-34	2.215e-35	-33.591	-34.655	-1.064
	BF4-	0.000e+00	0.000e+00	-42.361	-42.479	-0.118
	SiF6-2	0.000e+00	0.000e+00	-51.211	-51.684	-0.473
H(0)		9.812e-38				
	H2	4.906e-38	5.087e-38	-37.309	-37.294	0.016
K		3.114e-02				
	K+	2.911e-02	2.139e-02	-1.536	-1.670	-0.134
	KSO4-	1.128e-03	8.591e-04	-2.948	-3.066	-0.118
	KOH	8.971e-04	9.301e-04	-3.047	-3.031	0.016
	KHPO4-	2.315e-13	1.763e-13	-12.635	-12.754	-0.118
Mg		2.897e-06				
	MgOH+	2.326e-06	1.771e-06	-5.633	-5.752	-0.118
	Mg+2	3.410e-07	1.264e-07	-6.467	-6.898	-0.431
	MgSO4	1.466e-07	1.520e-07	-6.834	-6.818	0.016
	MgCO3	8.236e-08	8.539e-08	-7.084	-7.069	0.016
	MgF+	1.511e-09	1.151e-09	-8.821	-8.939	-0.118
	MgPO4-	9.469e-12	7.213e-12	-11.024	-11.142	-0.118
	MgHCO3+	3.648e-12	2.779e-12	-11.438	-11.556	-0.118
	MgHPO4	2.994e-16	3.104e-16	-15.524	-15.508	0.016
	MgH2PO4+	2.447e-23	1.864e-23	-22.611	-22.730	-0.118
N(5)		1.422e-03				
	NO3-	1.422e-03	1.024e-03	-2.847	-2.990	-0.143
	PbNO3+	6.486e-23	4.941e-23	-22.188	-22.306	-0.118
Na		6.623e-02				
	Na+	6.009e-02	4.572e-02	-1.221	-1.340	-0.119
	NaOH	3.654e-03	3.789e-03	-2.437	-2.422	0.016
	NaSO4-	1.988e-03	1.514e-03	-2.702	-2.820	-0.118
	NaCO3-	4.966e-04	3.783e-04	-3.304	-3.422	-0.118
	NaF	4.429e-06	4.593e-06	-5.354	-5.338	0.016
	NaHCO3	4.844e-08	5.023e-08	-7.315	-7.299	0.016
	NaHPO4-	4.949e-13	3.769e-13	-12.306	-12.424	-0.118
O(0)		1.899e-22				
	O2	9.497e-23	9.847e-23	-22.022	-22.007	0.016
P		2.123e-07				
	CaPO4-	2.120e-07	1.615e-07	-6.674	-6.792	-0.118
	PO4-3	2.759e-10	1.849e-11	-9.559	-10.733	-1.174
	HPO4-2	1.406e-11	4.228e-12	-10.852	-11.374	-0.522
	MgPO4-	9.469e-12	7.213e-12	-11.024	-11.142	-0.118
	CaHPO4	6.687e-12	6.933e-12	-11.175	-11.159	0.016
	NaHPO4-	4.949e-13	3.769e-13	-12.306	-12.424	-0.118
	KHPO4-	2.315e-13	1.763e-13	-12.635	-12.754	-0.118
	MgHPO4	2.994e-16	3.104e-16	-15.524	-15.508	0.016
	H2PO4-	7.762e-18	5.820e-18	-17.110	-17.235	-0.125
	CaH2PO4+	5.804e-19	4.421e-19	-18.236	-18.355	-0.118
	MgH2PO4+	2.447e-23	1.864e-23	-22.611	-22.730	-0.118
Pb		4.856e-08				
	Pb(OH)4-2	4.782e-08	1.610e-08	-7.320	-7.793	-0.473

	Pb(OH)3-	7.356e-10	5.603e-10	-9.133	-9.252	-0.118
	Pb(OH)2	3.753e-12	3.891e-12	-11.426	-11.410	0.016
	PbOH+	1.047e-15	7.975e-16	-14.980	-15.098	-0.118
	Pb(CO3)2-2	3.113e-16	1.048e-16	-15.507	-15.980	-0.473
	PbCO3	4.690e-17	4.863e-17	-16.329	-16.313	0.016
	PbSO4	1.270e-20	1.316e-20	-19.896	-19.881	0.016
	Pb+2	9.687e-21	3.261e-21	-20.014	-20.487	-0.473
	Pb(SO4)2-2	1.473e-21	4.959e-22	-20.832	-21.305	-0.473
	PbCl+	3.986e-22	3.036e-22	-21.399	-21.518	-0.118
	PbNO3+	6.486e-23	4.941e-23	-22.188	-22.306	-0.118
	PbHCO3+	6.643e-24	5.060e-24	-23.178	-23.296	-0.118
	PbCl2	1.914e-24	1.985e-24	-23.718	-23.702	0.016
	PbCl3-	6.172e-27	4.701e-27	-26.210	-26.328	-0.118
	PbCl4-2	1.954e-29	6.577e-30	-28.709	-29.182	-0.473
	Pb2OH+3	6.745e-34	5.822e-35	-33.171	-34.235	-1.064
S(6)		2.985e-02				
	SO4-2	2.203e-02	7.178e-03	-1.657	-2.144	-0.487
	CaSO4	4.667e-03	4.839e-03	-2.331	-2.315	0.016
	NaSO4-	1.988e-03	1.514e-03	-2.702	-2.820	-0.118
	KSO4-	1.128e-03	8.591e-04	-2.948	-3.066	-0.118
	SrSO4	3.603e-05	3.735e-05	-4.443	-4.428	0.016
	BaSO4	1.136e-06	1.178e-06	-5.945	-5.929	0.016
	MgSO4	1.466e-07	1.520e-07	-6.834	-6.818	0.016
	HSO4-	5.623e-14	4.283e-14	-13.250	-13.368	-0.118
	CaHSO4+	2.580e-15	1.965e-15	-14.588	-14.707	-0.118
	CuSO4	1.643e-20	1.704e-20	-19.784	-19.769	0.016
	PbSO4	1.270e-20	1.316e-20	-19.896	-19.881	0.016
	Pb(SO4)2-2	1.473e-21	4.959e-22	-20.832	-21.305	-0.473
	AlSO4+	4.375e-32	3.332e-32	-31.359	-31.477	-0.118
	Al(SO4)2-	9.347e-33	7.119e-33	-32.029	-32.148	-0.118
	AlHSO4+2	0.000e+00	0.000e+00	-45.195	-45.668	-0.473
Si		9.880e-05				
	H3SiO4-	5.469e-05	4.166e-05	-4.262	-4.380	-0.118
	H2SiO4-2	4.408e-05	1.484e-05	-4.356	-4.829	-0.473
	H4SiO4	3.472e-08	3.600e-08	-7.459	-7.444	0.016
	SiF6-2	0.000e+00	0.000e+00	-51.211	-51.684	-0.473
Sr		1.619e-04				
	Sr+2	8.813e-05	3.112e-05	-4.055	-4.507	-0.452
	SrSO4	3.603e-05	3.735e-05	-4.443	-4.428	0.016
	SrOH+	2.640e-05	2.002e-05	-4.578	-4.699	-0.120
	SrCO3	1.136e-05	1.178e-05	-4.944	-4.929	0.016
	SrHCO3+	7.927e-10	6.061e-10	-9.101	-9.217	-0.117

----------Saturation indices----------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-5.11	6.54	11.65	Al(OH)3
Albite	-9.22	-4.02	5.20	NaAlSi3O8
Alunite	-25.86	-25.65	0.21	KAl3(SO4)2(OH)6
Anglesite	-14.77	-22.63	-7.86	PbSO4
Anhydrite	-0.23	-4.56	-4.33	CaSO4
Anorthite	-6.00	21.97	27.97	CaAl2Si2O8
Aragonite	2.78	-5.48	-8.27	CaCO3
Barite	1.56	-8.63	-10.19	BaSO4
Ca-Montmorillonite	-17.24	-8.15	9.09	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	2.94	-5.48	-8.42	CaCO3

Celestite	-0.03	-6.65	-6.62	SrSO4
Cerrusite	-10.27	-23.55	-13.29	PbCO3
Chalcedony	-3.74	-7.44	-3.70	SiO2
Chlorite(14A)	14.01	87.25	73.24	Mg5Al2Si3O10(OH)8
Chrysotile	9.20	43.02	33.82	Mg3Si2O5(OH)4
CO2(g)	-11.06	-29.26	-18.20	CO2
Dolomite	1.34	-15.45	-16.79	CaMg(CO3)2
Fluorite	0.83	-9.93	-10.76	CaF2
Gibbsite	-2.31	6.54	8.84	Al(OH)3
Gypsum	0.02	-4.57	-4.59	CaSO4:2H2O
H2(g)	-34.20	-34.20	0.00	H2
Hydroxyapatite	8.45	-31.19	-39.64	Ca5(PO4)3OH
Illite	-12.57	0.68	13.24	K0.6Mg0.25Al2.3Si3.5O10(OH)2
K-feldspar	-6.82	-4.35	2.47	KAlSi3O8
K-mica	-5.89	8.72	14.61	KAl3Si3O10(OH)2
Kaolinite	-10.38	-1.81	8.57	Al2Si2O5(OH)4
O2(g)	-19.11	68.40	87.50	O2
Pb(OH)2	-2.89	5.71	8.60	Pb(OH)2
Quartz	-3.27	-7.44	-4.17	SiO2
Sepiolite	0.17	16.27	16.10	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-2.39	16.27	18.66	Mg2Si3O7.5OH:3H2O
SiO2(a)	-4.62	-7.44	-2.82	SiO2
Strontianite	1.71	-7.57	-9.28	SrCO3
Talc	5.25	28.14	22.89	Mg3Si4O10(OH)2
Witherite	-0.94	-9.55	-8.61	BaCO3

End of simulation.

Reading input data for simulation 2.

End of run.

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Reading data base.
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      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      PHASES
      EXCHANGE_MASTER_SPECIES
      EXCHANGE_SPECIES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      SOLUTION 1 Cell 3B
            temp  17
            pH    12.52
            pe    4
            redox pe
            units mg/l
            density     1
            Al    0.97
            B     0.26
            Ba    0.26
            Br    2.6
            C(4)  450
            Ca    760
            Cl    60
            F     3.1
            K     350
            Mg    0.1
            N(5)  22.3
            Na    125   charge
            P     2.11e-07    Mol/l
            Pb    0.01
            S(6)  1400
            Si    8.2
            Sr    5.1
-----------------------------------------
Beginning of initial solution calculations.
-----------------------------------------

Initial solution 1.     Cell 3B

-----------------------------Solution composition------------------------------

      Elements            Molality       Moles

      Al                  3.607e-05   3.607e-05
      B                   2.413e-05   2.413e-05
      Ba                  1.899e-06   1.899e-06
      Br                  3.264e-05   3.264e-05
      C(4)                7.398e-03   7.398e-03
      Ca                  1.902e-02   1.902e-02
      Cl                  1.698e-03   1.698e-03
```

F	1.637e-04	1.637e-04	
K	8.980e-03	8.980e-03	
Mg	4.126e-06	4.126e-06	
N(5)	1.597e-03	1.597e-03	
Na	2.603e-02	2.603e-02	Charge balance
P	2.117e-07	2.117e-07	
Pb	4.842e-08	4.842e-08	
S(6)	1.462e-02	1.462e-02	
Si	1.369e-04	1.369e-04	
Sr	5.839e-05	5.839e-05	

----------Description of solution----------

pH	=	12.520
pe	=	4.000
Activity of water	=	0.998
Ionic strength	=	7.489e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	4.056e-02
Total CO2 (mol/kg)	=	7.398e-03
Temperature (deg C)	=	17.000
Electrical balance (eq)	=	-1.340e-15
Iterations	=	11
Total H	=	1.110385e+02
Total O	=	5.561788e+01

----------Distribution of species----------

	Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
	OH-	2.240e-02	1.760e-02	-1.650	-1.754	-0.105
	H+	3.599e-13	3.020e-13	-12.444	-12.520	-0.076
	H2O	5.551e+01	9.984e-01	-0.001	-0.001	0.000
Al		3.607e-05				
	Al(OH)4-	3.607e-05	2.887e-05	-4.443	-4.540	-0.097
	Al(OH)3	4.982e-12	5.069e-12	-11.303	-11.295	0.007
	Al(OH)2+	2.421e-17	1.938e-17	-16.616	-16.713	-0.097
	AlOH+2	3.792e-24	1.556e-24	-23.421	-23.808	-0.387
	AlF3	8.663e-27	8.813e-27	-26.062	-26.055	0.007
	AlF2+	7.097e-27	5.680e-27	-26.149	-26.246	-0.097
	AlF4-	5.438e-28	4.352e-28	-27.265	-27.361	-0.097
	AlF+2	2.320e-28	9.518e-29	-27.635	-28.021	-0.387
	AlF5-2	2.125e-30	8.718e-31	-29.673	-30.060	-0.387
	AlSO4+	1.283e-30	1.026e-30	-29.892	-29.989	-0.097
	Al+3	3.902e-31	8.045e-32	-30.409	-31.094	-0.686
	Al(SO4)2-	1.752e-31	1.402e-31	-30.756	-30.853	-0.097
	AlF6-3	9.468e-34	1.276e-34	-33.024	-33.894	-0.870
	AlHSO4+2	0.000e+00	0.000e+00	-43.201	-43.588	-0.387
B		2.413e-05				
	H2BO3-	2.412e-05	1.930e-05	-4.618	-4.714	-0.097
	H3BO3	1.157e-08	1.177e-08	-7.937	-7.929	0.007
	BF(OH)3-	6.676e-13	5.343e-13	-12.175	-12.272	-0.097
	BF2(OH)2-	2.718e-21	2.176e-21	-20.566	-20.662	-0.097
	BF3OH-	1.302e-31	1.042e-31	-30.885	-30.982	-0.097
	BF4-	0.000e+00	0.000e+00	-40.695	-40.792	-0.097
Ba		1.899e-06				

	Ba+2		8.846e-07	3.686e-07	-6.053	-6.433	-0.380
	BaSO4		8.151e-07	8.292e-07	-6.089	-6.081	0.007
	BaCO3		1.479e-07	1.504e-07	-6.830	-6.823	0.007
	BaOH+		5.160e-08	4.130e-08	-7.287	-7.384	-0.097
	BaHCO3+		2.452e-11	1.962e-11	-10.611	-10.707	-0.097
Br		3.264e-05					
	Br-		3.264e-05	2.543e-05	-4.486	-4.595	-0.108
C(4)		7.398e-03					
	CaCO3		4.919e-03	5.004e-03	-2.308	-2.301	0.007
	CO3-2		2.179e-03	9.276e-04	-2.662	-3.033	-0.371
	NaCO3-		2.835e-04	2.269e-04	-3.548	-3.644	-0.097
	HCO3-		8.844e-06	7.143e-06	-5.053	-5.146	-0.093
	SrCO3		7.119e-06	7.243e-06	-5.148	-5.140	0.007
	CaHCO3+		3.590e-07	2.900e-07	-6.445	-6.538	-0.093
	MgCO3		2.883e-07	2.933e-07	-6.540	-6.533	0.007
	BaCO3		1.479e-07	1.504e-07	-6.830	-6.823	0.007
	NaHCO3		7.850e-08	7.986e-08	-7.105	-7.098	0.007
	SrHCO3+		1.594e-09	1.287e-09	-8.798	-8.890	-0.093
	MgHCO3+		3.802e-11	3.043e-11	-10.420	-10.517	-0.097
	BaHCO3+		2.452e-11	1.962e-11	-10.611	-10.707	-0.097
	CO2		5.373e-12	5.467e-12	-11.270	-11.262	0.007
	Pb(CO3)2-2		7.137e-14	2.928e-14	-13.147	-13.533	-0.387
	PbCO3		1.235e-14	1.257e-14	-13.908	-13.901	0.007
	PbHCO3+		5.527e-21	4.423e-21	-20.258	-20.354	-0.097
Ca		1.902e-02					
	Ca+2		8.579e-03	3.678e-03	-2.067	-2.434	-0.368
	CaCO3		4.919e-03	5.004e-03	-2.308	-2.301	0.007
	CaSO4		2.998e-03	3.051e-03	-2.523	-2.516	0.007
	CaOH+		2.522e-03	2.018e-03	-2.598	-2.695	-0.097
	CaF+		4.107e-06	3.287e-06	-5.386	-5.483	-0.097
	CaHCO3+		3.590e-07	2.900e-07	-6.445	-6.538	-0.093
	CaPO4-		2.114e-07	1.692e-07	-6.675	-6.772	-0.097
	CaHPO4		2.479e-11	2.522e-11	-10.606	-10.598	0.007
	CaHSO4+		6.151e-15	4.923e-15	-14.211	-14.308	-0.097
	CaH2PO4+		7.455e-18	5.967e-18	-17.128	-17.224	-0.097
Cl		1.698e-03					
	Cl-		1.698e-03	1.337e-03	-2.770	-2.874	-0.104
	PbCl+		4.230e-20	3.385e-20	-19.374	-19.470	-0.097
	PbCl2		8.224e-23	8.367e-23	-22.085	-22.077	0.007
	PbCl3-		1.056e-25	8.449e-26	-24.976	-25.073	-0.097
	PbCl4-2		1.237e-28	5.076e-29	-27.908	-28.294	-0.387
F		1.637e-04					
	F-		1.582e-04	1.243e-04	-3.801	-3.906	-0.105
	CaF+		4.107e-06	3.287e-06	-5.386	-5.483	-0.097
	NaF		1.398e-06	1.422e-06	-5.855	-5.847	0.007
	MgF+		3.312e-09	2.651e-09	-8.480	-8.577	-0.097
	BF(OH)3-		6.676e-13	5.343e-13	-12.175	-12.272	-0.097
	HF		4.802e-14	4.886e-14	-13.319	-13.311	0.007
	HF2-		2.714e-17	2.172e-17	-16.566	-16.663	-0.097
	BF2(OH)2-		2.718e-21	2.176e-21	-20.566	-20.662	-0.097
	AlF3		8.663e-27	8.813e-27	-26.062	-26.055	0.007
	AlF2+		7.097e-27	5.680e-27	-26.149	-26.246	-0.097
	AlF4-		5.438e-28	4.352e-28	-27.265	-27.361	-0.097
	AlF+2		2.320e-28	9.518e-29	-27.635	-28.021	-0.387
	AlF5-2		2.125e-30	8.718e-31	-29.673	-30.060	-0.387
	BF3OH-		1.302e-31	1.042e-31	-30.885	-30.982	-0.097
	AlF6-3		9.468e-34	1.276e-34	-33.024	-33.894	-0.870

	BF4-	0.000e+00	0.000e+00	-40.695	-40.792	-0.097
	SiF6-2	0.000e+00	0.000e+00	-49.236	-49.623	-0.387
H(0)		1.377e-36				
	H2	6.887e-37	7.007e-37	-36.162	-36.154	0.007
K		8.980e-03				
	K+	8.669e-03	6.829e-03	-2.062	-2.166	-0.104
	KSO4-	2.331e-04	1.866e-04	-3.632	-3.729	-0.097
	KOH	7.695e-05	7.828e-05	-4.114	-4.106	0.007
	KHPO4-	2.426e-13	1.942e-13	-12.615	-12.712	-0.097
Mg		4.126e-06				
	MgOH+	2.675e-06	2.141e-06	-5.573	-5.669	-0.097
	Mg+2	8.462e-07	3.747e-07	-6.073	-6.426	-0.354
	MgSO4	3.136e-07	3.190e-07	-6.504	-6.496	0.007
	MgCO3	2.883e-07	2.933e-07	-6.540	-6.533	0.007
	MgF+	3.312e-09	2.651e-09	-8.480	-8.577	-0.097
	MgHCO3+	3.802e-11	3.043e-11	-10.420	-10.517	-0.097
	MgPO4-	2.905e-11	2.325e-11	-10.537	-10.634	-0.097
	MgHPO4	3.414e-15	3.474e-15	-14.467	-14.459	0.007
	MgH2PO4+	9.671e-22	7.740e-22	-21.015	-21.111	-0.097
N(5)		1.597e-03				
	NO3-	1.597e-03	1.244e-03	-2.797	-2.905	-0.108
	PbNO3+	1.793e-20	1.435e-20	-19.746	-19.843	-0.097
Na		2.603e-02				
	Na+	2.478e-02	1.988e-02	-1.606	-1.702	-0.096
	NaSO4-	5.304e-04	4.245e-04	-3.275	-3.372	-0.097
	NaOH	4.269e-04	4.343e-04	-3.370	-3.362	0.007
	NaCO3-	2.835e-04	2.269e-04	-3.548	-3.644	-0.097
	NaF	1.398e-06	1.422e-06	-5.855	-5.847	0.007
	NaHCO3	7.850e-08	7.986e-08	-7.105	-7.098	0.007
	NaHPO4-	7.063e-13	5.653e-13	-12.151	-12.248	-0.097
O(0)		3.699e-23				
	O2	1.850e-23	1.882e-23	-22.733	-22.725	0.007
P		2.117e-07				
	CaPO4-	2.114e-07	1.692e-07	-6.675	-6.772	-0.097
	PO4-3	1.507e-10	1.847e-11	-9.822	-10.734	-0.912
	HPO4-2	3.707e-11	1.458e-11	-10.431	-10.836	-0.405
	MgPO4-	2.905e-11	2.325e-11	-10.537	-10.634	-0.097
	CaHPO4	2.479e-11	2.522e-11	-10.606	-10.598	0.007
	NaHPO4-	7.063e-13	5.653e-13	-12.151	-12.248	-0.097
	KHPO4-	2.426e-13	1.942e-13	-12.615	-12.712	-0.097
	MgHPO4	3.414e-15	3.474e-15	-14.467	-14.459	0.007
	H2PO4-	9.308e-17	7.427e-17	-16.031	-16.129	-0.098
	CaH2PO4+	7.455e-18	5.967e-18	-17.128	-17.224	-0.097
	MgH2PO4+	9.671e-22	7.740e-22	-21.015	-21.111	-0.097
Pb		4.842e-08				
	Pb(OH)4-2	4.529e-08	1.858e-08	-7.344	-7.731	-0.387
	Pb(OH)3-	3.066e-09	2.454e-09	-8.513	-8.610	-0.097
	Pb(OH)2	6.354e-11	6.464e-11	-10.197	-10.189	0.007
	Pb(CO3)2-2	7.137e-14	2.928e-14	-13.147	-13.533	-0.387
	PbOH+	6.279e-14	5.026e-14	-13.202	-13.299	-0.097
	PbCO3	1.235e-14	1.257e-14	-13.908	-13.901	0.007
	PbSO4	1.934e-18	1.968e-18	-17.714	-17.706	0.007
	Pb+2	1.900e-18	7.796e-19	-17.721	-18.108	-0.387
	Pb(SO4)2-2	1.130e-19	4.635e-20	-18.947	-19.334	-0.387
	PbCl+	4.230e-20	3.385e-20	-19.374	-19.470	-0.097
	PbNO3+	1.793e-20	1.435e-20	-19.746	-19.843	-0.097
	PbHCO3+	5.527e-21	4.423e-21	-20.258	-20.354	-0.097

	PbCl2	8.224e-23	8.367e-23	-22.085	-22.077	0.007
	PbCl3-	1.056e-25	8.449e-26	-24.976	-25.073	-0.097
	PbCl4-2	1.237e-28	5.076e-29	-27.908	-28.294	-0.387
	Pb2OH+3	6.509e-30	8.772e-31	-29.186	-30.057	-0.870
S(6)		1.462e-02				
	SO4-2	1.084e-02	4.488e-03	-1.965	-2.348	-0.383
	CaSO4	2.998e-03	3.051e-03	-2.523	-2.516	0.007
	NaSO4-	5.304e-04	4.245e-04	-3.275	-3.372	-0.097
	KSO4-	2.331e-04	1.866e-04	-3.632	-3.729	-0.097
	SrSO4	1.210e-05	1.231e-05	-4.917	-4.910	0.007
	BaSO4	8.151e-07	8.292e-07	-6.089	-6.081	0.007
	MgSO4	3.136e-07	3.190e-07	-6.504	-6.496	0.007
	HSO4-	1.391e-13	1.113e-13	-12.857	-12.953	-0.097
	CaHSO4+	6.151e-15	4.923e-15	-14.211	-14.308	-0.097
	PbSO4	1.934e-18	1.968e-18	-17.714	-17.706	0.007
	Pb(SO4)2-2	1.130e-19	4.635e-20	-18.947	-19.334	-0.387
	AlSO4+	1.283e-30	1.026e-30	-29.892	-29.989	-0.097
	Al(SO4)2-	1.752e-31	1.402e-31	-30.756	-30.853	-0.097
	AlHSO4+2	0.000e+00	0.000e+00	-43.201	-43.588	-0.387
Si		1.369e-04				
	H3SiO4-	1.090e-04	8.720e-05	-3.963	-4.059	-0.097
	H2SiO4-2	2.772e-05	1.137e-05	-4.557	-4.944	-0.387
	H4SiO4	2.354e-07	2.395e-07	-6.628	-6.621	0.007
	SiF6-2	0.000e+00	0.000e+00	-49.236	-49.623	-0.387
Sr		5.839e-05				
	Sr+2	3.591e-05	1.549e-05	-4.445	-4.810	-0.365
	SrSO4	1.210e-05	1.231e-05	-4.917	-4.910	0.007
	SrCO3	7.119e-06	7.243e-06	-5.148	-5.140	0.007
	SrOH+	3.269e-06	2.627e-06	-5.486	-5.581	-0.095
	SrHCO3+	1.594e-09	1.287e-09	-8.798	-8.890	-0.093

----------Saturation indices----------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-4.87	6.46	11.34	Al(OH)3
Albite	-7.57	-2.58	5.00	NaAlSi3O8
Alunite	-24.64	-25.03	-0.38	KAl3(SO4)2(OH)6
Anglesite	-12.62	-20.46	-7.83	PbSO4
Anhydrite	-0.44	-4.78	-4.34	CaSO4
Anorthite	-4.80	22.30	27.10	CaAl2Si2O8
Aragonite	2.82	-5.47	-8.29	CaCO3
Barite	1.33	-8.78	-10.11	BaSO4
Ca-Montmorillonite	-14.10	-5.50	8.60	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	2.97	-5.47	-8.44	CaCO3
Celestite	-0.54	-7.16	-6.62	SrSO4
Cerrusite	-7.91	-21.14	-13.23	PbCO3
Chalcedony	-2.97	-6.62	-3.65	SiO2
Chlorite(14A)	14.69	86.13	71.44	Mg5Al2Si3O10(OH)8
Chrysotile	9.38	42.60	33.22	Mg3Si2O5(OH)4
CO2(g)	-9.89	-28.07	-18.18	CO2
Dolomite	1.97	-14.93	-16.90	CaMg(CO3)2
Fluorite	0.45	-10.25	-10.70	CaF2
Gibbsite	-2.11	6.46	8.57	Al(OH)3
Gypsum	-0.20	-4.78	-4.58	CaSO4:2H2O
H2(g)	-33.04	-33.04	0.00	H2
Hydroxyapatite	8.09	-31.85	-39.94	Ca5(PO4)3OH

Illite	-10.16	2.57	12.73	K0.6Mg0.25Al2.3Si3.5O10(OH)2
K-feldspar	-5.37	-3.04	2.33	KAlSi3O8
K-mica	-4.01	9.89	13.90	KAl3Si3O10(OH)2
Kaolinite	-8.46	-0.31	8.15	Al2Si2O5(OH)4
O2(g)	-19.80	66.08	85.88	O2
Pb(OH)2	-1.50	6.93	8.43	Pb(OH)2
Quartz	-2.52	-6.62	-4.10	SiO2
Sepiolite	1.39	17.37	15.98	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-1.29	17.37	18.66	Mg2Si3O7.5OH:3H2O
SiO2(a)	-3.84	-6.62	-2.78	SiO2
Strontianite	1.43	-7.84	-9.27	SrCO3
Talc	7.03	29.36	22.34	Mg3Si4O10(OH)2
Witherite	-0.88	-9.47	-8.59	BaCO3

End of simulation.

Reading input data for simulation 2.

End of run.

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Reading data base.
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      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      PHASES
      EXCHANGE_MASTER_SPECIES
      EXCHANGE_SPECIES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      SOLUTION 1 Cell 4B
            temp  19
            pH    12.44
            pe    4
            redox pe
            units mg/l
            density     1
            Al    0.74
            B     0.23
            Ba    0.32
            Br    2.9
            C(4)  450
            Ca    800
            Cl    62
            F     3.8
            K     350
            Mg    0.08
            N(5)  21.5
            Na    115   charge
            P     2.11e-07    Mol/l
            Pb    0.01
            S(6)  1470
            Si    5
            Sr    5.5
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Beginning of initial solution calculations.
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Initial solution 1.     Cell 4B

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                 2.752e-05   2.752e-05
      B                  2.135e-05   2.135e-05
      Ba                 2.338e-06   2.338e-06
      Br                 3.641e-05   3.641e-05
      C(4)               7.399e-03   7.399e-03
      Ca                 2.003e-02   2.003e-02
      Cl                 1.755e-03   1.755e-03
```

F	2.007e-04	2.007e-04	
K	8.980e-03	8.980e-03	
Mg	3.301e-06	3.301e-06	
N(5)	1.540e-03	1.540e-03	
Na	2.465e-02	2.465e-02	Charge balance
P	2.117e-07	2.117e-07	
Pb	4.842e-08	4.842e-08	
S(6)	1.535e-02	1.535e-02	
Si	8.349e-05	8.349e-05	
Sr	6.298e-05	6.298e-05	

----------Description of solution----------

pH	=	12.440
pe	=	4.000
Activity of water	=	0.998
Ionic strength	=	7.573e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	3.966e-02
Total CO2 (mol/kg)	=	7.399e-03
Temperature (deg C)	=	19.000
Electrical balance (eq)	=	-1.732e-12
Iterations	=	10
Total H	=	1.110375e+02
Total O	=	5.561959e+01

----------Distribution of species----------

	Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
	OH-	2.197e-02	1.723e-02	-1.658	-1.764	-0.106
	H+	4.331e-13	3.631e-13	-12.363	-12.440	-0.077
	H2O	5.551e+01	9.984e-01	-0.001	-0.001	0.000
Al		2.752e-05				
	Al(OH)4-	2.752e-05	2.199e-05	-4.560	-4.658	-0.097
	Al(OH)3	4.477e-12	4.556e-12	-11.349	-11.341	0.008
	Al(OH)2+	2.229e-17	1.781e-17	-16.652	-16.749	-0.097
	AlOH+2	3.487e-24	1.422e-24	-23.458	-23.847	-0.389
	AlF3	1.552e-26	1.579e-26	-25.809	-25.802	0.008
	AlF2+	1.041e-26	8.321e-27	-25.982	-26.080	-0.097
	AlF4-	1.191e-27	9.520e-28	-26.924	-27.021	-0.097
	AlF+2	2.771e-28	1.130e-28	-27.557	-27.947	-0.389
	AlF5-2	5.681e-30	2.317e-30	-29.246	-29.635	-0.389
	AlSO4+	1.300e-30	1.039e-30	-29.886	-29.983	-0.097
	Al+3	3.784e-31	7.731e-32	-30.422	-31.112	-0.690
	Al(SO4)2-	1.839e-31	1.470e-31	-30.735	-30.833	-0.097
	AlF6-3	2.986e-33	3.969e-34	-32.525	-33.401	-0.876
	AlHSO4+2	0.000e+00	0.000e+00	-43.107	-43.496	-0.389
B		2.135e-05				
	H2BO3-	2.133e-05	1.705e-05	-4.671	-4.768	-0.097
	H3BO3	1.182e-08	1.203e-08	-7.927	-7.920	0.008
	BF(OH)3-	8.524e-13	6.812e-13	-12.069	-12.167	-0.097
	BF2(OH)2-	5.078e-21	4.058e-21	-20.294	-20.392	-0.097
	BF3OH-	3.435e-31	2.745e-31	-30.464	-30.561	-0.097
	BF4-	0.000e+00	0.000e+00	-40.109	-40.206	-0.097
Ba		2.338e-06				

	Ba+2	1.088e-06	4.509e-07	-5.963	-6.346	-0.383
	BaSO4	1.022e-06	1.040e-06	-5.991	-5.983	0.008
	BaCO3	1.748e-07	1.778e-07	-6.758	-6.750	0.008
	BaOH+	5.257e-08	4.201e-08	-7.279	-7.377	-0.097
	BaHCO3+	3.402e-11	2.719e-11	-10.468	-10.566	-0.097
Br		3.641e-05				
	Br-	3.641e-05	2.831e-05	-4.439	-4.548	-0.109
C(4)		7.399e-03				
	CaCO3	5.069e-03	5.158e-03	-2.295	-2.288	0.008
	CO3-2	2.035e-03	8.612e-04	-2.691	-3.065	-0.373
	NaCO3-	2.775e-04	2.217e-04	-3.557	-3.654	-0.097
	HCO3-	9.421e-06	7.599e-06	-5.026	-5.119	-0.093
	SrCO3	7.541e-06	7.673e-06	-5.123	-5.115	0.008
	CaHCO3+	4.297e-07	3.466e-07	-6.367	-6.460	-0.093
	MgCO3	2.188e-07	2.227e-07	-6.660	-6.652	0.008
	BaCO3	1.748e-07	1.778e-07	-6.758	-6.750	0.008
	NaHCO3	7.908e-08	8.047e-08	-7.102	-7.094	0.008
	SrHCO3+	1.955e-09	1.577e-09	-8.709	-8.802	-0.093
	BaHCO3+	3.402e-11	2.719e-11	-10.468	-10.566	-0.097
	MgHCO3+	3.231e-11	2.582e-11	-10.491	-10.588	-0.097
	CO2	6.646e-12	6.763e-12	-11.177	-11.170	0.008
	Pb(CO3)2-2	1.269e-13	5.175e-14	-12.897	-13.286	-0.389
	PbCO3	2.351e-14	2.392e-14	-13.629	-13.621	0.008
	PbHCO3+	1.207e-20	9.648e-21	-19.918	-20.016	-0.097
Ca		2.003e-02				
	Ca+2	9.304e-03	3.967e-03	-2.031	-2.402	-0.370
	CaCO3	5.069e-03	5.158e-03	-2.295	-2.288	0.008
	CaSO4	3.381e-03	3.440e-03	-2.471	-2.463	0.008
	CaOH+	2.265e-03	1.810e-03	-2.645	-2.742	-0.097
	CaF+	5.685e-06	4.543e-06	-5.245	-5.343	-0.097
	CaHCO3+	4.297e-07	3.466e-07	-6.367	-6.460	-0.093
	CaPO4-	2.115e-07	1.690e-07	-6.675	-6.772	-0.097
	CaHPO4	2.860e-11	2.911e-11	-10.544	-10.536	0.008
	CaHSO4+	8.534e-15	6.820e-15	-14.069	-14.166	-0.097
	CaH2PO4+	1.025e-17	8.192e-18	-16.989	-17.087	-0.097
Cl		1.755e-03				
	Cl-	1.755e-03	1.380e-03	-2.756	-2.860	-0.104
	PbCl+	9.439e-20	7.543e-20	-19.025	-19.122	-0.097
	PbCl2	1.817e-22	1.849e-22	-21.741	-21.733	0.008
	PbCl3-	2.442e-25	1.952e-25	-24.612	-24.710	-0.097
	PbCl4-2	3.014e-28	1.229e-28	-27.521	-27.910	-0.389
F		2.007e-04				
	F-	1.934e-04	1.517e-04	-3.714	-3.819	-0.106
	CaF+	5.685e-06	4.543e-06	-5.245	-5.343	-0.097
	NaF	1.615e-06	1.643e-06	-5.792	-5.784	0.008
	MgF+	3.335e-09	2.665e-09	-8.477	-8.574	-0.097
	BF(OH)3-	8.524e-13	6.812e-13	-12.069	-12.167	-0.097
	HF	7.295e-14	7.423e-14	-13.137	-13.129	0.008
	HF2-	5.136e-17	4.105e-17	-16.289	-16.387	-0.097
	BF2(OH)2-	5.078e-21	4.058e-21	-20.294	-20.392	-0.097
	AlF3	1.552e-26	1.579e-26	-25.809	-25.802	0.008
	AlF2+	1.041e-26	8.321e-27	-25.982	-26.080	-0.097
	AlF4-	1.191e-27	9.520e-28	-26.924	-27.021	-0.097
	AlF+2	2.771e-28	1.130e-28	-27.557	-27.947	-0.389
	AlF5-2	5.681e-30	2.317e-30	-29.246	-29.635	-0.389
	BF3OH-	3.435e-31	2.745e-31	-30.464	-30.561	-0.097
	AlF6-3	2.986e-33	3.969e-34	-32.525	-33.401	-0.876

	BF4-	0.000e+00	0.000e+00	-40.109	-40.206	-0.097
	SiF6-2	0.000e+00	0.000e+00	-48.644	-49.033	-0.389
H(0)		1.950e-36				
	H2	9.748e-37	9.919e-37	-36.011	-36.004	0.008
K		8.980e-03				
	K+	8.669e-03	6.817e-03	-2.062	-2.166	-0.104
	KSO4-	2.479e-04	1.981e-04	-3.606	-3.703	-0.097
	KOH	6.387e-05	6.500e-05	-4.195	-4.187	0.008
	KHPO4-	2.496e-13	1.994e-13	-12.603	-12.700	-0.097
Mg		3.301e-06				
	MgOH+	2.136e-06	1.707e-06	-5.670	-5.768	-0.097
	Mg+2	6.745e-07	2.971e-07	-6.171	-6.527	-0.356
	MgSO4	2.691e-07	2.738e-07	-6.570	-6.563	0.008
	MgCO3	2.188e-07	2.227e-07	-6.660	-6.652	0.008
	MgF+	3.335e-09	2.665e-09	-8.477	-8.574	-0.097
	MgHCO3+	3.231e-11	2.582e-11	-10.491	-10.588	-0.097
	MgPO4-	2.137e-11	1.708e-11	-10.670	-10.768	-0.097
	MgHPO4	2.897e-15	2.948e-15	-14.538	-14.531	0.008
	MgH2PO4+	9.778e-22	7.814e-22	-21.010	-21.107	-0.097
N(5)		1.540e-03				
	NO3-	1.540e-03	1.198e-03	-2.812	-2.922	-0.109
	PbNO3+	3.543e-20	2.831e-20	-19.451	-19.548	-0.097
Na		2.465e-02				
	Na+	2.351e-02	1.883e-02	-1.629	-1.725	-0.096
	NaSO4-	5.228e-04	4.178e-04	-3.282	-3.379	-0.097
	NaOH	3.362e-04	3.421e-04	-3.473	-3.466	0.008
	NaCO3-	2.775e-04	2.217e-04	-3.557	-3.654	-0.097
	NaF	1.615e-06	1.643e-06	-5.792	-5.784	0.008
	NaHCO3	7.908e-08	8.047e-08	-7.102	-7.094	0.008
	NaHPO4-	6.894e-13	5.509e-13	-12.162	-12.259	-0.097
O(0)		8.770e-23				
	O2	4.385e-23	4.462e-23	-22.358	-22.350	0.008
P		2.117e-07				
	CaPO4-	2.115e-07	1.690e-07	-6.675	-6.772	-0.097
	PO4-3	1.365e-10	1.648e-11	-9.865	-10.783	-0.918
	HPO4-2	3.839e-11	1.500e-11	-10.416	-10.824	-0.408
	CaHPO4	2.860e-11	2.911e-11	-10.544	-10.536	0.008
	MgPO4-	2.137e-11	1.708e-11	-10.670	-10.768	-0.097
	NaHPO4-	6.894e-13	5.509e-13	-12.162	-12.259	-0.097
	KHPO4-	2.496e-13	1.994e-13	-12.603	-12.700	-0.097
	MgHPO4	2.897e-15	2.948e-15	-14.538	-14.531	0.008
	H2PO4-	1.140e-16	9.080e-17	-15.943	-16.042	-0.099
	CaH2PO4+	1.025e-17	8.192e-18	-16.989	-17.087	-0.097
	MgH2PO4+	9.778e-22	7.814e-22	-21.010	-21.107	-0.097
Pb		4.842e-08				
	Pb(OH)4-2	4.471e-08	1.824e-08	-7.350	-7.739	-0.389
	Pb(OH)3-	3.622e-09	2.895e-09	-8.441	-8.538	-0.097
	Pb(OH)2	9.010e-11	9.169e-11	-10.045	-10.038	0.008
	Pb(CO3)2-2	1.269e-13	5.175e-14	-12.897	-13.286	-0.389
	PbOH+	1.072e-13	8.570e-14	-12.970	-13.067	-0.097
	PbCO3	2.351e-14	2.392e-14	-13.629	-13.621	0.008
	PbSO4	4.065e-18	4.136e-18	-17.391	-17.383	0.008
	Pb+2	3.919e-18	1.598e-18	-17.407	-17.796	-0.389
	Pb(SO4)2-2	2.449e-19	9.990e-20	-18.611	-19.000	-0.389
	PbCl+	9.439e-20	7.543e-20	-19.025	-19.122	-0.097
	PbNO3+	3.543e-20	2.831e-20	-19.451	-19.548	-0.097
	PbHCO3+	1.207e-20	9.648e-21	-19.918	-20.016	-0.097

	PbCl2	1.817e-22	1.849e-22	-21.741	-21.733	0.008
	PbCl3-	2.442e-25	1.952e-25	-24.612	-24.710	-0.097
	PbCl4-2	3.014e-28	1.229e-28	-27.521	-27.910	-0.389
	Pb2OH+3	2.307e-29	3.067e-30	-28.637	-29.513	-0.876
S(6)	1.535e-02					
	SO4-2	1.119e-02	4.602e-03	-1.951	-2.337	-0.386
	CaSO4	3.381e-03	3.440e-03	-2.471	-2.463	0.008
	NaSO4-	5.228e-04	4.178e-04	-3.282	-3.379	-0.097
	KSO4-	2.479e-04	1.981e-04	-3.606	-3.703	-0.097
	SrSO4	1.367e-05	1.391e-05	-4.864	-4.857	0.008
	BaSO4	1.022e-06	1.040e-06	-5.991	-5.983	0.008
	MgSO4	2.691e-07	2.738e-07	-6.570	-6.563	0.008
	HSO4-	1.789e-13	1.430e-13	-12.747	-12.845	-0.097
	CaHSO4+	8.534e-15	6.820e-15	-14.069	-14.166	-0.097
	PbSO4	4.065e-18	4.136e-18	-17.391	-17.383	0.008
	Pb(SO4)2-2	2.449e-19	9.990e-20	-18.611	-19.000	-0.389
	AlSO4+	1.300e-30	1.039e-30	-29.886	-29.983	-0.097
	Al(SO4)2-	1.839e-31	1.470e-31	-30.735	-30.833	-0.097
	AlHSO4+2	0.000e+00	0.000e+00	-43.107	-43.496	-0.389
Si	8.349e-05					
	H3SiO4-	6.694e-05	5.350e-05	-4.174	-4.272	-0.097
	H2SiO4-2	1.639e-05	6.685e-06	-4.785	-5.175	-0.389
	H4SiO4	1.608e-07	1.637e-07	-6.794	-6.786	0.008
	SiF6-2	0.000e+00	0.000e+00	-48.644	-49.033	-0.389
Sr	6.298e-05					
	Sr+2	3.883e-05	1.666e-05	-4.411	-4.778	-0.367
	SrSO4	1.367e-05	1.391e-05	-4.864	-4.857	0.008
	SrCO3	7.541e-06	7.673e-06	-5.123	-5.115	0.008
	SrOH+	2.929e-06	2.350e-06	-5.533	-5.629	-0.096
	SrHCO3+	1.955e-09	1.577e-09	-8.709	-8.802	-0.093

----------Saturation indices----------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-4.99	6.21	11.20	Al(OH)3
Albite	-8.34	-3.43	4.91	NaAlSi3O8
Alunite	-24.90	-25.54	-0.64	KAl3(SO4)2(OH)6
Anglesite	-12.31	-20.13	-7.82	PbSO4
Anhydrite	-0.40	-4.74	-4.34	CaSO4
Anorthite	-5.40	21.32	26.72	CaAl2Si2O8
Aragonite	2.83	-5.47	-8.30	CaCO3
Barite	1.39	-8.68	-10.07	BaSO4
Ca-Montmorillonite	-15.12	-6.73	8.39	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	2.98	-5.47	-8.45	CaCO3
Celestite	-0.49	-7.12	-6.62	SrSO4
Cerrusite	-7.66	-20.86	-13.20	PbCO3
Chalcedony	-3.16	-6.78	-3.62	SiO2
Chlorite(14A)	13.16	83.82	70.66	Mg5Al2Si3O10(OH)8
Chrysotile	8.53	41.49	32.96	Mg3Si2O5(OH)4
CO2(g)	-9.78	-27.94	-18.17	CO2
Dolomite	1.89	-15.06	-16.95	CaMg(CO3)2
Fluorite	0.63	-10.04	-10.67	CaF2
Gibbsite	-2.25	6.21	8.45	Al(OH)3
Gypsum	-0.16	-4.74	-4.58	CaSO4:2H2O
H2(g)	-32.88	-32.88	0.00	H2
Hydroxyapatite	8.16	-31.92	-40.07	Ca5(PO4)3OH

Illite	-11.23	1.28	12.51	K0.6Mg0.25Al2.3Si3.5O10(OH)2
K-feldspar	-6.14	-3.87	2.27	KAlSi3O8
K-mica	-5.06	8.54	13.60	KAl3Si3O10(OH)2
Kaolinite	-9.12	-1.16	7.97	Al2Si2O5(OH)4
O2(g)	-19.42	65.76	85.18	O2
Pb(OH)2	-1.28	7.08	8.36	Pb(OH)2
Quartz	-2.71	-6.78	-4.07	SiO2
Sepiolite	0.43	16.35	15.92	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-2.31	16.35	18.66	Mg2Si3O7.5OH:3H2O
SiO2(a)	-4.02	-6.78	-2.76	SiO2
Strontianite	1.43	-7.84	-9.27	SrCO3
Talc	5.82	27.92	22.10	Mg3Si4O10(OH)2
Witherite	-0.83	-9.41	-8.58	BaCO3

End of simulation.

Reading input data for simulation 2.

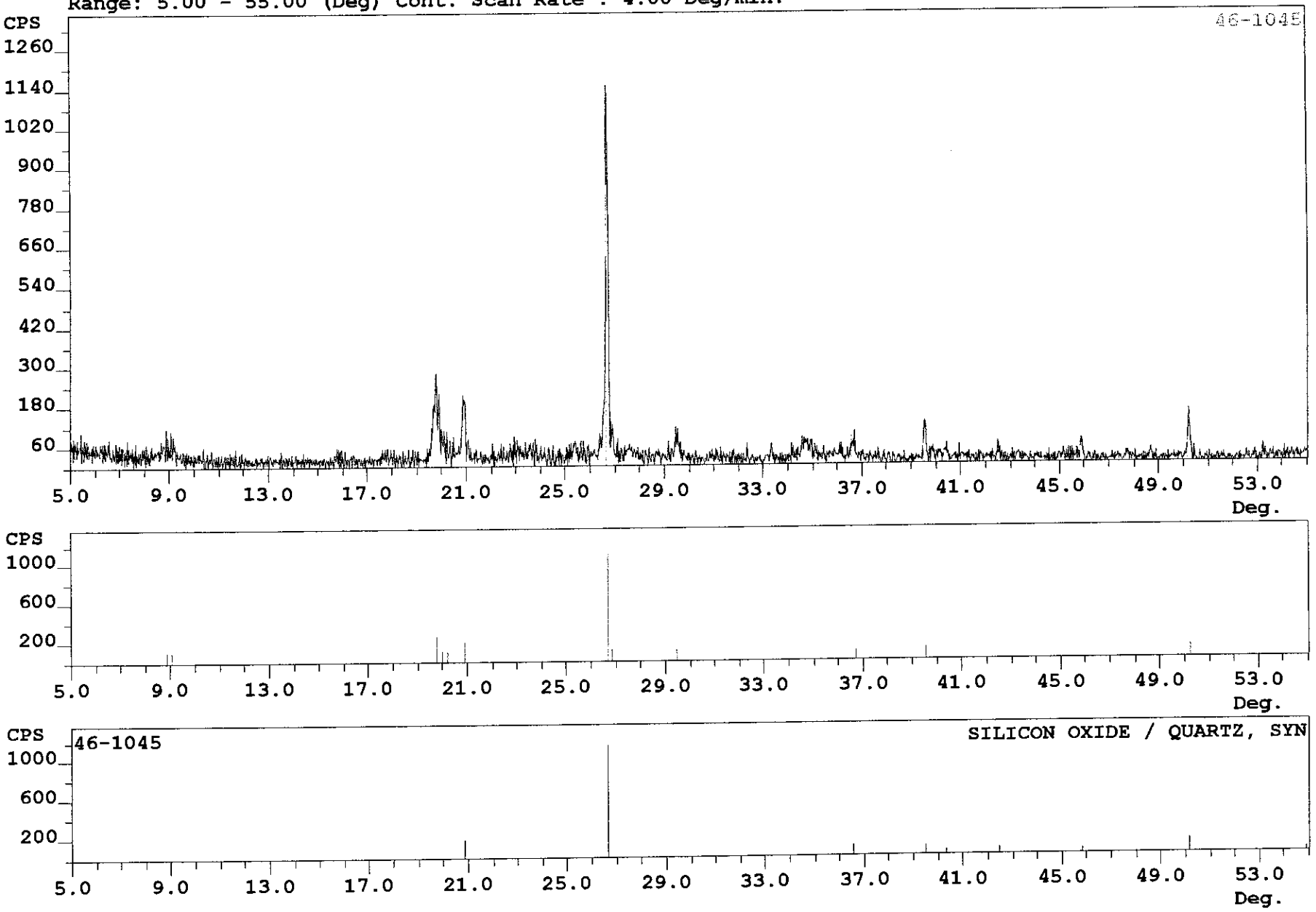
End of run.

Appendix 8.F

X-ray diffraction patterns of ash from test cells

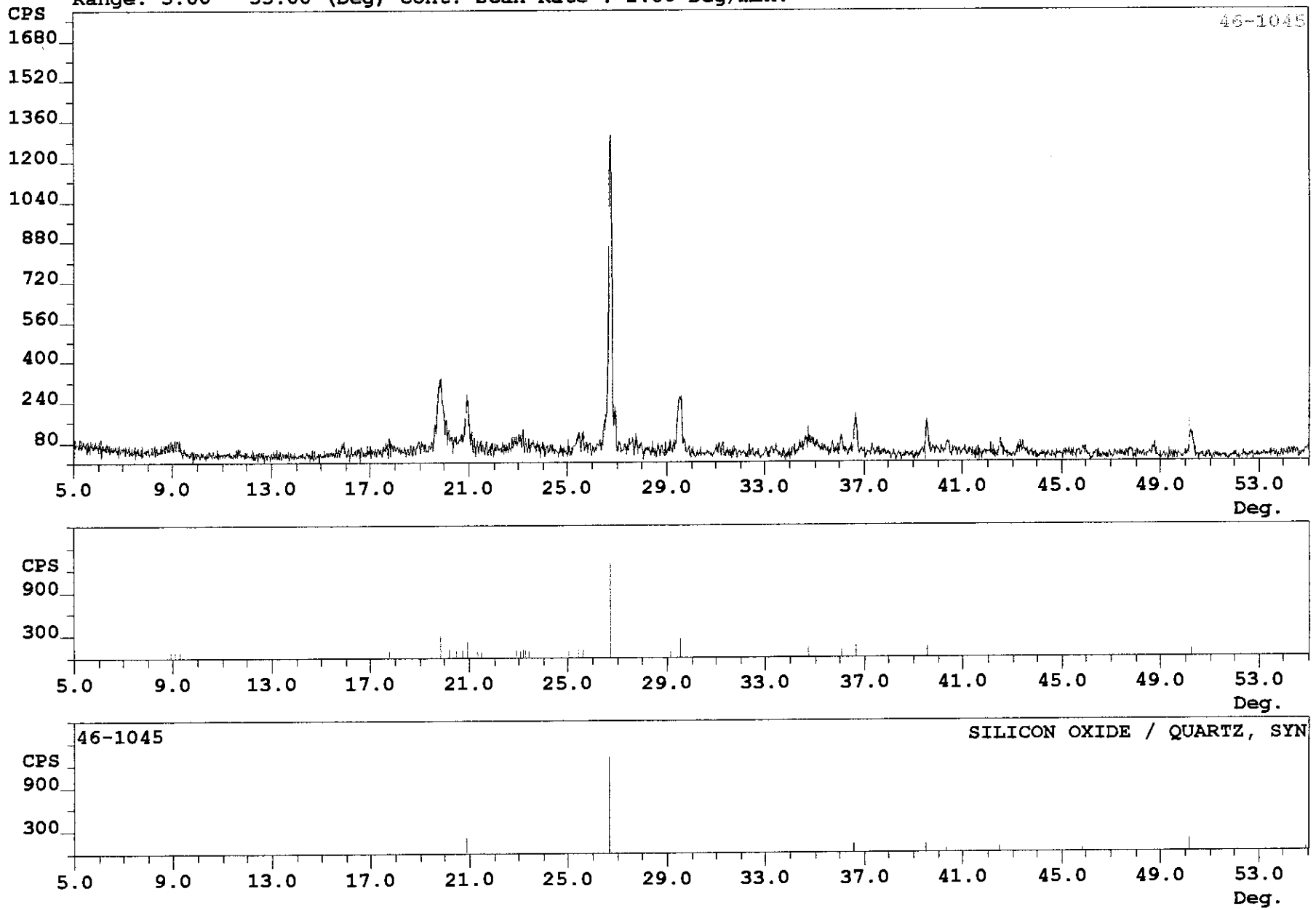
Cell 1
Location 2
5-7' depth
August 2000

File: knick 1-2 5-7', ID: knick 1-2 5-7'
Date: 12/05/00 17:14 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



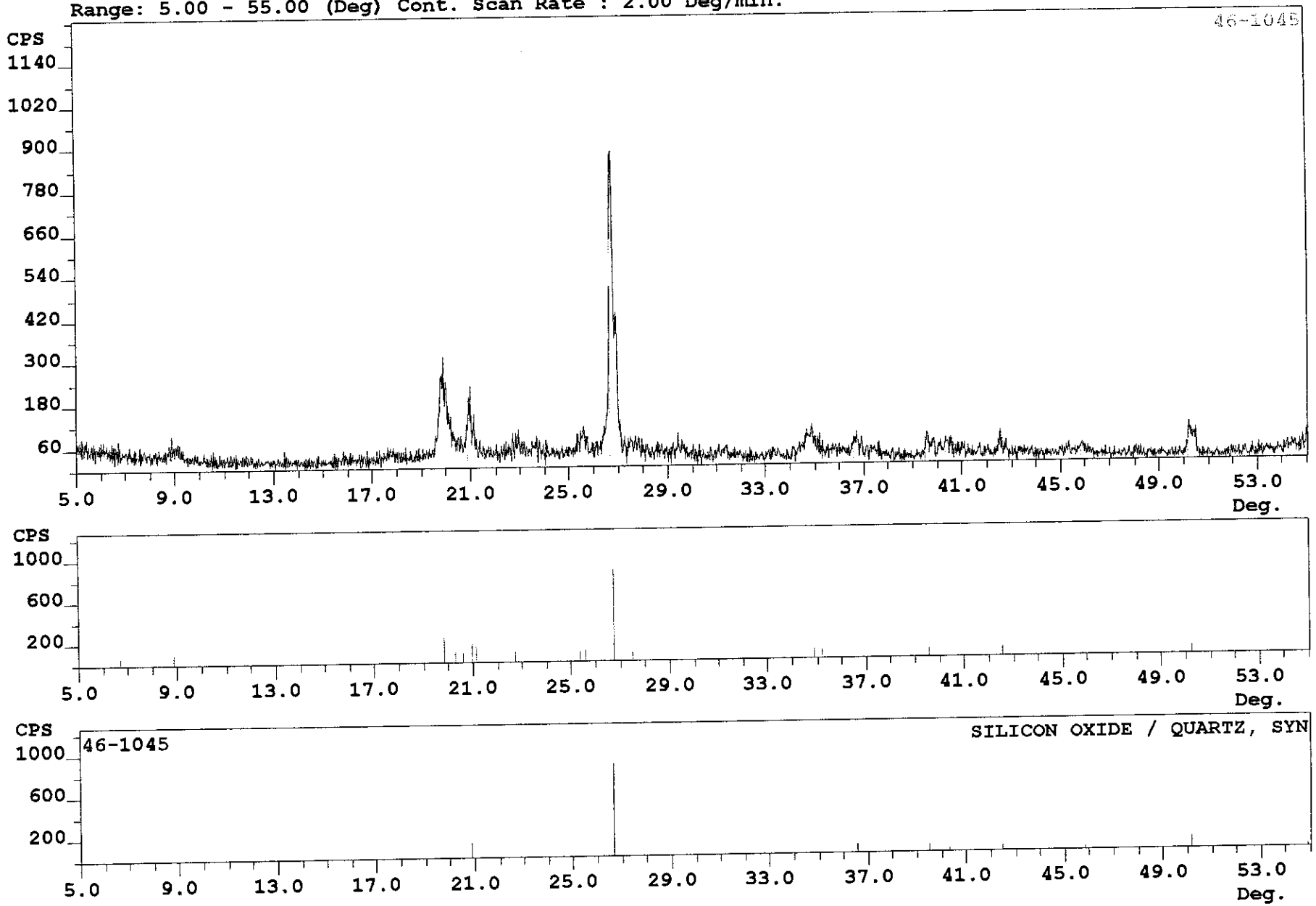
Cell 2
Sample C
0-2' depth
February 2000

File: 2knick, ID:
Date: 04/07/00 15:59 Step : 0.020° Cnt Time: 0.600 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 2.00 Deg/min.

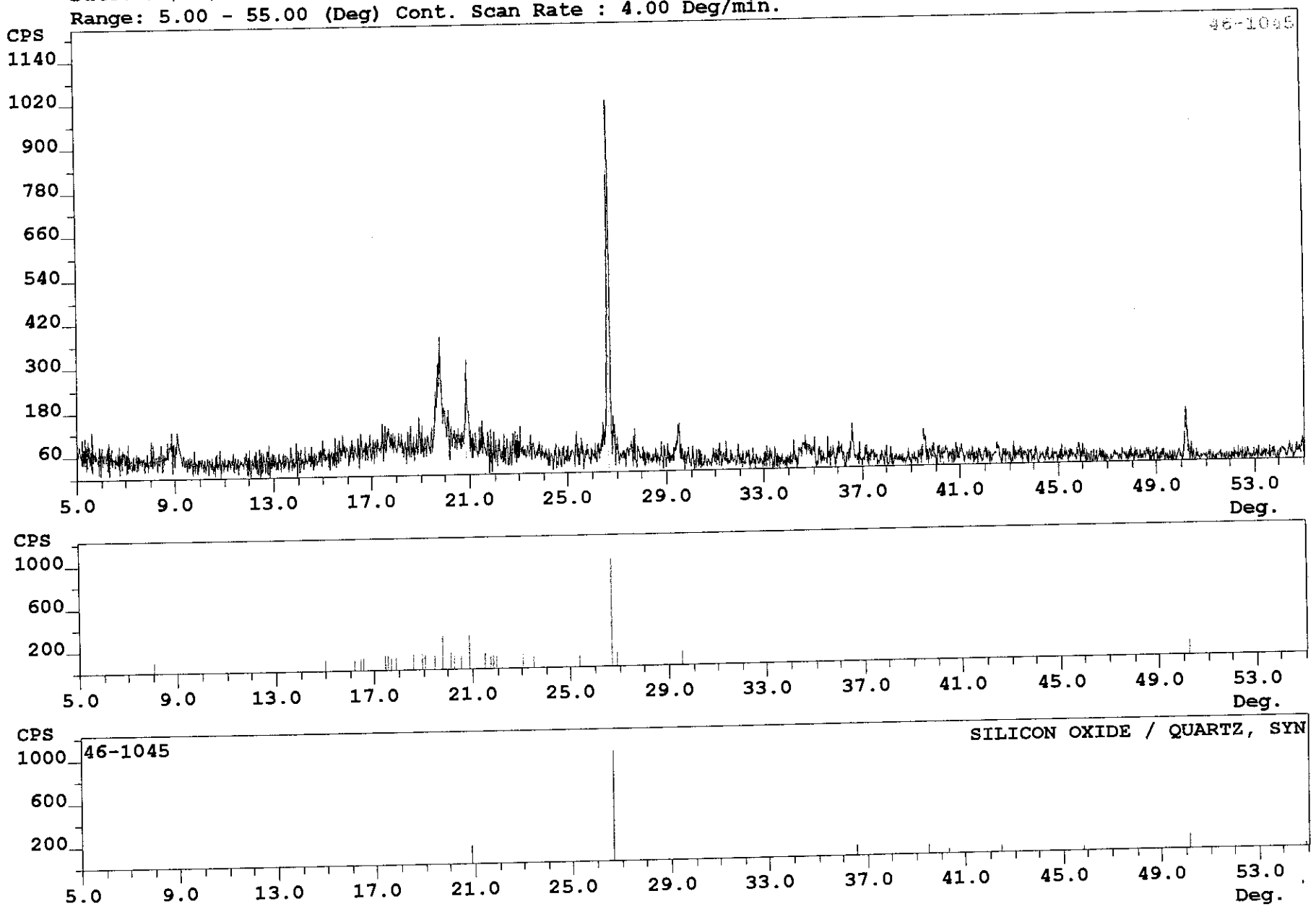


Cell 3
Sample A
6-8' depth
February 2000

File: knick3, ID:
Date: 04/07/00 16:27 Step : 0.020° Cnt Time: 0.600 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 2.00 Deg/min.

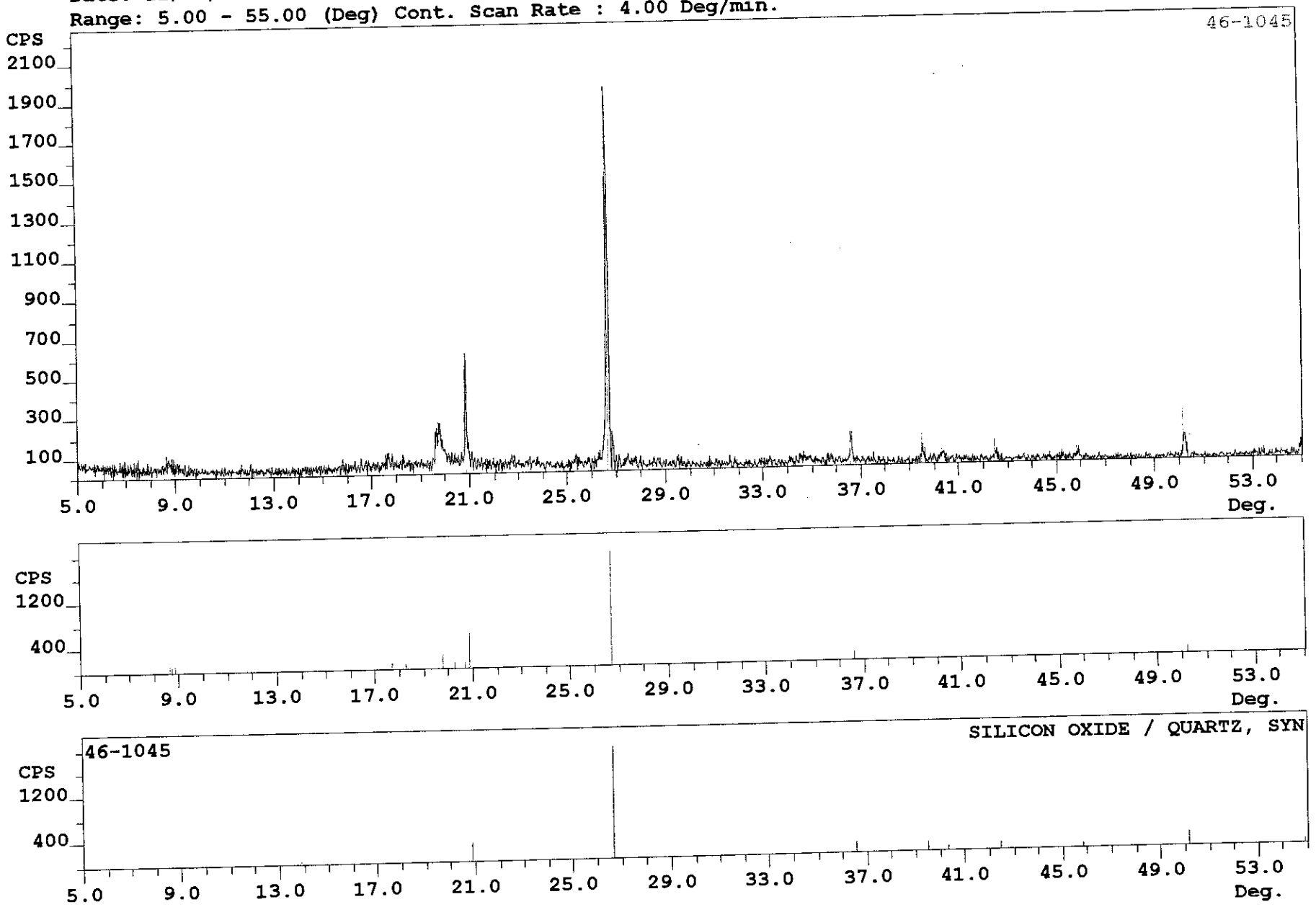


Cell 1
Location 2
0-2' depth
August 2000



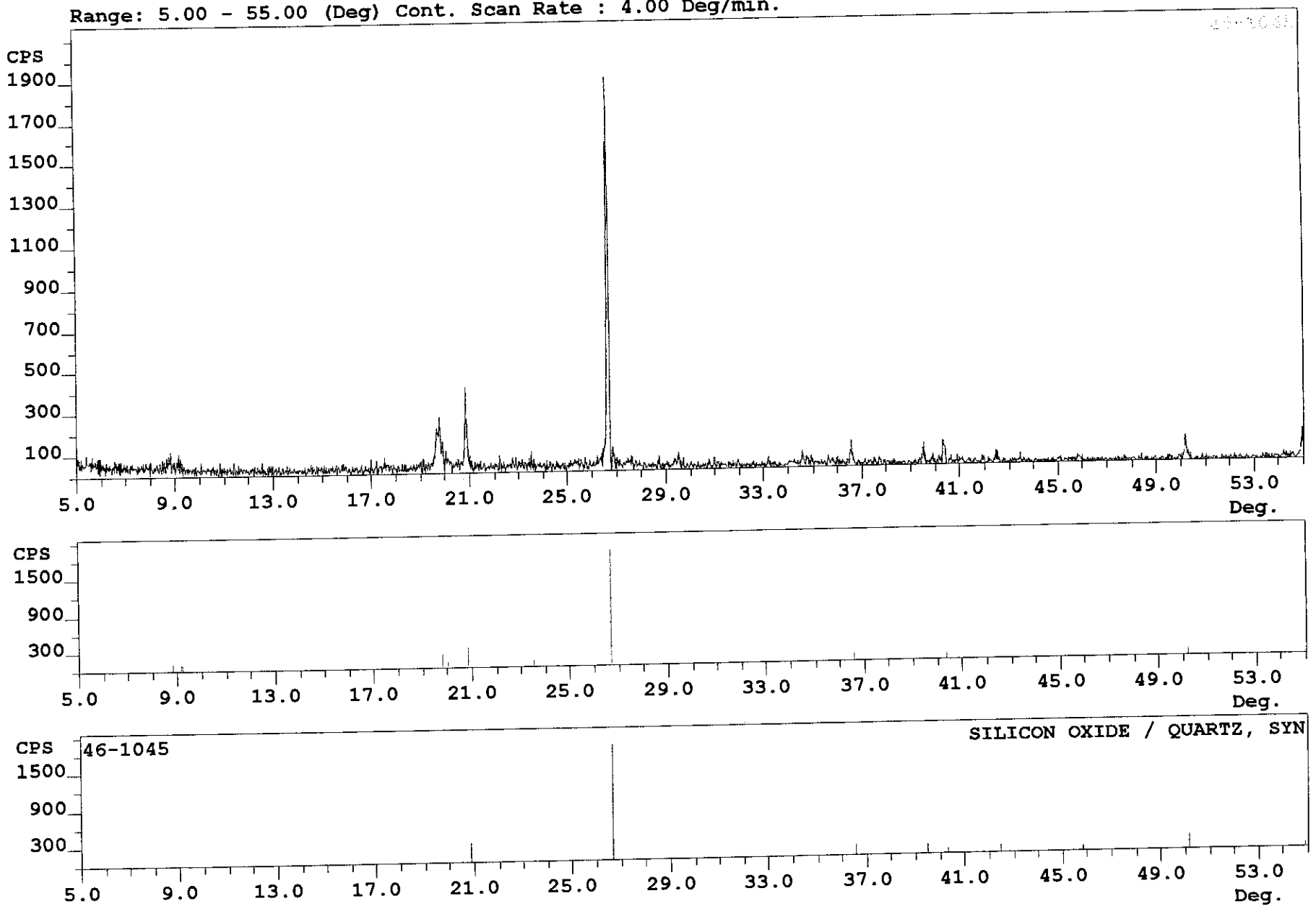
Cell 1
Location 2
15-17' depth
August 2000

File: knick1-2, 15-17'real, ID: knick 1-2, 15-17'real
Date: 12/04/00 16:35 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



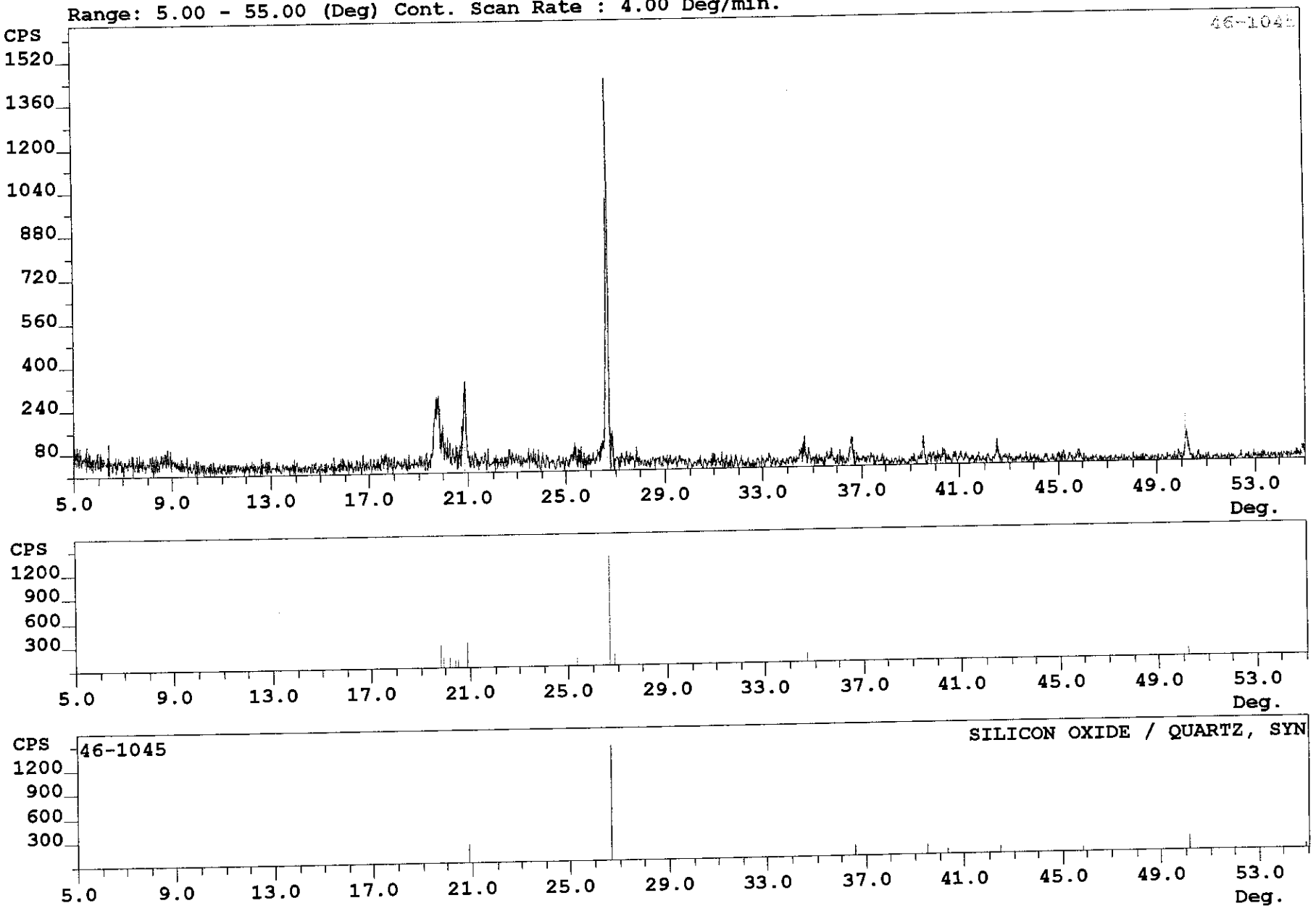
Cell :
Location 1
0-2' depth
August 2000

File: knick 2-1 0-2', ID: knick2-1 0-2'
Date: 12/04/00 17:25 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



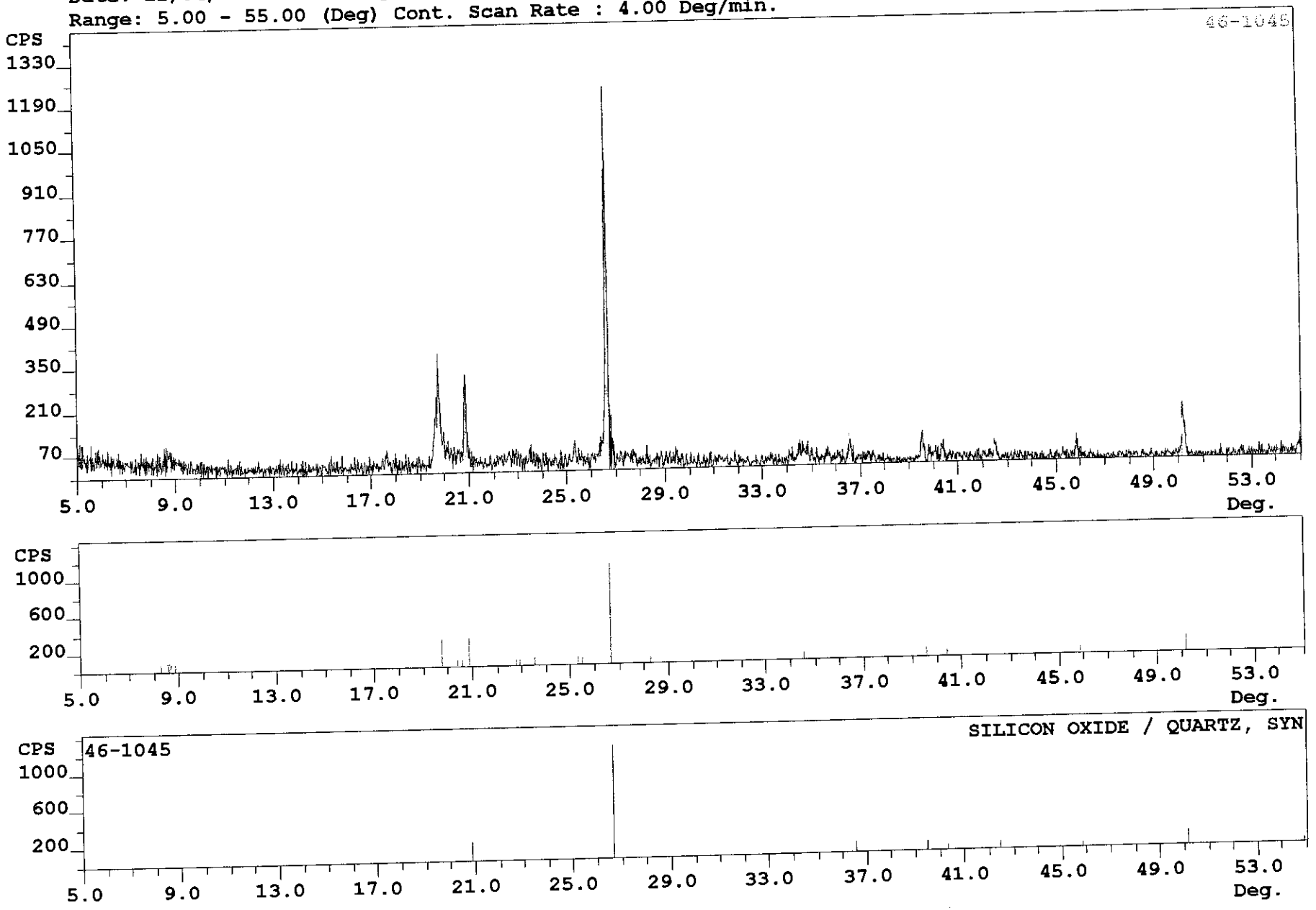
Cell .
Location 1
15-17' depth
August 2000

File: knick3-1 15-17', ID: knick3-1 15-17'
Date: 12/04/00 17:09 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



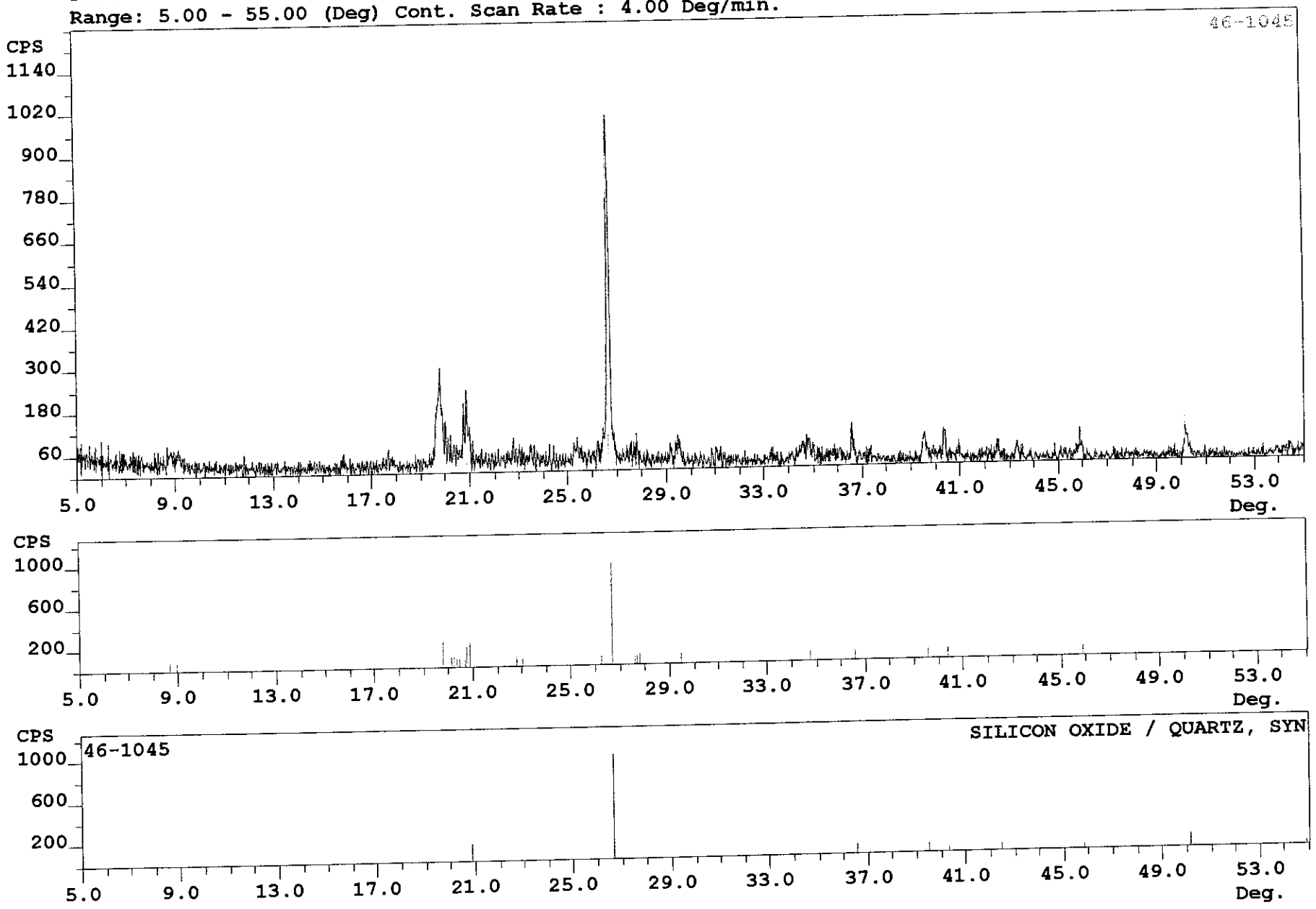
Cell -
Location 2
5-7' depth
August 2000

File: knick4-2 5-7', ID: knick4-2 5-7'
Date: 12/04/00 16:51 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



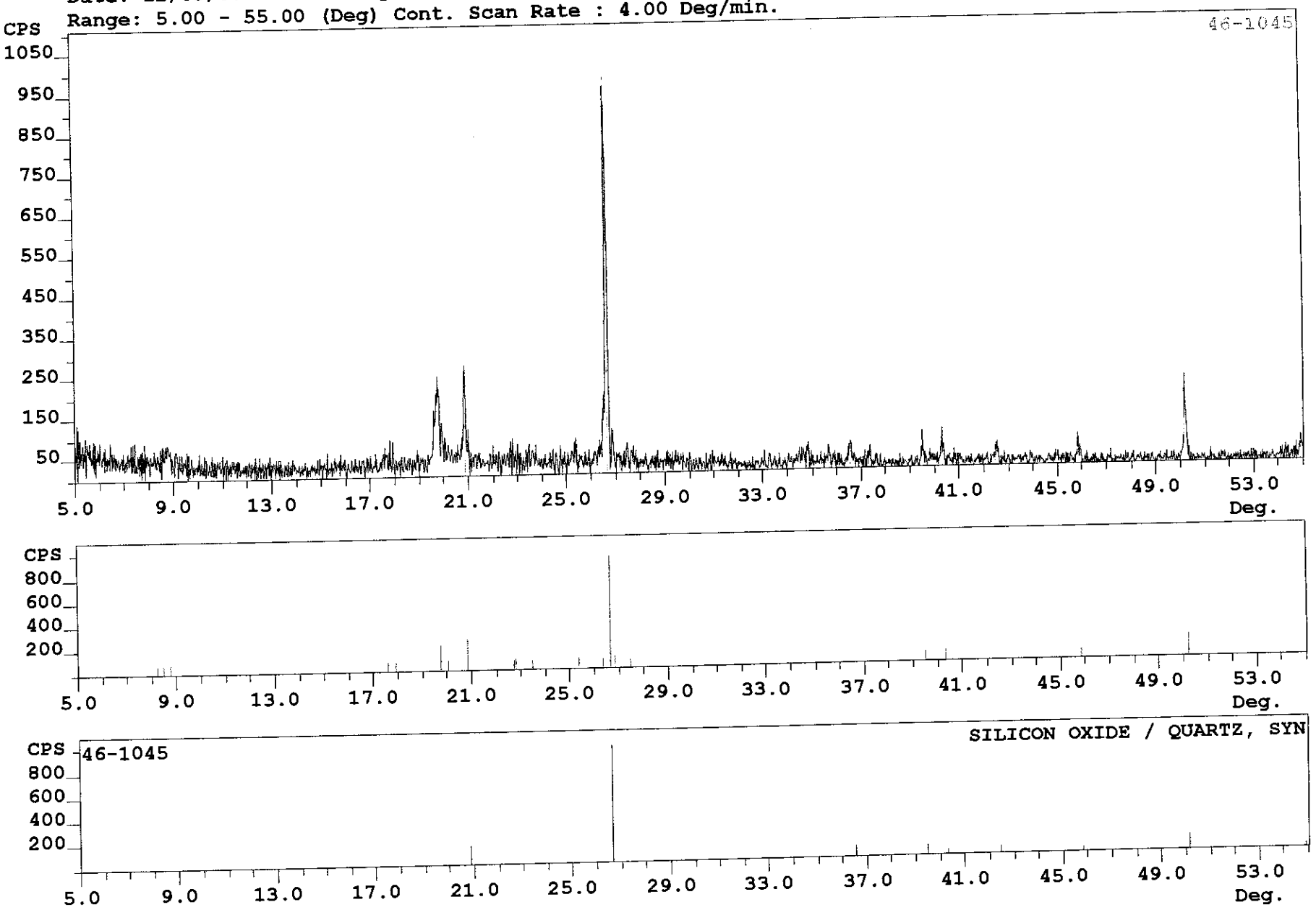
Cell 1
Location 2
4-6' depth
November 2000

File: knick nov00 1-2 4-6', ID: knick nov00 1-2 4-6'
Date: 12/05/00 17:31 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



Cell 4
Location 2
6-8' depth
Novemher 2000

File: knick nov00 4-2 6-8', ID: knick nov00 4-2 6-8'
Date: 12/05/00 17:48 Step : 0.020° Cnt Time: 0.300 Sec.
Range: 5.00 - 55.00 (Deg) Cont. Scan Rate : 4.00 Deg/min.



