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Coal Mining Detailed Study

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1.0 INTRODUCTION

The purpose of this report is to summarize the analytical approach, research activities, and findings of the Coal Mining Detailed Study that EPA conducted to evaluate the comments received from a public interest group and from states and industry urging revisions to pollutant limitations in the Coal Mining Effluent Limitations Guidelines and Standards (ELGs) (40 CFR Part 434) (see 71 FR 76644-76667, December 21, 2006; 72 FR 61342-61343, October 30, 2007).

To facilitate this study, EPA identified data sources, developed a methodology for estimating treatment costs and discharge loads, and initiated data collection activities in consultation with the Interstate Mining Compact Commission, state agencies in West Virginia and Pennsylvania, and the Office of Surface Mining, Reclamation, and Enforcement within the U.S. Department of the Interior (U.S. EPA, 2007). EPA's analysis focused primarily on Pennsylvania and West Virginia because acid mine drainage (AMD) from coal mining, commonly containing manganese, is most prevalent in these two states.

EPA also evaluated the technology basis for the existing Coal Mining ELGs rulemakings: chemical precipitation and settling (U.S. EPA, 1976). EPA evaluated the current application of this technology, treatment costs, and pollutant discharge loads (see Sections 6.1, 7.0, and 8.0, respectively). EPA reviewed scientific literature and participated in discussions with state regulatory personnel in order to assess the potential effects of manganese discharges to surface water and to determine whether other pollutants in coal mining discharges are of concern (see Section 9.0). EPA also addressed the question of whether coal mining companies are forfeiting bonds because of the cost of manganese treatment by examining bonding requirements, past bond forfeiture rates, and future potential bond forfeiture rates (see Section 10.0).

1.1 Summary of Public Comments

The public interest group, the Environmental Law and Policy Center (ELPC), asked EPA to place more stringent controls on total dissolved solids (TDS) (e.g., sulfates and chlorides), mercury, cadmium, manganese, and selenium in coal mining discharges. ELPC referenced a study by EPA Region 5 on potential adverse impacts of the discharge of sulfates on aquatic life (EPA-HQ-OW-2004-0032-2614 through 2617).

The Interstate Mining Compact Commission, which represents mining regulatory agencies in 28 states, state mine permitting agencies in Pennsylvania and Virginia, two Pennsylvania coal mining companies, and a Pennsylvania coal mining trade association, asked EPA to remove the current manganese limitations stating:

1. Manganese treatment doubles or triples overall treatment costs resulting in the forfeiture of Surface Mining Control and Reclamation Act (SMCRA) bonds;
2. Manganese treatment is unnecessary to protect aquatic life and there are no widespread toxicity problems from discharges of manganese;
3. Manganese treatment sometimes results in environmental harm because mining operators must add excessive chemicals to meet the discharge limits;
4. EPA should reconsider its rationale for setting manganese limits to ensure surrogate removal of other metals because data show that other metals occur only in low concentrations; and

5. Manganese limits discourage the use of passive treatment technologies which are more environmentally beneficial than active treatment because the limits are overly stringent.

Individual state and industry commenters cited the following factors in support of their comments:

1. States enacted more stringent coal mining reclamation bonding requirements after the promulgation of SMCRA to control water discharges from mines undergoing reclamation;
2. Studies support their contention that manganese is not harmful to aquatic life at levels above the current effluent limits; and
3. Active treatment with chemical additions is perceived to possibly complicate permit compliance and cause environmental harm.

1.2 Key Definitions

Proper understanding of the following terms is essential to understanding EPA's response to the public commenters. The following terms are from 40 CFR Part 434 Subpart A – General Provisions:

- Acid or ferruginous mine drainage. Mine drainage which, before any treatment, either has a pH of less than 6.0 or a total iron concentration equal to or greater than 10 mg/L (40 CFR 434.11(a)).
- Active mining area. The area, on and beneath land, used or disturbed in activity related to the extraction, removal, or recovery of coal from its natural deposits. This term excludes coal preparation plants, coal preparation plant associated areas and post-mining areas (40 CFR 434.11(b)).
- Alkaline, mine drainage. Mine drainage which, before any treatment, has a pH equal to or greater than 6.0 and total iron concentration of less than 10 mg/L (40 CFR 434.11(c)).
- Bond release. The time at which the appropriate regulatory authority returns a reclamation or performance bond based upon its determination that reclamation work (including, in the case of underground mines, mine sealing and abandonment procedures) has been satisfactorily completed (40 CFR 434.11(d)).
- Post-mining area. (1) A reclamation area or (2) The underground workings of an underground coal mine after the extraction, removal, or recovery of coal from its natural deposit has ceased and prior to bond release (40 CFR 434.11(k)).
- Reclamation area. The surface area of a coal mine which has been returned to required contour and on which re-vegetation (specifically, seeding or planting) work has commenced (40 CFR 434.11(l)).

1.3 Applicability of 40 CFR Part 434 Manganese Effluent Limits

It is important to note that EPA has promulgated manganese effluent limits only for the following subset of coal mining operations as codified in 40 CFR Part 434:

1. Active surface and underground mining areas with acid or ferruginous mine drainage discharges (Subpart C – Acid or Ferruginous Mine Drainage); and
2. Underground post-mining areas with acid or ferruginous mine drainage discharges (Subpart E – Post Mining Areas).

There are no national manganese effluent limits for surface post-mining areas with AMD, nor for any surface or underground alkaline mine drainage discharges. There are no national manganese effluent limits for AMD that may develop after SMCRA bond release has been granted, nor are there national manganese effluent limits for AMD from abandoned coal mines.

1.4 Key Findings Concerning Public Comments

The following is a summary of key findings of the Coal Mining Detailed Study in response to comments received from stakeholders. The findings are discussed in more detail throughout the remainder of the study.

1.4.1 Bond Forfeitures

EPA clarified states' comments regarding the costs of EPA's 40 CFR Part 434 manganese limits. In their initial public comments, state commenters did not distinguish the costs of manganese removal among the three phases of coal mining: active mining areas, post-mining areas, and post-bond release areas. This is important because the Part 434 manganese limits only apply to a subset of coal mining phases. EPA clarified through discussions with state agencies that states are most concerned about the cost of manganese treatment at post-mining areas where bonds cannot be released because effluent manganese concentrations in the discharges exceed the permit limits. States expressed a concern that operators at such mines may default on their bonds rather than renew their bonds as required every five years. States indicate that reduced manganese treatment costs at such mines may decrease the number of potential bond forfeitures (Codding, 2006). EPA, however, is not able to address this issue through revisions to Part 434 because there are no manganese limits for surface post-mining areas. EPA's review of state data indicates that manganese limits in permits for discharges from surface post-mining areas are derived by state permit writers from state manganese water quality standards or from site specific best professional judgment (BPJ) technology-based effluent limits. There are, however, manganese limits for underground post-mining areas with AMD which are adequate and to which no changes are warranted at this time. See Section 4.1 for additional information on the applicability of Part 434 and water quality standards and Section 5.2.1 for additional information on the manganese water quality-based limits.

EPA found that manganese removal does double or triple treatment costs, but for active surface and underground mining areas with AMD (regulated by Part 434 Subpart C Acid or Ferruginous Mine Drainage) and post-mining areas of underground mines with AMD (regulated by Subpart E Post-Mining Areas) manganese treatment technology is available (see Section 6.0), economically achievable (see 42 FR 23180-21390, April 26, 1977), and compliance rates with permit limits derived from the Part 434 management limits are high (see Section 5.2).

Based on information received from Pennsylvania and West Virginia, EPA concluded that only a small percentage of coal mine bond forfeitures are due to the cost of manganese treatment. Overall, EPA found that there is little potential for future bond forfeitures on SMCRA permits that have been granted during the past five years or will be granted in the future. Similarly, EPA believes that current trends will continue, making it unlikely that companies will forfeit bonds on permits that will be issued in the future. EPA's analysis indicates that forfeitures are largely a legacy of the first decade of SMCRA implementation during the 1980s and early 1990s. In particular, SMCRA requires a Probable Hydrologic Consequence (PHC) analysis prior to approval of the SMCRA permit in order to identify regional hydrologic impacts associated with the coal mining and reclamation operation. The PHC is a determination of baseline quality and quantity of ground water and surface water and the impact the proposed mining will have on these baseline conditions. When potential adverse impacts are identified (e.g., AMD) through use of the PHC, appropriate protection, mitigation, and rehabilitation plans are developed and included in mining and reclamation permit requirements. If the potential adverse impacts cannot be sufficiently mitigated the SMCRA permit may be denied. The ultimate goal of using the PHC in the SMCRA permit review is to prevent AMD after land reclamation is complete and the SMCRA bond is released. PHC analytical techniques have evolved over time due to increasing knowledge. The current methods for PHC analysis are more advanced and can adequately predict AMD formation, where as in the past predictions were not as accurate. Based on the advancements in the PHC analysis, Pennsylvania Department of Environmental Protection anticipates that less than one percent of recently SMCRA permitted mines will develop AMD after reclamation and bond release. See Section 10.0 for additional information on the reasons for bond forfeitures.

1.4.2 Potential Environmental Impacts

Due to data limitations, EPA was able to conduct only a very limited analysis of potential impacts from TDS (e.g., sulfates and chlorides), mercury, cadmium, manganese, and selenium in order to respond to comments that more stringent controls on these pollutants may be warranted. EPA reviewed readily available literature and analyzed mine drainage information provided by Pennsylvania and West Virginia in order to better understand the potential for human health and aquatic life effects of these pollutants. EPA found limited information concerning documented environmental impacts. The discharge data provided by OSMRE and the states was difficult to use for the purpose of assessing potential impacts because of the small sample sizes for certain pollutants and inconsistencies across data sets due to different collection purposes. EPA's review of potential impacts is discussed in Section 9.0 of this report.

1.4.3 Surrogate Removal of Metals through Manganese Treatment

EPA reviewed the technical development documents and federal register notices supporting the Coal Mining ELGs and did not identify any discussion regarding promulgating manganese effluent guidelines to ensure surrogate removal of other metals. EPA's review of these documents showed that EPA's rationale for requiring manganese control for a subset of coal mines was to address drinking water organoleptic effects (U.S. EPA, 1976).

1.4.4 Effectiveness of Passive Treatment Systems

EPA reviewed the cost and performance of passive treatment systems and concluded that they are less expensive than active treatment systems, but they generally do not perform as well as active treatment systems. See Section 6.2 for more information.