Appendix 8.G

Soil fertility analysis

03/03/00	5312	089074	CENTRE	00	CELL1	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

AGRICULTURAL ANALYTICAL SERVICES LABORATORY
COLLEGE OF AGRICULTURAL SCIENCES
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:
CAROLINE LOOP
209 MRL
00000

COPY SENT TO:
CAROLINE LOOP
209 MRL
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		9.5		XXXX

03/03/00	5313	089073	CENTRE	00	CELL2	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

AGRICULTURAL ANALYTICAL SERVICES LABORATORY
COLLEGE OF AGRICULTURAL SCIENCES
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:
CAROLINE LOOP
209 MRL
00000

COPY SENT TO:
CAROLINE LOOP
209 MRL
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		9.9		XXXX

03/03/00	5314	089076	CENTRE	00	CELL3	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

AGRICULTURAL ANALYTICAL SERVICES LABORATORY
COLLEGE OF AGRICULTURAL SCIENCES
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:
CAROLINE LOOP
209 MRL
00000

COPY SENT TO:
CAROLINE LOOP
209 MRL
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		9.9		XXXX

03/03/00	5315	089075	CENTRE	00	CELL4	UNSPECIFIED
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

AGRICULTURAL ANALYTICAL SERVICES LABORATORY
COLLEGE OF AGRICULTURAL SCIENCES
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PA 16802
(814 863-0841)

SOIL TEST REPORT FOR:
CAROLINE LOOP
209 MRL
00000

COPY SENT TO:
CAROLINE LOOP
209 MRL
00000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		9.9		XXXX

Appendix 8H

Groundwater Monitoring Data

Reading Anthracite Company
#54793206
Mahanoy Twp., Schuylkill Ct.

MODULE 25 COAL ASH PLACEMENT GROUNDWATER QUALITY PARAMETERS
BACKROUND AND ANNUAL REPORT

Less than this value

DATE SUBMITTED	DATE SAMPLED	ALUMINUM (Al)	ARSENIC (As)	CADMIUM (Cd)	CALCIUM (Ca)	CHLORIDE	CHROMIUM (Cr)	COPPER (Cu)	LEAD (Pb)	MAGNESIUM (Mg)	MERCURY (Hg)	NICKEL (Ni)	POTASS	SELENIUM (Se)	SODIUM	ZINC (Zn)	BARIUM (Ba)	SILVER (Ag)
West pit																		
Maple Hill Shaft #1		*40/48/51*	*76/10/34*															
	10/22/86	0.00	0.00	0.00			0.00	0.00	0.00	21.10	0.00			0.00		0.15	0.00	0.00
	12/05/86	0.00	0.00	0.00			0.00	0.00	0.00	17.50	0.00			0.00		0.15	0.00	0.00
	01/20/87	0.00	0.00	0.00			0.00	0.13	0.00	36.60	0.00			0.00		0.20	0.00	0.00
	02/04/87	0.00	0.00	0.00			0.06	0.00	0.10	23.00	0.00			0.00		0.13	0.00	0.00
	03/05/87	0.00	0.00	0.00			0.00	0.00	0.00	24.00	0.00			0.00		0.17	0.00	0.13
	03/31/87	0.00	0.00	0.00			0.00	0.00	0.00	28.10	0.00			0.00		0.15	0.00	0.00
	10/05/87	0.00	0.00	0.00			0.00	0.00	0.00	25.90	0.00			0.00		0.15	0.00	0.00
	11/02/87	0.00	0.00	0.00			0.00	0.00	0.00	29.20	0.00			0.00		0.12	0.00	0.00
	11/27/87	0.00	0.02	0.00			0.00	0.00	0.00	26.90	0.00			0.00		0.12	0.50	0.00
	12/31/87	0.00	0.00	0.00			0.00	0.00	0.00	22.40	0.00			0.00		0.13	0.00	0.00
	02/01/88	0.00	0.00	0.00			0.00	0.00	0.00	27.80	0.00			0.00		0.18	0.00	0.00
	02/29/88	0.00	0.00	0.00			0.00	0.00	0.00	25.10	0.00			0.00		0.20	0.00	0.00
	03/31/88	0.00	0.00	0.00			0.00	0.00	0.00	23.00	0.00			0.00		0.12	0.00	0.00
	05/02/88	0.00	0.00	0.00			0.00	0.00	0.00	18.80	0.00			0.00		0.10	0.00	0.00
	06/01/88	0.00	0.00	0.16			0.00	0.00	0.00	31.20	0.00			0.00		0.15	0.00	0.00
	06/30/88	1.10	0.00	0.00			0.00	0.00	0.00	28.00	0.00			0.00		0.60	0.00	0.00
	08/01/88	0.90	0.01	0.00			0.05	0.00	0.00	23.30	0.00			0.00		0.21	0.00	0.00
	09/01/88	0.00	0.06	0.00			0.06	0.00	0.00	26.40	0.01			0.00		0.25	0.00	0.00
	09/30/88	0.00	0.00	0.00			0.00	0.00	0.00	35.20	0.00			0.00		0.39	0.00	0.00
	01/03/89	0.00	0.06	0.00			0.09	0.00	0.00	64.60	0.00			0.00		0.14	0.00	0.00
	04/12/89	1.40	0.24	0.00			0.32	0.10	0.00	41.00	0.00			0.00		0.39	0.00	0.00
	06/29/89	1.30	0.00	0.00			0.06	0.08	0.00	82.60	0.00			0.00		0.54	0.00	0.00
	10/25/89		0.22	0.01			0.25	0.06	0.00	46.30	0.00			0.00		1.60	0.00	0.00
	12/22/89	3.80	0.00	0.00			0.12	0.00	0.10	70.00	0.00			0.00		1.20	0.00	0.06
09/27/90	03/23/90	0.00	0.03	0.00			0.00	0.00	0.00	23.80	0.00			0.00		0.60	0.00	0.00
	06/27/90	0.00	0.03	0.00			0.06	0.00	0.00	19.40	0.00			0.00		0.20	0.00	0.00
01/28/91	12/27/90	0.18	0.10	0.00			0.13	0.07	0.00	25.96	0.00			0.00		0.35	0.17	0.00
01/09/92	12/17/91	2.63	0.00	0.00			0.00	0.00	0.13	101.60	0.00			0.00		0.29	0.00	0.03
01/11/92	12/22/92		0.00	0.00			0.10	0.02	0.00	87.20	0.00			0.00		0.71	0.00	0.00
01/14/94	12/20/93		0.02	0.01			0.15	0.61	0.12	20.94	0.00			0.01		10.11	0.10	0.01
02/09/95	12/19/94	4.14	0.01	0.00	181.56		0.00	0.03	0.00	95.40	0.00	0.51		0.01		0.46	0.00	0.00
01/09/96	11/07/95	1.07	0.00	0.00	180.00		0.00	0.03	0.00	54.00	0.00	0.17		0.00		0.64	0.00	0.00
10/18/96	06/18/96	1.05	0.00	0.00	197.00		0.00	0.01	0.00	85.90	0.00	0.12		0.00		0.46	0.01	
	07/02/96	5.27	0.00	0.00	226.00		0.00	0.03	0.00	90.30	0.00	0.25		0.00		0.50	0.01	
	07/16/96	5.87	0.00	0.00	244.00		0.00	0.01	0.00	114.00	0.00	0.33		0.00		1.11	0.01	
	08/13/96	6.97	0.00	0.00	230.00		0.00	0.06	0.01	88.50	0.00	0.32		0.00		1.36	0.01	
01/23/97	10/22/96	7.29	0.03	0.00	160.00		0.00	0.03	0.00	68.80	0.00	0.14		0.00		0.24	0.00	0.00
02/02/98	10/28/97	7.30	0.00		205.00		0.00	0.05	0.00	83.30	0.00	0.21		0.00		0.50	0.00	0.00

02/01/99	11/18/98	3.66	0.00	0.00	200.00		0.00	0.00	0.18	127.00	0.00	0.21		0.00		0.31		
03/09/00	12/20/99	0.62	0.00	0.01	29.90	6.48	0.00	0.02	0.00	1.12	0.00	0.00	0.40	0.00	4.70	1.57		
03/06/01	01/31/01	0.47	*0.01*	*0.01*	6.40	4.86	*0.06*	*0.02*	*0.10*	0.73	*0.00*	0.06	0.06	*0.01*	2.80	0.63		
	11/21/01	0.14	*0.01*	*0.01*	3.65	10.10	*0.05*	*0.02*	*0.10*	0.78	*0.00*	*0.04*	0.29	*0.01*	3.30	0.84		
02/24/03	01/09/03	1.73	*0.01*	*0.01*	89.00	22.70	*0.01*	0.01	*0.03*	38.80	*0.00*	0.10	2.12	*0.01*	30.60	0.63		
Monitoring Holes-South			*40/48/16*		*76/11/53*													
	09/03/87	1.60	0.00	0.00			0.34	0.00	0.20	122.00	0.00			0.00		1.09	0.00	0.00
	10/05/87	0.00	0.00	0.00			0.26	0.00	0.00	165.00	0.00			0.00		0.20	0.00	0.00
	11/02/87	0.00	0.00	0.00			0.23	0.00	0.00	107.00	0.00			0.00		0.20	0.00	0.00
	11/27/87	0.00	0.00	0.00			0.35	0.00	0.00	152.00	0.00			0.00		0.20	0.00	0.00
	12/31/87	0.00	0.00	0.01			0.38	0.00	0.00	82.00	0.00			0.00		0.17	0.00	0.00
	02/01/88	0.00	0.00	0.00			0.48	0.00	0.00	112.00	0.00			0.00		0.59	0.00	0.00
	02/29/88	0.00	0.01	0.01			0.50	0.00	0.10	124.00	0.00			0.00		0.32	2.00	0.00
	03/31/88	0.00	0.00	0.00			0.34	0.00	0.00	90.00	0.00			0.00		0.15	0.00	0.00
	05/02/88	0.00	0.00	0.01			0.32	0.00	0.00	134.00	0.00			0.00		0.42	0.00	0.00
	06/01/88	0.80	0.00	0.00			0.38	0.00	0.00	130.00	0.00			0.00		0.12	0.00	0.00
	06/30/88	1.20	0.00	0.01			0.56	0.17	0.10	107.00	0.00			0.00		0.44	0.00	0.00
	08/01/88	1.20	0.00	0.00			0.38	0.00	0.00	146.00	0.00			0.00		0.50	0.00	0.00
	09/01/88	6.80	0.03	0.03			0.44	0.10	0.30	118.00	0.00			0.00		11.50	0.00	0.07
	09/30/88	1.40	0.00	0.02			0.33	0.00	0.00	118.00	0.00			0.00		0.97	0.00	0.00
	01/03/89	2.00	0.00	0.00			0.32	0.00	0.00	114.00	0.00			0.00		0.47	0.00	0.00
	04/25/89	1.40	0.00	0.00			0.58	0.00	0.70	85.00	0.00			0.00		0.54	0.00	0.00
	06/30/89	0.00	0.00	0.00			0.25	0.00	0.00	70.00	0.00			0.00		0.10	0.00	0.00
	09/28/89	0.80	0.00	0.00			0.25	0.00	0.00	110.00	0.00			0.00		1.15	0.40	0.00
	12/22/89	1.20	0.04	0.00			0.13	0.00	0.00	18.00	0.00			0.00		1.30	0.00	0.00
09/27/90	03/23/90	0.00	0.00	0.00			0.00	0.00	0.00	80.30	0.00			0.00		0.30	0.00	0.00
	06/27/90	0.18	0.00	0.00			0.00	0.00	0.00	84.00	0.00			0.00		0.59	0.00	0.00
01/28/91	12/27/90	0.10	0.00	0.00			0.00	0.00	0.00	59.98	0.00			0.00		0.02	0.21	0.00
01/09/92	12/17/91	0.46	0.00	0.00			0.00	0.04	0.18	1.14	0.00			0.00		0.10	0.00	0.01
01/11/92	12/22/92		0.00	0.01			0.07	0.09	0.00	10.45	0.00			0.00		2.73	0.26	0.00
01/14/94	12/22/93		0.01	0.01			0.05	0.03	0.10	20.93	0.00			0.01		0.38	0.01	0.01
02/09/95	12/19/94	4.57	0.01	0.00	95.19		0.00	0.25	0.33	70.80	0.00	0.41		0.00		3.16	0.00	0.00
01/09/96	11/08/95	3.82	0.00	0.00	260.00		0.00	0.07	0.00	73.30	0.00	0.23		0.00		1.85	0.00	0.00
10/18/96	06/18/96	1.32	0.00	0.00	134.00		0.00	0.02	0.02	37.50	0.00	0.42		0.00		1.12	0.01	
	07/02/96	0.20	0.00	0.00	108.00		0.00	0.00	0.01	29.30	0.00	0.00		0.00		0.15	0.01	
	07/16/96	0.00	0.00	0.00	127.00		0.00	0.00	0.00	34.30	0.00	0.00		0.00		0.12	0.01	
	08/13/96	0.00	0.00	0.00	119.00		0.00	0.01	0.01	31.60	0.00	0.03		0.00		0.33	0.02	
01/23/97	10/22/96	0.26	0.00	0.00	120.00		0.00	0.02	0.00	24.90	0.00	0.00		0.00		0.32	0.00	0.00
02/02/98	10/28/97	34.90	0.02		148.00		0.00	1.72	0.00	78.20	0.00	2.79		0.00		52.00	0.00	0.00
02/01/99	11/18/98	0.19	0.00	0.01	99.00		0.00	0.00	0.13	24.40	0.00	0.00		0.00		0.13		
03/09/00	12/20/99	1.34	0.00	0.01	81.10	11.80	0.00	0.04	0.00	27.10	0.00	0.33	1.87	0.00	13.20	1.17		
03/06/01	12/26/00	0.26	*0.01*	0.01	49.00	10.30	*0.05*	0.03	*0.10*	12.50	*0.00*	*0.04*	1.57	*0.01*	9.10	0.20		
	11/21/01	0.56	*0.01*	0.07	27.00	13.70	*0.05*	0.02	0.40	4.73	*0.00*	*0.05*	1.44	*0.01*	10.20	0.81		
02/24/03	01/09/03	1.73	*0.01*	*0.01*	90.60	11.80	*0.01*	0.01	*0.03*	38.80	0.00	0.10	2.14	*0.01*	30.30	0.65		
Packer V Discharge DG																		
01/09/96	11/07/95	0.23	0.00	0.00	190.00		0.00	0.00	0.00	78.00	0.00	0.08		0.00		0.01	0.00	0.00

10/18/96	06/18/96	0.00	0.00	0.00	232.00		0.00	0.00	0.00	115.00	0.00	0.07		0.00		0.02	0.01	
	07/02/96	0.00	0.00	0.00	179.00		0.00	0.00	0.00	85.50	0.00	0.07		0.00		0.06	0.01	
	07/16/96	0.00	0.00	0.00	182.00		0.00	0.00	0.00	103.00	0.00	0.09		0.00		0.30	0.01	
	08/13/96	0.29	0.00	0.00	172.00		0.00	0.00	0.00	80.10	0.00	0.06		0.00		0.13	0.01	
01/23/97	10/22/96	0.16	0.00	0.00	170.00		0.00	0.00	0.00	76.30	0.00	0.00		0.00		0.00	0.00	0.00
02/02/98	10/29/97	0.00	0.00		0.00		0.00	0.00	0.00	79.50	0.00	0.04		0.00		0.00	0.00	0.00
02/01/99	11/19/98	0.00	0.00	0.00	146.00		0.00	0.00	0.12	97.20	0.00	0.04		0.00		0.00		
03/09/00	12/20/99	0.34	0.00	0.01	137.00	11.50	0.00	0.00	0.00	61.10	0.00	0.11	1.93	0.00	18.70	0.02		
01/10/01	12/26/00	0.12	0.01	0.01	160.00	8.86	*0.05*	*0.02*	*0.10*	82.60	*0.00*	0.06	1.25	*0.01*	11.30	*0.01*		
	11/21/01	*0.10*	*0.01*	*0.01*	125.00	16.90	*0.05*	*0.02*	*0.10*	75.80	*0.00*	*0.04*	1.06	*0.01*	8.59	*0.01*		
02/24/03	01/09/03	*0.02*	*0.01*	*0.01*	142.00	17.00	*0.01*	*0.01*	*0.03*	75.80	*0.00*	0.04	1.66	*0.01*	13.10	0.01		
East pit 08																		
MW #1 - Upgradient well																		
appl	06/01/95	0.00	0.00	0.00	9.26		0.00	0.00	0.00	6.70	0.00	0.00		0.00		0.02	0.00	0.00
01/23/97	12/17/96	0.12	0.00	0.00	6.80		0.00	0.00	0.00	1.60	0.00	0.00		0.00		0.03	0.00	0.00
03/09/00	12/20/99	6.39	0.00	0.03	42.70	0.46	0.06	0.03	0.00	5.45	0.00	0.10	1.22	0.00	2.40	0.64		
01/10/01	12/26/00	0.22	*0.01*	0.01	9.00	*0.02*	*0.05*	*0.02*	*0.10*	4.44	*0.00*	*0.04*	0.95	*0.01*	0.98	0.12		
02/24/03	01/09/03	0.22	*0.01*	*0.01*	6.58	2.60	*0.01*	0.01	*0.03*	2.62	*0.00*	0.02	1.30	*0.01*	2.15	0.32		
MW #2 - Downgradient Well																		
appl	06/01/95	7.58	0.00	0.00	138.30		0.00	0.04	0.00	105.00	0.00	0.00		0.00		0.20	0.00	0.00
DEP	07/16/96	1.04	0.00	0.00	70.80		0.00	0.02	0.00	50.90	0.00	0.07		0.00		0.47	0.02	
01/23/97	10/22/96	1.74	0.00	0.00	97.00		0.00	0.02	0.00	64.00	0.00	0.00		0.00		0.51	0.00	0.00
02/02/98	10/28/97	0.00	0.00		53.00		0.00	0.00	0.00	40.70	0.00	0.00		0.00		0.12	0.13	0.00
	12/20/99	well dry																
01/10/01	12/26/00	0.54	*0.01*	0.01	33.00	5.73	*0.05*	0.02	*0.10*	250.00	*0.00*	0.08	1.64	*0.01*	3.61	0.53		
02/24/03	01/09/03	0.47	*0.01*	*0.01*	31.90	9.51	*0.01*	0.01	*0.03*	93.40	*0.00*	*0.01*	1.49	*0.01*	1.86	0.05		
MW #3 - Downgradient Well																		
appl	06/01/95	7.28	0.00	0.00	105.80		0.00	0.04	0.00	43.20	0.00	0.00		0.00		0.24	0.15	0.00
DEP	07/16/96	3.41	0.00	0.00	87.20		0.00	0.02	0.01	75.70	0.00	0.07		0.00		0.67	0.05	
01/23/97	10/22/96	7.38	0.00	0.05	70.00		0.00	0.05	0.00	69.60	0.00	0.00		0.00		0.34	0.14	0.00
02/01/99	12/17/98	3.91	0.00	0.00	81.00		0.00	0.03	0.00	61.50	0.00	0.09		0.00		0.23		
03/09/00	12/20/99	1.10	0.00	0.01	55.50	0.67	0.00	0.02	0.00	49.20	0.00	0.06	0.94	0.00	2.50	0.09		
01/10/01	12/26/00	0.67	*0.01*	0.01	15.00	2.91	*0.05*	0.02	*0.10*	47.80	*0.00*	*0.04*	0.84	*0.01*	0.86	0.13		
	11/21/01	1.09	*0.01*	0.01	31.70	20.90	*0.05*	0.03	*0.10*	84.10	*0.00*	*0.04*	0.92	*0.01*	3.98	0.29		
02/24/03	01/09/03	0.22	*0.01*	0.01	134.00	3.62	0.01	0.01	*0.03*	189.00	*0.00*	0.01	1.90	*0.01*	4.41	0.13		
MW #4 - Downgradient Well																		
appl	06/01/95	7.35	0.00	0.00	112.70		0.00	0.04	0.00	77.90	0.00	0.00		0.00		0.21	0.12	0.00
01/23/97	12/17/96	0.13	0.00	0.00	14.00		0.00	0.00	0.00	3.70	0.00	0.00		0.00		0.03	0.00	0.00
	12/20/99	well dry																
	12/26/00	well dry																
	11/21/01	well dry																

Reading Anthracite Company
#54793206
Mahanoy Twp., Schuylkill Ct.

Less than this value

MODULE 25 COAL ASH PLACEMENT GROUNDWATER QUALITY PARAMETERS
BACKROUND AND QUARTERLY REPORT

DATE SUBMITTED	DATE SAMPLED	FIELD pH	LAB pH	SPECIF. COND.	ALK	ACID	IRON (Fe)	MANGANESE (Mn)	SULFATE (SO4)	TOTAL DISSOLVED SOLIDS	TOTAL SUSP. SOLIDS	AMMONIA NITROGEN	NITRATE NITROGEN	BICARB	TURBIDITY	CHEM OX DEMAND	FLUORIDE (F)	CHLORIDE (Cl)	SODIUM (Na)
West pit																			
Maple Hill Shaft #1			**Upgradient**																
	10/22/1986		5.96		22.50	0.00	1.31	0.98	105.00	440.00		0.30	0.25				0.15	7.30	
	12/5/1986		6.10		22.00	0.00	1.50	0.86	130.00	248.00		0.20	0.08				0.13	3.40	
	1/20/1987		6.00		20.80	5.70	1.12	0.85	144.00	237.00		0.90	0.23				0.09	5.20	
	2/4/1987		5.95		19.60	1.10	1.26	0.93	130.00	240.00		0.78	0.00				0.10	6.40	
	3/5/1987		6.36		19.80	1.90	1.20	1.70	240.00	340.00		0.06	0.07				0.15	7.70	
	3/31/1987		5.98		19.80	0.00	1.50	1.28	145.00	262.00		0.41	0.11				0.11	6.00	
	10/5/1987		5.96		22.00	84.60	1.45	0.93	129.00	236.00	7.50	0.24	0.14				0.09	9.21	
	11/2/1987		5.83		21.60	18.00	0.95	0.97	119.00	247.00	8.50	0.40	0.06				0.12	4.00	
	11/27/1987		5.84		22.00	52.00	3.16	1.10	119.00	254.00	7.50	0.30	0.08				0.15	5.00	
	12/31/1987		5.89		22.00	66.00	2.40	1.29	213.00	321.00	5.00	0.10	0.07				0.14	5.90	
	2/1/1988		5.77		21.60	35.70	2.30	1.44	192.00	367.00	9.00	0.80	0.00				0.15	12.00	
	2/29/1988		5.96		21.20	27.30	2.60	1.20	150.00	225.00	5.50	1.40	0.09				0.13	7.80	
	3/31/1988		6.14		24.40	0.00	3.70	1.02	109.00	292.00	8.00	0.00	0.11				0.08	4.90	
	5/2/1988		6.03		22.50	0.00	1.18	0.79	149.00	168.00	15.50	0.60	0.06				0.09	16.60	
	6/1/1988		6.04		25.20	0.00	2.90	0.82	129.00	263.00	5.30	0.00	0.14				0.12	10.30	
	6/30/1988		6.15		28.00	0.00	6.50	1.00	160.00	346.00	105.00	0.00	0.10				0.10	4.80	
	8/1/1988		5.93		28.20	10.40	3.45	1.55	160.00	368.00	22.00	0.00	0.00				0.12	8.20	
	9/1/1988		6.05		25.20	0.00	2.40	1.81	149.00	351.00	15.30	0.00	0.17				0.08	8.10	
	9/30/1988		6.02		32.70	0.00	4.60	4.10	139.00	360.00	14.00	0.00	0.06				0.09	7.40	
	1/3/1989		6.39		78.50	129.00	16.90	15.30	248.00	443.00	57.30	0.66	0.63				0.15	1.90	
	4/12/1989		6.84		75.60	0.00	22.90	16.70	140.00	499.00	49.00	0.35	0.15				0.10	10.70	
	6/29/1989		4.94		14.00	49.30	11.60	10.60	645.00	1129.00	9.00	0.15	0.00				0.34	7.20	
	9/28/1989		6.33		33.40	0.00	18.20	5.90	170.00	396.00	34.00								
	12/22/1989		6.73		34.40	0.00	47.10	2.25	448.00	1138.00	278.00	0.00	0.00				0.17	7.70	
09/27/90	3/23/1990		6.02		22.00	0.00	3.50	2.38	139.00	269.00	17.00	0.48	0.21				0.09	7.60	
	6/27/1990		6.03		22.50	2.20	0.50	2.34	107.00	327.00	0.00	0.00	0.08				0.24	9.00	
01/28/91	12/27/1990		6.33	4.93	19.00	0.00	2.11	2.38	119.10	384.00	23.00	0.00	0.00				0.11	9.80	7.14
05/03/91	3/14/1991		6.73	422.00	17.00	0.00	0.95	2.72	229.20	341.00	1.00								
10/30/91	6/20/1991		5.97		17.20	21.00	0.43	2.80	415.00		19.70								
	9/19/1991		5.81		15.20	24.00	0.95	3.20	351.00		20.50								
02/19/92	12/17/1991		5.72	1609.00	72.00	62.00	68.90	15.09	1046.90	1548.00	23.00	0.00	0.00				0.00	2.60	50.40
04/13/92	3/11/1992		5.84	1844.00	71.00	56.00	53.53	17.91	964.30	1469.00	51.00								
07/09/92	4/13/1992		5.57	1995.00	29.00	92.00	47.98	19.93	1000.50		21.00								
	5/20/1992		5.29	1868.00	28.00	96.00	52.11	16.80	1062.90		28.00								
	6/19/1992		5.70	315.00	3.00	10.00	24.05	1.24	77.00		128.00								
04/06/93	1/26/1993		4.78	1915.00	7.00	109.00	31.12	15.91	1096.30		26.00								
	3/5/1993		5.30	2136.00	8.00	41.00	32.67	16.93	1113.50		24.00								
	4/6/1993		5.00	2010.00	8.00	65.00	31.50	16.98	1112.30		28.00								
	5/14/1993		6.48	470.00	21.00	0.00	13.60	1.82	167.50		57.00								
	6/14/1993		5.05	1901.00	5.00	117.00	37.22	17.95	656.90		51.00								
01/14/94	10/22/1993		5.67	1980.00	97.00	115.00	63.30	18.71	1065.20		13.00								
	11/17/1993		5.65	1976.00	45.00	91.00	65.15	17.33	1034.60		28.00								
	12/20/1993		6.25	1322.00	31.00	46.00	86.30	13.03	720.00		98.00	1.00	0.08				1.00	8.30	5.90
04/08/94	2/17/1994		5.61	1904.00	50.00	90.00	52.01	1.37	1056.20		25.00								
	3/9/1994		5.68	1920.00	35.00	74.00	45.73	13.89	949.30		26.00								
7/13/1994	4/27/1994		4.73	1909.00	6.00	81.00	31.41	13.59	1066.10		28.00								
	6/8/1994		5.17	2184.00	5.00	74.00	35.76	15.47	235.95		40.00								
	6/21/1994		5.23	2020.00	3.00	87.00	43.85	15.32	1156.50		52.00								
	7/21/1994		5.89	1778.00	20.00	57.00	51.62	15.56	1049.00	1522.00	52.00	0.00	0.00	20.00	48.00	24.10	0.00	5.52	43.00
2/9/1995	12/19/1994		5.41	2207.00	16.08	71.90	4.43	1.44	19.70	1673.00	24.00	0.00	0.00	16.80	28.00	27.31	0.15	4.58	45.00
5/19/1995	4/20/1995	5.50	5.55	2106.00	2.49	36.70	34.10	17.00	1191.00	1709.00	23.00	0.00	0.00	2.49	14.00	20.70	0.00	5.14	57.90
10/12/1995	8/17/1995	5.50	5.63	2413.00	29.30	57.00	45.85	17.10	1143.00	1570.00	61.00	0.00	0.00	29.30	86.00	23.80	0.00	3.90	64.70
1/9/1996	11/7/1995	4.50	4.22	1361.00	0.00	17.00	2.80	5.61	508.00	890.00	28.00	0.00	0.02	0.00	27.00	0.00	0.00	6.14	25.10

4/15/1996	1/24/1996	5.70	6.10	1378.00	88.00	0.00	43.56	8.77	607.00	931.00	40.00	0.00	0.00	88.00	25.00	0.00	0.00	4.90	6.60
7/17/1996	5/21/1996		6.40	1030.00	52.00	7.20	25.60	7.20	513.00	1028.00	4.00	0.29			1.30		0.00	4.00	10.80
	6/4/1996		6.00	1342.00	46.00	34.00	1.14	7.77	976.00	1260.00	18.00	0.30			24.00		0.20	5.00	9.19
10/18/1996	6/18/1996		5.80	1353.00	46.00	50.00	3.78	7.61	701.00	1432.00	34.00	0.34			91.50		0.00	5.00	15.70
	7/2/1996		5.70	1608.00	44.00	112.00	33.90	16.30	983.00	1714.00	14.00	0.33	0.00		79.50		0.24	5.00	156.00
	7/16/1996		5.60	1771.00	42.00	94.00	41.80	17.90	659.00	2064.00	42.00	0.35	0.04		36.00		0.33	5.00	72.80
	8/13/1996		5.50	1775.00	34.00	100.00	36.80	16.50	1050.00	2218.00	46.00	0.33	0.00		38.00		0.40	4.00	68.80
1/23/1997	12/17/1996		6.00	1072.00	62.00	24.00	11.90	7.30	505.00	920.00	12.00	0.31	0.00		23.00		0.00	3.00	7.36
2/2/1998	1/8/1997		5.30	884.00	16.60	22.00	2.91	6.02	414.00	720.00	8.00	0.05	0.07		7.20		0.00	3.00	26.70
	1/21/1997		5.30	852.00	16.80	54.00	2.59	6.02	411.00	668.00	4.00	0.02	0.05		5.80		0.00	3.00	10.80
	2/6/1997		5.40	759.00	15.20	15.40	1.65	5.38	501.00	468.00	0.00	0.00	0.05		12.30		0.00	4.00	8.52
	2/27/1997		5.60	505.00	15.80	14.20	3.98	3.98	196.00	368.00	0.00	0.00	0.15		11.20		0.00	6.00	11.10
	3/5/1997		5.40	674.00	14.60	13.40	5.49	5.15	284.00	704.00	0.00	0.05	0.11		13.10		0.00	6.00	16.20
4/25/1997	3/18/1997		5.70	515.00	17.20	15.00	2.53	3.62	243.00	418.00	0.00	0.00	0.10		8.70		0.00	7.00	8.32
	4/3/1997		5.70	482.00	18.20	4.80	3.08	30.40	193.00	394.00	6.00	0.00	0.06		5.30		0.00	7.00	7.81
	4/15/1997		5.80	480.00	18.00	6.40	8.52	26.50	197.00	394.00	4.00	0.00	0.09		3.10		0.00	8.00	7.19
	4/29/1997		5.90	507.00	22.00	12.60	2.45	31.20	195.00	436.00	10.00	0.00	0.00		7.60		0.00	8.00	9.06
	5/27/1997		5.80	490.00	22.00	26.00	5.68	4.00	166.00	454.00	22.00	0.00	0.00		18.70		0.00	10.00	9.80
	6/24/1997		5.80	435.00	20.00	3.40	15.10	3.58	151.00	420.00	14.00	0.00	0.00		15.90		0.00	10.00	9.48
	7/29/1997		5.80	436.00	24.00	14.60	9.83	3.17	40.00	378.00	30.00	0.00	0.00		64.50		0.00	10.00	9.38
	8/26/1997		4.90	1780.00	16.80	112.00	25.00	104.00	697.00	1798.00	42.00	0.25	0.00		32.00		0.00	6.00	78.80
8/18/1998	7/15/1998	5.40	5.60	2015.00	7.00	110.40	25.70	13.50	1313.00	1736.00	28.00	1.30	0.00	7.00	31.00	0.00	0.00	15.70	67.50
2/1/1999	11/18/1998	7.00	6.67	1776.00	25.60	48.20	48.80	13.70	960.00	1528.00	48.00								
3/9/2000	2/26/1999		6.36	1696.00	55.00	38.60	39.80	11.50	942.00	1556.00									
	5/12/1999		6.11	1710.00	15.00	25.30	41.10	11.60	952.00	1328.00									
	7/1/1999		6.14	1544.00	8.04	56.90	42.50	11.90	939.00	1274.00									
	8/20/1999		7.49	82.00	27.50	0.00	3.99	0.86	5.03	48.00									4.70
	12/20/1999		6.87	55.00	7.96	3.33	0.76	0.10	6.83	20.00									
10/27/2000	2/1/2000		5.14	61.00	5.38	1.94	1.51	0.23	5.38	43.00	10.00								
	5/25/2000		6.88	46.40	5.00	0.73	36.80	0.59	6.04	40.00	6.00								
	7/27/2000		7.12	38.39	8.00	0.40	0.34	0.02	5.34	16.00	1.00								2.80
3/6/2001	1/31/2001		6.69	46.86	13.80	*0.40*	0.98	0.30	6.30	6.00	24.00								
4/29/2001	3/20/2001		6.62	49.15	7.88	*0.40*	0.19	0.09	4.94	49.00	*1.00*								
10/25/2001	6/15/2001		6.95	36.87	4.90	26.20	0.75	0.34	4.59	15.00	6.00								
	8/10/2001		7.63	41.03	8.16	*0.40*	0.35	0.50	4.84	31.00	3.00								3.30
	11/21/2001		7.55	67.20	5.05	*0.40*	0.70	0.30	7.62	31.00	7.00								
	1/23/2002		7.44	48.30	12.50	*0.40*	1.31	0.74	6.24	26.00	15.00								
	2/25/2002		7.35	41.53	10.20	*0.40*	1.64	1.03	5.73	*1.00*	17.00								
9/11/2002	4/12/2002		7.11	38.62	6.50	*0.40*	1.22	0.74	10.30	11.00	9.00								
	5/16/2002		6.00	37.00	48.70	1.75	3.21	8.69	10.20	12.70	36.00								
	6/13/2002		5.99	1699.00	13.00	1.30	36.80	11.60	9.65	14.60	46.00								
	7/25/2002		8.46	193.00	21.00	*0.40*	7.42	0.18	49.30	17.00	57.00								
1/17/2003	8/15/2002		6.50	1803.00	32.50	0.49	39.50	11.40	1175.00	1620.00	47.00								
	11/29/2002		5.52	1917.00	78.40	*0.40*	28.50	9.68	1340.00	1670.00	50.00								
2/24/2003	1/9/2003		6.34	1569.00	55.40	21.40	24.80	4.91	925.00	1273.00	38.00								
	3/18/2003		6.20	1394.00	38.40	46.40	46.40	8.75	910.00	1254.00	115.00								
7/29/2003	5/14/2003	dry																	
10/27/2003	8/21/2003		6.18	1589.00	5.10	33.60	31.30	9.93	904.00	1350.00	47.00								
Monitoring HolesSouth Downgradient																			
	9/3/1987		6.33		101.00	163.00	174.00	15.40	546.00	1466.00		0.00	0.00				0.12	7.50	
	10/5/1987		6.19		70.40	218.00	99.00	7.30	448.00	1445.00	127.00	0.52	0.00				0.14	9.21	
	11/2/1987		6.10		85.80	219.00	140.00	11.20	546.00	1360.00	150.00	1.30	0.00				0.13	0.00	
	11/27/1987		6.09		132.00	226.00	157.00	14.00	796.00	1420.00	162.00	0.30	0.05				0.20	0.00	
	12/31/1987		6.58		171.00	401.00	167.00	13.50	992.00	1384.00	174.00	0.30	0.00				0.17	5.40	
	2/1/1988		6.30		155.00	318.00	180.00	13.70	910.00	1531.00	241.00	0.60	0.06				0.12	7.00	
	2/29/1988		6.29		162.00	163.00	169.00	13.50	896.00	1381.00	181.00	0.60	0.00				0.11	2.00	
	3/31/1988		6.27		104.00	89.40	145.00	12.20	796.00	1526.00	72.00	1.10	0.00				0.10	5.90	
	5/2/1988		6.35		77.20	129.00	180.00	14.20	909.00	1740.00	6.00	1.80	0.00				0.10	1.90	
	6/1/1988		6.12		92.00	79.00	163.00	13.60	824.00	1519.00	27.50	0.20	0.00				0.16	7.80	
	6/30/1988		6.14		111.00	105.00	172.00	14.20	1068.00	1462.00	282.00	0.00	0.00				0.13	0.00	
	8/1/1988		6.19		148.00	159.00	168.00	13.30	850.00	1759.00	151.00	1.40	0.00				0.14	0.00	

	9/1/1988		6.21		143.00	131.00	175.00	14.30	908.00	1555.00	282.00	0.35	0.00				0.09	0.00	
	9/30/1988		5.96		86.00	120.00	190.00	13.90	824.00	1595.00	143.00	0.77	0.16				0.09	4.80	
	1/3/1989		6.20		108.00	50.50	185.00	13.30	851.00	1438.00	122.00	0.91	0.00				0.14	0.00	
	4/25/1989		6.35		138.00	106.00	172.00	12.40	690.00	1503.00	1.00	0.67	0.09				0.06	0.00	
	6/30/1989		5.95		39.00	47.00	75.50	6.60	747.00	982.00	152.00	0.55	0.13				0.14	18.40	
	9/28/1989		6.36		44.90	3.80	59.50	5.70	520.00	990.00	136.00	0.28	0.00				0.11	11.50	
	12/22/1989		6.74		35.20	1.50	21.90	5.90	214.00	487.00	81.10	0.00	0.00				0.11	8.80	
09/27/90	3/23/1990		7.40		31.00	0.00	20.40	0.55	454.00	880.00	38.00	0.47	0.00				0.12	5.20	
	6/27/1990		6.76		17.10	3.90	17.30	0.60	320.00	896.00	46.00	0.00	0.00				0.20	8.00	
01/28/91	12/27/1990		6.68	1098.00	10.00	0.00	8.53	0.39	495.70	936.00	87.00	0.00	0.00				0.21	7.90	10.22
05/03/91	3/14/1991		5.90	798.00	7.00	11.00	59.10	0.60	479.80	720.00	122.00								
10/30/91	6/20/1991		5.63		10.20	23.00	11.00	1.60	427.00		59.00								
	9/19/1991		5.71		9.10	26.00	12.00	1.85	340.00		61.00								
02/11/90	12/17/1991		6.52	915.00	8.00	6.00	34.33	58.20	528.20	839.00	62.00	0.00	0.00				0.00	7.30	46.10
04/13/92	3/11/1992		5.31	864.00	24.00	78.00	85.60	7.92	378.80	569.00	205.00								
07/09/92	4/13/1992		5.67	912.00	16.00	42.00	53.21	10.46	382.40		127.00								
	5/20/1992		4.42	969.00	0.00	46.00	35.31	7.74	407.00		78.00								
	6/19/1992		5.69	672.00	16.00	8.00	32.49	5.15	173.00		101.00								
04/06/93	1/26/1993		5.43	859.00	12.00	44.00	15.23	6.01	435.40		70.00								
	3/5/1993		5.12	1014.00	5.00	58.00	24.24	10.57	445.40		326.00								
	4/6/1993		5.55	1112.00	14.00	48.00	30.20	12.20	449.10		345.00								
07/06/93	4/19/1993		4.95	1100.00	6.00	28.00	37.18	12.85	535.00		100.00								
	5/14/1993		5.90	1151.00	22.00	35.00	87.14	13.04	472.90		386.00								
	6/14/1993		6.15	901.00	23.00	42.00	92.60	12.14	326.10		225.00								
01/14/94	10/22/1993		5.53	1447.00	15.00	143.00	94.20	13.63	792.10		193.00								
	11/17/1993		5.78	1445.00	43.00	126.00	128.40	12.88	711.40		188.00								
	12/20/1993		5.72	1849.00	28.00	56.00	52.27	14.46	1010.00		25.00	1.00	0.04				1.00	4.42	14.00
7/13/1994	4/27/1994		6.21	1062.00	26.00	0.00	8.50	4.87	439.42		138.00								
	5/24/1994		6.10	1176.00	17.00	27.00	138.90	9.59	294.21		272.00								
	6/21/1994		5.89	1071.00	7.00	14.00	70.20	0.85	500.60		144.00								
	7/21/1994		6.08	1097.00	9.00	26.00	51.10	8.78	555.00	804.00	82.00	0.00	0.58	9.00	100.00	0.00	0.00	3.42	6.20
2/9/1995	12/19/1994		5.17	1194.00	5.03	25.68	2.94	1.18	536.61	802.00	39.00	0.00	0.00	5.03	32.00	47.17	0.12	2.98	3.00
	2/2/1995	6.10	6.07	1103.00	35.53	0.00	35.56	11.69	525.08										
5/19/1995	4/20/1995	4.70	4.97	896.00	1.50	36.70	16.80	9.83	492.00	657.00	42.00	0.00	0.30	1.50	21.00	20.70	0.00	4.28	2.80
	7/21/1995	6.40	5.05	928.00	3.30	19.70	36.40	8.64	472.00										
	8/17/1995	6.70	6.03	1086.00	17.10	10.50	28.62	8.79	457.70	642.00	54.00	0.00	0.00		105.00	35.80	0.00	1.64	2.79
1/9/1996	11/8/1995	4.90	5.40	1415.00	0.00	71.50	52.00	7.80	672.00	1060.00	44.00	0.00	0.00	0.00	33.00	37.90	0.00	7.81	7.80
4/15/1996	2/8/1996	6.40	6.03	1055.00	27.40	0.00	118.00	7.76	574.18	777.00	139.00	0.00	0.13	27.40	42.00	27.74	0.00	5.84	5.00
7/17/1996	5/21/1996		6.10	745.00	12.60	7.40	18.70	0.38	357.00	646.00	20.00	0.35			14.90		0.36	8.00	13.10
	6/4/1996		6.20	753.00	13.20	1.20	0.81	0.19	369.00	658.00	62.00	0.36			22.00		0.36	9.00	11.10
10/18/1996	6/18/1996		6.20	782.00	13.80	8.00	40.90	0.93	375.00	806.00	54.00	0.40			154.00		0.32	9.00	10.20
	7/2/1996		6.10	720.00	12.60	4.00	1.27	0.32	359.00	640.00	14.00	0.40	0.00		11.80		0.42	8.00	12.10
	7/16/1996		6.00	734.00	11.80	6.20	2.95	0.37	317.00	676.00	16.00	0.37	0.00		12.90		0.34	8.00	11.90
	8/13/1996		5.90	743.00	10.60	6.40	5.09	0.33	334.00	698.00	28.00	0.39	0.07		5.10		0.20	8.00	11.90
1/23/1997	12/17/1996		6.10	893.00	30.00	34.00	23.90	0.43	421.00	734.00	150.00	0.35	0.00		61.50		0.00	8.00	11.60
	1/7/1997		6.40	733.00	17.80	4.20	43.50	0.36	300.00	642.00	18.00	0.36	0.00		13.10		0.00	9.00	10.10
	1/21/1997		7.10	703.00	19.20	0.00	15.30	0.21	317.00	528.00	14.00	0.31	0.00		11.40		0.00	9.00	10.80
	2/4/1997		6.40	737.00	20.00	7.20	39.50	0.43	310.00	630.00	0.00	0.33	0.00		14.30		0.26	8.00	11.00
	2/18/1997		6.20	704.00	17.00	5.80	9.74	0.19	299.00	516.00	24.00	0.30	0.00		8.90		0.21	8.00	10.50
	3/5/1997		5.90	700.00	14.80	2.60	7.93	0.34	296.00	550.00	14.00	0.31	0.00		19.60		0.25	8.00	9.37
4/25/1997	3/18/1997		6.30	726.00	17.60	3.00	6.43	0.25	302.00	616.00	8.00	0.32	0.00		11.20		0.25	8.00	9.92
	4/3/1997		6.30	727.00	15.60	0.80	4.70	32.90	329.00	570.00	44.00	0.32	0.00		7.60		0.32	8.00	10.90
	4/15/1997		6.40	733.00	19.40	1.00	11.50	254.00	308.00	548.00	0.00	0.32	0.00		6.90		0.33	9.00	11.30
	4/29/1997		6.30	1243.00	102.00	100.00	18.40	387.00	579.00	1244.00	144.00	0.41	0.00		63.00		0.00	7.00	10.30
	5/27/1997		6.80	754.00	15.80	0.00	6.10	0.18	317.00	688.00	28.00	0.30	0.00		3.30		0.24	9.00	10.60
	6/24/1997		6.00	749.00	15.80	0.60	3.73	0.14	343.00	704.00	16.00	0.29	0.00		1.50		0.27	8.00	9.79
	7/29/1997		6.30	725.00	16.00	7.60	19.30	0.25	372.00	646.00	36.00	0.00	0.00		9.80		0.00	8.00	10.80
	8/26/1997		6.80	725.00	17.00	0.00	21.10	0.26	286.00	710.00	6.00	0.28	0.00		3.80		0.24	8.00	10.90
8/18/1998	7/15/1998	6.20	8.87	689.00	10.00	0.00	23.40	0.34	337.00	540.00	60.00	0.00	0.00	10.00	17.00	22.90	0.00	11.00	10.30
2/1/1999	11/18/1998	7.50	7.99	657.00	9.60	0.00	11.70	0.22	302.00	528.00	22.00								
3/9/2000	2/26/1999		9.31	692.00	15.40	0.00	5.52	0.10	384.00	516.00	32.00								
	5/12/1999		8.12	669.00	22.30	1.20	7.60	0.20	335.00	529.00	33.00								
	7/1/1999		8.84	657.00	28.50	8.90	8.10	0.18	303.00	572.00	34.00								

	8/20/1999		8.15	652.00	22.70	1.50	8.30	0.25	356.00	519.00	33.00									
	12/20/1999		7.88	666.00	39.80	26.80	6.90	0.87	310.00	396.00	39.00									13.20
10/27/2000	5/25/2000		7.52	573.00	19.00	0.40	36.70	0.59	271.00	420.00	78.00									
	7/27/2000		7.98	533.00	20.00	0.40	42.80	0.59	225.00	365.00	92.00									
3/6/2001	9/26/2000	access blocked																		
	12/26/2000		9.08	445.20	6.15	0.40	21.70	0.21	216.00	292.00	26.00									9.10
4/29/2001	3/20/2001	access blocked																		
10/25/2001	6/15/2001		7.48	476.00	11.00	0.40	3.00	0.34	233.00	305.00	38.00									
	8/10/2001		8.72	315.00	13.30	0.40	32.50	0.31	113.00	202.00	60.00									
	11/21/2001		9.23	275.60	15.20	0.40	37.00	0.40	84.50	157.00	112.00									10.20
	1/23/2002		9.06	246.00	15.20	0.40	28.00	0.38	88.00	116.00	89.00									
	2/25/2002		9.32	218.90	20.30	0.40	32.00	0.41	60.70	85.00	58.00									
9/11/2002	4/12/2002		9.19	204.40	16.40	0.40	23.30	0.31	52.60	104.00	84.00									
	5/16/2002		9.24	186.40	14.20	0.40	13.90	0.20	48.50	116.00	44.00									
	6/13/2002		9.16	178.00	13.00	0.40	13.00	0.11	40.00	125.00	42.00									
	7/25/2002		6.14	1920.00	26.30	0.54	40.70	0.11	103.00	160.90	42.00									
1/17/2003	8/15/2002		8.21	181.50	20.30	2.41	9.32	0.18	41.90	129.00	29.00									
	11/29/2002		9.01	144.00	16.30	0.40	11.10	0.20	28.00	107.00	31.00									
2/24/2003	1/9/2003		8.93	129.00	16.40	0.40	24.80	4.93	25.50	75.00	21.00									
	3/18/2003		9.58	122.00	17.50	0.40	7.55	0.08	12.90	86.00	24.00									
7/29/2003	5/14/2003		8.38	145.00	19.50	0.40	2.78	0.18	56.20	90.00	18.00									
10/27/2003	8/21/2003	well dry																		
Packer V Discharge Downgradient																				
	3/15/1995	5.90	6.17	1338.00	122.13	0.00	19.01	8.66	651.72											
5/19/1995	4/20/1995	6.00	6.50	1314.00	127.00	0.00	19.00	8.42	671.00	1083.00	4.00	0.00	0.00	127.00	7.60	0.00	0.00	5.74	8.60	
	7/24/1995	6.20	6.18	1469.00	118.00	0.00	18.50	8.66	679.00	1100.00	33.00	0.00	0.07	118.00		0.00	0.00	6.44	8.79	
1/9/1996	11/7/1995	6.20	6.50	1529.00	117.00	0.00	20.28	8.26	625.00	1030.00	17.00						0.00	5.45	10.00	
4/15/1996	1/24/1996	5.60	6.12	1442.00	129.00	0.00	20.60	8.59	619.00	1050.00	18.00	0.00	0.00	129.00	5.90	0.00	0.00	6.18	7.80	
7/17/1996	5/21/1996		6.30	1302.00	162.00	8.80	16.30	7.78	606.00	1360.00	0.00	0.36			5.80		0.00	5.00	9.36	
	6/4/1996		6.50	1314.00	162.00	0.00	17.80	8.28	657.00	1266.00	8.00	0.39			3.80		0.00	5.00	11.10	
10/18/1996	6/18/1996		6.30	1323.00	162.00	0.00	19.50	8.40	595.00	1514.00	2.00	0.38			134.40		0.00	5.00	10.40	
	7/2/1996		6.50	1279.00	160.00	0.00	20.60	8.38	680.00	1318.00	0.00	0.39	0.00		93.00		0.00	4.00	10.30	
	7/16/1996		6.30	1257.00	162.00	0.00	20.80	9.12	391.00	1518.00	0.00	0.36	0.00		10.70		0.00	6.00	11.00	
	8/13/1996		6.30	1242.00	160.00	0.00	16.30	7.51	587.00	1516.00	4.00	0.34	0.00		11.20		0.00	5.00	9.48	
1/23/1997	12/17/1996		6.30	1351.00	162.00	0.00	20.90	7.90	605.00	1160.00	4.00	0.37	0.00		4.30		0.00	5.00	11.00	
	1/7/1997		6.40	1217.00	166.00	0.00	23.20	8.75	137.00	1126.00	6.00	0.37	0.00		4.10		0.00	5.00	15.20	
	1/21/1997		6.40	1232.00	166.00	0.00	19.80	7.98	540.00	1066.00	4.00	0.34	0.00		4.70		0.00	5.00	11.20	
	2/4/1997		6.40	1236.00	166.00	1.00	75.00	8.21	577.00	1074.00	8.00	0.35	0.00		3.50		0.00	5.00	9.99	
	2/18/1997		6.40	1234.00	170.00	42.00	19.30	8.00	558.00	1016.00	18.00	0.37	0.00		2.50		0.00	5.00	10.30	
	3/5/1997		6.30	1221.00	162.00	0.00	18.10	6.85	567.00	1088.00	12.00	0.36	0.00		20.00		0.00	5.00	7.82	
4/25/1997	3/18/1997		6.50	1205.00	166.00	0.00	24.80	8.21	587.00	1124.00	4.00	0.35	0.00		17.20		0.00	5.00	13.70	
	4/3/1997		6.40	1206.00	160.00	0.00	19.50	68.30	562.00	1138.00	14.00	0.36	0.00		3.90		0.00	5.00	10.90	
	4/15/1997		6.50	1215.00	168.00	0.00	23.20	116.00	52.00	958.00	18.00	0.37	0.00		4.90		0.00	5.00	12.30	
	4/29/1997		6.40	1222.00	168.00	3.20	16.00	97.60	469.00	1278.00	4.00	0.36	0.00		2.40		0.00	5.00	10.40	
	5/27/1997		6.40	1232.00	126.00	17.60	17.20	7.31	476.00	1328.00	0.00	0.36	0.00		3.90		0.00	5.00	10.20	
	6/24/1997		6.40	1232.00	160.00	0.00	20.90	7.81	597.00	1310.00	30.00	0.34	0.00		6.80		0.00	5.00	12.30	
	7/29/1997		6.30	1191.00	154.00	3.00	17.30	7.83	536.00	1280.00	12.00	0.36	0.00		75.30		0.00	6.00	10.70	
	8/26/1997		6.30	1199.00	160.00	0.00	18.50	7.92	491.00	1188.00	16.00	0.38	0.00		6.50		0.00	5.00	10.10	
8/18/1998	6/22/1998		6.40	1293.00	144.00	0.00	18.00	7.90	634.00	666.00	4.00	0.00	0.00	144.00	10.00	32.60	0.00	13.80	13.23	
	7/14/1998	6.50	6.37	1299.00	135.30	0.00	16.50	7.26	617.00	899.00	12.00	0.00	0.00	135.30	1.70	0.00	0.00	9.74	9.20	
10/23/1998	9/28/1998	6.50	6.37	1326.00	121.30	0.00	19.40	7.04	648.00	1058.00	26.00	1.40	0.00	121.30	16.00	0.00	0.00	6.11	11.10	
2/1/1999	10/19/1998	6.70	6.31	1304.00	130.00	0.00	17.70	7.70	647.00	1010.00	6.00	1.40	0.00	130.00	22.00	59.00	0.00	8.11	12.00	
2/1/1999	12/17/1998		6.46	1287.00	139.10	0.00	23.60	7.66	586.00	1120.00	8.00									
7/14/1999	1/28/1999		6.41	1373.00	151.80	0.00	18.10	7.13	569.00	1076.00	12.00									
	2/26/1999		6.36	1326.00	140.80	0.00	17.60	7.10	596.00	1052.00	6.00									
	3/29/1999		6.52	1436.00	122.96	0.00	17.00	10.70	578.00	648.00	12.00									
	4/27/1999		6.94	1287.00	130.00	0.00	17.30	7.09	596.00	1118.00	6.00									
	6/9/1999		6.73	1213.00	126.00	0.00	15.70	9.80	620.00	1100.00	24.00									
3/9/2000	7/1/1999		6.30	1223.00	121.00	0.00	18.40	7.27	604.00	988.00	28.00									
	7/27/1999		6.87	1263.00	80.40	0.00	4.49	7.54	638.00	990.00	24.00									
	8/20/1999		6.83	1225.00	99.00	0.00	2.82	6.46	693.00	1030.00	24.00									

	9/16/1999		6.76	1236.00	112.00	0.00	6.87	5.99	631.00	1106.00	19.00									
	10/28/1999		6.85	1228.00	94.00	0.00	7.12	6.04	535.00	993.00	14.00									
	11/19/1999		6.81	1220.00	88.40	0.00	5.23	5.33	588.00	1025.00	16.00									
	12/20/1999		6.96	1177.00	104.70	0.00	4.31	5.10	506.00	971.00	12.00									18.70
7/31/2000	1/12/2000	no sample																		
	2/1/2000		5.68	1190.00	76.33	*0.40*	4.50	5.70	471.00	817.00	14.00									
	3/16/2000		6.94	1036.00	74.87	*0.40*	6.77	5.23	510.00	923.00	29.00									
	4/28/2000		6.92	1127.00	68.00	*0.40*	4.75	4.67	498.00	823.00	24.00									
	5/25/2000		6.75	950.00	66.00	*0.40*	5.63	4.60	439.00	726.00	53.00									
	6/21/2000		6.88	1084.00	68.00	*0.40*	8.24	5.83	513.00	844.00	39.00									
10/27/2000	7/27/2000		7.24	1092.00	63.00	*0.40*	3.03	5.52	515.00	850.00	16.00									
	8/28/2000		6.67	1124.00	65.33	*0.40*	3.82	6.30	516.00	844.00	35.00									
	9/26/2000		6.82	1097.00	61.30	*0.40*	3.44	6.90	505.00	816.00	20.00									
1/10/2001	10/23/2000		6.88	1142.00	66.30	*0.40*	2.07	6.10	529.00	968.00	7.00									
	12/26/2000		6.39	1336.00	144.00	*0.40*	19.10	8.06	568.00	995.00	8.00									11.30
4/29/2001	3/20/2001		6.35	1313.00	142.00	*0.40*	21.60	8.90	598.00	1004.00	5.00									
10/25/2001	5/21/2001		6.31	1286.00	156.00	*0.40*	18.90	7.74	593.00	970.00	17.00									
	6/15/2001		6.33	1289.00	126.40	*0.40*	19.27	8.50	608.00	967.00	6.00									
	7/9/2001		6.28	1275.00	136.00	*0.40*	20.20	8.23	592.00	972.00	11.00									
	8/10/2001		6.20	1270.00	137.70	*0.40*	21.50	6.25	577.00	1020.00	21.00									
	9/26/2001		6.48	1282.00	137.00	*0.40*	19.90	7.73	630.00	1021.00	*1.00*									
	10/26/2001		6.41	1277.00	135.00	*0.40*	20.00	7.88	625.00	1028.00	3.00									
	11/21/2001		6.39	1354.00	136.40	*0.40*	21.00	8.40	623.00	1026.00	8.00									8.59
	12/26/2001		6.40	1309.00	140.70	*0.40*	18.20	7.80	581.00	925.00	25.00									
	1/23/2002		6.52	1105.00	102.00	*0.40*	19.80	7.03	566.00	1001.00	14.00									
	2/25/2002		6.36	1302.00	147.20	*0.40*	19.20	7.26	582.00	948.00	1.00									
	3/26/2002		6.41	1206.00	112.00	*0.40*	18.80	7.36	602.00	975.00	8.00									
9/11/2002	4/12/2002		6.35	1293.00	145.60	*0.40*	17.40	6.92	601.00	1015.00	6.00									
	5/16/2002		6.33	1257.00	149.20	*0.40*	17.00	6.61	661.00	1007.00	11.00									
	6/13/2002		6.34	1270.00	125.00	*0.40*	23.00	7.82	537.00	1002.00	18.00									
	7/25/2002		6.43	1335.00	146.00	*0.40*	19.70	7.57	603.00	1004.00	16.00									
11/15/2002	8/15/2002		6.45	1272.00	130.00	*0.40*	17.00	6.15	608.00	1043.00	20.00									
	9/28/2002		6.17	1304.00	146.00	*0.40*	20.30	7.73	528.00	1055.00	8.00									
1/17/2003	10/18/2002		6.53	1280.00	128.00	*0.40*	18.40	7.06	632.00	997.00	6.00									
	11/29/2002		6.56	1255.00	147.00	*0.40*	19.00	7.22	687.00	1008.00	1.00									
2/24/2003	1/9/2003		6.21	1257.00	147.00	*0.40*	19.90	7.95	567.00	997.00	7.00									
	3/18/2003		6.31	1165.00	134.70	*0.40*	19.50	7.43	580.00	1030.00	3.00									
10/28/2003	5/14/2003		6.28	1180.00	115.00	*0.40*	18.70	7.14	690.00	1017.00	6.00									
	8/20/2003		6.51	1234.00	111.00	*0.40*	18.50	6.80	582.00	964.00	15.00									
East pit																				
MW #1 Upgradient Well																				
appi	10/24/1994	6.10	5.87	274.00	2.92	50.74	48.09	1.93	103.30	134.00	72.00	1.02	0.00	2.92	64.00	30.43	0.00	0.00	1.10	
	12/14/1994	6.50	5.92	224.00	2.01	37.09	74.00	2.62	92.60	138.00	90.00	0.00	0.00	2.01	61.00	0.00	0.00	2.22	0.70	
	2/2/1995	6.40	5.50	232.00	2.03	35.62	63.40	3.69	96.08	218.00	80.00	0.00	0.00	2.03	35.00	26.30	0.00	2.84	0.80	
	2/23/1995	8.10	5.76	226.00	2.03	48.95	52.23	2.36	95.80	180.00	46.00	0.00	0.00	2.03	59.00	0.00	0.00	0.00	0.30	
	3/15/1995	6.20	5.22	216.00	0.00	37.79	85.20	2.59	91.03	180.00	136.00	0.00	0.73	0.00	50.00	35.88	0.00	5.48	1.50	
	4/20/1995	6.80	5.43	216.00	1.50	39.00	40.90	2.37	90.60	136.00	52.00	0.00	0.32	1.50	28.00	0.00	0.00	3.94	0.90	
	6/1/1995		5.23	168.00	0.98	18.20	32.90	2.38	80.40	131.00	79.00	0.00	0.63	0.98		0.00	0.00	6.05	0.80	
1/15/1996	10/26/1995	9.90	8.43	118.00	10.90	0.00	41.25	0.59	27.90	40.00	108.00	3.18	0.00	10.90	38.00	43.70	0.00	0.00	2.10	
4/15/1996	2/21/1996	4.80	6.62	103.00	12.70	0.00	42.10	0.82	24.35	21.00	88.00	2.77	0.00	12.70	37.00	23.50	0.00	4.71	2.10	
7/17/1996	6/18/1996	5.30	6.12	68.00	16.90	0.00	32.50	0.51	25.87	12.00	70.00	1.20	0.00	16.90	125.00	0.00	0.00	0.00	0.70	
10/18/1996	8/27/1996		6.40	50.00	20.70	0.00	12.00	0.48	15.10	21.00	24.00	0.00	0.00	20.70	45.00	0.00	0.00	2.39	0.70	
1/23/1997	12/17/1996	5.70	7.52	38.00	19.50	0.40	7.92	0.21	0.02	70.00	12.00	0.00	0.00	19.50	8.00	0.00	0.00	1.58	1.10	
4/21/1997	2/27/1997	6.80	7.49	45.00	19.40	11.90	2.66	0.20	0.00	30.00	5.00	0.00	0.00	19.40	10.00	0.00	0.00	1.91	0.00	
2/2/1998	5/27/1997	6.80	7.47	49.00	18.40	0.00	27.70	0.57	0.00	23.00	42.00	0.00	0.00	18.40	17.00	0.00	0.00	2.23	1.20	
	8/26/1997	6.20	7.50	34.00	15.50	0.00	23.80	0.46	0.00	11.00	41.00	0.00	0.00	15.50	15.00	0.00	0.00	0.00	1.04	
	10/28/1997		5.14	852.00	1.96	118.00	46.80	7.38	448.00	684.00	253.00	0.00	0.03	1.96	130.00	0.00	0.00	4.02	4.00	
	11/25/1997	7.50	7.71	51.00	14.90	0.00	19.10	0.42	12.30	78.00	56.00	0.00	0.00	14.90	9.50	0.00	0.00	1.76	1.00	
8/18/1998	1/27/1998	6.00	7.80	62.00	14.90	0.00	13.60	0.34	16.30	34.00	20.00	0.00	0.00	14.90	25.00	0.00	0.00	1.77	0.90	
	6/22/1998		9.02	93.00	22.00	0.00	8.24	0.19	19.80	44.00	8.00	0.00	0.00	22.00	6.70	0.00	0.00	0.57	0.67	
	7/14/1998	7.70	8.95	93.00	23.90	0.00	8.31	0.20	35.60	39.00	20.00	1.20	0.03	23.90	22.00	0.00	0.00	4.38	0.53	
10/23/1998	8/26/1998	5.50	7.81	92.00	45.50	0.00	11.18	0.15	12.80	56.00	36.00	1.80	0.00	45.50	8.00	0.00	0.00	2.45	0.53	

	9/28/1998	8.70	9.02	88.00	14.60	0.00	11.90	0.13	13.60	66.00	42.00	1.80	0.00	14.60	16.00	145.00	0.00	0.00	0.66	
2/1/1999	10/19/1998	7.70	7.51	93.00	27.60	0.00	4.14	0.10	13.80	58.00	38.00	1.60	0.00	27.60	8.00	<20	0.00	5.22	0.78	
2/1/1999	12/17/1998	ns	8.98	86.00	26.80	0.00	19.80	0.28	9.48	74.00	26.00									
7/14/1999	1/28/1999		8.91	97.00	30.80	0.00	12.10	0.20	12.50	92.00	46.00									
	2/26/1999		9.09	100.00	30.80	0.00	7.49	0.12	13.40	28.00	54.00									
	3/29/1999		8.72	88.00	29.68	0.00	15.30	0.26	16.20	56.00	42.00									
	4/27/1999		9.53	107.00	28.60	0.00	6.74	0.07	24.00	20.00	8.00									
	6/10/1999		8.67	114.00	27.10	0.00	10.90	0.23	28.80	136.00	26.00									
11/15/1999	7/2/1999		8.70	118.00	28.10	0.00	8.63	0.17	27.00	96.00	28.00									
	7/27/1999		6.41	165.00	20.10	0.00	81.20	1.01	56.40	106.00	180.00									
	8/20/1999		7.93	123.00	44.00	0.00	28.90	0.46	27.10	62.00	82.00									
	9/16/1999		6.89	154.00	38.00	0.00	19.90	0.31	22.30	66.00	106.00									
3/9/2000	10/28/1999		6.43	144.00	35.00	0.00	22.10	0.34	25.60	64.00	55.00									
	11/19/1999		6.55	133.00	31.00	0.00	17.20	0.29	26.20	58.00	67.00									
	12/20/1999		6.61	145.00	14.90	0.00	29.40	0.32	32.20	86.00	106.00									
7/31/2000	1/12/2000	no sample																		
	2/1/2000	no sample																		
	3/16/2000		9.17	299.00	23.87	0.40	71.30	0.57	25.00	169.00	79.00									
	4/28/2000		9.38	107.10	21.60	0.40	16.50	0.21	20.40	49.00	28.00									
	5/25/2000		8.75	102.20	17.00	0.40	22.20	0.25	20.80	79.00	21.00									
	6/21/2000		8.28	110.30	20.00	0.40	65.90	0.53	25.20	59.00	102.00									
10/27/2000	9/26/2000		6.89	118.70	36.10	4.87	75.00	0.54	29.80	15.00	134.00									
1/10/2001	10/23/2000		6.55	139.30	15.10	*0.40*	36.40	0.64	41.90	118.00	97.00									
	12/26/2000		9.12	100.20	28.70	*0.40*	13.20	0.18	17.10	15.00	14.00									
4/29/2001	3/20/2001		6.44	157.90	9.85	5.12	46.70	0.88	54.00	150.00	146.00									
10/25/2001	6/15/2001		6.91	130.90	14.70	9.10	40.08	0.67	36.40	60.00	104.00									
	7/9/2001		6.77	122.10	12.30	4.20	31.00	0.59	41.00	66.00	112.00									
	8/10/2001		6.25	135.40	15.00	3.33	40.30	0.62	39.60	78.00	120.00									
	9/26/2001		6.76	155.00	13.20	0.40	40.00	0.77	45.40	119.00	98.00									
	10/26/2001		6.82	132.00	15.20	0.40	45.00	1.00	33.60	88.00	101.00									
	11/21/2001		7.78	120.20	22.20	0.40	64.00	1.20	27.20	68.00	103.00									
	12/26/2001		6.26	192.00	12.00	3.10	25.90	1.10	74.50	144.00	86.00									
	1/23/2002		6.60	118.00	15.60	*0.40*	19.30	0.20	35.00	92.00	106.00									
	2/25/2002		6.40	101.20	28.40	*0.40*	12.10	0.14	11.30	82.00	82.00									
	3/26/2002		6.50	107.60	21.30	*0.40*	14.50	0.20	26.00	87.00	95.00									
9/11/2002	4/12/2002		7.45	170.10	19.70	*0.40*	22.00	0.78	55.90	126.00	68.00									
	5/16/2002		9.25	75.80	24.40	*0.40*	2.98	0.20	8.92	39.00	16.00									
	6/13/2002		9.18	74.70	23.00	*0.40*	6.92	0.09	8.10	55.00	8.00									
	7/25/2002		9.47	88.20	29.40	*0.40*	2.84	0.05	8.22	56.00	10.00									
11/15/2002	8/15/2002		7.43	162.90	16.20	*0.40*	27.10	0.70	48.80	106.00	61.00									
	9/28/2002		9.47	86.30	27.30	*0.40*	11.30	0.16	8.95	62.00	19.00									
1/17/2003	10/18/2002		9.75	77.70	32.30	*0.40*	1.17	0.02	16.60	52.00	9.00									
	11/29/2002		7.83	169.00	21.80	*0.40*	27.50	0.72	54.00	128.00	66.00									
2/24/2003	1/9/2003		9.59	72.60	25.60	*0.40*	17.20	0.19	6.33	27.00	16.00									
	3/18/2003		9.54	63.70	24.10	*0.40*	9.27	0.11	4.34	87.00	16.00									
7/29/2003	5/14/2003		9.56	62.20	22.40	*0.40*	1.68	0.03	25.70	88.00	32.00									
10/27/2003	8/21/2003		9.43	58.00	24.40	*0.40*	7.65	0.12	4.04	64.00	16.00									
MW #2	**Downgradient Well**																			
appl	10/24/1994	6.30	6.31	1710.00	77.88	0.00	50.14	4.02	401.90	552.00	140.00	0.00	0.00	77.88	178.00	189.59	0.00	6.24	42.00	
	12/14/1995	6.90	6.49	1142.00	127.64	0.00	83.95	2.80	379.90	626.00	154.00	0.00	0.09	127.64	290.00	384.33	0.06	8.85	6.80	
	2/7/1995	7.20	6.89	729.00	169.51	0.00	43.84	1.22	296.20	594.00	94.00	0.00	0.00	169.51	110.00	21.52	0.00	3.14	3.40	
	3/15/1995	7.00	6.34	999.00	189.41	0.00	95.50	2.37	309.40	716.00	1588.00	0.00	0.88	189.41	660.00	843.24	0.00	6.72	4.60	
	4/20/1995	6.70	6.48	1085.00	164.00	0.00	118.00	2.53	394.00	704.00	1024.00	0.00	0.66	164.00	285.00	403.00	0.00	6.57	4.40	
	6/1/1995		6.10	1071.00	47.04	0.00	138.00	4.93	627.00	950.00	1205.00	0.00	0.69	47.00		88.10	0.00	8.11	2.50	
1/15/1996	12/13/1995	6.80	5.91	2318.00	6.50	124.00	172.00	6.06	1270.00	2020.00	389.00	0.00	0.00	6.50	890.00	73.70	0.21	4.06	3.40	
4/15/1996	2/21/1996	6.30	6.39	517.00	42.00	0.00	42.90	2.25	136.95	242.00	83.00	0.00	0.00	42.00	125.00	0.00	0.00	3.03	2.40	
7/17/1996	6/4/1996		6.40	421.00	74.00	2.00	22.40	2.14	258.00	388.00	32.00	0.09			51.00		0.00	2.00	1.97	
10/18/1996	6/18/1996		6.30	399.00	62.00	0.00	33.60	2.27	132.00	434.00	160.00	0.10			254.10		0.00	2.00	1.66	
	7/2/1996		6.50	458.00	86.00	0.00	33.90	3.20	233.00	400.00	48.00	0.10	0.00		215.00		0.00	3.00	1.79	
	7/16/1996		6.40	594.00	130.00	0.00	44.10	2.77	96.00	622.00	84.00	0.06	0.00		285.00		0.00	2.00	1.73	
	8/13/1996		6.40	591.00	134.00	0.00	27.80	2.58	227.00	564.00	64.00	0.04	0.00		90.30		0.00	2.00	1.66	
1/23/1997	12/17/1996		6.30	469.00	98.00	0.00	51.80	3.62	164.00	328.00	74.00	0.10	0.00		187.50		0.00	2.00	1.97	

?	1/8/1997		6.40	462.00	114.00	0.00	38.60	3.87	156.00	720.00	8.00	0.14	0.00		121.50		0.00	2.00	1.71
	1/21/1997		6.50	472.00	118.00	0.00	40.60	4.16	191.00	292.00	56.00	0.14	0.00		140.70		0.00	3.00	2.06
	2/4/1997		6.40	514.00	120.00	0.00	40.23	3.76	272.00	374.00	36.00	0.11	0.00		125.00		0.00	2.00	1.42
	2/28/1997		6.40	543.00	130.00	0.00	20.90	4.81	299.00	396.00	30.00	0.10	0.00		43.50		0.00	2.00	1.58
	3/6/1997		6.30	514.00	100.00	0.00	3.51	3.28	172.00	304.00	0.00	0.05	0.08		9.30		0.00	1.00	1.28
4/21/1997	3/18/1997		6.50	539.00	118.00	0.00	4.49	3.38	167.00	432.00	4.00	0.05	0.11		5.60		0.00	1.00	1.71
2/2/1998	4/3/1997		6.60	626.00	166.00	0.00	9.45	45.80	205.00	514.00	16.00	0.04	0.09		6.90		0.00	1.00	1.55
	4/15/1997		6.40	502.00	100.00	0.00	7.22	33.20	189.00	388.00	6.00	0.07	0.00		9.10		0.00	1.00	1.43
	4/29/1997		6.60	575.00	140.00	0.00	8.66	41.00	61.00	512.00	14.00	0.07	0.05		7.10		0.00	2.00	1.48
	5/27/1997		6.60	592.00	128.00	0.00	9.35	4.96	179.00	584.00	32.00	0.04	0.00		8.90		0.00	1.00	1.16
	6/24/1997		6.50	596.00	140.00	0.00	54.40	36.70	186.00	542.00	74.00	0.00	0.00		195.00		0.00	1.00	1.28
	7/29/1997		6.20	843.00	88.00	0.00	161.00	4.35	367.00	802.00	286.00	0.03	0.00		500.00		0.00	1.00	1.44
	8/26/1997		6.50	1188.00	564.00	0.00	167.50	1.23	553.00		20.90	0.43	0.00		60.00		0.00	2.00	2.73
8/18/1998	3/30/1998		6.70	212.00	306.90	0.00	29.68	1.11	309.00	0.00	59.00	0.00	0.12	306.90	2.00	0.00	0.00	1.44	2.15
	6/22/1998		6.61	657.00	98.00	0.00	49.90	1.17	256.00	374.00	92.00	0.00	0.00	98.00	78.00	0.00	0.00	1.14	1.31
	7/14/1998	6.90	6.51	779.00	68.70	0.00	51.00	1.30	339.00	467.00	108.00	0.00	0.10	68.70	64.00	28.00	0.00	1.42	0.98
10/23/1998	8/26/1998	6.10	7.52	828.00	65.00	0.00	8.39	0.60	429.00	548.00	24.00	0.00	0.00	65.00	16.00	0.00	0.00	0.00	1.44
	9/28/1998	7.30	6.35	1355.00	12.90	17.80	113.70	2.27	746.00	1284.00	200.00	1.40	0.00	12.90	52.00	53.00	0.00	1.57	1.06
2/1/1999	10/19/1998	well dry																	
2/1/1999	11/10/1998	well dry																	
2/1/1999	12/17/1998	well dry																	
7/14/1999	1/28/1999		6.54	1781.00	136.40	0.00	31.40	2.70	867.00	1410.00	376.00								
	2/26/1999		6.22	1934.00	37.40	37.30	107.00	3.80	1266.00	1834.00	114.00								
	3/29/1999		6.28	1989.00	3.18	56.80	79.50	4.90	1217.00	1652.00	146.00								
	4/27/1999		6.78	1701.00	31.80	0.00	73.00	2.51	1020.00	1510.00	130.00								
	6/9/1999		5.79	1789.00	10.10	32.10	92.70	2.73	1215.00	1722.00	152.00								
11/15/1999	8/19/1999		6.81	1813.00	33.00	22.75	37.70	2.56	1180.00	1555.00	108.00								
	9/16/1999		6.56	1801.00	35.40	18.70	31.00	2.40	1205.00	1540.00	115.00								
3/9/2000	10/28/1999		well dry																
	11/19/1999		well dry																
	12/20/1999		well dry																
7/31/2000	1/12/2000	no sample																	
	2/1/2000	no sample																	
	3/16/2000		6.31	1890.00	54.25	*0.40*	65.50	3.41	1210.00	1782.00	251.00								
	4/28/2000		6.86	1583.00	219.20	*0.40*	60.50	1.82	699.00	1121.00	108.00								
	5/25/2000		6.46	1477.00	239.00	*0.40*	43.30	0.84	660.00	1163.00	110.00								
	6/21/2000		6.70	1431.00	370.00	*0.40*	52.10	0.74	580.00	1060.00	103.00								
10/27/2000	7/27/2000		7.02	1410.00	235.00	*0.40*	47.40	0.72	581.00	1098.00	96.00								
	8/28/2000		6.36	1338.00	173.87	*0.40*	54.70	0.83	604.00	1062.00	118.00								
	9/26/2000		6.47	1350.00	110.30	*0.40*	96.00	1.22	596.00	995.00	147.00								
1/10/2001	10/23/2000		6.29	1490.00	54.30	*0.40*	94.00	1.75	735.00	1224.00	170.00								
	12/26/2000		6.16	2186.00	94.30	*0.40*	158.00	5.84	1260.00	1834.00	186.00								
4/29/2001	3/20/2001		6.14	2309.00	36.50	89.40	153.00	5.50	1510.00	1912.00	142.00								
10/25/2001	5/21/2001		6.41	1762.00	89.10	*0.40*	94.80	2.53	938.00	1452.00	188.00								
	6/15/2001		6.49	1779.00	122.50	*0.40*	104.30	2.29	886.00	281.00	167.00								
	7/9/2001		6.11	1622.00	87.00	*0.40*	61.00	2.33	912.00	1444.00	177.00								
	8/10/2001		5.93	1597.00	51.00	*0.40*	26.80	2.45	1242.00	1597.00	169.00								
	9/26/2001		well dry																
	11/21/2001		well dry																
	12/26/2001		well dry																
9/11/2002	5/16/2002		8.01	1040.00	365.40	*0.40*	5.26	0.41	280.00	647.00	41.00								
	6/13/2002		8.24	704.00	366.00	*0.40*	14.30	0.50	204.00	555.00	34.00								
	7/25/2002		8.79	899.00	320.00	*0.40*	9.50	0.23	186.00	559.00	34.00								
11/15/2002	8/15/2002		8.48	865.00	342.00	*0.40*	19.90	0.39	155.00	552.00	63.00								
	9/28/2002		7.61	1023.00	261.00	*0.40*	11.70	0.68	303.00	739.00	42.00								
1/17/2003	10/18/2002		8.02	948.00	225.00	*0.40*	9.93	0.81	329.00	662.00	46.00								
	11/29/2002		8.02	846.00	178.00	*0.40*	17.40	0.58	273.00	594.00	52.00								
2/24/2003	1/9/2003		8.08	813.00	159.00	*0.40*	14.90	0.61	288.00	541.00	43.00								
	3/18/2003		8.43	586.00	95.30	*0.40*	4.76	0.32	92.00	572.00	61.00								
7/29/2003	5/14/2003		8.40	670.00	87.70	*0.40*	4.97	0.38	284.00	538.00	24.00								
10/27/2003	8/21/2003		well dry																

MW #3 Downgradient Well

appl	10/24/1994	6.20	6.53	1254.00	14.61	0.00	24.77	0.99	438.50	606.00	80.00	2.66	0.00	14.61	51.00	189.59	0.00	11.68	102.00
	12/14/1994	9.30	8.98	963.00	29.15	0.00	16.54	0.63	319.40	916.00	636.00	2.53	0.00	27.13	54.00	144.43	0.16	2.72	52.00
	2/2/1995	7.20	6.36	758.00	11.17	0.89	32.34	0.80	363.50	508.00	63.00	3.41	0.00	11.17	35.00	43.03	0.00	5.07	22.20
	2/23/1995	7.40	7.55	1021.00	25.38	0.00	17.28	1.04	463.40	652.00	48.00	2.66	0.00	25.38	28.00	26.85	0.00	5.22	16.10
	3/15/1995	8.80	8.65	972.00	23.81	0.00	32.33	0.80	472.11	788.00	186.00	2.39	0.91	23.81	75.00	107.65	0.00	9.58	27.00
	4/20/1995	9.40	9.31	945.00	17.00	0.00	12.30	0.30	492.00	818.00	146.00	2.01	0.43	9.46	34.00	84.40	0.00	7.61	26.80
	6/1/1995		8.96	842.00	13.72	0.00	34.20	0.56	462.00	715.00	1665.00	1.93	0.84	13.30		37.80	0.00	11.10	25.10
1/15/1996	10/26/1995	10.30	9.49	1026.00	24.60	0.00	54.09	0.95	450.00	770.00	1100.00	2.90	0.00	24.60	340.00	598.00	0.00	3.53	29.00
4/15/1996	2/26/1996	6.10	6.85	1149.00	22.00	0.00	29.20	1.11	435.29	675.00	71.00	2.27	0.00	22.00	47.00	0.00	0.00	1.29	10.50
7/17/1996	5/21/1996		6.30	922.00	28.00	8.80	43.90	1.76	463.00	838.00	36.00	1.58			35.00		0.00	2.00	11.80
	6/4/1996		6.60	895.00	32.00	0.00	11.60	1.49	431.00	766.00	230.00	1.71			175.50		0.00	2.00	9.23
10/18/1996	6/18/1996		6.50	924.00	36.00	0.00	1.79	1.13	480.00	1058.00	18.00	1.40			12.10		0.00	2.00	7.44
	7/2/1996		7.00	822.00	36.00	0.00	3.72	1.17	418.00	864.00	8.00	1.47	0.00		11.60		0.00	2.00	8.92
	7/16/1996		7.40	857.00	36.00	0.00	43.70	1.58	394.00	912.00	184.00	1.29	0.00		65.10		0.00	1.00	9.61
	8/13/1996		7.50	828.00	36.00	0.00	4.32	0.63	403.00	910.00	14.00	1.46	0.00		4.60		0.00	0.00	8.65
1/23/1997	12/17/1996		6.50	725.00	88.00	0.00	25.40	1.40	317.00	532.00	36.00	1.14	0.00		54.00		0.00	1.00	5.90
	1/8/1997		6.60	684.00	82.00	0.00	10.30	1.71	311.00	462.00	22.00	1.36	0.00		22.60		0.00	0.00	6.72
	1/21/1997		7.10	675.00	88.00	0.00	6.67	1.55	333.00	488.00	14.00	1.38	0.00		13.60		0.00	1.00	6.42
	2/6/1997		7.00	691.00	82.00	0.00	4.57	1.36	429.00	510.00	0.00	1.28	0.00		12.60		0.00	1.00	5.13
	2/27/1997		6.80	682.00	84.00	0.00	7.84	1.51	306.00	502.00	8.00	1.25	0.00		17.90		0.00	1.00	5.93
	3/5/1997		6.60	698.00	74.00	0.00	4.43	1.37	276.00	512.00	4.00	1.18	0.00		24.00		0.00	1.00	5.41
4/21/1997	3/18/1997		6.70	680.00	72.00	0.00	4.65	1.38	287.00	570.00	4.00	1.15	0.00		24.00		0.00	1.00	5.74
	4/3/1997		6.80	687.00	68.00	0.00	5.02	77.60	300.00	556.00	24.00	1.16	0.00		10.90		0.00	0.00	5.63
	4/15/1997		6.80	678.00	62.00	0.00	4.59	44.10	297.00	560.00	18.00	1.13	0.00		11.20		0.00	0.00	5.27
	4/29/1997		7.30	723.00	68.00	0.00	88.50	1.85	298.00	1632.00	396.00	0.99	0.00		160.00		0.00	0.00	5.72
	5/27/1997		8.20	706.00	48.00	0.00	1.27	0.48	292.00	632.00	20.00	0.93	0.00		3.60		0.00	0.00	4.87
	6/24/1997		8.10	715.00	34.00	0.00	1.50	0.29	304.00	734.00	22.00	0.83	0.00		1.60		0.00	0.00	4.45
	7/29/1997		7.80	727.00	26.00	0.00	31.70	0.57	330.00	710.00	138.00	0.75	0.00		70.00		0.00	0.00	4.17
	8/26/1997		7.20	761.00	74.00	0.00	6.89	3.41	292.00	722.00	14.00	0.89	0.00		16.30		0.00	0.00	5.09
8/18/1998	1/27/1998	5.30	7.31	1147.00	141.00	0.00	32.09	1.98	515.00	1120.00	230.00	0.00	0.00	141.00	55.00	0.00	0.00	1.98	2.70
	6/22/1998		8.20	885.00	78.00	0.00	13.40	0.64	407.00	486.00	28.00	0.00	0.00	78.00	22.00	27.60	0.00	0.00	2.25
	7/14/1998	7.50	8.46	925.00	59.70	0.00	10.30	0.75	468.00	456.00	24.00	0.00	0.00	59.70	18.00	0.00	0.00	7.20	1.60
10/23/1998	8/26/1998	6.70	6.42	996.00	68.30	0.00	73.60	1.95	524.00	630.00	160.00	0.00	0.00	68.30	56.00	23.80	0.00	5.91	0.89
	9/28/1998	8.00	7.51	779.00	35.60	0.00	14.20	1.31	358.00	610.00	48.00	1.40	0.00	35.60	32.00	0.00	0.00	1.45	1.34
2/1/1999	10/19/1998	7.70	7.18	677.00	22.80	0.00	5.38	0.46	340.00	474.00	42.00	3.30	0.00	22.80	15.00	20.00	0.00	0.00	1.14
2/1/1999	12/17/1998		7.84	657.00	55.30	0.00	64.50	1.58	300.00	504.00	164.00								
7/14/1999	1/28/1999		7.17	752.00	99.00	0.00	11.90	1.66	284.00	538.00	42.00								
	2/26/1999		7.80	708.00	83.60	0.00	14.40	1.20	298.00	550.00	50.00								
	3/29/1999		7.06	818.00	53.00	0.00	5.84	1.37	324.00	632.00	40.00								
	4/27/1999		8.77	728.00	31.80	0.00	6.79	0.65	362.00	594.00	10.00								
	6/9/1999		7.83	708.00	44.20	0.00	14.30	0.91	360.00	0.00	58.00								
11/15/1999	7/2/1999		8.18	698.00	44.20	0.00	14.90	0.75	331.00	524.00	66.00								
	7/27/1999		7.75	712.00	52.30	0.00	24.60	0.27	306.00	486.00	80.00								
	8/20/1999		7.43	960.00	51.90	0.00	20.00	1.49	411.00	596.00	80.00								
	9/16/1999		7.51	775.00	58.20	0.00	23.00	1.15	388.00	574.00	61.00								
3/9/2000	10/28/1999		7.32	724.00	47.30	0.00	18.00	0.98	359.00	535.00	67.00								
	11/19/1999		7.45	711.00	52.60	0.00	21.00	1.01	324.00	530.00	62.00								
	12/20/1999		7.41	663.00	47.80	0.00	17.40	0.86	297.00	496.00	52.00								
7/31/2000	1/12/2000	no sample																	
	2/1/2000	no sample																	
	3/16/2000		7.39	656.00	48.83	*0.40*	16.50	0.97	318.00	602.00	48.00								
	4/28/2000		7.66	82.90	12.00	*0.40*	7.62	0.41	18.00	34.00	30.00								
	5/25/2000		6.88	634.00	37.00	1.03	12.10	0.64	288.00	482.00	38.00								
	6/21/2000		7.52	665.00	34.00	*0.40*	31.40	1.18	307.00	443.00	88.00								
10/27/2000	7/27/2000		7.44	656.00	35.00	*0.40*	27.40	1.21	280.00	379.00	73.00								
	8/28/2000		7.30	681.00	27.14	*0.40*	20.90	0.94	325.00	464.00	68.00								
	9/26/2000		7.60	655.00	20.10	*0.40*	28.80	0.76	294.00	443.00	68.00								
1/10/2001	10/23/2000		7.92	675.00	17.10	*0.40*	20.70	0.80	324.00	439.00	63.00								
	12/26/2000		7.09	680.00	89.20	*0.40*	31.60	1.53	231.00	436.00	34.00								
4/29/2001	3/20/2001		7.51	744.00	52.20	*0.40*	27.30	0.96	336.00	569.00	76.00								
10/25/2001	5/21/2001		7.63	751.00	33.50	*0.40*	26.40	0.88	361.00	512.00	82.00								
	6/15/2001		8.10	723.00	19.60	24.20	29.98	0.65	339.00	489.00	76.00								
	7/9/2001		7.95	755.00	34.00	*0.40*	27.22	0.71	344.00	512.00	77.00								

	8/10/2001		8.00	778.00	52.05	*0.40*	21.46	0.89	357.00	587.00	74.00									
	9/26/2001		7.27	899.00	102.50	*0.40*	24.80	1.17	379.00	672.00	65.00									
	1/23/2002		7.72	866.00	138.00	*0.40*	36.70	0.65	316.00	611.00	75.00									
	2/25/2002		8.07	904.00	203.00	*0.40*	35.10	0.74	283.00	582.00	67.00									
	3/26/2002		7.89	910.00	145.00	*0.40*	31.40	0.07	310.00	595.00	71.00									
9/11/2002	4/12/2002		8.05	959.00	279.20	*0.40*	13.80	0.54	248.00	726.00	36.00									
	5/16/2002		5.80	1040.00	132.50	*0.40*	37.50	0.52	353.00	820.00	103.00									
	6/13/2002		6.36	2008.00	120.00	*0.40*	92.20	3.84	114.00	1775.00	171.00									
	7/25/2002		6.46	2042.00	68.30	*0.40*	86.10	3.62	1200.00	1692.00	227.00									
11/15/2002	8/15/2002		dry																	
	9/30/2002		dry																	
1/17/2003	10/18/2002		dry																	
	11/29/2002		6.64	2635.00	163.00	*0.40*	335.00	11.90	1790.00	2571.00	512.00									
2/24/2003	1/9/2003		6.53	1911.00	172.00	*0.40*	86.00	3.73	1080.00	1575.00	160.00									
	3/18/2003		6.38	1627.00	45.00	*0.40*	91.30	3.03	990.00	1482.00	129.00									
7/29/2003	5/14/2003		6.49	1200.00	97.50	*0.40*	40.20	1.69	620.00	966.00	144.00									
10/27/2003	8/21/2003		6.22	852.00	12.20	0.64	108.00	3.52	449.00	697.00	204.00									
MW #4 Downgradient Well																				
appl	10/24/1994	6.60	6.55	513.00	68.15	0.00	40.35	3.45	149.60	340.00	152.00	0.00	0.08	68.15	140.00	44.47	0.00	2.82	2.80	
	12/14/1995	7.30	6.69	470.00	82.41	0.00	72.60	2.46	149.40	146.00	276.00	0.00	0.00	82.41	185.00	90.57	0.07	2.76	3.00	
	2/7/1995	7.40	6.78	112.00	102.52	0.00	40.16	2.57	142.10	338.00	102.00	0.00	0.00	102.52	91.00	26.30	0.00	2.96	1.70	
	3/15/1995	7.10	6.28	427.00	52.27	0.00	41.86	3.78	141.39	746.00	96.00	0.00	0.81	52.27	70.00	29.15	0.00	9.07	2.60	
	4/20/1995	6.80	6.48	448.00	79.00	0.00	102.00	4.10	157.00	288.00	234.00	0.00	0.62	79.00	57.00	32.50	0.00	6.58	3.90	
	6/1/1995		6.55	412.00	76.87	0.00	61.20	3.82	145.10	317.00	176.00	0.00	0.25	77.00		41.60	0.00	3.78	2.80	
10/18/1996	7/17/1996	6.00	7.33	124.00	12.60	0.00	23.47	0.60	53.40	123.00	90.00	0.00	0.00	12.60	5.40	0.00	0.00	2.72	1.20	
1/23/1997	12/17/1996	6.10	6.75	94.00	24.40	3.84	9.02	0.57	16.90	147.00	16.00	0.00	0.00	24.40	15.00	0.00	0.00	1.92	2.30	
4/21/1997	2/27/1997	7.10	7.93	110.00	24.20	7.91	4.15	0.41	32.60	56.00	7.00		0.00	24.20	10.00	22.80	0.00	2.32	1.40	
	6/24/1997	5.10	8.66	83.00	31.36	0.00	37.30	0.73	0.00	60.00	120.00		0.00	31.30	30.00	0.00	0.00	0.00	2.70	
8/18/1998	3/30/1998		7.24	1016.00	36.63	0.00	25.35	2.23	65.50	0.00	27.00	0.00	0.00	36.63	2.00	0.00	0.00	0.00	2.05	
	6/22/1998		6.72	287.00	52.00	0.00	22.80	2.66	106.00	157.00	44.00	0.00	0.00	52.00	57.00	22.30	0.00	2.20	1.48	
	7/14/1998	6.80	7.19	227.00	53.70	0.00	17.10	1.99	67.50	101.00	36.00	0.00	0.00	53.70	19.00	0.00	0.00	1.61	1.15	
	9/28/1998	well dry																		
	10/19/1998	well dry																		
	11/10/1998	well dry																		
2/1/1999	12/17/1998	well dry																		
7/14/1999	1/29/1999	well dry																		
	2/26/1999	well dry																		
	3/29/1999	well dry																		
	4/27/1999	well dry																		
	6/9/1999	well dry																		
7/31/2000	4/28/2000		7.66	82.90	12.00	0.40	7.62	0.41	18.00	34.00	30.00									
	5/25/2000		7.52	67.50	15.00	0.40	12.80	0.41	12.70	53.00	19.00									
	6/21/2000		7.82	74.30	16.00	0.40	15.70	0.29	13.10	16.00	34.00									
10/27/2000	7/27/2000		7.51	73.10	22.00	0.40	11.20	0.25	10.20	34.00	25.00									
	8/28/2000		8.12	71.20	18.09	0.40	5.17	0.13	10.50	15.00	12.00									
	9/26/2000	well dry																		
1/10/2001	10/23/2000	well dry																		
	12/26/2000	well dry																		
4/29/2001	3/20/2001	well dry																		
10/25/2001	5/21/2001		7.83	50.60	27.70	6.90	4.15	0.15	5.18	33.00	13.00									
	6/15/2001	well dry																		
	7/9/2001	well dry																		
	8/10/2001	well dry																		
	9/26/2001	well dry																		
	11/21/2001	well dry																		
9/11/2002	5/16/2002		7.32	139.30	36.50	*0.40*	0.66	0.38	28.10	100.00	27.00									
	1/9/2003	well dry																		
	3/18/2003	well dry																		
7/29/2003	5/14/2003	well dry																		
10/27/2003	8/21/2003	well dry																		

Reading Anthracite Company
#54793206
Mahanoy Twp., Schuylkill Ct.