1.5 EPA 2008 Decision on Revising Part 434 Effluent Guidelines

Based on its review of the available data and the findings described above, EPA is not proposing revisions to the pollutant limitations in the coal mining effluent guidelines (40 CFR Part 434). As with all industrial discharges, EPA will continue to examine discharges from coal mines in future annual reviews to determine if existing effluent guidelines are appropriate and sufficient.

1.6 Overview of Remainder of Report

Section 2.0 summarizes EPA's activities to identify and collect data to address public comments. Subsequent sections of this report summarize analyses conducted using data from these sources. In particular:

- **Section 3.0 characterizes U.S. coal mines** by type: type of mine (surface versus deep); type of coal (bituminous, lignite, anthracite); geographic location; type of treatment system (chemical precipitation with settling, solids settling only, passive treatment and type of passive treatment, etc.); type of discharge; and mine status. It also examines the financial state of the U.S. coal mining industry.
- **Section 4.0 reviews the complex regulatory framework that governs the coal mining industry.** It examines the relationship between the Clean Water Act (CWA), SMCRA, and state requirements. Most notably, it examines how regulatory authorities determine manganese limits and the applicability of these limits at different mining stages.
- **Section 5.0 characterizes coal mine drainage and presents EPA's comparison of pollutant concentrations to 40 CFR Part 434.** EPA characterized untreated and treated AMD. EPA limited its comparison of pollutant concentrations in AMD to Part 434 to Pennsylvania and West Virginia, because these two states are most affected by AMD.
- **Section 6.0 describes treatment technologies most commonly used to treat AMD.** Treatments include active treatment in which the facility actively adds chemicals to the discharge to maintain desired effluent characteristics; and passive treatment in which the treatment system is engineered to require little to no maintenance once the system is operational.
- **Section 7.0 reviews costs to treat AMD.** EPA examined data provided by commenters to determine the cost associated with treating a discharge to meet manganese permit limits and if treatment would lead to removal of metals not regulated by 40 CFR Part 434.
- **Section 8.0 describes EPA's estimate of pollutant loadings from coal mining outfalls that discharge AMD.** EPA limited its estimates to AMD in West Virginia and Pennsylvania, because these two states are most affected by AMD.
- **Section 9.0 presents EPA's comparison of concentrations of pollutants in AMD to values that have been documented to affect the fresh water environment.** Since the impacts of acidity and iron from AMD are well documented, EPA evaluated the potential for impacts from primarily manganese and also mercury, cadmium, selenium, and TDS in treated AMD.

- **Section 10.0 examines coal mine bonding.** It reviews trends in bond forfeiture and considers the role of manganese treatment in forfeitures in Pennsylvania and West Virginia.

1.7 Introduction References

1. Codding, Ellie. 2006. Memorandum to Docket EPA-HQ-OW-2004-0032. “RE: Draft Meeting Minutes for 6/15/06 Conference Call with Office of Surface Mining Reclamation and Enforcement.” (June 26). EPA-HQ-OW-2004-0032-2517.

2. U.S. EPA. 1976. Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the Coal Mining Point Source Category. EPA 440/1-76/057-a. (May). Washington, D.C. EPA-HQ-OW-2006-0771 DCN 06117.

3. U.S. EPA. 2007. *Detailed Study Plan for the Coal Mining Point Source Category (Part 434)*. (September). Washington, D.C. EPA-HQ-OW-2006-0771-0011.

2.0 DATA SOURCES

The purpose of this section is to summarize EPA's activities to identify and collect data to address public comments. In particular, EPA sought data to assist the Agency in the following areas:

- Understanding mine ownership structure;
- Identifying National Pollutant Discharge Elimination System (NPDES) and Surface Mining Control and Reclamation Act (SMCRA) permit holders;
- Ascertaining compliance rates;
- Determining treatment costs;
- Characterizing discharge pollutant concentrations;
- Estimating discharge loads; and
- Assessing potential impacts of discharges on surface water.

EPA conducted an extensive search of federal and state data, including numerous disparate data sets from the following sources:

- Energy Information Administration databases;
- Office of Surface Mining and Regulatory Enforcement databases;
- Pennsylvania Department of Environmental Protection;
- West Virginia Department of Environmental Protection;
- Other stakeholder data;
- U.S. Economic Census;
- EPA databases (Toxic Release Inventory and Permit Compliance System); and
- Mine Safety and Health Administration.

During this review, EPA found no comprehensive source containing the information needed to respond to concerns raised by the commenters. While EPA's data collection was not exhaustive, it does include the major sources of coal mining data at the federal level and for Pennsylvania and West Virginia, two states with high levels of acid mine drainage (AMD).

The data sources used for the Coal Mining Detailed Study have the following general limitations:

- The data are not current (most recent is typically 2006);
- The number of pollutant concentrations is limited or the pollutant concentrations do not include below detection limit indicators;
- The treatment system in place and details about the mine are not included;
- The pollutant concentrations were collected for selected discharges rather than from all discharges within a state or region (e.g., the database could be biased);
- The untreated and treated pollutant concentrations are limited for a discharge, both in the number data points and pollutants sampled for; and
- The pollutant concentrations from mines outside of Pennsylvania and West Virginia (these two states provided databases of pollutant concentration data) are limited.

Additionally, EPA found that it is difficult to compare certain information between Pennsylvania and West Virginia due to differences in how the states collect and maintain their data.

2.1 Energy Information Administration

EPA collected information from the Energy Information Administration (EIA), a statistical agency of the U.S. Department of Energy. EIA compiles information on all energy sectors to provide policy-independent data, forecasts, and analyses. All of EIA's analyses are available for public access on the EIA Web site, www.eia.doe.gov. EIA focuses on the following industrial sectors:

- Petroleum;
- Natural gas;
- Electricity;
- Coal;
- Nuclear; and
- Renewal and alternative fuels.

The coal section of the EIA Web site includes information on prices, production, reserves, distribution, and consumption. All of this information can be found at: www.eia.doe.gov/fuelcoal.html (EIA, 2007d). The EIA Web site also includes downloadable databases containing detailed information on coal mines from 1991 to 2005. This section describes the EIA databases relevant to this study, the creation of EPA's industry profile database (*CMIndustryProfile*), and the utility and limitations of the EIA databases (Section 2.1.1). This section also describes financial information from EIA that EPA used to develop a financial and economic profile of the coal mining industry (Section 2.1.2).

2.1.1 Industry Profile Database Development

EIA maintains databases containing annual coal production for mines and preparation plants for the years 1991 to 2006. The remainder of this section describes, in detail, the development of the *CMIndustryProfile* database, which generates counts of mines by type.

EPA downloaded the following databases for 1998 through 2005 from the EIA Web site:

- CoalPublic1998;
- CoalPublic1999;
- CoalPublic00;
- CoalPublic01;
- CoalPublic02;
- CoalPublic03;
- CoalPublic04; and
- CoalPublic05.

EPA did not download the databases for 1991 through 1997 because the data are stored in a different format (i.e., multiple records in each year for the same mine). In addition, most of the data in the 1991 through 1997 databases are in the more current databases. EPA combined the

CoalPublic databases for 1998 through 2005 into the *CMIndustryProfile* database. EPA used the 2005 data to characterize the current coal mining industry (see Section 3.0).

Each of the *CoalPublic* databases contains two tables. The table named as the year (e.g., in *CoalPublic1998* this table is named "1998") includes information on the mine identification, production, and employee information. The majority of the information on mine production is in codes that are defined in a table named "Code Definitions." Table 2-1 presents the field in the "Year" table and the field description from the "Code Definition" table.

Table 2-1. Field Descriptions from the *CoalPublic* Databases

Field in "Year" Table	Field Definition
Year	Year the data was collected.
MSHA ID	Unique identification number given to each mine by Mine Safety and Health Administration before operation begins.
Operating Company Name	Company operating the mine.
Mine Name	Name of the mine.
Operating Company Address	Address for the operating company.
City	
State	
ZIP Code	
Contact Name	Contact person for the mine.
Phone Number	Phone number of the contact person.
FIPS State Code	Two-digit number corresponding to a state.
FIPS State Code Modifier	One digit number created by EIA to differentiate between coal regions in the same state (e.g., the Anthracite and Bituminous regions of Pennsylvania).
County Code	Three-digit number corresponding to a county.
Mine Status	Description of work currently being completed at the mine (e.g., Active).
Operation Type	Type of facility (e.g., mine, preparation plant, or combination mine and preparation plant).
Mine Type	Type of mine (e.g., strip, auger, strip and auger combination, underground, and refuse recovery).
Union	Union mine workers belong to.
Labor Hours	Annual hours of labor.
Production	Annual coal production.
Average Employees	Average number of employees at the mine.

Source: *CoalPublic* Databases; Coal Database Page (EIA, 2007a).
FIPS – Federal Information Processing Standard Codes for the Identification of States, the District of Columbia and the Outlying Areas of the United States, and Associated Areas. The FIPS are created by the National Institute of Standards and Technology.
MSHA - Mine Safety and Health Administration.

EPA used the mine status, operation type, and mine type from the *CoalPublic* databases to summarize the number of operating coal mines.

For the purpose of this detailed study, EPA classifies mine status as the following:

- Active. “Active mining” is preparing for and extracting coal from the coal seams.
- Reclaimed. “Reclamation” occurs after the coal deposits have been extracted. Reclamation includes backfilling holes and pits, regrading, ditch and pond removal, and revegetating in an attempt to return the mine to its previous use.
- Remined. “Remining” is the additional mining of a reclaimed or abandoned mine site. Remining includes the reprocessing of coal refuse piles. Remining sites are hydrologically connected to pre-existing discharges that have pollution problems.
- Forfeited. “Forfeited mines” were forfeited after the enactment of the SMCRA (August 3, 1977). Forfeited mines are mines whose owner 1) filed for bankruptcy and 2) no longer assume control over the mine site and discharges.
- Abandoned. Coal extraction from “abandoned mines” was completed before SMCRA. Owners of abandoned mines typically left the mine prior to completing any reclamation (ERG, 2006).

EPA’s mine status classification is important for the Coal Mining Detailed Study because the study focuses on factors contributing to forfeiture at coal mines.

The mine status descriptions from the *CoalPublic* databases and the corresponding EPA status are presented in Table 2-2. EPA classified any mine that is in the process of preparing for coal extraction or actively extracting coal as an active mine. This includes the mine descriptions containing “active” and “new” in the *CoalPublic* databases.

The *CoalPublic* databases do not include information on abandoned mines because they pre-date EIA’s data collection. Additionally, the EIA tables do not differentiate between:

- Reclaimed;
- Remined; or
- Active versus currently undergoing remining.