Less than this value

MODULE 25A - ASH QUALITY INFORMATION
ASH DRY WT CONCENTRATIONS

DATE SUBMITTED	DATE SAMPLED	pH	ALUMINUM (Al)	ANTIMONY (Sb)	ARSENIC (As)	BARIUM (Ba)	BORON (B)	CADMIUM (Cd)	CHROMIUM (Cr)	COPPER (Cu)	IRON (Fe)	LEAD (Pb)	MANGANESE (Mn)	MERCURY (Hg)	MOLYBDENUM (Mo)	NICKEL (Ni)	SELENIUM (Se)	ZINC (Zn)	ACID NEUTRL POTENT. (ANP)	COBALT	POTASSIUM (K)	SILVER (Ag)
St. Nicholas Co-Gen																						0.00
DER	5/24/1990	10.40	36200.00	0.00	10.42	295.00		0.00	36.90	24.50	16600.00	*6.30*	78.70	0.48	*6.30*	9.70	5.27	20.40				0.00
DER	5/24/1990	10.56	38500.00	0.00	15.28	328.00		0.00	41.40	31.20	18060.00	8.60	81.10	0.99	*6.60*	10.20	8.90	21.80				0.00
DER	4/30/1991	10.60	22100.00	0.00	10.70	229.00	33.50	1.20	24.00	24.00	8520.00	19.00	57.00	0.42	*12.00*	*10.00*	5.80	35.00				0.00
DER	3/12/1992	10.47	26650.00	0.00	7.50	268.00	35.20	0.00	33.00	22.70	17200.00	23.00	81.00	0.39	2.20	8.44	3.70	16.70				0.00
7/27/1992	6/30/1992	11.36	28510.00	70.00	195.00	215.80	15.60	1.70	37.40	27.20	12510.00	30.60	51.10	0.12	0.00	29.50	2.15	26.70				0.00
1/21/1993	12/7/1992	9.18	23150.00	43.00	12.17	162.70	9.42	0.00	28.20	18.10	16170.00	16.50	70.40	0.33	23.00	7.50	0.77	14.40				0.00
7/16/1993	6/4/1993	10.18	22128.60	66.07	32.23	143.34	19.68	1.05	31.41	25.09	14219.37	39.07	62.48	0.37	108.20	13.21	2.62	68.94				0.40
2/27/1994	12/20/1993	9.06	35180.00	26.00	3.01	303.90	13.35	0.00	40.10	23.60	21164.00	31.39	78.60	1.00	14.00	16.30	0.00	19.30	89.00	10.60	7510.00	2.10
2/10/1995	12/19/1994	10.72	21870.00	0.00	39.18	172.00	0.00	0.00	28.40	22.30	17100.00	21.60	54.60	0.22	0.00	12.20	0.00	15.00	55.06	7.10	6600.00	0.00
3/5/1996	12/11/1995	12.05	15000.00	36.00	15.90	120.00	11.00	0.00	27.70	20.60	15500.00	29.20	65.00	0.23	49.00	12.70	0.00	15.00	29.80	0.00	5390.00	0.00
8/1/1996	6/7/1996	9.10	22100.00	28.00	14.00	189.00	0.00	0.00	46.00	21.00	12300.00	34.00	51.00	0.00	10.00	12.00	1.90	19.20	20.10	7.00	6800.00	0.00
3/12/1997	12/13/1996	8.92	23000.00	0.00	0.00	221.00	20.00	0.00	36.00	28.00	16000.00	16.00	64.00	0.00	0.00	10.00	0.00	19.10	28.60	12.00	8000.00	0.00
8/18/1998	10/15/1997	10.02	22000.00	0.00	0.00	180.00	14.30	0.00	35.00	18.00	1200.00	10.00	43.00	0.73	0.00	6.00	0.00	23.00	29.80	5.50	5400.00	0.00
8/18/1998	6/2/1998	10.16	26700.00	0.00	19.50	290.00	40.00	0.00	57.00	26.00	23800.00	0.00	65.00	0.61	0.00	9.40	0.00	25.00	13.30	10.00	9250.00	0.00
2/18/1999	10/28/1998	9.64	27900.00	0.00	13.40	287.00	0.00	0.00	47.00	48.00	24500.00	45.00	62.00	0.00	13.00	15.00	0.00	23.00	21.00	11.00	10600.00	1.00
3/9/2000	11/30/1999	10.22	13000.00	0.00	6.90	121.00	0.00	0.00	16.00	9.60	8360.00	0.00	50.00	0.41	0.00	38.00	0.00	8.07	20.80			
2/13/2001	11/10/2000	10.42	45600.00	*20.00*	42.40	243.00	17.20	*0.50*	27.00	17.00	26700.00	*10.00*	84.00	*0.02*	*10.00*	25.00	1.20	13.50	41.30			
12/18/2001	6/1/2001	9.61	27700.00	1.00	7.90	205.00	23.50	*0.50*	30.90	23.00	24.00	*10.00*	86.00	0.28	*10.00*	14.00	3.30	17.80				
1/29/2002	11/21/2001	9.65	23400.00	*3.50*	6.16	226.00	24.00	*1.80*	35.10	17.90	15200.00	5.00	107.00	0.10	*1.00*	8.20	*0.50*	16.60	34.00			
8/5/2002	4/17/2002	9.07	10300.00	*2.00*	9.87	108.00	44.50	*2.00*	25.00	14.00	13200.00	18.00	87.00	0.15	*1.00*	10.00	*0.50*	17.00	15.30			
2/24/2003	11/4/2002	9.53	11700.00	*2.00*	8.76	121.00	9.95	*0.50*	12.00	12.00	4385.00	13.00	60.00	0.05	*1.00*	4.00	5.00	10.00	100.00			
7/29/2003	7/3/2003	10.60	31800.00	*2.00*	8.40	307.00	33.10	0.70	36.00	21.00	17400.00	48.00	102.00	0.20	*1.00*	7.00	3.00	21.00	21.50			
Bottom																						1.80
6/7/1990	1/10/1990	11.31	17568.38	15.60	206.00	155.97		0.70	23.00	20.96	11160.00	0.00	58.89	0.00	61.89	8.98	0.00	18.97				
Condition-fly																						2.00
6/7/1990	1/10/1990	11.34	42470.27	28.00	158.00	473.42		1.00	52.00	30.98	28140.30	45.97	100.93	0.00	46.97	21.98	0.25	34.98				0.02
2/11/1991	12/28/1990	10.88	428.00	0.00	42.64	3.38	22.62	0.00	0.57	0.48	244.00	0.18	0.79	0.43	0.23	0.10	1.92	0.41				
AES Thames, Inc.																						
appl	05/03/01	11.70	32200	*20.00*	15.70	287.00	269.23	*0.50*	67.00	68.00	21900.00	24.00	102.00	0.21	19.00	55.00	9.42	3.40				
appl	05/03/01	11.89	12100.00	*20.00*	62.10	127.00	123.92	0.70	42.00	23.00	14300.00	*10.00*	192.00	*0.02*	24.00	45.00	*0.05*	18.40				
Logan Generating Plant																						
appl	05/16/01	11.33	16500.00	1.60	33.00	204.00	216.60	*0.50*	49.20	46.00	22700.00	26.00	88.00	1.55	38.00	56.00	22.00	45.20				
appl	05/16/01	9.45	3010.00	*0.50*	*0.50*	31.00	17.90	*0.50*	7.56	23.00	8170.00	*10.00*	35.00	0.36	32.00	16.00	0.60	29.10				

Leachate concentrations
(ppm)

Reading Anthracite Company
#54793206
Mahanoy Twp., Schuylkill Ct.

Less than this value

MODULE 25A - ASH QUALITY INFORMATION
LEACHATE CONCENTRATIONS

DATE SUBMITTED	DATE SAMPLED	pH	ALUMINUM (Al)	ANTIMONY (Sb)	ARSENIC (As)	BARIUM (Ba)	BORON (B)	CADMIUM (Cd)	CHROMIUM (Cr)	COPPER (Cu)	IRON (Fe)	LEAD (Pb)	MANGANESE (Mn)	MERCURY (Hg)	MOLYBDENUM (Mo)	NICKEL (Ni)	SELENIUM (Se)	ZINC (Zn)	SULFATE (SO4)	NITRATE (NO3-N)	CHLORIDE (Cl-)	SODIUM (Na)	PHENOLICS	TOT ORG CARBON (TOC)	TOT ORG HALOGEN (TOX)	CHEM OX DEMAND (COD)	COBALT	POTASSIUM	SILVER (Ag)	AMMONIA NITROGEN (NH3-N)	CYANIDE
St. Nicholas Co-Gen																							ns								
DER	5/24/1990	4.89	7.84	0.00	0.00	0.18	ns	0.00	0.09	0.00	0.00	0.00	0.50	0.00	0.00	0.05	0.11	0.04	338.00				ns	2.80	0.00	0.00			0.00		0.00
DER	5/24/1990	4.97	7.35	0.00	0.00	0.11	ns	0.00	0.02	0.00	0.00	0.00	0.30	0.00	0.06	0.00	0.26	0.15	479.00				ns	2.00	0.00	0.00			0.00		0.00
DER	4/30/1991	5.37	5.12	0.00	0.01	0.27	ns	0.00	0.00	0.00	0.20	0.09	0.27	0.00	0.05	0.18	0.12	0.07	389.00	0.09	5.00		0.00	ns	ns	ns			0.00	2.37	0.00
DER	3/12/1992	5.37	7.80	0.00	0.01	0.30	0.33	0.00	0.00	0.00	0.11	0.00	0.36	0.00	0.08	0.00	0.10	0.05	463.00	1.74	6.00		0.00	0.00	0.00	13.00			0.00	0.15	0.00
7/27/1992	6/30/1992	10.77	2.15	0.00	0.12	0.00	0.00	0.00	0.03	0.14	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.11	419.70	0.54	4.10		0.00	2.20	0.00	64.00			0.00	0.00	0.00
1/21/1993	12/7/1992	5.39	9.88	0.43	0.02	0.00	0.37	0.00	0.00	0.00	0.04	0.00	0.40	0.00	0.23	0.08	0.01	0.14	630.00	2.70	6.80		0.00	0.00	0.01	0.00			0.00	0.00	0.00
7/16/1993	6/4/1993	10.80	5.41	0.63	0.02	0.00	0.41	0.00	0.06	0.14	0.13	0.06	0.25	0.00	0.00	0.09	0.02	0.07	297.51	0.04	0.00		0.00	0.00	0.00	0.00			0.01	0.00	0.00
2/27/1994	12/20/1993	10.03	1.52	0.71	0.02	0.00	0.25	0.00	0.10	0.00	0.15	0.00	0.00	0.00	0.14	0.00	0.01	0.05	376.50	0.00	2.63	9.80	0.00	0.00	0.01	0.00	0.00	8.20	0.00	0.00	0.00
2/10/1995	12/19/1994	11.22	1.58	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	375.60	0.00	3.19	7.40	0.00	0.00	0.00	0.00	0.00	6.10	0.03	0.00	0.00
3/5/1996	12/11/1995	10.80	1.74	0.00	0.02	0.12	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.28	0.00	0.00	0.01	290.00	0.00	1.97	6.20	0.00	0.00	0.00	0.00	0.00	9.80	0.00	0.00	0.00
8/1/1996	6/7/1996	10.55	2.66	0.00	0.02	0.00	0.00	0.00	0.05	0.00	0.08	0.00	0.01	0.00	0.00	0.00	0.02	0.02	354.00	0.00	0.00	9.30	0.00	0.00	0.01	0.00	0.00	8.00	0.01	0.00	0.00
3/12/1997	12/13/1996	10.68	1.45	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.43	0.01	0.02	461.00	0.00	1.86	15.60	0.00	0.00	0.00	0.00	0.00	10.30	0.00	0.00	0.00
8/18/1998	10/15/1997	10.02	4.26	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.08	0.00	0.04	0.00	0.00	0.00	0.00	0.00	686.00	0.04	5.24	17.00	0.00	0.00	0.01	0.00	0.06	8.00	0.00	0.00	0.00
8/18/1998	6/2/1998	10.40	0.96	0.00	0.04	0.24	0.00	0.00	0.13	0.02	0.09	0.00	0.01	0.00	0.15	0.00	0.00	0.06	646.00	0.00	0.00	5.90	0.00	0.00	0.02	0.00	0.00	7.80	0.00	0.00	0.00
2/18/1999	10/28/1998	10.13	1.72	0.00	0.01	0.24	0.00	0.01	0.08	0.02	0.00	0.12	0.03	0.00	0.15	0.04	0.08	0.00	360.00	0.00	4.47	4.80	0.00	0.00	0.00	0.00	0.00	10.40	0.01	1.20	0.00
3/9/2000	11/30/1999	8.83	2.85	0.30	0.05	0.00	0.22	0.00	0.07	0.03	0.12	0.00	0.02	0.00	0.45	0.20	0.01	0.00	252.00	0.27	1.75	2.92									
2/13/2001	11/10/2000	10.30	1.67	*0.01*	*0.01*	*0.10*	*0.20*	0.02	*0.05*	0.02	*0.03*	*0.10*	0.07	*0.00*	*0.10*	*0.04*	*0.01*	*0.01*	219.00	*0.00*	0.55	1.91									
12/18/2001	6/1/2001	10.10	2.21	*0.01*	0.02	*0.10*	*0.20*	*0.01*	*0.05*	0.02	*0.07*	*0.10*	*0.01*	*0.00*	*0.10*	*0.04*	*0.01*	0.01	328.00	0.18	1.22	4.38									
1/29/2002	11/21/2001	9.99	1.58	*0.04*	0.03	0.02	*0.20*	*0.01*	0.01	*0.01*	*0.01*	*0.03*	0.01	*0.00*	*0.02*	*0.01*	*0.01*	0.01	233.00	0.05	0.68	5.25									
8/5/2002	4/17/2002	10.18	1.64	*0.06*	*0.04*	0.03	*0.07*	*0.01*	*0.01*	*0.01*	0.02	0.05	0.01	*0.00*	*0.01*	*0.01*	*0.01*	0.06	315.00	0.25	1.40	0.53									
2/24/2003	11/4/2002	9.95	2.27	*0.04*	0.01	0.02	0.04	*0.01*	*0.01*	*0.01*	0.01	0.05	*0.01*	*0.00*	0.01	*0.01*	*0.05*	0.01	207.00		0.02	2.35									
7/29/2003	7/3/2003	1.25	1.83	*0.04*	0.01	0.03	0.03	*0.01*	0.03	*0.01*	0.02	0.05	*0.01*	*0.00*	0.02	*0.01*	*0.01*	0.01	269.00	0.22	*0.02*	4.49									
Bottom																							0.00	1.13	0.01	ns			0.04		0.00
6/7/1990	1/10/1990	5.00	13.82	0.70	0.00	0.00	0.40	0.30	0.00	0.12	4.26	0.42	0.56	0.00	0.63	0.00	0.00	0.17	885.50												
Condition-fly																							0.01	1.92	0.02	ns			0.03		0.00
6/7/1990	1/10/1990	5.10	14.38	0.86	0.00	0.00	ns	0.32	0.00	0.10	0.06	0.24	0.00	0.46	0.00	0.35	0.69	0.29	0.09	922.20			0.00	4.30	0.00	ns			0.01		0.00
2/11/1991	12/28/1990	4.86	19.10	0.00	0.02	0.52	6.25	0.00	0.10	0.06	0.24	0.00	0.46	0.00	0.35	0.69	0.29	0.09	922.20												
AES Thames																															
appl	05/03/01	12.30	0.10	*0.01*	*0.01*	0.80	*0.20*	0.01	*0.05*	0.04	*0.03*	*0.10*	0.04	*0.00*	0.15	0.13	0.01	0.03	1680.00	70.20	1.31										
appl	05/03/01	12.30	*0.10*	*0.01*	*0.01*	*0.10*	*0.20*	*0.01*	*0.05*	0.04	*0.03*	*0.10*	0.04	*0.00*	*0.10*	0.10	*0.01*	0.02	1830.00	4.20	1.80										
Logan Generating Plant																															
appl	05/16/01	11.20	1.82	*0.01*	*0.01*	0.64	*0.20*	*0.01*	*0.05*	*0.02*	0.08	*0.10*	*0.01*	*0.00*	0.46	0.06	0.01	0.06	14.30	321.00	40.00										
appl	05/16/01	7.07	*0.10*	*0.01*	*0.01*	*0.10*	*0.20*	*0.01*	*0.05*	*0.02*	0.04	*0.10*	0.05	*0.00*	*0.10*	*0.04*	*0.01*	0.04	5.58	0.12	1.39										

Reading Anthracite Co.
54793206
Yatesville Co-Gen, Schuylkill Energy Resources
Knickerbocker site

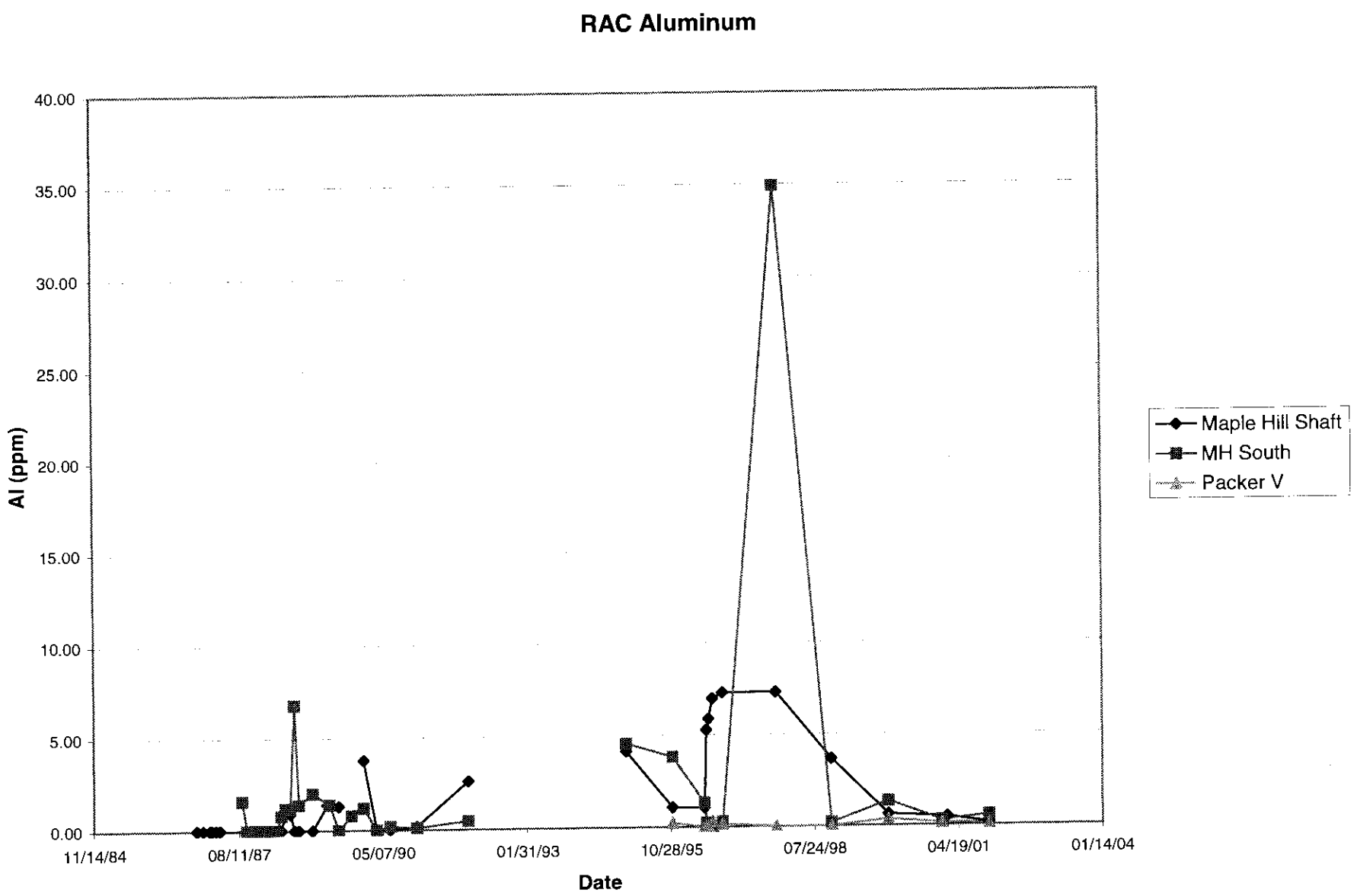
Approval:	1986(west)	
	(east) C6	
Area Authorized:	32 acres (west pit)	**3 separate ash areas**
	44 acres (east pit)	
Capacity:	(west) as of Jan.93 is 19,641,953 tons	
	(east) 3,653,000 tons - 4 years	

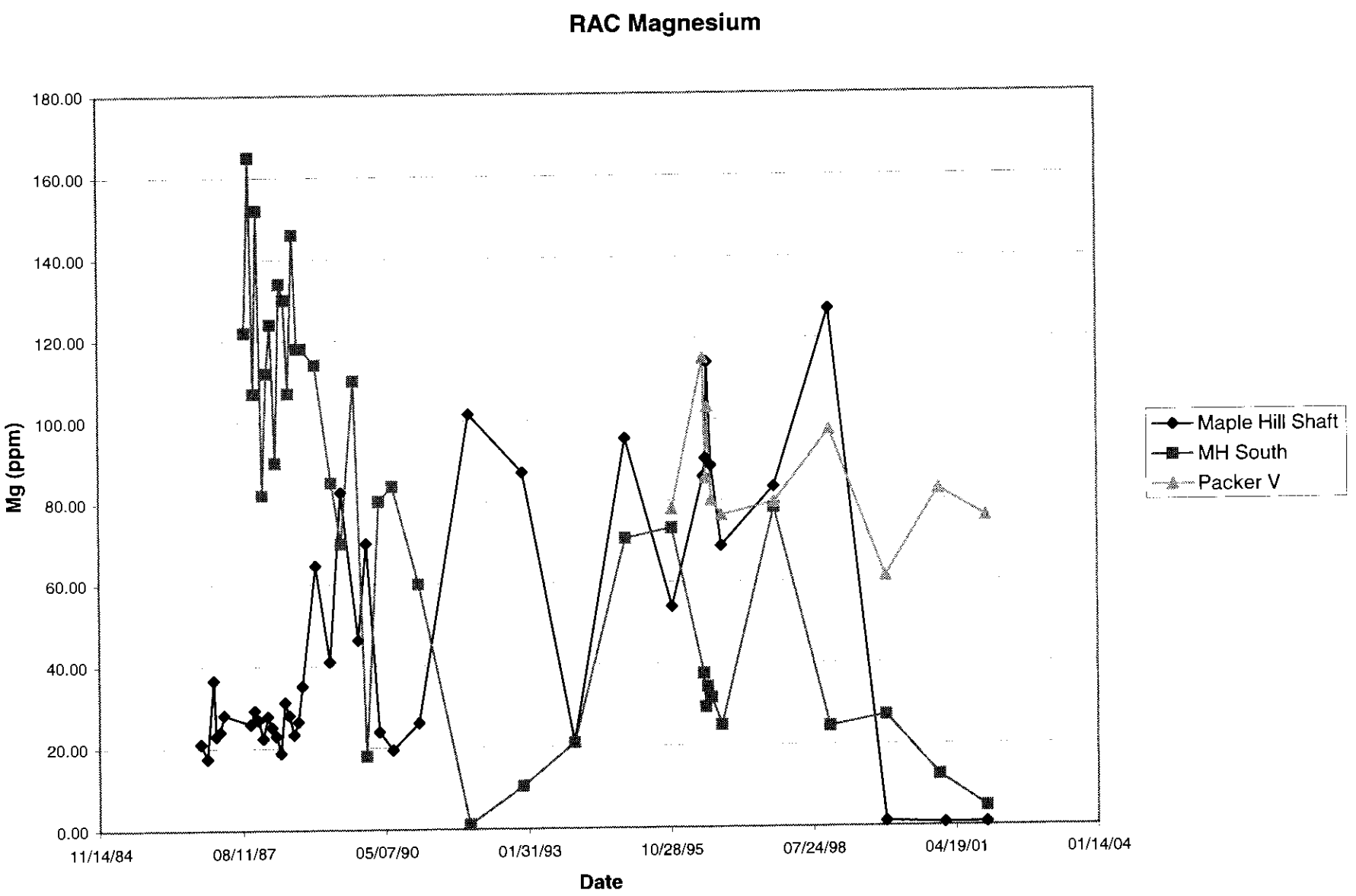
Monitoring Points (west)
001-Pit Sump
South Hole - Downgradient
Maple Hill Shaft- Upgradient

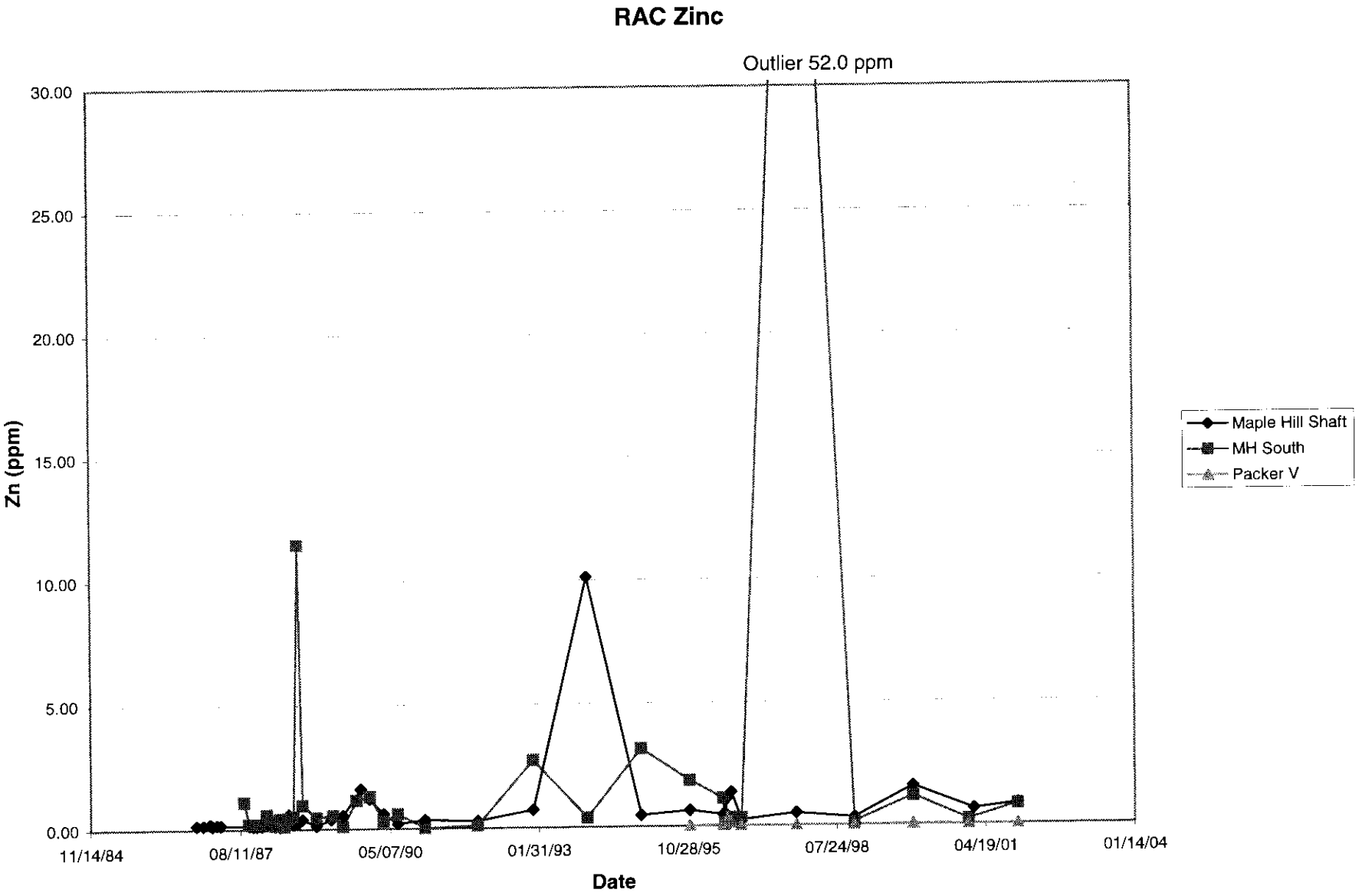
(east)
MW #1 - upgradient
MW #2 - downgradient
MW #3 - downgradient
MW #4 - downgradient

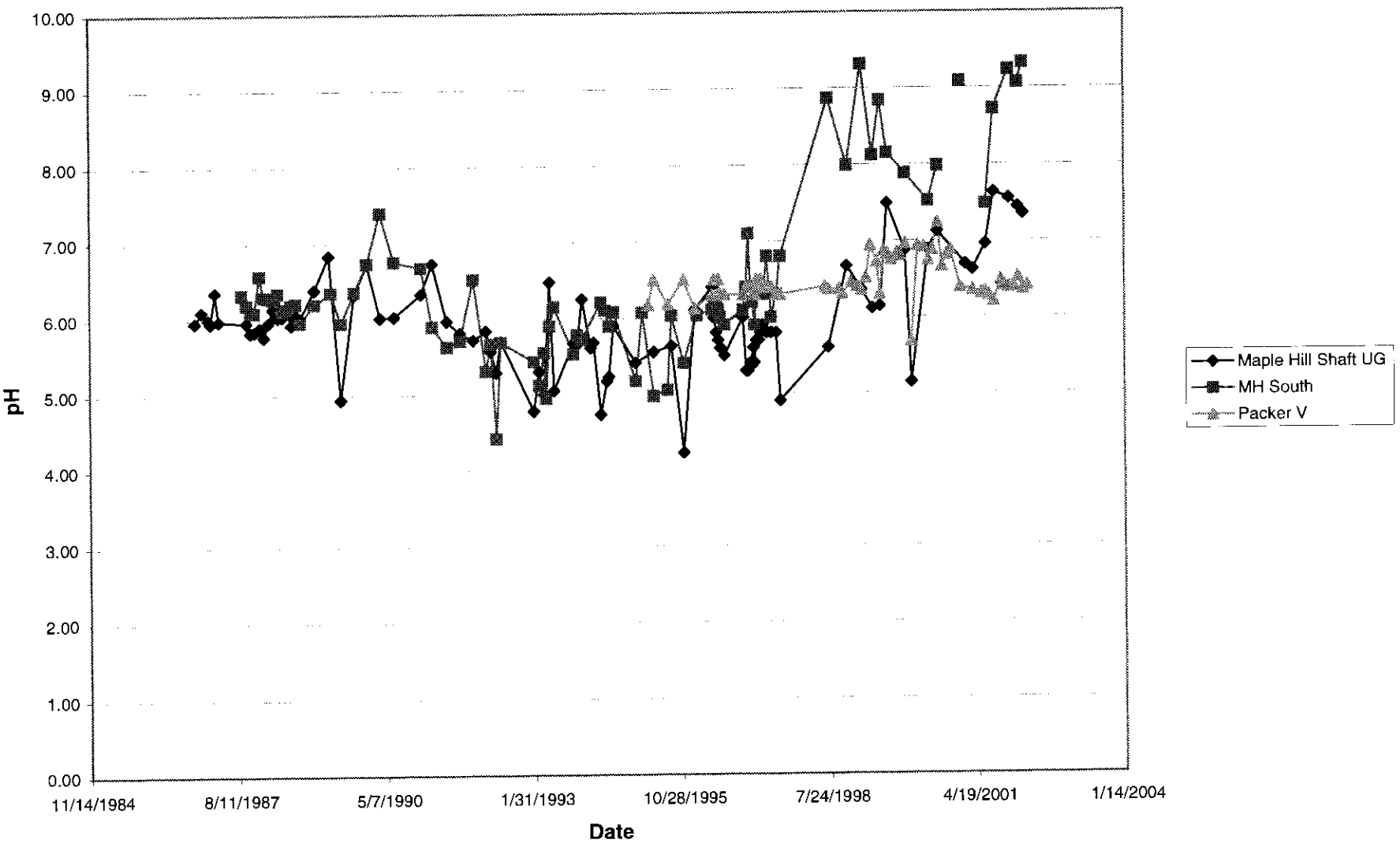
Sources
Co-gen
AES Thames, Inc.
Logan (Keystone) Generating Plant

Disposal	Tons	Remaining	Knickerbocker pit (in tons)
1994	867,030		
1995	817,770	16,993,945	
1996	844,352	20,749,593	
1997	825,177	19,924,416	
1998	790,296	19,134,120	174772
1999	858,616	18,275,504	616912
2000	857,345	17,418,159	690547
2001	219,904		494319
2002	687,388		65999

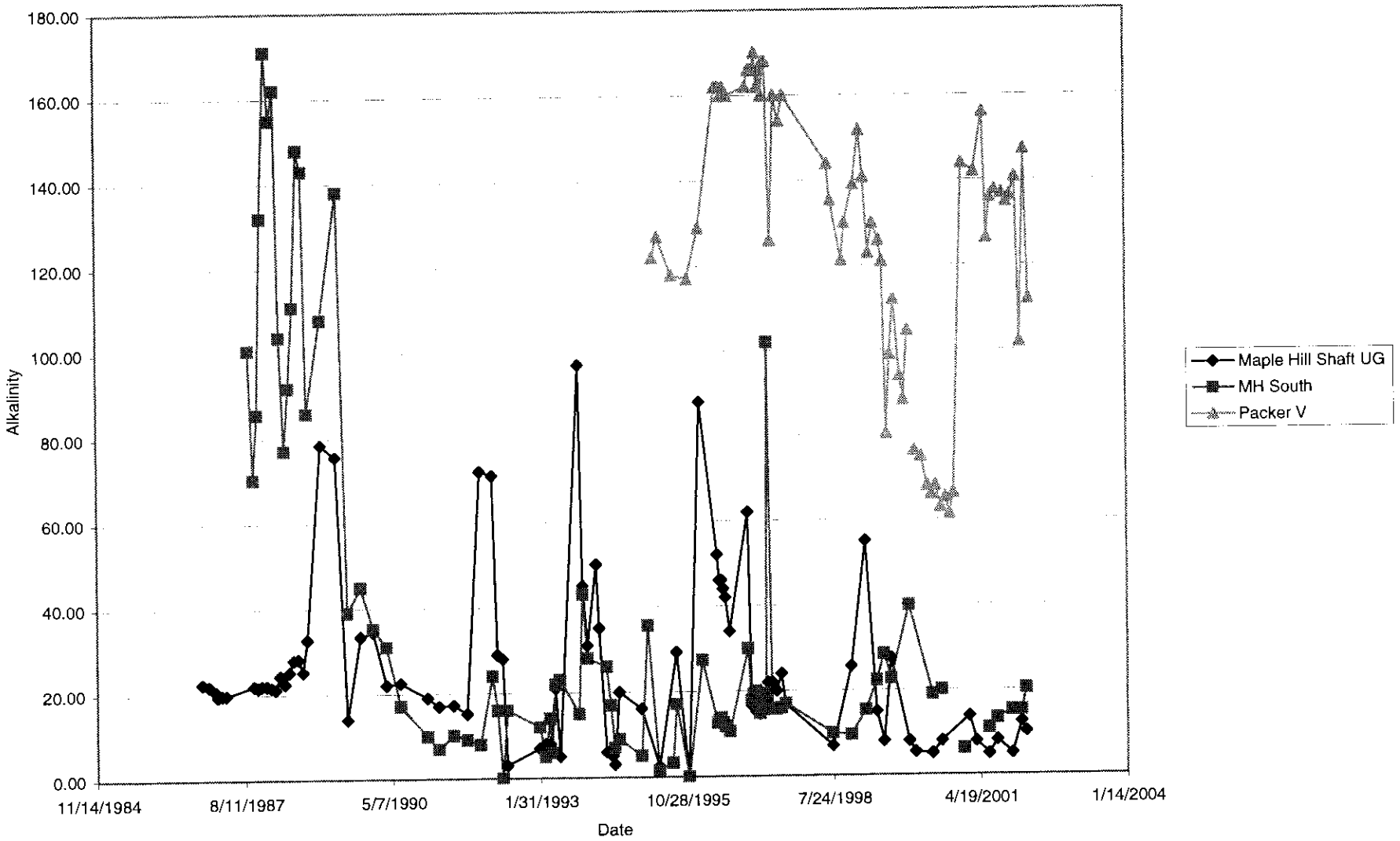

RAC Aluminum
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Al (ppm)
11/14/84
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
Date
Maple Hill Shaft
MH South
Packer V

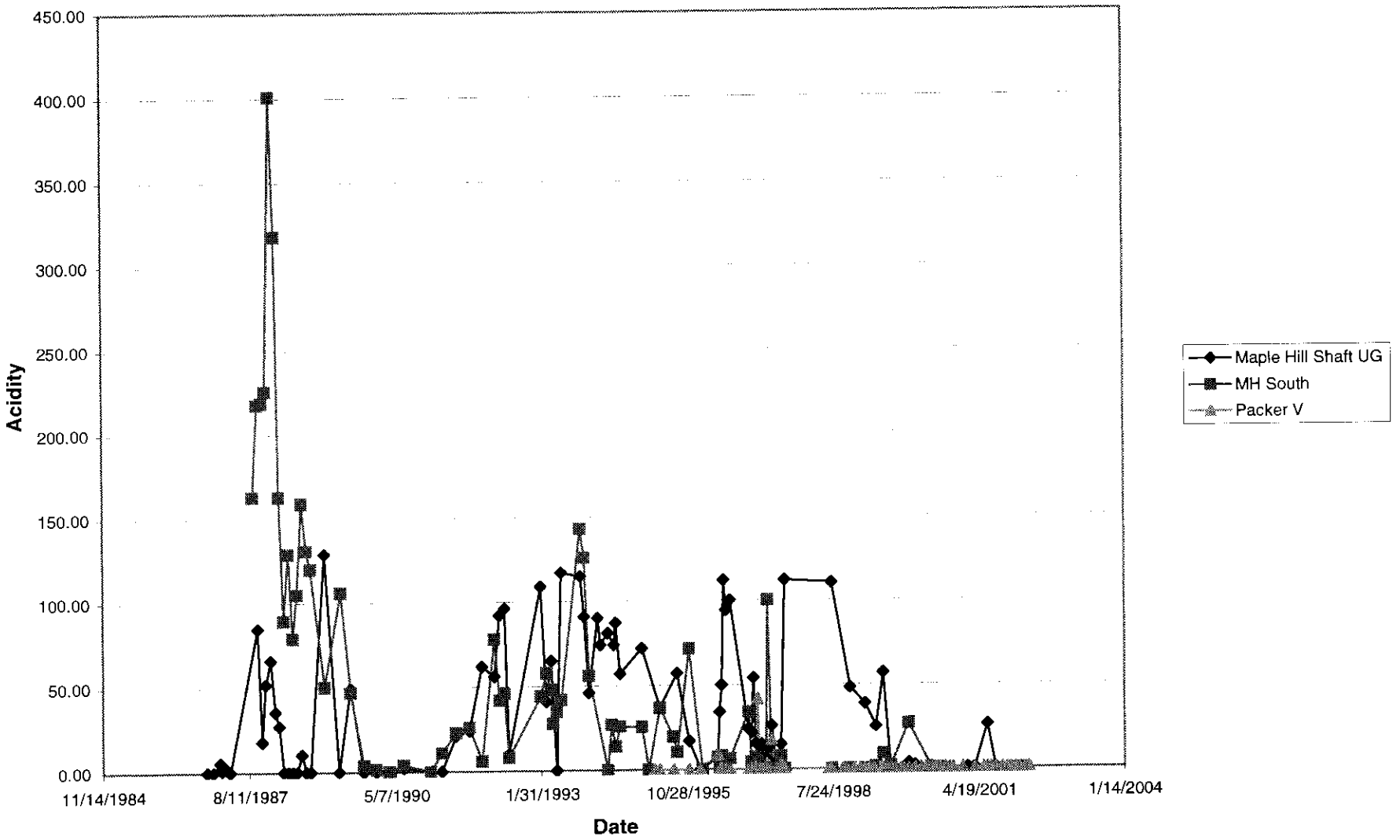

RAC Magnesium
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Mg (ppm)
11/14/84
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
Date
Maple Hill Shaft
MH South
Packer V

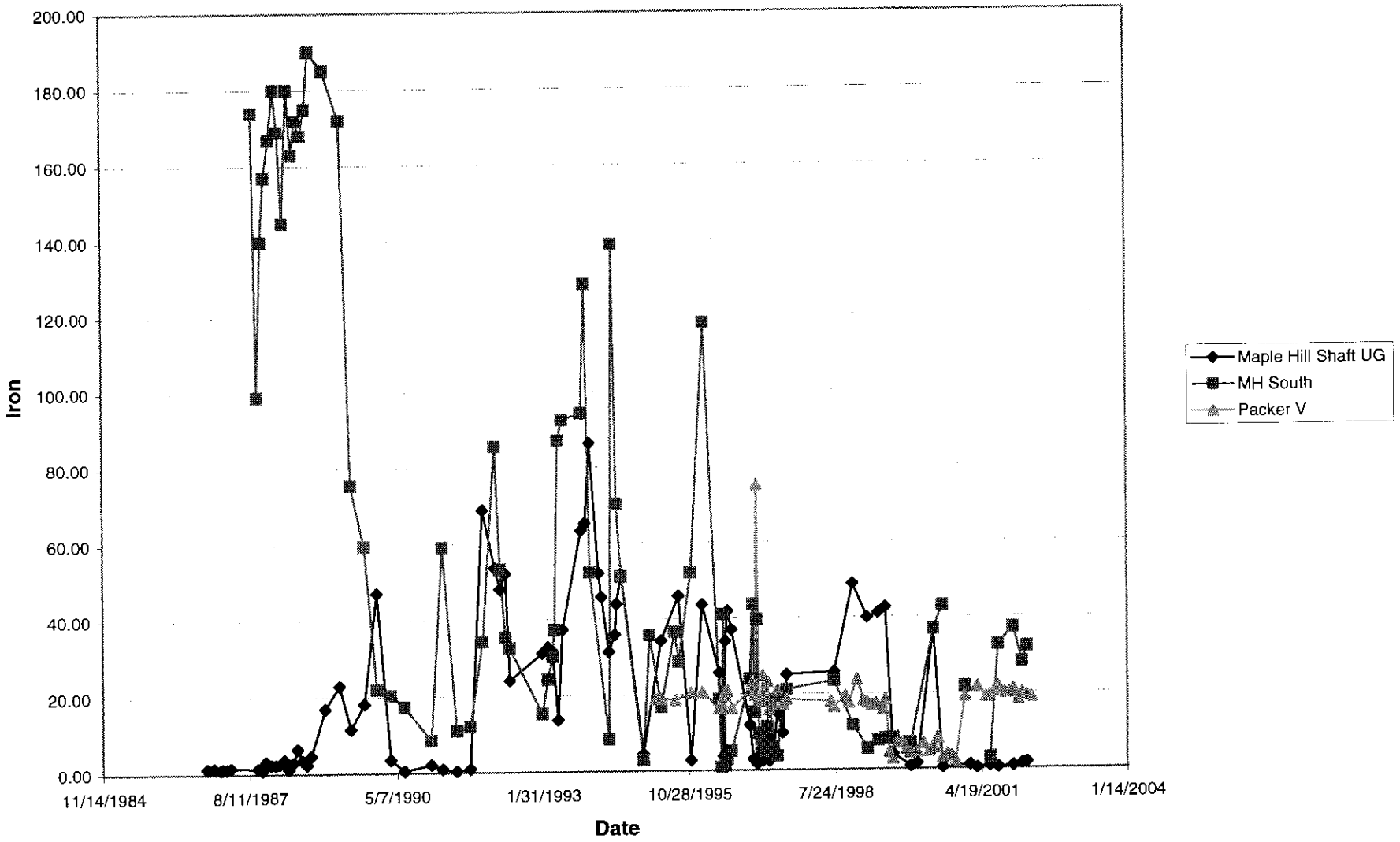

RAC Zinc
Outlier 52.0 ppm
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Zn (ppm)
11/14/84
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
Date
Maple Hill Shaft
MH South
Packer V

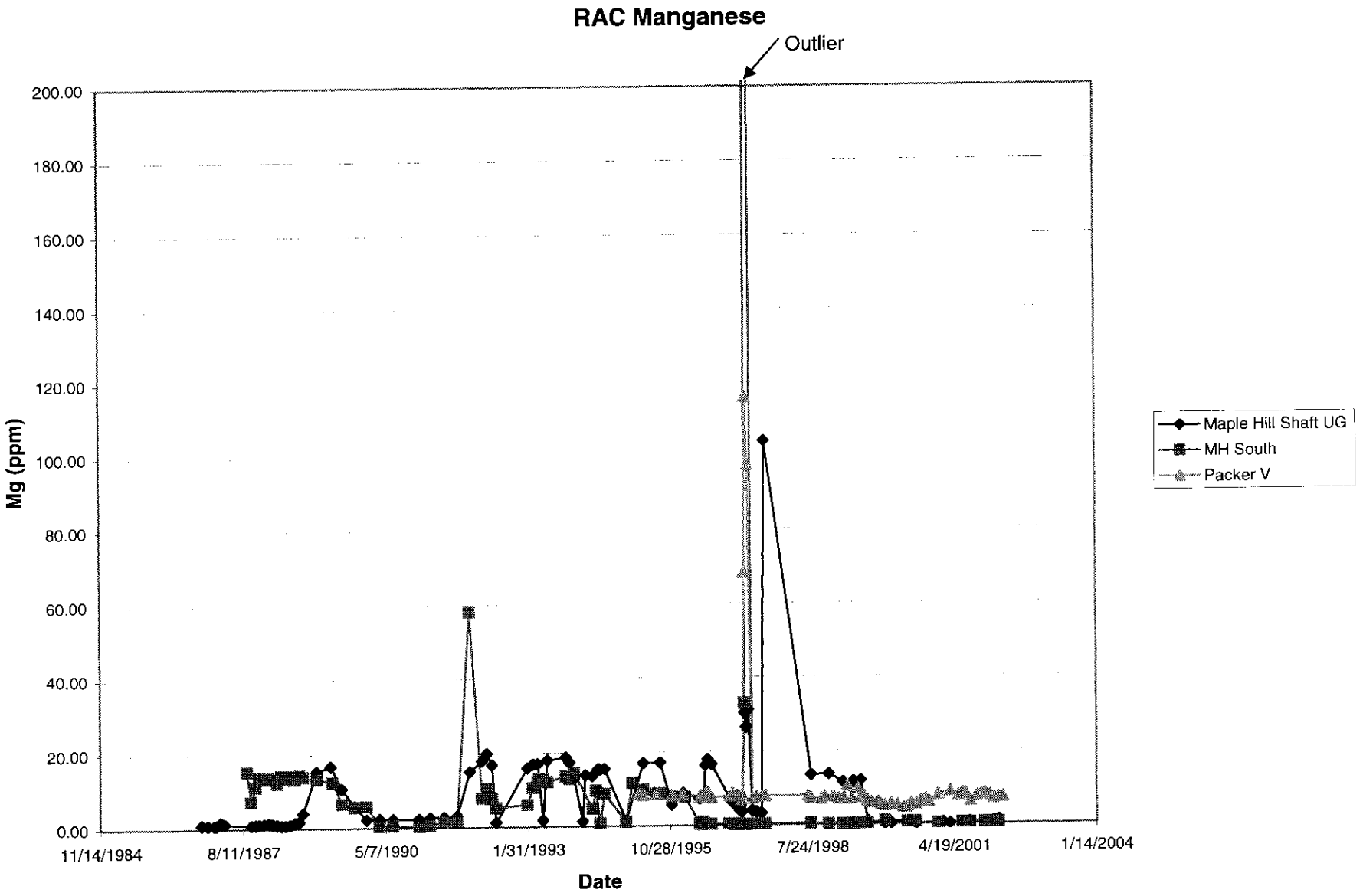

RAC pH
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V

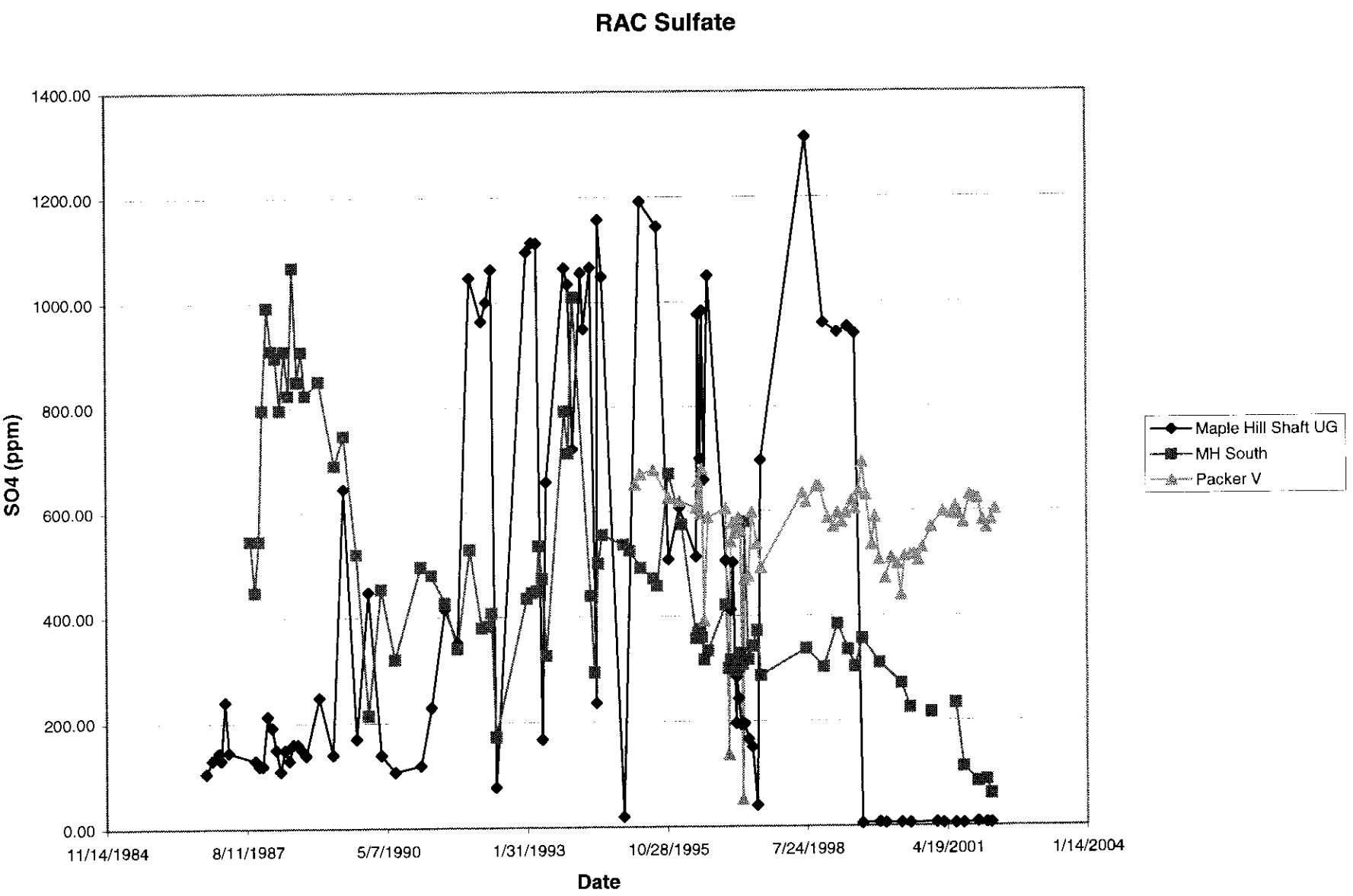
RAC Alkalinity

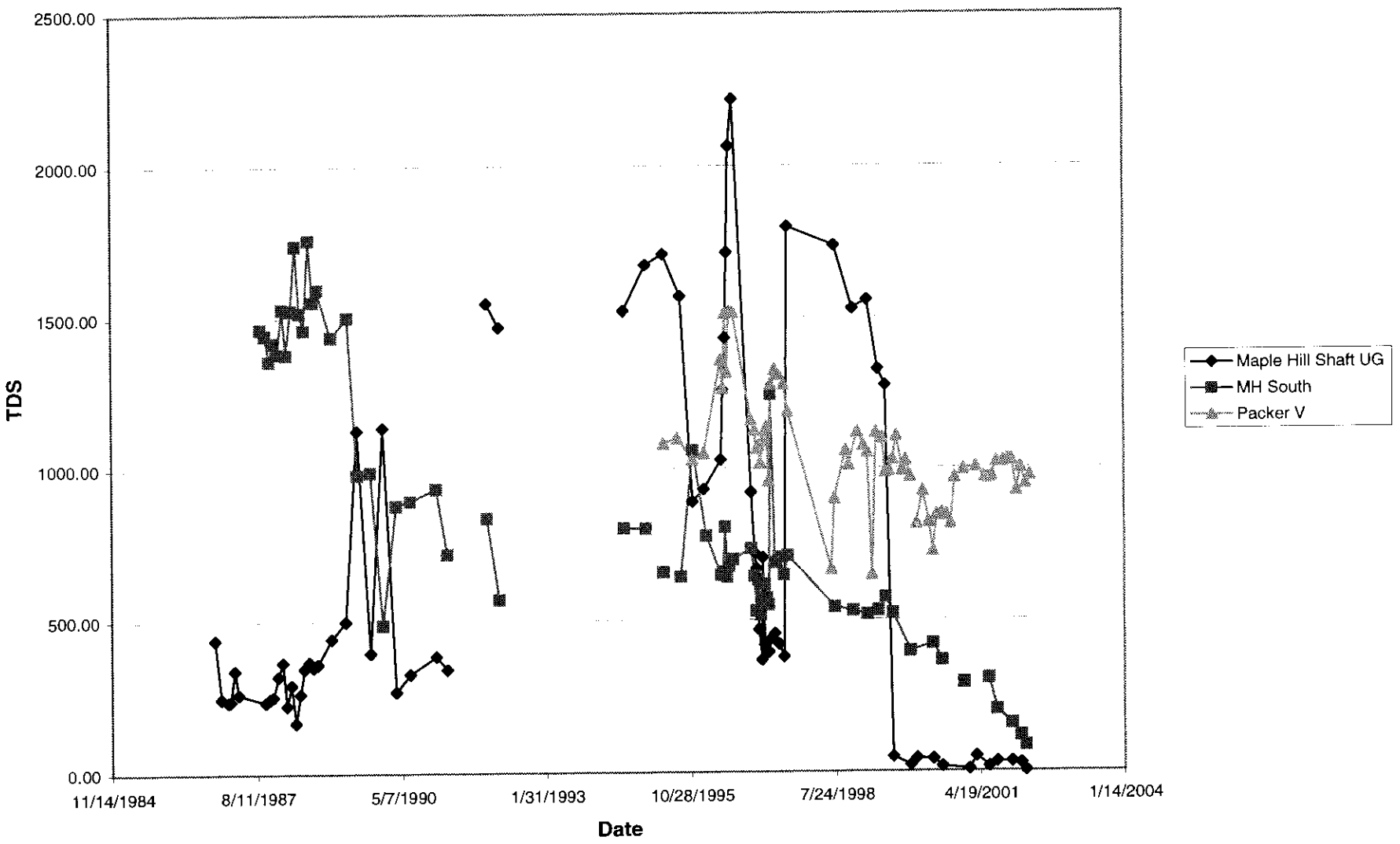



RAC Acidity
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Acidity
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V

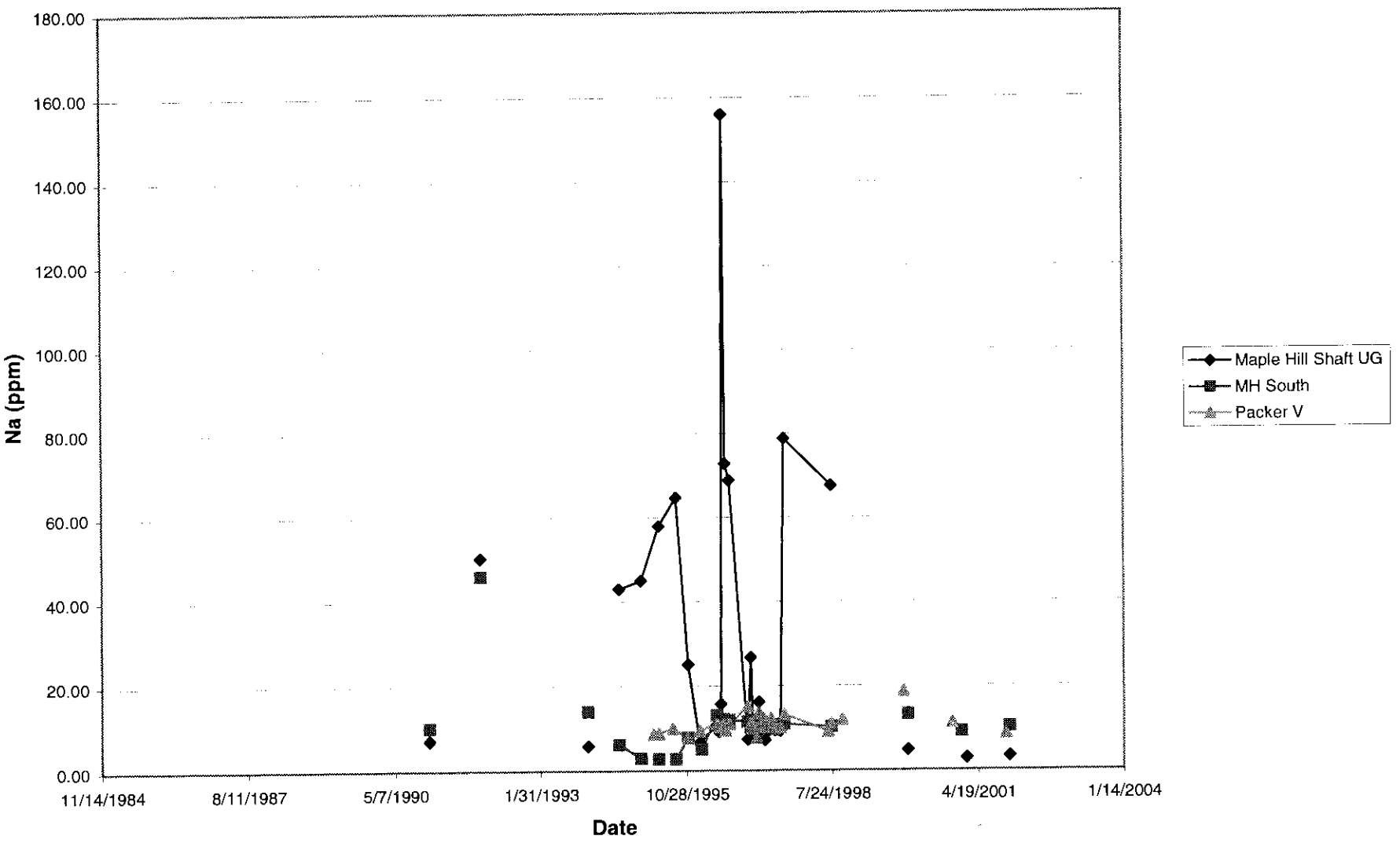

RAC Iron
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Iron
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V


RAC Manganese
Outlier
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Mg (ppm)
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V


RAC Sulfate
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
SO4 (ppm)
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V


RAC Tot Diss Solids
2500.00
2000.00
1500.00
1000.00
500.00
0.00
TDS
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V

RAC Sodium


180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Na (ppm)
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
Date
Maple Hill Shaft UG
MH South
Packer V

Appendix 9.A
Aerial photographs of the NEPCO site

a) April 1991
b) March 1995
c) March 1999
d) March 2000
e) April 2001
f) March 2002
g) April 2003

a)



b)



c)



d)



e)



f)



g)



Appendix 9.B

DEP Quarterly Sampling Data from the Silverbrook Basin

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	06/07/93	07/02/93	07/02/93	07/02/93	10/08/97	10/28/97
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID						
location		center of pool	center of pool	center of pool	at boat ramp	center of pool
sample depth	0	0	35'	70'	0	0
Laboratory	PETL	PETL	PETL	PETL	in-house	
Field pH	3.2					10.0
Lab pH		3.2	3.6	3.4	6.8	9.4
Temperature [C]						
D.O.						
Tot. Hardness	47.4	47	53.2	69.6		435
Conductivity	205	210	235	275	10.0	34.0
Alkalinity	<1	<1	<1	<1	0.0	<1
Hot Acidity	38.2	37.8	46.0	61.0	0.030	0.113
Iron (T)	0.520	0.400	0.660	1.220		
Iron (D)						0.011
Manganese (T)	0.710	0.720	0.790	0.970		
Manganese (D)						196
Sulfate (T)	55	59	75	79		
Sulfide	<0.02	<0.02	<0.02	<0.02		0.40
Fluoride	<0.2	<0.2	<0.2	<0.2		1.5
Chloride	1.0	6.0	2.0	2.2		4.56
Sodium	1.15	1.15	1.06	1.10		306
Dis. Solids	95	98	110	150		4
Sus. Solids	<1	<1	<1	<1		<0.5
Ammonia N	<0.5	<0.5	<0.5	<0.5		<0.5
Nitrate N	<0.5	<0.5	<0.5	<0.5		34.00
Bicarbonate						0.89
Turbidity	0.27	0.24	0.36	0.40		<10
COD	<10	<10	<10	<10		
TOC						
Silica (T)						
Silica (D)						
Annual Parameters						0.569
Aluminum (T)	3.500	4.200	5.200	9.000		0.478
Aluminum (D)						<0.02
Arsenic (T)	<0.001	<0.001	<0.001	0.002		
Arsenic (D)						0.016
Barium (T)	<0.1	<0.1	<0.1	<0.1		
Barium (D)						<0.005
Cadmium (T)	<0.005	0.001	0.001	0.001		
Cadmium (D)						98.00
Calcium (T)	4.20	3.95	4.15	5.25		
Calcium (D)						0.005
Chromium (T)	<0.05	<0.001	<0.001	<0.001		
Chromium (D)						<0.005
Copper (T)	0.020	0.020	0.020	0.030		
Copper (D)						<0.05
Lead (T)	<0.001	0.0010	0.0020	0.0020		
Lead (D)						3.96
Magnesium (T)	4.50	4.50	5.05	6.50		
Magnesium (D)						<0.0002
Mercury (T)	<0.0002	<0.0002	<0.0002	<0.0002		
Mercury (D)						<0.01
Nickel (T)	<0.04	<0.04	0.040	0.040		
Nickel (D)						<0.01
Selenium (T)	<0.002	<0.002	<0.002	<0.002		
Selenium (D)						<0.005
Silver (T)	<0.01	<0.01	<0.01	<0.01		
Silver (D)						0.008
Zinc (T)	0.220	0.200	0.195	0.240		
Zinc (D)						
Potassium (T)	0.88	1.00	1.02	1.09		
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/28/97	10/28/97	11/03/97	11/24/97	03/13/98	06/29/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID						
location	center of pool	center of pool	at boat ramp	at boat ramp	at boat ramp	at boat ramp
sample depth	35'	70'	0	0	0	0
Laboratory			in-house			PETL
Field pH				9.4	6.2	9.6
Lab pH	9.9	10.0	8.1	8.9	6.2	8.9
Temperature [C]						
D.O.						
Tot. Hardness				450	400	480
Conductivity	455	455		30.0	7.0	42.0
Alkalinity	42.0	47.0	18.0	<1	12.0	<1
Hot Acidity	<1	<1		0.130	0.050	<0.05
Iron (T)	0.173	0.183	0.030			
Iron (D)				0.020	0.400	0.016
Manganese (T)	0.006	0.008	0.040			
Manganese (D)				172	208	228
Sulfate (T)	196	180				
Sulfide				0.41	<2	<1
Fluoride	0.32	0.33		2.0	2.0	2.5
Chloride	2.0	1.5		4.52	4.49	25.00
Sodium	4.91	5.04		307	326	428
Dis. Solids	278	298		3	14	2
Sus. Solids	2	12		<0.2	<0.2	<0.2
Ammonia N	<0.5	<0.5		<0.2	<0.5	<1
Nitrate N	<0.5	<0.5		30.00	7.00	42.00
Bicarbonate	42.00	47.00		2.10	1.80	2.20
Turbidity	0.56	1.90		<10	<10	<10
COD	<10	<10				
TOC						
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	0.500	0.863		0.540		0.754
Aluminum (D)		0.491		0.430		0.131
Arsenic (T)	<0.02	0.022		<0.02		<0.005
Arsenic (D)		<0.02				<0.005
Barium (T)	<0.005	<0.005		0.150		0.032
Barium (D)						0.011
Cadmium (T)	<0.005	<0.005		<0.005		<0.002
Cadmium (D)						<0.002
Calcium (T)	140.00	138.00		68.90		101.00
Calcium (D)		130.00				48.20
Chromium (T)	0.008	0.010		0.007		0.020
Chromium (D)		0.005				<0.002
Copper (T)	<0.005	<0.005		<0.005		0.058
Copper (D)						0.002
Lead (T)	<0.05	<0.05		<0.05		<0.005
Lead (D)						<0.005
Magnesium (T)	4.68	4.69		3.94		10.80
Magnesium (D)	4.61	4.59				1.64
Mercury (T)	<0.0002	<0.0002		<0.002		<0.0002
Mercury (D)						<0.0002
Nickel (T)	<0.01	<0.01		<0.01		0.007
Nickel (D)						<0.005
Selenium (T)	0.0100	0.0150		0.0200		0.0160
Selenium (D)						<0.005
Silver (T)	0.005	0.007		<0.005		<0.005
Silver (D)		<0.005				<0.005
Zinc (T)	0.087	0.070		0.016		0.124
Zinc (D)				<0.005		0.019
Potassium (T)						
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	07/09/98	07/09/98	07/09/98	07/09/98	07/09/98	07/09/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	511	510	509	506	507	502
location	east of rise (4)	east of rise (4)	east of rise (4)	west end (3)	west end (3)	near ash face (2)
sample depth	20'	40'	70'	30'	40'	20'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	10.9	11.3	11.4	11.0	11.1	11.2
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	800		1026	847	942	900
Alkalinity	92.0	148.0	168.0	106.0	122.0	120.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.071		0.055	<0.020	<0.020	
Iron (D)						
Manganese (T)	<0.010		<0.010	<0.010	<0.010	
Manganese (D)			<0.010	<0.010	<0.010	
Sulfate (T)	196		202	212	184	
Sulfide						
Fluoride	0.78		0.95	0.82	0.84	
Chloride	2.0	2.0	2.0	2.0	2.0	2.0
Sodium	8.12	7.40	8.49	7.08	7.83	
Dis. Solids	510		646	542	590	566
Sus. Solids	<2		6	<2	<2	2
Ammonia N	0.02	0.04	0.04	0.03	0.03	0.03
Nitrate N	0.09		0.08	0.09	0.09	0.09
Bicarbonate						
Turbidity	1.86	2.00	3.40	1.50	1.06	1.08
COD						
TOC						
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.070		1.190	0.952	1.100	
Aluminum (D)			1.110	0.952	1.030	
Arsenic (T)	0.008		0.013	0.006	0.011	0.007
Arsenic (D)			0.013	0.006	0.011	0.007
Barium (T)	0.016	<0.010	<0.010	<0.010	<0.010	
Barium (D)		<0.010	<0.010	<0.010	<0.010	
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	
Cadmium (D)		<0.010	<0.010	<0.010	<0.010	
Calcium (T)	152.00	141.00	173.00	135.00	172.00	
Calcium (D)		135.00	173.00	135.00	157.00	
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	
Chromium (D)		<0.050	<0.050	<0.050	<0.050	
Copper (T)	0.062	<0.010	<0.010	**0.018**	<0.010	
Copper (D)			<0.010	**<0.010**	<0.010	
Lead (T)	0.0046		0.0019	**0.0021**	<0.001	0.0094
Lead (D)			0.0017	**0.0014**	<0.001	0.0014
Magnesium (T)	0.63	0.53	0.31	0.63	0.39	
Magnesium (D)		0.53	0.30	0.63	0.38	
Mercury (T)	<0.001		<0.001	<0.001	<0.001	<0.001
Mercury (D)			<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050		<0.050	<0.050	<0.050	
Nickel (D)			<0.050	<0.050	<0.050	
Selenium (T)	0.0341		0.0463	0.0306	0.0421	0.0322
Selenium (D)			0.0448	0.0306	0.0419	0.0305
Silver (T)						
Silver (D)						
Zinc (T)	0.037		<0.010	<0.010	<0.010	
Zinc (D)			<0.010	<0.010	<0.010	
Potassium (T)						
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	07/09/98	07/09/98	07/09/98	07/09/98	08/12/98	08/12/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	504	505	500	501	519	518
location	near ash face (2)	near ash face (2)	at ash face (1)	at ash face (1)	east of rise (4)	east of rise (4)
sample depth	60'	70'	20'	30'	20'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	10.8	11.3	11.1	11.1	11.4	11.6
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	721	1004	862	815	1273	1620
Alkalinity	80.0	142.0	108.0	108.0	172.0	244.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	<0.020	0.023	0.074	0.061	<0.020	0.067
Iron (D)						
Manganese (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Manganese (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sulfate (T)	262	107	223	195	369	393
Sulfide						
Fluoride	0.77	0.89	0.83	0.83	1.15	1.15
Chloride	2.0	2.0	2.0	2.0	3.0	3.0
Sodium	7.40	7.85	7.23	<0.2	9.87	10.30
Dis. Solids	494	618	572	536	311	679
Sus. Solids	2	8	<2	<2	<2	8
Ammonia N	0.02	0.04	0.03	0.03	0.06	0.06
Nitrate N	0.10	0.08	0.17	0.10	0.09	0.08
Bicarbonate						
Turbidity	1.34	3.20	1.09	1.55	1.60	3.00
COD						
TOC					19.11	19.52
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.020	1.160	1.040	1.400	1.320	1.440
Aluminum (D)	0.963	1.050	0.984	1.070	1.320	1.350
Arsenic (T)	0.007	0.010	0.005	**0.009**	<0.004	<0.004
Arsenic (D)	0.007	0.010	0.005	**0.006**	<0.004	<0.004
Barium (T)	0.012	0.014	0.013	0.013	0.013	0.015
Barium (D)	0.012	0.013	0.012	0.013	0.013	0.014
Cadmium (T)	<0.010	<0.010	<0.01	<0.01	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.01	<0.01	<0.010	<0.010
Calcium (T)	169.00	169.00	139.00	182.00	196.00	212.00
Calcium (D)	169.00	168.00	139.00	182.00	195.00	212.00
Chromium (T)	<0.050	<0.050	<0.05	<0.05	0.051	0.055
Chromium (D)	<0.050	<0.050	<0.05	<0.05	0.051	0.055
Copper (T)	0.071	<0.010	0.132	0.020	0.018	0.021
Copper (D)	<0.010	<0.010	0.014	<0.010	0.012	<0.010
Lead (T)	0.0018	0.0014	0.0175	0.0019	<0.001	<0.001
Lead (D)	0.0012	0.0010	0.0019	0.0016	<0.001	<0.001
Magnesium (T)	0.63	0.40	0.78	0.60	0.19	0.17
Magnesium (D)	0.62	0.39	0.71	0.40	0.19	0.17
Mercury (T)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.05	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.05	<0.050	<0.050	<0.050
Selenium (T)	0.0327	0.0395	0.0284	**0.0376**	<0.007	<0.007
Selenium (D)	0.0327	0.0395	0.0284	**0.0323**	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	0.039	<0.010	0.087	0.024	<0.010	<0.010
Zinc (D)	0.011	<0.010	0.017	0.010	<0.010	<0.010
Potassium (T)					10.40	11.60
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	08/12/98	08/12/98	08/12/98	08/12/98	08/12/98	08/12/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	516	515	514	512	513	517
location	east of rise (4)	west end (3)	west end (3)	at ash face (1)	at ash face (1)	at ash face (1)
sample depth	60'	40'	30'	20'	30'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.5	11.5	11.6	11.5	11.5	11.4
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	1458	1366	1577	1379	1381	1355
Alkalinity	214.0	192.0	238.0	196.0	200.0	192.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.199	<0.020	<0.020	0.074	0.039	0.111
Iron (D)		<0.020				
Manganese (T)	<0.010	0.014	0.013	0.012	0.013	<0.010
Manganese (D)	<0.010	0.014	0.012	0.012	0.013	<0.010
Sulfate (T)	400	358	354	329	336	307
Sulfide						
Fluoride	1.12	1.19	1.18	1.13	1.18	1.10
Chloride	3.0	3.0	3.0	3.0	3.0	3.0
Sodium	11.60	10.80	11.30	10.60	10.80	10.70
Dis. Solids	782	706	861	762	822	775
Sus. Solids	10	40	12	<2	<2	8
Ammonia N	0.06	0.05	0.05	0.04	0.05	0.06
Nitrate N	0.09	0.09	0.09	0.11	0.10	0.09
Bicarbonate						
Turbidity	8.10	2.50	1.30	3.30	4.10	3.90
COD						
TOC						
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	2.180	1.490	1.460	1.640	1.510	1.720
Aluminum (D)	2.080	1.470	1.430	1.500	1.480	1.720
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.024	0.017	0.019	0.018	0.018	0.018
Barium (D)	0.024	0.017	0.018	0.016	0.017	0.018
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	237.00	206.00	234.00	202.00	215.00	219.00
Calcium (D)	229.00	204.00	232.00	202.00	215.00	219.00
Chromium (T)	0.062	0.053	0.057	0.056	0.057	0.057
Chromium (D)	0.060	0.053	0.057	0.056	0.051	0.057
Copper (T)	0.037	0.024	0.053	0.017	0.021	0.019
Copper (D)	0.029	<0.010	0.026	<0.010	0.021	0.011
Lead (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium (T)	**0.26**	0.18	0.14	0.20	0.17	0.21
Magnesium (D)	**0.21**	0.18	0.14	0.19	0.17	0.21
Mercury (T)	<0.001	<0.001	0.003	0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	0.002	0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	**0.045**	0.018	0.041	0.011	0.014	0.016
Zinc (D)	**0.019**	0.010	0.011	0.011	0.011	0.016
Potassium (T)						
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	09/15/98	09/15/98	09/15/98	09/15/98	09/15/98	09/15/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	526	533	534	529	527	528
location		west end (3)	west end (3)	near ash face (2)	near ash face (2)	near ash face (2)
sample depth		30'	40'	60'	20'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.5	11.5	11.5	11.5	11.5	11.5
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	1763	1781	1851	1817	1781	1728
Alkalinity	272.0	256.0	272.0	282.0	274.0	258.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.062	0.038	0.138	0.135	0.098	0.040
Iron (D)						
Manganese (T)	<0.010	0.022	**0.024**	0.022	0.021	0.018
Manganese (D)		0.012	**<0.010**	0.020	0.019	0.018
Sulfate (T)	415	410	401	389	395	383
Sulfide						
Fluoride	1.35	1.35	1.37	1.40	1.40	1.36
Chloride	4.0	3.0	4.0	5.0	4.0	4.0
Sodium	14.80	12.50	12.40	11.80	11.80	11.70
Dis. Solids	892	988	962	999	1009	928
Sus. Solids	<2	<2	12	80	<2	<2
Ammonia N	0.06	0.07	0.07	0.07	0.06	0.06
Nitrate N	0.08	0.10	0.09	0.09	0.08	0.08
Bicarbonate						
Turbidity	5.50	1.78	1.69	77.00	1.67	1.29
COD						
TOC						
Silica (T)	20.99	20.46	20.91	22.04	20.24	19.65
Silica (D)						
Annual Parameters						
Aluminum (T)	1.470	1.400	1.560	1.710	1.410	1.290
Aluminum (D)		1.400	1.410	1.340	1.250	1.240
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)		<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.023	0.021	0.022	0.024	0.023	0.020
Barium (D)		0.020	0.019	0.020	0.019	0.019
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)		<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	286.50	266.00	265.00	258.00	252.00	252.00
Calcium (D)		261.00	257.00	256.00	244.00	251.00
Chromium (T)	0.070	0.068	0.073	0.072	0.067	0.066
Chromium (D)		0.066	0.067	0.068	0.065	0.065
Copper (T)	0.046	0.029	0.030	0.020	0.030	0.022
Copper (D)		<0.010	<0.010	<0.010	<0.010	<0.010
Lead (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (D)		<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium (T)	0.11	0.11	**0.24**	0.17	0.10	0.08
Magnesium (D)		0.11	**0.10**	0.09	0.09	0.08
Mercury (T)	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)		<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)		<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	0.029	0.021	0.020	0.016	0.019	0.014
Zinc (D)		0.010	0.020	0.014	0.014	<0.010
Potassium (T)	15.10	12.70	13.70	14.00	13.70	12.70
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	09/15/98	09/15/98	09/15/98	10/14/98	10/14/98	10/14/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	531	532	530	539	540	541
location	east of rise (4)	east of rise (4)	east of rise (4)	west end (3)	west end (3)	at ash face (1)
sample depth	40'	60'	20'	20'	40'	20'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.5	11.5	11.4	11.7	11.7	11.7
Temperature [C]						
D.O.						
Tot. Hardness	1782	1755	1731	2040	2040	2060
Conductivity	258.0	250.0	252.0	328.0	320.0	326.0
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	0.322	1.880	<0.020	0.056	0.057	0.058
Iron (T)						
Iron (D)	0.025	0.027	0.022	<0.010	0.010	0.010
Manganese (T)	0.017	0.021	0.022	<0.010	<0.010	0.010
Manganese (D)	388	406	396	852	455	418
Sulfate (T)						
Sulfide	1.34	1.32	1.33	1.52	1.56	1.57
Fluoride	4.0	4.0	4.0	4.0	5.0	4.0
Chloride	12.50	13.20	12.60	15.60	15.40	16.20
Sodium	1064	1004	902	1129	1085	1037
Dis. Solids	<2	<2	<2	16	8	14
Sus. Solids	0.05	0.05	0.05	0.06	0.07	0.07
Ammonia N	0.09	0.09	0.08	0.11	0.10	0.10
Nitrate N						
Bicarbonate	3.30	1.95	2.10	13.90	11.20	19.70
Turbidity						
COD						
TOC	21.23	38.95	20.89	18.32	18.53	18.85
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.740	7.820	1.360	0.899	0.923	1.020
Aluminum (D)	1.310	1.340	1.260	0.835	0.877	0.807
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.023	0.071	0.020	0.023	0.023	0.023
Barium (D)	0.020	0.019	0.019	0.022	0.023	0.021
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	275.00	277.00	262.00	294.00	285.00	312.00
Calcium (D)	275.00	263.00	248.00	293.00	285.00	305.00
Chromium (T)	0.070	0.073	0.076	0.081	0.085	0.086
Chromium (D)	0.070	0.065	0.066	0.079	0.085	0.081
Copper (T)	0.026	0.018	0.015	0.028	0.016	0.019
Copper (D)	<0.010	<0.010	<0.010	0.011	0.013	<0.010
Lead (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium (T)	0.15	0.68	0.09	0.09	0.09	0.10
Magnesium (D)	0.09	0.09	0.09	0.08	0.09	0.08
Mercury (T)	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.070	<0.007	<0.007	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	0.018	0.017	0.014	0.031	0.013	0.016
Zinc (D)	0.011	<0.010	<0.010	0.019	0.012	0.010
Potassium (T)	13.60	12.50	13.80	16.00	15.90	15.90
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/14/98	10/14/98	10/14/98	10/14/98	10/14/98	10/14/98
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	542	543	544	545	546	547
location	at ash face (1)	near ash face (2)	near ash face (2)	near ash face (2)	east of rise (4)	east of rise (4)
sample depth	40'	20'	40'	60'	20'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.7	11.7	11.7	11.7	11.7	11.7
Temperature [C]						
D.O.						
Tot. Hardness	2050	2070	2060	2080	2050	2050
Conductivity	324.0	320.0	318.0	314.0	312.0	306.0
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	0.042	0.043	0.036	0.077	0.038	0.055
Iron (T)						
Iron (D)	0.011	0.023	0.011	0.012	0.013	0.012
Manganese (T)	0.011	0.023	0.011	0.011	0.013	0.010
Manganese (D)	388	344	402	373	371	327
Sulfate (T)						
Sulfide	1.56	1.57	1.57	1.57	1.55	1.54
Fluoride	5.0	4.0	4.0	4.0	4.0	4.0
Chloride	15.70	15.70	15.30	16.00	15.70	16.20
Sodium	1073	1154	1091	1085	1089	1078
Dis. Solids	18	20	20	20	22	20
Sus. Solids	0.07	0.07	0.07	0.07	0.07	0.08
Ammonia N	0.10	0.10	0.10	0.10	0.10	0.10
Nitrate N						
Bicarbonate	11.20	9.70	16.70	23.00	16.80	16.80
Turbidity						
COD						
TOC	18.92	18.49	17.12	18.32	18.43	18.45
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.110	0.927	0.873	1.040	0.904	0.992
Aluminum (D)	1.080	0.927	0.795	0.849	0.848	0.813
Arsenic (T)	<0.004	0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.024	0.022	0.021	0.023	0.023	0.022
Barium (D)	0.024	0.022	0.020	0.022	0.022	0.021
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	309.00	301.00	292.00	311.00	317.00	315.00
Calcium (D)	308.00	298.00	292.00	311.00	313.00	296.00
Chromium (T)	0.085	0.082	0.079	0.082	0.085	0.084
Chromium (D)	0.078	0.082	0.079	0.082	0.082	0.081
Copper (T)	0.025	**0.036**	0.028	0.021	0.028	0.034
Copper (D)	0.023	**0.010**	0.013	0.017	<0.010	<0.010
Lead (T)	<0.001	**0.0028**	0.0027	0.0024	0.0022	0.0027
Lead (D)	<0.001	**0.0013**	0.0019	0.0016	0.0015	0.0017
Magnesium (T)	0.11	**0.12**	0.09	0.10	0.09	0.10
Magnesium (D)	0.11	**0.10**	0.08	0.08	0.08	0.10
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	0.0532	**0.0528**	0.0532	**0.0527**	0.0531
Selenium (D)	<0.007	0.0518	**0.0513**	0.0520	**0.0522**	0.0509
Silver (T)						
Silver (D)						
Zinc (T)	0.023	**0.045**	0.023	0.019	0.023	0.022
Zinc (D)	0.018	**0.022**	0.018	0.019	0.019	0.014
Potassium (T)	15.90	16.10	15.30	15.90	16.00	16.30
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/14/98	11/24/98	11/24/98	11/24/98	11/24/98	02/01/99
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	548	561	559	557	560	565
location	east of rise (4)	at ash face (1)	east of rise (4)	near ash face (2)	east of rise (4)	at boat ramp
sample depth	60'	20'	20'	20'	30'	0
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.7	11.9	11.9	11.9	11.8	10.0
Temperature [C]						
D.O.						
Tot. Hardness						588
Conductivity	2100	2660	2700	2700	2700	36.0
Alkalinity	318.0	444.0	466.0	472.0	454.0	0.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.150	0.046	0.167	<0.020	0.481	0.054
Iron (D)						
Manganese (T)	**0.032**	<0.010	<0.010	<0.010	<0.010	0.053
Manganese (D)	**0.023**	<0.010	<0.010	<0.010	<0.010	0.053
Sulfate (T)	332	149	152	143	143	267
Sulfide						
Fluoride	1.56	1.40	1.50	1.40	1.50	0.56
Chloride	4.0	5.0	5.0	5.0	5.0	2.0
Sodium	15.30	19.50	20.60	19.20	19.30	9.96
Dis. Solids	1173	1348	1158	1316	1222	408
Sus. Solids	166	28	86	30	46	<2
Ammonia N	0.08	0.08	0.08	0.08	0.08	0.05
Nitrate N	0.10	0.10	0.10	0.12	0.10	0.11
Bicarbonate						
Turbidity	130.00	16.00	40.00	7.40	21.00	4.01
COD						
TOC	18.00	12.43	14.21	12.54	17.48	10.76
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.280	0.279	0.739	0.208	1.950	0.582
Aluminum (D)	1.040	<0.200	0.246	<0.200	<0.200	0.582
Arsenic (T)	0.004	<0.004	<0.004	<0.004	<0.004	<0.040
Arsenic (D)	<0.0040	<0.004	<0.004	<0.004	<0.004	<0.040
Barium (T)	0.024	0.022	0.026	0.025	0.034	0.018
Barium (D)	0.020	0.022	0.023	0.025	0.021	0.018
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	301.00	382.00	375.00	358.00	372.00	108.00
Calcium (D)	301.00	382.00	369.00	357.00	372.00	104.00
Chromium (T)	0.078	0.106	0.106	0.105	0.107	<0.050
Chromium (D)	0.075	0.106	0.106	0.105	0.107	<0.050
Copper (T)	0.015	0.016	0.045	0.042	0.028	<0.010
Copper (D)	<0.010	<0.010	<0.010	0.011	<0.010	<0.010
Lead (T)	0.0020	0.0019	0.0034	0.0026	0.0034	<0.010
Lead (D)	<0.001	0.0014	0.0020	0.0020	0.0014	<0.010
Magnesium (T)	**0.22**	0.13	0.18	0.12	0.26	3.42
Magnesium (D)	**0.13**	0.12	0.17	0.12	0.12	3.42
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	**0.0522**	0.0467	0.0483	0.0471	0.0489	<0.070
Selenium (D)	**0.0519**	0.0454	0.0483	0.0471	0.0489	<0.070
Silver (T)						
Silver (D)						
Zinc (T)	0.017	0.034	**0.189**	0.038	0.036	0.022
Zinc (D)	<0.010	0.034	**0.051**	0.038	0.031	0.017
Potassium (T)	15.20	17.30	18.20	18.10	18.40	7.50
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/24/99	04/22/99	04/22/99	04/22/99	04/22/99	04/22/99
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	593	600	599	606	605	603
location	at boat ramp	at ash face (1)	at ash face (1)	east of rise (4)	east of rise (4)	west end (3)
sample depth	0	50'	20'	40'	20'	20'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.4	11.3	11.2	11.4	11.3	11.3
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	1462	1370	1260	1311	1241	1245
Alkalinity	190.0	146.0	130.0	148.0	136.0	136.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	<0.020	<0.020	0.046	<0.020	0.034	<0.020
Iron (D)						
Manganese (T)	<0.010	<0.010	**0.015**	<0.010	<0.010	<0.010
Manganese (D)	<0.010		**<0.010**	<0.010	<0.010	<0.010
Sulfate (T)	406	402	377	386	382	383
Sulfide						
Fluoride	1.00	1.14	1.10	1.01	0.98	1.04
Chloride	4.0	4.0	4.0	4.0	5.0	5.0
Sodium	15.80	14.70	14.80	15.30	16.80	14.90
Dis. Solids	774	764	766	674	774	870
Sus. Solids	10	6	14	8	<2	<2
Ammonia N	0.05	0.05	0.03	0.04	0.04	0.04
Nitrate N	0.13	0.13	0.13	0.13	0.13	0.13
Bicarbonate						
Turbidity	1.34	2.28	1.41	2.33	1.62	2.67
COD						
TOC	8.67	10.02	10.42	8.37	8.73	7.30
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	**0.743**	0.637	0.768	0.669	0.675	0.617
Aluminum (D)	**0.651**		0.748	0.664	0.675	0.638
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004		<0.004	<0.004	<0.004	<0.004
Barium (T)	0.018	0.018	0.019	0.018	0.017	0.016
Barium (D)	0.018		0.019	0.018	0.017	0.016
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010		<0.010	<0.010	<0.010	<0.010
Calcium (T)	220.00	203.00	185.00	242.00	228.00	188.00
Calcium (D)	214.00		183.00	242.00	228.00	188.00
Chromium (T)	0.054	0.063	0.062	0.059	0.055	0.057
Chromium (D)	0.054		0.058	0.057	0.052	0.055
Copper (T)	<0.010	0.033	0.066	0.025	0.027	0.036
Copper (D)	<0.010		0.014	0.012	0.015	0.014
Lead (T)	<0.001	0.0025	0.0033	0.0015	0.0014	0.0020
Lead (D)	<0.001		0.0011	0.0012	0.0012	0.0014
Magnesium (T)	0.18	0.15	**0.32**	0.15	0.15	0.17
Magnesium (D)	0.17		**0.18**	0.15	0.15	0.17
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050		<0.050	<0.050	<0.050	<0.050
Selenium (T)	0.0203	0.0179	0.0182	0.0212	0.0210	0.0188
Selenium (D)	0.0184		0.0176	0.0212	0.0187	0.0194
Silver (T)						
Silver (D)						
Zinc (T)	**0.015**	0.027	0.047	0.018	0.017	0.026
Zinc (D)	**<0.010**		0.024	0.010	0.016	0.017
Potassium (T)	11.20	11.60	14.40	3.78	3.66	10.30
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	04/22/99	04/22/99	04/22/99	06/30/99	06/30/99	06/30/99
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	602	601	604	828	826	824
location	near ash face (2)	near ash face (2)	west end (3)	east of rise (4)		near ash face (2)
sample depth	60' DEP	20' DEP	60' DEP	40' DEP	DEP	50' DEP
Laboratory						
Field pH	11.4	11.3	11.4	11.1	10.8	11.3
Lab pH						
Temperature [C]						
D.O.						
Tot. Hardness	1355	1251	1357	106.0	72.0	132.0
Conductivity	162.0	136.0	156.0	0.0	0.0	0.0
Alkalinity	0.0	0.0	0.0	<0.02	0.235	**0.055**
Hot Acidity	<0.020	<0.020	<0.020			**<0.020**
Iron (T)				0.020	0.021	0.025
Iron (D)	<0.010	<0.010	<0.010			0.012
Manganese (T)		<0.010	<0.010	418	438	434
Manganese (D)	397	393	386			
Sulfate (T)						
Sulfide	1.14	1.11	1.03			
Fluoride	5.0	4.0	5.0	15.50	16.60	17.10
Chloride	16.90	14.60	16.00			
Sodium	834	778	790	14	54	6
Dis. Solids	4	<2	20			
Sus. Solids	0.04	0.04	0.04			
Ammonia N	0.14	0.13	0.13			
Nitrate N						
Bicarbonate	4.40	3.01	9.73			
Turbidity						
COD						
TOC	8.17	7.94	9.10	8.88	10.81	9.93
Silica (T)						
Silica (D)						
Annual Parameters				0.598	1.150	0.712
Aluminum (T)	0.657	0.657	0.557			0.654
Aluminum (D)		0.657	0.538			
Arsenic (T)	<0.004	<0.004	<0.004			
Arsenic (D)		<0.004	<0.004			
Barium (T)	0.018	0.019	0.019			
Barium (D)		0.019	0.019			
Cadmium (T)	<0.010	<0.010	<0.010			
Cadmium (D)		<0.010	<0.010			
Calcium (T)	217.00	192.00	218.00			
Calcium (D)		192.00	218.00			
Chromium (T)	0.063	0.060	0.063			
Chromium (D)		0.060	0.063			
Copper (T)	0.019	0.015	0.036			
Copper (D)		0.015	0.013			
Lead (T)	0.0022	**0.0013**	0.0024			
Lead (D)		**<0.001**	0.0019			
Magnesium (T)	0.15	**0.18**	0.15			
Magnesium (D)		**0.16**	0.15			
Mercury (T)	<0.001	<0.001	<0.001			
Mercury (D)	<0.001	<0.001	<0.001			
Nickel (T)	<0.050	<0.050	<0.050			
Nickel (D)		<0.050	<0.050			
Selenium (T)	0.0201	0.0176	0.0220			
Selenium (D)		0.0176	0.0220			
Silver (T)						
Silver (D)						
Zinc (T)	0.019	0.016	0.026			
Zinc (D)		0.016	0.026			15.20
Potassium (T)	17.10	10.50	13.00	12.70	14.50	14.20
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	06/30/99	06/30/99	06/30/99	06/30/99	06/30/99	8/11/1999
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	823	827	821	825	822	641
location	near ash face (2)	east of rise (4)	at ash face (1)	west end (3)	at ash face (1)	east of rise (4)
sample depth	20' DEP	20' DEP	20' DEP	20' DEP	50' DEP	40' DEP
Laboratory						
Field pH	10.9	10.5	10.4	9.5	11.4	11.3
Lab pH						
Temperature [C]						
D.O.						
Tot. Hardness						1678
Conductivity	82.0	58.0	52.0	34.0	164.0	188.0
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	**0.027**	<0.020	**0.134**	<0.020	**0.052**	0.096
Iron (T)	**<0.020**		**<0.020**		**<0.020**	
Iron (D)	**0.036**	0.016	0.022	0.018	0.023	0.011
Manganese (T)	**0.017**		0.014		0.018	<0.010
Manganese (D)	421	433	503	416	455	496
Sulfate (T)						1.20
Sulfide						5.0
Fluoride						17.60
Chloride	17.30	14.30	16.30	15.40	17.00	848
Sodium						50
Dis. Solids	8	12	6	10	10	*0.05*
Sus. Solids						0.14
Ammonia N						
Nitrate N						6.46
Bicarbonate						
Turbidity						
COD						
TOC	9.31	8.11	9.63	8.80	9.39	
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	**0.882**	0.598	0.775	0.618	0.653	1.350
Aluminum (D)	**0.576**		0.672		0.653	1.250
Arsenic (T)						<0.004
Arsenic (D)						<0.004
Barium (T)						0.033
Barium (D)						0.026
Cadmium (T)						0.010
Cadmium (D)						<0.010
Calcium (T)						254.00
Calcium (D)						251.00
Chromium (T)						0.086
Chromium (D)						0.077
Copper (T)						0.023
Copper (D)						<0.010
Lead (T)						0.0016
Lead (D)						0.0016
Magnesium (T)						0.14
Magnesium (D)						0.13
Mercury (T)						<0.001
Mercury (D)						<0.001
Nickel (T)						<0.050
Nickel (D)						<0.050
Selenium (T)						0.0355
Selenium (D)						0.0355
Silver (T)						
Silver (D)						**0.035**
Zinc (T)						**0.023**
Zinc (D)						
Potassium (T)	16.20	11.90	14.30	13.00	15.20	
Potassium (D)	16.20		15.40		16.00	

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	8/11/1999	8/11/1999	8/11/1999	8/11/1999	8/11/1999	8/11/1999
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	640	639	638	636	635	634
location	east of rise (4)	west end (3)		near ash face (2)	at ash face (1)	at ash face (1)
sample depth	20'	40'		20'	40'	20'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.2	11.2	11.2	11.2	11.4	11.4
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	1556	1588	1573	1570	1769	1872
Alkalinity	162.0	168.0	172.0	166.0	218.0	236.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.078	0.122	0.159	0.234	1.180	0.846
Iron (D)						
Manganese (T)	<0.010	0.023	0.029	0.032	0.053	**0.203**
Manganese (D)	<0.010	0.023	0.023	0.030	0.053	**0.043**
Sulfate (T)	500	509	462	461	464	514
Sulfide						
Fluoride	1.20	1.20	1.20	1.20	1.30	1.30
Chloride	5.0	5.0	5.0	5.0	5.0	5.0
Sodium	18.40	17.90	20.00	19.00	20.10	19.40
Dis. Solids	756	976	960	870	954	980
Sus. Solids	14	16	6	6	<2	<2
Ammonia N	*0.04*	*0.05*	*0.05*	*0.04*	*0.05*	*0.05*
Nitrate N	0.15	0.15	0.15	0.15	0.15	0.14
Bicarbonate						
Turbidity	3.85	6.44	7.33	6.17	6.22	4.20
COD						
TOC						
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)	1.120	1.260	1.520	1.270	1.290	**1.620**
Aluminum (D)	0.960	1.230	1.230	1.230	1.290	**1.210**
Arsenic (T)	0.005	<0.004	0.004	<0.004	0.005	0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.030	0.023	0.025	0.022	0.028	**0.038**
Barium (D)	0.024	0.023	0.023	0.022	0.028	**0.024**
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	274.00	270.00	318.00	286.00	302.00	283.00
Calcium (D)	271.00	270.00	297.00	286.00	302.00	281.00
Chromium (T)	0.077	0.076	0.083	**0.086**	0.074	0.079
Chromium (D)	0.066	0.076	0.078	**0.073**	0.073	0.074
Copper (T)	0.020	0.018	0.013	0.022	0.021	**0.048**
Copper (D)	0.012	<0.010	<0.010	<0.010	0.016	**0.038**
Lead (T)	0.0014	0.0016	0.0018	0.0069	0.0274	**0.0248**
Lead (D)	0.0014	0.0016	0.0017	0.0019	0.0274	**0.2090**
Magnesium (T)	0.11	0.14	0.16	0.16	0.12	**0.33**
Magnesium (D)	0.10	0.14	0.12	0.15	0.12	**0.13**
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	**0.284**
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	**<0.050**
Selenium (T)	0.0388	0.0352	0.0388	0.0372	0.0411	0.0396
Selenium (D)	0.0368	0.0352	0.0357	0.0351	0.0390	0.0366
Silver (T)						
Silver (D)						
Zinc (T)	**0.021**	**0.041**	0.039	**0.058**	0.162	**1.250**
Zinc (D)	**<0.010**	**0.012**	<0.010	**0.038**	0.162	**0.110**
Potassium (T)						
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/27/1999	10/27/1999	10/27/1999	10/27/1999	10/27/1999	10/27/1999
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	11	12	13	16	17	18
location	at ash face (1)	at ash face (1)	near ash face (2)	west end (3)	east of rise (4)	east of rise (4)
sample depth	20' DEP	40' DEP	20' DEP	40' DEP	20' DEP	40' DEP
Laboratory						
Field pH						
Lab pH	11.8	11.8	11.8	11.8	11.8	11.8
Temperature [C]						
D.O.						
Tot. Hardness	2840	2820	2810	2850	2780	2740
Conductivity	452.0	440.0	436.0	398.0	380.0	370.0
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	<0.020	0.061	0.084	<0.020	<0.020	0.053
Iron (T)						
Iron (D)	**0.010**	**0.002**	**0.011**	0.045	**0.066**	<0.010
Manganese (T)	**<0.010**	**<0.010**	**0.010**	0.031	**0.029**	<0.010
Manganese (D)	200	564	562	549	547	678
Sulfate (T)						
Sulfide	1.65	1.64	1.61	1.60	1.62	1.60
Fluoride	7.0	6.0	7.0	6.0	6.0	7.0
Chloride	23.90	23.50	22.30	25.80	24.90	25.40
Sodium	1384	1348	1384	1380	1394	1394
Dis. Solids	10	10	12	16	8	16
Sus. Solids	*0.04*	*0.04*	*0.04*	*0.05*	*0.04*	*0.04*
Ammonia N	0.18	0.16	0.16	0.16	0.16	0.16
Nitrate N						
Bicarbonate	10.90	6.69	3.55	13.20	8.01	6.52
Turbidity						
COD						
TOC						
Silica (T)	**11.86**	13.46	12.41	13.80	14.74	14.02
Silica (D)	**10.74**	12.43	11.73	13.63	14.74	13.80
Annual Parameters						
Aluminum (T)	**0.377**	0.621	**0.451**	**0.526**	**0.605**	0.430
Aluminum (D)	**0.361**	0.607	**0.448**	**0.362**	**0.301**	0.312
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	**0.034**	0.038	0.034	0.036	0.037	0.035
Barium (D)	**0.033**	0.035	0.033	0.036	0.037	0.035
Cadmium (T)	<0.010	**<0.010**	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	**0.010**	<0.010	<0.010	<0.010	<0.010
Calcium (T)	424.00	429.00	**425.00**	436.00	424.00	426.00
Calcium (D)	423.00	417.00	**423.00**	436.00	424.00	426.00
Chromium (T)	**0.120**	0.130	0.124	0.117	0.119	0.119
Chromium (D)	**0.117**	0.126	0.121	0.116	0.117	0.119
Copper (T)	0.050	0.030	0.028	0.021	**0.061**	0.026
Copper (D)	0.023	0.015	<0.010	0.012	**0.029**	<0.010
Lead (T)	0.0039	0.0030	0.0021	0.0030	**0.0094**	0.0029
Lead (D)	0.0030	0.0021	0.0016	0.0024	**0.0030**	0.0022
Magnesium (T)	0.07	**0.15**	0.08	**0.22**	**0.14**	0.07
Magnesium (D)	0.07	**0.09**	0.07	**0.07**	**0.06**	0.06
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	0.0523	0.0540	0.0523	0.0518	0.0526	0.0530
Selenium (D)	0.0523	0.0534	0.0523	0.0502	0.0504	0.0521
Silver (T)						
Silver (D)				0.024	**0.517**	**0.059**
Zinc (T)	**0.052**	**0.040**	**0.123**	0.024	**0.019**	**0.018**
Zinc (D)	**0.030**	**0.022**	**0.024**	27.60	27.50	28.60
Potassium (T)	**27.50**	29.70	27.80	27.10	27.30	28.60
Potassium (D)	**24.30**	28.90	26.50			

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	11/23/1999	12/29/1999	3/7/2000	3/27/2000	4/25/2000	4/25/2000
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	29	54	185	190	206	207
location	at boat ramp	at boat ramp	at boat ramp	at boat ramp	at ash face (1)	at ash face (1)
sample depth	0	0	0	0	20'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.6	11.9	10.5	9.9	11.3	11.7
Temperature [C]						
D.O.						
Tot. Hardness	2590	2820	744	782	1337	2310
Conductivity	390.0	462.0	60.0	56.0	146.0	340.0
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	0.054	0.046		0.068	<0.020	<0.020
Iron (T)				0.030	<0.010	<0.010
Iron (D)	0.059	<0.010		0.030	<0.010	<0.010
Manganese (T)	0.059	<0.010		368	421	499
Manganese (D)	549	165	283			
Sulfate (T)				0.60	0.89	1.28
Sulfide	1.60	1.47	0.46	4.0	5.0	6.0
Fluoride	10.0	6.0	3.0	15.10	19.30	20.50
Chloride	25.80	28.50		574	842	1216
Sodium	1238	1492	498	28	4	6
Dis. Solids	4	6	26	*0.03*	0.02	<0.02
Sus. Solids	*<0.02*	*0.04*	*0.03*	0.11	0.14	0.17
Ammonia N	0.17	0.15	0.26			
Nitrate N				2.40	<1	<1
Bicarbonate	1.10	5.58	1.94			
Turbidity						
COD				9.54	8.75	8.80
TOC	9.80	10.79				
Silica (T)	9.80					
Silica (D)						
Annual Parameters				1.150	0.588	0.495
Aluminum (T)	**0.281**	0.322		0.996	0.558	0.489
Aluminum (D)	**0.214**	<0.20		<0.004	<0.004	<0.004
Arsenic (T)	<0.04	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	0.019	0.019	0.020
Barium (T)	0.031	0.034		0.019	0.016	0.019
Barium (D)	0.030	0.031		<0.010	<0.010	<0.010
Cadmium (T)	<0.010	<0.010		<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010		142.00	195.00	225.00
Calcium (T)	368.00	396.00		136.00	176.00	224.00
Calcium (D)	360.00	369.00		<0.050	0.066	0.079
Chromium (T)	0.111	0.135		<0.050	0.058	0.076
Chromium (D)	0.110	0.131		<0.010	0.020	0.014
Copper (T)	<0.010	<0.010		<0.010	0.011	0.012
Copper (D)	<0.010	<0.010		<0.001	0.0010	<0.001
Lead (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (D)	<0.001	<0.001	<0.001	1.84	0.32	0.26
Magnesium (T)	**0.14**	0.10		1.84	0.29	0.24
Magnesium (D)	**0.06**	0.08		<0.001	<0.001	<0.001
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.050	<0.050	<0.050
Nickel (T)	<0.050	<0.050		<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050		**0.0238**	0.0238	**0.0265**
Selenium (T)	0.0482	0.0468	**0.0166**	**0.0218**	0.0228	**0.0263**
Selenium (D)	0.0482	0.0468	**0.0171**			
Silver (T)						
Silver (D)				0.010	**0.147**	**0.043**
Zinc (T)	**0.037**	<0.010		0.010	**0.018**	**0.026**
Zinc (D)	**<0.010**	<0.010		14.00	14.60	19.00
Potassium (T)	27.10	25.10				
Potassium (D)	27.10					

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	4/25/2000	4/25/2000	4/25/2000	5/24/2000	6/27/2000	6/27/2000
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	209	210	211	260	284	285
location	west end (3)	east of rise (4)	east of rise (4)	at boat ramp	at ash face (1)	at ash face (1)
sample depth	40'	20'	40'	0	20'	40'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.7	11.1	11.6	11.3	11.6	11.6
Temperature [C]						
D.O.						
Tot. Hardness				1397	2520	2610
Conductivity				142.0	382.0	310.0
Alkalinity	304.0	108.0	264.0	0.0	0.0	0.0
Hot Acidity	0.0	0.0	0.0	0.0	0.039	<0.020
Iron (T)	<0.020	<0.020	0.031	0.020		
Iron (D)					<0.010	**0.021**
Manganese (T)	<0.010	<0.010	<0.010	0.010	<0.010	**<0.010**
Manganese (D)	<0.010	<0.010	<0.010	<0.010	360	565
Sulfate (T)	457	453	401	511		
Sulfide					1.42	1.32
Fluoride	1.22	0.86	1.14	1.02	7.0	7.0
Chloride	6.0	5.0	6.0	6.0	23.50	22.90
Sodium	20.60	20.50	22.30	20.10	1326	1168
Dis. Solids	1174	812	1136	898	14	16
Sus. Solids	<2	12	10	14	*0.04*	*0.04*
Ammonia N	0.21	<0.02	<0.02	*0.04*	0.18	0.18
Nitrate N	0.15	0.14	0.14	0.20		
Bicarbonate					1.94	3.71
Turbidity	1.35	1.45	1.57	4.48		
COD						
TOC					12.93	12.03
Silica (T)	8.84	8.86	9.27	9.61		
Silica (D)						
Annual Parameters						
Aluminum (T)	**0.518**	0.548	0.486	0.725	0.471	**0.604**
Aluminum (D)	**0.444**	0.480	0.455	0.663	0.428	**0.535**
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.020	0.019	0.023	0.020	0.032	0.028
Barium (D)	0.019	0.018	0.020	0.020	0.030	0.026
Cadmium (T)	<0.010	<0.010	<0.010	**0.018**	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	**<0.010**	<0.010	<0.010
Calcium (T)	226.00	218.00	250.00	**243.00**	394.00	359.00
Calcium (D)	221.00	204.00	243.00	**240.00**	373.00	335.00
Chromium (T)	0.079	0.076	0.092	<0.050	0.119	0.109
Chromium (D)	0.075	0.072	0.086	<0.050	0.108	0.099
Copper (T)	0.110	0.040	0.054	<0.010	0.050	0.031
Copper (D)	0.032	0.022	0.017	<0.010	0.030	0.012
Lead (T)	<0.001	0.0017	0.0022	<0.001	0.0047	0.0026
Lead (D)	0.0011	<0.001	0.0017	<0.001	0.0038	0.0016
Magnesium (T)	0.26	0.28	0.25	0.25	**0.15**	**0.24**
Magnesium (D)	0.24	0.25	0.22	0.20	**0.08**	**0.09**
Mercury (T)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	0.0263	0.0273	**0.0312**	0.0281	0.0339	0.0358
Selenium (D)	0.0265	0.0266	**0.0299**	0.0281	0.0338	0.0337
Silver (T)						
Silver (D)					0.045	0.027
Zinc (T)	0.020	0.028	0.015	0.017	0.035	0.022
Zinc (D)	0.017	0.014	<0.010	0.015	27.50	27.30
Potassium (T)	17.40	19.30	21.00	20.10		
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	6/27/2000	6/27/2000	6/27/2000	7/26/2000	8/22/2000	11/8/2000
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	287	288	289	310	400	487
location	west end (3)	east of rise (4)	east of rise (4)	at boat ramp	at boat ramp	east of rise (4)
sample depth	40'	20'	40'	0	0	20'
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
Field pH						
Lab pH	11.5	11.6	11.7	12.0	12.1	12.0
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	2860	2380	2620	3130	3750	3760
Alkalinity	270.0	340.0	388.0	516.0	626.0	602.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)	0.136	0.045				
Iron (D)						
Manganese (T)	<0.010	**0.031**		<0.010	**0.017**	**0.016**
Manganese (D)	<0.010	**<0.010**		<0.010	**<0.010**	**<0.010**
Sulfate (T)	577	576	548	775	538	754
Sulfide						
Fluoride	1.29	1.38	1.42	1.63	1.80	1.60
Chloride	7.0	7.0	7.0	9.0	10.0	13.0
Sodium	22.70	25.10		28.10	28.30	39.90
Dis. Solids	1172	1250	1314	1514	1628	1984
Sus. Solids	26	8	20	14	12	10
Ammonia N	*0.04*	*0.05*	*0.05*	0.05	*0.07*	
Nitrate N	0.19	0.18	0.17	0.19	0.20	0.20
Bicarbonate						
Turbidity	3.92	2.48	2.61	3.56	2.79	3.55
COD			0.00			
TOC						
Silica (T)	13.16	13.57		9.76	6.74	**4.43**
Silica (D)				8.97	6.70	**4.34**
Annual Parameters						
Aluminum (T)	0.947	**0.927**		0.434	*0.566*	**0.309**
Aluminum (D)	0.482	**0.548**		0.430	*0.362*	**<0.200**
Arsenic (T)	<0.004	<0.004		<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004		<0.004	<0.004	<0.004
Barium (T)	0.030	0.032		0.037	0.042	**0.064**
Barium (D)	0.025	0.029		0.036	0.040	**0.058**
Cadmium (T)	<0.010	<0.010		0.011	<0.010	<0.010
Cadmium (D)	<0.010	<0.010		<0.010	<0.010	<0.010
Calcium (T)	363.00	378.00		403.00	458.00	**573.00**
Calcium (D)	333.00	368.00		436.00	409.00	**566.00**
Chromium (T)	0.107	0.118		**0.143**	0.153	0.208
Chromium (D)	0.105	0.116		**0.011**	0.137	0.198
Copper (T)	0.047	0.050		<0.010	<0.010	<0.010
Copper (D)	0.015	0.021		<0.010	<0.010	<0.010
Lead (T)	0.0035	0.0030		<0.001	<0.001	0.0041
Lead (D)	0.0020	0.0023		<0.001	<0.001	0.0011
Magnesium (T)	0.14	**0.28**		**0.12**	**0.23**	**0.11**
Magnesium (D)	0.10	**0.09**		**0.07**	**0.05**	**0.05**
Mercury (T)	<0.001	<0.001		<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001		<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050		<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050		<0.050	<0.050	<0.050
Selenium (T)	0.0336	0.0418		0.0549	0.0785	0.0734
Selenium (D)	0.0336	0.0410		0.0528	0.0734	0.0732
Silver (T)						
Silver (D)				0.129	<0.010	**0.091**
Zinc (T)	0.049	0.046		<0.010	<0.010	**0.022**
Zinc (D)	0.028	0.036		30.70	28.30	42.60
Potassium (T)	26.90	26.80		30.30	27.20	41.50
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	11/8/2000	11/8/2000	3/20/2001	5/21/2001	8/28/2001	12/4/2001	3/11/2002	5/23/2002
sample name	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla	Gorilla
sample ID	486	485	628	74	90	4553	4550	4553 116
location	?	at boat ramp	at boat ramp	at boat ramp	at boat ramp	near ash face	at boat ramp	near ash face
sample depth	?	0	0	0	0	0	0	0
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Field pH								
Lab pH	12.0	12.0	11.1	12.0	12.1	11.4	11.8	11.7
Temperature [C]								
D.O.								
Tot. Hardness								
Conductivity	3790	3750	1150	3650	3670	2230	2730	2290
Alkalinity	606.0	604.0	90.0	588.0	596.0	182.0	356.0	356.0
Hot Acidity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron (T)			0.027	**0.168**	**0.145**	**0.370**	**0.220**	0.078
Iron (D)			0.023	**<0.020**	**0.040**	**0.080**	**0.090**	
Manganese (T)	**0.012**	<0.010	**0.012**	**0.016**	**0.014**	**0.020**	**0.030**	0.032
Manganese (D)	**<0.010**	<0.010	**<0.010**	**<0.010**	**<0.010**	**<0.010**	**<0.010**	
Sulfate (T)	772	587	414	950	1021	800	739	591
Sulfide								
Fluoride	1.50	1.50						
Chloride	12.0	13.0	5.0	12.0	18.0	22.0	20.0	13.0
Sodium	40.70	39.60	17.50	38.20	52.60	53.10	56.80	34.90
Dis. Solids	2032	1770	420	2200	2186	1720	1752	1320
Sus. Solids	26	12	6	20	4	6	28	32
Ammonia N								
Nitrate N	0.20	0.23						
Bicarbonate								
Turbidity	2.67	2.91						
COD								
TOC								
Silica (T)	**4.30**	4.43	4.79	7.30	6.29	6.40	11.79	
Silica (D)	**4.22**	4.22	4.75	5.48	6.08		10.81	
Annual Parameters								
Aluminum (T)	<0.2	<0.20	**0.237**	**0.403**	**0.412**	**0.437**	0.469	0.537
Aluminum (D)	<0.2	<0.20	**0.202**	**<0.200**	**0.245**	**<0.200**	0.384	
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.004	
Barium (T)	**0.059**	0.057						
Barium (D)	**0.055**	0.054	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Cadmium (D)	<0.010	<0.010	**175.00**	533.00	614.00	346.00	457.00	350.00
Calcium (T)	**537.00**	**570.00**	**170.00**	499.00	562.00	333.00	436.00	
Calcium (D)	**531.00**	**566.00**	<0.050	0.180	0.246	0.260	0.240	0.140
Chromium (T)	**0.208**	0.209	<0.050	0.163	0.236	0.230	0.210	
Chromium (D)	**0.203**	0.214	0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Copper (D)	<0.010	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Lead (D)	<0.001	<0.001	**1.12**	**0.22**	**0.22**	**0.55**	**0.47**	0.37
Magnesium (T)	**0.05**	0.05	0.05	**0.75**	**0.06**	**0.06**	**0.09**	**0.11**
Magnesium (D)	**0.04**	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	
Nickel (D)	<0.050	<0.050	**0.0286**	0.0682	0.1010	0.0928	0.0892	0.0697
Selenium (T)	**0.0737**	**0.0732**	**0.0268**	0.0640	0.0917	0.0890	0.0893	
Selenium (D)	**0.0709**	**0.0724**						
Silver (T)								
Silver (D)			0.032	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc (T)	**0.072**	**0.053**	<0.010	<0.010	<0.010	<0.010	<0.010	
Zinc (D)	**<0.010**	**<0.010**	**15.90**	41.30	56.80	58.20	56.80	35.60
Potassium (T)	43.80	**42.90**	**15.60**	39.10	56.60	56.80	55.40	
Potassium (D)	43.30	**41.90**						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	6/3/2003
sample name	Gorilla
sample ID	4550 121
location	surface
sample depth	0
Laboratory	DEP
Field pH	
Lab pH	8.3
Temperature [C]	
D.O.	
Tot. Hardness	
Conductivity	756
Alkalinity	21.2
Hot Acidity	0.0
Iron (T)	0.070
Iron (D)	0.051
Manganese (T)	**0.011**
Manganese (D)	**<0.010**
Sulfate (T)	378
Sulfide	
Fluoride	
Chloride	2.9
Sodium	17.70
Dis. Solids	17
Sus. Solids	4
Ammonia N	
Nitrate N	
Bicarbonate	
Turbidity	
COD	
TOC	
Silica (T)	
Silica (D)	
Annual Parameters	
Aluminum (T)	0.767
Aluminum (D)	0.529
Arsenic (T)	0.008
Arsenic (D)	0.007
Barium (T)	
Barium (D)	
Cadmium (T)	<0.010
Cadmium (D)	<0.010
Calcium (T)	139.00
Calcium (D)	134.00
Chromium (T)	<0.050
Chromium (D)	<0.050
Copper (T)	<0.010
Copper (D)	<0.010
Lead (T)	<0.001
Lead (D)	<0.001
Magnesium (T)	2.87
Magnesium (D)	2.75
Mercury (T)	<0.001
Mercury (D)	<0.001
Nickel (T)	<0.050
Nickel (D)	<0.050
Selenium (T)	0.0265
Selenium (D)	0.0265
Silver (T)	
Silver (D)	
Zinc (T)	0.394
Zinc (D)	0.360
Potassium (T)	15.60
Potassium (D)	15.20

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	05/03/89	08/14/89	11/18/89	02/17/90	05/14/90	08/27/90	12/09/90	02/24/91
sample name	Well 1	Well 1	Well 1	Well 1	Well 1	Well 1	Well 1	Well 1
sample ID								
location								
Laboratory								
depth	1589	1560	1560	1566	1570	1563	1572	1567
Field pH	4.4	5.0	4.0	4.0	4.4	4.6	4.2	4.1
Lab pH	9	9	9	8	9	9	8	8
Temperature [C]								
D.O.								
Tot. Hardness	100	88	91	95	84	89	85	81
Conductivity	<1	1.4	<1	<1	<1	1.0	<1	<1
Alkalinity	29.2	34.0	33.0	32.4	33.0	34.0	36.5	68.4
Hot Acidity	4.100	7.300	4.500	2.700	2.400	2.500	2.450	4.200
Iron (T)								
Iron (D)	0.340	0.360	0.300	0.310	0.350	0.340	0.320	0.340
Manganese (T)								
Manganese (D)	38	29	32	36	34	35	32	32
Sulfate (T)								
Sulfide	<0.2				<0.2			
Fluoride	0.9				1.0			
Chloride	0.24				0.26			
Sodium	85	70	83	90	72	74	68	60
Dis. Solids	2	3	1	10	2	1	1	<1
Sus. Solids	0.11				<0.5			
Ammonia N	<0.1				<0.1			
Nitrate N								
Bicarbonate								
Turbidity								
COD								
TOC								
Silica (T)								
Silica (D)								
Annual Parameters								
Aluminum (T)	<0.1	<0.1	1.100	0.890	0.200	0.450	0.400	0.890
Aluminum (D)								
Arsenic (T)	<0.001				<0.001			
Arsenic (D)								
Barium (T)	<0.1				<0.1			
Barium (D)								
Cadmium (T)	0.010				<0.005			
Cadmium (D)								
Calcium (T)	4.10				0.12			
Calcium (D)								
Chromium (T)	<0.05				<0.05			
Chromium (D)								
Copper (T)	<0.005				<0.01			
Copper (D)								
Lead (T)	0.1000				0.1700			
Lead (D)								
Magnesium (T)	5.05				0.35			
Magnesium (D)								
Mercury (T)	<0.0002				<0.0002			
Mercury (D)								
Nickel (T)								
Nickel (D)								
Selenium (T)	<0.002				<0.002			
Selenium (D)								
Silver (T)	<0.01				<0.01			
Silver (D)								
Zinc (T)	0.100				0.130			
Zinc (D)								
Potassium (T)	<0.05				0.75			
Potassium (D)								

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/09/90	02/03/91	02/24/91	03/26/91	04/29/91	05/24/91	08/23/91
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID	1656						
location	150						
Laboratory							
depth	1570	1567	1564	1566	1564	1563	1553
Field pH	4.2	4.5	4.4	4.8	5.3	5.4	5.6
Lab pH							
Temperature [C]	8	9	8	8	9	9	9
D.O.							
Tot. Hardness							
Conductivity	65	77	81	53	65	85	80
Alkalinity	<1	<1	<1	4.8	4.3	6.3	5.1
Hot Acidity	28.7	50.8	58.0	38.2	43.4	30.8	54.4
Iron (T)	0.050	0.050	0.070	0.340	0.490	0.290	1.900
Iron (D)							
Manganese (T)	0.210	0.360	0.450	0.230	0.350	0.520	0.400
Manganese (D)							
Sulfate (T)	22	27	29	18	22	31	29
Sulfide							
Fluoride		<0.2					
Chloride		1.6					
Sodium		0.57					
Dis. Solids	56	58	33	107	45	204	110
Sus. Solids	3	4	<1	4	<1	3	5
Ammonia N		<0.5					
Nitrate N		<0.5					
Bicarbonate							
Turbidity							
COD							
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	0.240	0.120	0.130	0.270	0.350	0.180	0.480
Aluminum (D)							
Arsenic (T)		<0.001					
Arsenic (D)							
Barium (T)		<0.1					
Barium (D)							
Cadmium (T)		0.0400					
Cadmium (D)							
Calcium (T)							
Calcium (D)							
Chromium (T)		<0.05					
Chromium (D)							
Copper (T)		0.160					
Copper (D)							
Lead (T)		<0.05					
Lead (D)							
Magnesium (T)		4.60					
Magnesium (D)							
Mercury (T)		<0.0002					
Mercury (D)							
Nickel (T)							
Nickel (D)							
Selenium (T)		<0.002					
Selenium (D)							
Silver (T)		<0.01					
Silver (D)							
Zinc (T)		0.400					
Zinc (D)							
Potassium (T)							
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	11/18/91	02/21/92	05/19/92	08/31/92	11/20/92	03/12/93	06/07/93
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location						PETL	PETL
Laboratory							
depth	1549	1554	1568	1561	1565	1561	1564
Field pH	5.6	5.4	4.8	5.3	5.4	5.4	5.2
Lab pH						5.4	5.2
Temperature [C]	9	9	9.5	9.5	9	9	9
D.O.							
Tot. Hardness							
Conductivity	84	101	60	91	83	56	81
Alkalinity	2.8	4.0	2.4	1.0	1.2	3.0	4.6
Hot Acidity	53.0	65.6	37.8	48.4	50.2	52.0	32.0
Iron (T)	0.640	0.850	0.080	0.920	0.650	0.490	0.060
Iron (D)							
Manganese (T)	0.500	0.650	0.350	0.400	0.490	0.340	0.700
Manganese (D)							
Sulfate (T)	29	37	21	22	30	18	23
Sulfide							<0.2
Fluoride			0.57				2.0
Chloride			0.8				0.66
Sodium			0.50				82
Dis. Solids	78	75	35	72	68	73	<1
Sus. Solids	2	<1		3	2	10	<0.5
Ammonia N			<0.5				<0.5
Nitrate N			<0.1				
Bicarbonate							
Turbidity							
COD							
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)			0.090	0.180	0.130	0.440	0.270
Aluminum (D)							<0.001
Arsenic (T)			44.000				
Arsenic (D)							<0.1
Barium (T)			<0.1				
Barium (D)							<0.0005
Cadmium (T)			<0.005				
Cadmium (D)							2.95
Calcium (T)							
Calcium (D)							<0.05
Chromium (T)			<0.05				
Chromium (D)							0.210
Copper (T)			0.190				
Copper (D)							<0.001
Lead (T)			<0.05				
Lead (D)							4.95
Magnesium (T)			2.68				
Magnesium (D)							<0.0002
Mercury (T)			<0.0002				
Mercury (D)							
Nickel (T)							
Nickel (D)							<0.002
Selenium (T)			<0.002				
Selenium (D)							<0.01
Silver (T)			<0.01				
Silver (D)							0.420
Zinc (T)			0.065				
Zinc (D)					0.70		0.59
Potassium (T)							
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	09/14/93	11/16/93	03/29/94	05/27/94	08/15/94	11/21/94	02/20/95
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory	PETL	PETL					
depth	1556	1559	1575	1567	1560	1559	1565
Field pH	4.9	5.0	5.1	5.0	5.2	5.1	5.2
Lab pH	4.9	5.0	5.0	5.0	4.9	4.9	5.2
Temperature [C]	10	9	9				
D.O.							
Tot. Hardness							
Conductivity	90	92	50	44	85	55	50
Alkalinity	2.1	94.4	2.4	2.5	2.3	4.0	3.1
Hot Acidity	124.1	4.3	42.0	59.4	108.4	94.8	85.0
Iron (T)	0.310	2.200	0.040	<0.01	0.040	0.050	0.030
Iron (D)							
Manganese (T)	0.850	1.960	0.200	0.120	0.130	0.110	0.200
Manganese (D)							
Sulfate (T)	29	30	17	16	30	17	18
Sulfide				<0.2	<0.2	<0.2	<0.2
Fluoride				1.2	1.5	1.0	1.4
Chloride				0.35	0.59	1.67	4.05
Sodium				40	75	30	35
Dis. Solids	55	62	38	<1	<1	1	<1
Sus. Solids	<1	<1	<1	<0.1	<0.5	<0.5	<0.5
Ammonia N				0.29	<0.5	<0.5	<0.5
Nitrate N				2.50	2.30	4.00	3.10
Bicarbonate				0.29	3.70	0.49	0.29
Turbidity				<10	<10	12.00	<10
COD							
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	0.210	0.210	0.310	0.160			
Aluminum (D)							
Arsenic (T)				<0.05	<0.001		
Arsenic (D)							
Barium (T)				<0.1	<0.1		
Barium (D)							
Cadmium (T)				0.0100	<0.0005		
Cadmium (D)							
Calcium (T)							
Calcium (D)							
Chromium (T)				<0.05	<0.001		
Chromium (D)							
Copper (T)				0.060	nd		
Copper (D)							
Lead (T)				<0.05	<0.001		
Lead (D)							
Magnesium (T)				1.91	nd		
Magnesium (D)							
Mercury (T)				<0.0002	<0.0002		
Mercury (D)							
Nickel (T)				<0.05			
Nickel (D)							
Selenium (T)				0.0960	<0.002		
Selenium (D)							
Silver (T)				0.010	<0.01		
Silver (D)							
Zinc (T)				0.050	nd		
Zinc (D)							
Potassium (T)						0.70	
Potassium (D)							

Data from the NEPCO site

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sample date	06/06/95	08/25/95	11/14/95	02/19/96	05/14/96	09/10/96	12/31/96
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory							
depth	1558.5	1555	1563	1568	1568	1561	1571
Field pH	5.0	5.1	5.0	5.0	5.0	5.4	5.1
Lab pH	4.9	4.9	5.5	5.3	5.0	5.1	5.0
Temperature [C]							
D.O.							
Tot. Hardness					50	84	62
Conductivity	60	93	64	84	3.8	4.2	5.0
Alkalinity	3.2	2.8	6.0	6.5	104.0	192.0	154.0
Hot Acidity	156.0	170.0	164.0	38.0	0.120	2.600	0.040
Iron (T)	0.980	4.800	3.100	0.100			
Iron (D)					0.300	0.900	0.200
Manganese (T)	0.790	1.000	2.000	2.000			
Manganese (D)					21	36	22
Sulfate (T)	21	1	<1	1			
Sulfide					<0.2	<0.2	<0.2
Fluoride	<0.2	<0.2	<0.2	<0.2	2.3	1.5	1.4
Chloride	2.0	1.2	13.0	1.2	0.88	0.56	0.54
Sodium	1.32	0.56	0.60	0.63	23	20	50
Dis. Solids	40	49	32	70	2	<1	<1
Sus. Solids	<1	6	<1	<1	<0.5	<0.5	<0.5
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate N	2.69	<0.5	<0.5	<0.5	3.80	4.20	5.00
Bicarbonate	3.20	2.80	6.00	6.50	0.38	3.40	0.57
Turbidity	3.50	11.00	0.86	0.32	<10	<10	<10
COD	10.00	<10	<10	<10			
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)					0.477		
Aluminum (D)	0.900				0.360		
Arsenic (T)	0.270				<0.02		
Arsenic (D)	<0.05				<0.02		
Barium (T)	<0.05				0.230		
Barium (D)	<0.1				0.210		
Cadmium (T)	<0.01				<0.005		
Cadmium (D)	<0.01				<0.005		
Calcium (T)	<0.01						
Calcium (D)					<0.005		
Chromium (T)	<0.05				<0.005		
Chromium (D)	<0.05				0.060		
Copper (T)	0.080				0.054		
Copper (D)	0.073				<0.05		
Lead (T)	<0.05				<0.05		
Lead (D)	<0.05				2.31		
Magnesium (T)	3.07				2.17		
Magnesium (D)	2.81				<0.001		
Mercury (T)	<0.0002				<0.001		
Mercury (D)	<0.0002				0.018		
Nickel (T)	<0.05				0.016		
Nickel (D)	<0.05				<0.01		
Selenium (T)	<0.05				<0.01		
Selenium (D)	<0.05				<0.005		
Silver (T)	<0.01				<0.005		
Silver (D)	<0.01				0.069		
Zinc (T)	0.130				0.062		
Zinc (D)	0.087						
Potassium (T)							
Potassium (D)							

Data from the NEPCO site

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sample date	03/11/97	06/13/97	09/09/97	10/28/97	11/24/97	03/13/98	06/29/98
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							PETL
Laboratory							1563.5
depth	1567	1563	1554	1551.5	1552	1573	
Field pH	4.7	4.9	5.0	5.0	5.9	5.4	5.4
Lab pH	4.8	4.9	5.1	5.0	5.2	5.1	5.2
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	48	46	55	56	80	52	80
Alkalinity	4.5	5.0	4.5	4.8	4.0	5.0	5.0
Hot Acidity	38.0	60.0	9.2	42.0	260.0	62.0	104.0
Iron (T)	0.050	0.010	0.270	0.190	1.770	0.070	0.252
Iron (D)							
Manganese (T)	0.100	0.100	0.200	0.160	0.470	0.300	0.453
Manganese (D)							
Sulfate (T)	17	17	14	19	29	20	20
Sulfide							
Fluoride	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<1
Chloride	1.5	1.0	1.3	1.3	1.8	2.0	1.5
Sodium	0.81	0.67	0.66	0.72	1.00	<1	1.24
Dis. Solids	53	80	36	67	51	75	80
Sus. Solids	2	<1	4	<1	3	5	<1
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.2	<0.2	<0.2
Nitrate N	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<1
Bicarbonate	4.50	5.00	4.50	4.80	4.00	5.00	104.00
Turbidity	0.51	0.47	0.60	0.58	3.10	0.31	0.40
COD	<10	<10	<10	<10	<10	<10	<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)		0.448		0.452	0.460		0.288
Aluminum (D)		0.390		0.395	0.385		0.276
Arsenic (T)		<0.02		<0.02	<0.02		<0.005
Arsenic (D)		<0.02		<0.02			<0.005
Barium (T)		0.026		0.023	0.023		0.024
Barium (D)		0.024		0.023			0.024
Cadmium (T)		<0.005		<0.005	<0.005		<0.002
Cadmium (D)		<0.005		<0.005			<0.002
Calcium (T)							2.90
Calcium (D)							2.82
Chromium (T)		<0.005		<0.005	<0.005		<0.002
Chromium (D)		<0.005		<0.005			<0.002
Copper (T)		0.069		0.052	0.115		0.179
Copper (D)		0.065		0.052			0.176
Lead (T)		<0.05		<0.05	<0.05		<0.005
Lead (D)		<0.05		<0.05			<0.005
Magnesium (T)		2.50		2.48	4.46		5.01
Magnesium (D)		2.42		2.39			4.92
Mercury (T)		<0.001		<0.0002	<0.0002		<0.0002
Mercury (D)		<0.001		<0.002			<0.0002
Nickel (T)		0.015		0.018	0.043		0.045
Nickel (D)		0.015		0.018			0.045
Selenium (T)		<0.01		<0.01	<0.01		0.0080
Selenium (D)		<0.01		<0.01			0.0070
Silver (T)		<0.005		<0.005	<0.005		<0.005
Silver (D)		<0.005		<0.005			<0.005
Zinc (T)		0.063		0.054	0.519		0.478
Zinc (D)		0.058		0.054			0.472
Potassium (T)		0.59					
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	08/12/98	9/15/1998	10/19/98	11/24/98	02/01/99	03/24/99	04/22/99
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	5.1	5.1	5.1	5.1	5.0	5.0	5.2
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	81	82	88	85	57	51	83
Alkalinity	11.8	11.8	11.0	11.8	10.8	10.8	12.4
Hot Acidity	5.2	0.0	12.0	8.0	2.0	4.2	3.6
Iron (T)	0.516	1.180	0.825	0.862	0.055	0.062	0.255
Iron (D)							
Manganese (T)	0.523	0.503	0.540	0.562	0.184	0.139	0.317
Manganese (D)	0.523		0.528	0.527	0.175	0.139	0.317
Sulfate (T)	332	32	41	<20	<20	<20.00	21
Sulfide							
Fluoride	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Chloride	1.0	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Sodium	0.60	0.62	0.64	0.72	0.88	0.73	0.75
Dis. Solids	60	94	84	50	246	26	56
Sus. Solids	<2	<2	6	8	<2	18	4
Ammonia N	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate N	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bicarbonate							
Turbidity	2.40	11.70	8.60	2.70	<1	0.00	1.26
COD							
TOC	7.98			9.20	6.70	5.97	8.13
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	**0.421**	0.386	0.371	0.314	0.438	0.425	0.290
Aluminum (D)	**0.346**		0.371	0.305	0.389	0.425	0.277
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	**0.040**	<0.004	<0.004
Arsenic (D)	<0.004		<0.004	<0.004	**<0.040**	<0.004	<0.004
Barium (T)	0.023	0.024	0.028	0.023	0.028	0.025	0.024
Barium (D)	0.022		0.027	0.023	0.025	0.025	0.024
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010		<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	**3.48**	2.74	**4.11**	**8.16**	**3.49**	1.98	3.04
Calcium (D)	**2.93**		**2.89**	**3.22**	**1.98**	1.93	3.04
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	0.155	0.138	0.233	0.128	0.093	0.075	0.305
Copper (D)	0.155		0.233	0.118	0.083	0.075	0.298
Lead (T)	0.0146	<0.001	<0.001	0.0042	<0.010	0.0031	0.0037
Lead (D)	0.0125		<0.001	0.0037	<0.010	0.0031	0.0023
Magnesium (T)	5.41	5.06	5.60	5.31	3.35	2.54	5.32
Magnesium (D)	5.41		5.40	5.09	3.22	2.54	5.32
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	0.055	0.054	<0.050	0.054	<0.050	<0.050	<0.050
Nickel (D)	0.055		<0.050	0.052	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.070	<0.007	0.0102
Selenium (D)	<0.007		<0.007	<0.007	<0.070	<0.007	0.0102
Silver (T)							
Silver (D)							
Zinc (T)	0.556	0.545	0.625	0.648	0.093	**0.105**	**0.228**
Zinc (D)	0.552		0.625	0.604	0.093	**0.070**	**0.191**
Potassium (T)	<0.50	<1.00		<1.00	<1.00	<1.00	<1
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	05/26/99	06/23/99	7/29/1999	8/24/1999	9/29/1999	10/27/1999	12/29/99
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	5.0	4.9	5.1	5.1	5.2	5.1	5.0
Temperature [C]							
D.O.							
Tot. Hardness						88	57
Conductivity	75		83	80		12.4	13.4
Alkalinity	10.8	8.4	10.8	11.0	10.6	1.0	6.4
Hot Acidity	10.6	3.8	3.2	2.4	1.8	0.353	0.038
Iron (T)	0.531	0.584	0.441	1.230	0.175		
Iron (D)					0.473	**0.475**	0.168
Manganese (T)	0.308	0.499	**0.527**	**0.549**		**0.450**	0.168
Manganese (D)	0.297		**0.477**	**0.482**	32	27	21
Sulfate (T)	<20	34	36	28			
Sulfide						<0.20	<0.20
Fluoride	<0.20		<0.20	<0.2		<1.00	<1.00
Chloride	<1.00		<1.00	<1.00		0.86	0.71
Sodium	0.77	0.71	0.63	0.40	0.66	52	52
Dis. Solids	56		<2.0	70		<2	<2
Sus. Solids	<2	12	<2.0	6	24	*<0.02*	*<0.02*
Ammonia N	<0.02		*<0.02*	*<0.02*		<0.04	<0.04
Nitrate N	<0.04		<0.04	<0.04			
Bicarbonate							<1
Turbidity	6.10		2.85	8.54			
COD							
TOC						**8.24**	6.87
Silica (T)	7.40			7.30	7.04	**7.66**	
Silica (D)							
Annual Parameters							
Aluminum (T)					0.309	**0.631**	**0.608**
Aluminum (D)	0.462	0.272	**0.860**	**0.804**		**0.321**	**0.496**
Arsenic (T)	0.390		**0.267**	**0.293**		<0.004	<0.004
Arsenic (D)	<0.004		<0.004	**0.040**		<0.004	<0.004
Barium (T)	<0.004		<0.004	**<0.040**		0.025	0.026
Barium (D)	0.029		0.002	0.027		0.025	0.025
Cadmium (T)	0.028		0.002	0.026		<0.010	<0.010
Cadmium (D)	<0.010		<0.010	<0.010		<0.010	<0.010
Calcium (T)	<0.010		<0.010	<0.010		**3.92**	2.34
Calcium (D)	**3.45**		**3.56**	**3.42**		**3.24**	2.34
Chromium (T)	**2.58**		**2.87**	**2.66**		<0.050	<0.050
Chromium (D)	<0.050		<0.050	<0.050		<0.050	<0.050
Copper (T)	<0.050		<0.050	<0.050		0.322	0.071
Copper (D)	0.131		0.124	**0.135**		0.309	0.071
Lead (T)	0.122		0.100	**0.130**		0.0029	0.0022
Lead (D)	0.0036		0.0030	<0.010		0.0022	0.0022
Magnesium (T)	0.0025		0.0028	<0.010		5.92	2.93
Magnesium (D)	4.52		4.77	**5.21**		5.90	2.90
Mercury (T)	4.44		4.77	**4.78**		<0.001	<0.001
Mercury (D)	<0.001		<0.001	<0.001		<0.001	<0.001
Nickel (T)	<0.001		<0.001	<0.001		0.051	<0.050
Nickel (D)	<0.050		0.064	**0.069**		<0.050	<0.050
Selenium (T)	<0.050		0.064	**<0.050**		0.0115	**0.0074**
Selenium (D)	0.0076		<0.007	0.0700		0.0110	**0.0070**
Silver (T)	0.0075		<0.007	0.0700			
Silver (D)							
Zinc (T)						**0.417**	0.083
Zinc (D)	**0.246**		0.528	**1.070**		**0.360**	0.083
Potassium (T)	**0.161**		0.528	**0.569**		<1.00	<1.0
Potassium (D)	<1			<1.00	<1.00	<1.00	

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	1/26/2000	3/7/2000	3/27/2000	4/25/2000	5/24/2000	6/27/2000	7/26/2000
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	5.1	4.8	5.1	5.1	5.1	5.0	5.0
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	63	78	49	54	49	46	51
Alkalinity	11.8	10.4	11.2	13.6	11.0	11.0	11.8
Hot Acidity	4.0	12.4	0.8	2.0	3.8	2.0	4.2
Iron (T)	0.151		0.042	0.101	0.036	0.051	0.040
Iron (D)	0.020						
Manganese (T)	**0.262**		0.173	0.180	0.132	0.138	0.166
Manganese (D)	**0.255**		0.170	0.166	0.119	0.127	0.154
Sulfate (T)	26	23	23	<20	<20	<20	<20.0
Sulfide							
Fluoride	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Chloride	<1	<1	<1	1.0	1.0	<1.00	<1.0
Sodium	0.72		1.73	0.80	0.37	0.65	0.78
Dis. Solids	12	512	30	42	40	50	58
Sus. Solids	4	18	4	8	4	8	<2
Ammonia N	*<0.02*	*<0.02*	*<0.02*	<0.02	*<0.02*	*<0.02*	*<0.02*
Nitrate N	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bicarbonate							
Turbidity	4.05	2.69	<1	<1	1.26	<1	<1
COD							
TOC							
Silica (T)	7.88		6.98	7.38	6.08	6.48	**6.81**
Silica (D)							**6.66**
Annual Parameters							
Aluminum (T)	0.494		0.455	0.675	0.435	0.475	0.458
Aluminum (D)	0.474		0.455	0.570	0.424	0.380	0.514
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.029		<0.010	0.028	0.022	0.023	0.025
Barium (D)	0.028		<0.010	0.026	0.021	0.022	0.025
Cadmium (T)	<0.010		<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010		<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	**3.05**		5.36	**6.76**	**3.95**	**9.88**	**6.65**
Calcium (D)	**2.52**		4.60	**2.44**	**1.89**	**1.94**	**2.09**
Chromium (T)	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	0.117		<0.010	0.085	0.061	0.058	**0.072**
Copper (D)	0.111		<0.010	0.075	0.053	0.053	**0.066**
Lead (T)	0.0023	0.0025	**0.0016**	0.0042	0.0023	0.0031	**0.0027**
Lead (D)	0.0019	0.0024	**0.0014**	0.0021	0.0023	0.0026	**0.0026**
Magnesium (T)	3.76		3.66	2.97	2.53	2.71	**2.89**
Magnesium (D)	3.75		3.56	2.83	2.43	2.68	**2.86**
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	0.0083	0.0079	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)							
Silver (D)							
Zinc (T)	**0.202**		0.071	0.078	**0.079**	0.083	**1.640**
Zinc (D)	**0.174**		0.071	0.071	**0.071**	0.083	**0.072**
Potassium (T)	1.07		<1.00	3.34	<1.00	<1.00	**1.37**
Potassium (D)							**<1.00**

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	8/22/2000	11/8/2000	3/6/2001	5/21/2001	12/4/2001	3/11/2002	5/23/2002
sample name	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	5.1	5.1	4.7	4.9	5.0	4.9	5.0
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	54	56	86	71	63	66	59
Alkalinity	13.0	13.0	1.6	4.6	4.6	5.0	4.6
Hot Acidity	6.8	6.2	8.2	6.0	51.0	45.4	34.6
Iron (T)	0.041	0.094	**0.788**	0.394	1.420	1.800	0.033
Iron (D)			**0.433**	0.028	0.050	0.020	
Manganese (T)	0.158	0.207	0.448	0.252	0.190	0.200	0.175
Manganese (D)	0.158	0.204	0.441	0.209	0.160	0.180	
Sulfate (T)	<20.0	<20.0	36	32	<20	<20	<20
Sulfide							
Fluoride	<0.20	<0.20					
Chloride	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sodium	0.73	0.73	1.10	3.25	2.02	4.10	0.74
Dis. Solids	48	92	70	64	36	82	42
Sus. Solids	20	<2	<2	<2	8	10	<2
Ammonia N	*<0.02*						
Nitrate N	<0.04	<0.04					
Bicarbonate							
Turbidity	<1	1.06					
COD							
TOC							
Silica (T)	6.36	6.70	9.20	7.53	7.23	**7.75**	
Silica (D)	6.31	6.55	9.18	7.36		**7.55**	
Annual Parameters							
Aluminum (T)	**0.450**	0.384	**0.479**	0.945	0.629	0.799	1.110
Aluminum (D)	**0.410**	0.378	**0.476**	0.526	0.397	0.484	
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	
Barium (T)	0.025	**0.032**					
Barium (D)	0.023	**0.026**					
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Calcium (T)	2.39	**2.94**	3.32	**34.60**	**11.10**	**28.00**	2.21
Calcium (D)	2.39	**2.43**	2.81	**3.06**	**2.41**	**2.09**	
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	
Copper (T)	0.067	0.082	<0.010	0.089	0.080	0.110	0.071
Copper (D)	0.067	0.074		0.059	0.070	0.080	
Lead (T)	0.0040	0.0028	**0.0025**	0.0040	0.0058	0.0059	0.0023
Lead (D)	0.0036	0.0027	**0.0024**	0.0016	0.0036	0.0018	
Magnesium (T)	2.87	3.13	4.69	3.71	3.29	3.44	2.81
Magnesium (D)	2.82	3.08	4.66	3.44	3.19	3.24	
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	
Selenium (T)	<0.007	<0.007	<0.007	**0.0096**	**0.0100**	**0.0126**	<0.007
Selenium (D)	<0.007	<0.007	<0.007	**<0.007**	**0.0080**	**0.0086**	
Silver (T)							
Silver (D)							
Zinc (T)	0.081	**0.309**	0.521	0.137	0.080	0.100	0.091
Zinc (D)	0.081	**0.103**	0.394	0.134	0.080	0.080	
Potassium (T)	<1.0	<1.00	<1.00	**3.32**	**2.13**	**3.50**	<1.00
Potassium (D)	<1.0	<1.00	<1.00	**<1.00**	**<1.00**	**<1.00**	

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	9/10/2002	11/4/2002	4/28/2003	6/3/2003	9/18/2003
sample name	Well 2	Well 2	Well 2	Well 2	Well 2
sample ID					
location					
Laboratory	DEP	DEP	DEP	DEP	DEP
depth					
Field pH					
Lab pH	4.8	4.9	4.9	5.0	5.4
Temperature [C]					
D.O.					
Tot. Hardness					
Conductivity	61	83	55	53	77
Alkalinity	3.0	3.6	3.6	3.8	6.4
Hot Acidity	55.8	64.4	33.4	31.0	39.8
Iron (T)	1.840	0.170	0.041	0.100	0.042
Iron (D)	0.388	0.121	0.021	<0.020	0.023
Manganese (T)	**0.312**	**0.325**	0.182	0.131	**0.365**
Manganese (D)	**0.306**	**0.324**	0.158	0.128	**0.364**
Sulfate (T)	45	31	30	<20	27
Sulfide					
Fluoride					
Chloride	<1.0	<1.0	<1.0	1.1	1.5
Sodium	181.00	1.20	0.74	0.96	0.81
Dis. Solids	58	64	62	52	72
Sus. Solids	18	4	<2	18	4
Ammonia N					
Nitrate N					
Bicarbonate					
Turbidity					
COD					
TOC					
Silica (T)		8.56			
Silica (D)		8.47			
Annual Parameters					
Aluminum (T)	0.615	1.230	1.090	0.641	0.211
Aluminum (D)	0.599	1.100	1.090	0.599	0.208
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)					
Barium (D)					
Cadmium (T)	<0.010	<0.010	<0.010	**0.0110**	0.0004
Cadmium (D)	<0.010	<0.010	<0.010	**<0.010**	0.0004
Calcium (T)	2.36	**9.56**	**3.22**	**3.33**	2.71
Calcium (D)	2.27	**2.99**	**2.11**	**1.91**	3.24
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	0.064	0.098	**0.065**	0.065	0.200
Copper (D)	0.064	0.095	**0.064**	0.063	0.197
Lead (T)	0.0029	**0.0054**	0.0035	0.0031	0.0024
Lead (D)	0.0018	**0.0036**	0.0034	0.0031	0.0023
Magnesium (T)	**3.64**	4.24	**2.62**	2.74	4.89
Magnesium (D)	**3.54**	4.14	**2.53**	2.70	4.87
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)			<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	0.0087
Selenium (D)	<0.007	<0.007	<0.007	<0.007	0.0089
Silver (T)					
Silver (D)					
Zinc (T)	**0.382**	**1.130**	**0.516**	0.127	0.291
Zinc (D)	**0.212**	**0.189**	**0.069**	0.100	0.261
Potassium (T)	<1.00	**1.19**	<1.00	<1.0	<1.0
Potassium (D)	<1.00	**1.05**	<1.00	<1.0	<1.0

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	09/27/96	12/31/96	03/11/97	06/13/97	09/09/97	10/28/97	11/24/97
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID	1611						
location	95						
Laboratory							
depth	1556	1568	1563.5	1560	1551	1548	1548.5
Field pH	4.5	4.2	5.1	5.1	5.1	4.2	4.2
Lab pH	4.3	3.9	5.1	5.6	5.0	3.6	3.6
Temperature [C]							
D.O.							
Tot. Hardness	270	260	79	60	81	300	280
Conductivity	<1	<1	4.0	7.0	3.0	<1	<1
Alkalinity	102.4	164.0	162.0	82.0	34.0	60.0	144.0
Hot Acidity	0.350	0.150	0.020	0.020	0.250	2.660	2.540
Iron (T)							
Iron (D)	1.090	1.020	0.200	0.110	0.200	1.020	0.930
Manganese (T)							
Manganese (D)	115	118	10	<1	25	118	96
Sulfate (T)							
Sulfide	<0.2	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2
Fluoride	1.4	1.8	1.8	1.1	1.5	1.0	11.5
Chloride	2.70	4.86	1.60	1.03	1.02	3.02	2.85
Sodium	193	157	95	94	50	170	180
Dis. Solids	2	3	<1	1	5	<1	6
Sus. Solids	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2
Nitrate N	<1	<1	4.00	7.00	3.00	<1	<1
Bicarbonate	0.50	0.61	0.70	0.49	0.26	1.60	0.68
Turbidity	<10	<10	<10	<10	<10	<10	<10
COD							
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	4.310	4.810		0.161		4.400	4.130
Aluminum (D)	4.300	4.680		0.150		4.400	
Arsenic (T)	<0.02	<0.02		<0.02		<0.02	<0.02
Arsenic (D)	<0.02	<0.02		<0.02		<0.02	
Barium (T)	0.031	0.084		0.008		0.025	0.024
Barium (D)	0.031	0.047		0.008		0.025	
Cadmium (T)	<0.005	<0.005		<0.005		<0.005	<0.005
Cadmium (D)	<0.005	<0.005		<0.005		<0.005	
Calcium (T)	16.70	18.80		2.37		18.50	13.00
Calcium (D)	16.40	17.70		2.18		17.90	
Chromium (T)	<0.005	<0.005		<0.005		<0.005	<0.005
Chromium (D)	<0.005	<0.005		<0.005		<0.005	
Copper (T)	0.043	0.058		<0.005		0.050	0.027
Copper (D)	0.041	0.051		<0.005		0.050	
Lead (T)	<0.05	<0.05		<0.05		<0.05	<0.05
Lead (D)	<0.05	<0.05		<0.05		<0.05	
Magnesium (T)	7.56	7.52		4.38		7.48	6.77
Magnesium (D)	7.48	7.27		4.09		7.48	
Mercury (T)	<0.001	<0.001		<0.001		<0.0002	<0.0002
Mercury (D)	<0.001	<0.001		<0.001		<0.0002	
Nickel (T)	**0.068**	0.072		0.019		0.066	0.060
Nickel (D)	**0.067**	0.064		0.015		0.066	
Selenium (T)	<0.01	<0.01		<0.01		<0.01	<0.01
Selenium (D)	<0.01	<0.01		<0.01		<0.01	
Silver (T)	<0.005	0.016		0.010		<0.005	<0.005
Silver (D)	<0.005	0.008		<0.005		<0.005	
Zinc (T)	0.328	0.351		0.073		0.412	0.320
Zinc (D)	0.320	0.335		0.068		0.402	
Potassium (T)							
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/13/98	06/29/98	08/12/98	09/15/98	10/19/98	11/24/98	02/01/99
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID							
location							
Laboratory		PETL	DEP	DEP	DEP	DEP	DEP
depth	1569	1560					
Field pH	4.7	4.5					
Lab pH	3.9	3.8	4.0	4.0	4.1	4.1	3.7
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	290	445	490	462	391	389	487
Alkalinity	<1	<1	2.0	2.8	3.6	3.2	0.0
Hot Acidity	90.0	56.0	58.0	46.0	50.0	50.0	66.0
Iron (T)	0.180	0.505	2.500	2.940	3.270	4.910	6.580
Iron (D)							
Manganese (T)	0.800	0.619	0.971	1.110	0.998	0.998	1.180
Manganese (D)			0.971	1.070	0.992	0.947	1.170
Sulfate (T)	140	200	25	205	138	44	129
Sulfide							
Fluoride	<2	<1	0.21	<0.20	<0.20	<0.20	<0.20
Chloride	12.5	1.5	1.0	1.0	1.0	1.0	8.0
Sodium	3.69	6.52	5.63	6.30	5.67	5.30	11.70
Dis. Solids	235	225	417	356	292	270	216
Sus. Solids	5	5	10	<2	<2	6	<2
Ammonia N	<0.2	<0.2	0.05	0.05	0.03	0.05	0.06
Nitrate N	<0.5	<1	<0.04	<0.04	<0.04	<0.04	<0.04
Bicarbonate	<1	56.00					
Turbidity	0.35	0.20	<1	<1	<1	<1	15.60
COD	<10	<10					
TOC			17.61	14.36		13.14	15.69
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)		4.000	6.720	5.460	4.430	4.020	6.740
Aluminum (D)		3.730	6.720	5.270	4.190	3.880	6.590
Arsenic (T)		<0.005	<0.004	<0.004	<0.004	<0.004	<0.040
Arsenic (D)		<0.005	<0.004	<0.004	<0.004	<0.004	<0.040
Barium (T)		0.026	0.031	0.031	0.028	**0.039**	0.027
Barium (D)		0.026	0.031	0.030	0.027	**0.027**	0.027
Cadmium (T)		<0.002	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)		<0.002	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)		53.60	55.50	48.40	34.30	32.80	30.60
Calcium (D)		51.30	55.50	46.20	34.00	32.80	30.60
Chromium (T)		<0.002	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)		<0.002	<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)		0.033	**0.069**	0.050	0.039	0.042	<0.044
Copper (D)		0.030	**0.050**	0.050	0.039	0.042	<0.044
Lead (T)		0.0090	<0.001	0.0140	<0.001	0.0130	0.0106
Lead (D)		0.0070	<0.001	0.0140	<0.001	0.0121	0.0101
Magnesium (T)		6.08	7.91	7.73	7.06	7.44	8.27
Magnesium (D)		5.75	7.86	7.49	6.83	7.09	8.20
Mercury (T)		<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)		<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)		0.046	0.075	0.071	0.069	0.070	0.079
Nickel (D)		0.043	0.075	0.071	0.067	0.061	0.075
Selenium (T)		<0.005	<0.007	<0.007	<0.007	<0.007	<0.070
Selenium (D)		<0.005	<0.007	<0.007	<0.007	<0.007	<0.070
Silver (T)		<0.005					
Silver (D)		<0.005					
Zinc (T)		0.293	0.433	**0.492**	0.348	0.380	0.291
Zinc (D)		0.278	0.433	**0.408**	0.344	0.380	0.291
Potassium (T)			3.11	2.94		2.30	2.00
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/24/99	04/22/99	05/26/99	06/23/99	7/29/1999	8/24/1999	9/29/1999
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	4.0	4.0		3.9	4.0	4.0	4.1
Temperature [C]							
D.O.							
Tot. Hardness					384	393	
Conductivity	361	345	401		2.2	3.2	2.8
Alkalinity	1.6	1.4		0.0	38.0	42.0	22.0
Hot Acidity	32.0	32.0	36.0	34.0	4.500	5.550	0.095
Iron (T)	0.602	0.810	2.000	2.480			
Iron (D)					0.850	1.000	0.745
Manganese (T)	0.808	0.871	0.813	0.834	0.850	0.977	
Manganese (D)	0.808	0.871	0.795		113	114	85
Sulfate (T)	129	126	143	124			
Sulfide					<0.20	<0.2	
Fluoride	<0.20	<0.20	<0.20		1.0	1.0	
Chloride	1.0	1.0	2.0	5.42	5.69	6.64	3.72
Sodium	5.49	5.20			240	324	
Dis. Solids	132	214	290	34	<2	<2	<2
Sus. Solids	28	4	<2		*0.05*	*0.07*	
Ammonia N	0.02	0.02	0.03		<0.04	<0.04	
Nitrate N	<0.04	<0.04					
Bicarbonate					8.59	2.42	
Turbidity	0.00	1.19					
COD							
TOC						11.34	9.74
Silica (T)	10.68	11.43					
Silica (D)							
Annual Parameters							
Aluminum (T)				3.300		4.190	2.230
Aluminum (D)	**3.680**	3.320	3.580		3.350	4.040	
Arsenic (T)	**3.290**	3.320	3.480		3.220	<0.040	
Arsenic (D)	<0.004	<0.004	<0.004		<0.004	<0.040	
Barium (T)	<0.004	<0.004	<0.004		<0.004	**0.026**	
Barium (D)	0.023	0.023			0.023	**0.025**	
Cadmium (T)	0.023	0.023			0.023	<0.010	
Cadmium (D)	<0.010	<0.010	<0.010		<0.010	<0.010	
Calcium (T)	<0.010	<0.010	<0.010		<0.010	33.00	
Calcium (D)	33.50	28.20			30.30	32.40	
Chromium (T)	31.50	27.40			30.10	<0.050	
Chromium (D)	<0.050	<0.050	<0.050		<0.050	<0.050	
Copper (T)	<0.050	<0.050	<0.050		<0.050	**0.037**	
Copper (D)	0.037	0.028	0.028		0.027	**0.030**	
Lead (T)	0.037	0.028	0.028		0.020	0.0114	
Lead (D)	0.0076	0.0077	**0.0132**		0.0100	0.0114	
Magnesium (T)	0.0075	0.0075	**0.0102**		0.0100	7.51	
Magnesium (D)	6.13	6.61			6.23	7.18	
Mercury (T)	6.13	6.61			6.21	<0.001	
Mercury (D)	<0.001	<0.001	<0.001		<0.001	<0.001	
Nickel (T)	<0.001	<0.001	<0.001		<0.001	**0.110**	
Nickel (D)	0.065	0.050	0.056		0.070	**0.059**	
Selenium (T)	0.065	<0.050	0.054		0.068	<0.070	
Selenium (D)	<0.007	<0.007	<0.007		<0.007	<0.070	
Silver (T)	<0.007	<0.007	<0.007		<0.007		
Silver (D)							
Zinc (T)					0.322	**1.690**	
Zinc (D)	0.248	0.253	0.284		0.322	**0.341**	
Potassium (T)	0.248	0.253	0.284			2.20	1.87
Potassium (D)	1.80	2.55					1.87

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/27/1999	11/23/1999	12/29/1999	1/26/2000	3/7/2000	3/27/2000	4/25/2000
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID							
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory							
depth							
Field pH	4.0	4.0	4.0	4.0	4.2	4.9	4.9
Lab pH							
Temperature [C]							
D.O.							
Tot. Hardness	340	333	302	288	208	89	90
Conductivity	1.4	1.6	2.4	2.4	4.8	9.4	10.8
Alkalinity	34.0	44.0	32.0	26.0	17.6	2.8	8.2
Hot Acidity	5.330	5.050	0.159	0.100		0.152	0.061
Iron (T)				0.068			
Iron (D)	0.899	0.879	0.877	**0.848**		0.120	**0.194**
Manganese (T)	0.849	0.879	0.877	**0.840**		0.120	**0.189**
Manganese (D)	81	100	101	91	63	31	26
Sulfate (T)							
Sulfide	<0.20	<0.220	<0.20	<0.20	<0.20	<0.20	<0.20
Fluoride	1.0	2.0	<1.00	1.0	1.0	<1.00	2.0
Chloride	4.76	5.17	4.29	4.22		1.05	1.55
Sodium	208	170	168	60	114	44	92
Dis. Solids	<2	<2	<2	18	18	4	<2
Sus. Solids	*0.02*	*0.03*	*0.02*	*0.03*	*<0.02*	*<0.02*	*0.04*
Ammonia N	<0.04	<0.04	0.04	0.08	0.04	<0.04	0.05
Nitrate N							
Bicarbonate	23.10	9.10	<1	1.24	<1	<1	<1
Turbidity							
COD							
TOC	9.91	11.36	11.11	11.26		5.76	7.94
Silica (T)	9.69	11.36					
Silica (D)							
Annual Parameters							
Aluminum (T)	3.000	2.990	2.810	**2.890**		0.449	0.464
Aluminum (D)	2.760	2.990	2.810	**2.750**		0.449	0.438
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	**0.020**	0.050	0.021	0.022		0.022	<0.010
Barium (D)	**0.019**	0.028	0.020	0.022		0.022	<0.010
Cadmium (T)	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010
Calcium (T)	**29.90**	21.00	22.30	**21.60**		4.64	**7.81**
Calcium (D)	**23.30**	20.90	22.30	**20.70**		1.84	**5.22**
Chromium (T)	<0.050	<0.050	<0.050	<0.050		<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050		<0.050	<0.050
Copper (T)	0.027	0.023	0.032	**0.030**		0.058	<0.010
Copper (D)	0.024	0.023	0.032	**0.028**		0.058	<0.010
Lead (T)	0.0064	0.0071	0.0142	0.0111	**0.0063**	**0.0027**	0.0027
Lead (D)	0.0060	0.0064	0.0142	0.0108	**0.0059**	**0.0026**	0.0016
Magnesium (T)	6.74	6.50	6.41	**6.39**		2.53	**3.96**
Magnesium (D)	6.50	6.40	6.41	**6.36**		2.53	**3.83**
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	0.058	0.051	0.070	**0.052**		<0.050	<0.050
Nickel (D)	0.052	<0.050	0.070	**<0.050**		<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	0.0101	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	0.0096	<0.007
Silver (T)							
Silver (D)						0.065	**0.088**
Zinc (T)	**0.346**	**0.363**	0.320	**0.290**		0.065	**0.087**
Zinc (D)	**0.248**	**0.269**	0.320	**0.286**		<1.00	<1.00
Potassium (T)	**1.64**	1.91	1.98	1.77			
Potassium (D)	**1.11**	1.91					

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	6/27/2000	7/26/2000	8/22/2000	11/8/2000	3/20/2001	5/21/2001	8/28/2001
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID							
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory							
depth							
Field pH	4.9	4.9	4.8	4.5	4.8	5.0	4.5
Lab pH							
Temperature [C]							
D.O.							
Tot. Hardness	97	103	122	154	149	91	137
Conductivity	8.0	9.4	8.6	7.4	2.0	2.6	0.0
Alkalinity	3.6	6.2	8.4	12.6	9.2	3.2	43.2
Hot Acidity	<0.020	0.056	<0.020	0.028	0.224	0.039	0.255
Iron (T)					0.043	0.034	0.068
Iron (D)	**0.243**	0.230	0.245	**0.320**	**0.565**	**0.247**	**0.282**
Manganese (T)	**0.215**	0.216	0.245	**0.276**	**0.546**	**0.244**	**0.280**
Manganese (D)	26	39	46	43	55	27	42
Sulfate (T)							
Sulfide	<0.20	<0.20	<0.20	<0.20	<1.0	<1.0	<1.0
Fluoride	<1.00	<1.0	1.0	<1.0	3.13	1.64	1.84
Chloride	1.59	1.98	2.17	2.84	88	86	130
Sodium	86	90	88	94	18	<2	<2
Dis. Solids	<2	<2	6	12			
Sus. Solids	<0.02	<0.02	<0.2				
Ammonia N	0.06	0.08	0.08	0.14			
Nitrate N							
Bicarbonate	<1	1.82	1.36	<1			
Turbidity							
COD							
TOC	8.13	8.37	8.13	**8.17**	7.81	**7.85**	7.90
Silica (T)		8.13	7.81	**7.75**	7.64	**7.68**	7.77
Silica (D)							
Annual Parameters							
Aluminum (T)	0.495	0.634	0.628	**1.010**	**0.811**	0.337	0.455
Aluminum (D)	0.478	0.500	0.628	**0.748**	**0.716**	0.333	0.376
Arsenic (T)	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004
Arsenic (D)	<0.004	<0.04	<0.004	<0.004		<0.004	<0.004
Barium (T)	<0.010	0.011	0.012	**0.043**	<0.004		
Barium (D)	<0.010	0.010	0.012	**0.017**	<0.004		
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	6.25	**9.51**	8.86	**12.60**	18.40	**6.49**	**7.02**
Calcium (D)	6.17	**6.58**	8.86	**11.30**	10.60	**5.64**	**6.25**
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	<0.010	<0.010	<0.010	<0.010	0.001	<0.010	**0.013**
Copper (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	**<0.010**
Lead (T)	0.0020	0.0002	0.0020	0.0047	<0.010	<0.010	0.0027
Lead (D)	0.0018	0.0013	0.0019	0.0044	0.0030	0.0016	0.0023
Magnesium (T)	4.22	4.38	4.16	**4.45**	0.0029	0.0014	**4.14**
Magnesium (D)	4.22	4.10	4.09	**4.23**	4.86	**4.04**	**4.09**
Mercury (T)	<0.001	<0.001	<0.001	<0.001	4.81	**3.93**	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	<0.050	<0.050	<0.050	<0.050	<0.001	<0.001	<0.001
Nickel (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.050	<0.050	<0.050
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)					<0.007	<0.007	<0.007
Silver (D)							
Zinc (T)	0.100	**0.104**	0.108	**0.232**	0.252	0.170	**0.122**
Zinc (D)	0.100	**0.101**	0.108	**0.146**	0.192	0.132	**0.102**
Potassium (T)	1.03	**1.33**	1.04	***1.54***	3.81	**1.02**	**1.24**
Potassium (D)		**1.15**	<1.00	**1.44**	3.07	**1.00**	**1.11**