Table 2-2. Mine Status Descriptions from *CoalPublic* Databases

***CoalPublic* Database**	***CMIndustryProfile* Database**
Active	Active
Active, Men Not Working, Not Producing	Active [a]
Active, Men Working, Not Producing	Active [b]
Inactive	Inactive
Mine Closed by MSHA	Active
New, No Men Working	Active
New, Under Construction	Active
Permanently Abandoned	Reclaimed
Temporarily Closed	Active [c]
Unknown	Unknown

Source: *CMIndustryProfile*; Coal Database Page (EIA, 2007a).

a – Could include reclamation tasks such as backfilling, regrading, and revegetating.

b – Could include remined mines that are continuing to treat discharges.

c – Could include remined mines that do not have discharges.

The operation and mine type are also important in the Coal Mining Detailed Study because the focus of the study is on discharges from coal mines, rather than preparation plants. The operation type differentiates facilities by mine; preparation plant; and mine and preparation plant combination. The mine type differentiates facilities by strip mine; auger mine/highwall mine; strip and auger combination mine; underground mine; and refuse recovery mine. See Section 3.0 for additional operation and mine type descriptions.

The EIA tables combined in the *CMIndustryProfile* are particularly useful for evaluating the number of coal mines and coal preparation plants because:

1. The EIA tables are national in scope and include data from all coal-producing states;
2. The EIA tables differentiate the facilities by mines and preparation plants;
3. The EIA tables differentiate the mines by type of mining practice (e.g., strip and underground);
4. The EIA tables include production and average number employees; and
5. The EIA tables include the mine's Mine Safety and Health Administration (MSHA) ID.

For the purposes of the Coal Mining Detailed Study, limitations of the data collected in the EIA tables include the following:

1. The age of the data (1998 through 2006) because it is not current; and
2. Lack of information about wastewater discharges (permit identification numbers, quantities, concentrations, type of treatment, etc.).

2.1.2 EIA Financial Information

EPA used EIA annual reports and special studies to develop a financial and economic profile of the coal mining industry against which to compare the effects of bonding requirements for the treatment of manganese. For example, EIA's *Annual Energy Review* contains times series data for prices (EIA, 2007b). EIA's *Annual Coal Report*s and *Coal Industry Annual*s provide yearly "snapshots" of coal production, productive capacity, recoverable reserves, employment, productivity, and domestic markets. EPA used these reports to examine how key variables change over time and provide insight into the changing nature of the industry (EIA, 2007c; EIA, 2005; EIA, 1999; EIA, 1994). EPA used two special reports that examined changes in the industry structure and characteristics and the underlying factors in these changes:

- *The U.S. Coal Industry in the 1990's: Low Prices and Record Production* (Bonskowski, 1999); and
- *The Changing Structure of the U.S. Coal Industry: An Update* (EIA, 1993).

2.2 Office of Surface Mining, Reclamation, and Enforcement

The Office of Surface Mining, Reclamation, and Enforcement (OSMRE), a division of the Department of the Interior, is responsible for monitoring and enforcing SMCRA. The OSMRE web site includes information on:

- SMCRA requirements (granted permits, implementation, and violations);
- How coal is mined;
- Coal mine production;
- AMD prevention; and
- AMD treatment technologies.

In addition to the information on the OSMRE Web site, in 2006, OSMRE provided EPA with two databases containing water quality data for coal mines: the Appalachian Regional Acid Mine Drainage Inventory Database and the Acid Mine Drainage Inventory (Robinson, 2006; ARAMD, Unknown; AMDI, Unknown). EPA also obtained the Applicant Violator System Database that tracks SMCRA permit applications, operators, and violations (DeVinney, 2007). These databases are described below.

2.2.1 Acid Mine Drainage Inventory Database

EPA used data from the Acid Mine Drainage Inventory database (*AMDI*) to characterize untreated mine drainage. OSMRE provided EPA with the *AMDI* database in July 2006. The data in *AMDI* was collected by OSMRE inspectors at discharges from coal mines in Pennsylvania to validate information in the Appalachian Regional Acid Mine Drainage Inventory database (*ARAMD*) (see Section 2.2.2) and to document long-term discharges at Pennsylvania coal mines that began extracting coal after SMCRA (1977). *AMDI* contains discharge characteristics for more than 500 Pennsylvania coal mines. Some of the discharges in *AMDI* are also in *ARAMD* because *AMDI* was developed to identify discharges in Pennsylvania that OSMRE should include in *ARAMD.*

The database tracks the following types of information by SMCRA permit number: type of mine (surface or underground); treatment system in place; and water quality data from samples taken during inspections (Robinson, 2006). The *AMDI* database includes the following information:

- Facility information including: company name, location, NPDES ID, mining permit ID, coal seem, type of mine, permit acreage, permit issuance date, and permit status;
- Bond information including: bonded acreage and bond amount; and
- Sampling information including: discharge description, receiving stream, pollutant concentrations for (AMDI, Unknown):
  - Conductivity;
  - Dissolved oxygen;
  - Ferric iron;
  - Ferrous iron;
  - Flow;
  - pH;
  - Sulfate;
  - Total alkalinity;
  - Total aluminum;
  - Total iron; and
  - Total manganese.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *AMDI* include the following:

- Only mines located in Pennsylvania are included;
- Both active and forfeited mines are included but not clearly identified;
- Some sampling data overlaps with data in *ARAMD*;
- A limited number of samples were collected at the same discharge point (one grab sample rather than repeat measurements);
- Samples were not analyzed for the same pollutants at all mines;
- Sample results do not include below detection indicators; and
- Some records lack a sampling date or have an invalid sampling date (dated in the future).

Although there are limitations to the data contained in *AMDI*, EPA used the data to characterize untreated AMD. The Coal Mining Effluent Limitations Guidelines and Standards (ELGs) (40 CFR Part 434) define AMD as mine drainage, which before any treatment, has a pH less than 6 standard units (s.u.) or an iron content greater than or equal to 10 mg/L. While alkaline mine drainage, which before any treatment, is mine drainage that has a pH greater than or equal to 6 and an iron content less than 10 mg/L. EPA used the following steps to determine the wastewater characteristics for untreated discharges in *AMDI*, presented in Section 5.1:

1. Classified the discharge by type as defined by Part 434;
2. Averaged all pollutant concentrations for each unique discharge to take into account variability in measured concentrations and multiple sampling dates; and
3. Calculated the minimum, average, and maximum of the pollutant concentrations from Step 2 for each pollutant and discharge type to characterize pollutants found in mine drainage.

2.2.2 Appalachian Regional Acid Mine Drainage Database

The *ARAMD* database is similar in structure and content to the *AMDI* database, and EPA used it to characterize untreated mine drainage. OSMRE provided EPA with *ARAMD* in July 2006. *ARAMD* includes data from more than 700 coal mines located in the Appalachian Region (Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia) that began extracting coal after SMCRA (1977). Some of the discharges in *ARAMD* are also in *AMDI* because *AMDI* was developed to identify discharges in Pennsylvania that OSMRE should include in *ARAMD*.

The database tracks the following types of information by SMCRA permit identification number: type of mine, discharge characteristics of untreated mine drainage, treatment system in place, and treatment system costs (Robinson, 2006). *ARAMD* includes the following information:

- Facility information including: company name, location, NPDES ID, mining permit ID, coal seem, type of mine, permit acreage, permit issuance date, and permit status;
- Bond information including: bonded acreage and bond amount; and

- Sampling information including: discharge ID, treatment type, receiving stream, pollutant concentrations for (ARAMD, Unknown):
  - Dissolved oxygen;
  - Ferric iron;
  - Ferrous iron;
  - Flow;
  - pH;
  - Net acidity;
  - Sulfate;
  - Total acidity;
  - Total alkalinity;
  - Total aluminum;
  - Total iron; and
  - Total manganese.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *ARAMD* include the following:

- Only includes some mines from states the Appalachian Region:
  - Kentucky (37),
  - Maryland (5),
  - Ohio (20),
  - Pennsylvania (250),
  - Tennessee (15),
  - Virginia (30), and
  - West Virginia (482);
- Both active and forfeited mines are included but not clearly identified;
- A limited number of samples were collected at the same discharge point (one grab sample rather than repeat measurements);
- Samples were not analyzed for the same pollutants at all mines;
- Sample results do not include below detection indicators;
- Data are at least five years old (1996 through 2001);
- A majority of the reported pollutant concentrations lack a sampling date or have an invalid sampling date (dated in the future); and
- Treatment and cost information is missing for some mines.

EPA used *ARAMD* for characterizing AMD: determining typical ranges of pollutant concentrations in AMD. EPA used the following steps to determine the wastewater characteristics for untreated discharges in *ARAMD*, presented in Section 5.1:

1. Classified the discharge by type as defined by Part 434 (see Section 1.2);
2. Averaged all pollutant concentrations for each unique discharge to take into account variability in measured concentrations and multiple sampling dates; and
3. Calculated the minimum, average, and maximum of the pollutant concentrations from Step 2 for each pollutant and discharge type to characterize pollutants found in mine drainage.

2.2.3 Applicant Violator System Database

The Applicant Violator System (AVS) Office is a unit within OSMRE, Appalachian Regional Coordinating Center. OSMRE's mission is to carry out the requirements of the SMCRA. Section 510(c) of SMCRA prohibits the issuance of new permits to applicants who own or control operations with outstanding violations. The AVS Office maintains the *AVS* database: an automated information system of coal producers that have violated their bonding requirements. AVS includes the applicant, permittee, operator, violation and related data maintained by States and OSM (AVS, 2007).

OSMRE provided EPA with two Excel files containing the following fields from *AVS*: state, permit number, application number, entity number, permittee name, issue date, expiration date, forfeiture date, and mine name. Together the two files contained data on 7,383 bond forfeitures by 4,897 companies from the inception of the program in 1977 to the present. Thus, the dataset represents all coal-producing states for a three-decade period (DeVinney, 2007).

The *AVS* data set, however, is only as complete as the information the states submit to it. Some states may be more conscientious in reporting data than other states. Another limitation is that the reason for the bond forfeiture is not listed. Thus, it is not possible to ascertain the role played by the costs of post-mining treatment of coal mine discharges or the role of treating AMD to meet manganese limits.

2.3 Pennsylvania Department of Environmental Protection

Through meetings with Pennsylvania Department of Environmental Protection (PA DEP), EPA collected the following databases on coal mine forfeitures, pollutant concentrations in untreated and treated mine drainage, and effluent permit limit compliance:

- Bond forfeiture table;
- Bureau of Abandoned Mine Reclamation (BAMR) sampling database;
- Inspection compliance table;
- Permits with active monitoring data indicator sampling database; and
- Treatment facilities sampling database.