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/4/2001	3/11/2002	5/23/2002	9/10/2002	11/4/2002	4/28/2003	6/3/2003	9/18/2003
sample name	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3	Well 3
sample ID								
location								
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth						(check w/ mw 4)		
Field pH								
Lab pH	4.4	4.0	4.6	4.3	4.4	4.5	4.5	3.9
Temperature [C]								
D.O.								
Tot. Hardness	124	290	105	144	139	129	132	493
Conductivity	0.0	0.0	1.4	0.0	0.0	0.4	0.0	0.0
Alkalinity	36.6	50.8	29.6	67.0	64.2	17.2	24.0	3.8
Hot Acidity	0.380	7.730	0.067	1.330	**0.426**	**0.035**	0.072	2.750
Iron (T)	0.170	7.020		1.320	**0.269**	**0.029**	<0.020	1.690
Iron (D)	0.310	0.950	0.285	0.388	**0.354**	0.335	0.304	0.851
Manganese (T)	0.300	0.880		0.385	**0.346**	0.329	0.294	0.836
Manganese (D)	44	103	36	33	46	45	45	182
Sulfate (T)								
Sulfide								
Fluoride	1.0	1.0	<1.0	<1.0	1.2	1.3	1.5	2.9
Chloride	2.07	5.50	1.89	214.00	2.56	2.52	2.35	9.91
Sodium	58	178	6	106	122	330	100	380
Dis. Solids	8	4	<2	2	<2	<2	12	<2
Sus. Solids								
Ammonia N								
Nitrate N								
Bicarbonate								
Turbidity								
COD								
TOC								
Silica (T)	8.05	11.58			9.01			
Silica (D)		11.19			9.01			
Annual Parameters								
Aluminum (T)	0.607	2.450	0.566	**1.020**	0.824	0.761	0.714	3.010
Aluminum (D)	0.531	2.200		**1.010**	0.817	0.750	0.675	2.910
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004		<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)								
Barium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	**0.0005**
Cadmium (T)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010	**0.0004**
Cadmium (D)	**7.90**	20.40	6.36	**11.30**	**9.50**	**9.69**	8.40	51.00
Calcium (T)	**7.76**	19.90		**11.20**	**8.78**	**9.00**	8.13	49.70
Calcium (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (T)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.010	0.020	<0.010	<0.010	<0.010	**0.014**	**0.010**	<0.010
Copper (T)	<0.010	0.020		<0.010	<0.010	**<0.010**	**<0.010**	<0.010
Copper (D)	0.0039	0.0044	0.0018	**0.0028**	**0.0064**	**0.0041**	0.0047	0.0043
Lead (T)	0.0032	0.0040		**0.0027**	**0.0056**	**0.0040**	0.0042	0.0041
Lead (D)	4.36	7.04	4.59	4.68	4.56	4.46	4.84	8.05
Magnesium (T)	4.30	6.68		4.56	4.52	4.37	4.66	7.92
Magnesium (D)	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (T)	<0.001	<0.001				<0.001	<0.001	<0.001
Mercury (D)	<0.050	0.060	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (T)	<0.050	0.060		<0.050	<0.050	<0.050	<0.050	<0.050
Nickel (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (T)	<0.007	<0.007		<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)								
Silver (T)								
Silver (D)	0.170	0.220	0.114	**0.408**	**0.436**	**0.328**	0.191	0.263
Zinc (T)	0.120	0.210		**0.134**	**0.131**	**0.146**	0.169	0.261
Zinc (D)	**1.43**	**1.86**	1.02	**1.46**	**1.39**	**1.32**	**1.23**	4.66
Potassium (T)	**1.37**	**1.78**		**1.44**	**1.35**	**1.26**	**1.22**	4.56
Potassium (D)								

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	09/27/96	12/31/96	03/11/97	06/13/97	09/09/97	11/24/97
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID	1606					
location	90					
Laboratory						
depth	1555	1565.5	1562	1558.5	1549	1548
Field pH	4.3	3.8	3.8	3.9	3.6	4.2
Lab pH	3.5	3.3	3.8	4.0	3.4	3.5
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	520	400	410	460	480	500
Alkalinity	<1	<1	<1	<1	<1	<1
Hot Acidity	255.0	288.0	190.0	240.0	202.0	230.0
Iron (T)	8.170	0.720	0.230	0.240	0.160	0.840
Iron (D)						
Manganese (T)	1.810	1.260	1.700	3.200	1.600	1.200
Manganese (D)						
Sulfate (T)	300	220	210	300	230	260
Sulfide						
Fluoride	0.22	<0.2	<0.2	<0.4	<0.2	0.25
Chloride	13.4	5.0	7.0	25.0	13.7	11.0
Sodium	18.30	8.58	10.50	9.67	12.00	14.40
Dis. Solids	391	168	338	176	401	320
Sus. Solids	244	2	17	49	12	9
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2
Nitrate N	<0.5	<0.5	<0.5	<0.5	<0.5	0.30
Bicarbonate	<1	<1	<1	<1	<1	<1
Turbidity	90.00	1.00	5.60	48.00	3.50	2.90
COD	<10	<10	<10	<10	<10	<10
TOC						
Silica (T)						
Silica (D)						
Annual Parameters				17.800		
Aluminum (T)	20.500	15.800		15.800		
Aluminum (D)	16.500	15.300		<0.02		
Arsenic (T)	<0.02	<0.02		<0.02		
Arsenic (D)	<0.02	<0.02		0.064		
Barium (T)	0.162	0.027		0.014		
Barium (D)	0.014	0.022		<0.005		
Cadmium (T)	<0.005	0.007		<0.005		
Cadmium (D)	<0.005	<0.005		22.20		
Calcium (T)	19.30	13.80		20.20		
Calcium (D)	19.20	13.30		<0.005		
Chromium (T)	0.006	<0.005		<0.005		
Chromium (D)	<0.005	<0.005		0.131		
Copper (T)	0.146	0.150		0.127		
Copper (D)	0.135	0.150		<0.05		
Lead (T)	<0.05	<0.05		<0.05		
Lead (D)	<0.05	<0.05		11.80		
Magnesium (T)	9.65	7.56		9.86		
Magnesium (D)	9.06	7.35		<0.001		
Mercury (T)	<0.001	<0.001		<0.001		
Mercury (D)	<0.001	<0.001		0.176		
Nickel (T)	0.135	0.181		0.144		
Nickel (D)	0.135	0.166		<0.01		
Selenium (T)	<0.01	<0.01		<0.01		
Selenium (D)	<0.01	<0.01		<0.005		
Silver (T)	<0.005	<0.005		<0.005		
Silver (D)	<0.005	<0.005		0.387		
Zinc (T)	0.378	0.269		0.371		
Zinc (D)	0.362	0.247				
Potassium (T)						
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/13/98	06/29/98	08/12/98	9/15/1998	10/19/98	11/24/98
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID					1606	
location					90	
Laboratory			DEP	DEP	DEP	DEP
depth	1568.5	1559				
Field pH	4.3	4.4				
Lab pH	3.5	3.6	3.8	3.8	3.8	3.9
Temperature [C]						
D.O.						
Tot. Hardness						469
Conductivity	460	440	510	472	454	<1
Alkalinity	<1	<1	<1	<1	<1	
Hot Acidity	244.0	272.0	128.0	110.0	116.0	
Iron (T)	0.090	3.210	0.133	0.053	0.053	
Iron (D)						
Manganese (T)	1.300	1.639	1.760	1.580	1.560	
Manganese (D)			1.740		1.560	
Sulfate (T)	290	290	193	170	173	
Sulfide						
Fluoride	<2	<1	0.30	0.21	0.25	
Chloride	20.0	8.0	8.0	6.0	5.0	6.0
Sodium	18.90	10.00	14.40	10.60	9.12	10.20
Dis. Solids	383	361	392	456	280	
Sus. Solids	7	39	36	16	<2	
Ammonia N	<0.2	<0.2	0.03	0.02	<0.02	<0.02
Nitrate N	<0.5	1.10	0.24	0.19	0.16	0.18
Bicarbonate	<1	272.00				
Turbidity	0.39	10.00	3.10	11.40	<1	<1
COD	<10	<10				
TOC			50.29	50.50		
Silica (T)						
Silica (D)						
Annual Parameters						
Aluminum (T)		16.100	19.700	17.300	16.300	
Aluminum (D)		16.100	19.300		16.300	
Arsenic (T)		<0.005	<0.004	<0.004	<0.004	<0.004
Arsenic (D)		<0.005	<0.004		<0.004	<0.004
Barium (T)		0.054	0.014	0.013	0.017	
Barium (D)		0.015	0.014		0.017	
Cadmium (T)		<0.002	<0.010	<0.010	<0.010	
Cadmium (D)		<0.002	<0.010		<0.010	
Calcium (T)		17.90	24.40	19.10	20.40	20.20
Calcium (D)		16.50	24.40		20.40	20.20
Chromium (T)		0.004	<0.050	<0.050	<0.050	
Chromium (D)		<0.002	<0.050		<0.050	
Copper (T)		0.141	0.159	0.144	0.166	
Copper (D)		0.138	0.159		0.166	
Lead (T)		0.0100	<0.001	<0.001	<0.001	**0.0129**
Lead (D)		0.0070	<0.001		<0.001	**0.0128**
Magnesium (T)		8.49	9.50	8.36	8.39	9.16
Magnesium (D)		8.35	9.50		8.39	9.15
Mercury (T)		<0.0002	<0.001	<0.001	<0.001	
Mercury (D)		<0.0002	<0.001	<0.001	<0.001	
Nickel (T)		0.166	0.144	0.130	0.162	
Nickel (D)		0.164	0.144		0.162	
Selenium (T)		<0.005	<0.007	<0.007	<0.007	<0.007
Selenium (D)		<0.005	<0.007		<0.007	<0.007
Silver (T)		<0.005	0.462			
Silver (D)		<0.005		0.326	**0.395**	
Zinc (T)		0.356	**0.462**		**0.330**	
Zinc (D)		0.339	**0.397**			2.87
Potassium (T)			2.75	2.45		
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	02/01/99	03/24/99	04/22/99	05/26/99	06/23/99	7/29/1999
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID	1606	1606	1606	1606		
location	90	90	90	90		
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
depth						
Field pH	3.9	3.7	3.7	3.8	3.7	3.8
Lab pH						
Temperature [C]						
D.O.						
Tot. Hardness	542	393	388	480		532
Conductivity	<1	<1	<1	<1	<1	<1
Alkalinity	110.0	114.0	112.0	130.0	138.0	142.0
Hot Acidity	0.120	0.103	0.351	0.163	0.109	0.069
Iron (T)						
Iron (D)	2.530	1.100	1.230	1.750	1.960	**1.960**
Manganese (T)	2.530	1.070	1.180	1.750		**1.760**
Manganese (D)	140	102	137	190	270	189
Sulfate (T)						
Sulfide	0.33	0.22	0.24	0.29		<0.20
Fluoride	17.0	2.0	2.0	6.0		8.0
Chloride	21.10	4.68	3.56	12.30	15.60	13.30
Sodium	352	332	344	382		406
Dis. Solids	<2	48	4	8	24	14
Sus. Solids	<0.02	<0.02	<0.02	<0.02		*<0.02*
Ammonia N	0.11	0.06	0.07	0.19		0.24
Nitrate N						
Bicarbonate	1.58	10.70	4.25	11.50		2.33
Turbidity						
COD						
TOC	41.94	57.14	62.70	52.00		
Silica (T)						
Silica (D)						
Annual Parameters					23.500	21.200
Aluminum (T)	17.100	16.200	16.300	21.000		21.200
Aluminum (D)	15.600	15.300	15.400	20.200		<0.004
Arsenic (T)	<0.040	<0.004	<0.004	<0.004		<0.004
Arsenic (D)	<0.040	<0.004	<0.004	<0.004		**0.014**
Barium (T)	0.015	0.013	0.016	0.015		**0.011**
Barium (D)	0.015	0.013	0.014	0.015		<0.010
Cadmium (T)	<0.010	<0.010	<0.010	<0.010		<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010		**24.90**
Calcium (T)	24.10	**15.10**	9.52	21.40		**23.40**
Calcium (D)	22.60	**11.20**	9.52	21.40		<0.050
Chromium (T)	<0.050	<0.050	<0.050	<0.050		<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050		0.145
Copper (T)	0.139	0.129	0.145	0.166		0.135
Copper (D)	0.139	0.127	0.142	0.166		0.0056
Lead (T)	<0.010	0.0161	0.0065	0.0091		0.0056
Lead (D)	<0.010	0.0146	0.0060	0.0089		**9.75**
Magnesium (T)	10.90	6.51	7.86	9.12		**8.78**
Magnesium (D)	10.90	6.36	7.60	9.12		<0.001
Mercury (T)	<0.001	<0.001	<0.001	<0.001		<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001		**0.179**
Nickel (T)	0.139	0.171	0.195	0.164		**0.137**
Nickel (D)	0.139	0.170	0.187	0.163		<0.007
Selenium (T)	<0.070	<0.007	<0.007	<0.007		<0.007
Selenium (D)	<0.070	<0.007	<0.007	<0.007		
Silver (T)						**0.464**
Silver (D)						**0.363**
Zinc (T)	0.433	0.210	**0.263**	0.424		
Zinc (D)	0.433	0.203	**0.231**	0.424		
Potassium (T)	2.69	1.93	2.38	2.85		
Potassium (D)						

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	8/24/1999	9/29/1999	10/27/1999	12/29/1999	1/26/2000	3/7/2000
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID						
location	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory						
depth						
Field pH	3.8	3.7	3.8	3.8	3.8	3.8
Lab pH						
Temperature [C]						
D.O.						
Tot. Hardness	527		534	444	473	448
Conductivity	<1	<1	<1	<1	<1	<1
Alkalinity	144.0	116.0	134.0	124.0	140.0	128.0
Hot Acidity	0.121	1.070	0.325	0.100	**0.108**	
Iron (T)					**0.075**	
Iron (D)	1.990	1.650	1.910	1.610	1.590	
Manganese (T)	1.980		1.820	1.610	1.520	
Manganese (D)	172	126	210	176	179	155
Sulfate (T)						
Sulfide	<0.2		0.31	0.28	0.30	0.26
Fluoride	7.0		8.0	2.0	4.0	4.0
Chloride	14.10	9.20	12.80	7.94	6.48	
Sodium	460		436	400	366	388
Dis. Solids	20	20	8	64	<2	66
Sus. Solids	*<0.02*		*<0.02*	*<0.02*	*<0.02*	*<0.02*
Ammonia N	<0.04		0.26	0.11	0.15	<0.04
Nitrate N						
Bicarbonate	10.20		2.10	12.20	2.00	21.80
Turbidity					2.57	
COD						
TOC	47.94	55.85	59.28	58.85	71.05	
Silica (T)			54.99			
Silica (D)						
Annual Parameters						
Aluminum (T)	21.000	19.200	21.800	18.500	21.900	
Aluminum (D)	20.900		19.900	17.300	21.600	
Arsenic (T)	<0.040		<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.040		<0.004	<0.004	<0.004	<0.004
Barium (T)	**0.016**		0.017	0.015	0.015	
Barium (D)	**0.015**		0.016	0.014	0.015	
Cadmium (T)	<0.010		<0.010	<0.010	<0.010	
Cadmium (D)	<0.010		<0.010	<0.010	<0.010	
Calcium (T)	**22.40**		**23.30**	16.30	**15.50**	
Calcium (D)	**22.00**		**22.80**	16.10	**15.30**	
Chromium (T)	<0.050		<0.050	<0.050	<0.050	
Chromium (D)	<0.050		<0.050	<0.050	<0.050	
Copper (T)	**0.173**		0.155	0.156	0.159	
Copper (D)	**0.171**		0.149	0.150	0.155	
Lead (T)	**0.0107**		0.0101	0.0141	**0.0034**	0.0104
Lead (D)	**0.0106**		0.0097	0.0141	**0.0031**	0.0102
Magnesium (T)	**10.80**		10.30	8.98	9.38	
Magnesium (D)	**10.70**		9.77	8.98	9.03	
Mercury (T)	<0.001		<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001		<0.001	<0.001	<0.001	<0.001
Nickel (T)	**0.183**		0.171	0.190	0.184	
Nickel (D)	**0.161**		0.157	0.190	0.165	
Selenium (T)	<0.070		<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.070		<0.007	<0.007	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	**0.655**		**0.444**	0.338	0.302	
Zinc (D)	**0.427**		**0.375**	0.338	0.295	
Potassium (T)	3.01	2.64	2.43	2.82	2.84	
Potassium (D)		2.64	2.43			

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	3/27/2000	4/25/2000	5/24/2000	6/27/2000	7/26/2000	8/22/2000	11/8/2000	3/20/2001
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID								
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory								
depth								
Field pH	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Lab pH								
Temperature [C]								
D.O.								
Tot. Hardness	397	420	399	415	384	446	464	433
Conductivity	<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity	118.8	110.0	112.0	104.0		112.0	112.0	5.2
Hot Acidity	0.135	0.200	0.189	0.523		0.053	0.066	0.253
Iron (T)								0.216
Iron (D)	1.830	1.460	1.530	1.510		**1.560**	1.760	1.550
Manganese (T)	1.830	1.440	1.460	1.440		**1.510**	1.720	1.530
Manganese (D)	139	137	112	105	129	155	138	122
Sulfate (T)								
Sulfide	0.23	0.23	<0.20	0.23	0.25	0.24	0.31	
Fluoride	2.0	5.0	3.0	4.0	3.0	4.0	5.0	3.0
Chloride	10.00	5.29	7.53	7.06	7.09	9.70	10.20	8.09
Sodium	382	374	350	384	380	318	350	374
Dis. Solids	20	12	20	26	6	26	10	12
Sus. Solids	*<0.02*	<0.02	*<0.02*	*<0.02*	*<0.02*	*<0.02*		
Ammonia N	0.06	0.06	0.08	0.11	0.10	0.17	0.18	
Nitrate N								
Bicarbonate	1.28	1.45	2.16	6.46		8.57	3.59	
Turbidity								
COD								
TOC	62.06	77.49	65.91	63.56	45.37	37.88	44.08	59.92
Silica (T)						35.52	49.22	52.00
Silica (D)								
Annual Parameters								
Aluminum (T)	16.800	17.200	18.600	15.200		17.400	18.200	17.700
Aluminum (D)	16.800	17.000	17.500	14.700		16.100	17.300	16.000
Arsenic (T)	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004
Barium (T)	0.015	0.017	0.015	0.019		0.014	0.014	
Barium (D)	0.015	0.015	0.013	0.013		0.013	0.014	
Cadmium (T)	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	**17.60**	**14.80**	<0.010	<0.010	<0.010
Calcium (T)	20.00	**13.40**	17.10	**15.90**	**14.10**	**21.20**	**21.20**	17.70
Calcium (D)	15.60	**13.20**	16.20	<0.050		**18.90**	**20.70**	15.40
Chromium (T)	<0.050	<0.050	<0.050	<0.050		<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	0.127		<0.050	<0.050	<0.050
Copper (T)	0.140	0.162	**0.154**	0.123		0.153	0.147	0.152
Copper (D)	0.138	0.159	**0.137**	0.0114		0.153	0.146	0.152
Lead (T)	0.0065	0.0167	0.0171	0.0108		0.0037	**0.0073**	**0.0082**
Lead (D)	0.0062	0.0167	0.0163	7.85	6.79	0.0035	**0.0072**	**0.0080**
Magnesium (T)	9.16	8.42	8.19	7.69	6.85	8.27	8.96	8.44
Magnesium (D)	9.16	8.36	7.74	<0.001		8.05	8.79	8.27
Mercury (T)	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	0.152		<0.001	<0.001	<0.001
Nickel (T)	0.176	0.194	0.156	0.150		0.147	**0.156**	0.169
Nickel (D)	0.175	0.191	0.150	<0.007		0.139	**0.155**	0.167
Selenium (T)	0.0073	<0.007	<0.007	<0.007		<0.007	<0.007	
Selenium (D)	0.0071	<0.007	<0.007	<0.007		<0.007	<0.007	
Silver (T)								
Silver (D)						0.366	**0.422**	0.419
Zinc (T)	0.299	**0.286**	**0.321**	0.274		0.366	**0.349**	0.331
Zinc (D)	0.286	**0.285**	**0.299**	0.269	**2.86**	2.86	**2.78**	2.53
Potassium (T)	3.00	35.80	2.50	2.53	**2.73**	2.86	**2.68**	2.42
Potassium (D)								

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	5/21/2001	8/28/2001	12/4/2001	3/11/2002	5/23/2002	9/10/2002	11/4/2002	4/28/2003
sample name	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9	Well 9
sample ID								
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory								
depth								
Field pH	3.8	3.8	3.8	3.7	3.8	3.7	3.7	3.7
Lab pH								
Temperature [C]								
D.O.								
Tot. Hardness	417	448	442	503	396	482	453	389
Conductivity	<1	<1	<1	<1	0.0	0.0	0.0	0.0
Alkalinity	112.0	158.8	151.0	171.0	174.2	179.8	13.6	145.0
Hot Acidity	0.616	0.419	0.310	1.460		**0.134**	0.787	**0.090**
Iron (T)	0.103	0.054	0.080	0.730		**0.107**	0.596	**0.070**
Iron (D)	1.280	1.830	1.780	1.990		**1.790**	0.156	1.210
Manganese (T)	1.240	1.760	1.680	1.950		**1.780**	0.156	1.210
Manganese (D)	128	158	199	199	153	183	202	166
Sulfate (T)								
Sulfide								
Fluoride	3.0	4.0	4.0	5.0	2.0	4.9	2.7	1.8
Chloride	5.72	8.53	7.59	10.70	7.12	228.00	5.80	3.54
Sodium	406	442	354	390	406	426	400	388
Dis. Solids	<2	<2	12	58	<2	18	8	<2
Sus. Solids								
Ammonia N								
Nitrate N								
Bicarbonate								
Turbidity								
COD								
TOC							73.19	
Silica (T)	73.19	60.13	56.28	58.64			63.13	
Silica (D)	67.41	56.71		55.00				
Annual Parameters								
Aluminum (T)	15,200	1,950	17,700	21,500		19,100	19,800	15,500
Aluminum (D)	13,700	1,810	16,800	20,000		19,100	18,900	14,800
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004
Barium (T)								
Barium (D)								
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Calcium (T)	**14.00**	21.30	18.00	**23.10**	15.70	20.90	**16.00**	**14.40**
Calcium (D)	**13.90**	20.90	17.80	**22.80**		20.90	**15.10**	**13.30**
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050		<0.050	<0.050	<0.050
Copper (T)	0.159	0.159	0.160	0.160		**0.149**	0.154	0.157
Copper (D)	0.157	0.160	0.150	0.150		**0.148**	0.154	0.154
Lead (T)	0.0104	0.0057	0.0041	0.0095	0.0050	**0.0052**	**0.0103**	0.0159
Lead (D)	0.0095	0.0057	0.0040	0.0080		**0.0050**	**0.0095**	0.0157
Magnesium (T)	7.17	9.17	9.43	10.30	9.43	9.30	9.00	7.44
Magnesium (D)	7.14	8.87	9.09	10.20		9.22	8.97	7.43
Mercury (T)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001				<0.001
Nickel (T)	0.172	0.155	0.170	0.180		**0.148**	0.199	0.186
Nickel (D)	0.161	0.148	0.160	0.170		**0.147**	0.192	0.185
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.07	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007		<0.007	<0.007	<0.007
Silver (T)								
Silver (D)								
Zinc (T)	**0.307**	**0.382**		0.400		**0.506**	0.693	**0.367**
Zinc (D)	**0.269**	**0.353**	0.340	0.400		**0.389**	0.340	**0.279**
Potassium (T)	2.79	2.77	2.48	2.85	2.73	**2.81**	2.85	**2.80**
Potassium (D)	2.67	2.67	2.40	2.69		**2.73**	2.83	**2.83**

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/4/2001	03/11/02	9/10/2002	11/4/2002	4/28/2003	6/3/2003	9/18/2003
sample name	Culm						
sample ID	Buck Mtn. DEP	Buck Mountain DEP	Buck Mountain DEP	Buck Mountain DEP	Buck Mountain DEP (check w/mw 3)	Buck Mountain DEP	Buck Mountain DEP
location							
Laboratory							
depth							
Field pH	3.9	3.4	3.9	3.8	3.3	3.3	3.9
Lab pH							
Temperature [C]							
D.O.							
Tot. Hardness	650	611	424	428	505	518	486
Conductivity	0	<1	0	0	0	0	0
Alkalinity	148	114.4	97.4	100	88.8	117.2	12.2
Hot Acidity	38.8	7.000	18.2	**8.86**	1.4	0.552	18.6
Iron (T)	36.6	6.270	17.8	**8.82**	1.34	0.501	17.2
Iron (D)	29.1	**2.480**	1.56	**1.63**	1.59	1.566	1.66
Manganese (T)	28.5	**2.440**	1.53	**1.59**	1.52	1.482	1.6
Manganese (D)	265	216	127.8	158.2	165.6	171.4	192.2
Sulfate (T)							
Sulfide							
Fluoride	<1	<1.0	<1.00	1.3	1.1	1.3	1.6
Chloride	4.26	5.14	3.22	5.26	4.92	4.999	5.51
Sodium	532	516	340	356	352	288	492
Dis. Solids	10	2	<2	4	2	20	<2
Sus. Solids							
Ammonia N							
Nitrate N							
Bicarbonate							
Turbidity							
COD							
TOC	33.38	**31.46**		**20.993**			
Silica (T)		**29.53**		**19.581**			
Silica (D)							
Annual Parameters							
Aluminum (T)	13.9	**12.700**	6.63	**7.12**	6.7	7.002	7.51
Aluminum (D)	13.9	**12.000**	6.59	**7**	6.37	6.534	7.23
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)							
Barium (D)							
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	0.0100	0.0009
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.0009
Calcium (T)	43.4	35.00	23.7	26	**24.6**	24.8	30.8
Calcium (D)	41.8	34.00	23.1	25.6	**23.8**	23.8	30.7
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	0.07	**0.050**	**0.017**	0.013	0.018	0.014	0.015
Copper (D)	0.07	**0.040**	**<0.010**	0.013	0.014	0.014	0.015
Lead (T)	0.013	0.0317	0.0154	0.033	0.015	0.0155	0.0102
Lead (D)	0.0125	0.0286	0.0153	0.0324	0.015	0.0154	0.0101
Magnesium (T)	18.8	17.10	10.5	**10.5**	10.8	11	11.7
Magnesium (D)	18.2	16.90	10.3	**10.1**	10.3	10.6	11.3
Mercury (T)	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001			<0.001	<0.001	<0.001
Nickel (T)	0.18	**0.160**	**0.099**	0.103	0.097	0.093	**0.098**
Nickel (D)	0.18	**0.150**	**0.098**	0.094	0.095	0.085	**0.096**
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)							
Silver (D)							
Zinc (T)	0.63	**0.620**	**0.573**	**0.906**	**0.518**	0.489	**0.415**
Zinc (D)	0.62	**0.610**	**0.398**	**0.442**	**0.416**	0.446	**0.404**
Potassium (T)	2.70	**2.25**	**2.02**	2.37	**1.97**	1.946	2.26
Potassium (D)	2.66	**2.00**	**1.96**	2.13	**1.96**	1.884	2.26

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	08/14/89	11/10/89	02/17/90	05/14/90	08/27/90	11/29/90	02/24/91
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory							
depth							
Field pH	3.8	3.6	3.2	3.7	4.0	3.8	3.6
Lab pH							
Temperature [C]	9	9	9	9	9	9	9
D.O.	3.1	3	3.2	3.8	3.6	4	4.2
Tot. Hardness	64	82.6	75.2	60.2	74.4	68.2	59.4
Conductivity	250	340	330	250	290	270	255
Alkalinity	<1	<1	<1	<1	<1	<1	<1
Hot Acidity	63.0	83.6	70.2	62.0	64.6	65.2	59.2
Iron (T)	8.400	10.450	8.800	3.100	8.500	7.500	3.600
Iron (D)							
Manganese (T)	1.100	1.500	1.200	0.750	0.950	0.900	0.950
Manganese (D)							
Sulfate (T)	103	115	104	110	115	105	94
Sulfide			0	0	0	0	0
Fluoride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Chloride	10.5	11.3	19.0	20.0	5.0	7.5	10.0
Sodium				5.50	5.50	10.00	
Dis. Solids	153	200	217	158	188	162	133
Sus. Solids	1	10	3	4	3	2	<1
Ammonia N	0.11	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate N	0.26	11.60	6.32	<0.5	<0.5	<0.5	<0.5
Bicarbonate							
Turbidity	1.56	1.25	1.10	1.20	1.30	1.00	0.95
COD	<10	40.00	<10	25.00	<10	<10	<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	5.150	5.300	0.950	1.400	5.000	5.000	3.150
Aluminum (D)							
Arsenic (T)	<0.001	0.010	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic (D)							
Barium (T)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium (D)							
Cadmium (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.005
Cadmium (D)							
Calcium (T)	4.80	4.10	4.60	0.40	0.70	0.60	2.40
Calcium (D)							
Chromium (T)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium (D)							
Copper (T)	<0.02	0.020	0.050	0.020	<0.02	<0.02	<0.02
Copper (D)							
Lead (T)	<0.05	0.1000	0.4000	<0.05	0.3000	<0.05	<0.05
Lead (D)							
Magnesium (T)	2.40	7.30	6.50	4.10	3.00	4.50	3.00
Magnesium (D)							
Mercury (T)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Mercury (D)							
Nickel (T)	<0.04	0.050	0.060	0.020	<0.04	0.150	<0.04
Nickel (D)							
Selenium (T)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium (D)							
Silver (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (D)							
Zinc (T)	0.180	0.400	0.230	0.230	0.150	0.150	0.150
Zinc (D)							
Potassium (T)				0.90	0.65	1.00	
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	05/24/91	08/23/91	11/18/91	02/21/92	05/19/92	08/31/92	11/20/92
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory							
depth							
Field pH	4.2	4.6	4.6	4.5	4.3	3.9	4.0
Lab pH							
Temperature [C]	9	9	9	9	9.5	9	9
D.O.	3.6	3.4	1.6	<1	<1	1.4	<1
Tot. Hardness	58.8	86.8	125	119.8	77.2	72.4	76.8
Conductivity	260	310	395	355	310	290	310
Alkalinity	<1	<1	<1	<1	<1	<1	<1
Hot Acidity	96.2	101.0	108.2	98.0	62.2	64.2	65.0
Iron (T)	5.880	14.000	14.000	11.000	12.000	15.600	9.600
Iron (D)							
Manganese (T)	0.900	1.260	1.470	1.500	1.160	1.750	1.230
Manganese (D)							
Sulfate (T)	110	137	129	135	89	37	120
Sulfide	0	0	0	0	0	0	1
Fluoride				<0.2			0.22
Chloride	11.5	15.0	12.0	13.5	20.0	12.0	14.0
Sodium	10.00				12.00		
Dis. Solids	154	204	284	210	180	205	215
Sus. Solids	<1	1	6	<1	<1	<1	<1
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bicarbonate							
Turbidity	0.75	0.65	0.62	0.82	0.76	0.50	0.68
COD	<10	<10	10.00	<10	<10	<10	<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	1.000	5.000	12.000	5.000	4.600	6.700	4.800
Aluminum (D)							
Arsenic (T)	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001
Arsenic (D)							
Barium (T)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium (D)							
Cadmium (T)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (D)							
Calcium (T)	0.33	7.50	1.00	0.45	7.00	3.20	8.60
Calcium (D)							
Chromium (T)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium (D)							
Copper (T)	<0.02	0.020	<0.02	<0.02	<0.02	0.030	<0.02
Copper (D)							
Lead (T)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (D)							
Magnesium (T)	9.80	5.00	6.29	9.50	5.80	7.80	6.90
Magnesium (D)							
Mercury (T)	<0.0002	<0.0002	0.001	<0.0002	<0.0002	<0.0002	<0.0002
Mercury (D)							
Nickel (T)	<0.04	0.150	<0.04	0.060	<0.04	0.080	<0.04
Nickel (D)							
Selenium (T)	<0.002	<0.002	<0.002	<0.002	<0.002	0.0600	<0.002
Selenium (D)							
Silver (T)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (D)							
Zinc (T)	0.160	0.180	0.280	0.320	0.200	0.370	0.190
Zinc (D)							
Potassium (T)	1.13				1.30		
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/01/93	06/07/93	09/14/93	11/16/93	03/15/94	05/27/94	08/15/94
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	PETL	PETL	PETL	PETL			
depth							
Field pH	4.3	4.0	4.2	4.1	3.6	3.9	4.4
Lab pH						3.6	4.0
Temperature [C]	9	9	9	9	9	9	9
D.O.	<1	<1	<1	<1	<1	<1	<1
Tot. Hardness	66.6	67.8	102.2	114	96	87.2	74
Conductivity	310	260	310	325	350	295	290
Alkalinity	<1	<1	<1	<1	<1	<1	<1
Hot Acidity	47.0	39.8	82.6	116.6	90.4	88.1	102.6
Iron (T)	8.400	5.400	12.300	13.300	2.580	7.240	8.780
Iron (D)							
Manganese (T)	1.250	1.120	1.590	1.400	1.040	1.360	1.380
Manganese (D)							
Sulfate (T)	95	42	130	125	84	72	82
Sulfide	0	0	0	0	0	0	0
Fluoride	<0.2	<0.2	<0.2	<0.4	0.10	<0.2	<0.2
Chloride	13.5	12.0	11.2	14.8	31.9	23.6	13.5
Sodium		8.05				11.90	9.40
Dis. Solids	165	145	160	172	190	198	250
Sus. Solids	2	4	<1	<1	<1	7	<1
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.5
Nitrate N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.5
Bicarbonate						<1	<1
Turbidity	0.52	0.45	0.48	0.24	0.90	5.70	4.60
COD	14.00	<10	<10	<5	<10	<10	<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	3.500	4.400	1.150	5.310	3.730	3.740	4.430
Aluminum (D)							
Arsenic (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05
Arsenic (D)							
Barium (T)	<0.1	<0.1	<0.1	<0.1	<0.1	0.059	0.041
Barium (D)							
Cadmium (T)	<0.005	<0.005	0.001	<0.001	<0.001	0.007	0.013
Cadmium (D)							
Calcium (T)	12.80	8.95	10.70	11.00	12.80	9.24	13.40
Calcium (D)							
Chromium (T)	<0.05	<0.05	0.001	<0.001	<0.001	0.022	0.012
Chromium (D)							
Copper (T)	0.020	0.020	<0.01	<0.02	0.050	0.084	0.076
Copper (D)							
Lead (T)	<0.05	0.0010	0.0020	<0.001	<0.001	0.0120	0.0080
Lead (D)							
Magnesium (T)	7.10	5.60	9.18	7.50	6.51	6.61	7.69
Magnesium (D)							
Mercury (T)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Mercury (D)							
Nickel (T)	0.080	<0.04	0.040	0.070	<0.05	0.086	0.083
Nickel (D)							
Selenium (T)	<0.002	<0.002	<0.002	<0.002	0.1100	0.2600	0.0700
Selenium (D)							
Silver (T)	<0.01	<0.01	<0.01	<0.045	<0.01	0.064	0.041
Silver (D)							
Zinc (T)	0.225	0.300	0.310	0.320	0.170	0.300	0.350
Zinc (D)							
Potassium (T)						2.33	
Potassium (D)		1.14					

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	11/21/94	02/20/95	06/06/95	08/25/95	11/14/95	02/19/96	05/01/96
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							DEP
location							
Laboratory							
depth							
Field pH	4.9	4.3	4.1	4.4	4.3	3.9	3.8
Lab pH	4.4	4.0	3.5	3.5	3.6	3.6	
Temperature [C]	9	9	9	9	9	9	
D.O.	5.93	<1	<1	<1	<1	<1	
Tot. Hardness		76	78.4	88	87.8	78	
Conductivity	310	350	380	310	320	310	<1
Alkalinity	<1	<1	<1	<1	<1	<1	50.0
Hot Acidity	81.6	114.6	170.0	140.0	126.0	115.0	2.700
Iron (T)	10.700	6.860	5.000	1.240	0.850	0.490	
Iron (D)							1.230
Manganese (T)	1.120	1.000	2.020	1.480	1.400	1.400	
Manganese (D)							88
Sulfate (T)	125	89	116	130	94	96	
Sulfide	0	0	<0.1		<0.1	<0.1	
Fluoride	<0.2	<0.2	0.21	<0.2	<0.2	<0.2	
Chloride	29.7	19.2	25.0	17.5	16.3	2.0	14.10
Sodium	10.70	14.10	11.20	11.70	11.20	13.90	
Dis. Solids	210	165	190	155	158	181	<3
Sus. Solids	<1	<1	<1	<1	<1	4	
Ammonia N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Nitrate N	<0.5	<0.5	2.51	<0.5	<0.5	<0.5	
Bicarbonate	1.00	<1	<1	<1	<1	<1	
Turbidity	0.40	0.36	0.28	0.53	0.64	2.50	
COD	<10	<10	<10	<10	<10	<10	
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							4.620
Aluminum (T)	4.370	3.670	3.720	4.590	4.930	8.960	
Aluminum (D)			3.720				
Arsenic (T)	0.002	<0.05	<0.05	<0.02	<0.02	<0.02	
Arsenic (D)			<0.05				
Barium (T)	0.034	<0.1	<0.1	0.024	0.027	0.032	
Barium (D)			<0.10				
Cadmium (T)	<0.002	<0.01	0.001	<0.001	0.001	0.002	
Cadmium (D)			0.001				
Calcium (T)	13.20	12.80	12.30	16.80	18.40	21.60	
Calcium (D)			10.70				
Chromium (T)	<0.005	<0.05	0.008	<0.001	<0.001	<0.001	
Chromium (D)			<0.001				
Copper (T)	0.064	0.021	0.024	0.030	0.080	0.080	
Copper (D)			<0.02				
Lead (T)	0.0090	0.0060	0.0103	0.0060	0.0060	<0.002	
Lead (D)			0.0100				
Magnesium (T)	6.89	6.57	6.76	7.38	8.09	6.54	
Magnesium (D)			6.76				
Mercury (T)	<0.0002	<0.0002	<0.0002	0.001	<0.001	<0.001	
Mercury (D)			<0.0002				
Nickel (T)	0.052	<0.05	0.110	0.064	0.069	0.059	
Nickel (D)			0.063				
Selenium (T)	<0.01	<0.05	<0.05	0.0220	<0.01	<0.01	
Selenium (D)			<0.05				
Silver (T)	<0.01	<0.12	<0.01	<0.01	<0.005	0.018	
Silver (D)			<0.01				
Zinc (T)	0.330	0.290	0.300	0.227	0.251	0.275	
Zinc (D)			0.260				
Potassium (T)			1.13				
Potassium (D)							

Data from the NEPCO site

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bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	05/14/96	06/13/96	09/10/96	09/30/96	10/31/96	11/19/96	11/26/96
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location		DEP		DEP			DEP
Laboratory							
depth							
Field pH	4.0	4.1	3.9	4.1	4.2	4.6	4.3
Lab pH	3.7		3.4			3.5	
Temperature [C]	9		10			9	
D.O.	<1		<1			<1	
Tot. Hardness	82		88			88	
Conductivity	340		310	389	390	340	350
Alkalinity	<1	4.2	<1	3.6	4.8	<1	8.8
Hot Acidity	164.2	64.0	145.0	74.0	58.0	118.0	5.8
Iron (T)	1.500	5.490	1.420	10.710	11.300	1.260	8.990
Iron (D)	1.680	1.320	0.840	1.400	1.480	1.000	1.300
Manganese (T)	140	96	172	67	74	138	66
Manganese (D)	<0.1		<0.1			<0.2	
Sulfate (T)	<0.2		<0.2	9.0	16.0	17.0	11.0
Sulfide	25.0		21.0	8.31	13.90	12.70	9.57
Fluoride	15.60	12.20	9.54	298	598	196	200
Chloride	169		180	<2	<2	4	12
Sodium	1	<3	<1			<0.5	
Dis. Solids	<0.5		<0.5			<0.5	
Sus. Solids	<0.5		<0.5			<1	
Ammonia N	<1		<1			0.92	
Nitrate N	0.37		0.82			<10	
Bicarbonate	<10		<10				
Turbidity							
COD							
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	4.440	4.760	1.520	4.520	5.170	3.000	4.590
Aluminum (D)	4.380		<0.02			<0.02	
Arsenic (T)	<0.02		0.029			0.027	
Arsenic (D)	<0.02		<0.005			0.000	
Barium (T)	0.031		16.00	16.20	13.80	18.00	12.90
Barium (D)	0.031		<0.005			0.003	
Cadmium (T)	<0.005		0.040			0.050	
Cadmium (D)	<0.005		<0.002			<0.002	
Calcium (T)	12.20		7.50	7.64	7.50	7.18	7.26
Calcium (D)	12.10		<0.001			<0.001	
Chromium (T)	<0.005		0.067			0.064	
Chromium (D)	<0.005		<0.01			<0.01	
Copper (T)	0.020		<0.05			<0.05	
Copper (D)	0.180		0.840	0.247	0.246	0.228	0.182
Lead (T)	<0.05			1.55	1.56		1.46
Lead (D)	<0.05						
Magnesium (T)	6.91						
Magnesium (D)	6.80						
Mercury (T)	<0.001						
Mercury (D)	<0.001						
Nickel (T)	0.066						
Nickel (D)	0.063						
Selenium (T)	<0.01						
Selenium (D)	<0.01						
Silver (T)	<0.005						
Silver (D)	<0.005						
Zinc (T)	0.263						
Zinc (D)	0.255						
Potassium (T)	1.34						
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/27/96	01/30/97	03/11/97	03/29/97	04/29/97	05/14/97	05/31/97
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location	DEP	DEP		DEP	DEP	DEP	DEP
Laboratory							
depth							
Field pH			3.9		4.0		
Lab pH	4.0	4.0	3.8	3.9	4.2	4.1	4.1
Temperature [C]			10				
D.O.			<1				
Tot. Hardness			100				370
Conductivity	280	321	455	370	380		4.0
Alkalinity	3.0	1.6	<1	<1	6.6	3.8	68.0
Hot Acidity	42.0	58.0	64.0	60.0	68.0	62.0	8.140
Iron (T)	1.040	3.300	1.100	6.020	7.170	6.210	
Iron (D)							1.450
Manganese (T)	1.160	11.500	1.430	1.420	1.370	1.240	
Manganese (D)							74
Sulfate (T)	107	56	132	62	89	126	
Sulfide			<0.1				
Fluoride			<0.2				19.0
Chloride	10.0	12.0	21.5	22.0	19.0		16.12
Sodium	10.50	10.70	15.50	17.20	15.70	14.70	232
Dis. Solids	160	176	179	216	252		4
Sus. Solids	<2	2	1	6	<2	<3	
Ammonia N			<0.5				
Nitrate N			<0.5				
Bicarbonate			<1				
Turbidity			1.20				
COD			<10				
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	4.580	4.690	4.900	4.950	4.720	4.540	5.000
Aluminum (D)			<0.02				
Arsenic (T)							
Arsenic (D)			0.029				
Barium (T)							
Barium (D)			0.001				
Cadmium (T)							16.80
Cadmium (D)							
Calcium (T)	13.60	16.60	20.80	17.00	17.40		
Calcium (D)			<0.001				
Chromium (T)							
Chromium (D)			0.100				
Copper (T)							
Copper (D)			<0.002				
Lead (T)							7.91
Lead (D)							
Magnesium (T)	6.50	7.93	7.21	7.90	7.60		
Magnesium (D)							
Mercury (T)			<0.0002				
Mercury (D)							
Nickel (T)			0.063				
Nickel (D)							
Selenium (T)			<0.01				
Selenium (D)							
Silver (T)			<0.005				
Silver (D)							0.269
Zinc (T)	0.264	0.333	0.290	0.274	0.258		
Zinc (D)							1.35
Potassium (T)	1.82	1.73		1.85	1.33		
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	06/13/97	06/28/97	07/19/97	08/23/97	09/09/97	09/13/97	10/28/97
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory							
depth							
Field pH	4.3	4.1	4.1	4.0	4.5	4.1	4.5
Lab pH	3.8			4.0	3.8		3.6
Temperature [C]	10				10		
D.O.	<1				<1		
Tot. Hardness	100				114		
Conductivity	400	349	341	374	395	412	400
Alkalinity	<1	4.4	3.8	2.8	<1	6.2	<1
Hot Acidity	184.0	66.0	60.0	88.0	160.0		52.0
Iron (T)	1.120	9.340	10.100	14.200	1.570	16.300	14.800
Iron (D)							
Manganese (T)	1.400	1.610	1.560	1.670	1.600	2.010	1.670
Manganese (D)							
Sulfate (T)	148	82	86	54	144	104	132
Sulfide	<0.1				<0.1		
Fluoride	<0.4				<0.2		<0.2
Chloride	19.3	16.0	14.0	11.0	15.5	13.0	17.5
Sodium	14.40	13.20	14.50	10.70	11.80	11.70	1.11
Dis. Solids	100	212	296	330	293	172	267
Sus. Solids	<1	8	<2	<2	<1	10	3
Ammonia N	<0.5				<0.5		<0.5
Nitrate N	<0.5				<0.5		<0.5
Bicarbonate	<1				<1		<1
Turbidity	0.57				0.27		5.20
COD	10.00				<10		<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	4.850	5.080	5.430	6.360	1.520	7.480	6.670
Aluminum (D)	4.750				<0.02		<0.02
Arsenic (T)	<0.02						
Arsenic (D)	<0.02				0.028		0.027
Barium (T)	0.028						
Barium (D)	0.028				0.001		<0.005
Cadmium (T)	0.001						
Cadmium (D)	0.001			19.40	20.80	19.80	22.40
Calcium (T)	16.20	15.00					
Calcium (D)	15.50				<0.001		<0.005
Chromium (T)	<0.001						
Chromium (D)	<0.001				0.080		<0.005
Copper (T)	0.008						
Copper (D)	0.006				<0.002		<0.05
Lead (T)	<0.05						
Lead (D)	<0.05	8.17	8.41	9.70	9.50	11.90	9.17
Magnesium (T)	8.26						
Magnesium (D)	7.88				0.001		<0.0002
Mercury (T)	<0.001						
Mercury (D)	<0.001				0.088		0.081
Nickel (T)	0.072						
Nickel (D)	0.067				<0.01		<0.01
Selenium (T)	<0.01						
Selenium (D)	<0.01				<0.005		<0.005
Silver (T)	<0.005						
Silver (D)	<0.005				0.308	0.362	0.291
Zinc (T)	0.267	0.261	0.242	0.302			
Zinc (D)	0.255					1.43	
Potassium (T)	1.49	1.57	1.68	1.54			
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	10/25/97	11/15/97	11/24/97	12/20/97	01/24/98	02/21/98	03/13/98
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location	DEP	DEP	DEP	DEP	DEP	DEP	DEP
Laboratory							
depth							
Field pH	4.5		4.7				4.6
Lab pH	4.1	4.2	3.1	4.1	4.0	3.8	3.7
Temperature [C]			9				9
D.O.			<1				<1
Tot. Hardness			122				
Conductivity	409	407	490	388	417	439	420
Alkalinity	7.2	6.6	<1	3.6	5.0	<1	<1
Hot Acidity	82.0	90.0	130.0	80.0	68.0	60.0	180.0
Iron (T)	15.100	16.000	14.700	19.400	9.100	9.170	2.920
Iron (D)							
Manganese (T)	1.780	1.890	1.730	1.900	1.510	1.500	1.800
Manganese (D)							
Sulfate (T)	71	67	148	84	62	72	156
Sulfide			<0.1				<0.1
Fluoride			<0.2				<2
Chloride	17.0	14.0	17.0	19.0	31.0	38.0	47.5
Sodium	13.00	11.90	12.00	16.20	20.50	25.00	24.10
Dis. Solids	266	290	314	282	228	268	258
Sus. Solids	28	12	1	<2	10	10	2
Ammonia N			<0.2				<0.2
Nitrate N			<0.2				<0.5
Bicarbonate			<1				<1
Turbidity			0.26				6.20
COD			<10				<10
TOC							
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	6.890	7.180	6.970	6.530	4.660	5.280	1.560
Aluminum (D)			6.760				<0.005
Arsenic (T)			<0.02				
Arsenic (D)							0.031
Barium (T)			0.027				
Barium (D)							<0.002
Cadmium (T)			<0.005				
Cadmium (D)							20.00
Calcium (T)	14.70	15.50	15.00	18.40	14.50	13.90	
Calcium (D)							<0.002
Chromium (T)			<0.005				
Chromium (D)							0.180
Copper (T)			<0.005				
Copper (D)							<0.002
Lead (T)			<0.05				
Lead (D)							8.26
Magnesium (T)	9.21	9.72	9.00	9.83	7.89	8.19	
Magnesium (D)							<0.0002
Mercury (T)			<0.0002				
Mercury (D)							0.067
Nickel (T)			0.080				
Nickel (D)							<0.005
Selenium (T)			<0.01				
Selenium (D)							<0.005
Silver (T)			<0.005				
Silver (D)							0.244
Zinc (T)	0.302	0.328	0.300	0.309	0.235	0.223	
Zinc (D)							
Potassium (T)	1.42	1.60		2.45	1.48	1.29	
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	03/21/98	04/25/98	05/16/98	06/05/98	06/20/98	07/18/98	08/12/98
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH				4.4			
Lab pH	3.8	3.9	3.8	3.9	4.0	4.0	4.3
Temperature [C]							
D.O.							
Tot. Hardness							443
Conductivity	416	430	421	425	423	440	6.2
Alkalinity	<1	<1		<1	2.8	2.0	78.0
Hot Acidity	54.0	54.0	56.0	138.0	54.0	62.0	17.700
Iron (T)	9.520	8.100	9.270	1.360	10.200	12.500	
Iron (D)							1.640
Manganese (T)	1.500	1.400	1.490	1.400	1.400	1.480	1.640
Manganese (D)							193
Sulfate (T)	82	89	112	156	114	117	
Sulfide							0.30
Fluoride				<2			9.0
Chloride	24.0	29.0	24.0	34.0	13.0	10.0	9.85
Sodium	20.40	21.40	19.00	16.10	12.60	11.40	268
Dis. Solids	246	296	230	275	294	308	<2
Sus. Solids	10	16	2	<1	8	6	0.09
Ammonia N				<0.2			<0.04
Nitrate N				<0.2			
Bicarbonate				<1			<1
Turbidity				0.32			
COD				<10			
TOC							15.96
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	5.140	4.830	4.810	4.260	4.910	5.550	6.810
Aluminum (D)							6.810
Arsenic (T)				<0.005			<0.004
Arsenic (D)							<0.004
Barium (T)				0.028			0.028
Barium (D)							0.028
Cadmium (T)				<0.002			<0.010
Cadmium (D)							<0.010
Calcium (T)	16.40	19.30	18.80	18.30	22.10	24.20	27.00
Calcium (D)							27.00
Chromium (T)				<0.002			<0.050
Chromium (D)							<0.050
Copper (T)				0.006			**0.023**
Copper (D)							**<0.010**
Lead (T)				0.0060			<0.001
Lead (D)							<0.001
Magnesium (T)	8.37	7.84	8.20	7.21	7.61	8.55	9.60
Magnesium (D)							9.60
Mercury (T)				<0.0002			<0.001
Mercury (D)							<0.001
Nickel (T)				0.060			0.091
Nickel (D)							0.091
Selenium (T)				<0.005			<0.007
Selenium (D)							<0.007
Silver (T)				<0.005			
Silver (D)							
Zinc (T)	0.247	0.236	0.236	0.235	0.239	0.252	0.295
Zinc (D)							0.295
Potassium (T)	<0.50	1.71	1.77		1.85	1.83	1.84
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	08/22/98	09/15/98	09/26/98	10/14/98	10/24/98	11/17/98	02/01/99
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	4.2	3.8	3.9	4.2	4.3	4.2	3.8
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	486	508	521	488	492	482	424
Alkalinity	6.6	<1	<1	5.8	6.6	5.2	0.0
Hot Acidity	84.0	88.0	92.0	94.0	96.0	96.0	48.0
Iron (T)	18.600	19.900	20.200	21.600	21.600	24.800	5.040
Iron (D)							
Manganese (T)	1.790	7.850	1.990	1.840	2.140	2.040	1.180
Manganese (D)		1.820				1.970	1.140
Sulfate (T)	153	183	165	195	137	171	109
Sulfide							
Fluoride		<0.20		<0.20		0.21	<0.20
Chloride	9.0	9.0	10.0	10.0	13.0	12.0	29.0
Sodium	10.80	10.10	11.50	10.30	11.40	12.10	23.40
Dis. Solids	388		456	352	342	346	186
Sus. Solids	6		20	10	<2	<2	4
Ammonia N		0.08		0.12		0.10	0.05
Nitrate N				<0.04		<0.04	<0.04
Bicarbonate							
Turbidity		6.00		<1		<1	17.30
COD							
TOC				16.61			11.43
Silica (T)							
Silica (D)							
Annual Parameters							
Aluminum (T)	8.060	8.490	8.840	8.400	8.920	8.230	4.360
Aluminum (D)		8.360				7.890	4.200
Arsenic (T)		<0.004		<0.004		<0.040	<0.040
Arsenic (D)		<0.004				<0.040	<0.040
Barium (T)		0.029		0.028		0.037	0.033
Barium (D)		0.029				0.027	0.031
Cadmium (T)		<0.010		<0.010		<0.010	<0.010
Cadmium (D)		<0.010				<0.010	<0.010
Calcium (T)	24.70	32.60	27.00	30.80	25.60	26.60	16.60
Calcium (D)		32.60				25.80	16.00
Chromium (T)		<0.050		<0.050		<0.050	<0.050
Chromium (D)		<0.050				<0.050	<0.050
Copper (T)		**0.101**		<0.010		<0.010	**0.060**
Copper (D)		**<0.010**				<0.010	**0.018**
Lead (T)		**0.0078**		0.0066		<0.010	**0.0116**
Lead (D)		**0.0058**		0.0057		<0.010	**0.0109**
Magnesium (T)	10.50	11.80	11.50	10.20	11.90	12.50	6.90
Magnesium (D)		11.80				12.20	6.80
Mercury (T)		<0.001		<0.001		<0.001	<0.001
Mercury (D)		<0.001				<0.001	<0.001
Nickel (T)		0.106		0.095		0.106	0.066
Nickel (D)		0.099				0.100	0.060
Selenium (T)		<0.007		<0.007		<0.070	<0.070
Selenium (D)		<0.007				<0.070	<0.070
Silver (T)							
Silver (D)							
Zinc (T)	0.303	**0.386**	0.319	**0.391**	0.344	3.410	**0.278**
Zinc (D)		**0.289**		**0.329**		0.314	**0.222**
Potassium (T)	1.95		1.88	1.94	2.25		1.34
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	04/22/99	05/26/99	06/30/99	7/29/1999	8/11/1999	10/27/1999	11/23/1999
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	4.1	4.1	4.2	4.2	4.2	4.2	4.2
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	480	474		487	489	499	512
Alkalinity	3.6	3.8	4.8	5.4	5.4	5.6	5.0
Hot Acidity	56.0	66.0	64.0	74.0	80.0	82.0	80.0
Iron (T)	14.800	15.800	17.400	17.200	19.600	23.100	22.000
Iron (D)			16.200				
Manganese (T)	1.590	1.490	1.600	1.540	1.580	2.010	1.770
Manganese (D)	1.590	1.480	1.460	1.450	1.580	1.870	1.750
Sulfate (T)	109	151	131	149	172	156	140
Sulfide							
Fluoride	<0.20	<0.20		<0.020	<0.2	<0.20	<0.20
Chloride	31.0	27.0		18.0	15.0	19.0	19.0
Sodium	22.10	19.00	15.90	14.70	13.90	16.50	15.90
Dis. Solids	254	232		360	292	370	298
Sus. Solids	8	<2	8	<2	<2	<2	<2
Ammonia N	0.08	0.09		*0.09*	*0.10*	*0.08*	*0.14*
Nitrate N	<0.04	<0.04		<0.04	<0.04	<0.04	<0.04
Bicarbonate							
Turbidity	2.45	5.88		<1	1.07	2.12	7.40
COD							
TOC						13.94	13.29
Silica (T)	12.97	12.31	13.33			13.27	13.18
Silica (D)							
Annual Parameters							
Aluminum (T)	4.590	4.880	5.400	5.890	6.380	7.420	5.760
Aluminum (D)	4.590	4.880	4.860	5.440	5.750	5.980	5.610
Arsenic (T)	<0.004	<0.004		<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004		<0.004	<0.004	<0.004	<0.004
Barium (T)	0.030	0.028		0.026	0.027	**0.032**	0.028
Barium (D)	0.030	0.028		0.026	0.027	**0.030**	0.028
Cadmium (T)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Calcium (T)	19.30	23.20		27.00	**37.70**	**44.80**	27.70
Calcium (D)	19.30	23.20		25.20	**27.00**	**31.30**	27.70
Chromium (T)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050
Copper (T)	<0.010	<0.010		<0.010	<0.010	**0.011**	<0.010
Copper (D)	<0.010	<0.010		<0.010	<0.010	**<0.010**	<0.010
Lead (T)	0.0054	0.0052		0.0063	0.0054	0.0060	**0.0062**
Lead (D)	<0.001	0.0052		0.0063	0.0054	0.0046	**0.0057**
Magnesium (T)	8.49	8.10		8.33	8.84	12.10	9.43
Magnesium (D)	8.49	8.10		7.90	8.84	11.40	9.10
Mercury (T)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Nickel (T)	0.073	0.070		0.088	0.097	0.104	0.079
Nickel (D)	0.073	0.070		0.079	0.089	0.098	0.079
Selenium (T)	<0.007	<0.007		<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007		<0.007	<0.007	<0.070	<0.007
Silver (T)							
Silver (D)							
Zinc (T)	0.247	0.259		0.272	**0.335**	0.318	**0.785**
Zinc (D)	0.247	0.259		0.272	**0.267**	0.315	**0.262**
Potassium (T)	1.59	1.80	**2.57**			2.66	1.91
Potassium (D)			**2.00**			2.42	1.91

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/29/1999	1/26/2000	3/7/2000	3/27/2000	4/25/2000	5/24/2000	6/27/2000
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	4.3	4.3	3.6	4.1	4.2	4.0	4.1
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	438	431	520	479	422	459	429
Alkalinity	7.6	7.0	0.0	3.8	6.8	1.8	3.6
Hot Acidity		68.0	64.0	58.6	50.0	52.0	52.0
Iron (T)	19.600	19.900		15.600	14.600	13.900	10.000
Iron (D)		19.900					
Manganese (T)	1.640	1.670		1.410	1.280	1.320	1.330
Manganese (D)	1.560	1.610		1.370	1.280	1.320	1.260
Sulfate (T)	149	131	125	111	114	110	104
Sulfide							
Fluoride	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Chloride	16.0	15.0	18.0	32.0	18.0	19.0	18.0
Sodium	16.10	13.90		23.40	18.30	17.90	16.80
Dis. Solids	326	230	250	278	260	262	322
Sus. Solids	<2	16	12	26	18	16	<2
Ammonia N	*0.09*	*0.09*	*0.07*	*0.08*	*<0.02*	*0.08*	*0.06*
Nitrate N	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bicarbonate							
Turbidity		<1	3.31	4.26	3.97	14.70	1.38
COD							
TOC							
Silica (T)	13.03	13.57		11.53	11.17	11.53	12.26
Silica (D)							
Annual Parameters							
Aluminum (T)		4.930		4.100	3.430	**3.960**	4.290
Aluminum (D)		4.740		3.920	3.340	**3.940**	4.020
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	**0.025**	0.026		0.026	0.025	0.026	0.025
Barium (D)	**0.024**	0.026		0.026	0.025	0.026	0.024
Cadmium (T)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Calcium (T)	22.00	**22.20**		22.20	20.20	23.20	25.10
Calcium (D)	22.00	**21.70**		22.20	19.90	22.80	24.40
Chromium (T)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050
Copper (T)	<0.010	**0.019**		<0.010	0.031	<0.010	<0.010
Copper (D)	<0.010	**0.010**		<0.010	0.026	<0.010	<0.010
Lead (T)	0.0053	0.0048	**0.0056**	0.0045	0.0092	0.0043	**0.0041**
Lead (D)	0.0047	0.0047	**0.0050**	0.0043	0.0044	0.0043	**0.0042**
Magnesium (T)	8.78	9.10		**7.45**	7.38	7.45	7.72
Magnesium (D)	8.36	8.81		**4.30**	7.38	7.42	7.37
Mercury (T)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)		0.083		0.068	0.067	**0.056**	0.064
Nickel (D)	0.077	0.070		0.068	0.067	**0.053**	0.059
Selenium (T)		<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)		<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)							
Silver (D)							
Zinc (T)		**0.237**		0.196	0.211	**0.237**	0.200
Zinc (D)		**0.230**		0.196	0.211	**0.220**	0.194
Potassium (T)	1.40	2.16		1.67	1.83	1.68	1.88
Potassium (D)							

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	7/26/2000	8/22/2000	11/8/2000	3/3/2001	5/21/2001	8/28/2001
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID						
location						
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP
depth						
Field pH						
Lab pH	4.3	4.3	4.2	4.3	4.2	4.3
Temperature [C]						
D.O.						
Tot. Hardness						
Conductivity	419	498	626	525	517	574
Alkalinity	6.8	7.2	7.0	0.0	0.0	0.0
Hot Acidity	54.0	76.0	102.0	80.0	64.0	95.6
Iron (T)	14.200	16.100	23.000	19.700	18.200	23.000
Iron (D)				18.900	17.500	21.900
Manganese (T)	1.350	1.460	1.950	1.610	1.540	1.810
Manganese (D)	1.350	1.380	1.720	1.680	1.510	1.790
Sulfate (T)	136	166	208	177	117	200
Sulfide						
Fluoride	<0.20	<0.20	0.21			
Chloride	10.0	10.0	10.0	18.0	26.0	17.0
Sodium	12.50	12.60	15.10	18.80	22.80	21.20
Dis. Solids	330	344	474	394	352	842
Sus. Solids	<2	<2	<2	<2	4	<2
Ammonia N	*0.07*	*0.09*				
Nitrate N	<0.04	<0.04	<0.04			
Bicarbonate						
Turbidity	6.45	<1	1.06			
COD						
TOC						
Silica (T)	**13.44**	15.79	17.95	14.15	12.18	16.09
Silica (D)	**13.35**	15.24	16.01	13.50	12.07	15.81
Annual Parameters						
Aluminum (T)	**4.600**	6.390	9.350	5.860	4.470	8.400
Aluminum (D)	**4.410**	6.810	10.600	5.640	4.350	7.050
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium (T)	0.025	0.003	**0.052**			
Barium (D)	0.024	0.003	**0.034**			
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (T)	**27.60**	38.40	48.30	59.10	31.30	53.70
Calcium (D)	**27.20**	37.00	45.10	33.60	30.20	51.30
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Copper (T)	<0.010	<0.010	0.010	<0.010	0.013	<0.010
Copper (D)	<0.010	<0.010	0.010		<0.010	<0.010
Lead (T)	**0.0046**	**0.0051**	**0.0075**	0.0052	**0.0049**	**0.0053**
Lead (D)	**0.0045**	**0.0050**	**0.0072**	0.0050	**0.0047**	**0.0051**
Magnesium (T)	**7.95**	8.83	10.70	9.22	8.46	9.75
Magnesium (D)	**7.92**	8.43	9.60	8.85	8.28	9.56
Mercury (T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (T)	**0.066**	0.075	0.095	0.079	**0.067**	0.083
Nickel (D)	**0.062**	0.085	0.100	0.076	**0.065**	0.081
Selenium (T)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Silver (T)						
Silver (D)						
Zinc (T)	**0.220**	0.243	**0.552**	**0.405**	**0.349**	**0.388**
Zinc (D)	**0.218**	0.249	**0.516**	**0.385**	**0.240**	**0.279**
Potassium (T)	**2.42**	2.81	3.69	2.77	**2.54**	**3.76**
Potassium (D)	**2.23**	2.64	3.27	2.65	**2.40**	**3.73**

Data from the NEPCO site

all concentrations reported in mg/L except for conductivity (µS/cm) and turbidity (ntu)
bold = dissolved and total concentrations initially reversed by the lab, italics = sample not fixed properly
T = total concentration, D = dissolved concentration

sample date	12/4/2001	3/11/2002	5/23/2002	9/10/2002	11/4/2002	4/28/2003	6/3/2003
sample name	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook	Silverbrook
sample ID							
location							
Laboratory	DEP	DEP	DEP	DEP	DEP	DEP	DEP
depth							
Field pH							
Lab pH	4.2	4.1	3.8	4.1	4.3	3.5	3.9
Temperature [C]							
D.O.							
Tot. Hardness							
Conductivity	567	526	548	602	569	570	536
Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hot Acidity	105.8	96.4	18.8 (not hot?)	117.6	118.4	76.0	80.2
Iron (T)	22.500	22.200	16.500	**21.100**	23.400	1.690	8.656
Iron (D)	22.100	21.700		**19.400**	23.300	1.590	8.432
Manganese (T)	1.890	1.880	1.820	1.600	**1.980**	1.700	1.468
Manganese (D)	1.840	1.860		1.590	**1.930**	1.630	1.438
Sulfate (T)	239	181	125	202	210	165	178
Sulfide							
Fluoride							
Chloride	12.0	19.0	38.0	11.3	19.5	35.9	24.3
Sodium	16.30	20.10	29.00	232.00	20.60	29.60	23.10
Dis. Solids	448	356	324	506	480	342	344
Sus. Solids	<2	8	18	10	8	<2	6
Ammonia N							
Nitrate N							
Bicarbonate							
Turbidity							
COD							
TOC							
Silica (T)	16.58				**16.26**		
Silica (D)					**16.11**		
Annual Parameters							
Aluminum (T)	7.930	**5.500**	5.250	7.980	7.050	6.960	5.996
Aluminum (D)	7.910	**5.450**		7.860	6.980	6.640	5.875
Arsenic (T)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Arsenic (D)	<0.004	<0.004		<0.004	<0.004	<0.004	<0.004
Barium (T)							
Barium (D)							
Cadmium (T)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (D)	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Calcium (T)	43.40	32.90	25.70	**56.10**	**42.80**	**30.00**	38.70
Calcium (D)	42.90	32.70		**51.10**	**42.30**	**29.60**	37.50
Chromium (T)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chromium (D)	<0.050	<0.050		<0.050	<0.050	<0.050	<0.050
Copper (T)	<0.010	<0.010	<0.010	<0.010	<0.010	**0.050**	0.014
Copper (D)	<0.010	<0.010		<0.010	<0.010	**0.023**	<0.010
Lead (T)	0.0054	0.0043	0.0053	**4.5780**	0.0058	0.0077	0.0051
Lead (D)	0.0054	0.0040		**4.5450**	0.0049	0.0077	0.0050
Magnesium (T)	10.60	9.91	9.88	9.64	**10.50**	9.51	9.48
Magnesium (D)	10.40	9.88		9.62	**10.40**	9.01	9.20
Mercury (T)			<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (D)	<0.001	<0.001				<0.001	<0.001
Nickel (T)	0.100	0.090	0.082	0.089	0.099	**0.080**	0.071
Nickel (D)	0.100	0.080		0.082	0.095	**0.078**	0.070
Selenium (T)	0.0070	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Selenium (D)	0.0070	<0.007		<0.007	<0.007	<0.007	<0.007
Silver (T)							
Silver (D)							
Zinc (T)	**0.680**	**0.280**	0.248	**0.925**	**1.160**	**0.881**	0.333
Zinc (D)	**0.290**	**0.260**		**0.272**	**0.284**	**0.280**	0.329
Potassium (T)	3.54	**2.68**	2.42	**4.63**	**3.93**	**3.49**	3.24
Potassium (D)	3.54	**2.69**		**4.59**	**3.49**	**2.85**	3.20

Appendix 9.C

Ash Chemistry 1997-2003

Pottsville Environmental Testing Laboratory, Inc.
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7/3/97

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 06/12/97 (COMP.)
Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.40	11.06	9045
2.	Aluminum	16,200.	1.79	6010A
3.	Antimony	< 1.50	< 0.030	6010A
4.	Arsenic	< 1.00	< 0.020	6010A
5.	Barium	130.	0.113	6010A
6.	Boron	2.38	0.111	212.3
7.	Cadmium	< 0.250	< 0.005	6010A
8.	Chromium	19.5	0.047	6010A
9.	Cobalt	3.08	< 0.005	6010A
10.	Copper	20.0	0.005	6010A
11.	Iron	7,250.	0.067	6010A
12.	Lead	13.1	< 0.050	6010A
13.	Manganese	22.5	< 0.005	6010A
14.	Mercury	0.693	< 0.001	7471
15.	Molybdenum	1.73	0.035	6010A
16.	Nickel	9.96	< 0.010	6010A
17.	Potassium	3,990.	11.1	6010A
18.	Selenium	15.0	< 0.010	6010A
19.	Silver	< 0.250	< 0.005	6010A
20.	Zinc	7.03	0.014	6010A
21.	Sulfate	---	147.	9038
22.	Ammonia Nitrogen	---	< 0.50	350.3
23.	Nitrate Nitrogen	---	< 0.50	9200
24.	Chloride	---	43.0	3250
25.	Cyanide	---	< 0.005	9010
26.	Sodium	---	8.27	6010A
27.	Phenolics	---	0.005	9065
28.	TOC	---	< 1.0	9060
29.	TOX	---	0.02	9022
30.	COD	---	< 10.0	410.4
31.	Acid Neut. Pot.	467,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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7/3/97

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 06/12/97 (COMP.) Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.70	12.15	9045
2.	Aluminum	6,780.	0.293	6010A
3.	Antimony	< 1.50	< 0.030	6010A
4.	Arsenic	< 1.00	< 0.020	6010A
5.	Barium	60.	0.020	6010A
6.	Boron	2.28	0.012	212.3
7.	Cadmium	< 0.250	< 0.005	6010A
8.	Chromium	5.17	< 0.005	6010A
9.	Cobalt	0.530	< 0.005	6010A
10.	Copper	5.07	< 0.005	6010A
11.	Iron	2,340.	0.035	6010A
12.	Lead	6.18	< 0.050	6010A
13.	Manganese	10.6	< 0.005	6010A
14.	Mercury	< 0.020	< 0.001	7471
15.	Molybdenum	0.300	0.022	6010A
16.	Nickel	2.83	< 0.010	6010A
17.	Potassium	2,650.	6.49	6010A
18.	Selenium	1.71	< 0.010	6010A
19.	Silver	< 0.250	< 0.005	6010A
20.	Zinc	3.08	< 0.005	6010A
21.	Sulfate	---	68.2	9038
22.	Ammonia Nitrogen	---	< 0.50	350.3
23.	Nitrate Nitrogen	---	8.00	9200
24.	Chloride	---	230.	3250
25.	Cyanide	---	< 0.005	9010
26.	Sodium	---	2.23	6010A
27.	Phenolics	---	0.007	9065
28.	TOC	---	1.37	9060
29.	TOX	---	3.16	9022
30.	COD	---	< 10.0	410.4
31.	Acid Neut. Pot.	430,000.	---	C400-87

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Sample Location: FLY ASH
Sample Date/Time: 11/24/97 (COMP.) Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.5	---	9045
2.	Aluminum	28,800.	3.12	6010A
3.	Antimony	< 2.28	< 0.050	6010A
4.	Arsenic	29.4	< 0.050	6010A
5.	Barium	236.	0.130	6010A
6.	Boron	18.0	0.296	212.3
7.	Cadmium	< 0.381	< 0.050	6010A
8.	Chromium	30.0	0.052	6010A
9.	Cobalt	4.29	< 0.050	6010A
10.	Copper	26.9	< 0.050	6010A
11.	Iron	9,510.	< 0.100	6010A
12.	Lead	27.9	< 0.050	6010A
13.	Manganese	202.	< 0.050	6010A
14.	Mercury	0.721	< 0.001	7471
15.	Molybdenum	3.06	< 0.100	6010A
16.	Nickel	14.0	< 0.050	6010A
17.	Potassium	6,800.	7.40	6010A
18.	Selenium	18.9	< 0.050	6010A
19.	Silver	< 0.381	< 0.050	6010A
20.	Zinc	32.6	0.027	6010A
21.	Sulfate	---	< 200.0	9038
22.	Ammonia Nitrogen	---	< 0.2	350.3
23.	Nitrate Nitrogen	---	0.4	9200
24.	Chloride	---	2.	3250
25.	Cyanide	---	< 0.005	9010
26.	Sodium	---	10.9	6010A
27.	Phenolics	---	< 0.010	9065
28.	TOC	---	< 1.	9060
29.	TOX	---	< 0.02	9022
30.	COD	---	< 10.	410.4
31.	Acid Neut. Pot.	890,000.	---	C400-87

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12/31/97

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P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 11/24/97 (COMP.)
Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.5	---	9045
2.	Aluminum	10,600.	1.57	6010A
3.	Antimony	< 1.54	< 0.050	6010A
4.	Arsenic	5.05	< 0.050	6010A
5.	Barium	106.	0.175	6010A
6.	Boron	4.80	0.180	212.3
7.	Cadmium	0.257	< 0.050	6010A
8.	Chromium	9.26	< 0.050	6010A
9.	Cobalt	0.929	< 0.050	6010A
10.	Copper	5.63	< 0.050	6010A
11.	Iron	4,090.	< 0.100	6010A
12.	Lead	7.66	< 0.050	6010A
13.	Manganese	48.5	< 0.050	6010A
14.	Mercury	< 0.05	< 0.001	7471
15.	Molybdenum	0.568	< 0.100	6010A
16.	Nickel	4.99	< 0.050	6010A
17.	Potassium	3,810.	3.75	6010A
18.	Selenium	5.46	< 0.050	6010A
19.	Silver	< 0.257	< 0.050	6010A
20.	Zinc	8.15	0.028	6010A
21.	Sulfate	---	< 200.0	9038
22.	Ammonia Nitrogen	---	< 0.2	350.3
23.	Nitrate Nitrogen	---	0.4	9200
24.	Chloride	---	1.	3250
25.	Cyanide	---	< 0.005	9010
26.	Sodium	---	5.35	6010A
27.	Phenolics	---	< 0.010	9065
28.	TOC	---	< 1.	9060
29.	TOX	---	< 0.02	9022
30.	COD	---	< 10.	410.4
31.	Acid Neut. Pot.	1,050,000.	---	C400-87

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6/22/98

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 05/27/98 (COMP.) Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	8.95	9.68	9045
2.	Aluminum	23,000.	0.510	6010
3.	Antimony	1.12	< 0.050	6010
4.	Arsenic	16.4	< 0.050	6010
5.	Barium	239.	0.143	6010
6.	Boron	15.3	0.227	6010
7.	Cadmium	< 0.653	< 0.050	6010
8.	Chromium	26.4	0.224	6010
9.	Cobalt	3.59	< 0.050	6010
10.	Copper	27.7	< 0.050	6010
11.	Iron	4,100.	< 0.100	6010
12.	Lead	10.7	0.302	6010
13.	Manganese	53.4	< 0.500	6010
14.	Mercury	0.670	< 0.001	7471/7470
15.	Molybdenum	4.79	0.291	6010
16.	Nickel	9.31	< 0.050	6010
17.	Potassium	9,930.	18.3	6010
18.	Selenium	10.7	0.074	6010
19.	Silver	< 0.653	< 0.050	6010
20.	Zinc	20.5	0.025	6010
21.	Sulfate	---	805.	9038
22.	Ammonia Nitrogen	---	< 0.2	417G
23.	Nitrate Nitrogen	---	0.66	9200
24.	Chloride	---	4.66	9250
25.	Cyanide	---	< 0.005	9010A
26.	Sodium	---	27.6	6010
27.	Phenolics	---	< 0.01	9065
28.	TOC	---	< 1.	9060A
29.	TOX	---	0.06	9020A
30.	COD	---	< 10.	5220
31.	Acid Neut. Pot.	690,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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6/22/98

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 05/27/98 (COMP.) Sampled By: J.W.

MODULE 25A - ASH QUALITY INFORMATION

	PARAMETER	ASH DRY WT. (mg/kg)	LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	12.0	12.1	9045
2.	Aluminum	13,300.	2.93	6010
3.	Antimony	< 0.534	< 0.050	6010
4.	Arsenic	2.34	< 0.050	6010
5.	Barium	143.	0.159	6010
6.	Boron	7.1	0.130	6010
7.	Cadmium	< 0.534	< 0.050	6010
8.	Chromium	10.5	< 0.050	6010
9.	Cobalt	1.29	< 0.050	6010
10.	Copper	8.93	< 0.050	6010
11.	Iron	2,400.	< 0.100	6010
12.	Lead	11.5	< 0.050	6010
13.	Manganese	42.2	< 0.500	6010
14.	Mercury	< 0.0534	0.014	7471/7470
15.	Molybdenum	0.547	< 0.100	6010
16.	Nickel	4.71	< 0.050	6010
17.	Potassium	< 534.	15.5	6010
18.	Selenium	< 0.534	< 0.050	6010
19.	Silver	< 0.534	< 0.050	6010
20.	Zinc	7.55	0.033	6010
21.	Sulfate	---	66.9	9038
22.	Ammonia Nitrogen	---	< 0.2	417G
23.	Nitrate Nitrogen	---	0.62	9200
24.	Chloride	---	< 2.00	9250
25.	Cyanide	---	< 0.005	9010A
26.	Sodium	---	9.72	6010
27.	Phenolics	---	< 0.01	9065
28.	TOC	---	< 1.	9060A
29.	TOX	---	< 0.02	9020A
30.	COD	---	< 10.	5220
31.	Acid Neut. Pot.	1,380,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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12/18/98

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 11/11/98 (A.M.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.67	11.1	9045
2.	Aluminum	26,000.	3.19	6010
3.	Antimony	1.06	< 0.050	6010
4.	Arsenic	17.7	< 0.050	6010
5.	Barium	247.	< 0.050	6010
6.	Boron	5.83	< 0.050	6010
7.	Cadmium	< 0.726	< 0.050	6010
8.	Chromium	28.2	< 0.050	6010
9.	Copper	31.3	< 0.050	6010
10.	Iron	11,887.	< 0.100	6010
11.	Lead	22.4	< 0.050	6010
12.	Manganese	55.3	< 0.500	6010
13.	Mercury	0.871	< 0.001	7471
14.	Molybdenum	3.11	< 0.100	6010
15.	Nickel	12.5	< 0.050	6010
16.	Selenium	10.1	< 0.050	6010
17.	Zinc	18.1	< 0.050	6010
18.	Sulfate	---	107.	300.0
19.	Chloride	---	1.38	300.0
20.	Sodium	---	5.85	6010
21.	Acid Neut. Pot.	440,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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12/18/98

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 11/11/98 (A.M.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.7	11.5	9045
2.	Aluminum	13,600.	4.62	6010
3.	Antimony	< 0.566	< 0.050	6010
4.	Arsenic	2.40	< 0.050	6010
5.	Barium	137.	0.140	6010
6.	Boron	2.54	0.064	6010
7.	Cadmium	< 0.566	< 0.050	6010
8.	Chromium	11.1	< 0.050	6010
9.	Copper	9.61	< 0.050	6010
10.	Iron	8,460.	< 0.100	6010
11.	Lead	7.85	< 0.050	6010
12.	Manganese	107.	< 0.500	6010
13.	Mercury	< 0.113	0.0069	7471
14.	Molybdenum	< 0.566	< 0.100	6010
15.	Nickel	5.99	< 0.050	6010
16.	Selenium	< 0.566	< 0.050	6010
17.	Zinc	10.9	< 0.050	6010
18.	Sulfate	---	30.1	300.0
19.	Chloride	---	< 1.00	300.0
20.	Sodium	---	4.85	6010
21.	Acid Neut. Pot.	2,040,000.	---	C400-87

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5/13/99

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 04/20/99 (COMP.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.88	10.8	9045
2.	Aluminum	28,200.	2.77	6010
3.	Antimony	< 0.719	< 0.050	6010
4.	Arsenic	18.3	< 0.050	6010
5.	Barium	243.	0.157	6010
6.	Boron	7.1	0.085	6010
7.	Cadmium	< 0.719	< 0.050	6010
8.	Chromium	28.2	0.051	6010
9.	Copper	32.8	< 0.050	6010
10.	Iron	12,700.	< 0.100	6010
11.	Lead	26.6	< 0.050	6010
12.	Manganese	52.5	< 0.500	6010
13.	Mercury	1.01	< 0.001	7471
14.	Molybdenum	3.11	< 0.100	6010
15.	Nickel	11.9	< 0.050	6010
16.	Selenium	13.4	< 0.050	6010
17.	Zinc	17.3	< 0.050	6010
18.	Sulfate	---	140.	300.0
19.	Chloride	---	2.19	300.0
20.	Sodium	---	8.58	6010
21.	Acid Neut. Pot.	490,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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5/13/99

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 04/20/99 (COMP.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	12.05	11.4	9045
2.	Aluminum	14,400.	2.86	6010
3.	Antimony	< 0.547	< 0.050	6010
4.	Arsenic	2.78	< 0.050	6010
5.	Barium	123.	0.076	6010
6.	Boron	3.3	< 0.050	6010
7.	Cadmium	< 0.547	< 0.050	6010
8.	Chromium	10.5	< 0.050	6010
9.	Copper	8.36	< 0.050	6010
10.	Iron	5,650.	< 0.100	6010
11.	Lead	12.4	< 0.050	6010
12.	Manganese	54.8	< 0.500	6010
13.	Mercury	< 0.109	< 0.001	7471
14.	Molybdenum	0.617	< 0.100	6010
15.	Nickel	4.41	< 0.050	6010
16.	Selenium	< 0.547	< 0.050	6010
17.	Zinc	6.53	< 0.050	6010
18.	Sulfate	---	101.	300.0
19.	Chloride	---	< 1.00	300.0
20.	Sodium	---	4.29	6010
21.	Acid Neut. Pot.	780,000.	---	C400-87

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12/08/99

JIM WETZEL
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Sample Location: FLY ASH
Sample Date/Time: 11/01/99 (COMP.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.6	10.3	9045
2.	Aluminum	12,200.	1.45	6010
3.	Antimony	< 0.718	< 0.050	6010
4.	Arsenic	11.1	< 0.050	6010
5.	Barium	122.	0.121	6010
6.	Boron	3.4	0.213	6010
7.	Cadmium	< 0.718	< 0.050	6010
8.	Chromium	10.7	0.053	6010
9.	Copper	17.7	< 0.050	6010
10.	Iron	3,860.	< 0.100	6010
11.	Lead	14.4	< 0.050	6010
12.	Manganese	2,030.	< 0.500	6010
13.	Mercury	< 0.144	< 0.001	7471
14.	Molybdenum	1.49	< 0.100	6010
15.	Nickel	6.12	< 0.050	6010
16.	Selenium	3.79	< 0.050	6010
17.	Zinc	10.8	< 0.020	6010
18.	Sulfate	---	452.	300.0
19.	Chloride	---	2.	300.0
20.	Sodium	---	10.5	6010
21.	Acid Neut. Pot.	920,000.	---	C400-87

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Sample Location: BOTTOM ASH
Sample Date/Time: 11/01/99 (COMP.) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	12.1	11.4	9045
2.	Aluminum	10,700.	1.64	6010
3.	Antimony	< 0.526	< 0.050	6010
4.	Arsenic	5.46	< 0.050	6010
5.	Barium	126.	0.156	6010
6.	Boron	2.6	0.116	6010
7.	Cadmium	< 0.526	< 0.050	6010
8.	Chromium	7.92	< 0.050	6010
9.	Copper	10.4	< 0.050	6010
10.	Iron	2,660.	< 0.100	6010
11.	Lead	9.52	< 0.050	6010
12.	Manganese	5,160.	< 0.500	6010
13.	Mercury	< 0.105	< 0.001	7471
14.	Molybdenum	1.18	< 0.100	6010
15.	Nickel	4.33	< 0.050	6010
16.	Selenium	< 0.526	< 0.050	6010
17.	Zinc	9.26	< 0.020	6010
18.	Sulfate	---	629.	300.0
19.	Chloride	---	< 1.00	300.0
20.	Sodium	---	6.68	6010
21.	Acid Neut. Pot.	430,000.	---	C400-87

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05/12/00

JIM WETZEL
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Sample Location: FLY ASH
Sample Date/Time: 04/19/00 (----) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.6	10.4	9045
2.	Aluminum	26,100.	1.42	6010
3.	Antimony	0.851	< 0.050	6010
4.	Arsenic	22.5	< 0.050	6010
5.	Barium	239.	0.118	6010
6.	Boron	13.3	0.236	6010
7.	Cadmium	< 0.631	< 0.050	6010
8.	Chromium	27.0	< 0.050	6010
9.	Copper	27.3	< 0.050	6010
10.	Iron	8,210.	< 0.100	6010
11.	Lead	31.6	< 0.050	6010
12.	Manganese	186.	< 0.500	6010
13.	Mercury	0.97	< 0.001	7471
14.	Molybdenum	3.16	< 0.100	6010
15.	Nickel	10.9	< 0.050	6010
16.	Selenium	11.4	< 0.050	6010
17.	Zinc	25.4	0.480	6010
18.	Sulfate	---	388.	300.0
19.	Chloride	---	2.32	300.0
20.	Sodium	---	9.29	6010
21.	Acid Neut. Pot.	470,000.	---	C400-87

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05/12/00

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Sample Location: BOTTOM ASH
Sample Date/Time: 04/19/00 (----) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.4	10.7	9045
2.	Aluminum	9,950.	4.56	6010
3.	Antimony	< 0.585	< 0.050	6010
4.	Arsenic	3.10	< 0.050	6010
5.	Barium	93.1	0.139	6010
6.	Boron	3.9	0.163	6010
7.	Cadmium	< 0.585	< 0.050	6010
8.	Chromium	7.54	< 0.050	6010
9.	Copper	5.65	< 0.050	6010
10.	Iron	2,050.	< 0.100	6010
11.	Lead	7.08	< 0.050	6010
12.	Manganese	22.0	< 0.500	6010
13.	Mercury	< 0.05	< 0.001	7471
14.	Molybdenum	0.726	< 0.100	6010
15.	Nickel	3.17	< 0.050	6010
16.	Selenium	< 0.585	< 0.050	6010
17.	Zinc	5.54	0.032	6010
18.	Sulfate	---	88.2	300.0
19.	Chloride	---	< 1.00	300.0
20.	Sodium	---	7.17	6010
21.	Acid Neut. Pot.	740,000.	---	C400-87

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11/25/00

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 11/06/00 (A.M.)
Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.6	---	9045
2.	Aluminum	21,300.	2.56	6010
3.	Antimony	< 0.746	< 0.050	6010
4.	Arsenic	18.2	< 0.050	6010
5.	Barium	199.	0.071	6010
6.	Boron	2.91	0.118	6010
7.	Cadmium	< 0.746	< 0.050	6010
8.	Chromium	18.7	< 0.050	6010
9.	Copper	26.4	< 0.050	6010
10.	Iron	11,500.	< 0.100	6010
11.	Lead	25.2	< 0.050	6010
12.	Manganese	64.3	< 0.500	6010
13.	Mercury	0.834	< 0.001	7470
14.	Molybdenum	3.18	< 0.100	6010
15.	Nickel	10.4	< 0.050	6010
16.	Selenium	8.45	< 0.050	6010
17.	Zinc	17.5	0.032	6010
18.	Sulfate	---	321.	9038
19.	Chloride	---	2.	9250
20.	Sodium	---	9.87	6010
21.	Acid Neut. Pot.	810,000.	---	C400-87

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11/25/00

JIM WETZEL
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P.O. BOX 7
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Sample Location: BOTTOM ASH
Sample Date/Time: 11/06/00 (A.M.)
Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.2	---	9045
2.	Aluminum	11,100.	2.95	6010
3.	Antimony	< 0.568	< 0.050	6010
4.	Arsenic	3.11	< 0.050	6010
5.	Barium	106.	0.117	6010
6.	Boron	1.18	0.087	6010
7.	Cadmium	< 0.568	< 0.050	6010
8.	Chromium	7.45	< 0.050	6010
9.	Copper	7.32	< 0.050	6010
10.	Iron	5,940.	< 0.100	6010
11.	Lead	9.92	< 0.050	6010
12.	Manganese	23.5	< 0.500	6010
13.	Mercury	< 0.455	< 0.001	7470
14.	Molybdenum	0.841	< 0.100	6010
15.	Nickel	5.23	< 0.050	6010
16.	Selenium	< 0.568	< 0.050	6010
17.	Zinc	8.68	0.037	6010
18.	Sulfate	---	97.	9038
19.	Chloride	---	< 1.	9250
20.	Sodium	---	6.74	6010
21.	Acid Neut. Pot.	1,280,000.	---	C400-87

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06/11/01

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 05/01/01 (----) Sampled By: J.W.