The following sections describe the databases above.

2.3.1 PA DEP Bond Forfeiture Table

PA DEP sent EPA a data file listing bond forfeiture sites in which forfeiture actions were initiated after January 1, 1998 (Agnew, 2008). The file contained the following fields:

- Coal mine location information, including district name, mailing name, permit number, and facility name;
- Type of mine, underground or surface;
- Description of the site's discharge; and
- Forfeiture information, including forfeiture status, reclamation status, case number, pre-primacy indicator, and date forfeited.

PA DEP used two criteria to categorize the role of manganese treatment costs: (1) if a company's overall manganese treatment obligations led to bankruptcy, all sites for that company were categorized as "major role" even if there was no discharge at a particular site, and (2) if the failure of a company due to manganese treatment costs caused the failure of a related company, all sites for both companies were categorized as "major role." These two categorization rules could lead to attributing a higher proportion of bond forfeitures to manganese treatment costs than would result of the analysis were done on a mine-specific basis. The categorizations were indicated by color-coding the mailing name field (Agnew, 2008).

EPA used these data in the reasons for forfeiture analysis presented in Section 10.3.

2.3.2 PA DEP Bureau of Abandoned Mine Reclamation Sampling Database

PA DEP BAMR provided EPA with sampling data (*BAMR*) from a single abandoned mine with two discharges (A and B) in May 2007 (PA DEP BAMR, 2007). *BAMR* contains analytical data characterizing abandoned mine drainage before and after treatment through two vertical flow ponds. It contains pollutant concentration data from 1998 to 2007, as measured by PA DEP BAMR. Although the discharges are not subject to Part 434 ELGs because they result from abandoned mines, the data are representative of coal mine drainage and vertical flow pond pollutant removal.

The *BAMR* database includes monthly sampling data from July 1998 through May 2006 for influent and effluent from discharges A and B. The sampling data include flow rate and the following pollutants: pH, total iron, total manganese, total acidity, total aluminum, total alkalinity, sulfate, total calcium, hardness, phosphate, total suspended solids (TSS), magnesium, and specific conductivity. The majority of the sampling events include measurements for all of the pollutants.

EPA determined the discharges in the *BAMR* database are classified as AMD because the untreated pH is less than 6.0 and the untreated iron content is greater than 10 mg/L.

For the purposes of the Coal Mining Detailed Study, the limitation of the BAMR data is that they represent only one abandoned mine. However, EPA used the data summarized in *BAMR* for characterizing pollutant concentrations in treated AMD. Discharge data from the *BAMR* database are summarized in Section 5.1.

2.3.3 PA DEP Inspection Compliance Tables

PA DEP provided EPA with the Inspection Compliance tables (*CoalMineInspections*) in December 2007. The tables include the summary counts for the number of inspections performed and the number of inspections where inspectors noted effluent limit violations. PA DEP mining inspectors performed the inspections from January 1, 2003 through December 14, 2007. Overall, 92,897 inspections resulted in at least 453 effluent limit violations. The *CoalMineInspections* database includes only inspections that would review effluent violations (does not include Mine Safety Inspections, Explosives Safety Inspections, etc.) (PA DEP, 2007).

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in the *CoalMineInspections* tables include the following:

- Inspectors identify violations of discharge permit limits, but the database does not contain enough information to determine if the permit limits were based on water quality standards or technology-based limits (ELGs);
- In addition to discharge permit violations, the database may include violations of in-stream permit limits; and
- The pollutant for which the effluent limit was violated is not identified.

EPA used the *CoalMineInspections* tables to review Pennsylvania coal mine compliance status. The results of this review are presented in Section 5.2.5.

2.3.4 PA DEP Permits with Active MDI Points Database

PA DEP provided EPA with the Permits with Active Monitoring Data Indicator Points database (*PADEPMDI*) in May 2007. *PADEPMDI* includes data for more than 350 Pennsylvania coal mines that began extracting coal after SMCRA (1977).

The database includes the average pollutant concentrations for untreated discharges from every sampling event prior to May 2007. For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *PADEPMDI* include the following:

- Only mines in Pennsylvania are included;
- Active, reclaimed, and forfeited mines are included but not differentiated;
- Averages all of the sampling results for each pollutant together (eliminates the ability to review outliers);
- The pollutants measured were not consistent, sample to sample.

Although there are limitations to the data contained in *PADEPMDI*, EPA used the following steps to determine the wastewater characteristics for untreated discharges in *PADEPMDI*, presented in Section 5.1:

1. Classified the discharge by type as defined by Part 434 (see Section 1.2); and
2. Calculated the minimum, average, and maximum of the concentrations for each pollutant and discharge type to determine the industry-wide characterization.

2.3.5 PA DEP Treatment Facilities Sampling Database

PA DEP provided EPA with the Treatment Facility Sampling database (*PADEPInspector*) in December 2007. *PADEPInspector* includes PA DEP mining inspector-collected pollutant concentration measurements representing effluent discharges from coal mining treatment plants. Mining inspectors collect more samples from mines with permit compliance difficulties than mines with consistent compliance (U.S. EPA, 2007).

PADEPInspector database tables list 4,624 monitoring points and 1,809 primary facility IDs. However, the samples and results provided in the database do not represent all of the mines and monitoring points. Table 2-3 summarizes the data included in the *PADEPInspector* database.

Table 2-3. Summary of Mines and Monitoring Points in the *PADEPInspector* Database

	Number of Mines	Number of Monitoring Points
Total Listed in Database (Primary Facility IDs and Monitoring Point IDs)	1,809	4,624
Sampling Data Included	487 [a]	715
Pollutant Concentrations (Results) Included	294	723

Source: *PADEPInspector*.
a – Three outfalls did not have a facility ID listed. Therefore, there may be up to three additional mines represented by the data.

The database includes five years of data (2003 through 2007) for 715 outfalls (monitoring points) at 487 mines.[1] The database includes the following types of information:

- Facility information including: SMCRA ID, NPDES ID, MSHA ID, location, facility status (e.g., active, reclamation complete), and type of mine (surface versus underground).
- Sampling date and flow rate.
- Analytical monitoring results: pollutant concentration (with below detection indicators where applicable).

The NPDES ID is not included for all of the outfalls in the database, and EPA used the Primary Facility ID to determine the number of mines. Although the database includes SMCRA, NPDES, and MSHA IDs, EPA did not link data from *PADEPInspector* to other databases, such as the *CMIndustryProfile* database (see Section 2.1.1) or *ARAMD* (see Section 2.2.2).

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *PADEPInspector* include the following:

- Only mines in Pennsylvania are included:
- Both active and forfeited mines are included but not clearly identified;
- More samples may be collected for outfalls that have difficulty meeting the permit requirements than for compliant outfalls;
- The pollutants measured were not consistent, sample to sample at the same sampling point and between different sampling points;
- Discharge type is not included; and
- Treatment type is not included.

Although there are limitations to the data contained in *PADEPInspector*, EPA used the database for three analyses:

1. Wastewater characterization (see Section 5.1);
2. Comparison to 40 CFR Part 434 limitations (see Section 5.2); and
3. Estimate of pollutant loadings (see Section 8.0).

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[1] Three outfalls did not have a facility ID listed. Therefore, there may be up to three additional facilities represented by the data.

PA DEP estimated that approximately 50 percent of discharges in Pennsylvania include water quality-based limitations (U.S. EPA and PADEP, 2007).

The *PADEPInspector* database includes 29 analytes measured using 58 different test methods. More than one test method may be used for each pollutant parameter for different sampling events. For example: for one sampling event, pH is analyzed using Test Methods 00403, while for a different sampling event pH is analyzed using Test Method 00403M. The *PADEPInspector* database includes a long and short description of the test methods (e.g., iron, total by trace elements in waters and wastes by ICP versus iron T, respectively). EPA identified the test methods used to analyze samples of pH, total aluminum, total iron, total manganese, and TSS by the short description. EPA then used the concentration values for each pollutant (and all test methods) to complete the analyses.

The following sections provide additional discussion of how the *PADEPInspector* database was used for each analysis.

Wastewater Characterization

EPA used the data from the *PADEPInspector* database to characterize treated AMD. EPA used the following steps to determine the wastewater characteristics for untreated discharges in *ARAMD*, presented in Section 5.1:

1. Classified the outfalls by type;
2. Averaged all pollutant concentrations for each unique outfall to take into account variability in measured concentrations and multiple sampling dates; and
3. Calculated the minimum, average, and maximum of the pollutant concentrations from Step 2 for each pollutant and outfall type to characterize pollutants found in mine drainage.

Comparison of Effluent Concentrations to 40 CFR Part 434 Limitations and Pollutant Loadings

EPA used the data from the *PADEPInspector* database to compare measured effluent concentrations to 40 CFR Part 434 Subpart C NSPS limitations and to estimate pollutant loadings. The comparison to limitations includes only: iron, manganese, pH, and TSS. Pollutant loads were calculated for aluminum, iron, manganese, and TSS using concentration and flow data.

For comparing measured effluent concentrations to ELGs and for estimating pollutant loadings, EPA included outfalls that meet the following two criteria:

1. Outfall flow rate must be greater than zero (i.e., excludes monitoring points that may not represent the outfall discharge from the treatment plant); and
2. Outfall represents AMD discharges (i.e., those outfalls that monitor for manganese).

For the first criterion, the *PADEPInspector* database includes initial and final flow rates for each sampling event (i.e., unique sample date for a mine's outfall). EPA determined that of the 6,376 total sampling events, 1,674 did not include flow rate data. These sampling events were excluded from these analyses. EPA also compared the initial and final flow rates. The flow rates are equal for all but 180 sample dates, and for those dates, the final flow rate is always higher. EPA used the final flow rate for the pollutant loading estimate.

EPA compared effluent concentrations to only the 40 CFR Part 434 limitations and estimated pollutant loadings for AMD outfalls because the focus of the Coal Mining Detailed Study is on AMD. Once the sampling events without flow rate data were excluded, EPA identified outfalls for which manganese concentrations were reported as AMD. EPA identified 333 outfalls with flow rates greater than zero as AMD.

As discussed above, the *PADEPInspector* database includes several test methods for individual pollutants. EPA identified the following test methods for the pollutants included in EPA's analyses:

- Total aluminum: Method 01105A and 01105Z (over 93 percent of the samples are from Method 01105Z).
- Total iron: Method 01045A and 01045Z (over 93 percent of the samples are from Method 01045Z).
- Total manganese: Method 01055A and 01055Z (over 93 percent of the samples are from Method 01055Z).
- pH: Method 00403, F00400, and F00406 (over 98 percent of the samples are from Method F00406).
- TSS: Method 00530 and 00530A (over 93 percent of the samples are from Method 00530A).

EPA did not make any distinction between the samples collected by different test methods. EPA's comparison of measured effluent concentration to 40 CFR Part 434 ELGs is presented in Section 5.2, while the pollutant loadings are presented in Section 8.0.

2.4 West Virginia Department of Environmental Protection

Through meetings with West Virginia Department of Environmental Protection (WV DEP), EPA collected the following databases on coal mine forfeitures, pollutant concentrations in untreated and treated mine drainage, and effluent permit limit compliance:

- Bond forfeiture table;
- Discharge monitoring report database;
- Manganese permit limits database; and
- Abandoned Mine Lands and Reclamation special reclamation sampling database.

The following sections describe the databases above.

2.4.1 WV DEP Bond Forfeiture Table

WV DEP provided an e-mail and a file containing bond forfeiture data from June 30, 2001 to present (Halstead, 2008). The email contained information on the total number of forfeitures (127) and the number of forfeitures related to mine drainage treatment costs (23). The file contained the following parameters for each of the 23 bond forfeitures potentially related to mine drainage treatment costs:

- Company;
- Permit ID;
- Water status;
- Permit acres;
- Disturbed acres;
- Estimated total capital dollars for water treatment;
- Estimated annual operating dollars for water treatment; and
- An opinion on the role played by manganese treatment in mine drainage treatment costs (none, minor, or major).

EPA used these data in the analysis presented in Section 10.3.

2.4.2 WV DEP Discharge Monitoring Report Database

WV DEP provided EPA with the Discharge Monitoring Report database (*WVDMR*) in March 2007. NPDES permits require permitted facilities, including coal mines, to collect samples and analyze them for the permitted pollutants (pollutants with limits and pollutants with report only requirements). Facilities must submit the analytical results in a discharge monitoring report (DMR) to the permitting agency so the permitting agency can track permit limit compliance. The *WVDMR* database contains the reported pollutant concentrations or quantities from the DMRs for coal mines from April 2003 through March 2005 (WVDMR, 2007).

The *WVDMR* database includes 8,934 outfalls regulated under 1,289 NPDES permits. The DMRs require facilities to report one or more of the following for each permitted pollutant:

- Maximum concentration (MCMX);
- Average concentration (MCAV);
- Minimum concentration (MCMN);
- Maximum quantity (MQMX);
- Average quantity (MQAV); and
- Minimum quantity (MQMN).

The *WVDMR* database includes concentration and/or quantity data for 88 parameters.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *WVDMR* include the following:

- Only coal mines located in West Virginia are included;
- No mine information such as owner and location is included;
- No monitoring data are available for untreated water (data are all post-treatment);
- No information is provided on the type of treatment system in place at each coal mine;
- No information is provided on the location of the outfall (could include in-stream); and

- No indication of mine status is provided (active, reclaimed, remined, abandoned, or forfeited), and forfeited and abandoned mines may not be contained in database.

Although there are limitations to the data contained in *WVDMR*, EPA used the database for three analyses:

1. Wastewater characterization (see Section 5.1);
2. Comparison to 40 CFR Part 434 limitations (see Section 5.2); and
3. Estimate of pollutant loadings (see Section 8.0).

The following sections provide additional discussion of how the *WVDMR* database was used for each analysis.

Wastewater Characterization

EPA used the data from the *WVDMR* database to characterize treated AMD. EPA used the following steps to determine the wastewater characteristics for treated discharges in *WVDMR*, presented in Section 5.1:

1. Classified the outfalls by type;
2. Averaged all pollutant concentrations for each unique outfall to take into account variability in reported concentrations and multiple sampling dates; and
3. Calculated the minimum, average, and maximum of the pollutant concentrations from Step 2 for each pollutant and outfall type to characterize pollutants found in mine drainage.

Comparison of Effluent Concentrations to 40 CFR Part 434 Limitations and Pollutant Loadings

EPA used the data from the *PADEPInspector* database to compare measured effluent concentrations to 40 CFR Part 434 Subpart C NSPS limitations and to estimate pollutant loadings. The comparison to limitations includes only: iron, manganese, pH, and TSS. Pollutant loads were calculated for aluminum, iron, manganese, and TSS using concentration and flow data.

For comparing measured effluent concentrations to ELGs and for estimating pollutant loadings, EPA included outfalls that meet the following two criteria:

1. Outfall is at the treatment plant (i.e., excludes outfalls at the receiving stream); and
2. Outfall represents AMD discharges.

The *WVDMR* database includes the following flow rate parameters:

- 00058 - flow rate;
- 00061 - stream flow, instantaneous; and
- 50050 - flow, in conduit through treatment plant.

For the first criterion, EPA limited its analysis to the 4,224 outfalls (and 1,048 NPDES IDs) with flow rate data measuring the flow from the treatment plant or through the treatment plant (00058 and 50050). EPA excluded outfalls measuring the receiving stream flow rate (00061). Some of the outfalls reported multiple types of flow rate (e.g., 00061 and 50050). EPA excluded an additional 299 outfalls that reported the stream flow parameter (00061) more than 50 percent of the time.

EPA compared effluent concentrations to only the 40 CFR Part 434 limitations and estimated pollutant loadings for AMD outfalls because the focus of the Coal Mining Detailed Study is on AMD. Once the sampling events without flow rate data were excluded, EPA identified outfalls for which manganese concentrations were reported as AMD. EPA identified 333 outfalls with flow rates greater than zero as AMD.

EPA's comparison of measured effluent concentration to 40 CFR Part 434 ELGs is presented in Section 5.2, while the pollutant loadings are presented in Section 8.0.

2.4.3 WV DEP Manganese Permit Limits Database

WV DEP provided EPA with the Manganese Permit Limits database (*WVMnLimit*) in June 2007. WV DEP tracks permit limits for coal mines over time in a mainframe permit limits database. WV DEP extracted all of the manganese permit limits from the mainframe to create the *WVMnLimit* database. *WVMnLimit* includes 31,484 outfalls at 2,973 mines (NPDES IDs).

The *WVMnLimit* database includes the following types of information:

- NPDES ID and outfall description;
- Permit issuance and expiration date;
- Permit status (active or inactive);
- Limit effective and expiration date;
- Concentration and quantity limits (minimum, average, and maximum);
- "Report only" requirements (no numeric limit in the permit); and
- Limit basis.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *WVMnLimit* include the following:

- Only coal mines located in West Virginia are included;
- No mine information such as owner and location is included;
- No information is provided on the type of treatment system in place at each coal mine;
- No information is provided on the location of the outfall (could include in-stream);
- No indication of mine status is provided (active, reclaimed, remined, abandoned, or forfeited), and forfeited and abandoned mines may not be contained in database; and
- Includes manganese permit limits incorrectly identified as technology-based because they are less than the ELGs.

EPA used the data summarized in *WVMnLimit* to evaluate NPDES manganese permit limits. EPA identified some limit bases that were outside the scope of the Coal Mining Detailed Study. Table 2-4 presents the limit bases that were included in EPA's analysis. EPA analysis was also limited to manganese limits from active permits, identified by the permit status. Manganese permit limits from the *WVMnLimit* database are summarized in Section 5.2.1.

Table 2-4. *WVMnLimit* Database Limit Basis and EPA Determination

Limit Basis	Included in Analysis [a]
Acid Tech. Based	Y
Post Deep Acid Tech. Based	Y
Post Surface Acid Tech. Based	Y
Water Quality Based	Y

Source: *WVMnLimit*.
a – Limit bases included in EPA's analysis are limits within the scope of the Coal Mining Detailed Study.

2.4.4 WV DEP Special Reclamation Untreated Sampling Database

WV DEP's Office of Abandoned Mine Lands and Reclamation (AMLR) provided EPA with the Special Reclamation Untreated Sampling database (*WVDEPSpecialRec*) in July 2007. WV DEP's AMLR manages the reclamation of lands and waters affected by mining prior to SMCRA (1977). WV DEP's AMLR constructs treatment systems from abandoned mine drainage. The *WVDEPSpecialRec* database includes sampling data that WV DEP's AMLR collected from the untreated discharge prior to determining which treatment system to install. The *WVDEPSpecialRec* database includes sampling data for 47 outfalls at 17 mines. WV DEP's AMLR also collects samples after installing the treatment system. However, WV DEP's AMLR did not provide EPA with the sampling data for the treated mine drainage.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *WVDEPSpecialRec* include the following:

- Only abandoned (pre-SMCRA) coal mines located in West Virginia are included;
- No mine information such as location is included;
- No information is provided on the location of the discharge (could include in-stream);
- The pollutants measured were not consistent from mine to mine;
- Sample results do not include below detection indicators; and
- Discharge type is not included.

EPA used the data summarized in *WVDEPSpecialRec* for characterizing pollutant concentrations in treated AMD. Discharge data from the *WVDEPSpecialRec* database are summarized in Section 5.1.

2.5 Other Stakeholder Data

EPA received a sampling database (*AMD143*) from Dr. Charles Cravotta, United States Geological Survey (USGS), in May 2007. The *AMD143* database includes sampling data from untreated discharges from abandoned deep mines with large flows in Pennsylvania. Dr. Cravotta collected the sampling data using clean sampling techniques, so trace metals results are included in *AMD143*. *AMD143* includes below detection indicators and all pollutants were measured during every sampling event.

For the purposes of the Coal Mining Detailed Study, limitations of the data contained in *AMD143* include the following:

- Only abandoned (pre-SMCRA) coal mines located in Pennsylvania are included;
- Only discharges from deep mines with large flows are included;
- No information is provided on the location of the discharge (the database could include in-stream monitoring);
- Discharge type is not identified; and
- A limited number of samples were conducted at the same discharge point (one grab sample rather than repeat measurements).

EPA used the data summarized in *AMD143* for characterizing pollutant concentrations in untreated AMD. Discharge data from the *AMD143* database are summarized in Section 5.1.

2.6 U.S. Economic Census

The U.S. Economic Census, conducted by the U.S. Department of Commerce, is the systematic measurement of almost all national economic activity in the United States. The census collects information about the number of manufacturing establishments and the kind, quantity, and value of goods manufactured. Although the census provides data on the number of establishments by North American Industry Classification System and U.S. Standard Industrial Classification (SIC) codes, it does not publish the list of facilities. New facilities might have started operation since the census was taken, and facilities that were counted in the census might have been shut down. Nonproduction facilities such as sales offices, distribution warehouses, etc., are also counted as establishments in the census. EPA compares the number of mines identified in other data sources to the number summarized by the U.S. Economic Census in Section 3.0 (U.S. Census, 2002).