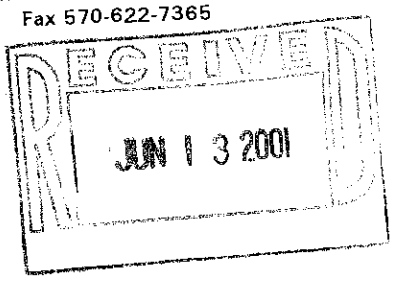
MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.5	---	9045
2.	Aluminum	52,400.	1.34	6010
3.	Antimony	< 0.7	< 0.050	6010
4.	Arsenic	23.4	< 0.050	6010
5.	Barium	411.	0.110	6010
6.	Boron	14.9	0.173	6010
7.	Cadmium	< 0.7	< 0.050	6010
8.	Chromium	48.6	< 0.050	6010
9.	Copper	49.3	< 0.050	6010
10.	Iron	17,500.	< 0.100	6010
11.	Lead	31.4	< 0.050	6010
12.	Manganese	259.	< 0.500	6010
13.	Mercury	0.787	< 0.001	7471
14.	Molybdenum	4.34	< 0.100	6010
15.	Nickel	19.1	< 0.050	6010
16.	Selenium	13.9	< 0.050	6010
17.	Zinc	38.4	0.026	6010
18.	Sulfate	---	355.	300.0
19.	Chloride	---	3.	300.0
20.	Sodium	---	9.99	6010
21.	Acid Neut. Pot.	720,000.	---	C400-87

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06/11/01

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 05/01/01 (----)
Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.5	---	9045
2.	Aluminum	28,700.	5.43	6010
3.	Antimony	< 0.6	< 0.050	6010
4.	Arsenic	2.59	< 0.050	6010
5.	Barium	208.	0.138	6010
6.	Boron	4.47	0.105	6010
7.	Cadmium	< 0.6	< 0.050	6010
8.	Chromium	20.9	< 0.050	6010
9.	Copper	11.1	< 0.050	6010
10.	Iron	8,100.	< 0.100	6010
11.	Lead	4.57	< 0.050	6010
12.	Manganese	66.6	< 0.500	6010
13.	Mercury	< 0.0447	< 0.001	7471
14.	Molybdenum	0.884	< 0.100	6010
15.	Nickel	7.42	< 0.050	6010
16.	Selenium	< 0.559	< 0.050	6010
17.	Zinc	10.9	0.023	6010
18.	Sulfate	---	71.	300.0
19.	Chloride	---	< 1.	300.0
20.	Sodium	---	5.78	6010
21.	Acid Neut. Pot.	1,230,000.	---	C400-87

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10/22/01

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 10/01/01 (----)
Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.4	---	9045
2.	Aluminum	29600.	2.04	6010
3.	Antimony	< 0.740	< 0.050	6010
4.	Arsenic	22.9	< 0.050	6010
5.	Barium	266.	0.083	6010
6.	Boron	2.97	0.102	6010
7.	Cadmium	< 0.740	< 0.050	6010
8.	Chromium	32.0	< 0.050	6010
9.	Copper	41.3	< 0.050	6010
10.	Iron	14500.	< 0.100	6010
11.	Lead	32.7	< 0.050	6010
12.	Manganese	69.5	< 0.500	6010
13.	Mercury	0.809	< 0.001	7471
14.	Molybdenum	3.92	< 0.100	6010
15.	Nickel	15.1	< 0.050	6010
16.	Selenium	10.3	< 0.050	6010
17.	Zinc	24.6	< 0.020	6010
18.	Sulfate	---	297.	9038
19.	Chloride	---	3.	9250
20.	Sodium	---	7.46	6010
21.	Acid Neut. Pot.	2,440,000.	---	C400-87

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10/22/01

JIM WETZEL
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P.O. BOX 7
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Sample Location: BOTTOM ASH
Sample Date/Time: 10/01/01 (----) Sampled By: J.W.

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.4	---	9045
2.	Aluminum	14200.	4.10	6010
3.	Antimony	< 0.564	< 0.050	6010
4.	Arsenic	2.64	< 0.050	6010
5.	Barium	166.	0.112	6010
6.	Boron	1.82	0.088	6010
7.	Cadmium	< 0.564	< 0.050	6010
8.	Chromium	11.1	< 0.050	6010
9.	Copper	10.7	< 0.050	6010
10.	Iron	6090.	< 0.100	6010
11.	Lead	9.75	< 0.050	6010
12.	Manganese	72.3	< 0.500	6010
13.	Mercury	< 0.0451	< 0.001	7471
14.	Molybdenum	0.938	< 0.100	6010
15.	Nickel	4.71	< 0.050	6010
16.	Selenium	< 0.564	< 0.050	6010
17.	Zinc	11.4	< 0.020	6010
18.	Sulfate	---	78.	9038
19.	Chloride	---	< 1.	9250
20.	Sodium	---	5.53	6010
21.	Acid Neut. Pot.	620,000.	---	C400-87

If there are any questions regarding this data, feel free to contact me.

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07/15/02

JIM WETZEL
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P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 06/14/02 (----)
Rec'd Date/Time: 06/20/02 (1245)

Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.90	---	SW9045B
2.	Aluminum	34800.	2.14	SW6010B
3.	Antimony	< 0.736	< 0.050	SW6010B
4.	Arsenic	43.4	< 0.050	SW6010B
5.	Barium	292.	0.647	SW6010B
6.	Boron	5.82	0.939	SW6010B
7.	Cadmium	< 0.736	< 0.050	SW6010B
8.	Chromium	35.0	< 0.050	SW6010B
9.	Copper	49.1	< 0.050	SW6010B
10.	Iron	15200.	0.114	SW6010B
11.	Lead	46.0	< 0.050	SW6010B
12.	Manganese	62.7	< 0.500	SW6010B
13.	Mercury	0.573	< 0.001	SW7471
14.	Molybdenum	< 7.36	< 0.100	SW6010B
15.	Nickel	17.3	< 0.050	SW6010B
16.	Selenium	14.6	< 0.050	SW6010B
17.	Zinc	20.9	1.11	SW6010B
18.	Sulfate	---	436.	E300
19.	Chloride	---	2.52	E300
20.	Sodium	---	14.7	SW6010B
21.	Acid Neut. Pot.	570000.	---	C400

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07/15/02

Sample Location: BOTTOM ASH
Sample Date/Time: 06/14/02 (----)
Rec'd Date/Time: 06/20/02 (1245)

Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	10.80	---	SW9045B
2.	Aluminum	18100.	2.21	SW6010B
3.	Antimony	< 0.627	< 0.050	SW6010B
4.	Arsenic	4.61	< 0.050	SW6010B
5.	Barium	140.	0.551	SW6010B
6.	Boron	2.32	0.727	SW6010B
7.	Cadmium	< 0.627	< 0.050	SW6010B
8.	Chromium	12.5	< 0.050	SW6010B
9.	Copper	10.9	< 0.050	SW6010B
10.	Iron	5780.	< 0.100	SW6010B
11.	Lead	12.9	< 0.050	SW6010B
12.	Manganese	32.5	< 0.500	SW6010B
13.	Mercury	< 0.024	< 0.001	SW7471
14.	Molybdenum	< 6.27	< 0.100	SW6010B
15.	Nickel	5.80	< 0.050	SW6010B
16.	Selenium	< 0.627	< 0.050	SW6010B
17.	Zinc	9.28	0.863	SW6010B
18.	Sulfate	---	231.	E300
19.	Chloride	---	< 1.00	E300
20.	Sodium	---	10.2	SW6010B
21.	Acid Neut. Pot.	3670000.	---	C400

If there are any questions regarding this data, feel free to contact me.

Michael C. Fabian
Laboratory Director

Pottsville Environmental Testing Laboratory, Inc.

164 East Bacon Street
Palo Alto, Pennsylvania 17901

Telephone 570-622-7315
Fax 570-622-7365

11/22/02

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: FLY ASH
Sample Date/Time: 10/31/02 (----)
Rec'd Date/Time: 11/04/02 (1125)

Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.07	---	SW9045B
2.	Aluminum	37900.	3.13	SW6010B
3.	Antimony	< 0.606	< 0.050	SW6010B
4.	Arsenic	45.4	< 0.050	SW6010B
5.	Barium	286.	0.096	SW6010B
6.	Boron	6.79	0.108	SW6010B
7.	Cadmium	< 0.606	< 0.050	SW6010B
8.	Chromium	35.8	< 0.050	SW6010B
9.	Copper	53.6	< 0.050	SW6010B
10.	Iron	13000.	< 0.100	SW6010B
11.	Lead	50.8	< 0.050	SW6010B
12.	Manganese	63.1	< 0.500	SW6010B
13.	Mercury	0.310	< 0.001	SW7471
14.	Molybdenum	< 6.06	< 0.100	SW6010B
15.	Nickel	20.4	< 0.050	SW6010B
16.	Selenium	18.0	< 0.050	SW6010B
17.	Zinc	36.4	0.022	SW6010B
18.	Sulfate	---	118.	E300
19.	Chloride	---	1.14	E300
20.	Sodium	---	12.7	SW6010B
21.	Acid Neut. Pot.	1710000.	---	C400

If there are any questions regarding this data, feel free to contact me.

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11/22/02

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

Sample Location: BOTTOM ASH
Sample Date/Time: 10/31/02 (----)
Rec'd Date/Time: 11/04/02 (1125)

Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.85	---	SW9045B
2.	Aluminum	18000.	0.620	SW6010B
3.	Antimony	< 0.548	< 0.050	SW6010B
4.	Arsenic	6.73	< 0.050	SW6010B
5.	Barium	149.	0.179	SW6010B
6.	Boron	2.37	0.100	SW6010B
7.	Cadmium	< 0.548	< 0.050	SW6010B
8.	Chromium	17.0	< 0.050	SW6010B
9.	Copper	10.5	< 0.050	SW6010B
10.	Iron	8550.	< 0.100	SW6010B
11.	Lead	15.1	< 0.050	SW6010B
12.	Manganese	44.7	< 0.500	SW6010B
13.	Mercury	< 0.022	< 0.001	SW7471
14.	Molybdenum	< 5.48	< 0.100	SW6010B
15.	Nickel	7.89	< 0.050	SW6010B
16.	Selenium	< 0.548	< 0.050	SW6010B
17.	Zinc	17.3	0.035	SW6010B
18.	Sulfate	---	80.8	E300
19.	Chloride	---	< 1.00	E300
20.	Sodium	---	8.85	SW6010B
21.	Acid Neut. Pot.	2480000.	---	C400

If there are any questions regarding this data, feel free to contact me.

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06/30/03

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

COPY

Sample Location: FLY ASH
Sample Date/Time: 06/11/03 (----)
Rec'd Date/Time: 06/12/03 (1305)

Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/1)	ANALYSIS METHOD
1.	pH Solid	10.88	---	SW9045B
2.	Aluminum	39600.	1.19	SW6010B
3.	Antimony	< 0.677	< 0.050	SW6010B
4.	Arsenic	22.4	< 0.050	SW6010B
5.	Barium	288.	0.177	SW6010B
6.	Boron	7.01	0.214	SW6010B
7.	Cadmium	< 0.677	< 0.050	SW6010B
8.	Chromium	34.7	0.085	SW6010B
9.	Copper	37.4	< 0.050	SW6010B
10.	Iron	8960.	< 0.100	SW6010B
11.	Lead	35.6	< 0.050	SW6010B
12.	Manganese	51.1	< 0.500	SW6010B
13.	Mercury	0.623	< 0.001	SW7471
14.	Molybdenum	< 6.77	< 0.100	SW6010B
15.	Nickel	15.4	< 0.050	SW6010B
16.	Selenium	12.7	< 0.050	SW6010B
17.	Zinc	18.7	0.050	SW6010B
18.	Sulfate	---	148.	E300
19.	Chloride	---	2.08	E300
20.	Sodium	---	11.0	SW6010B
21.	Acid Neut. Pot.	494000.	---	C400

If there are any questions regarding this data, feel free to contact me.

Michael C. Fabian
Laboratory Director

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Telephone 570-622-7315
Fax 570-622-7365

06/30/03

JIM WETZEL
% NORTHEASTERN POWER COMPANY
P.O. BOX 7
McADOO, PA 18237

COPY

Sample Location: BOTTOM ASH
Sample Date/Time: 06/11/03 (----)
Rec'd Date/Time: 06/12/03 (1305)
Sampled By: J.W.
Rec'd By: MCF

MODULE 25 - COAL ASH AND LEACHATE ANALYSIS

	PARAMETER	ASH DRY WT. (mg/kg)	SPLP LEACHATE (mg/l)	ANALYSIS METHOD
1.	pH Solid	11.11	---	SW9045B
2.	Aluminum	15100.	1.56	SW6010B
3.	Antimony	< 0.551	< 0.050	SW6010B
4.	Arsenic	2.48	< 0.050	SW6010B
5.	Barium	137.	0.179	SW6010B
6.	Boron	2.37	0.266	SW6010B
7.	Cadmium	< 0.551	< 0.050	SW6010B
8.	Chromium	10.4	< 0.050	SW6010B
9.	Copper	7.54	< 0.050	SW6010B
10.	Iron	4010.	0.136	SW6010B
11.	Lead	9.41	< 0.050	SW6010B
12.	Manganese	25.3	< 0.500	SW6010B
13.	Mercury	< 0.022	< 0.001	SW7471
14.	Molybdenum	< 5.51	< 0.100	SW6010B
15.	Nickel	5.41	< 0.050	SW6010B
16.	Selenium	< 0.551	< 0.050	SW6010B
17.	Zinc	7.10	0.077	SW6010B
18.	Sulfate	---	144.	E300
19.	Chloride	---	< 1.00	E300
20.	Sodium	---	8.93	SW6010B
21.	Acid Neut. Pot.	2470000.	---	C400

If there are any questions regarding this data, feel free to contact me.

Michael C. Fabian
Laboratory Director

HAWKMTN LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

Certificate of Analysis

Customer: Nepco
P.O. Box 7
McAdoo, PA 18237

Report Date: December 10, 2003

Material Tested: Ash
Date Sampled: 10/30/2003
Date Received: 10/30/2003
Client Sample ID: Nepco 50/50 Fly Ash/Bottom Ash, Semi Annual Ash Analysis

HawkMtn WO #: 0310-00604-001
Sampler: JR/HML
Sample Point ID: 50/50

Test Name	Test Results	Method	Technician	Analysis Dat
Module 25A-Ash Quality				
MOD25, Total Analysis				
pH, Solid	9.49 su	SW846-9040	AMM	11/03/2003
Aluminum, Dry Weight	34800 mg/kg	SW846-6010B	SKS	11/11/2003
Antimony, Dry Weight	<2.0 mg/kg	SW846-6010B	SKS	11/11/2003
Arsenic, Dry Weight	11.3 mg/kg	SW846-7060A	SKS	11/12/2003
Barium, Dry Weight	275 mg/kg	SW846-6010B	SKS	11/11/2003
Boron, Dry Weight	49 mg/kg	SW846-6010B	SKS	11/11/2003
Cadmium, Dry Weight	1.0 mg/kg	SW846-6010B	SKS	11/11/2003
Calcium, Dry Weight	12700 mg/kg	SW846 6010B	SKS	11/11/2003
Chromium, Dry Weight	39 mg/kg	SW846-6010B	SKS	11/11/2003
Copper, Dry Weight	36 mg/kg	SW846-6010B	SKS	11/11/2003
Iron, Dry Weight	19100 mg/kg	SW846-6010B	SKS	11/11/2003
Lead, Dry Weight	66 mg/kg	SW846-6010B	SKS	11/11/2003
Manganese, Dry Weight	69 mg/kg	SW846-6010B	SKS	11/11/2003
Mercury, Dry Weight	0.2 mg/kg	SW846-7471A	AMM	11/20/2003
Molybdenum, Dry Weight	<1.00 mg/kg	SW846-6010B	SKS	11/11/2003
Nickel, Dry Weight	18 mg/kg	SW846-6010B	SKS	11/11/2003
Selenium, Dry Weight	8.5 mg/kg	SW846 7740	SKS	11/12/2003
Zinc, Dry Weight	34 mg/kg	SW846-6010B	SKS	11/11/2003
Acid Neutralization Potent	55 **	EPA 600/2-78-054	AMM	11/07/2003
MOD25, SPLP Leachate				
SPLP Fluid #1, pkg			SKS	11/04/2003
SPLP, fluid #1	10.60 su, ending	SW846-1312	SKS	11/04/2003
Aluminum, leachate	4.24 mg/l	SW846-6010B	SKS	11/18/2003
Arsenic, Leachate	0.013 mg/l	SW846-7060A	SKS	11/14/2003
Antimony, Leachate, Furnace	<0.04 mg/l	SW846-6010B	SKS	11/17/2003
Barium, Leachate	0.03 mg/l	SW846-6010B	SKS	11/17/2003
Boron, Leachate	0.05 mg/l	SW846-6010B	SKS	11/18/2003
Cadmium, Leachate	<0.005 mg/l	SW846-6010B	SKS	11/17/2003
Chromium, Leachate	0.01 mg/l	SW846-6010B	SKS	11/17/2003
Copper, Leachate	0.01 mg/l	SW846-6010B	SKS	11/17/2003
Iron, Leachate	0.05 mg/l	SW846-6010B	SKS	11/17/2003
Lead, Leachate	0.05 mg/l	SW846-6010B	SKS	11/17/2003
Manganese, Leachate	<0.005 mg/l	SW846-6010B	SKS	11/17/2003
Mercury, Leachate	<0.0002 mg/l	SW846-7470A	AMM	11/06/2003

ISO 9001:2000
REGISTERED COMPANY

HAWKMTN LABS INC
201 West Clay Avenue / West Hazleton, PA 18202
PHONE (570) 455-6011 • FAX (570) 455-6321

Customer: Nepco
P.O. Box 7
McAdoo, PA 18237

Report Date: December 10, 2003

Material Tested: Ash
Date Sampled: 10/30/2003
Date Received: 10/30/2003
Client Sample ID: Nepco 50/50 Fly Ash/Bottom Ash. Semi Annual Ash Analysis

HawkMtn WO #: 0310-00604-001
Sampler: JR/HML
Sample Point ID: 50/50

Test Name	Test Results	Method	Technician	Analysis Date
Molybdenum, Leachate	<0.005 mg/l	SW846-6010B	SKS	11/17/2003
Nickel, Leachate	<0.010 mg/l	SW846-6010B	SKS	11/17/2003
Selenium, Leachate	0.010 mg/l	SW846-7740	SKS	11/14/2003
Zinc, Leachate	0.01 mg/l	SW846-6010B	SKS	11/17/2003
SPLP Fluid #3, Water	10.70 su, ending	SW846-1312	SKS	11/05/2003
Sodium, Leachate	1.80 mg/l	SW846-6010B	SKS	11/18/2003
Anions, Scan, Leachate			AL	11/05/2003
Fluoride	0.73 mg/l	EPA 300 HPLC IC	AL	11/05/2003
Chloride, Leachate	1.86 mg/l	EPA 300 HPLC IC	AL	11/05/2003
Nitrite, Leachate	<0.02 mg/l	EPA 300 HPLC IC	AL	11/05/2003
Nitrate, Leachate	0.36 mg/l	EPA 300 HPLC IC	AL	11/05/2003
Sulfate, Leachate	289 mg/l	EPA 300 HPLC IC	AL	11/05/2003
Proctor Density			WS	11/05/2003
Optimum Water Content	20.00 %		WS	11/05/2003
Max Dry Density	91.90 lb/cu.ft.		WS	11/05/2003
Density 90% Dry	82.71 lb/cu.ft.		WS	11/05/2003
0.375 in, 9.5mm P	99.2 %	ASTM D 310, ASTM	WS	11/05/2003
No.4, 4 mesh, 4.75mm, P	95.7 %	ASTM D 310, ASTM	WS	11/05/2003
No.10, 9 mesh, 2.00mm, P	83.8 %	ASTM D 310, ASTM	WS	11/05/2003
No.40, 35 mesh, 425mm, P	50.5 %	ASTM D 310, ASTM	WS	11/05/2003
No.100, 100 mesh, 150um, P	22.5 %	ASTM D 310, ASTM	WS	11/05/2003
No.200, 200 mesh, 75um P	9.8 %	ASTM D 310, ASTM	WS	11/05/2003

Andrea Mengel, Enviro Lab Coordinator

Jeff Gittleman, Lab Director

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF MINING AND RECLAMATION

COAL ASH QUALITY ASSESSMENT FOR BENEFICIAL USE

DEP USE ONLY
Date Received

COAL ASH GENERATOR AND FACILITY INFORMATION

1. Name of Coal Ash Generator (Facility) _____
2. Identification/SMP No. _____ 3. Contact Person _____ 4. Phone No. _____
5. Beneficial Use(s): ☐ Placement (Reclamation) ☐ Soil additive/amendment ☐ Alkaline addition
   ☐ Low-permeability material ☐ Other _____
6. Sampling location and description of sample (combined, etc.):
7. Sample Collection Date(s): _____
8. Submission type: ☐ New source request ☐ Biannual Sampling results ☐ Other

COAL ASH AND LEACHATE ANALYSES

9. **Ash solid and leachate results** – Complete the attached table for all constituents and the additional measurements, as applicable. For non-detect values, enter detection limit and '<' symbol. Attached ☐

LABORATORY REPORTS AND AFFIDAVIT

10. **Documentation** - Attach copies of lab reports. Lab reports must contain the test method used or attach separate sheet with details. All numbers and letters on the report must be readable. Attached ☐

Analytical Laboratory Name, Address

Analyst(s) Name

Phone No.

I, _____, certify under penalty of law that I have personally examined and am familiar with the information submitted under Coal Ash Generator Information, Coal Ash and Leachate Analyses and the attached analytical results, and that based upon my inquiry of those individuals immediately responsible for obtaining the information. I believe the submitted information is true and correct to the best of my knowledge and belief. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

_____ Day of _____ (month) _____ (year)

_____
Signature of Responsible Official

_____
Name (Typed)

_____
Address

_____

_____
Title

DRAFT

CHEMICAL AND PHYSICAL PROPERTIES OF ASH

Submit one sheet for each source and sample/composite date. Corresponding lab documentation must be attached.

CA #	Source Name
Date(s) Sampled	Date Analyzed

Constituent	Dry Wt. mg/kg or ppm	SPLP Leachate mg/l	Certification Limit	Constituent	Dry Wt. mg/kg or ppm	SPLP Leachate mg/l	Certification Limit
pH, solid	□		7 or greater	Nickel (Ni)			2.5 mg/l
Aluminum (Al)	□	□	5.0 mg/l	Potassium (K)			N/A
Antimony (Sb)	□	□	0.15 mg/l	Selenium (Se)			1.0 mg/l
Arsenic (As)	□	□	0.25 mg/l	Silver (Ag)			2.5 mg/l
Barium (B)	□	□	50.0 mg/l	Thallium (Tl)			0.05 mg/l
Beryllium (Be)	□	□	0.10 mg/l	Vanadium (V)			6.5 mg/l
Boron (B)	□	□	15.0 mg/l	Zinc (Zn)			50.0 mg/l
Cadmium (Cd)	□	□	0.125 mg/l	Sulfur (S)			N/A
Calcium (Ca)	□	□	N/A	Sulfate (SO_4)			2500 mg/l
Chromium (Cr)	□	□	2.5 mg/l	Chloride (Cl)			2500 mg/l
Cobalt (Co)	□	□	17.5 mg/l	Sodium (Na)			N/A
Copper (Cu)	□	□	25.0 mg/l	Nitrate (NO_3)			10 mg/l
Iron (Fe)	□	□	7.5 mg/l	Nitrite (NO_2)			1 mg/l
Lead (Pb)	□	□	0.375 mg/l	Ammonia (NH_3)			30 mg/l
Magnesium (Mg)	□	□	N/A				
Manganese (Mn)	□	□	2.5 mg/l				
Mercury (Hg)	□	□	0.05 mg/l				
Molybdenum (Mo)	□	□	4.375 mg/l				

Acid Neutralizing Potential

If use is liming agent for a soil substitute or additive, or as alkaline addition, submit one of the following calcium carbonate equivalency measurements.

$CaCO_3$ equivalent	□	In tons of CaCO3 per 1,000 tons of ash	100 or greater
% $CaCO_3$ Dry Wt.	□	By percentage	10% or greater

Permeability

If use is low-permeability material, submit a hydraulic conductivity measurement.

Hydraulic conductivity		In cm/sec	1.0 x 10^{-6} cm/sec or lower

Nitrogen Content

If use is for soil substitute or additive, submit leachate analysis for Total Kjeldahl Nitrogen (TKN) and Ammonia-Nitrogen (NH3-N). Use Standard Method 4500.

TKL		In mg/l
NH_3-N		In mg/l

DRAFT

ASH VOLUME REPORTING

YEAR _____

PERMIT NO. _____

COMPANY NAME _____

PF NAME/OPERATION _____

TYPE OF BENEFICIAL USE (Check all that apply)

- ☐ **PLACEMENT/BACKFILL**
- ☐ **SOIL SUBSTITUTE**
- ☐ **ALKALINE ADDITION**
- ☐ **LOW PERMEABILITY MATERIAL**

Source of ash	Volume (cu yds.)	Amount (tons)	Check if mixed with spoil (provide ratio)	Check if FBC ash
			☐	☐
			☐	☐
			☐	☐
			☐	☐
			☐	☐
			☐	☐
			☐	☐

Coal Ash Beneficial Use website:
http://www.dep.state.pa.us/dep/deputate/minres/bmr/programs/beneficial.htm

Water Quality at the BD Mining Company Ash Placement Site, Schuylkill County, PA

Keith Brady, P.G. and Sharon Hill, P.G.

April 14, 2009

Introduction

At a meeting on November 13, 2008, a concerned party[1] presented the Department with a graph showing occasional spikes in lead and what was perceived to be an upward trend in lead at the Gilberton mine shaft (Figure 1). The mine shaft is the down-gradient monitoring point for the BD Mining ash placement area. It was insinuated to the Department that these spikes and the "trend" indicated pollution that, by his reasoning, was due to ash placement. This Department investigation considers multiple chemical parameters in the BD Mining monitoring data through time and compares the down-gradient monitoring point concentrations to the other monitoring points. We also examine the bulk-chemistry and leaching concentrations for lead in the ash being placed at BD Mining.

The BD Mining site is in Schuylkill County and is permitted for 175 acres to be reclaimed using ash. Ash placement began in 1989. As of the end of 2008 over 5 million cubic yards of ash have been placed at the mine.

The BD Mining site must be evaluated in context. It is located in the Western Middle Field of the Anthracite Region, and more specifically, within the Mahanoy Basin, a narrow synclinal basin that has been deep mined from stem to stern. The deep mining took place from about 1840 to the 1950s. Mining in the Mahanoy Basin and adjacent Shenandoah complex removed an estimated 1.6 billion tons of anthracite during this time period (Reed et al., 1987).[2] The waste rock and unmarketable coal from these mines was deposited on the surface. Virtually the entire valley bottom of the synclinal basin is covered by coal waste (Figure 2). In addition to disturbance from waste coal, surface mining occurred where coal approached the surface. These activities took place before modern environmental laws that would prohibit such devastation. Any analysis of areas involving abandoned mine lands must take into consideration that baseline water quality is severely impacted by "pre-law" mining. This is quite evident at the BD Mining site, where monitoring data from before ash placement shows elevated constituents well above what would be expected in a location that had not been impacted by human activities (Table 1). Two examples are given from early in the data collection period and two more recent samples. Extensive documentation of the impacts to groundwater, surface water, and impacts on aquatic communities by past mining practices within the Mahanoy Basin are provided in Cravotta (2005). Additional background on the BD Mining site can be found in Hornberger et al. (2004).

[1] Jeff Stant

[2] As a comparison, Pennsylvania currently produces a total of about 70 million tons of coal per year. Anthracite production in 2007 was 210 thousand tons by deep mining and 2.3 million tons by surface mining. Whereas, nearly six million tons of anthracite waste coal was mined during 2007.

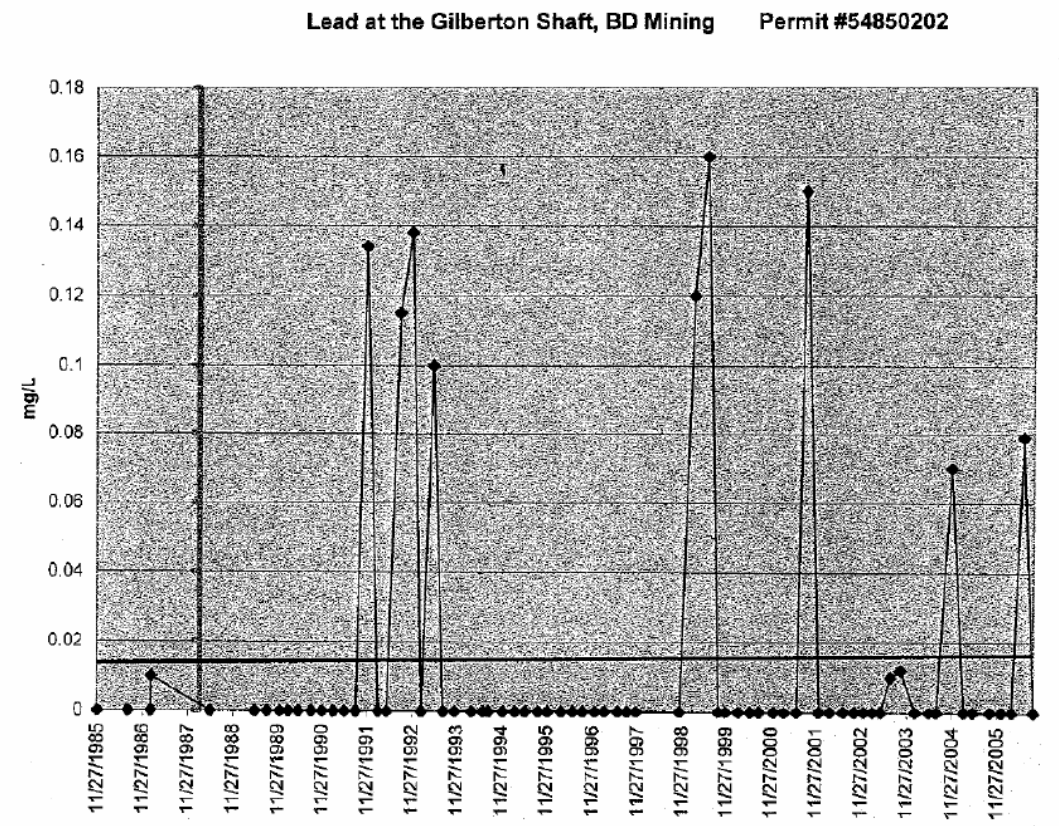


Figure 1. Plot through time of lead concentrations at the down-gradient Gilberton Shaft as presented to the Department on November 13, 2008. This graph is deceptive in that some of the detection limits are as high as 0.1 mg/L, with many more at 0.05 mg/L. No detection limit is zero, as depicted. Thus, the graph exaggerates the contrast between non-detects and detectable concentrations. See Figure 8 for a more valid presentation of data.

Table 1. Representative water quality from the Gilberton Shaft monitoring point. The 1986 data are from before ash placement. Numbers in parentheses are the recommended secondary drinking water standards in milligrams per liter. TDS is total dissolved solids.

Date Sampled	pH	Acidity mg/L	Iron (0.3) mg/L	Mn (0.05) mg/L	Sulfate (250) mg/L	TDS mg/L
07/24/86	6.29	164	54.0	10.70	672	1041
08/26/86	6.29	163	14.0	9.70	644	1250
05/02/08	6.11	4	35.3	6.46	496	770
07/15/08	5.84	<1	35.4	6.99	591	766



Figure 2. The area pictured is just to the north of BD Mining. Everything in this picture, with the exception of the hill in the distance (and to some extent, it too) is abandoned mine lands. Most of the material that can be seen is waste coal. This waste coal is being used to fuel local fluidized bed combustion power plants. The building in the upper right is the abandoned St. Nicholas coal breaker.

Figure 3 is a portion of the USGS topographic map for the Shenandoah Quadrangle. The purple stipple pattern is abandoned mine lands, which includes surface mines, waste coal features and other mining related disturbances. Satellite imagery also shows the environmental devastation from historical mining in the vicinity of BD Mining (Figure 4). This degree of abandoned mine disturbance is not uncommon in the Anthracite Region. Most of the material covering the surface of the Mahanoy Basin and the basins to the north is coal waste. Much of this waste still has BTU value and is being mined to fire Fluidized Bed Combustion power plants that were located nearby to take advantage of this resource. The waste coal has high BTU content because in the past only coal without rock would be burned and fine coal was not considered a resource. Many of the most valuable waste coal deposits are areas where coal slurry was placed. This slurry is often nearly 100% anthracite coal. Coal waste is a nasty source of mine drainage pollutants. Its removal and eventual reclamation of the land has positive impacts on the water quality of the underlying mine pool. There are plenty of other potential sources of pollution in the basin as well. Immediately north of the BD Mining site is a large rail yard. Figure 5 shows a portion of the BD Mining coal ash placement area, with the rail yard in the foreground.

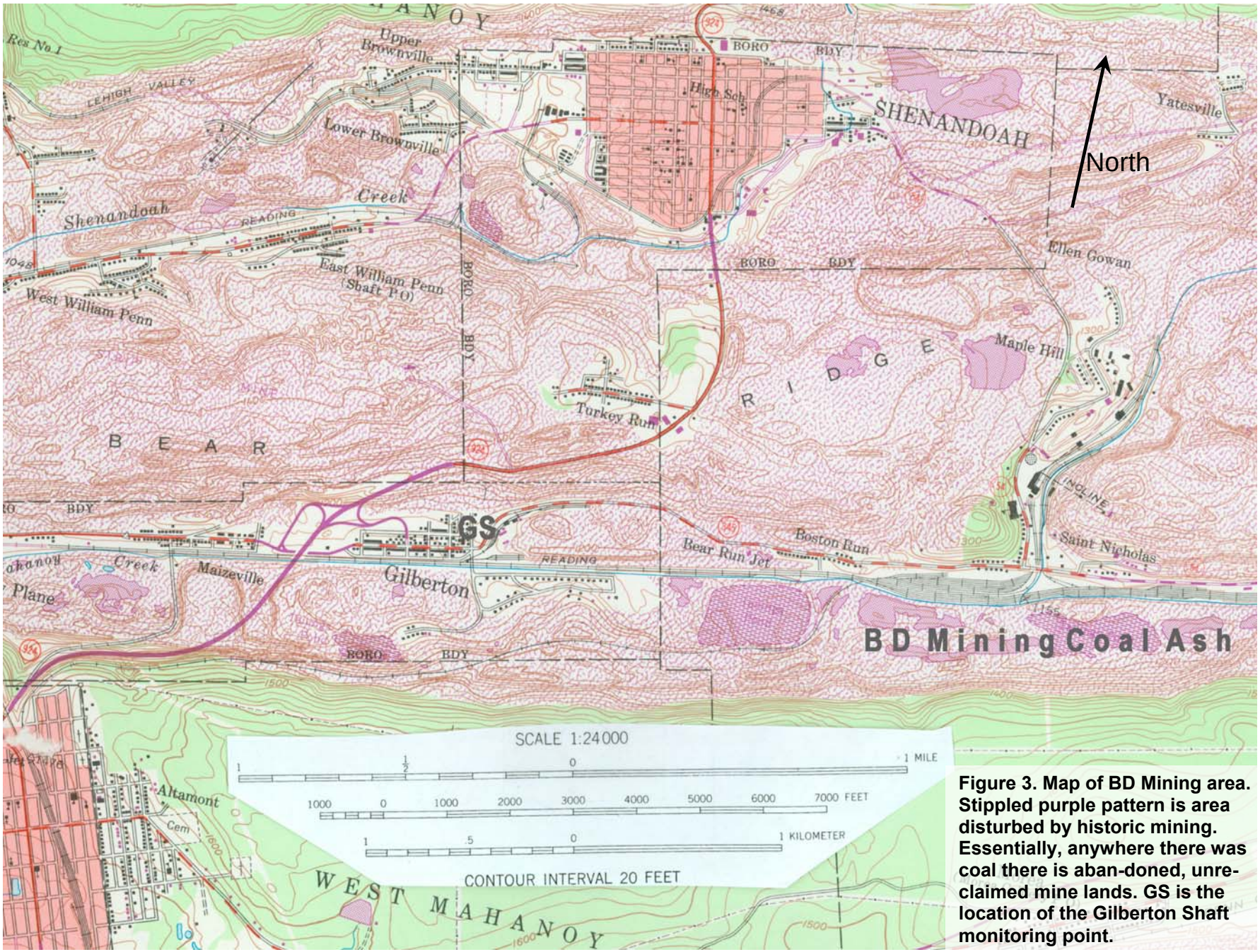


Figure 3. Map of BD Mining area. Stippled purple pattern is area disturbed by historic mining. Essentially, anywhere there was coal there is aban-doned, unre-claimed mine lands. GS is the location of the Gilberton Shaft monitoring point.



Figure 4. BD Mining area. AML indicates some of the abandoned mine features. The Coal Waste from the area just north of BD Mining is going to the Schuylkill Energy site and the ash is being placed at the Ellengowan site. BD Mining's ash is coming from the Gilberton power plant, which is south of the area shown. The revegetated (green) areas are the reclaimed areas where ash was placed. (Image from MSN Live Search Maps)



Figure 5. The BD Mining coal ash placement site is the brown and reddish hill in the mid-distance. The brownish portion is covered with soil and in the process of being revegetated. The reddish material is coal ash that is actively being emplaced. In the foreground is a rail yard. The black material between the train cars and the mine site is abandoned mine material.

Mine Pool Hydrology and the Gilberton Shaft

The Mahanoy Basin is part of the Anthracite Western Middle Field. It is 25-miles long and about 5 miles wide, and runs in an east-west direction. The Mahanoy basin is separated from the rest of the Western Middle Field by the Suffolk Fault (Figures 6 and 7). The extensive deep and surface mining has dramatically altered the surface and groundwater hydrology of the region. Separate mines are hydrologically connected by shafts and tunnels and breached barrier pillars. Unregulated mining deranged the surface topography, and thus surface drainage, such that surface water is often directly conveyed to the deep mine pools. In general groundwater flow is from east to west, although on a local scale water can flow in almost any direction depending on the orientation of mined out rooms and location of tunnels and barrier pillars (Reed, 1987).

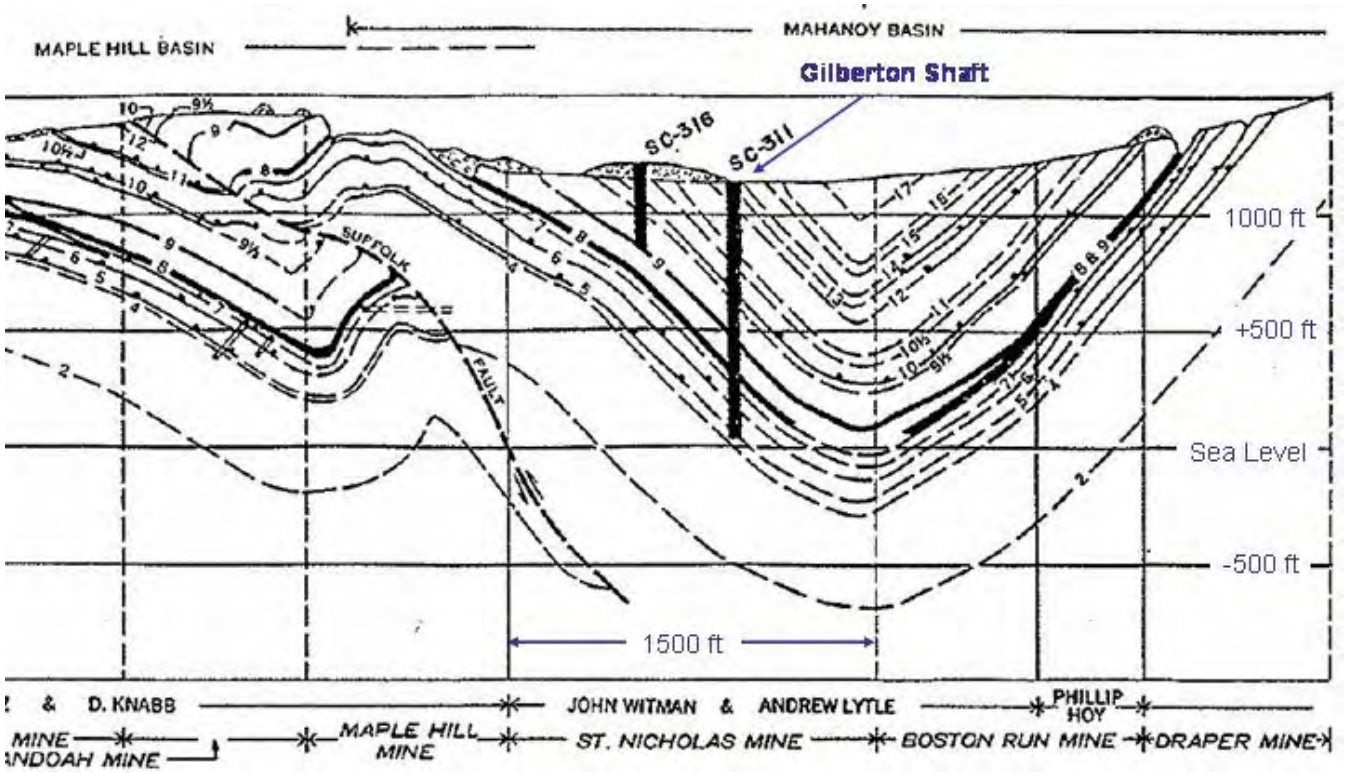


Figure 6. Cross section showing the Mahanoy Basin in the vicinity of the Gilberton Shaft. Location of cross-section is shown in Figure 7. Location and stratigraphic position of the shaft are shown on the cross section. Coal seams are in black and have numbers identifying the seam. There is no vertical exaggeration. Figure is modified from Reed et al., 1987.

The Gilberton Shaft (Figures 6 and 7) is the downgradient monitoring point for the BD Mining site. The shaft is nearly 1100 feet deep and bottoms at an elevation of 66 feet above sea level. Originally the Bureau of Abandoned Mine Reclamation (BAMR) installed a pump to keep the basements at a half-dozen homes in Gilberton from flooding. When the mine pool is higher than 1118 ft above sea level the basements flood. The BAMR pump is set at around 50 feet below the surface and is thus pumping the shallow portion of the mine pool. From 2005 to 2008 the BAMR pump removed an average of 2.8 billion gallons of water per year. In addition to the BAMR pump the shaft has four other pumps. Two were installed by the Gilber-

ton power plant, one by the Gilberton coal breaker, and one by the local fire company. The amount of water that is removed by these is unknown.[3] Pumping is done on an as needed basis and is not continuous by any of the water users.

The portion of the mine pool that is pumped by Gilberton is largely isolated from some other portions of the Mahanoy Basin by Barrier Pillars I and XVII shown on Figure 7. The integrity of the barrier pillars between pillars I and XVII is believed to be compromised.[4] Evidence of the integrity of Barrier Pillar I is the presence of several discharges just upgradient from the pillar. One of these discharges, the Vulcan-Buck Mountain borehole, averaged 3400 gpm from April 1975 to March 1976. Large discharges indicate that water has difficulty flowing past the pillar and thus discharges to the surface. The flooding of basements in Gilberton suggests that Barrier Pillar XVII is also intact and backing up water that would otherwise continue to flow west.

The pumped nature of the Gilberton Shaft results in water being pulled from the upgradient portions of the mine pool and drawn toward the Gilberton shaft. The BD Mining ash placement site is within the recharge area for the water being withdrawn at the Gilberton Shaft.

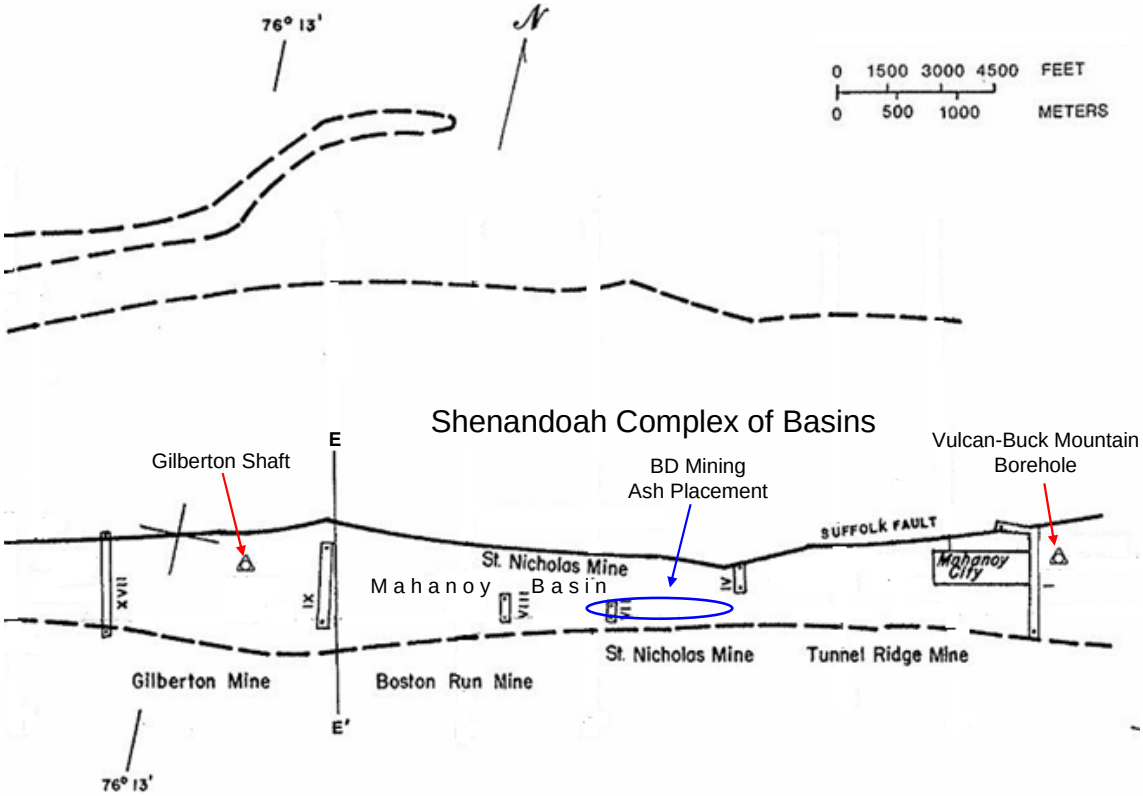


Figure 7. Schematic map showing relative locations of BD Mining ash placement area, location of Gilberton Shaft and location of barrier pillars. Barrier pillars are the bars with dotted ends that are identified by Roman numeral. Barrier pillars I and XVII are shown as intact in Kehn and Wagner (1955) and Danilchik et al. (1955). Barrier pillars IV, VII, VIII and IX are of very questionable integrity. Line E-E' indicates the location of the cross section shown in Figure 6. Figure modified from Reed et al., 1987.

[3] Personal communication with and data supplied by Jack Buckwalter, Bureau of Abandoned Mine Reclamation, April 7 and 8, 2009.

[4] For example, they are not continuous across the basin. Also their locations are shown differently depending on which map one consults. The depictions on Danilchik et al. (1955) and Kehn and Wagner (1955) are different from those shown in Reed (1987).

Lead Concentrations in Groundwater

Figure 8 shows lead concentrations at the Gilberton Shaft and at two other monitoring points. The Gilberton Shaft data are the same as those used by the concerned party. The data are from Department files and are accessible by anyone in the general public.

From the beginning of data collection in 1986, through 1998, the lead values were reported as '0' reflecting a "non-detection" (or below an unspecified detection limit) of lead in the water sample. This indicates a low concentration, but not '0'. From 1998 forward data less than the detection limit were reported as the detection limit value. From 1999-2001, the lab detection limit was 0.10 mg/l, after that, at various times, it was 0.05, 0.03, 0.01 and for current samples (2008) it is 0.002 mg/l. A trend line generated through these data shows an apparent increase in lead. However, the trend line is derived primarily from the detection limit values, not the actual measured values.

The lead concentrations at the Gilberton Shaft (i.e., mine pool) were compared with values at the other monitoring points. In Figure 8, it is clear that post 1998, when the mine pool lead values (shown in red) were high, the other monitoring point(s) (blue and green) were equal to or in excess of the down-gradient value.

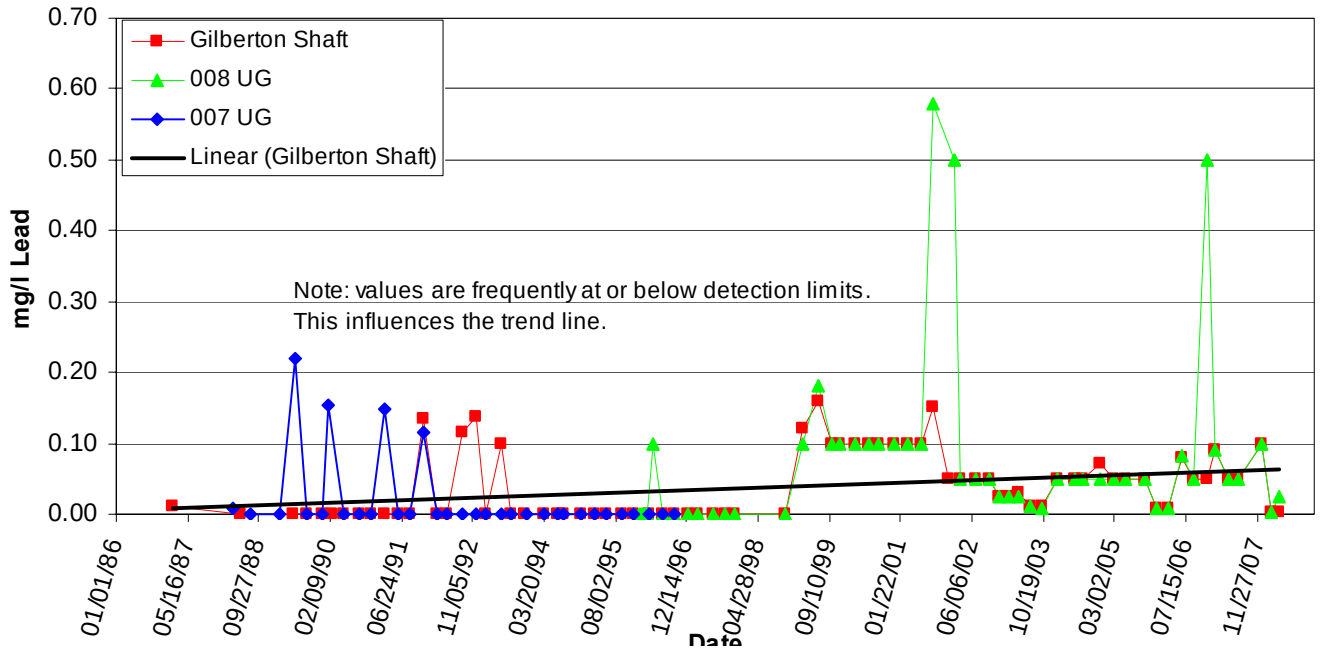


Figure 8. Plot through time of lead concentrations at the monitoring wells and Gilberton Shaft monitoring points. "Plateaus" of values, where all measurements are the same concentration (such as from 09/10/99 to 01/22/01), indicate detection limits. The trendline is through the down-gradient Gilberton shaft data. The trendline represents nonsense since it is primarily a derivative of varying non-detect and "less than" values, which have been reported differently through time.

Total suspended solids (TSS) were examined to see if that variable had an influence on the lead concentration, since it is known that suspended solids can influence lead concentrations (Cravotta, 2005). Sample preservation, which includes acidification of the sample to keep metals in solution, can dissolve metals from suspended particles and rocks. The metal released

from these particles would not normally be released to the groundwater since they would remain with the particle. When this occurs the metals can appear higher than what would actually be in the groundwater.[5] Lead and suspended solids are both plotted on Figure 9, with TSS as the dotted line corresponding to the same color for the appropriate monitoring point. This comparison shows basically no relationship between TSS and lead.

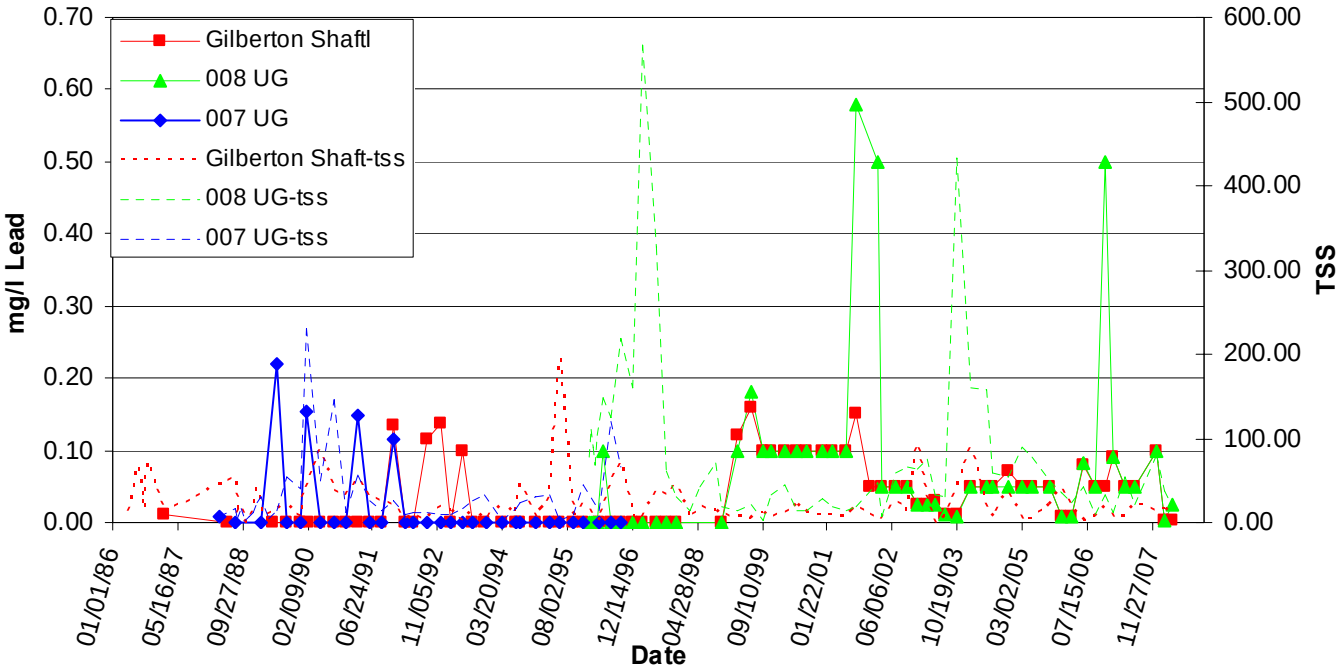


Figure 9. Comparison of lead and total suspended solids (TSS) through time. Lead concentrations are shown by symbols and solids lines connecting the symbols. Suspended solids are shown by a dashed line. Dashed and solid lines of the same color represent the same sample point.

Figure 10 is a boxplot comparing the monitoring wells and down-gradient lead analyses. The similarity of the two boxes shows that the distribution of lead concentrations is essentially the same at the two types of monitoring points. The medians are essentially meaningless numbers because of the large number of non-detects or below-detection analyses, since more than half the values were below detection. The upper quartiles (75% of the data falls below this value, which is represented by the top of the box) are 0.065 mg/L for down-gradient and 0.066 up-gradient, that is, essentially identical. The monitoring well water has some outlier values represented by asterisks.[6]

[5] Acid is added to "fix" samples for laboratory analysis by achieving a pH below 2.0. This keeps metals in solution and prevents them from precipitating onto the sample container. However, the low pH can also dissolve metals from particulate matter and release them into the water sample. These particulate-bound metals in most instances would not have been mobile under field conditions. DEP is implementing sampling protocols that will reduce the occurrence of this issue, including field filtering of samples and purging of wells before sampling.

[6] Outliers are values greater than 1.5 times the interquartile range beyond the 75th percentile (upper boundary of box).

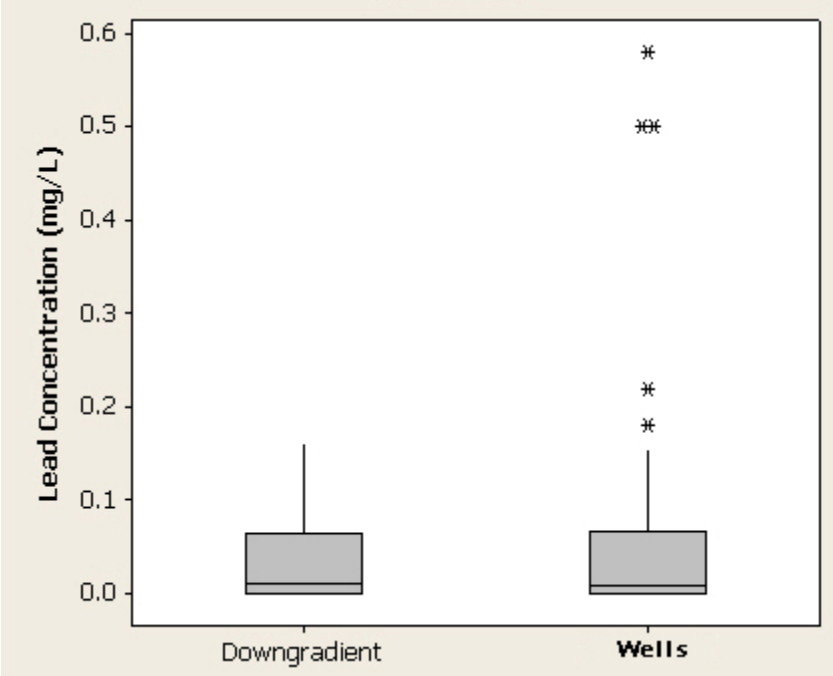


Figure 10. Comparison of lead concentrations at monitoring wells and down-gradient (Gilberton Shaft) monitoring points. The two populations are essentially identical.

In examining Figures 8, 9 and 10, the following is clear: (a) The monitoring wells also show occasional spikes in lead, often coincident with the increases at the Gilberton Shaft monitoring point. Spikes at the wells often show higher concentrations than at the down-gradient point. (b) Spikes in lead do not correlate with spikes in suspended solids. (c) There is no meaningful trend through time for lead at the Gilberton Shaft.

Lead Concentrations in the Ash

The same concerned party that presented us with Figure 1 mentioned to the first author on July 17, 2008 that during the Clean Air Task Force study of Pennsylvania coal ash they had observed elevated lead concentrations for leachate for the Schuylkill Energy and Gilberton coal ashes. Gilberton ash goes to the BD Mining site. Schuylkill Energy ash does not go to the BD Mining site, but the source is similar to that for Gilberton (both use waste coal from the area around BD Mining) so an examination of both sources is worthwhile. The data were evaluated and are shown in Figures 11 and 12. In both cases the higher values were during the early period of sampling and recent values are well under the leaching limits.

DEP requires two types of chemical analyses for evaluation of the suitability of coal ash for beneficial use: bulk chemical analysis and leaching data. Bulk chemistry provides the total amount of an element that is present in the ash. The fact that something is present in the bulk analysis does not mean that it is mobile. Therefore leaching is required to determine the elements that could leach into the groundwater. Both types of data are evaluated in the discussion below.

Schuylkill Energy Plant: The Schuylkill Energy ash, showed some higher concentrations of lead during the first year of data collection (1990) (Figure 11). These samples are not part of the fly ash/bottom ash mixture that has been routinely placed at the site, but were "bottom ash" (apparently alone) and "conditioned fly ash" (whatever that may be). In any event, no values higher than the (new) leaching limit of 0.375 mg/L have been observed after 1990. It should be pointed out that the acceptable leaching threshold in 1990 would have been 1.25 mg/L and the highest values are well under that level. All recent measurements for lead (since 2000) have been below detection.

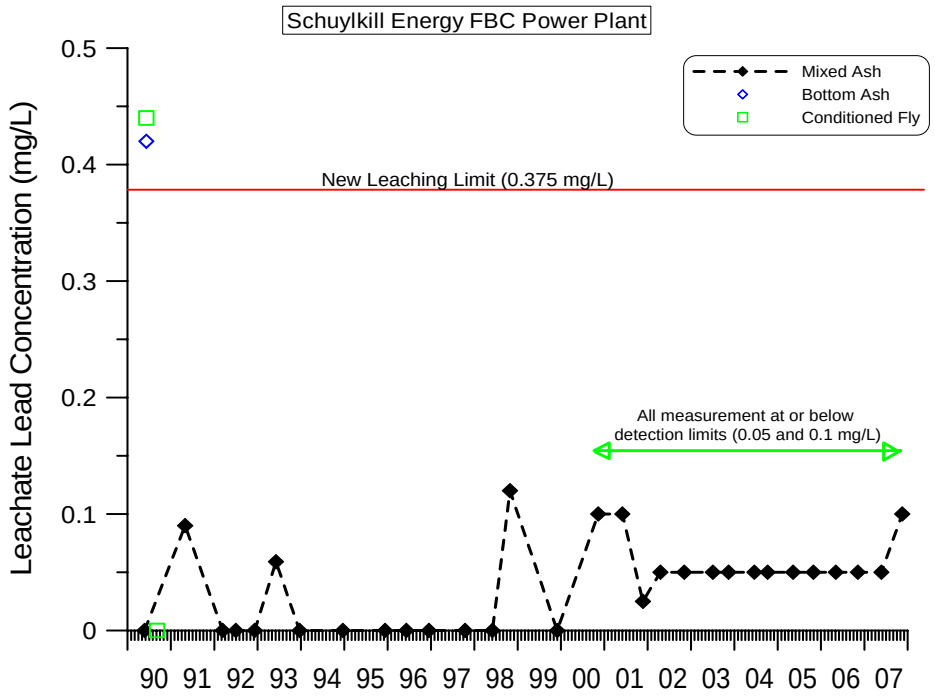


Figure 11. Schuylkill Energy lead leachate concentrations through time.

Gilberton Plant: The highest concentrations at the Gilberton plant are associated with samples from "Boiler 1" and "Boiler 2" fly and bottom ash (Figure 12). Samples identified as such were not collected after 1990. The mixture of ash normally shipped to the mine site has been sampled since 1988. None of these analyses exceed the new leaching limit of 0.375 mg/L. In 1990 the leaching limit would have been 1.25 mg/L and the highest values were well within that limit. All samples since 2000 have been below detection.

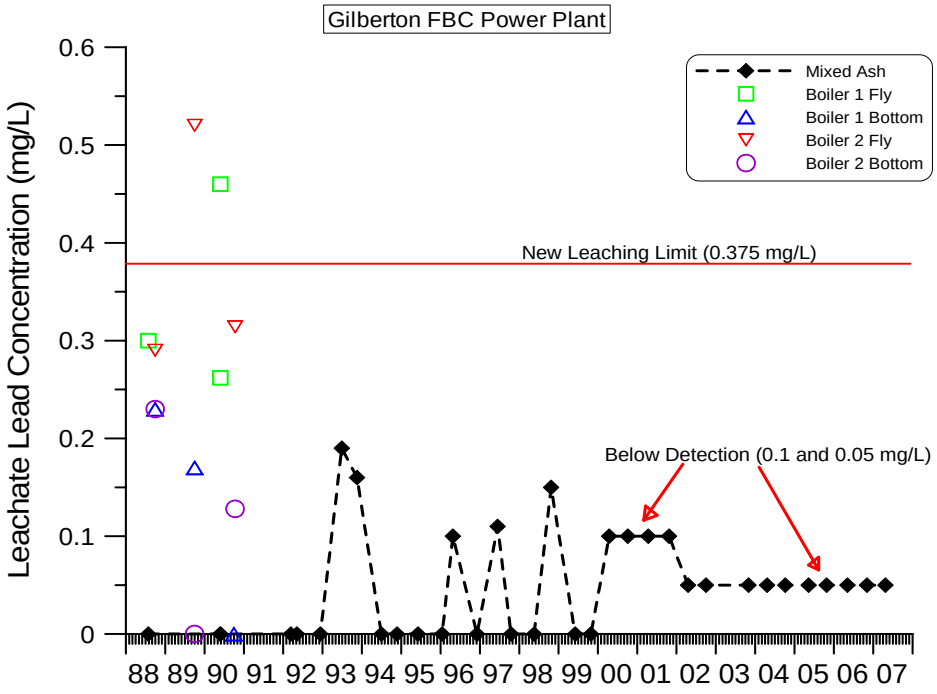


Figure 12. Lead leachate concentrations for the ash from the Gilberton power plant through time.

The bulk analyses for lead were also examined for the Gilberton ash. Figure 13 is a boxplot showing the distribution of lead in the ash from the Gilberton power plant. The median is 27.6 mg/kg. The highest value (represented by the tip of the upper whisker) is 57.2 mg/kg. For comparison, granite typically has 20 mg/kg of lead[7] and the DEP lead limit for clean fill is 450 mg/kg. Thus, the median is in the range of that for granite and the highest value is nearly an order of magnitude lower than the clean fill standard.

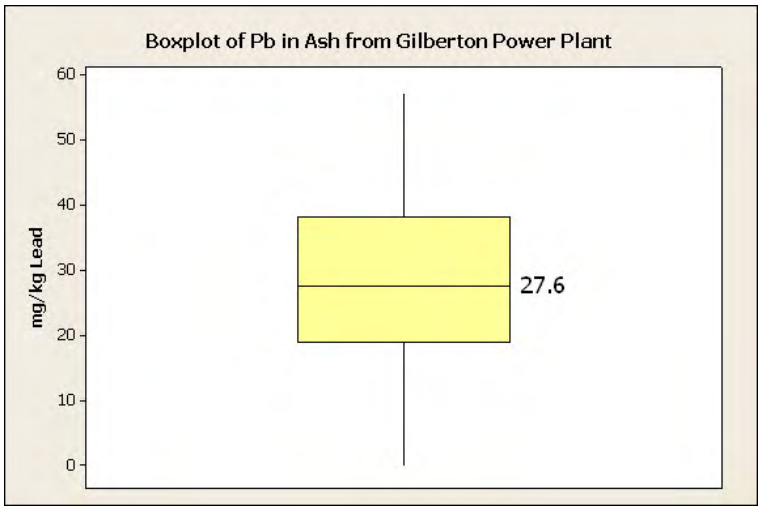


Figure 13. Distribution of lead in the ash from the Gilberton power plant. Q1 = 19.0, Q3 = 38.1.

[7] See Table 2.8 in Smith and Huyck, (1998).

AES Thames: About one third of the ash brought to BD Mining since 2002 has been from the AES Thames power station in Connecticut. They have been providing separate samples for their fly and bottom ashes. Figure 12 is a boxplot showing the distribution of lead in the sampled ash. Plots of the leaching data for AES Thames are not included because lead has always leached just at or below detection.

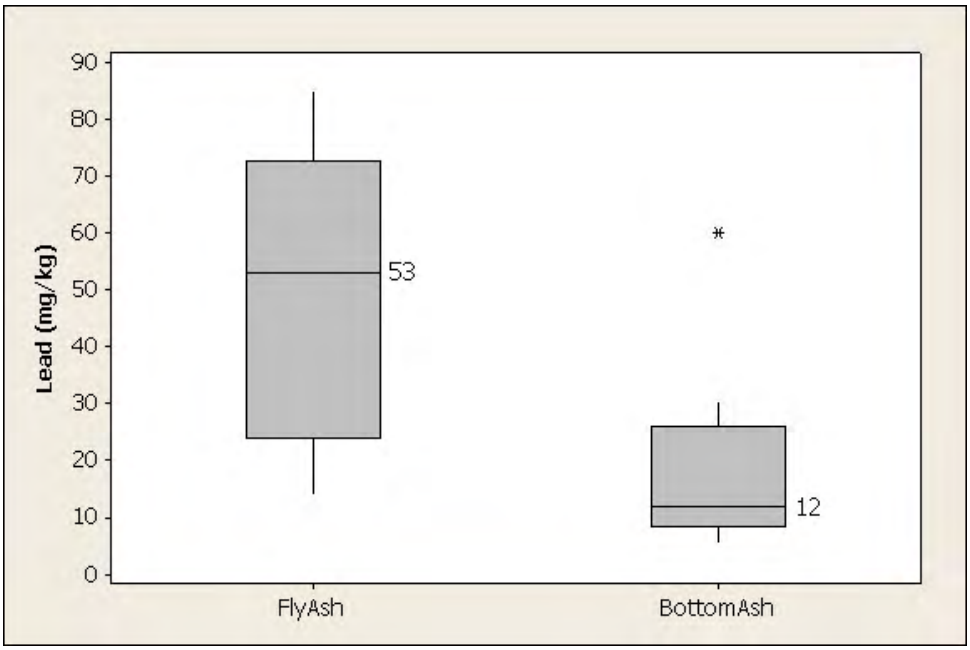


Figure 12. Distribution of lead in the fly and bottom ash from the Thames power plant source. The number to the right of the box is the median concentration.

Syracuse Energy Corporation – Trigen: Ash has been coming from the Syracuse-Trigen source for only the past couple of years and is a fairly small proportion of the overall ash. The highest lead measured from this source is 10.4 mg/kg, just above the detection limit of 10 mg/kg. Other samples were below the detection limit. Leachate lead is below detection.

Discussion on Lead in BD Mining Ash: The lead in all the ashes coming to the BD Mining site is well below the lead concentration that would qualify a material as “clean fill” in Pennsylvania. The greatest source of ash at BD Mining, Gilberton plant ash, has about the same lead concentration as granite. None of the ashes leach lead at levels of concern, nearly always being below detection. An examination of leaching chemistry and bulk chemical analysis for lead in the ashes used at BD Mining indicate that they contain low concentrations of lead and will not leach lead at problematic levels.

Iron Concentrations

Figure 13 shows the monitoring data for iron. The trendline in black is modeled for the data points in red (Gilberton Shaft down-gradient of ash). In a pattern that will be repeated with other constituents, the trend in the mine pool concentrations is improvement – lower iron through time.

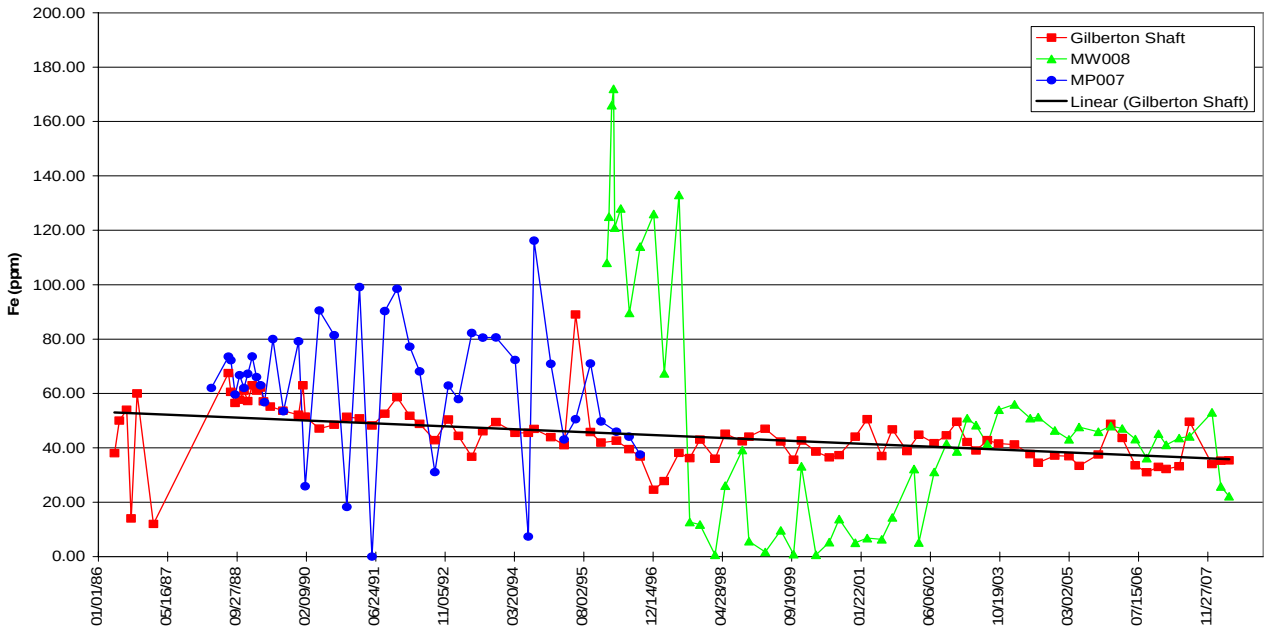


Figure 13. Concentration of iron through time. The trendline is through the data for the down-gradient Gilberton Shaft. Monitoring well 007 (in blue) was replaced in 1995 by well 008 (in green).

The post 1995 well data (in green) shows high values through 1997, low values from 1997 to mid-2002 and consistent middle values from 2002 to 2007 with a current trend downward. This high-low-high pattern will be repeated in some of the following graphs. We have no explanation for this behavior.

Throughout 1988-present, the down-gradient Gilberton mine shaft (in red) is fairly consistent and clearly trending downward. Thus, iron concentrations have been improving through time at the down-gradient Gilberton Shaft.

Manganese Concentrations

Manganese results (Figure 14) show a similar pattern to the iron. The trend for the down-gradient point is downward (improvement) through time. The monitoring wells show similar responses through time as those observed for iron. The well data are variable with extreme values in 007 and a high-middle-high pattern on the 008 up-gradient point. As with iron, the most recent samples at the downgradient Gilberton Shaft have lower concentrations than earlier data.

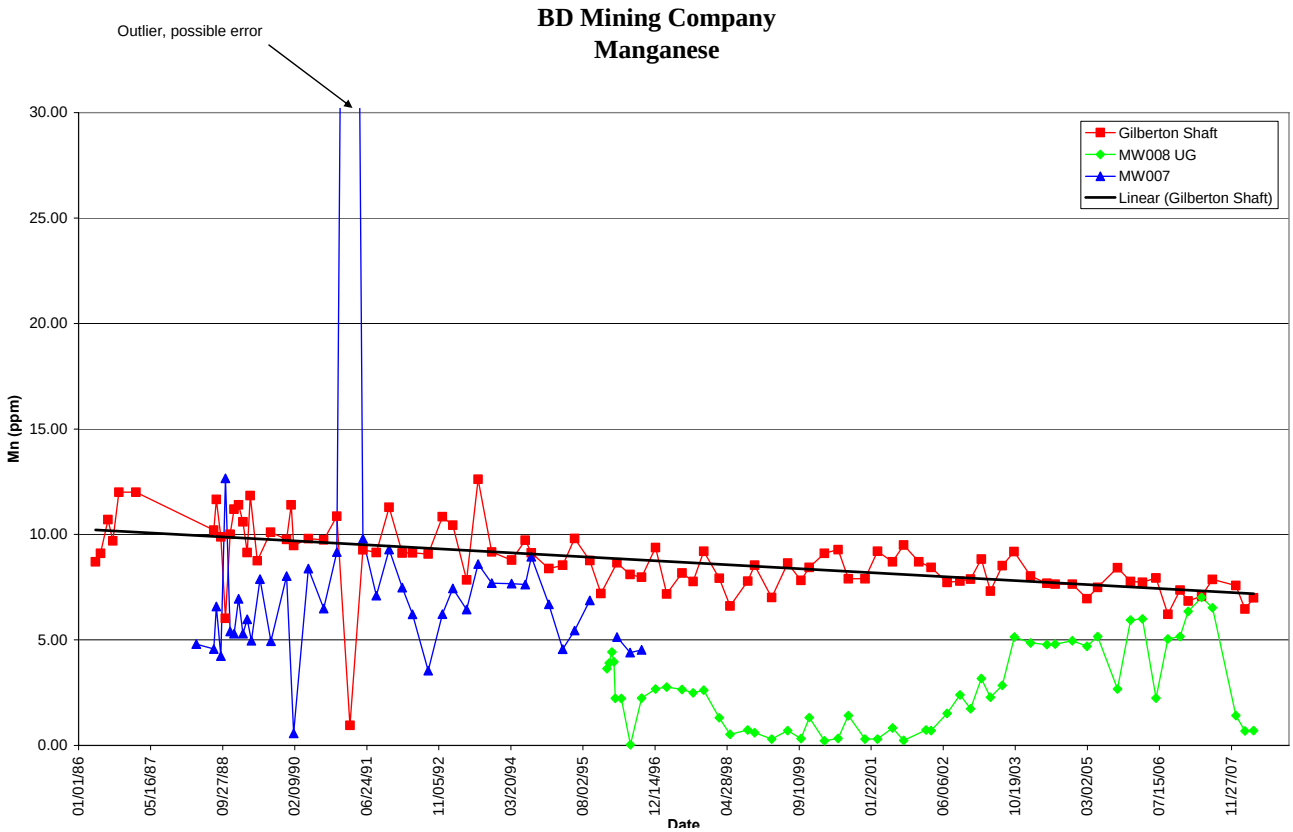


Figure 14. Concentration of manganese through time. The trendline is through the data for the down-gradient Gilberton Shaft.

Sulfate Concentrations

Sulfate is a common constituent of mine drainage and is a prevalent constituent of many coal ashes, especially fluidized bed ashes such as those produced by the Gilberton power plant. Sulfate (Figure 15) at the down-gradient point shows the same pattern (decreasing through time) as iron and manganese. The monitoring wells show variability and the same pronounced high-low-high pattern from 1995 to 2006 as with iron and manganese with recent samples having lower concentrations. Sulfate is a parameter that tends to leach readily from ash, so a decline in sulfate levels indicates that leachate from the ash is not having a negative affect on the mine pool.

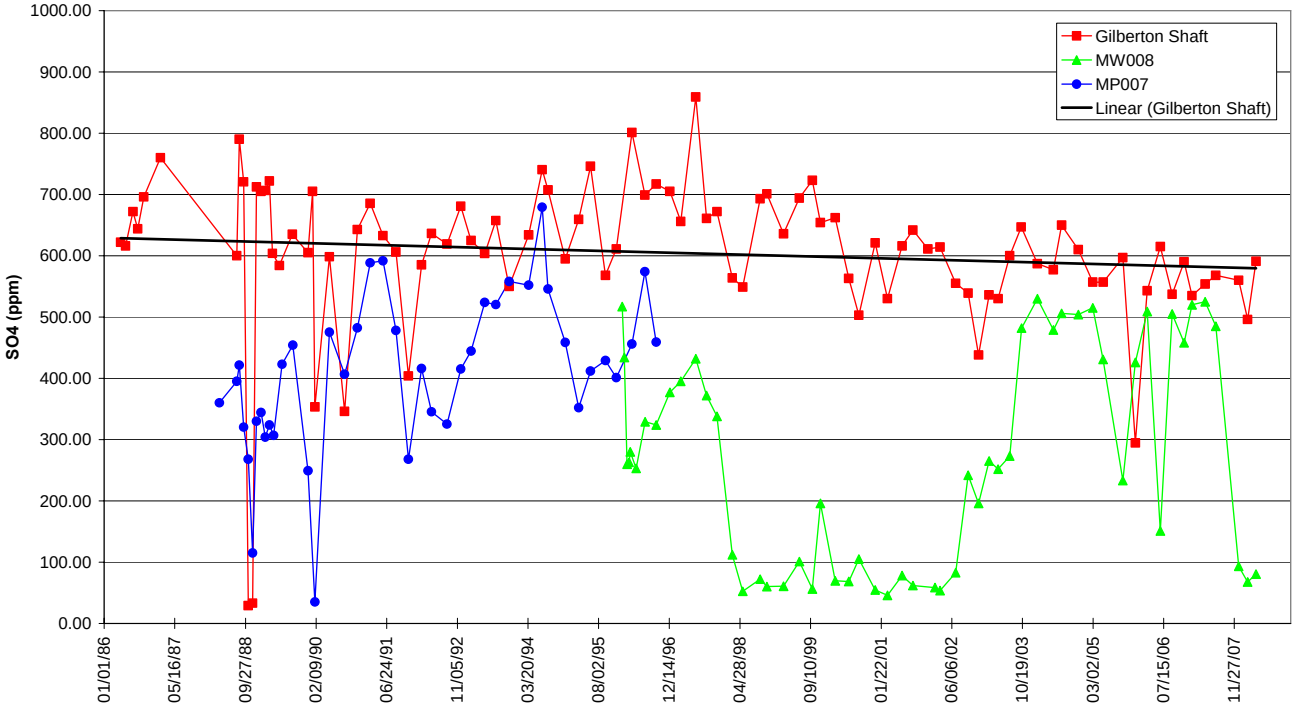


Figure 15. Concentration of sulfates through time. The trendline is through the data for the down-gradient Gilberton Shaft.

Alkalinity Concentrations

The alkalinity (Figure 16) is highly variable but produces an overall increasing trend. Increasing alkalinity is an improvement to mine discharge quality and probably indicates a decrease in acid sources within and into the mine pool.

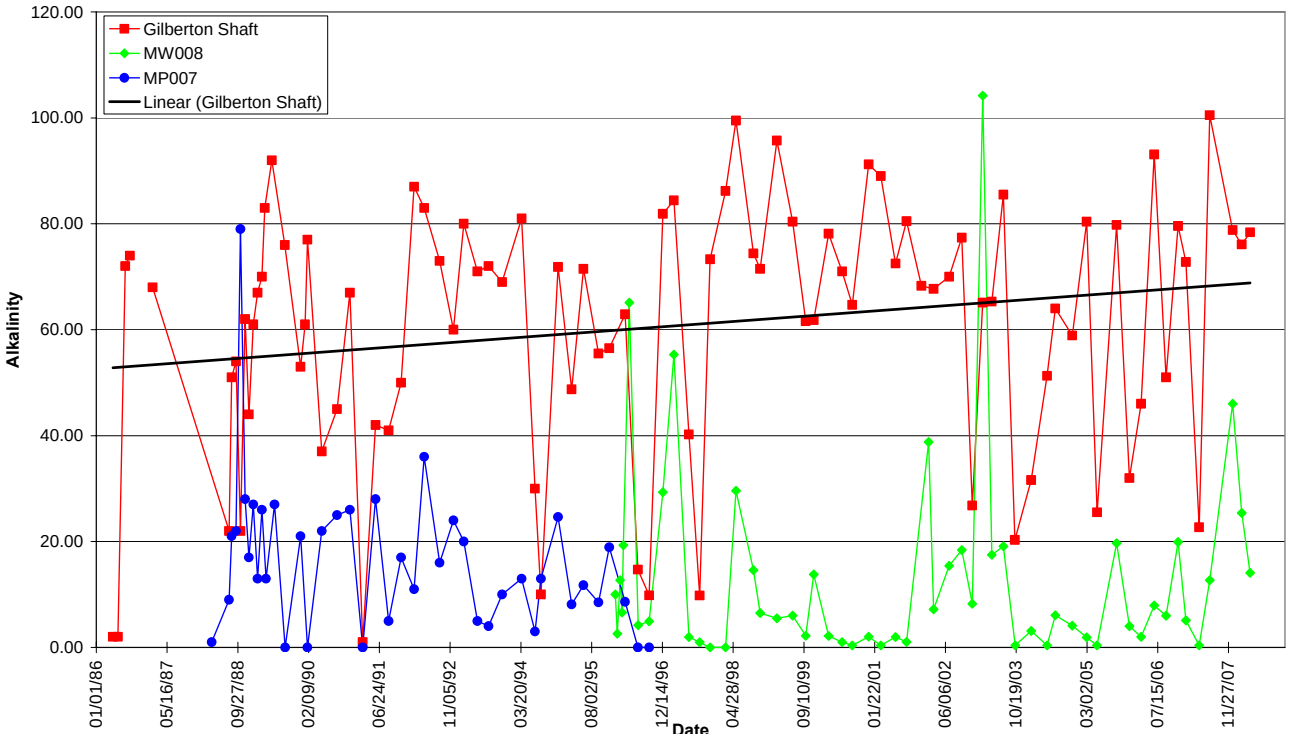


Figure 16. Concentration of alkalinity through time. The trendline is through the data for the down-gradient Gilberton Shaft.