2.7 EPA Databases

EPA maintains two databases of pollutant measurement data:

1. Toxic Release Inventory (TRI); and
2. Permit Compliance System (PCS).

Discharges from coal mines for the majority of coal mines are not included in these databases. The following sections describe the databases above.

2.7.1 Toxic Release Inventory

TRI is the common name for Section 313 of the Emergency Planning and Community Right-to-Know Act. Each year, facilities that meet certain thresholds must report to EPA their releases and other waste management activities for listed toxic chemicals. Facilities must report the quantities of toxic chemicals recycled, collected and combusted for energy recovery, treated for destruction, or disposed of. A separate report must be filed for each chemical that exceeds the reporting threshold. The TRI list of chemicals for reporting years 2002 and 2003 includes more than 600 chemicals and chemical categories (U.S. EPA, 2005; U.S. EPA, 2006).

As part of its 304(m) planning process, EPA analyzes TRI data biennially to characterize industrial wastewater discharges. Section 4.0 of the document entitled, *Technical Support Document for the 2006 Effluent Guidelines Program Plan*, dated December 2006, describes how EPA downloaded and processed the TRI data (U.S. EPA, 2006).

TRI contains data for facilities in certain SIC codes, including those for coal mining (1221, 1222, and 1231). However, only coal mines with at least 10 full-time employees or their equivalent, and that manufacture, use, or otherwise process certain chemicals at or above an activity threshold report to TRI (U.S. EPA, 2005; U.S. EPA, 2006). TRI data are useful because of their national scope and large number of chemicals. However, the 2004 database (*TRIReleases2004_v3*) includes only 61 coal mines, and only 21 have pollutant data in the database. Because they represent a small number of mines, these TRI data are not representative of national coal mine discharges.

2.7.2 Permit Compliance System

PCS is a computerized information management system maintained by EPA's Office of Enforcement and Compliance Assurance. It was created to track permit, compliance, and enforcement status of facilities regulated by the NPDES program under the Clean Water Act. Among other data, PCS houses discharge data for these facilities. The discharge data are stored in tables and may include (U.S. EPA, 2005; U.S. EPA, 2006):

- Permit limitations;
- Pollutant concentrations and/or load, by month, quarter, or other time period; and
- Flow, by month quarter, or other time period.

As part of its 304(m) planning process, EPA analyzes PCS data biennially to characterize industrial wastewater discharges. Section 4.0 of the document, *Technical Support Document for the 2006 Effluent Guidelines Program Plan*, dated December 2006, describes how EPA downloaded and processed the PCS data (U.S. EPA, 2006).

PCS contains extensive data for major dischargers and fewer data for minor and other dischargers. Permitting authorities classify dischargers as major based on an assessment of six characteristics (U.S. EPA, 2006):

- Toxic pollutant potential;
- Discharge flow to stream flow ratio;
- Conventional pollutant loading;
- Public health impact;
- Water quality factors; and
- Proximity to coastal waters.

Table 2-5 lists how discharges from coal mines with data in PCS for 2005 are classified. Most permitting authorities classify coal mine discharges as minor or other. PCS contained only pollutant load and concentration data for 15 coal mines (those classified as major dischargers). As a result, PCS does not contain quantified pollutant loads or concentrations for most coal mines. Because they represent a small number of mines, these PCS data are not representative of national coal mine discharges or coal mine discharges in the Appalachian Region.

Table 2-5. Counts of Coal Mine Permits Listed in PCS, by Permit Type

SIC and Description	Facility Classification			Permit Type	
	Major	**Minor**	**Total Major/ Minor**	**Total General and Other [a]**	**Total Permit Count**
1221: Bituminous Coal and Lignite Surface Mining	14	901	915	2,245	4,460
1222: Bituminous Coal Underground Mining	1	79	80	14	25
1231: Anthracite Mining	0	0	0	1	1
1241: Coal Mining Services	0	64	64	27	41
Total	**15**	**1,044**	**1,059**	**2,287**	**4,527**

Source: Memorandum to Tom Born and Carey Johnston, U.S. EPA (Hazelwood, 2006).

a – General permits cover multiple facilities within a specific category under a single permit. General permits can be based on the federal multi-sector general permit and state general permits. In addition to general permits facilities can also have stormwater or other permits.

2.8 Mine Safety and Health Administration

MSHA, a division of the U.S. Department of Labor, enforces compliance with mandatory safety and health standards based on the provisions of the Federal Mine Safety and Health Act of 1977. MSHA tracks the number of mines, assigns MSHA IDs, and reports and tracks safety incidents. MSHA data do not include discharge data; and EPA did not use any data from MSHA's Web site for the Coal Mining Detailed Study.

2.9 Data Sources References

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3.0 INDUSTRY PROFILE

This section provides a summary of the coal mining industry in the following order:

- Section 3.1 discusses coal mining processes and operations; and
- Section 3.2 discusses the industry's financial statistics.

3.1 Coal Mining Processes and Operations

This section discusses:

- Physical characteristics and geographic distribution of coal (Section 3.1.1);
- How coal is mined (Section 3.1.2);
- Specific types of surface mining (Section 3.1.3);
- Specific types of underground mining (Section 3.1.4);
- How coal is processed and prepared for use (Section 3.1.5); and
- Production statistics (Section 3.1.6).

3.1.1 Physical Characteristics and Geographic Distribution of Coal

Coal is created from thick deposits of vegetative material (peat) that are subjected to a series of geochemical processes (collectively known as coalification) that change the mineralogy and texture of the original deposits. These geochemical actions are caused by heat and pressures from deep burial and continued sediment deposition on top of the peat. The heat and pressure require a considerable amount of time to create coal.

The environmental conditions that are present during plant material deposition and coal formation determine the coal's chemical and physical properties. For example, coals that formed in areas with marine water influences tend to have higher concentrations of sulfur than coals formed in areas with predominantly fresh water influences. Inorganic compounds (mineral matter) in coal commonly compose from two to 20 percent of coal by weight. Inorganic components of coal typically include minerals containing the following elements (U.S. EPA, 1981; U.S. EPA, 1982):

- Iron;
- Phosphorous;
- Sulfur;
- Calcium;
- Aluminum;
- Silica;
- Potassium; and
- Magnesium.

Other trace inorganic compounds in coal may include the following elements (U.S. EPA, 1981; U.S. EPA, 1982):

- Arsenic;
- Barium;
- Beryllium;
- Bismuth;
- Boron;
- Cadmium;
- Chromium;
- Cobalt;
- Copper;
- Fluorine;
- Gallium;
- Germanium;
- Lanthanum;
- Lead;
- Lithium;
- Manganese;
- Mercury;
- Nickel;
- Scandium;
- Selenium;
- Strontium;
- Tin;
- Uranium;
- Vanadium;
- Ytterbium;
- Yttrium;
- Zinc; and
- Zirconium.

The Energy Information Administration (EIA) classifies coal based on the fixed carbon, volatile matter, heating value, and caking properties. Table 3-1 presents the types of coal and their uses, ranked by heating value. In the United States 26 states mine coal (EIA, 2004) and coal types are associated with geographic regions. The EIA classifies three geographic regions, listed in Table 3-2. Figure 3-1 presents the U.S. coal distribution, by type (EIA, 2003).

Table 3-1. Types of Coal

Coal Type	Rank [a]	Primary Uses
Anthracite	1	Residential and commercial space heating.
Bituminous	2	Coking, steel making, and steam-electric power generation.
Subbituminous	3	Steam-electric power generation.
Lignite	4	Steam-electric power generation.

Source: Coal Glossary (EIA, 2004); *Development Document for Effluent Limitations Guidelines and Standards for the Coal Mining Point Source Category* (U.S. EPA, 1982).
a – Ranked from highest to lowest heating value, and highest to lowest by cost.

Table 3-2. Geographic Coal Regions and Types of Coal

EIA Geographic Region	States Included	Associated Type(s) of Coal
Appalachian	Alabama	Bituminous
	Kentucky – Eastern	Bituminous
	Maryland	Bituminous
	Ohio	Bituminous
	Pennsylvania	Anthracite and Bituminous
	Tennessee	Bituminous
	Virginia	Bituminous
	West Virginia	Bituminous
Interior	Arkansas	Bituminous
	Illinois	Bituminous
	Indiana	Bituminous
	Kansas	Bituminous
	Kentucky – Western	Bituminous
	Louisiana	Lignite
	Mississippi	Lignite
	Missouri	Bituminous
	Oklahoma	Bituminous
	Texas	Bituminous and Lignite

Table 3-2. Geographic Coal Regions and Types of Coal

EIA Geographic Region	States Included	Associated Type(s) of Coal
Western	Alaska	Subbituminous
	Arizona	Bituminous
	Colorado	Bituminous and Subbituminous
	Montana	Lignite and Subbituminous
	New Mexico	Bituminous and Subbituminous
	North Dakota	Bituminous and Subbituminous
	Utah	Bituminous
	Washington	Subbituminous
	Wyoming	Bituminous and Subbituminous

Source: Coal Glossary (EIA, 2004).

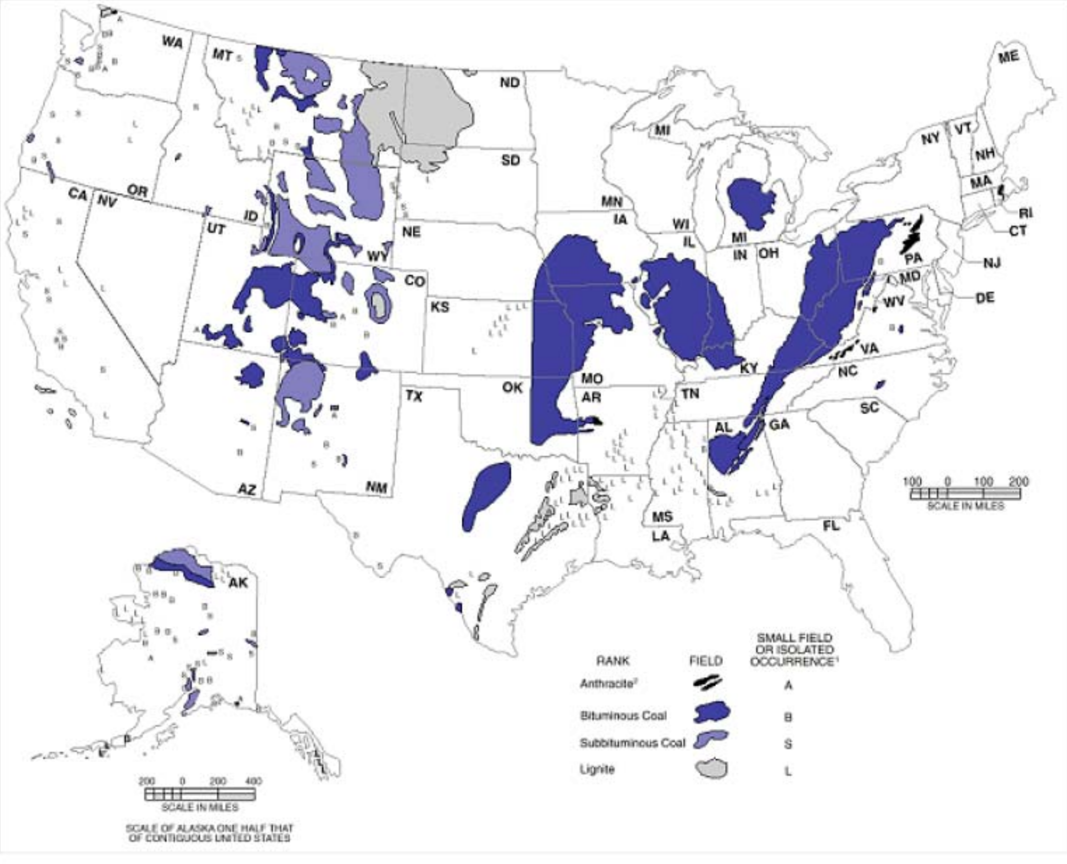

Figure 3-1. Locations of Coal by Type in the United States
Source: EIA Coal Reserves Data (EIA, 2003).

3.1.2 *Coal Mining Processes*

Coal is mined in one of two ways: surface and deep (underground). The type of mining is determined by the location of the coal relative to the surface. Surface mining is prevalent today because large machinery makes large-scale surface mining economical. After the coal is extracted from the ground, it is processed (cleaned) at a coal preparation plant (U.S. EPA, 1982).

Table 3-3 presents the number of surface and underground mines and preparation plants identified in the *CMIndustryProfile* database for 2005 (see Section 2.1.1 for discussion of the development of this database); Surface Mining Control and Reclamation Act (SMCRA) permits for 2004; and the 2002 U.S. Economic Census.

Table 3-3. Counts by Type of Facility

Type of Facility	Number of Mines in *CMIndustryProfile* Database for 2005 [a]	Number of SMCRA Permits for 2004	2002 U.S. Economic Census
Preparation Plant	362	NR	NA
Surface Mine	820	2,048	NA
Underground Mine	607	1,105	NA
Total Number of Facilities	**1,789**	**2,253**	**1,178**

Source: *CMIndustryProfile*; Coal Production Index (EIA, 2006b); U.S. Economic Census (U.S. Census, 2002).
a – In some cases, on mine location may have multiple SMCRA permits. In other cases, one SMCRA permit may cover multiple mines.
SMCRA – Surface Mining Control and Reclamation Act.
NR – Not reported.
NA – Not applicable. The U.S. Economic Census tracks facilities by NAICS and SIC code, not type of facility.

The U.S. Economic Census tracks facilities by North American Industry Classification System (NAICS) and Standard Industrial Classification (SIC) code, including facilities reporting under the following (U.S. Census, 2002):

- NAICS 212111 (SIC 1221): Bituminous Coal and Lignite Surface Mining. Establishments primarily engaged in producing bituminous coal or lignite at surface mines or in developing bituminous coal or lignite surface mines. This industry includes auger/highwall mining, strip mining, culm bank mining, and other surface mining, by owners or lessees or by establishments, which have complete responsibility for operating bituminous coal and lignite surface mines for others on a contract or fee basis. Bituminous coal and lignite preparation plants performing such activities as cleaning, crushing, screening, or sizing are included if operated in conjunction with a mine site, or if operated independently of any type of mine.
- NAICS 212112 (SIC 1222): Bituminous Coal Underground Mining. Establishments primarily engaged in producing bituminous coal in underground mines or in developing bituminous coal underground mines. This industry includes underground mining by owners or lessees or by establishments, which have complete responsibility for operating bituminous coal underground mines for others on a contract or fee basis. Bituminous coal preparation plants performing such activities as cleaning, crushing, screening, or sizing are included if operated in conjunction with a mine. Independent bituminous coal preparation plants are classified in SIC code 1221.
- NAICS 212113 (SIC 1231): Anthracite Mining. Establishments primarily engaged in producing anthracite or in developing anthracite mines. All establishments in the United States that are classified in this industry are located in Pennsylvania. This industry includes mining by owners or lessees or by

establishments, which have complete responsibility for operating anthracite mines for others on a contract or fee basis. Also included are anthracite preparation plants, whether or not operated in conjunction with a mine.

Below are descriptions of the categories of coal mines:

1. Active. Active mining is the first phase of coal mining in which coal is extracted. During active mining, miners pump stormwater and groundwater, treat it when necessary, and discharge it under a National Pollutant Discharge Elimination System (NPDES) permit (ERG, 2006).
2. Reclaimed. The reclamation phase of mining occurs after the coal has been extracted. During reclamation, the miners backfill holes and pits, regrade, and revegetate land in an attempt to return it to its previous use, such as farmland, pasture land, and forest (ERG, 2006).
3. Remined. Remining is the additional mining of a reclaimed or abandoned mine site. Remining includes the reprocessing of coal refuse piles. Remining sites are hydrologically connected to pre-existing discharges that have pollution problems (U.S. EPA, 2001).
4. Abandoned. Abandoned mines are mines where “mining operations have occurred in the past” and “the applicable reclamation bond or financial assurance has been released or forfeited or if no reclamation bond or other financial assurance has been posted, no mining operations have occurred for five years or more” (40 CFR § 434.11(r).)
    a. Forfeited mines. In this study, forfeited mines include those mines whose bonds were forfeited after the enactment of the SMCRA (August 3, 1977). SMCRA permitting authorities assume control of and liability for the mine and its discharges when owners forfeit their bond for mines begun after 1977 (post-SMCRA) (ERG, 2006).

EPA uses the term “forfeited mine” in this study to distinguish between those mines that are abandoned and eligible for federal Abandoned Mine Land reclamation funds versus those whose liability has been assumed by the SMCRA permitting authority.

Table 3-4 presents the number of mines by phase from the *CMIndustryProfile* database for 2005. Table 3-4 lists the phase as described by EIA, and its corresponding EPA description.

Table 3-4. Counts by Mine Phase for 2005

EIA Mining Phase	EPA Phase	Number of Facilities
Active	Active [a]	1,462
Mine Closed by MSHA		171
Temporarily Closed		47
Permanently Abandoned [b]	Reclaimed	106
Unknown	Unknown	3
Total Number of Facilities		**1,789**

Source: *CMIndustryProfile*.

a – Includes remines.

b – By permanently abandoned, the *CMIndustryProfile* database means that no more coal will be mined by the original company, not that the mine pre-dated the 1977 SMCRA. The EIA classification of “permanently abandoned” may include forfeited mines.

3.1.3 Surface Mines

Surface mining is typically used when the coal is close enough to the surface to enable the overburden (the soil and rock above the coal) to be removed economically and later replaced and regraded. Surface mining is classified into area mining, refuse recovery mining, and contour mining (U.S. EPA, 1981; U.S. EPA, 1982).

Area mining is typically used on flat terrain to remove coal by creating long pits. The overburden from the current pit is deposited into the previous pit. The most common types of area mining are strip mining and mountaintop mining. Strip mining is most common in the Western and Midwest U.S. where coal seams lie shallow in planes beneath the surface. Mountaintop mining is common in the Eastern U.S. The mountaintop mining method removes the entire mountaintop above the coal seam(s), at times creating a “tabletop” landscape when the mining is completed. Valley fills of the excess spoil are often associated with mountaintop removal operations (U.S. EPA, 1981; EIA, 2004).

Refuse recovery mining is considered a type of surface mining. Coal is recovered from waste piles at previously mined sites and preparation plants (EIA, 2004). The waste material remaining after coal processing is called “culm” or “slit” from anthracite coal and “gob” or “boney” from bituminous coal. The waste coal piles contain coal, shale, and other impurities. The waste coal recovered by refuse recovery mining typically has lower Btu value and contains higher concentrations of rock sulfur (ICCI, 1999).

Contour mining is typically used in the mountainous areas of the Eastern United States, where coal seams are exposed along outcrops (OSMRE, 2002). The coal seam is exposed by removing the overburden, creating a bench or shelf on the side of the mountain and a highwall at roughly 90° to the bench, as presented in Figure 3-2. After it is no longer economical to remove overburden, additional coal can be removed from the highwall using the auger mining or highwall mining methods. In auger mining, miners bore large-diameter horizontal holes into the highwall to remove additional coal (EIA, 2004). Auger mining can also be used in locations where contour mining is not economically feasible, such as in isolated locations (U.S. EPA, 1981). Highwall mining, while similar to auger mining, uses a continuous miner system to cut rectangular entries into the coal. The highwall mining can remove more coal at greater depths (approximately 1,000 feet) than auger mining.

Figure 3-2. Unreclaimed Contour Mine in Eastern Tennessee
Source: Partnership Success Stories – Abandoned Mine Lands Reclamation (U.S. DOI, 2004).

The *CMIndustryProfile* divides surface mines into auger mines, refuse recovery mines, strip mines, and combination auger and strip mines. The number of mines by type and region for 2005 are presented in Tables 3-5 and 3-6.

Table 3-5. Counts by Type of Surface Mine for 2005

Type of Surface Mine	Number of Mines
Auger Mine	88
Refuse Recovery Mine	19
Strip Mine	614
Strip/Auger Mine Combination	99
Total	**820**

Source: *CMIndustryProfile*.

Table 3-6. Counts of Surface Mines by Coal Mining Region for 2005

Coal Region	Number of Mines
Auger Mine	
Appalachian	80
Interior	6
Western	2
Refuse Recovery Mines	
Appalachian	16
Interior	2
Western	1

Table 3-6. Counts of Surface Mines by Coal Mining Region for 2005

Coal Region	Number of Mines
Strip Mine	
Appalachian	509
Interior	67
Western	38
Strip/Auger Mine Combinations	
Appalachian	95
Interior	3
Western	1

Source: *CMIndustryProfile*.