Trace Metals

Figures 17 through 19 show zinc and nickel concentrations through time. Figure 17 shows data for the down-gradient Gilberton shaft and monitoring well results for zinc. This figure shows all data, including extreme (outlier) values. Figure 18 is just the down-gradient data, minus the most extreme value. Figure 19 shows nickel concentrations through time. Monitoring for nickel began in 1994. These two parameters show decreasing trends through time, consistent with all the other decreasing trends observed at the down-gradient Gilberton Shaft monitoring point.

Other trace metals (As, Cr, Cu, Cd, Hg, and Se) were not plotted because the vast majority of values were below detection throughout the history of monitoring, making a plot essentially meaningless. As with lead, a few rare higher values occasionally occur, but show no trend.

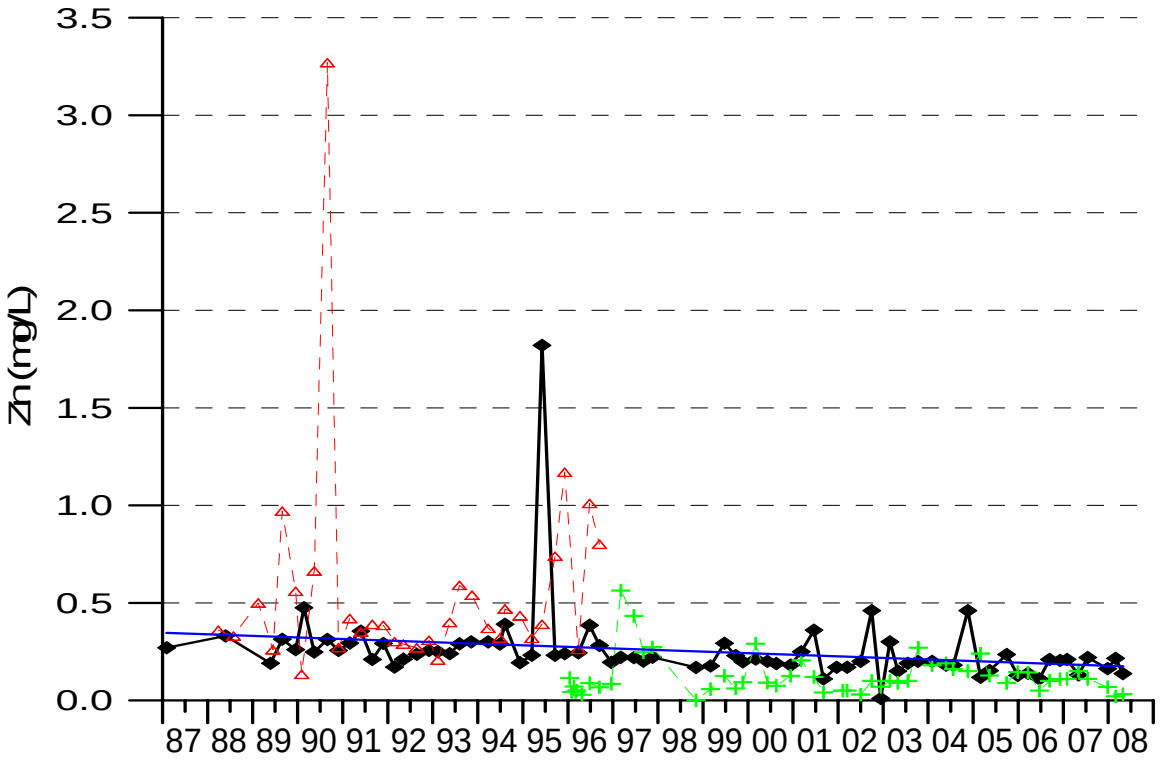


Figure 17. Zinc concentrations at up-gradient and down-gradient (Gilberton Shaft) monitoring points. All data are shown.

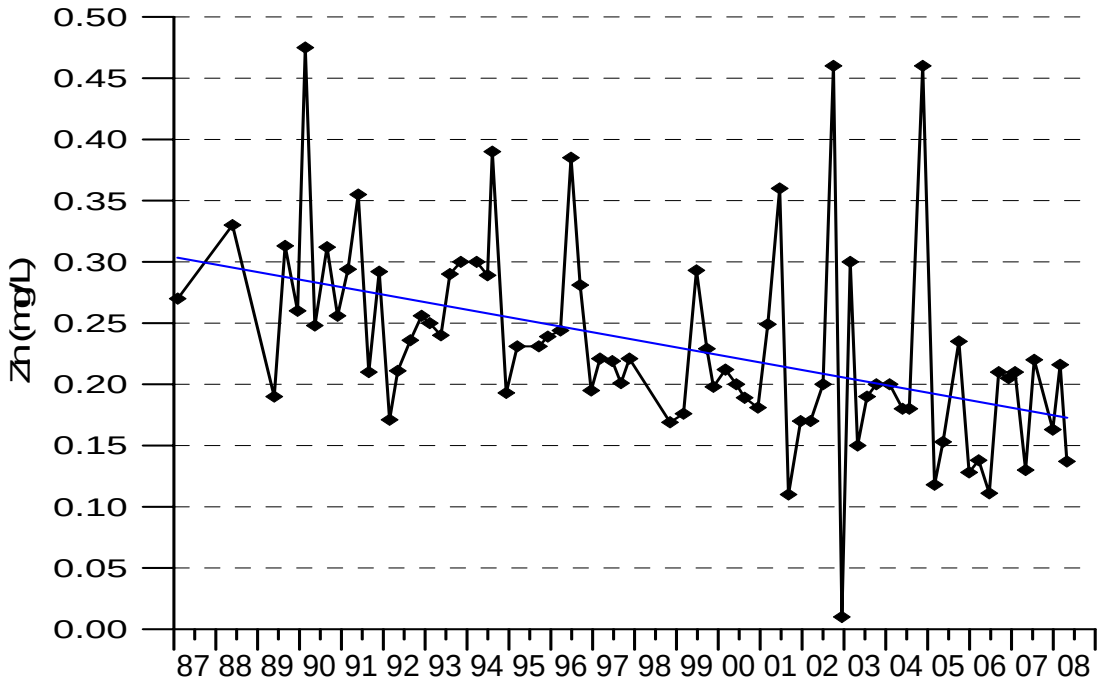


Figure 18. Zinc concentrations at the down-gradient (Gilberton Shaft) monitoring point, absent the one value that was greater than 0.5 mg/L.

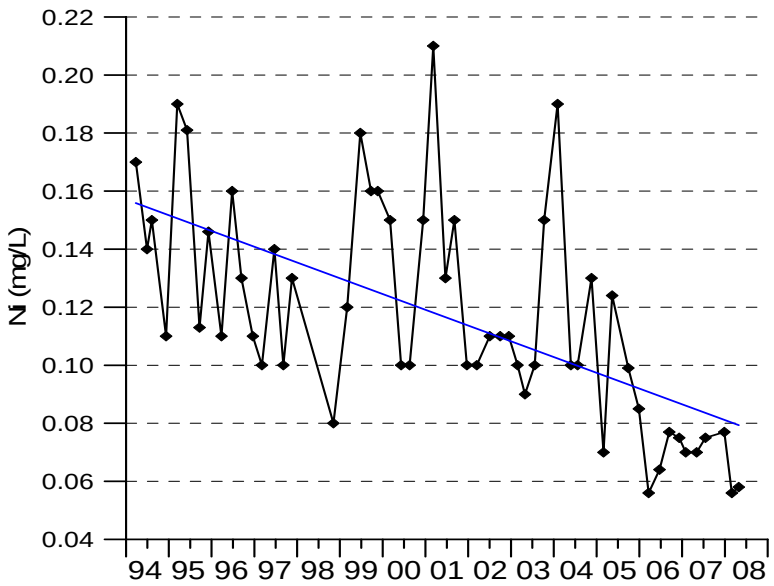


Figure 19. Nickel at the down-gradient (Gilberton Shaft) monitoring point.

Calcium and Magnesium

If anything should be leaching from the ash it would be calcium and magnesium, which occur in large concentrations and are fairly mobile. Figure 20 shows calcium and magnesium concentrations plotted through time. Both elements are decreasing through time.

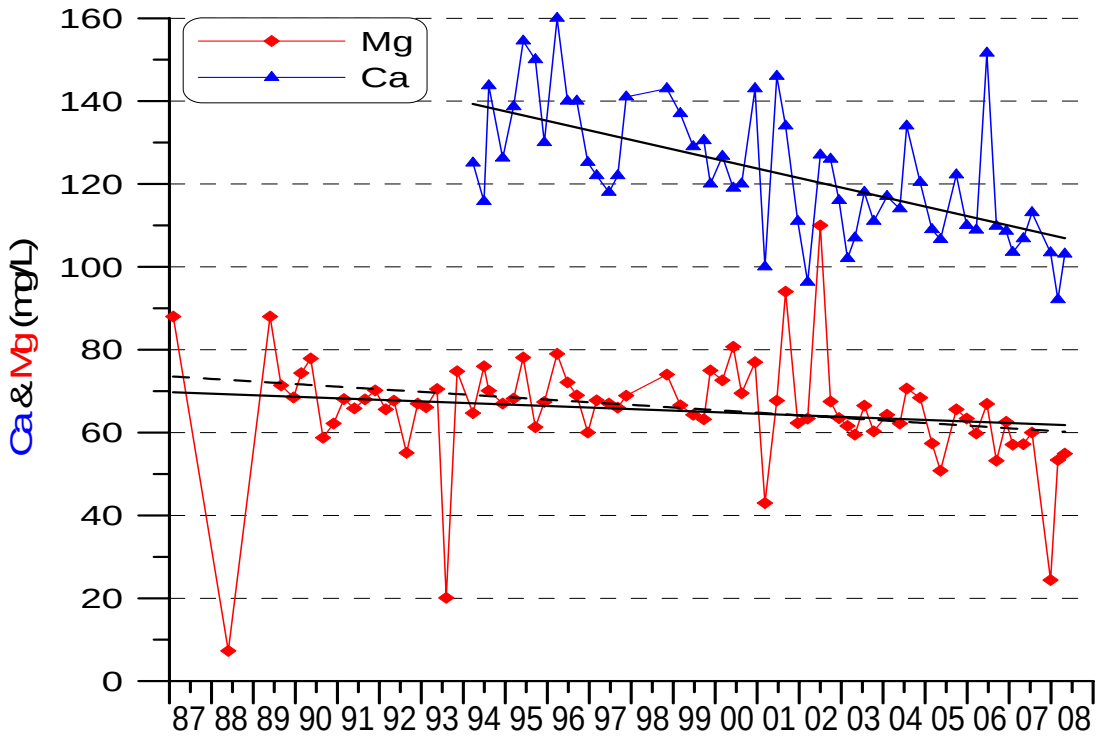


Figure 20. Plots of calcium and magnesium through time. The dashed best-fit line through the calcium data is the best fit when the most extreme low value is eliminated. The solid line represents the best fit using all data.

Total Dissolved Solids

Finally, Total dissolved solids (Figure 21) follows a similar pattern to iron, manganese and sulfate – a general trend downward for the mine pool and the high-low-high pattern with a recent trend downward for monitoring point 008. Total dissolved solids are a reflection of the cumulative concentration of all chemical constituents in the water. Figure 17 shows that the overall concentration of "stuff" in the water is less in 2008 than was the case in 1986.

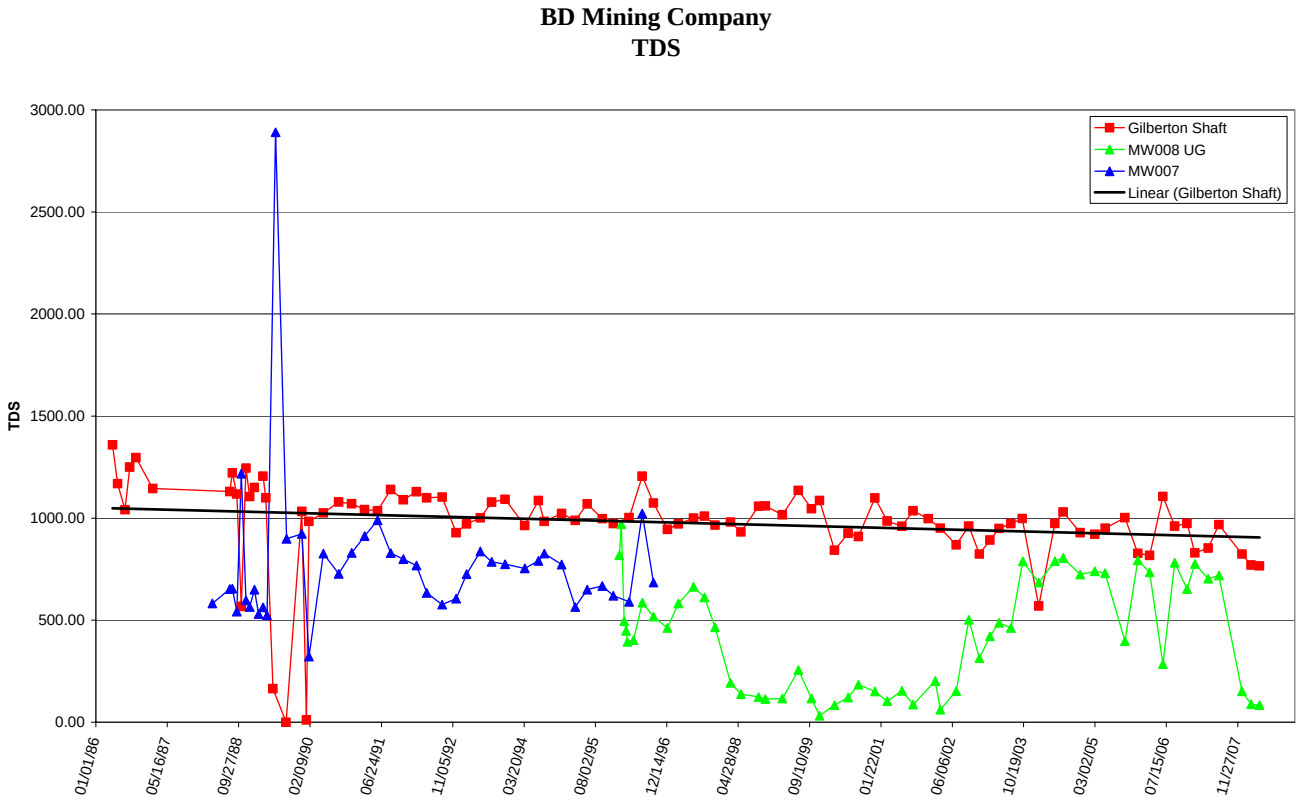


Figure 21. Concentration of Total Dissolved Solids (TDS) through time. The trendline is through the data for the down-gradient Gilberton Shaft.

Discussion and Conclusions

A few observations can be safely made:

1. The lead concentrations at the Gilberton Shaft are below detection about 80 percent of the time. There are occasional spikes that are above detection. The spikes that occur at the downgradient Gilberton Shaft monitoring point are similar to, but often lower than, those at the monitoring wells. Statistically the wells and down-gradient lead populations are the same.

2. Assuming, for the sake of discussion, that the few upward spikes in lead are real (that is, not the result of sampling or laboratory error), to simply assume that ash is the cause is naïve, it would ignore other more probable sources, and is scientifically disingenuous. Numerous current and former human activities result in drainage to the underlying deep

mine pool. The whole area was extensively impacted by previous mining. There is a rail yard immediately adjacent to the BD Mining site, which has been there for decades or longer.

3. Mine pool water quality is improving through time. Improvements are seen in iron, manganese, sulfate, total dissolved solids, zinc, nickel, calcium, magnesium and alkalinity. These are substances known to occur in coal ash. It is clear that the ash, at a minimum, is not having a negative effect on the underlying mine pool since the mine pool is improving through time for all these parameters. It is reasonable to suggest that reclamation, removal of waste coal and ash placement have resulted in improvements to the mine pool quality.

4. The "spiky" nature of the lead is completely different from the behavior of any of the other parameters plotted. The other parameters show clear trends toward improvement. It is unlikely that lead could independently leach from the ash while so many other parameters in the mine pool are improving through time. Even calcium, sulfate and magnesium, which constitute a huge portion of the ash, are decreasing through time. If anything were to leach one would expect it to be calcium, sulfate and magnesium. If lead were truly leaching from the ash there should be other parameters, such as nickel and zinc, showing similar behavior, but this is not occurring. It is not supported that the ash is leaching measurable quantities of any constituents but, instead, functioning as a low permeability stable mass. The most reasonable explanations for the occasional high lead are that it is from a non-ash source or it is sample collection or analytical error of some sort. The vast majority of the time lead is below detection.

5. Lead levels in the bulk chemistry for the ash being placed at BD Mining are well below the 450 mg/kg that would make a material acceptable as clean fill. The Gilberton ash, which makes up the bulk of the ash at BD Mining, has lead concentrations similar to granite. The leaching levels for lead for all sources are almost always below detection. The chemical analyses of the ash do not support ash as a source for lead.

6. The assumption that lead must somehow be tied to ash is unsupported as discussed above. If lead is actually occasionally elevated, it is more likely that there is some other explanation than ash as the source. Ash is the one material that has been placed in the area that has been subjected to extensive chemical testing and permitting requirements.

7. To apply drinking water standards as the compliance standard for the mine pool water in the Mahanoy Syncline is unreasonable. The water has been polluted for decades, perhaps a century. This water has not been potable, nor will it be potable in the foreseeable future. Table 1 shows that the water was undrinkable before ash placement and, although the water has improved, it is still undrinkable.

8. The commentator concerned about water quality in this location ignored the overall improvements of the mine pool through time, clearly exhibited by other indicative parameters closely associated with coal ash. These data were available to the commentator.

9. Over 5 million tons of ash have been placed above the mine pool that is sampled at the Gilberton Shaft. Despite this, or perhaps as a result of this, chemical constituents are decreasing through time. That is, the mine pool quality is improving. Elements such as calcium, sulfate and magnesium, which occur in very large quantities in ash, are decreasing in the mine pool water.

There is no evidence to support the allegation that ash at the BD Mining site is having a negative impact on the mine pool water quality as sampled at the Gilberton Shaft. To the contrary there have been clear improvements to water quality through time at the Gilberton Shaft.

References

Cravotta, C.A. III, 2005. Effects of abandoned coal-mine drainage on streamflow and water quality in the Mahanoy Creek Basin, Schuylkill, Columbia, and Northumberland Counties, Pennsylvania, 2001. U.S. Geological Survey Scientific Investigations Report 2004-5291, 60 p.

Danilchik, W., H.E. Rothrock and H.C. Wagner, 1955. Geology of anthracite in the western part of the Shenandoah Quadrangle, Pennsylvania. US Geological Survey Coal Investigations Map C-21.

Hornberger, R.J., S.A. Hill, M.J. Menghini, T.D. Owen and D.J. Koury, 2004. Coal ash beneficial use (conventional ash placement) on anthracite mine sites. Chapter 4, In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. PA Dept of Environmental Protection and Penn State Materials Research Institute, pp. 71-117.

Kehn, T.M. and H.C. Wagner, 1955. Geology of anthracite in the eastern part of the Shenandoah Quadrangle, Pennsylvania. US Geological Survey Coal Investigations Map C-19.

Reed, L.A., M.M. Beard, and D.J. Growitz, 1987. Quality of water in mines in the Western Middle Coal Field, Anthracite Region, east-central Pennsylvania. U.S. Geological Survey Water-Resources Investigations Report 85-4038, 51 p.

Smith, K.S. and H.L.O. Huyck, (1998). An overview of the abundance, relative mobility, bioavailability and human toxicity of metals. In: The Environmental Geochemistry of Mineral Deposits. Part A: Processes, Techniques and Health Issues. Reviews in Economic Geology, Vol. 6A, p. 29-70.

Coal Ash Beneficial Use at Mine Sites



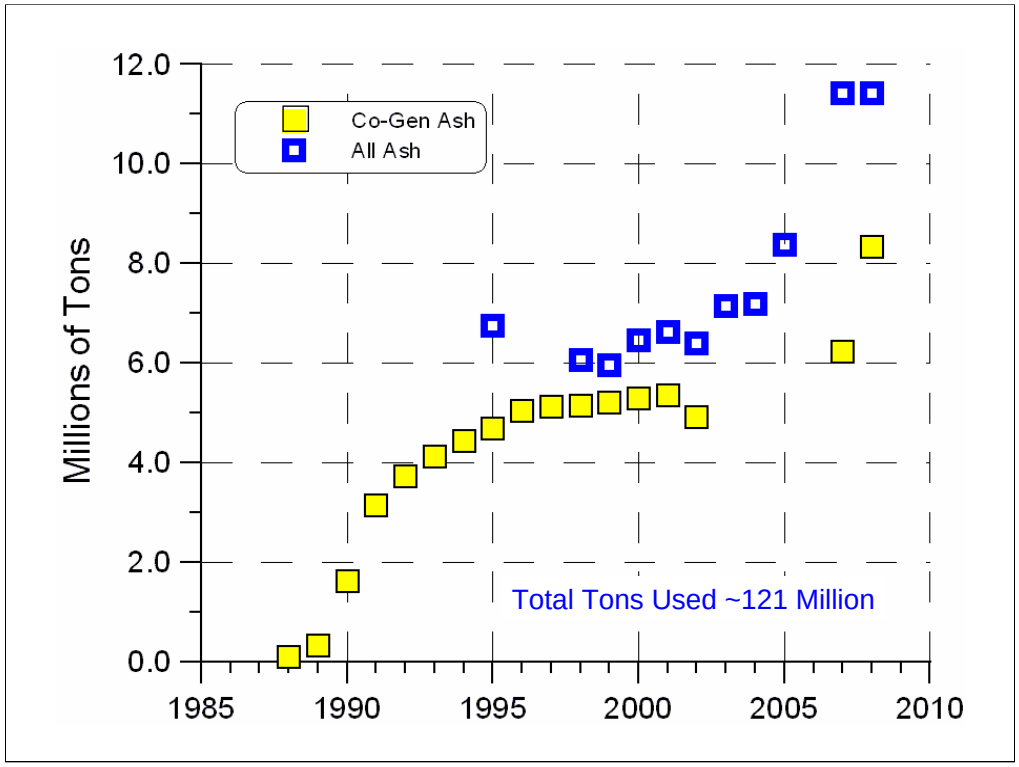
Keith Brady & Sharon Hill

DEP – Bureau of Mining and Reclamation



A note on the background picture. The site is near Gilberton, PA. The reddish coal ash is from the Schuylkill Energy power plant. The black material in the foreground is waste coal that will eventually go to the power plant. The dozer is placing and compacting the ash in 2 ft lifts. The area depicted was drastically disturbed abandoned mine lands that are being reclaimed with coal ash. The ash material is covered with four feet of material and revegetated.

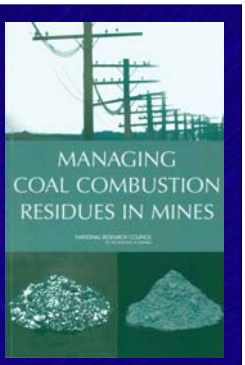
The cost savings that is calculated is likely conservative. Landfilling can be $35 or more per ton and use at mines can be as little as $3.50 per ton.



The jump in “all ash” use from 2005 to 2007 is due to better record keeping, not a massive increase in the program.

Why New Policy & Regs

- Process improvements (Clear standards. Reduce confusion, inefficiency, potential oversights)
- Expanded monitoring requirements (# of points, frequency, parameters & limits)
- Constant public scrutiny
- High-level national focus
  - EPA, OSM, NAS







Not All Coal Ash is Created Equal

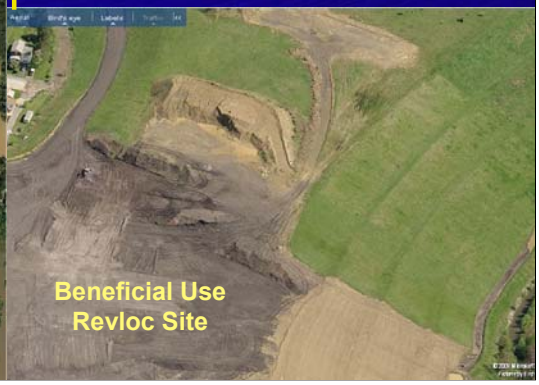
Doesn't Meet Specs

It's Residual Waste & Goes to a Landfill

Meets Specs

Can be Beneficially Used at Mines





Beneficial Use is NOT Disposal

- Mines are not to be used as an excuse for getting rid of a waste material
- There must be a benefit to mine site - reclamation &/or water quality


Material disposed as waste
Historic ash impoundments
FGD:
gypsum,
calcium sulfite
"Alternate Fuels"
Need General Permit
Not "Coal Ash"

Summary of Policy Changes

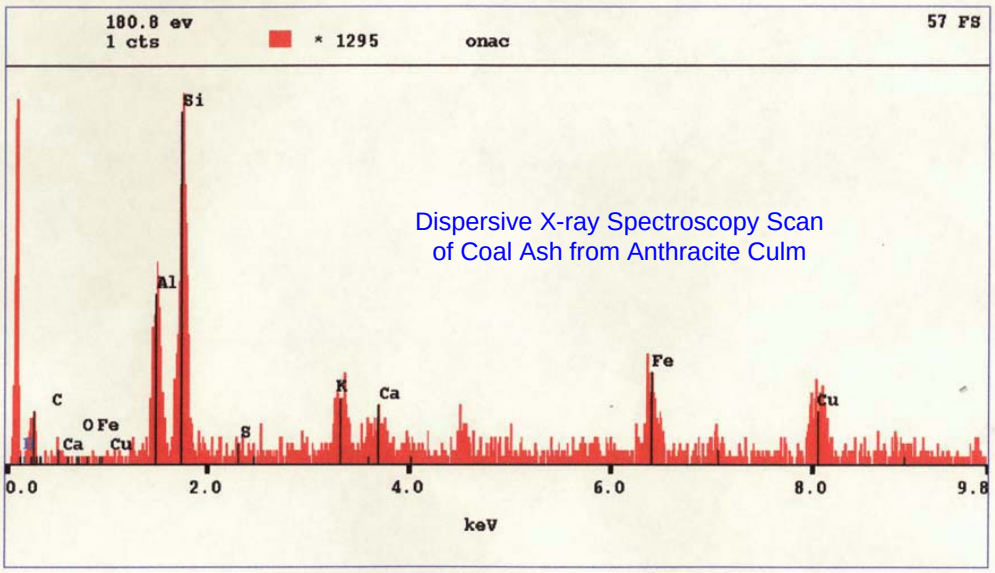
Ash Monitoring

- 20 → 32 parameters
- 2 samples/yr to 4 samples/yr
- Lowered As from 1.25 to 0.25 mg/L
- Lowered Se from 1.0 to 0.5 mg/L
- Central certification process

Water Monitoring

- 26 → 36 parameters
- 1 full sample/yr to 4 samples/yr
- Filtered samples
- Purged wells
- 6 → 12 background samples
- 3 downgradient & 1 upgradient monitoring pts
- 10 yrs post placement monitoring

Coal Ash Chemistry



Dispersive X-ray Spectroscopy Scan
of Coal Ash from Anthracite Culm

Sampling Parameters

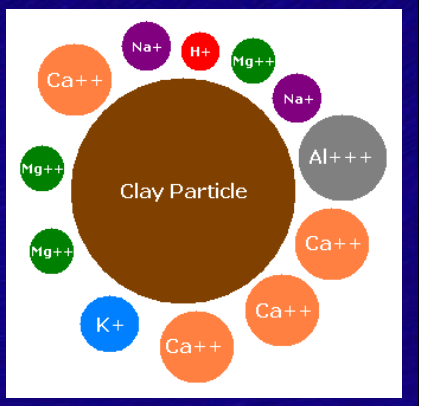
*Ag	Hg	*F
Al	Mn	Cl
As	Mo	Na
B	Ni	pH
Ba	Pb	*Ca
*Be	S	*Mg
Cd	Sb	*K
*Co	**Se**	***NO_3**
Cr	*Tl	*NO_2
Cu	*V	*NH_4
Fe	**Zn**	

Parameters discussed below

* New parameter

Leaching Limits

- Cations: 25 times the MCL
  Allows for attenuation
  Reason for 8 ft separation from water table
- Anions: equal to the MCL
  Assumes no attenuation

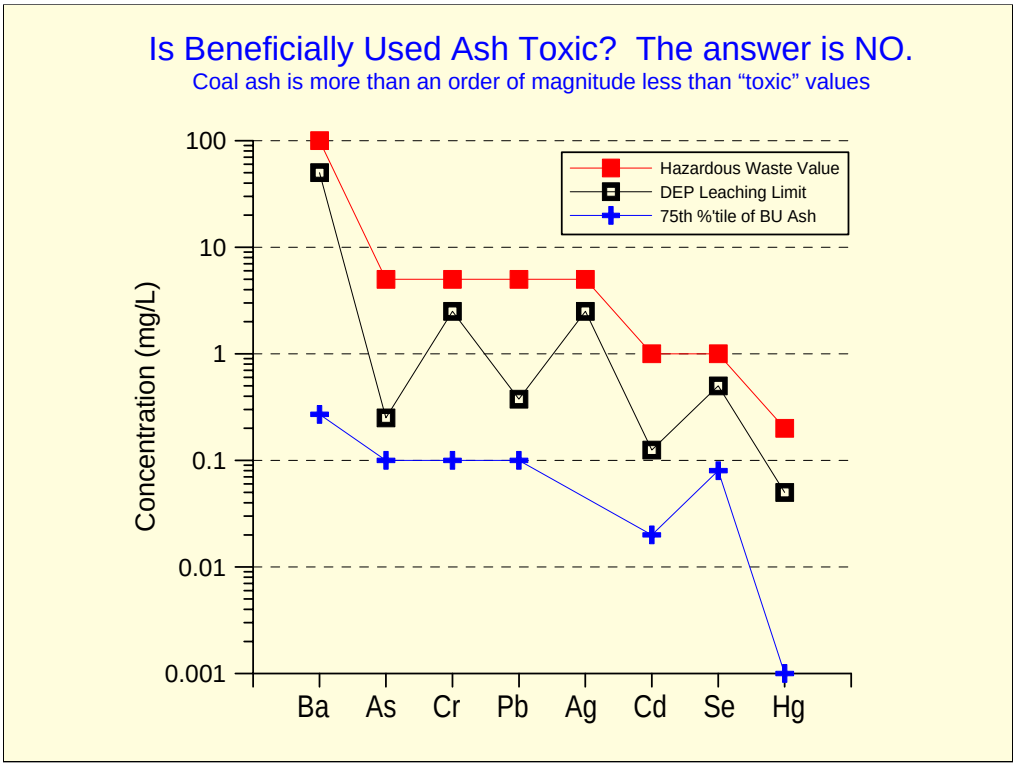


A Comparison of Numbers

Parameter	Hazardous	DEP	75th Percentile		
	TCLP	SPLP	PC	A-FB	B-FB
Arsenic	5.0	0.25	0.10	0.05	0.05
Barium	100	50	0.25	0.26	0.27
Cadmium	1.0	0.125	0.005	0.02	0.02
Chromium	5.0	2.5	0.08	0.10	0.08
Lead	5.0	0.375	0.05	0.1	0.1
Mercury	0.2	0.05	0.0002	0.0004	0.001
Selenium	1.0	0.5	0.08	0.05	0.06
Silver	5.0	2.5	not enough data yet		

Units are mg/L

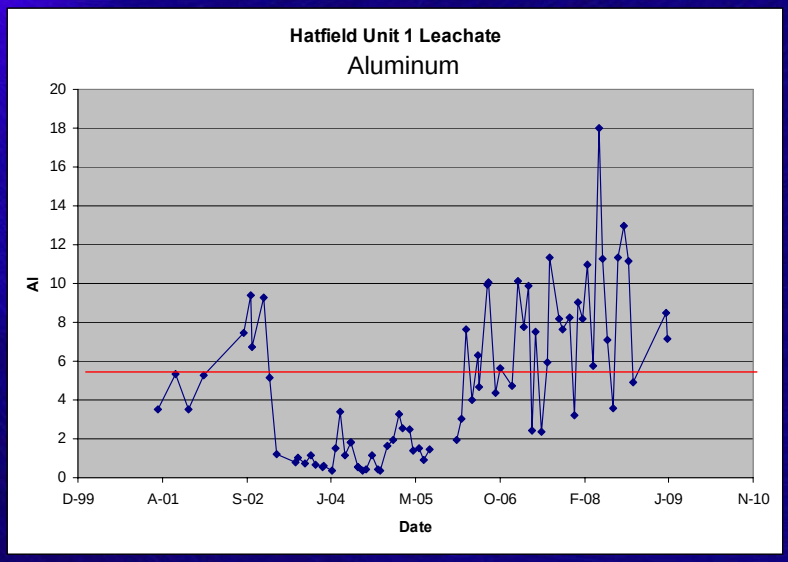
Units are mg/L. TCLP is Toxicity Characteristic Leaching Procedure. SPLP is Synthetic Precipitation Leaching Procedure. PC is pulverized coal ash. A-FB is anthracite fluidized bed combustion ash. B-FB is bituminous fluidized bed combustion ash. 75th Percentile is the value where 75% of the data is less than or equal to this value. For example, 75% of measured SPLP results are less than 0.08 mg/L chromium. Because so many values are below detection, even the 75th percentile is often influenced by detection limits.

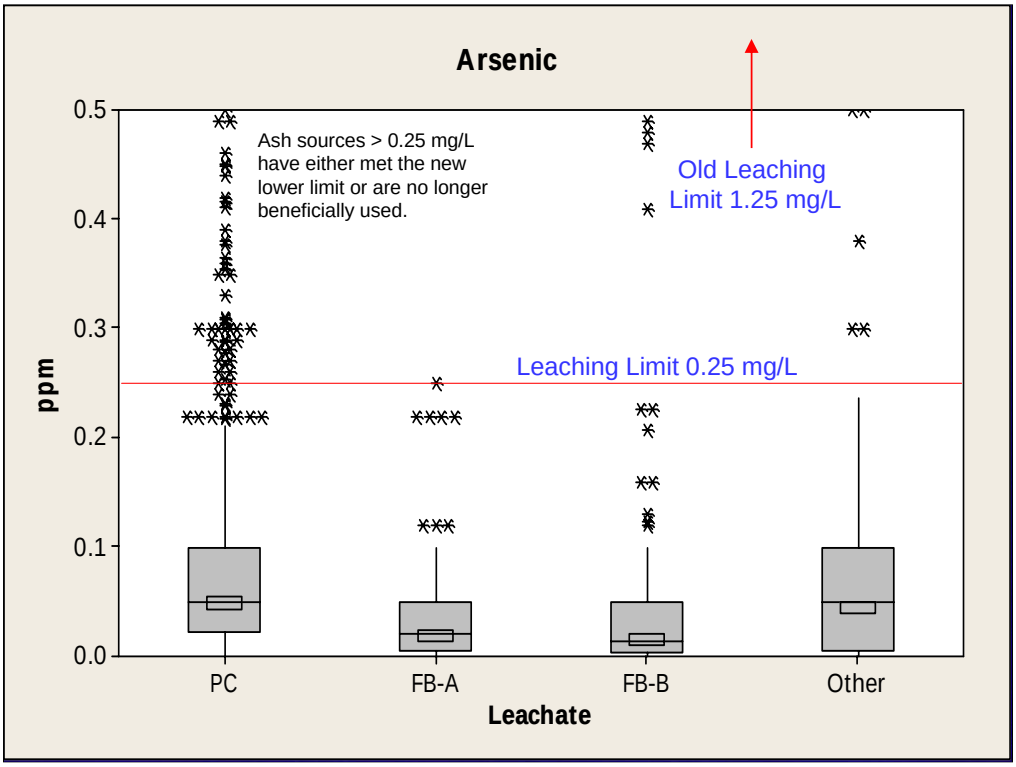


Note that the actual ash values are consistently an order of magnitude or more lower than the levels that define "toxic" waste. Also note that the DEP leaching limit is never greater than 50% of the toxic waste number. Actual values of ash are consistently less than the acceptable leaching values.

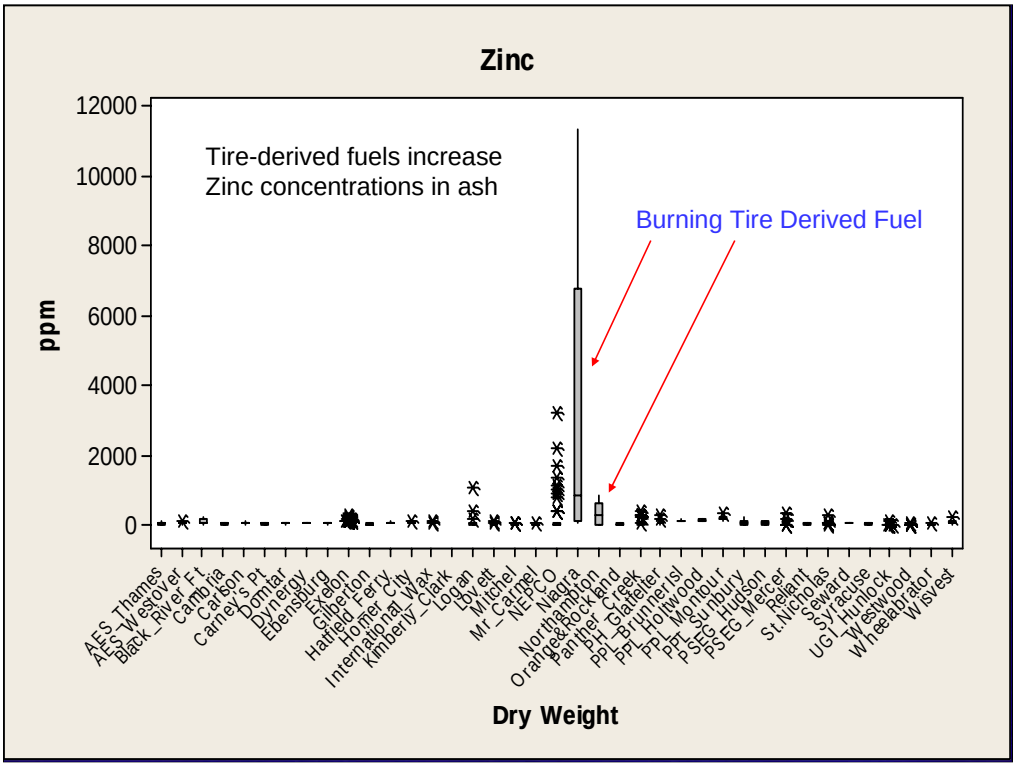
Evaluating Leaching Data

Trends through Time

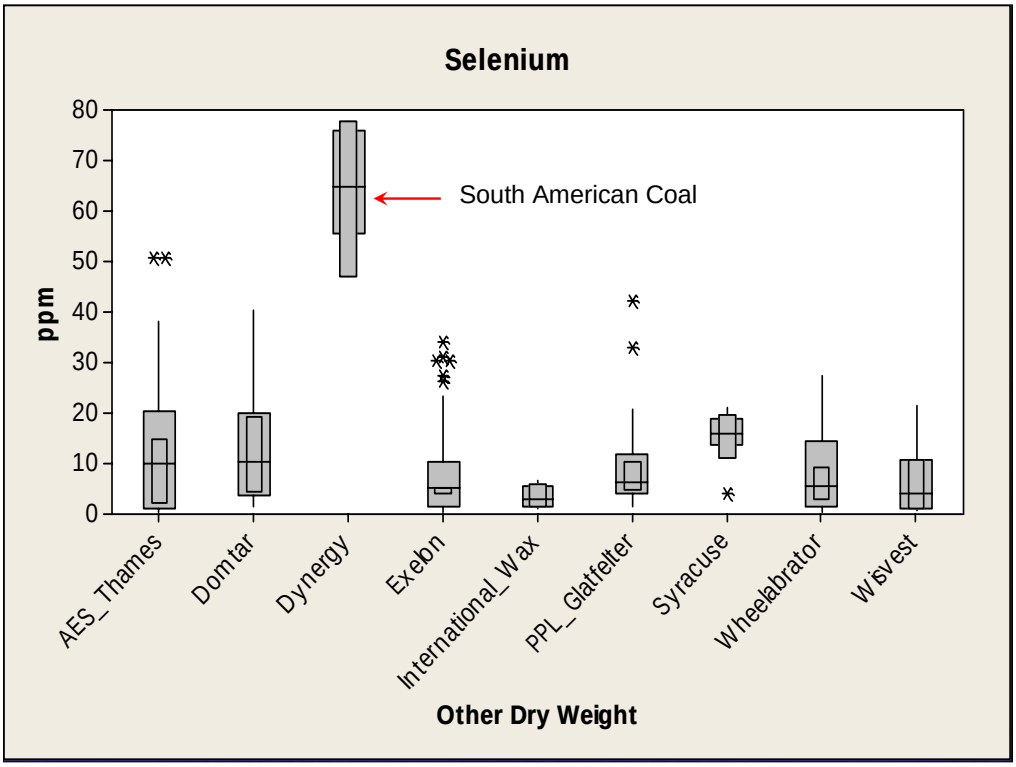




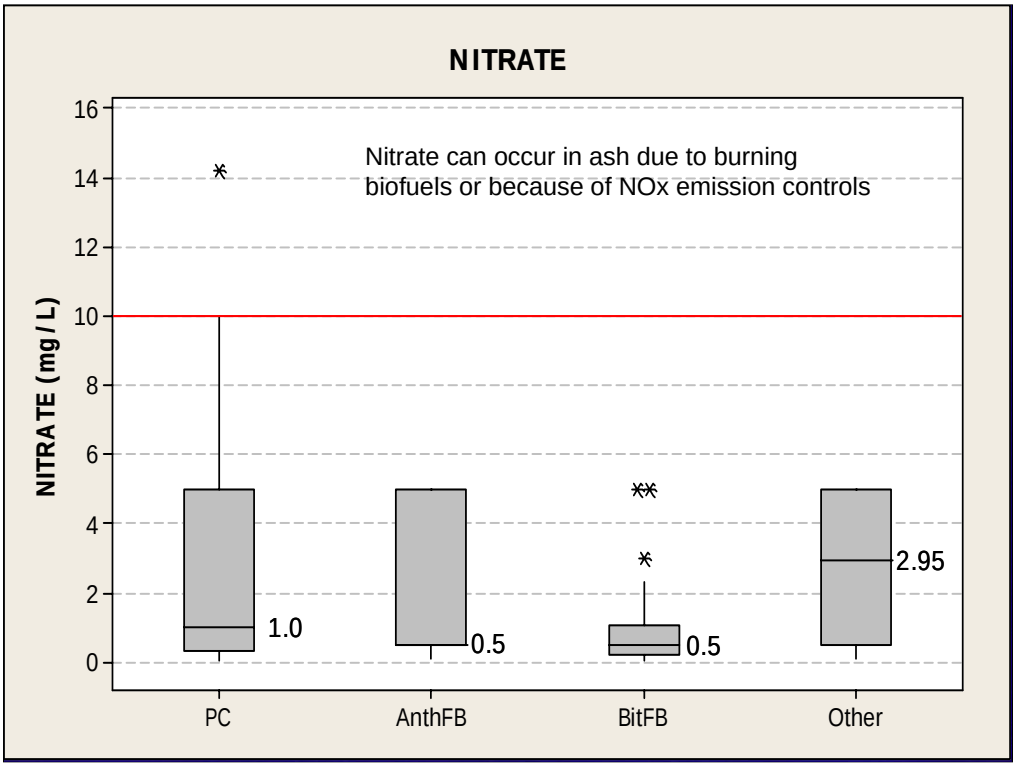
Power plants that were not meeting the new arsenic leaching limit of 0.25 mg/L have either found ways to comply or are no longer being beneficially used.



Tire-derived fuel results in higher zinc concentrations in ash.



Pennsylvania coals are low in selenium compared to some other coals, such as the South American coal illustrated here.


NITRATE
Nitrate can occur in ash due to burning
biofuels or because of NOx emission controls
NITRATE (mg/L)
16
14
12
10
8
6
4
2
0
1.0
0.5
0.5
2.95
PC
AnthFB
BitFB
Other

Regulations

- Existing Regs – 287.661-665
- Being Revised – Ash its own Chapter 290
- Incorporating Technical Guidance
- Draft Regs found at: http://is.gd/39q3Z

  "2009 EQB meeting schedule – July 21, 2009" (http://www.depweb.state.pa.us/pubpartcenter/cwp/view.asp?a=3&q=544036#07212009)

More questions to be asked and answered

In order to continue this program,

- Industry Must Step Up and Do Research - and publish results
- Sound scientific findings must be established
- Responsible site management must be the standard

Beneficial use is NOT disposal

Therefore, be prepared to show

Water Quality Benefits

287.663(c): The use of coal ash as part of the mining reclamation activity shall be designed to

- achieve an overall improvement in water quality or
- shall be designed to prevent the degradation of water quality

Reclamation Benefits

287.663(b): The request for use at coal mining activity sites shall be addressed in the reclamation plan…

287.663(b)(1): Beneficial use as a soil substitute or additive

Two-Step Process



Source approval – certification BMR
(TGD 563-2112-224 Ash quality)

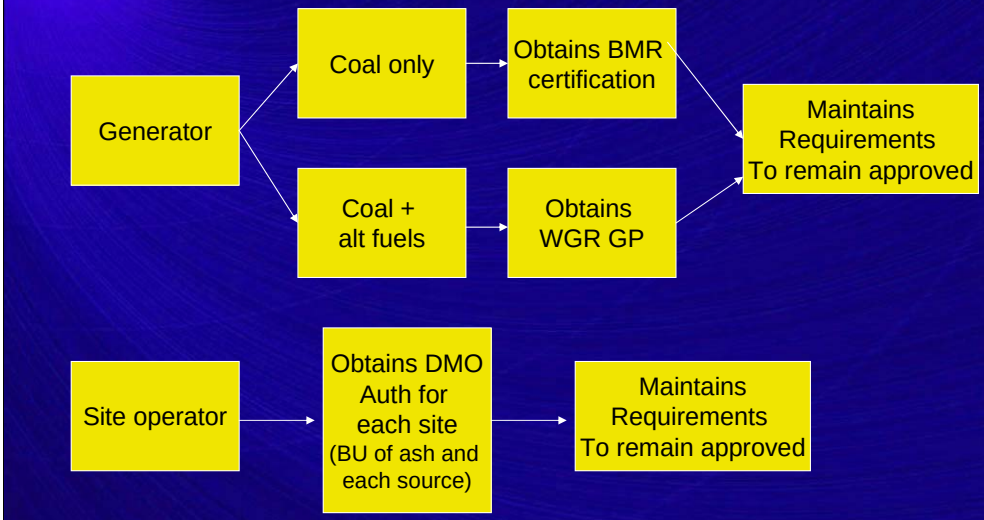
Site approval – permit/contract DMO
(563-2112-225 Mine sites)

Interim Final - April 6, 2009



BMR – Harrisburg Mining & Rec
WGR – Harrisburg waste mgmt
DMO – District Mining Office

Ash process



Certification

Responsibility of generator



Tested at generation site



Can be prepared, but not submitted, by other party

Assumed ash will continue to meet standards and be used at mine sites

Certification Criteria

Characterization of ash

Quality
- Meets parameters
- Consistent

Process
- Must be coal ash
- Not mixed with any waste
- Not historically “impounded”

What Does *Certification* Provide

- Consistency in review and approval
- On the list statewide for mine reclamation uses
- Regular submission of samples and volume reports
- Centralized: Improved tracking of sources statewide, better quality control

Single-Site-Specific Approvals

- Given by the DMOs for GP materials and ash that exceeds some secondary parameter.
- Requires justification (groundwater evaluation, enhanced reclamation plan, etc.)
- Additional performance standards set in permit or contract (quality limits for ash/gw)

Ash Testing



Representative

At the generation station

2 times in 6 months (quarterly)

Submitted to BMR on proper forms (MR0012) with lab reports

Can be submitted via email: RA-coalash@state.pa.us

Water Testing



Comprehensive ground-water & surface water pts

Quarterly for entire suite

Submitted to DMO for each permit on proper forms (MR0014)

Check with individual DMO to see if it can be submitted electronically. New Department system in development.

Paperwork

MR0011 = BU certification form

Used for new certs, revisions, QGP material.

MR0012 = Quality assessment

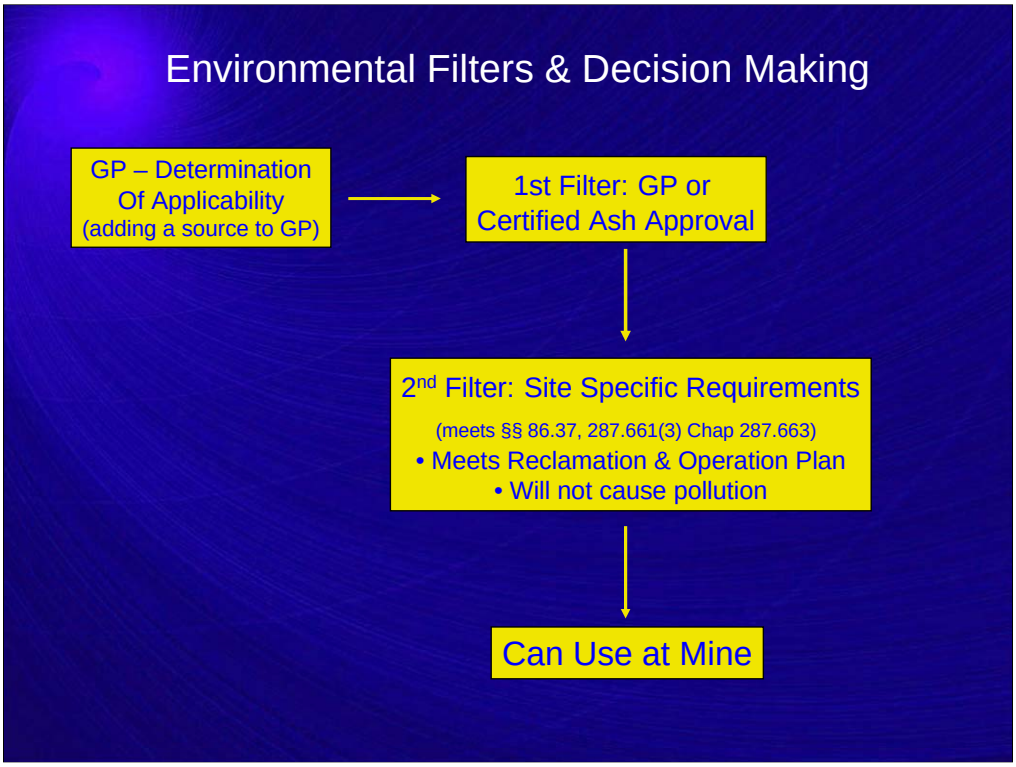
Used for ash samples (background and quarterly, other)

Form MR0011 to be revised in the next few weeks. Do not need to resubmit.

Asking for

- source information
- anything mixed with ash
  - GPs or at the mine site
- new parameters
  - as appropriate per type of use
- volume info from generators
  - placed at mine sites




Environmental Filters & Decision Making
GP – Determination Of Applicability (adding a source to GP)
1st Filter: GP or Certified Ash Approval
2nd Filter: Site Specific Requirements
(meets §§ 86.37, 287.661(3) Chap 287.663)
• Meets Reclamation & Operation Plan
• Will not cause pollution
Can Use at Mine

Contact

Keith Brady or Sharon Hill
(717) 787-5103
kbrady@state.pa.us or shill@state.pa.us
RA-coalash@state.pa.us
http://tinyurl.com/d75pja
(Beneficial Use web page)

Beneficial Use of Coal Ash: PA DEP Current Approved and Pending List

Those sources operating solely under a WMGP are not included on this list.

Cert. No.	*Generator*	*Approved uses*	*Status **
CA003	Inter-Power (Ahlcon Partners) Colver	P, AA, SS	Approved
CA004-5	Northern Star Gen (Cambria CoGen) (Fly-Bottom)	P, AA	Approved
CA006	Panther Creek Partners	P	Approved
CA007	Scrubgrass Generating Station	P, AA, SS	Approved
CA009	Hatfield's Ferry Units 1, 2, and 3 (Bottom)	P	Approved
CA010	Wheelabrator Frackville Energy Company	P	Approved
CA013	Monongahela Power Co. Fort Martin Units 1 & 2 (Bottom)	P	Approved
CA014	PPL Montour	P	Approved
CA016	Sunbury Generation (Fly)	P	Approved
CA017 (QGP)	Northampton Generating Co.	P	Approved
CA020	Sunbury (Bottom)	P	Approved
CA022	Ebensburg Power	P, AA, SS	Approved
CA023 (QGP)	Piney Creek (Fly)	P, AA, SS	Approved
CA024 (QGP)	Piney Creek (Bottom)	P, AA, SS	Approved
CA025	Reliant Energy Seward (Fly)	P, AA, SS	Approved
CA026	Reliant Energy Seward (Bottom)	P, AA, SS	Approved
CA028	Fayette Thermal	P, AA, SS	Approved
CA029	Greensburg Thermal	P	Approved
CA030	AES Beaver Valley (Fly)	P	Approved
CA032	RC Cape May Holdings - B.L. England	P	Approved
CA033	Mt. Carmel Cogen, Inc.	P	Approved
CA034	WPS Westwood Generation, LLC - Westwood	P	Approved
CA035(S)	EME Homer City (CRDA #32753702)	P	Approved
CA036	Norfolk Southern - Juniata	P	Approved
CA037	Carney's Point Generating Station	P	Flagged
CA038	Northeastern Power Co.	P	Approved

* "Pending " indicates official approval is likely forthcoming. Source can not be used until approved.
"Flagged" indicates a potential problem with source and it should not be authorized for any new site. Contact DEP-BMR for further information.

Cert. No.	*Generator*	*Approved uses*	*Status **
CA039	PPL - Brunner Isl	P	Approved
CA040	Syracuse Energy Corp.	P	Flagged
CA041	Schuylkill Energy Resources - St. Nicholas	P	Approved
CA042	Logan Generating Plant	P	Flagged
CA043	AES Thames - fly	P	Approved
CA044	AES Thames - bed	P	Approved
CA045	Team Ten, LLC - American Eagle Paper Mills	P	Approved
CA046	Exelon - Eddystone fly ash	P	Approved
CA047	Exelon - Eddystone bottom ash	P	Approved
CA048	Exelon - Eddystone wet ash	P	Approved
CA049	Exelon - Cromby fly ash	P	Approved
CA050	PSEG Power Connecticut LLC - Bridgeport Harbor	P	Approved
CA051	Cargill Salt	P	Approved
CA052(S)	Consol Energy Bailey thermal dryers(CRDA#30810703)	P	Approved
CA053	AES Westover	P, AA, LP	Approved
CA054	Gilberton Power Co.	P	Approved
CA055	RRI Energy Titus Station	P	Approved
CA056	Cogentrix - Logan Station Bottom ash	P	Approved
CA0xx	Kimberly Clark	P	Pending
QGP	UGI Hunlock Station	P	Under DMO review

* "Pending " indicates official approval is likely forthcoming. Source can not be used until approved.
"Flagged" indicates a potential problem with source and it should not be authorized for any new site. Contact DEP-BMR for further information.

An Evaluation of Recent Allegations of Trace Metal Contamination At the McDermott and Ernest Mine Sites

Tim Kania, P.G.

4/14/2009

Introduction

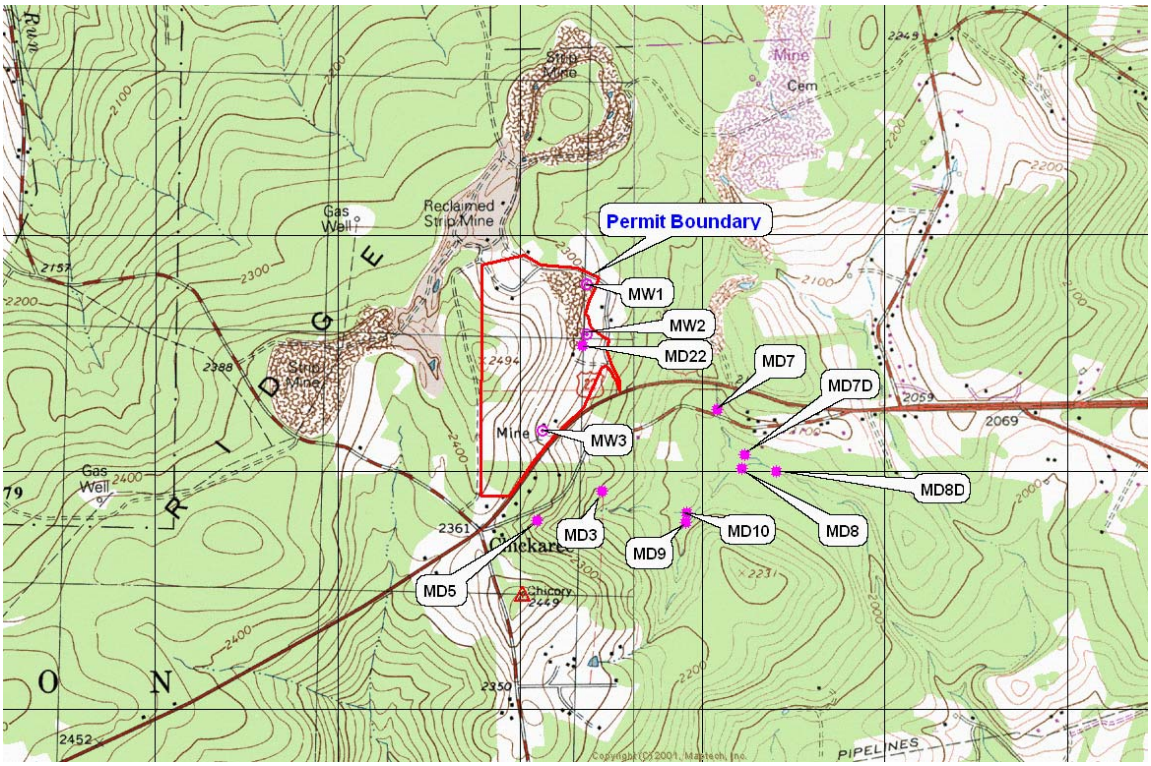
At a November 13, 2008 meeting at the Rachel Carson State Office Building Jeff Stant, representing Environmental Integrity Project, alleged trace metal contamination from coal ash at various mine sites in Pennsylvania, including the McDermott and Ernest sites. Mr. Stant demanded an immediate response from Department of Environmental Protection (DEP) staff. DEP staff present declined to respond without having had the opportunity to evaluate data pertinent to the allegations. The evaluation of the allegations is now completed for the McDermott and Ernest sites and the result follows. This response is limited to an analysis of the specific allegations made.

McDermott Site

The allegation here was one of off-site selenium (Se) contamination that exceeds aquatic-based sensitivity levels at monitoring point MD3. In evaluating the MD3 data it is first important to note that MD3 is not a stream or any other type of water body inherently capable of supporting aquatic life. Therefore, application of a criterion designed to protect aquatic uses is not appropriate. MD3 is a several-decades old, polluting, abandoned deep mine discharge that was documented to exist prior to the McDermott operation. Background data clearly establish the chemical nature of MD3, including that it typically has had a pH of less than 3.0 both before and after the McDermott operation.

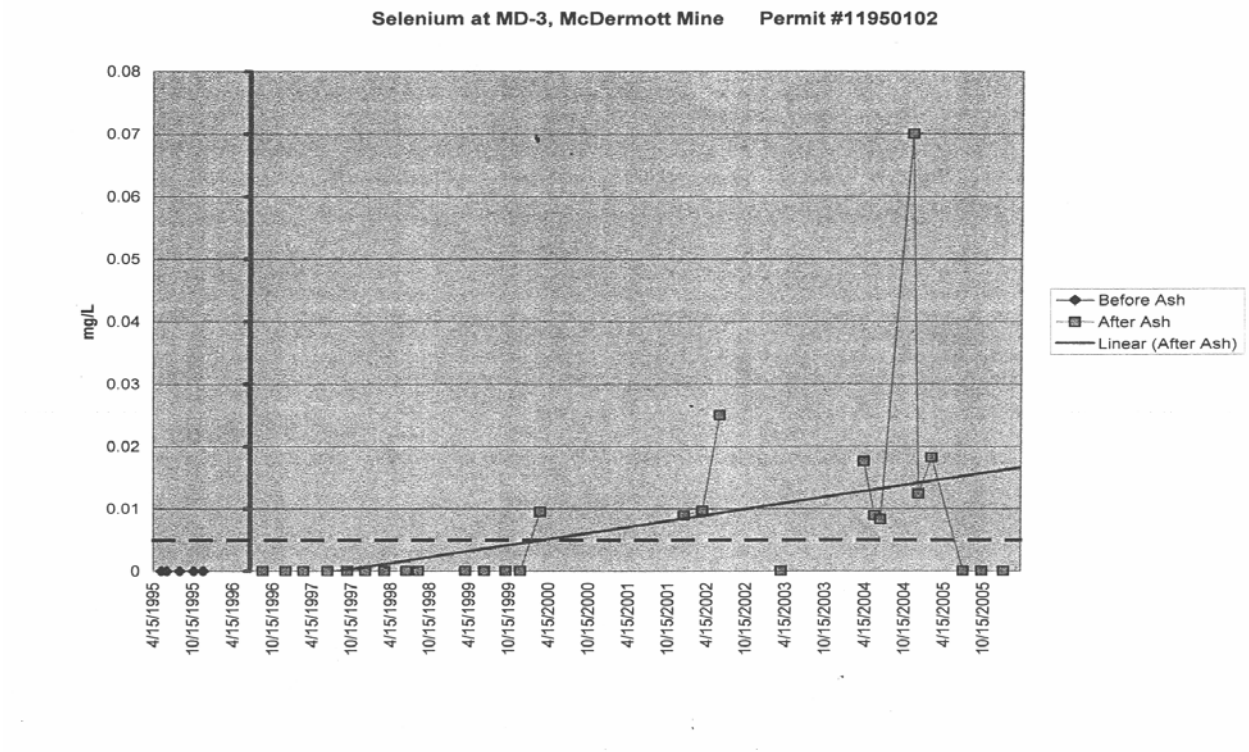
The location of MD3 relative to the McDermott site is shown on Map 1 along with other relevant monitoring points that will be discussed in this evaluation. Map 1 is a reproduction of the Nanty Glo, PA 7.5 minute topographic map with the referenced monitoring points and site boundary added.

The information presented to support the allegation was a graph that included a portion of the available data from MD3; Graph 1 is a scanned copy of that document.


Permit Boundary
MW1
MW2
MW3
MD22
MD7
MD7D
MD8D
MD8
MD10
MD9
MD3
MD5
Reclaimed Strip Mine
Strip Mine
Gas Well
Mine
Cem
Chicory
PIPELINES

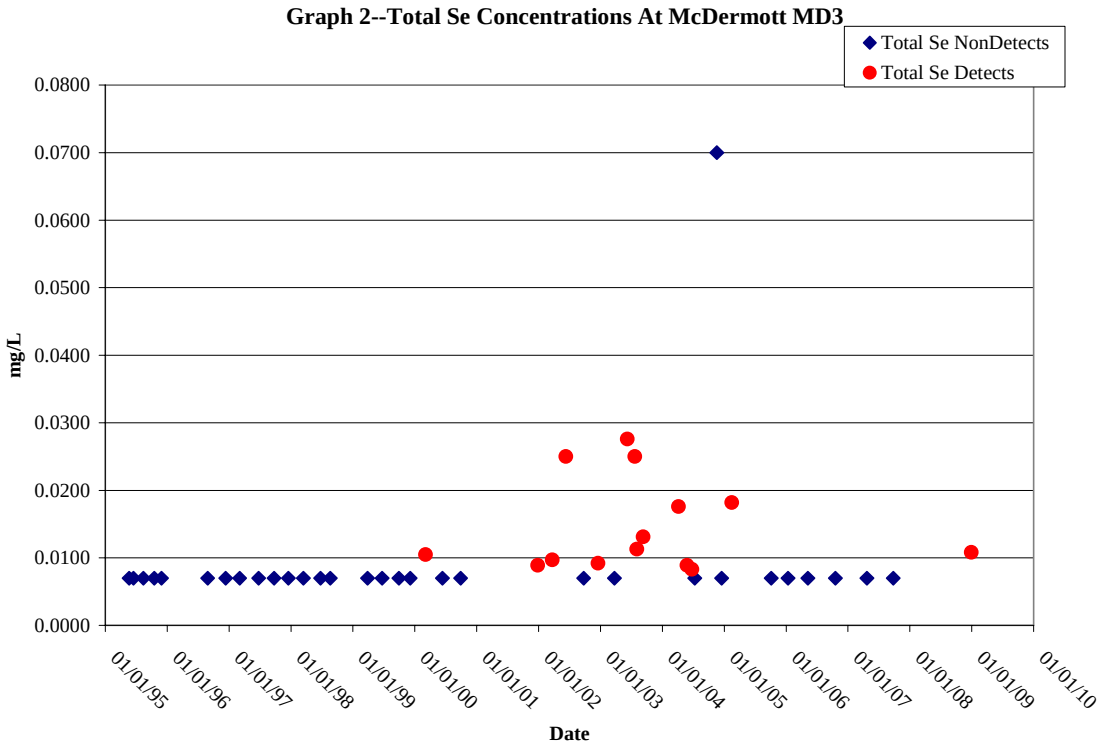
MAP 1

Graph 1


Selenium at MD-3, McDermott Mine Permit #11950102
mg/L
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
4/15/1995
10/15/1995
4/15/1996
10/15/1996
4/15/1997
10/15/1997
4/15/1998
10/15/1998
4/15/1999
10/15/1999
4/15/2000
10/15/2000
4/15/2001
10/15/2001
4/15/2002
10/15/2002
4/15/2003
10/15/2003
4/15/2004
10/15/2004
4/15/2005
10/15/2005
Before Ash
After Ash
Linear (After Ash)

In evaluating the MD3 Se data it is first important to note that the 70 ppb value reported on November 18, 2004 was the detection limit the lab was able to achieve on that particular sample; it is not an actual value. On Graph 1 the determination reported as a 70 ppb detection limit was treated as an actual value of 70 ppb, while determinations reported at a detection limit of 7 ppb were treated as zero values. If the detection-limit values were included in the calculation of the trend line on Graph 1, which it appears they were, then they contribute to the appearance of a steeply rising trend line.

Graph 2 is a graph prepared by DEP that includes the available total Se data for MD3. (Some dissolved Se values are also available at the McDermott site. The dissolved metal data were examined and considered as part of this investigation. However, they do not differ notably from the data for total Se and thus were not included on the graphs.) The data at MD3 show that much of the time Se values have been below the detection limit of 7 parts per billion (ppb) employed by the DEP laboratory. On Graph 2 and the other graphs of McDermott data presented in this response, data values that were reported as less than the detection limit are depicted with a different symbol than those that represent actual determinations to aid in understanding of the data.



The Se data at MD3 show that there were occurrences, mostly in the late 2002 to 2005 time frame, when the Se value at MD3 exceeded background levels. Over the past four years Se determinations have been mostly below the detection limit. Graph 1 includes only a portion of the available Se data up into early 2005 and does not include more recent data that help establish the return to background conditions. The coal operator that mined the McDermott site abandoned it early in 2003 leaving unreclaimed pits and coal ash open to weathering. Reclamation of the site began at the very end of 2005 under a contract between DEP and the insurer that had bonded the site. The cluster of data when Se levels at MD3 were above background seems to correspond to this period during which the site was not being maintained. These data do show Se levels during an approximate two-year period were elevated compared to background levels; however, these data do not support the allegations of contamination and a concern over an aquatic impact.

To be meaningful allegations of negative impacts must be tied to some concrete consequence. For example, used properly the concept of aquatic impact should indicate that an established aquatic life-based water quality standard for a stream is being violated *in that stream* or that biological surveys have demonstrated a negative impact. Contamination also should mean that some real standard such as a maximum contaminant level (MCL) in a water supply source or water quality standard in a stream has been violated. MCLs should never be applied as a contamination threshold to points that are not supplies, and in-stream standards should never be applied to sampling points that are not streams. The mere occurrence of a substance at detectable levels does not constitute contamination. It is also inappropriate to base claims of contamination, pollution or degradation on partial data sets, when examination of the entire data sets tells a different story.

There are much more Se data available at McDermott then those presented in Graph 1 that must be considered and discussed before an allegation of Se contamination can be either legitimately made or dismissed. Since the allegation here is an implied aquatic impact, an examination of in-stream Se determinations down gradient of the McDermott site is most appropriate. There are considerable such data available. These data were in the same file as the MD3 data, but apparently were not considered before the allegation of Se contamination was made. The available in-stream Se determinations at McDermott are included in the attached Table 1. These data show that 48 of the available 49 total Se determinations from stream samples collected downstream of the McDermott site are below the detection limit. Note that on the date that the one in-stream Se determination greater than the detection limit occurred another sample collected downstream showed a nondetect for Se. One occurrence above the detection limit out of 49 downstream Se determinations does not support an allegation of an aquatic impact, but soundly contradicts such an allegation.

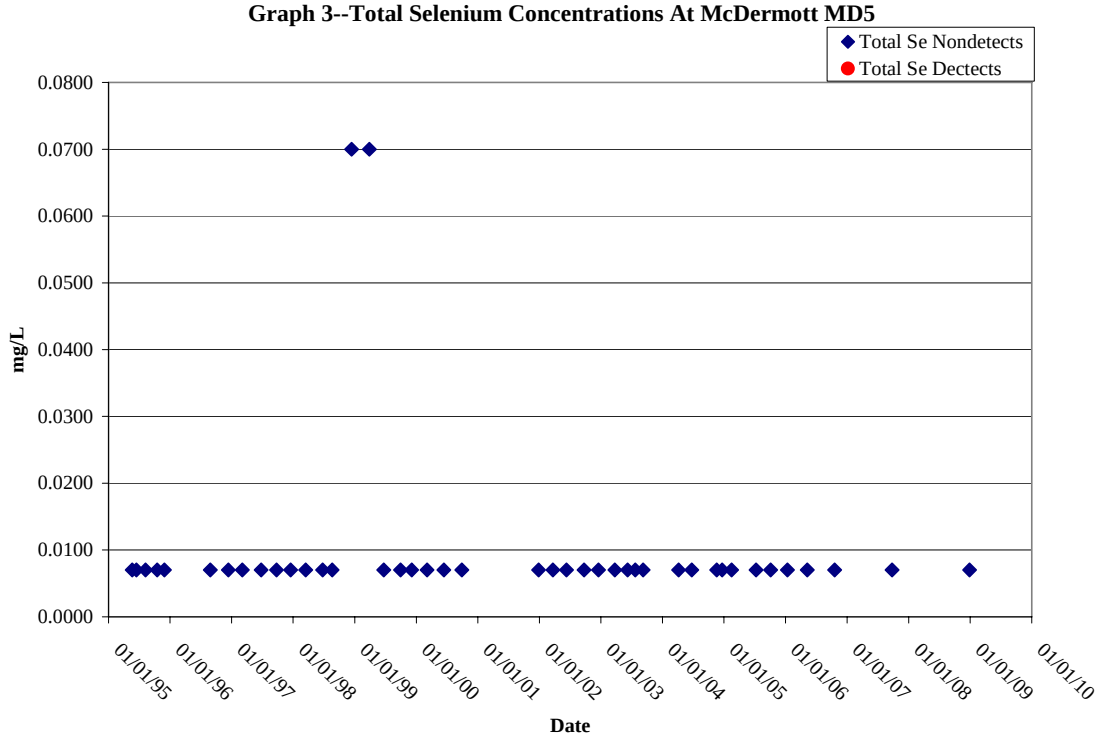
MD5 is the other off-site abandoned deep mine discharge monitored for the McDermott site. MD5 is believed to drain an area of deep mining on a seam mined on the McDermott site. The attached Graph 3 shows the available Se data for MD3. Every Se value is below the detection limit, including the two values shown at 70 ppb.

Table 1—In-stream Se Downstream of McDermott (mg/L)

Date	MD10	MD7	MD7D	MD8	MD8D
05/22/95				**0.0070**	
06/16/95		**0.0070**			
08/14/95		**0.0070**			
08/09/95				**0.0070**	
05/27/03			**0.0070**	**0.0070**	
07/15/03	0.0092		**0.0070**	**0.0070**	
04/07/04		**0.0070**	**0.0070**	**0.0070**	**0.0070**
05/27/04		**0.0070**	**0.0070**		
06/24/04		**0.0070**	**0.0070**	**0.0070**	
07/29/04		**0.0070**			
11/18/04		**0.0070**	**0.0070**	**0.0070**	
12/17/04		**0.0070**	**0.0070**	**0.0070**	
05/27/05		**0.0070**			
07/11/05		**0.0070**			
10/05/05		**0.0070**	**0.0070**	**0.0070**	
11/08/05		**0.0070**	**0.0070**	**0.0070**	
01/13/06			**0.0070**	**0.0070**	
05/10/06				**0.0070**	
10/19/06		**0.0070**			
04/23/07		**0.0070**			
09/26/07				**0.0070**	
12/29/08			**0.0070**	**0.0070**	

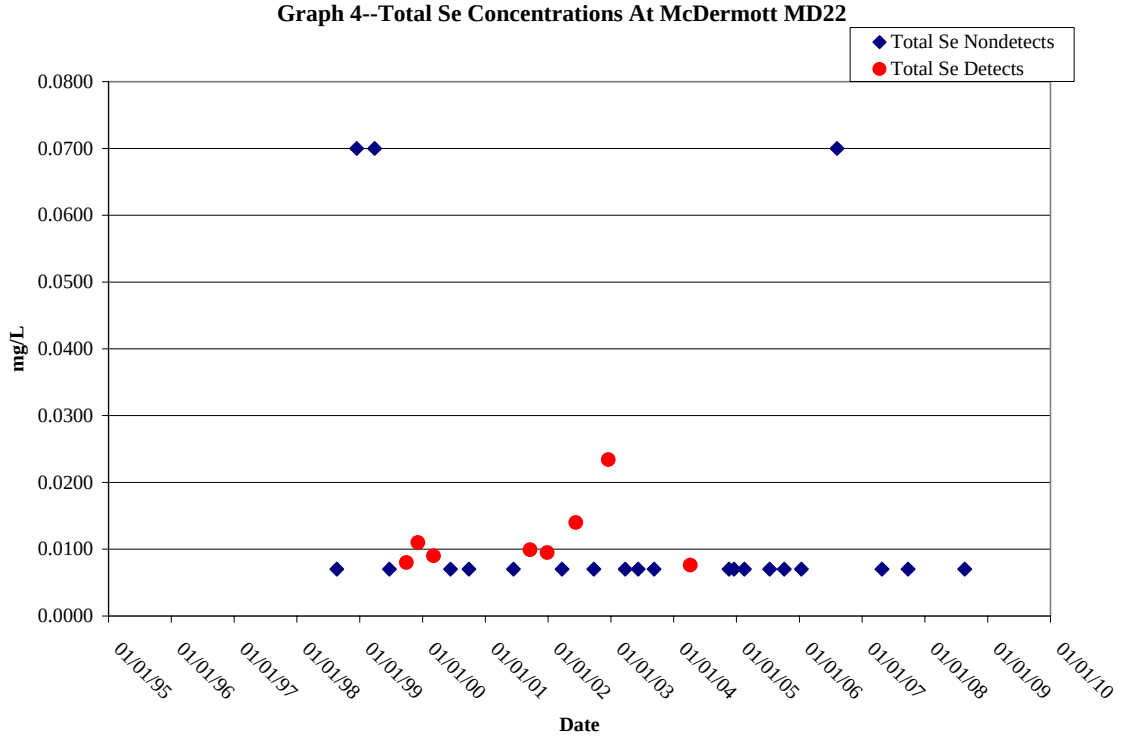
Values in **bold** are below detection.

Graph 3--Total Selenium Concentrations At McDermott MD5



MD22 is an on-site discharge from a limestone pit floor drain on McDermott. The water from MD22 emanates directly from the mine spoil/ash backfill. Graph 4 shows the available total Se data for MD22. These data do not show high Se values nor any trend of contamination. The Selenium values of 70 pbb are all detection limits as are all the values of 7 ppb. While there were occasions of detectable Se, none have occurred in the past 4 years and there is no evidence of a downstream elevation in Se levels.

Graph 4--Total Se Concentrations At McDermott MD22



MW1, MW2 and MW3 are monitoring wells drilled directly downgradient from the ash placement area on McDermott and on the permit area. As reported elsewhere by DEP these wells are very clearly directly hydrologically connected to mining and ash placement on McDermott. A review of the available total Se data on the 3 wells shows that **of the 117 available total Se determinations only 6 are above the detection limit of 7 pbb**. The highest reported value in any of the wells is 12 ppb, and no value greater than the detection limit has occurred in the last six years at these wells.

Over the years DEP has also collected Se data from other points at the McDermott site. These other miscellaneous points represent various springs, wetlands, culverts, and similar points on and around the site. Those data show that Se values in the springs and wetlands downgradient of McDermott are below 7 ppb. Onsite seeps sometimes produce Se results in the single-digit to low double-digit ppb range. All of these miscellaneous points as well as point MD22 report to stream points MD7, MD7D, MD8 and/or M8D where sampling has shown Se has not been detected. The data on all these points are available in the McDermott permit file alongside the data from MD3.

The allegation of Se contamination at McDermott was based on a graph of data from one monitoring point (MD3) that included 32 data points. However, the file from which those data were derived included 64 Se determinations for MD3, 44 total determinations and 20 dissolved determinations. The file also included approximately 650 Se determinations collected from over 20 sampling points. The Se data offered to support the allegation of contamination makes up only 5% of the available Se data readily available from the site file. That approach to data evaluation will nearly always lead to incorrect conclusions.

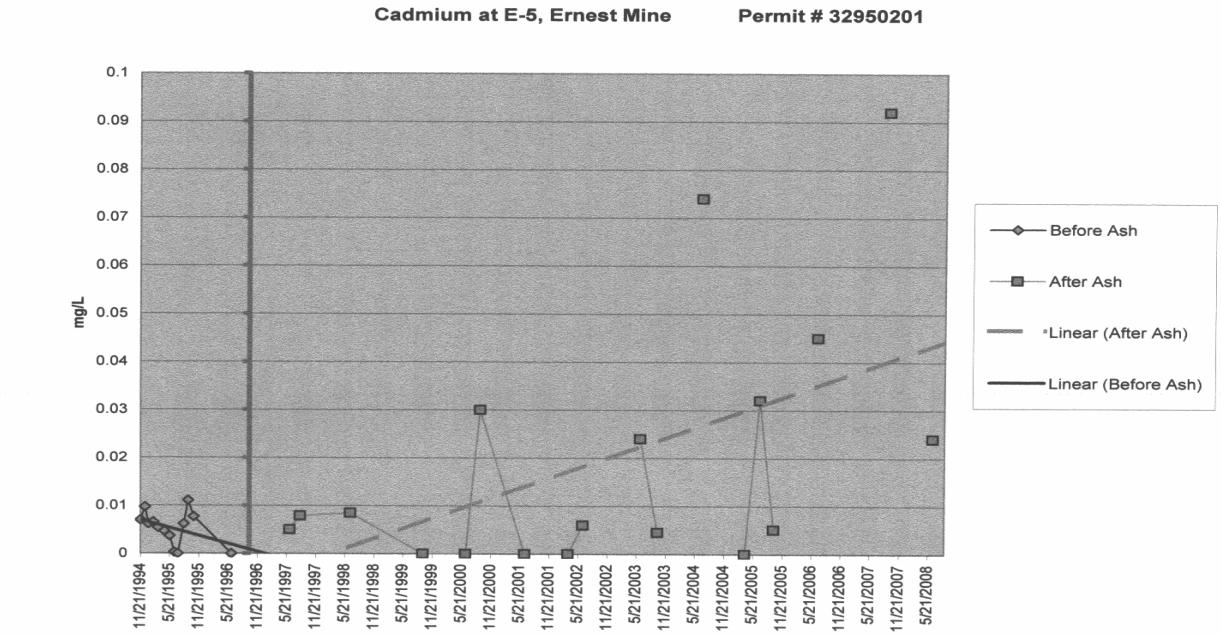
If the other 95% of the Se data were considered before making an allegation of contamination, one must answer several pertinent questions before reaching such a conclusion: 1) Why are the Se concentrations in the three on-site monitoring wells with a proven hydrologic connection to the ash placement area nearly all nondetects? 2) Why were data collected from MD3 after mid 2005 not included in the graph used to support the allegation of an off-site aquatic impact? 3) Why is Se contamination not evident in the water that emanates from the site pit floor drain (MD22 data shown in Graph 4)? 4) If the site has produced off-site contamination above an aquatic sensitivity threshold, which was the specific allegation, why were stream data not considered and why are 48 of the available 49 in-stream Se determinations nondetects? 5) Why are all 63 of the available Se determinations from MD5, the other abandoned deep mine discharge monitored for the McDermott site, nondetects?

In conclusion, a thorough review of available Se data at McDermott show that the allegations of Se contamination and an aquatic threat at McDermott are not only unsupported by the data, they are contradicted by the data. Downstream monitoring data, the appropriate place to look for potential aquatic impacts, show that Se levels have consistently been below the DEP laboratory detection limit of 7 ppb. The data from the three on-site monitoring wells and from the largest backfill discharge also show Se mostly below detection limits, with only an occasional determination with single-digit to low-double digit ppb Se. The allegation was based on only a portion of the available data from an abandoned off-site acid mine drainage discharge and other pertinent data were not considered. Even if one ignores the large amount of Se data from points other than MD3, which obviously is not appropriate, the data from MD3 when viewed alone does not demonstrate an off-site aquatic threat, as was alleged.

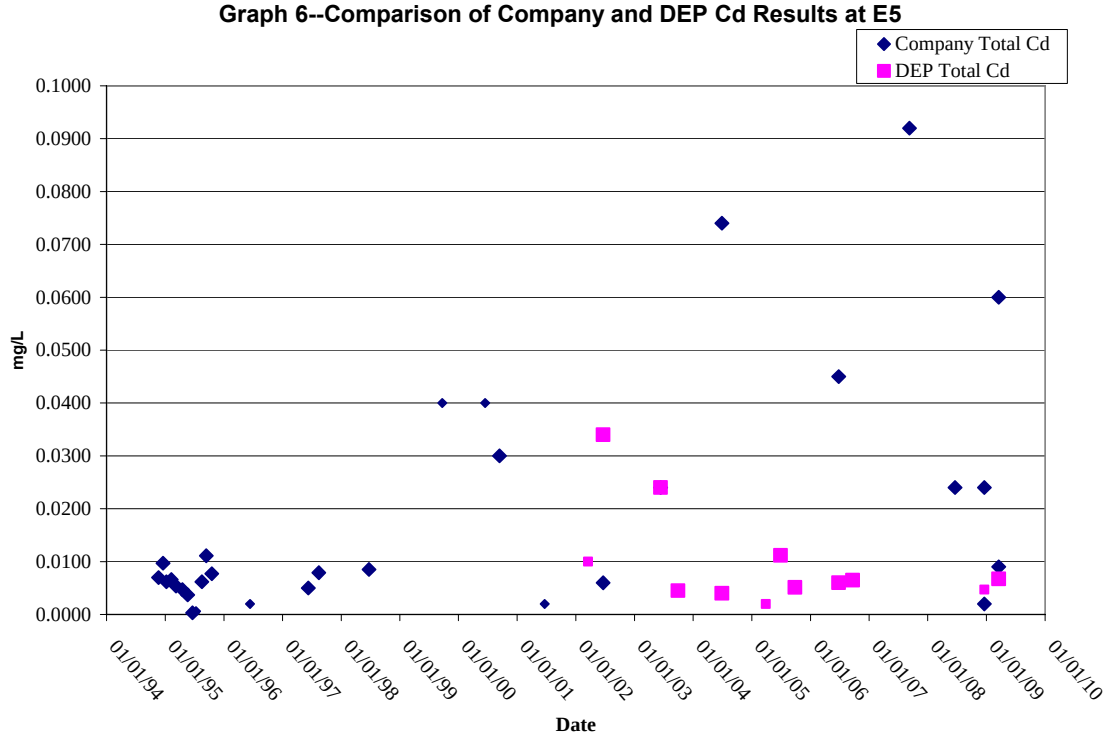
Ernest Site

The claim expressed regarding the Ernest site was that the ash placement has led to cadmium (Cd) contamination at monitoring points E5 and MW1. The evidence presented for E5 was a graph which has been scanned and is labeled as Graph 5.

Graph 5



Graph 6--Comparison of Company and DEP Cd Results at E5



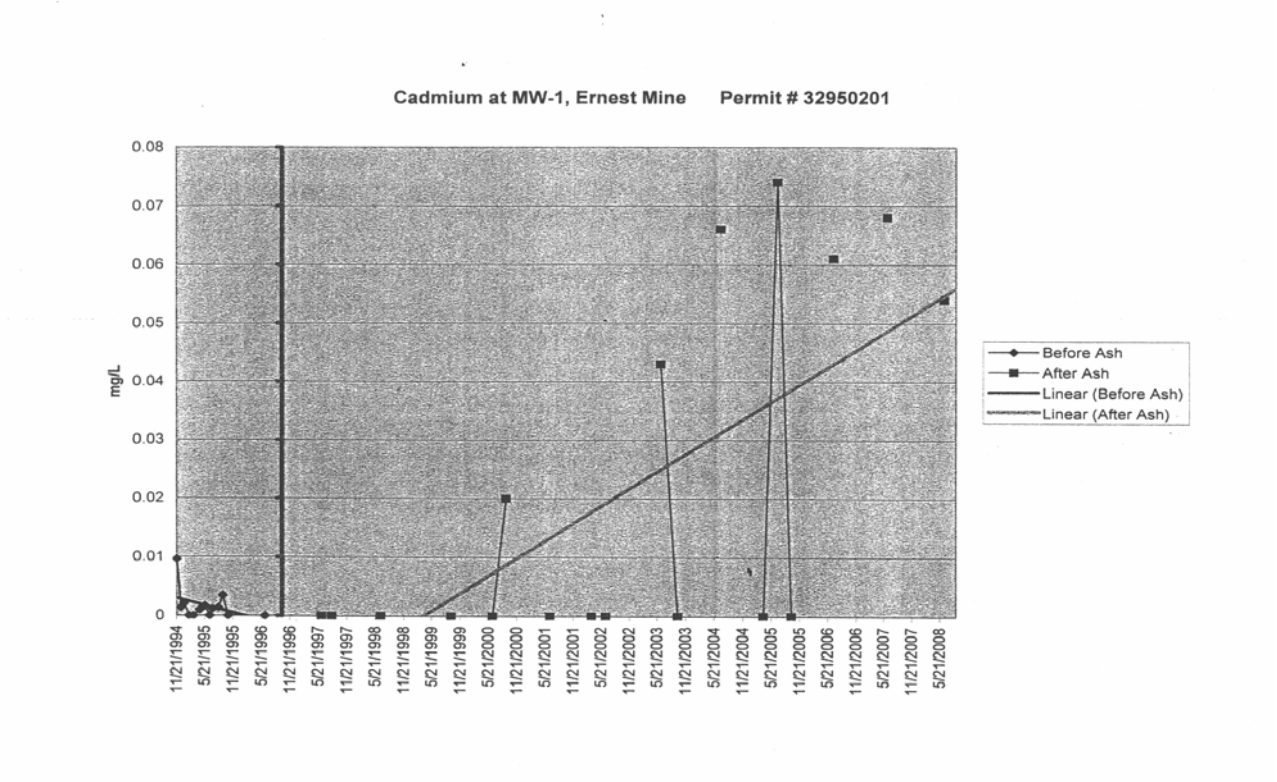
Graph 6 is a graph of all the available Cd data available at E5. A comparison between Graphs 5 and 6 shows that not all the available Cd data at E5 were considered in reaching the allegation that the data showed Cd contamination. With the exception of the data collected on December 19, 2008 and March 19, 2009, all of the data included on Graph 6 were available in the same file from which the data displayed in Graph 5 were obtained. On Graph 6 occurrences of Cd less than detection limits are denoted by smaller-sized symbols than the actual determinations. The data on Graph 6 show sampling conducted by the Department and sampling conducted by the mining company have not been producing comparable results for Cd. While the company data show that company-determined Cd levels have increased at E5, sampling conducted by the Department shows Cd remains at background levels. This contradiction raises legitimate questions, but it does not support an allegation of contamination, **and part of a data set should never be excluded from an evaluation**.

The data from E5 show that the abandoned coal refuse at the Ernest site leaches Cd at single-digit and low double-digit ppb levels; this conclusion is supported by the background data (pre-early 1996) that includes detectable Cd at those levels. The two occurrences of DEP Cd that are elevated relative to background (collected in late 2002 and early 2003) correspond with the time period when there was elevated acidity discharging at E5, likely due to disturbance of the abandoned refuse by the re-mining operation. Over the last five years the DEP Cd determinations are unchanged from the background data. Please note that two company-determined Cd values of 40 ppb reported in 1999 and 2000 are occurrences where the laboratory reported a detection limit of 40 ppb.

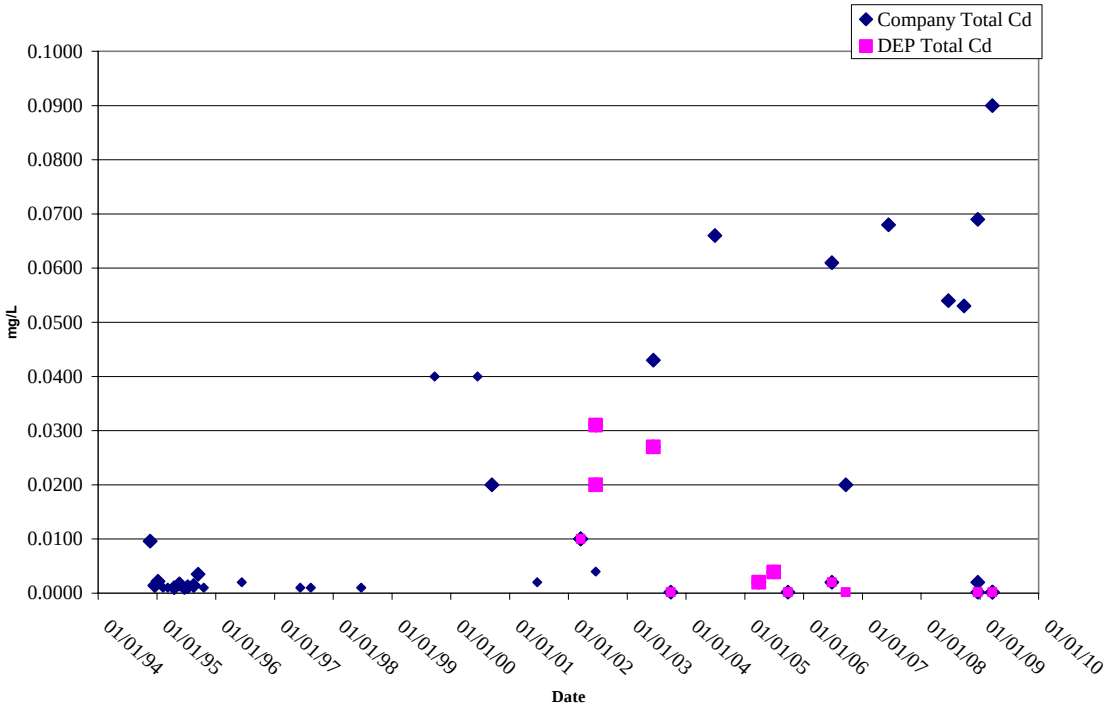
Graphs 7 and 8 show a pattern of Cd data for MW1 very similar to that for E5. Graph 7 is a scanned copy of the graph presented to support the allegation of Cd contamination at that point. Graph 8 shows that recent Department data are similar to background levels. The elevated Department data in 2002 and 2003 corresponds temporally to the similar occurrence in E5, which may be the result of the increased mine drainage (acidity) levels during that time period. Please note that two company-determined Cd values of 40 ppb reported in 1999 and 2000 are occurrences where the laboratory could only report a detection limit of 40 ppb. As with E5, the company Cd data and DEP Cd data from recent years are not comparable.

The Cd concentrations at the other Ernest downgradient monitoring point, well MW2, were not mentioned in the allegation of Cd contamination but were evaluated by DEP none-the-less. While Cd levels in MW2 are typically lower than in either MW1 or E5, the same general pattern applies. Recent DEP data are comparable to background; recent company data are not.

Graph 7



Graph 8--Comparison of Company and DEP Cd Results at MW1



On December 19, 2008 and March 19, 2009 the Department conducted simultaneous sampling with Cambria Reclamation Corporation to help evaluate the discrepancy in the two entities' results. On both dates a third sample was simultaneously collected from each of the points and was sent to a third laboratory. The results of those three-way sampling events for E5 and MW1 are included on Graphs 7 and 8. For each sample point the DEP laboratory and the third private laboratory produced comparable Cd results on both dates, while the laboratory used by Cambria Reclamation produced much higher results. These two sampling events suggest that the elevated Cd in the company data for E5 and MW1 at Ernest may be related to sampling and/or analytical issues. For example the total Cd concentrations reported from MW1 for the March 19, 2009 three-way sampling event were as follows: company monitoring, 90.0 ppb; DEP lab, <0.2 ppb; third-party lab, <0.2 ppb.

In order to further define and understand the data additional future split sampling events will be conducted. Also, additional monitoring at new points and at an increased frequency will take place.

There are some other DEP data available from the Ernest site that cast further light on Cd occurrence at the site. The attached Table 2 includes data that the Department collected from E52 during 2005. E52 is a point through which most of the drainage from the abandoned coal refuse at the Ernest site flows; the water from E5 flows through point E52. The data for E52 are included in Table 2. As is typical for water leaching from abandoned bituminous coal refuse piles, the E52 water is severe mine drainage and includes detectable levels of some trace metals. However, note that the highest Cd level reported is 1.2 ppb, which is less than most of the background data from E5 and MW1.

During 2005 and 2006 the Department was able to collect samples of water that was runoff from partially reclaimed areas of ash placement at Ernest. This point is identified as "White Pipe" on sample sheets. Because of on-going site development, this point became more difficult to sample with time, but the Department was able to obtain a sample from it on March 19, 2009. While there was some coal refuse encapsulated in the ash up gradient of the White Pipe, the point was physically separate from the large mass of abandoned coal refuse. The results of available samples at the white pipe are shown in Table 2 along with the data from E52.

Because the White Pipe data is little influenced by the abandoned coal refuse, a comparison of the data from E52 and the White Pipe provides interesting and valuable insight to the differences between water running off of and leaching from abandoned coal refuse at Ernest and water running off of the FBC ash at Ernest. First, since Cd was the parameter of concern in the recent contamination allegation, it should be noted that each of the six Cd values collected over a period of two years of direct runoff from the ash placement area is less than the detection limit of 0.2 ppb.

In terms of its general character, the ash-associated water (White Pipe) has a somewhat elevated pH but modest alkalinity; potassium concentrations are very high when compared to E52, or other coal refuse leachate such as that found in E5. These elevated

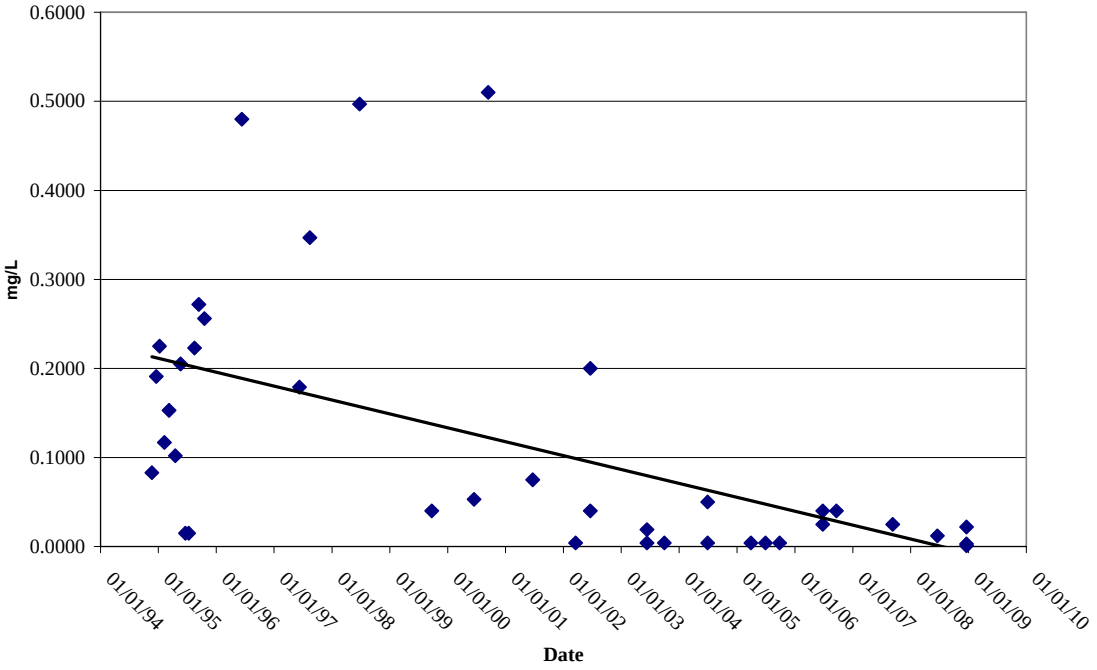
potassium levels in the high double digit to triple digit part per million (ppm) range seem to be characteristic of waters heavily influenced by FBC ash. This conclusion is based on observations of water quality from FBC ash derived from waste coal primarily from Cambria, Indiana and Somerset Counties, PA. It is important to note, however, that one cannot immediately assume that any sample showing elevated potassium levels owes its entire character to coal ash. As is always the case the interpreter of the data needs to place the sample result in the context from which the sample was collected, a critical and fundamental step that investigators of ash beneficial use sites often seem to overlook.

The Ca levels in both the acid mine drainage and the moderately alkaline ash water are both elevated and approximately the same. (Ca is generally not a good indicator parameter for FBC ash when it has been placed on a mine site because Ca levels are almost always elevated in mine drainage from Pennsylvania bituminous coal mines.) Magnesium levels are higher in the mine drainage water as compared to the ash runoff. Sulfate concentrations are elevated in the ash water, but not nearly as high as in the coal refuse runoff. The detectable levels of some trace metals, especially nickel, zinc, lead, and arsenic occur more frequently in the refuse water than in the ash water. The lone exception is Se. Five of the available seven Se levels from the White Pipe are nondetects and the other two are 7.1 and 13.1 ppb, while none of the samples from E52 show detectable Se. (The White Pipe is not aquatic habitat, and the levels and frequency of Se seen there does not constitute contamination.) The White Pipe water is clearly of a different character from the water that leaches from the abandoned coal refuse at Ernest, it is more heavily influenced by ash than refuse, and there has been no detectable Cd at that point.

DEP has also collected water samples for coal ash parameters from various other locations on the Ernest site over the past few years. Some of those samples show detectable Cd downgradient of areas where abandoned coal refuse has been recently disturbed.

It is possible for one parameter to change while all the others stay the same, but that is more the exception than the rule. For that reason and others it is not good practice to base allegations on examination of only one parameter. The E5 data from Ernest provide an interesting demonstration of that point. The attached Graph 9 includes all the available Arsenic (As) data from Ernest point E5. A simple trend line has been added. Compare Graph 9 to Graph 5.

Graph 9--Arsenic At E5



Applying the same interpretive rationale used to arrive at the allegation of that coal ash has led to Cd contamination, one would have to conclude that coal ash has led to an improvement in As concentrations at E5. However, at this point in the operation, that conclusion is not likely to be correct. The water quality at E5 is characteristic of leachate from abandoned coal refuse, and appears chemically unaffected to date by FBC ash. The abandoned coal refuse at the Ernest site leaches As. The Ernest operation has removed several million tons of abandoned coal refuse from the recharge area of E5; that is one factor that has likely contributed to the apparent decrease in As discharge from the site. Another factor that cannot be discounted is historic problems with the consistency of the data generated by the company monitoring at this site. Graph 9 includes both company and DEP data, but the background data (pre-mid 1996) are all company data. The factors that cause an objective evaluator of the data to not assume a cause-and-affect relationship between ash placement and an As decline at E5 do not allow an objective evaluator to assume such a relationship between Cd levels and ash placement at the site.

The comparison of the E5 data for Cd and As demonstrates why one should not choose only one parameter to represent a sampling point. Such an approach opens up very appropriate questions such as: 1) How and why was Cd chosen as the lone representative parameter? 2) Was the As data examined prior to the allegation of contamination, and, if so, would not a fair evaluation include an acknowledgement of the As data and consideration of why the company data for the two parameters trend in opposite directions?

Given these considerations, the available data do not support the allegation that there is historic or on-going Cd contamination from ash placement at the Ernest site. The allegation can only be made by not considering the data collected by DEP. It is never valid to base an allegation on only a portion of a data set. A comparison between company data and DEP data show a clear discrepancy between DEP data and company data.

Background sampling shows that the abandoned coal refuse at Ernest has the ability to leach Cd in the single digit to low double digit ppb range. Sampling conducted by DEP at points affected by recently-disturbed coal refuse shows detectable Cd in some cases. However, a discharge affected by the ash placement area, when sampled by DEP, consistently had a Cd concentration less than the detection limit of 0.2 ppb. Two three-way sample events showed that the laboratory used by the company for their recent monitoring did not produce Cd data comparable to DEP and a third lab. These factors strongly suggest that the elevated Cd seen in the company monitoring data have an explanation other than ash placement. Further testing and evaluation is underway that should reveal the reasons for the discrepancy between the company Cd data and DEP Cd data.

Conclusion

A thorough review of the monitoring data from the McDermott and Ernest sites reveals that the allegations concerning Se at McDermott and Cd at Ernest are not valid. Se data at McDermott do not support the allegation that the site has led to off-site Se levels that threaten aquatic resources; in fact the data strongly contradict that conclusion. The allegation of Cd contamination was made excluding DEP-collected data from the evaluation. The data do reveal a discrepancy between monitoring results produced by the permittee and those produced by DEP. A further evaluation of that discrepancy is underway and thus far suggests sampling and/or analytical reasons behind the discrepancy.

TABLE 2
E52 AND THE WHITE PIPE

Table 2. Water quality data for the "White Pipe" and E52 at the Ernest Mine Site

WHITE PIPE

Date	Flow (GPM) or Static Water	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Dissolved Iron (mg/L)	Total Iron (mg/L)	Dissolved Mn (mg/L)	Total Mn (mg/L)	Dissolved Al (mg/L)	Total Al (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Dissolved Sodium (mg/L)	Total Sodium (mg/L)	Dissolved Potassium (mg/L)	Total Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved B (mg/L)	Total B (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)
06/30/05	20.0		7.50	1971	39.8	-29.6		**0.02**		**0.010**	0.433	**0.200**	1090		22.80		21.80		133.00	1816	***2.0***								0.0055	0.0053			0.005	
07/28/05			7.60	2070	50.0	-30.6		0.04		**0.010**		**0.200**					23.90		155.00	1924	10.0									**0.0040**				
10/26/05			7.10	1559	75.6	-49.2		**0.02**		**0.010**		**0.200**	943		14.90		21.10		125.00	1752	6.0									**0.0040**				
01/30/06			7.00	1345	37.2	-24.6		**0.02**		0.022		**0.200**	667		15.70		16.00		81.20	1124	12.0									**0.0040**				
02/22/06			7.20	1745	32.6	-21.6		**0.02**		**0.010**		**0.200**	930		21.10		20.60		109.00	1500	6.0									**0.0040**				
06/28/06			7.20	1583	39.0	-35.0		1.03		**0.010**		**0.200**	787				18.50		108.00	1386	2.0									**0.0080**				
03/19/09			6.90	1233	34.4	-20.0	**0.02**	**0.02**	**0.01**	**0.010**	**0.200**	**0.200**	647			13.29	13.02	67.57	68.20	1072	**5.0**						**0.010**	**0.010**	**0.0030**	**0.0030**	**0.2000**	**0.2000**	**0.010**	**0.010**

Date	Dissolved Be (mg/l)	Total Be (mg/l)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Co (mg/L)	Total Co (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Mo (mg/l)	Total Mo (mg/l)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Sb (mg/L)	Total Sb (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Tl (mg/l)	Total Tl (mg/l)	Dissolved V (mg/l)	Total V (mg/l)	Dissolved Zn (mg/L)	Total Zn (mg/L)		
06/30/05			**0.0002**	**0.0002**	356.00	344.00			***0.0500***	**0.0500**	0.018	**0.010**	**0.0010**	**0.0010**	4.61	4.52			**0.0500**	**0.0500**	**0.0010**	**0.0010**			0.0075	0.0071					0.010	0.010		
07/28/05				**0.0002**		401.00				**0.0500**		**0.010**		**0.0010**		4.04				**0.0500**		**0.0010**				**0.0070**						0.070		
10/26/05				**0.0002**		310.00				**0.0500**		**0.001**		**0.0010**		9.53				**0.0500**		**0.0010**				**0.0131**						**0.010**		
01/30/06				**0.0002**		233.00				**0.0500**		**0.010**		**0.0010**		12.10				**0.0500**		**0.0010**				**0.0070**						**0.010**		
02/22/06				**0.0002**		309.00				**0.0500**		**0.010**		**0.0010**		9.13				**0.0100**		**0.0010**				**0.0070**						**0.010**		
06/28/06				**0.0002**		299.00				**0.0500**		**0.010**	.	**0.0010**		5.78				**0.0500**		**0.0010**				0.0140						**0.010**		
03/19/09	**0.001**	**0.001**	**0.0020**	**0.0002**	216.00	216.00	**0.05**	**0.05**	**0.0500**	**0.0500**	**0.010**	**0.010**	**0.0010**	**0.0010**	9.86	9.51	**0.07**	**0.07**	**0.0500**	**0.0500**	**0.0010**	**0.0010**	**0.002**	**0.002**	**0.0070**	**0.0070**	**0.0020**	**0.0020**	**0.020**	**0.020**	**0.010**	**0.010**		

E52

Date	Flow (GPM) or Static Water	Field pH (Standard Units)	Lab pH (Standard Units)	Specific Conductivity (umhos/cm)	Alkalinity (mg/L)	Acidity (mg/L)	Dissolved Iron (mg/L)	Total Iron (mg/L)	Dissolved Mn (mg/L)	Total Mn (mg/L)	Dissolved Al (mg/L)	Total Al (mg/L)	SO4 (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Dissolved Sodium (mg/L)	Total Sodium (mg/L)	Dissolved Potassium (mg/L)	Total Potassium (mg/L)	TDS (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Bicarbonate (mg/L)	Turbidity (NTU)	Chemical Oxygen Demand (mg/L)	Dissolved Ag (mg/L)	Total Ag (mg/L)	Dissolved As (mg/L)	Total As (mg/L)	Dissolved B (mg/L)	Total B (mg/L)	Dissolved Ba (mg/L)	Total Ba (mg/L)
03/20/05			3.40	965	0.0	339.8		74.90		1.48		29.70	461		6.60		4.74		2.79	868	4.0									**0.0040**				
09/27/05			3.10	4520	0.0	2516.0		628.00		32.70	209.00	228.00	3608		14.70		20.20		10.88	6712	32.0								**0.0040**	0.0040				
09/28/05			3.10	4750	0.0	2782.8				33.80		274.00	3640		12.50		16.10		11.50	7104	34.0									0.0045				
10/26/05	6.1		3.70	1504	0.0	540.0		128.00		7.71		56.30	1072		4.00		4.70		3.10	1708	**2.0**									**0.0040**				

Date	Dissolved Be (mg/l)	Total Be (mg/l)	Dissolved Cd (mg/L)	Total Cd (mg/L)	Dissolved Ca (mg/L)	Total Ca (mg/L)	Dissolved Co (mg/L)	Total Co (mg/L)	Dissolved Cr (mg/L)	Total Cr (mg/L)	Dissolved Cu (mg/L)	Total Cu (mg/L)	Dissolved Hg (mg/L)	Total Hg (mg/L)	Dissolved Mg (mg/L)	Total Mg (mg/L)	Dissolved Mo (mg/l)	Total Mo (mg/l)	Dissolved Ni (mg/L)	Total Ni (mg/L)	Dissolved Pb (mg/L)	Total Pb (mg/L)	Dissolved Sb (mg/L)	Total Sb (mg/L)	Dissolved Se (mg/L)	Total Se (mg/L)	Dissolved Tl (mg/l)	Total Tl (mg/l)	Dissolved V (mg/l)	Total V (mg/l)	Dissolved Zn (mg/L)	Total Zn (mg/L)		
03/30/05				**0.0002**						**0.0500**		**0.010**		**0.0010**		12.00				0.134		**0.0010**				**0.0070**						0.339		
09/27/05			**0.0002**	**0.0002**	376.00	409.00			**0.0500**	**0.0500**	**0.010**	**0.010**	**0.0010**	**0.0010**	136.00	147.00			1.099	1.175	0.0066	0.0067			**0.0070**	**0.0070**					2.390	2.540		
09/28/05				**0.0002**		442.00				**0.5000**		**0.010**		**0.0010**		165.00				1.160		0.0079				**0.0070**						2.720		
10/26/05				0.0014		134.00				**0.0500**		**0.010**		**0.0010**		44.00				0.091		0.0015				**0.0070**						0.727		

Numbers in bold are below detectior

Numbers in bold print denote values =/< the detection limit.

Pennsylvania Department of Environmental Protection Response to Clean Air Task Force Report: "Impacts On Water Quality From Placement Of Coal Combustion Waste In Pennsylvania Coal Mines"

DEP Bureau of Mining and Reclamation
DEP Bureau of District Mining Operations

November 9, 2007

In September 2007, the Clean Air Task Force (CATF) released a report entitled "Impacts on Water Quality from Placement of Coal Combustion Waste in Pennsylvania Coal Mines" based on its investigation of Pennsylvania practices of utilizing coal combustion material (coal ash) for beneficial uses throughout the state. The report contains many allegations that beneficial use of coal ash at numerous mine placement sites has caused pollution. The Department has prepared this response to that document.

Introduction

Pennsylvania coal fueled this country's industrial revolution. At that time there were no environmental regulations that required the mined land be reclaimed or the water to be protected. This legacy has left 189,000 acres of abandoned mines, over 200 miles of highwalls, thousands of miles of polluted streams, and large areas of contaminated groundwater. There are also over 800 coal refuse piles encompassing more than 8,500 acres. These abandoned mine features are dangerous and deadly. Correction of these problems would cost over 10 billion dollars. Pennsylvania is employing a variety of approaches to address this legacy; among them is the beneficial use of coal ash.[1]

Pennsylvania currently generates more than half its electricity from coal. When coal is burned ash remains and this ash has to go somewhere. There is a special type of power plant that can burn coal refuse. These plants utilize a technology known as fluidized bed combustion (FBC). FBC plants alone burn 10 million tons of coal refuse per year. Power plants that burn coal refuse produce a higher percentage of ash than other types of power plants because much of the fuel is rock that does not burn, plus these plants add limestone to the boiler to prevent air pollution. The limestone adds to the volume of ash, but it also imparts alkalinity to FBC ash.

In the mid-1980s, the Pennsylvania Department of Environmental Protection began to approve coal ash utilization for mine reclamation. Coal ash is used where alternate fill and cover material is either unavailable in adequate volumes or uneconomical. Coal ash is also a low-permeability, high-alkaline material that can be transported in large quanti-

[1] Sources for these figures are: Dalberto, A.D., et al., 2004. Chapter 1. Overview: Coal ash beneficial use and mine land reclamation. In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. PA DEP and Penn State Materials Research Institute; National Abandoned Land Inventory System, 2003. Pennsylvania Department of Environmental Protection, Harrisburg, PA; and EPA, 2001. Coal Remining – Best Management Practices Guidance Manual, EPA-621-8-01-010.

ties. Because coal-fired power plants are often near the coalfields, ash is readily available in the vicinity of the abandoned mine lands. Ash is often returned to the area from which the coal refuse was extracted, thus substituting an alkaline material for an acidic material.

When an applicant proposes to use a source of coal ash for beneficial use in Pennsylvania, extensive chemical testing is required of the ash to determine concentrations of elements that might cause environmental problems. The Department has guidelines for permissible concentration levels. For example, the ash must have a pH value between 7 and 12.5, aluminum must be below 5 mg/l in water passed through the ash (leached) and arsenic must be below 1.25 mg/l. Twenty-one different parameters are used to assess the dry ash composition and the leachate characteristics. If an ash exceeds the limits, it cannot be used beneficially and must be disposed in a lined facility.

To approve a location that can accept ash for beneficial use, the Department reviews the geology and hydrology of the mine site to assure that the ash can be placed in an environmentally safe manner. If the Department determines that placement of ash at a mine would create a problem (either because of the site or the ash quality), the proposal is rejected. This approach has resulted in an effective program in which coal ash has been used to safely reclaim mine sites.

Because the main beneficial use for coal ash has been placement at mine sites for reclamation, it is imperative to understand the environment into which the material is placed. Foremost, one must recognize the historical legacy discussed above. The surface water and groundwater in the coal regions can be severely impacted by acid mine drainage (AMD). AMD renders the local groundwater undrinkable and regional streams hostile to native aquatic life. Common characteristics of mine drainage are low pH (<6.0, frequently as low as 3.0); high concentrations of metals such as iron, manganese, aluminum, lesser concentrations of zinc, nickel, selenium and other metals; and high concentrations of sulfate. Iron, manganese and aluminum can be at concentrations in tens of parts per million, and occasionally over 100 parts per million. The other metals can occur up to a few parts per million. Sulfate is typically hundreds to thousands of parts per million. But, not all mine drainage is acidic and not all has high metals.

The environment for ash placement typically consists of abandoned mine features such as coal refuse (waste rock associated with coal) piles, and mine pits and underground workings – areas that are often polluted by mine drainage. These features provide a means by which precipitation and clean surface waters can become polluted by interacting with acid-producing minerals to generate more AMD. Through the use of coal ash these old mines can be restored to productive land and reduce the amount of pollution coming from the old mines. Many of the sites reclaimed with coal ash would not likely be otherwise reclaimed.

Most of the allegations made by the CATF in its report are a rehash of issues raised by CATF associates in the past. These have been time after time examined through Department investigations and found to be erroneous. The CATF is an advocacy organization that had stated its opposition to the beneficial use of coal ash combustion products repeatedly to the public prior to the investigations documented in their report. This response to the CATF report demonstrates, once again, that the CATF allegations of pollution from ash are seriously flawed. This response will not attempt to address every de-

tail raised in the CATF report, but will point out why there are differences in interpretation and conclusions between the CATF and the Department.

DEP's Success at Preventing Mine Drainage Pollution

AMD is now largely a historical problem rendered by past mining. Modern laws require reclamation of mined lands and prevention of pollution. Beginning in about 1979, permit applicants began to include scientific data that was used to assess the site potential to generate AMD. The Department's ability to interpret these data has improved dramatically through time. A science-based approach to permitting and an emphasis on preventing AMD has been very effective in minimizing the incidence and severity of new discharges. Figure 1 shows the percentage of mine sites, through time, that resulted in polluted discharges. In comparison to the 1970s and early 1980s, few modern permits are issued that result in a problem. Department studies have shown that even those sites that do have problems are not nearly as severe as what occurred long ago.

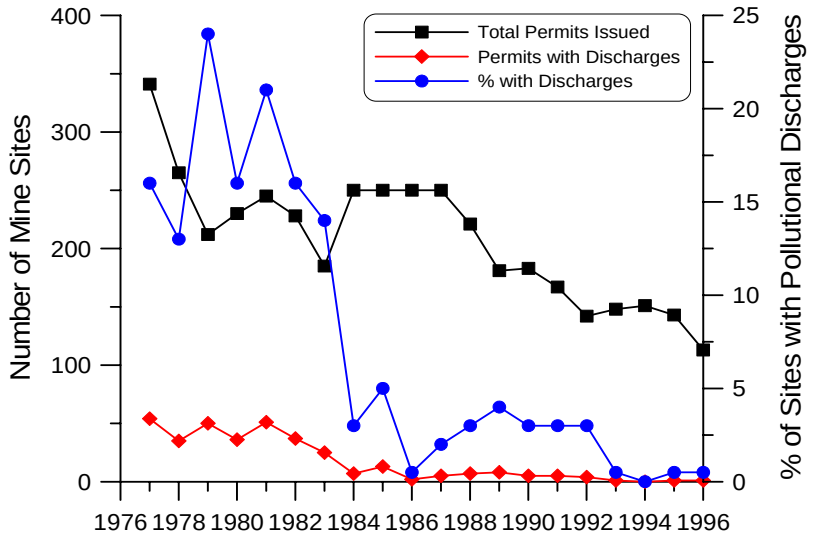


Figure 1. Graph showing improved permit decision making through time for permitting of surface coal mines. Data from: *Evaluation of Mining Permits Resulting In Acid Mine Drainage 1987-1996: A Post Mortem Study*". [2]

The Department uses a variety of tools in its decision-making process. These tools are described in the book "*Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*."[3] It is this toolbox that has resulted in Pennsylvania's ability to successfully predict and prevent post-mining water quality problems.

Along the same theme, the Department, in cooperation with the Materials Research Institute of the Pennsylvania State University, documented the results of coal ash utilization in a 2004 publication, "*Coal Ash Beneficial Use in Mine Reclamation and Mine*

[2] Available online at http://www.dep.state.pa.us/dep/deputate/minres/districts/AMDPostMortem.htm#Appendice
[3] Available online at: http://www.ott.wrcc.osmre.gov/library/pub/cmdpppp.htm and http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/main.htm

Drainage Remediation in Pennsylvania". [4] For this book, the Department and Penn State studied numerous sites (some of which were also examined by CATF) in both anthracite and bituminous coal fields that had conventional ash placement and experimental trials, called demonstration projects.

All beneficial use sites require background data on the ash quality and groundwater quality. The ash is analyzed in a dry state (bulk analysis) and via a leaching procedure. The leaching procedure is to determine what the water contains after it percolates through the ash material, potentially picking up and removing any constituents from the ash. The water from this leachate and at groundwater monitoring sites is analyzed for a wide spectrum of potential contaminants. These data were evaluated using various scientific and statistical methods.

The Department staff in the District Mining Offices looks for trends in the groundwater data to determine if degradation is occurring. A trend is identified when the data set shows a statistically detectable tendency to move in a specific direction, such as a rising concentration over time. If a trend is found, it must then be determined if it is a result of the many variables that play a part in water quality changes in the system or to the placement of the coal ash.

One-time anomalous water quality readings are common. These occur because samples are collected and analyzed by humans. There are many causes for "wacky data" that have nothing to do with pollution. The causes are described below under the discussion on outlier data points. A single value does not constitute a trend. If the data exhibits a genuine trend in a constituent that is attributable to the ash, the Department acknowledges it. Sodium and boron can be hallmarks of ash influences because they are relatively uncommon in background data. The Department has determined that some sites of ash placement have exhibited changes in the groundwater that are likely related to ash placement. Some of these changes are only temporary. None of the changes were determined to constitute a hazardous condition to public health and safety or aquatic life. Again, it must be recognized that the groundwater in these areas is not pristine; it is frequently non-potable and therefore not being used as drinking water. Therefore, if the use of ash to fill mine pits is achieving overall environmental benefit, it is not logical to discontinue the practice if the groundwater shows minor, temporary, essentially harmless effects.

Currently, the coal ash program is undergoing modification based on Department studies and experience, contributions from the Office of Surface Mining and the U.S. Environmental Protection Agency, and suggestions made by the National Research Council – National Academies in a study they completed on coal ash use. Some of the recommendations made by the above named groups appear in the CATF report. Federal regulations for coal ash are in the draft process. In addition, Pennsylvania is in the process of codifying by regulation its policies and procedures and adding language to reflect its improved understanding of coal ash beneficial use.

Therefore, the Department is well on the way to addressing legitimate concerns of CATF such as sample frequency and duration. However, a main purpose of this response document is to clarify, explain and point out the failings and shortcomings of some of the

[4] Available online at
http://www.dep.state.pa.us/dep/deputate/minres/bmr/beneficial_use/Index.htm

CATF's methods and conclusions in its report. Staff from the Department's District Mining Offices and Bureau of Mining and Reclamation, with firsthand knowledge of the sites and data sets, reviewed the CATF's interpretation and conclusions and compiled these comments.

General comments about the CATF report

Proper interpretation of water monitoring data requires an understanding of the hydrogeologic and geochemical context of the placement site, inherent limitations of water quality data (including common errors), and seasonal factors that influence water chemistry. Although each ash placement site reviewed in the CATF report is addressed individually in the next section, the Department identified some consistent fallacies and misinterpretations of data that appear repeatedly throughout the CATF report. They are as follows:

CATF fails to consider AMD as the source of pollution. The historical legacy of mine drainage has already been addressed above. The effects of coal mining have impacted most mines that receive ash and the water associated with these mines is characteristic of coal mine drainage. CATF routinely jumps to the conclusion that the observed pollution is caused by ash. Most of the constituents that it attributes to the ash are common to coal mine drainage and the Department's observations are that the pollution is a result of the coal mine drainage. Also, as discussed above, the Department's ability to predict mine drainage has improved through time and less and less problems of this type are occurring. However, blame for the pollution must be properly assigned.

CATF gives undue weight to outlier data. Outliers are data points that are numerically distant from typical values. Fortunately they are infrequent events. Most large sets of water quality data contain outliers. CATF routinely assumes that outliers identify pollution events; this is an invalid assumption. Outliers occur for a lot of reasons including improper sample collection, errors in sample analysis, switching of samples (sample was collected somewhere else), reporting error (such as a decimal error or multiplication by 10), and inclusion of large quantities of suspended matter during sample collection. Typically, outliers are visually obvious, but if they are not evident, there are statistical approaches that can identify outliers (see Figure 2). Another flaw in the logic of citing individual sample events as evidence of degradation is that one must then be equally willing to declare the sampling point improved when the very next sampling event reveals lower concentrations, yet such conclusions are not found in the CATF report. From the Department's experience with mine sites, when pollution events occur they (unfortunately) persist. Pollution at mines is not a one time or infrequent event, but a continuing trend.

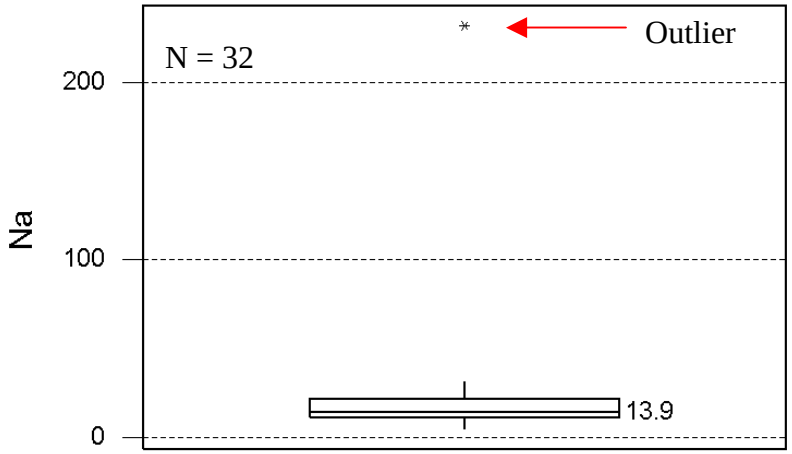


Figure 2. Boxplot of the sodium data depicted in Figure 8 showing outlier, which is identified by an asterisk (*). The "box" encompasses 50% of the data, the "tails" include all the other data except for the one outlier. All the data, except the outlier, cluster within a tight zone ranging from a low of 4.3 to a high of 31.3; the median is 13.9. The outlier is 232.

CATF uses statistical trend lines inappropriately. Trend lines are used throughout the report to imply cause-and-effect relationships that often are not otherwise demonstrated nor discussed. Additionally, two CATF interpretation errors are frequently made: (a) Trend lines are placed through data that contains one or two outliers (See example of this in Figure 3). These outlier values, more likely than not being spurious data, are frequently the result of sample collection or analytical error. Placing trend lines through these types of data give outliers undue weight. (b) Trend lines are placed through data that fluctuate widely (Figure 4). These fluctuations are common with mine-impacted waters and are due to seasonal variations and individual precipitation events. Wet times of the year will often result in mine drainage with low concentrations of chemical parameters, or conversely, if a rain event follows a period of drought concentrations can be elevated due to flushing of accumulated pyrite weathering products.

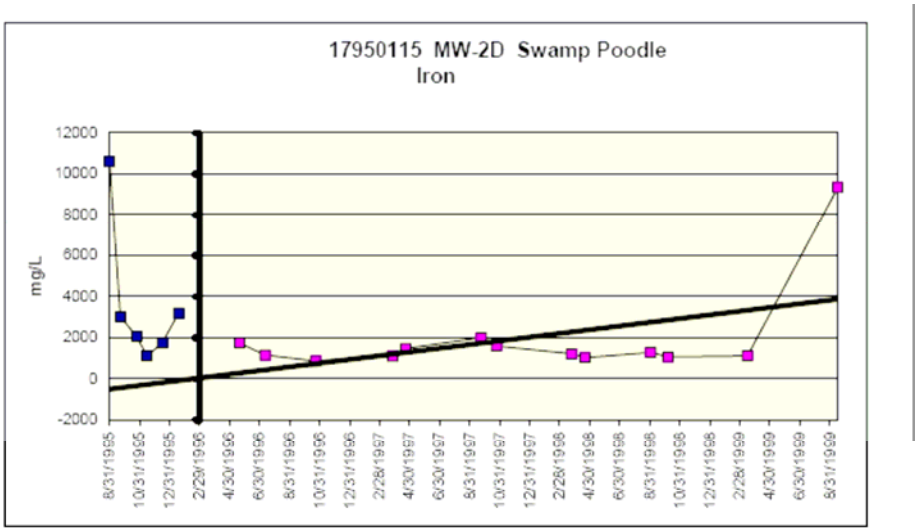


Figure 3. Example of one outlier (8/1999) skewing the trend line that is generally flat. There is also an outlier in the pre-ash placement data, which is higher than any post-ash placement value. (Fig. 4.10 from CATF report)

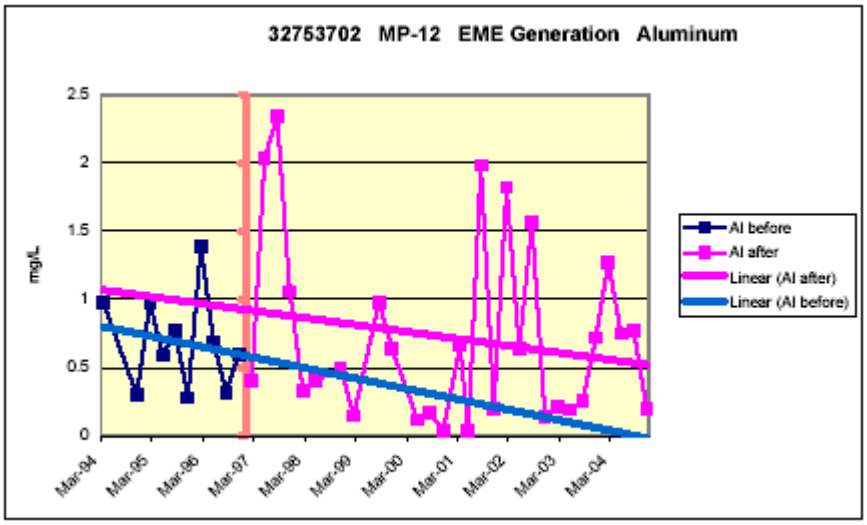


Figure 4. An example of CATF trend lines put through wildly fluctuating data. These levels of aluminum concentrations are commonly found in coal mine drainage. (Fig 8.20b from CATF report)

CATF ignores the effects of suspended solids. The CATF fails to recognize the influence of suspended solids on total concentrations of water quality constituents. Suspended solids, as opposed to dissolved solids, is particulate matter that can get dislodged from the sides of monitoring wells or is scooped up during sample collection of discharges. Dissolved solids, on the other hand, are elements that are actually dissolved in the water. Many of the outlier values can be tied to high suspended solids. When samples are collected they are "preserved" in the field with a concentrated acid. This acid will dissolve the suspended particles and if these particles (often just pieces of rock) contain elements being tested, these elements will dissolve into the sample being collected. These elements were not likely to go into solution except under the extreme conditions of the "preserved" sample. Groundwater moves too slowly to contain any appreciable quantity of suspended particles. Thus, high suspended solids in any groundwater sample are a reliable sign that solid material has been dislodged or stirred up during sample collection. The solution to this problem is to require field-filtered samples, which will filter out the suspended particles and give a true reading of the dissolved constituents. The Department is considering making it a requirement to sample ash site for dissolved constituents.

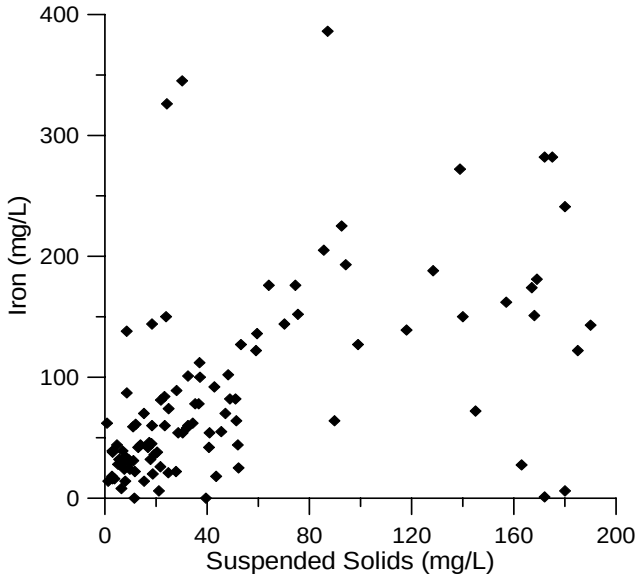


Figure 5. A plot of iron and suspended solids. There is a tendency for samples with high suspended solids to also have high iron. The sample point used here is the "Monitoring Well South" that is monitored for the Ellengowan-Knickerbocker Mine.

CATF's definition of success is the generation of alkalinity and water meeting drinking water standards. The CATF defines success of beneficial use as an increase in alkalinity at a mine site. This approach ignores the important benefits of using coal ash to reclaim abandoned mines that are environmental and safety hazards. The lack of alkalinity production from some ashes is evidence that the ash is not leaching pollution. CATF consistently compares the water quality to drinking water standards, even secondary drinking water standards. As has already been discussed, the water at most of the sites did not meet such high standards before ash placement due to impacts from abandoned mines. Drinking water standards are not the effluent standards to which mine sites are typically held. For example, the drinking water standard for iron is 0.3 mg/L. Effluent limits for mining are between 3 and 7 mg/L. Likewise, the manganese drinking water standard is 0.05 mg/L. Effluent limits are between 2 and 5 mg/L. The standards for iron and manganese were developed for aesthetic reasons, not health and safety.

CATF theories attributing degradation to ash do not make sense. The CATF's conjectures linking ash to pollution from mine sites are unreasonable in various respects. Three examples are provided below:

(A) Department studies show ash does not leach contaminants at levels likely to cause environmental degradation. Its low permeability effectively prohibits water flow through ash. The CATF fails to consider that research has shown that the hardening of the ash and sealing of pores will continue to make the elemental constituents of the ash immobile[5].

(B) A comparison of CATF's examination of the Ernest, McDermott and Bender sites (Sites 1, 2 and 3 below) is an example of the CATF's lack of a coherent theory regarding

[5] see page 301 of DEP, 2004. Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. DEP and Penn State Materials Research Institute.

ash effect on groundwater. The allegations of degradation at Ernest include multiple references and claims of trace metal degradation; those at McDermott mention some concerns with trace metal degradation; but rely mostly on other parameters; while at Bender, CATF acknowledges no trends of trace metal contamination and relies almost exclusively on increases in parameters commonly found in AMD to make its case. This raises a question about how such varying water quality conditions can be universally traced back to ash utilization and why the levels of trace metals at the sites differ so much. The obvious answer is that the concentrations have nothing to do with ash placement. The cause of the different water chemistries at these three sites is due to the relative severity of the acid mine drainage (the average acidity at the Ernest ash monitoring seep is 4342 mg/l, the average at MW-2 on McDermott is 273 mg/l, and the average at MD18 at Bender is 64 mg/l). Elevated trace metals are frequently found in severe AMD in Pennsylvania, such as that found on bituminous coal refuse piles (e.g., Ernest), but are much less common in more typical AMD discharges (e.g., McDermott and Bender).

(C) The CATF considers calcium an acceptable tracer for detecting ash. Calcite - the principle (but not only) mineral that contains calcium - is commonly found on mine sites, with our without ash placement. For more discussion see the Ernest site below.

<u>The CATF report is often equivocal while the summary conclusions are not</u>. The data contained in the report is equivocal, and is often stated to be so, yet the CATF summaries show it as decisively indicating contamination. CATF strongly contends in its report and in past documents that a fundamental flaw with Pennsylvania's CFB beneficial use program, and with the specific sites reviewed, is that inadequate data are collected to characterize the sites. Yet, CATF generates none of its own data, but relies completely on the very data it deems as flawed to reach its conclusions. CATF's arguments are therefore mutually exclusive and in conflict with one another. CATF's conclusions do not withstand scientific scrutiny.

Assessment of Individual Mine Sites Utilized for Ash Placement

1. Ernest Mine, SMP No. 32950201, Indiana County

This site remains a work-in-progress and any claim that it has been either a failure or a success is premature and not supported by existing data. It is a large abandoned coal refuse pile that is being reprocessed for fuel for a fluidized bed combustor (FBC) power plant. Alkaline ash from the plant is being used to reclaim the site. The abandoned coal refuse is a significant source of pollution in the form of both AMD parameters and trace metals at levels that exceed those found in most mine drainage. Because the abandoned coal refuse at the site leaches relatively high levels of trace metals, this site has been a favorite target of CATF in the past. However, the background data clearly establish that elevated trace metals were present prior to any ash placement.

Very little area has been completely reclaimed as yet. Large areas of exposed coal refuse are still being disturbed and remain a source of mine drainage. That has likely led to some fluctuations in data, and the operator has tripped triggers for the Subchapter F (remining) monitoring point mostly due to increases in flow. Such results are not unusual at refuse pile remining sites during active operations with or without ash utilization.

The site data have significant fluctuations, and very little in the way of clear trends, negative or positive. The strongest trends of increase for most parameters, show up in the background data (before ash placement), which complicates the interpretation but suggests it is not attributable to the ash. Most of the CATF claims of increasing trace metals are based on spikes from individual sampling events not trends in the data.

The CATF report claims that decreasing acidity at some points (e.g., MW-1) is attributable to ash placement (page 56) while increasing acidity at at least one other point down gradient of the same ash placement area (e.g., E-70) is due to the operation (pages 99-100). This contradiction is an example of the CATF's lack of a coherent theory about how ash may affect groundwater that is evident throughout the report. It also demonstrates how one may reach contradictory conclusions if not careful in assuming cause-and-effect relationships that do not actually exist. Further, the FBC ash placed on the Ernest site is highly alkaline and is incapable of generating acidity.

The Department will further evaluate the claims regarding the abandoned discharge, E70. That is not an ash monitoring point.

An example of how the CATF and the Department look at the same data and reach different conclusions is illustrated by considering total lead concentrations at monitoring well MW-1 at the Ernest site. On page 57 of its report CATF includes several statements that imply a significant increase in lead at MW-1 over time and state that it "may" be due to ash. On page 65 of the report this alleged increase is characterized as "degradation." The available lead data from MW-1 are graphed in Figure 6. The Department's conclusions regarding the data in Figure 1 include: 1) the abandoned coal refuse at the Ernest site is capable of leaching detectable levels of lead based on the pre-remining (pre-October 1996) data; 2) the high detection limits of 0.40 mg/l reported by the company in the 9-23-99 and 6-16-00 results and of 0.05 mg/l on 6-12-96 and 6-29-04 may not be appropriate, but do not represent actual lead levels; 3) there are detect-

able lead concentrations scattered through the data set; 4) there is no discernible trend in the data that can be accurately characterized as a trend or “degradation.”

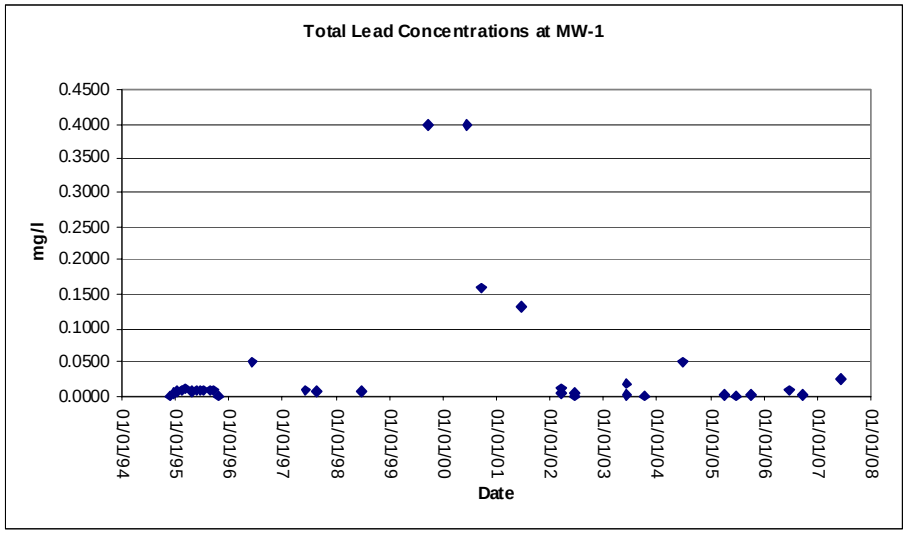


Figure 6. A plot of lead concentration through time at the Ernest site.

An examination of the data at the Ernest monitoring point E-5 helps demonstrate with specific data why CATF's conclusions that calcium is unlikely to be elevated on mine sites where acid-base accounting overburden shows low neutralization potential are incorrect. Monitoring point E-5 is leachate from abandoned coal refuse, which is reject rock from a deep mine. Material from such rock piles typically exhibits almost no neutralization potential. Yet the average calcium concentration in the E-5 leachate background data, prior to any ash placement on that site was 299.5 mg/l; the average calcium concentrations in the Bender discharge point 18 is 114 mg/l including the data collected after both coal ash and limestone were added to the Bender site. Average magnesium concentrations in E-5 background data and Bender point 18 data are 70 and 50 mg/l respectively. In this comparison the site comprised solely of mine waste material leaches higher levels of both Ca and Mg than does the mine site where both coal ash and limestone have been added to the site overburden. Obviously, CATF's premise that calcium and magnesium are not available for leaching in mine rock with low neutralization potential and that Ca and Mg are therefore reliable ash tracer parameters is seriously flawed. Conclusions made throughout the CATF report based on that premise therefore must be rejected as flawed.

The Department believes that the current remining operation and ash utilization will ultimately result in significant improvements in water quality at the Ernest site and has concluded that none of the data reveal pollution from ash placement. As already noted, very little of this site has been completed.

2. McDermott Mine, SMP No. 11950102, Cambria County

Highly alkaline FBC ash was used for alkaline addition at this site because it was known that the rock above the coal would produce acidity if not treated. Unfortunately, the ash did not produce the needed alkalinity to offset the acidity and the site is producing acid mine drainage. However, it does not logically follow that the alkaline ash is producing the

acid mine drainage or is the source of all elevated parameters at the site. Such a conclusion would be exactly parallel to claiming that limestone is the source of AMD on sites where alkaline addition using limestone has not prevented AMD formation. All the parameters that have increased, with the exception of sodium and chloride, are common to mine drainage. Some abandoned mines (pre-1966) were producing elevated lead concentrations before the more recent mining at McDermott; again consistent with the problem being acid mine drainage, not ash-related.

Sodium and chloride have increased modestly and the Department attributes this in part to the ash. However, the concentrations are hardly of concern and are well below 250 mg/L, the recommended drinking water standard for chloride. This combination of ions, in the form of salt, is routinely kept on the dining room table at far higher concentrations. Investigators should also be aware that some of the McDermott monitoring points, especially those around the southern end of the site, are influenced by heavy road salting on US Route 22.

The McDermott site data suggest that one of the shortcomings of the mining plan, is that the ash was not as reactive as believed and thus did not generate sufficient alkalinity to offset the acid producing potential of the overburden. The premise for ash use at this site was to derive alkalinity from the ash and this has not occurred. This strongly suggests that other chemical constituents that are present in far smaller concentrations are likewise not leaching.

CATF's conclusions that there have been increases in trace metals at the site are not based on any clearly defined trends, but simply point out individual sampling events where concentrations exceeded baseline concentrations and conclude those results are due to ash; no cause-and-effect link is established and no explanation is given when further sampling shows the concentrations to have returned to baseline conditions or less. Because more data were collected after ash placement as compared to before ash placement, one would expect some higher individual concentration results in the larger post-mining data sets, even if the data were purely random and the site had never been mined. Another flaw in CATF's logic of citing individual sample events as evidence of degradation is that one must then be equally willing to declare the sampling point improved when the very next sampling event reveals lower concentrations, yet such conclusions are not found in the CATF report.

The Department has concluded that: 1) The mining on the McDermott site produced acid mine drainage and convincingly degraded some down-gradient monitoring points with AMD; 2) The alkaline addition plan for the site did not work and the amount of ash used was either inadequate or the alkalinity in the ash was not as chemically available as was predicted; 3) Trace metal data, other than lead, remain essentially unchanged throughout the life of the monitoring plan; 4) Lead concentrations were elevated on the northern end of the site prior to activation of the McDermott site and increased when the northern area was mined; however, lead concentrations on the southern end of the site were low prior to site activation and remained low after mining and ash placement, <u>despite ash placement rates being generally higher on the southern end of the site</u>—this clearly demonstrates a lead source in the overburden.

The mine company was properly cited by the Department for causing increases in mine drainage pollution at the McDermott site. Unfortunately, the company went out of business and abandoned the site rather than correcting the problems.

The department's study of this site is available in:

Kania, T.C. and J.M. Tarantino, 2004. Chapter 5. Coal ash beneficial use on bituminous mine sites. In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. Department of Environmental Protection and Penn State Material Research Institute, pp.135-145.

3. EP Bender Mine, SMP No. 11930102, Cambria County

This was a Subchapter F (remining) site initially issued without ash placement. When the two primary monitoring points started to degrade, the permit was modified to allow ash placement as part of an attempt at abating a developing problem. The abatement did not work and the company eventually commenced treatment. The company has accepted its responsibility for increased AMD at the site and is currently successfully treating the degraded water using passive treatment methods.

A critical point regarding this site is that ash placement was proposed as abatement after the Department and the company recognized that mining on the site had started to degrade abandoned mine discharges. This fact is clearly established in Department files for the site. Yet throughout its discussion on this site CATF includes statements that imply AMD parameters began to increase after ash placement began. Since the established purpose of ash placement at this site was to try to abate an already recognized trend of degradation, these types of statements clearly imply a relationship between ash placement and the onset of AMD increases that is not supported by fact. As mining on the site continued so did the increases in some AMD parameters at some monitoring points. So it would be accurate to conclude that the abatement plan using ash (and limestone) as an alkaline addition agent was not successful, but it is equally inaccurate to state that the use of ash created the increase in AMD parameters on the site.

All the parameters that have increased at the Bender site are common to AMD and it is proven fact that the onset of increased AMD predated ash placement at this site. CATF acknowledges that "there were no substantial upward trends found in trace metals at this site aside from nickel…" on page 201 of its report, but goes on to cite individual sampling events with detectable levels of some trace metals. The Department concurs that trace metal levels have not increased at the site and point out that nickel at detectable levels is quite typical in acid mine drainage and usually increases with an increase in acidity. Because the alkaline addition plan at this site did not seem to be working, the company abandoned the use of ash in favor of limestone. The amount of ash used on the Bender site was therefore less than 75,000 tons, an amount dwarfed by the millions of tons of rock overburden on the site. It is not surprising that the ash placement on the site did not neutralize the mine drainage or otherwise affect the discharge quality.

The CATF seems to think that increased calcium concentrations are attributable to the ash because of the low neutralization potential of the overburden strata. That does not necessarily follow in that the rocks can still contain small amounts of calcite and other calcium-bearing minerals. In fact, calcium levels almost universally increase with increasing levels of AMD pollution. The same is true of magnesium. Manganese and aluminum are also quite common components of mine drainage. Therefore, it is generally not appropriate to attempt to use these parameters to define an influence from ash

on mine sites as CATF does throughout its report. CATF cites an increase in chloride levels at the Bender site. The chloride levels at the Bender site are well within what would be expected for shallow groundwater in that part of Pennsylvania.

4. Reading Anthracite Company, Ellengowan/Knickerbocker Mine, SMP No. 54793206, Schuylkill County

This demonstration site (along with the NEPCO/Silverbrook/Big Gorilla site) has been extensively studied by the Department and the Penn State Materials Research Institute. Published studies include:

Loop, C.M., W.B. White and B.E. Scheetz, 2004. Chapter 8. The Knickerbocker demonstration project. In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. Department of Environmental Protection and Penn State Material Research Institute, pp. 229-245.

Loop, Caroline M. 2000. The Impact of Ash Placement in a Surface Mine Pool on the chemistry of the Silverbrook Basin. MS Thesis, PSU

Loop, Caroline M. 2003. Aqueous and Precipitate Chemistry of Coal Mine Drainage Water in Alkaline Environments. PhD Dissertation, PSU.

None of the above studies found pollution attributable to the placement of ash at these sites.

The CATF relies on extreme outlier values that are not statistically significant. Extreme outliers are more likely to be caused by poor sample collection techniques, laboratory error, sample contamination, or a spurious rare event than actual pollution.

There is a lack of actual trends. If pollution is occurring, it would not be a one-time or infrequent event; it would be an upward trend or at least a constant problem. An absence of a trend is most likely an absence of pollution.

The CATF fails to recognize the normal characteristics of mine drainage pollution. Mine drainage contains nearly all of the constituents they are attributing to ash. Mine drainage chemistry often varies through time due to precipitation events and seasonal influences. Variations in concentrations are natural, not abnormal.

The CATF overemphasizes that parameter ‘a’ increased ‘x’ times when in fact the data show concentrations for the element are still quite low. For example, sodium and calcium at Maple Hill & Holes South site (Figure 6) increased over time but remained well below levels routinely consumed in food and drink. There was an increase, but it is inconsequential.

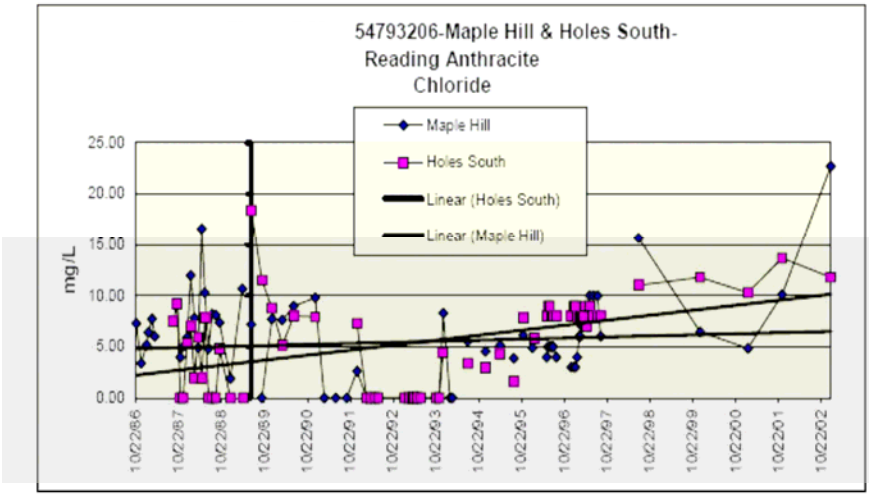


Figure 6. Chloride values appear to have increased but values are still far below drinking water secondary MCL values of 250 mg/l. (Figure 5.22a from CATF report)

Mr. Gadinski, an author for the CATF report, filed a complaint with the Pottsville District Mining Office in February 2007 regarding this ash site. The Department completed an investigative report in response to the complaint, dated August 8, 2007. Many of the same allegations were made by Mr. Gadinski as are in the CATF report. Upon close inspection, the Department found that compared to published data on anthracite mine pools, the mine pool water at this site was not unusual. The monitoring points did not show increasing trends as was alleged. The claim that "severe mine pool contamination" was occurring is unsubstantiated.

5. Northeastern Power Company, Silverbrook/Big Gorilla Site, SMP No. 54920201, Schuylkill & Carbon Counties

The CATF report contains inappropriate trend lines that project into the past or future where there is no data. Obviously, this is a misleading practice. In the sodium graph, the trend line is highly skewed by one errant sample and becomes a clearly false representation of the data since most of the measured values are contained below it (Figure 8). This errant point is an excellent example of a statistical outlier.

In some cases, the scale is inflated, the values are very small thus portraying the trend as significant where it is not. That is a hallmark of using a graph to lead the viewer towards a conclusion that is, in essence, not self-evident or significant.

This site was also part of the Penn State Materials Research Institute studies that resulted in the second two publications cited under site 4 above. It is also discussed in:

Loop, C.M., B.E. Scheetz, and W.B. White, 2004. Chapter 9. The Big Gorilla demonstration project. In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. Department of Environmental Protection and Penn State Material Research Institute, pp. 246-301.

The CATF review is far, far less rigorous than the studies performed by the Penn State Materials Research Institute. It is not even comparable considering the degree of testing, analysis and interpretation on all aspects of this project performed by Penn State experts. The CATF review is superficial and unsupported in its conclusions that are contradictory to the Department's and PSU's findings.

Penn State found that the supply of minerals contributing to alkalinity is either consumed quickly or is only available in the top layers of ash.[6] The ash essentially forms an impermeable plug. The metals are held, not leached in appreciable concentrations as the CATF alleges. This project did not cause pollution.

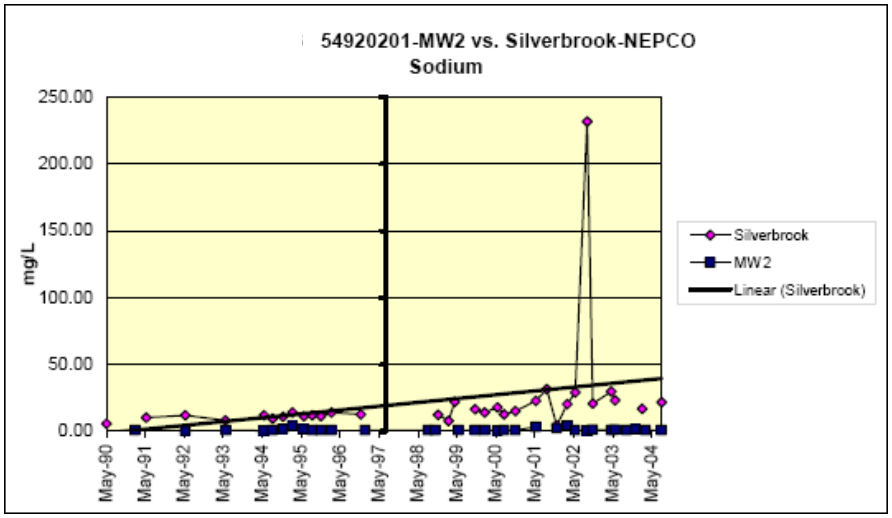


Figure 8. One value causes a clear misrepresentation of a trend. The post-ash data fall mostly below the trend line. Again, the concentrations are inconsequentially low. (Fig. 6.13 from CATF report).

6. BD Mining Company Mine, SMP No. 54850202, Schuylkill County

Again, here is an example of the CATF using the trend lines to misrepresent the data as showing contamination. Lines purported to represent trends in pH are inaccurate, because values are fluctuating as a result of seasonal influences and precipitation events. Linear trend lines are actually not the best fit for the data. Trend lines are shown as projecting past the point where regular sampling has taken place. That is not justifiable due to the variation in the data.

Alkalinity spikes can be indicative of water quality improvements, not contamination, based on less inflow to the mine pool. The metals concentrations do not signal a trend when most of the results are still below detectable levels. The Department does not agree that the comparisons of lead values in watersheds is appropriate since there are differences in rock chemistry between watersheds, and comparisons are made between undisturbed and mined areas. In any event, the data here is complex and variation may well be attributable to interacting factors, not one simple cause and effect.

[6] Loop, C.M. et al., 2004. Chapter 9. The Big Gorilla demonstration project. In: Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. PA DEP and Penn State Materials Research Institute, pp. 246-301.

CATF concludes that there is not enough data to effectively assess the causes for metals in the mine pool (p. 374) yet the CATF summary sheet states the ash is responsible.

7. Russelton Mine, SMP No. 02930201, Allegheny County
No WQ problem stated

8. Wildwood Mine, SMP No. 02940201, Allegheny County
No WQ problem stated

Both of these sites have improved water quality. CATF would like to see more monitoring at both sites to try and explain data outliers and confirm that the trends are long term.

It is not reasonable to assume, as the CATF does, that the conditions at the sites will 'use up' the alkalinity and that the resulting acid condition will leach the metals from the refuse and the ash. In both cases 90% of the refuse was burned and came back as ash, leaving both sites overwhelmingly alkaline.

9. Larson Enterprises, Swamp Poodle Site, SMP No. 17950115, Clearfield County

As with the other sites, no rigorous statistical analyses was conducted to support the strong conclusions made by CATF: there were no tests to determine significant changes between premining and postmining data; trend lines are placed upon the various charts, but no statistical tests for trend significance were conducted; the correlation coefficients for the various trend lines are not given. And again, as at other sites, some trend lines may have some meaning, but outliers skew many and/or the correlation coefficient is probably very low due to randomness in the data.

CATF made no attempt to place the monitoring of the wells within the context of the hydrology of the site and the various stages of mining. The CATF often concludes that certain trace elements (arsenic, cadmium, lead, and selenium) had increased due to the mining and ash placement, but they do not consider when ash was placed where at a mine. Some elevated concentrations are outliers and may be an artifact of improper sampling methods and/or equipment contamination.

Within the narrative, most remarks, interpretations, and conclusions are based upon the visual display of the plots. As mentioned above, visually observing the data in plots that have "trend lines" superimposed without considering correlation coefficients, outliers, and trend analysis can be misleading. Furthermore, the CATF portrays the water quality concentrations as being "x times" higher than the EPA drinking water standards. The water failed to meet drinking water standards prior to ash placement and the incidents of measurements above this level are inconsistent, sometimes returning to below the maximum contaminant level. This is not a trend.

Some monitoring points have mine drainage parameters, such as manganese and sulfate, with increasing trends (primarily MW-3D and, to a lesser extent, MW-4D). Again, these changes are typical of mine water chemistry, which is the more likely explanation of their existence.

10. EME Generation Mine, SMP No. 32753702, Indiana County

The site is a “no discharge” ash/coal refuse disposal facility. The entire ash/coal refuse disposal footprint is underlain by a 50 mil HDPE liner. (Note that a liner does not underlie some of the previous coal refuse disposal area.) The leachate and all surface runoff is collected and pumped to the power plant for treatment and make-up water. An underdrain collects any groundwater below the liner system, sampled at MP-15, which shows no evidence of liner failure. The water quality is typical of shallow groundwater. The leachate water quality is sampled at MP-14 and is completely different from that of MP-15. The MP-14 water quality is typical of coal refuse leachate, with highly elevated AMD parameters and low pH.

As the Department has repeatedly observed in the CATF report, the graphs and trend analysis are very misleading. Projecting trends on limited data is speculative. Even though the trend lines of most chemical parameters are declining post ash/refuse disposal, the CATF highlights peak data values. Trend line generation is a function of the complete data set where high and low points are weighted equally.

The CATF ignored key data regarding sulfate in the stream. Monitoring points, MP-3, 4, 16, 17 and 18, were not included in the evaluation. These data are available in Department files and the CATF was notified in 2005 that in order to have a complete hydrologic assessment, these points must be considered. Still, the CATF chose to ignore this data set. Monitoring points MP-3 (upstream) and MP-4 (mid-stream) are sample locations on an unnamed tributary to Cherry Run. CATF included only MP-13 in their evaluation, which is at the mouth of this unnamed tributary. The CATF relies heavily on MP-11 (upstream Cherry Run), MP-12 (downstream Cherry Run), and MP-13 to conclude that ash disposal is the sole source of rising sulfate levels in Cherry Run downstream, and that Cherry Run has been significantly degraded to a level which renders the stream non-potable.

Sulfate is the only chemical parameter at MP-12 that shows an increasing trend. One would logically expect that other typical AMD parameters would trend similarly to sulfate concentrations if contamination from an ash/coal refuse facility was indeed occurring. However, the data here indicates otherwise. The trend for iron and manganese is decreasing and pH is increasing. The same trends are noticed at MP-13. Had CATF considered the upstream monitoring points MP- 3 and MP-4 in the evaluation, it would have observed an elevated sulfate trail that can be followed upstream to the Helvetia mine drainage treatment plant. The plant treats water pumped from the Lucerne #6 deep mine and leachate from the Lucerne #6 coal refuse disposal area. The observed sulfate levels are typical of treated acid mine drainage.

Contrary to the CATF summary on EME ash disposal, the Department finds no evidence of sulfate contamination to Cherry Run related to the beneficial ash disposal and concludes, instead, the obvious source of sulfate is the upstream treatment plant, not the ash.

Based on the evidence, the facts do not support the CATF allegation that the ash is not only contaminating the groundwater at this location, but managing to circumvent the liner

system to do so. It is difficult to imagine a clearer example of how the CATF selectively chose the data to show the intended conclusion.

11. Lawrence Coal Company, Hartley Strip Mine, SMP No. 30713008, Greene County

The CATF report does not hesitate to use a lack of data to draw hard conclusions where no data exists. Trend lines are drawn and conclusions are made even though there are wide variations in data or missing data points (see Figure 9). The CATF does not hesitate to use outliers to see problems. The CATF has built its arguments for pollution by making unsupported assumptions and theorized hydrologic connections.

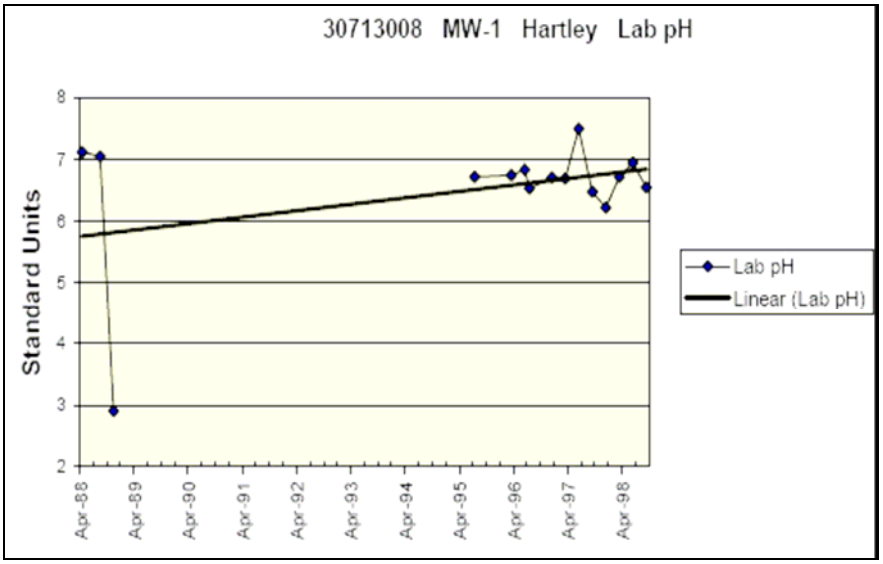


Figure 9. The trend line does not realistically represent the behavior of the data. (Fig. 9.3A from CATF report)

12. Sky Haven Coal Company, Bloom #1 Site, SMP No. 17950110 Clearfield County

The CATF selectively used data for this site to suggest that ash placement was responsible for contamination. It is not clear that contamination has occurred.

Mining up-gradient of monitoring point FA-30 did not commence until the spring of 1999. All spikes in parameters occur during the spring of 2003 when mining was taking place up-gradient of FA-30. Manganese spiked due to mining in the area above FA-30. Sulfate levels are at the highest levels during fall of 2002 and spring of 2003. The average manganese value of 3.8 mg/l falls within the range of background samples. If the two outliers are thrown out, the average concentration is 3.11 mg/l, lower than the background average.

Spikes in sulfate and total dissolved solids correspond to those in manganese due to mining in the immediate area of FA-30. The levels of sulfate, manganese and dissolved solids otherwise remain at background levels for this monitoring point. The elevated

magnesium and calcium might also be attributed to mining in the immediate area of FA-30.

Monitoring point FA-30 was net acidic prior to mining and is now neutral. Acidity and pH have decreased in concentration and alkalinity has shown a slight increase in concentration.

Monitoring point FA-19 is affected by acid mine drainage from the mine site. Increases in concentrations of iron, manganese, sulfate, acidity and TDS are evident. In addition, the alkalinity and pH have decreased. The water chemistry is indicative of coal mine drainage and there is no evidence of impacts on water quality from the ash at this monitoring point.

Monitoring point FA-32 is a dug well that extends below the Middle Kittanning coal elevation and is located just down-gradient of the mine site and is affected by acid mine drainage from the mine site. Again, there is no evidence of impacts on water quality from the ash at this monitoring point.

Monitoring point FA-20 sampling data shows degradation from acid mine drainage. Mining of the initial phase resulted in the flows increasing up to two times the background rates. The mining, along with the increase in flow, has led to increases in loadings for iron and manganese.

MW-3 is a monitoring well drilled into the backfill of the mine site down to the Middle Kittanning coal seam. The bottom of the well is located 5 feet below the pit floor. The well is cased through the spoil and fly ash so that samples of groundwater within the spoil can be collected. Only one sample has been collected from this monitoring point that included the ash parameters. The elevated parameters are most likely due to high suspended solids within the sample (418 mg/L). High suspended solids at this sample point has been a routine problem at this monitoring point with other samples (samples collected for mine drainage parameters) having 89 mg/L suspended solids or higher for every sample. The data show increasing alkalinity and decreasing acidity, which is attributed to the ash. The elevated sulfate is probably attributable to both the mining and ash placement. Figure 9 shows the increase in sulfate. For those who are unfamiliar with water chemistry, this graph is deceptive: all three parameters plotted on the graph essentially depict the same thing and should look the same. Sulfate is a dominant anion and its concentration would be directly related to total dissolved solids (TDS). Specific conductivity (SC) is simply a way to estimate TDS using an electrode. All three measure the same property.

Elevated concentrations of many constituents are probably due to suspended matter that entered the water during collection and not due to dissolved ions in the water. More samples and filtered samples would resolve the issue of the source of elevated ions.

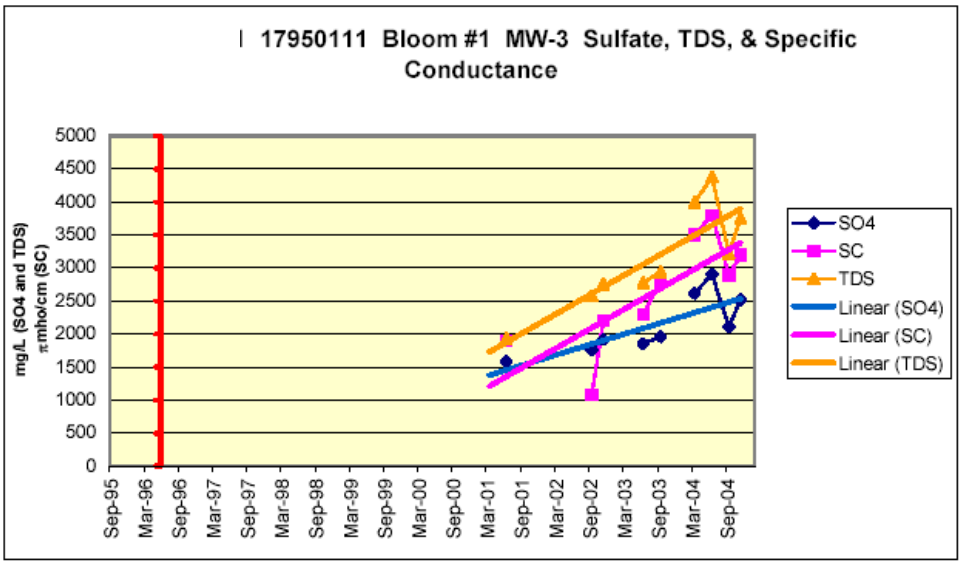


Figure 10. This graph could be interpreted as being three separate parameters increasing through time. However, they essentially measure the same property of the water. (Figure 10.51 of CATF report)

13. TDK Sandy Hollow Mine, SMP No. 16910104, Clarion County

CATF's conclusion that there is "… a definite degradation of groundwater at the Sandy Hollow Mine…" contradicts statements in the body of its report. The last sentence of page 507 states, "*If* chloride and sodium are ash indicator parameters at MW-3, then ash placement has had little effect on groundwater." The last sentence on page 508 states "…it is not possible to determine the ash's effect on trace element concentrations in down-gradient waters."

Calcium and magnesium rose after ash placement in down-gradient monitoring well MW-3. This is expected with the placement of FBC ash. Manganese and iron also were elevated during mining but fell to pre-mining levels. Sulfates are elevated from the 100 plus range to between 300 and 400 mg/l.

The CATF considers any rise of any parameter degradation. The CATF also states in the conclusion that "However, it is difficult to determine the degree to which ash placement or AMD from mining activity is contributing to this increasing degradation with the information at hand".

Monitoring data shows that there was an increase in mining-related groundwater parameters that. with the exception of sulfate, returned to pre-mining levels. Chloride and sodium are indicator parameters for FBC ash. The flat lying trend with these parameters (Figure 11) does indicate that there has been no degradation as a result of ash placement on the Sandy Hollow site.

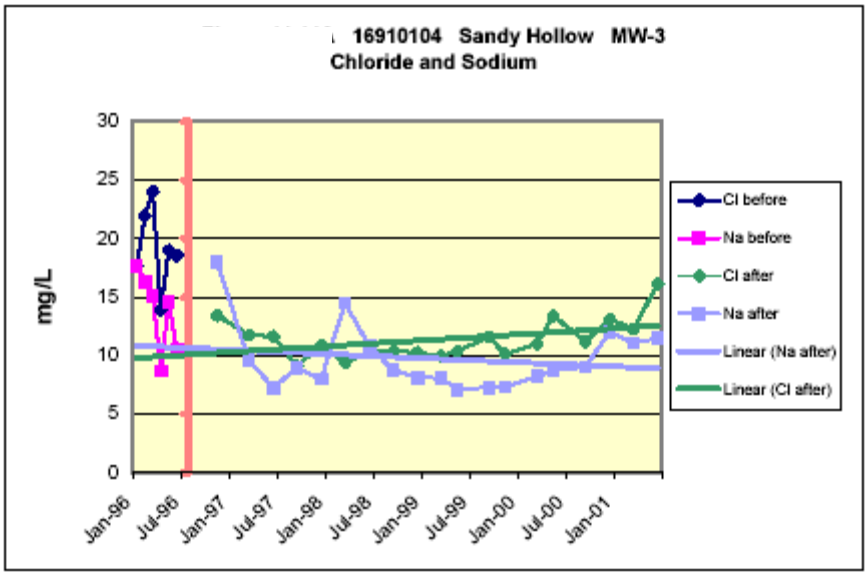


Figure 11. Chloride and sodium concentrations before and after ash placement. Note that pre-placement values are as high or higher than post-ash placement. All concentrations are low and inconsequential. (Figure 11.11A of CATF report).

14. C&K Coal Mine, SMP No. 16703006, Clarion County

The CATF concluded that a rise in calcium, magnesium, chloride, alkalinity and pH is an impact on groundwater from ash placement. This was anticipated and, for the most part, is a beneficial impact on groundwater. The CATF summarizes that there has been buffering and neutralization of acid mine drainage from coal ash over time. The CATF concludes that the rise of these constituents can result from mining, mine drainage, ash placement or any combination of these activities.

It is not clear what the CATF was implying when it stated: "Higher major and trace element concentrations in the spoil aquifer can result from mining activity and the placement of the ash and coal waste directly into spoil water." If the CATF thinks that the rise in the concentrations of the above noted parameters is contamination and it expects this to continue into the future, there is no data that confirms this assertion.

The CATF does not conclude that placement of coal ash has degraded the groundwater at this site.

15. Forcey Coal Company, Buterbaugh Mine, SMP No. 17990112 Clearfield County

The CATF report states that the placement area covered 72 acres. The actual placement area was much smaller than 72 acres. The ash source, Westvaco's Tyrone Paper Mill was closed from October 2001 through November 2003. There was no fly ash delivered to the Buterbaugh Mine during this time period because the mill did not generate ash. The total volume of ash disposed of during the four-year period was 24,538 tons. Two water-monitoring points (BC-3 & BC-14) were addressed in the CATF narrative.

The CATF report alleges that both points were impacted/degraded by ash placement. CATF incorrectly assessed the data relative to these two monitoring points.

BC-3 emerges as a toe of spoil discharge from the pre-law surface mine down slope from the Buterbaugh Mine. There is a clear degradation trend at BC-3 from acid mine drainage. The Department completed a hydrologic investigation in May 2007. Beneficial use of coal ash was approved in December 2000 and occurred after degradation had first appeared at BC-3. The Department's position is that the trend reflects degradation from surface mining activity not ash placement. The hydrologic investigation of BC-3 concluded that surface mining was initiated in the recharge area of BC-3 in April 2000 and preceded approval of ash disposal.

BC-14 is the upstream water sampling point for an intermittent unnamed tributary to Banian Run. The CATF report identifies what, at first blush, appears to be an increasing trend in iron concentrations at BC-14. A closer look at the water data for BC-14 clearly indicates that the iron trend is linked to increased total suspended solids (TSS). Total suspended solids were not considered as a parameter of interest in the report. The increased suspended solids evident in the sampling analysis explain the elevated iron concentration reported in June 2004. Steep gradient streams often have elevated suspended solids from bed load transport. BC-14 sampling frequently exhibits elevated suspended solids in the sampling coupled to elevated metal concentrations. For example, BC-14 baseline metal concentrations for iron and manganese were recorded at 10.56 mg/L and 7.69 mg/L, respectively with a high total suspended solids sample (108.5 mg/L) collected in February 2000 before ash disposal approval. If one removes the "outlier" values contributable to elevated total suspended solids, there is no degradation trend at BC-14 for any of the parameters mentioned in the CATF report.

The source of pollution at BC-3 is acid mine drainage generated by the Forcey Coal, Inc. Buterbaugh Mine. The source of pollution is primarily from the pyritic shale units in the lower geologic section of the Middle Kittanning coal formation that were disturbed during the surface mining process. On-site alkaline strata was not spread adequately to offset acid mine drainage production from low-cover mining areas. On Phases I and II of this mine, Forcey Coal spoiled approximately 7,332,000 tons of overburden through the surface mining process. The total ash used on this mine was 24,538 tons, which equates to 0.3% of the material within the backfill of this mine. The data analyzed do not support the claim that ash contributed to the contamination of the water in the mining operation, because the contamination at BC-3 preceded approval of ash placement and the quantity of ash placed within the mine is minuscule relative to the overall material spoiled and reclaimed through the surface mining process.

There is no degradation evident at monitoring point BC-14.