3.1.4 Underground Mines

Underground mines are used in locations where the coal is too deep to be surface mined economically (U.S. EPA, 1982). Table 3-7 presents the counts of underground mines by coal mining region for 2005 from the *CMIndustryProfile* database. Underground mines are classified based on the type of opening used to reach the coal seam: drift, slope, and shaft. Drift mines have a horizontal or nearly horizontal mine entrance. Slope mines have an angled entry into the mine. Shaft mines reach the coal seam by a vertical entrance (EIA, 2004).

Table 3-7. Counts of Underground Mines by Coal Mining Region for 2005

Coal Region	Number of Mines
Appalachian	548
Interior	35
Western	24

Source: *CMIndustryProfile*.

Once the coal seam is reached, the coal is primarily extracted using the room-and-pillar method, longwall method, or rarely, the shortwall method. The room-and-pillar method is the traditional method of mining in which coal is removed in a systematic pattern to create the rooms. Pillars of coal are left between the rooms to help support the mine roof. Once the mine has been fully developed, additional coal is mined from the pillars (second mining) increasing the overall coal recovery (U.S. EPA, 1981). Once the mine is advanced to its maximum, additional extraction from the pillars will be conducted as the miners withdraw from the mine. This is termed “retreat mining.” The room-and-pillar method in the U.S. has been primarily replaced by longwall mining, with only two room-and-pillar operations remaining in the U.S. The longwall mining method extracts large rectangular blocks of coal using a high-powered cutting machine. The cutting machine passes across the coal face and shears away coal, as shown in Figure 3-3. Coal is continuously removed using a conveyer system along a pan line. Longwall mining removes all of the coal within the block using movable roof supports (jacks and shields). The only coal not removed is located in the pillars in adjacent support areas (head and tail gates and bleeder and support entries). Longwall mining can remove coal in blocks exceeding 1,000 feet wide and more than 8,000 feet long (EIA, 2004).

Figure 3-3. Bureau of Land Management Photograph of a Longwall Miner Shearer Head
Source: Solid Mineral Programs on the Nation's Federal Land (U.S. BLM, Unknown).

3.1.5 Coal Preparation

After coal is mined, it is processed at a coal preparation plant to increase the heating value and improve the quality by removing impurities such as rock, ash, and sulfur. The coal undergoes the following steps (U.S. EPA, 1981):

1. Initial coal preparation;
2. Coal processing; and
3. Dewatering and drying.

The dried coal is stored in coal silos for transport to the end user, such as steel mills or coal-fired power-plants.

3.1.6 Coal Mining Production Data

EPA collected coal production data from the EIA and Office of Surface Mining Reclamation and Enforcement (OSMRE) Web sites to profile trends in coal mine location and type. This section presents the production data and discusses trends, including differences in EIA and OSMRE data.

Table 3-8 presents the EIA data on U.S. quarterly and annual coal production from 2000 to 2006. Table 3-9 presents the EIA data on coal reserves as of January 1, 2006, by state. The reserves are separated by recoverable reserves and total reserves. Recoverable reserves are the amount of coal that can be mined from the coal deposits at active producing mines, while total reserves are the amount of coal that is recoverable. Illinois, Montana, and Wyoming account for almost 60 percent of total coal reserves as of January 1, 2006. Additionally, the majority of total coal reserves are from underground mines; however, the majority of recoverable reserves are from surface mines.

Table 3-8. EIA Records of U.S. Coal Production from 2000 to 2006

Year	Production (Thousand Short Tons)				
	January – March	April - June	July - September	October - December	Total
2000 [a]	274,339	261,257	270,577	267,439	1,073,612
2001	283,770	279,394	279,729	284,796	1,127,689
2002	282,573	266,667	270,898	274,156	1,094,295
2003	264,202	268,499	268,565	270,487	1,071,753
2004	275,492	274,335	281,484	280,787	1,112,099
2005	285,802	278,793	285,293	281,610	1,131,498
2006	288,870	292,965	288,896	NR	870,732

Source: Table 4 from Quarterly Coal Report – July to September 2006 (EIA, 2006b).
a – Excludes refuse recovery coal mining.
NR – Not Reported. Data for October to December 2006 were not reported at the time of data collection.

Table 3-9. EIA Records of Coal Reserves by State as of January 1, 2006

State	Underground - Minable Coal		Surface - Minable Coal		Total	
	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]
Alabama	306	1,007	50	3,198	355	4,205
Alaska	—	5,423	W	687	W	6,110
Arizona	—	—	W	—	W	NA
Arkansas	—	272	—	144	—	417
Colorado	338	11,461	44	4,762	382	16,223
Georgia	—	2	—	2	—	4
Idaho	—	160	—	—	—	160
Illinois	708	87,919	40	16,550	747	104,469
Indiana	249	8,741	133	742	382	9,483
Iowa	—	1,732	—	457	—	2,189
Kansas	—	—	W	972	W	972
Eastern Kentucky	603	1,178	181	9,337	784	10,516
Western Kentucky	362	15,877	23	3,628	385	19,504
Kentucky Total	965	17,055	204	12,965	1,169	30,020
Louisiana	—	—	W	422	W	422
Maryland	W	578	W	65	35	643
Michigan	—	123	—	5	—	128
Mississippi	—	—	W	—	W	NA
Missouri	—	1,479	W	4,510	W	5,989
Montana	W	70,958	W	48,272	1,234	119,230
New Mexico	W	6,156	W	5,975	526	12,131

Table 3-9. EIA Records of Coal Reserves by State as of January 1, 2006

State	Underground - Minable Coal		Surface - Minable Coal		Total	
	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]	Recoverable Reserves (Million Short Tons) [a]	Total Reserve (Million Short Tons) [b]
North Carolina	—	11	—	—	—	11
North Dakota	—	—	1,214	9,053	1,214	9,053
Ohio	205	17,546	166	5,754	371	23,300
Oklahoma	W	1,231	W	323	15	1,554
Oregon	—	15	—	3	—	17
Anthracite Region of Pennsylvania	2	3,844	18	3,355	21	7,198
Bituminous Region of Pennsylvania	518	19,377	78	896	596	20,274
Pennsylvania Total	520	23,221	96	4,251	616	27,472
South Dakota	—	—	—	366	—	366
Tennessee	8	510	11	264	19	774
Texas	—	—	772	12,385	772	12,385
Utah	281	5,128	—	268	281	5,396
Virginia	235	1,130	59	562	294	1,693
Washington	—	1,332	W	8	W	1,340
Northern West Virginia	290	NA	35	NA	325	NA
Southern West Virginia	888	NA	527	NA	1,416	NA
West Virginia Total	1,179	29,184	562	3,775	1,741	32,960
Wyoming	W	42,500	W	21,319	7,975	63,819
U.S. Total	**5,502**	**334,876**	**13,442**	**158,059**	**18,944**	**492,935**

Source: Table 15 from *Annual Coal Report – 2005* (EIA, 2006a).
a – Amount of coal that can be mined from the coal deposits at active producing mines as of January 1, 2006.
b – Amount of in-place coal.
NA – Not available. The estimated value is not available due to insufficient data or inadequate data/model performance.
W – Withheld. Data was withheld to avoid disclosure of individual company data.

Table 3-10 presents the number of SMCRA permits and production by state and type of mining method used (surface or underground). Using the 2005 production data from the EIA (2006 EIA data do not include the last quarter), both the EIA and OSMRE estimate that, most recently, the U.S. mined approximately 1.13 billion tons of coal annually. Both agencies also show that most coal is mined in the Western Region, although there are fewer Western mines.

Table 3-10. OSMRE Records of SMCRA Permits and 2006 Production by State

State	Surface Mining		Underground Mining		All Mining Methods	
	Number of Permits	**Total Production (tons)**	**Number of Permits**	**Total Production (tons)**	**Number of Permits**	**Total Production (tons)**
Alabama	81	8,675,072	11	11,140,877	92	19,815,949
Alaska	3	1,156,267	0	0	3	1,156,267
Arizona - Hopi	1	10,715,082	0	0	1	10,715,082
Arizona - Navajo	0	0	0	0	0	0
Arkansas	4	198,603	0	0	4	198,603
California	0	0	0	0	0	0
Colorado	8	9,151,397	8	25,369,271	16	34,520,668
Georgia	0	0	0	0	0	0
Iowa	0	0	0	0	0	0
Illinois	45	6,411,939	21	24,569,555	66	30,981,494
Indiana	29	22,974,584	14	10,703,208	43	33,677,792
Kansas	3	267,747	0	0	3	267,747
Kentucky	576	47,905,792	462	72,578,081	1,038	120,483,872
Louisiana	2	4,094,890	0	0	2	4,094,890
Maryland	41	2,515,565	4	2,755,779	45	5,271,344
Mississippi	1	3,507,180	0	0	1	3,507,180
Missouri	3	590,818	0	0	3	590,818
Montana	9	33,795,927	1	265,950	10	34,061,878
Montana Crow	1	6,354,994	0	0	1	6,354,994
New Mexico	4	5,891,421	2	6,970,895	6	12,862,316
New Mexico Navajo	2	13,638,218	0	0	2	13,638,218
North Dakota	8	30,537,062	0	0	8	30,537,062
Ohio	131	8,536,488	11	14,912,448	142	23,448,936
Oklahoma	17	1,198,562	3	484,732	20	1,683,294
Pennsylvania	603	12,377,391	134	54,417,873	737	74,654,805
Tennessee	23	1,906,636	23	1,233,422	46	3,140,058
Texas	20	45,644,393	0	0	20	45,644,393
Utah	2	4,471	16	24,308,137	18	24,855,255
Virginia	113	10,425,126	128	15,857,283	241	26,282,409
Washington	2	3,976,185	0	0	2	3,976,185
West Virginia	302	63,394,877	324	84,301,035	626	148,017,951
Wyoming	30	417,859,047	1	282,318	31	418,141,365
Totals	**2,064**	**773,705,734**	**1,163**	**350,150,863**	**3,227**	**1,132,580,823**

Source: Coal Production Index (OSMRE, 2006).

3.2 Coal Mining Financial Statistics

For the purpose of this study, the analysis of financial and economic data begins with the passage of the SMCRA in 1977. SMCRA created a permitting process that requires coal operators to determine the reclamation requirements and bonding of reclamation costs before coal mining can begin. Additional discussion of SMCRA is presented in Section 4.2. SMCRA requires the examination of trends in coal prices, mine size, and ownership, which places the discussion of bond forfeitures and company failures (see Section 10.0) within the larger context of the economic conditions for the industry.

3.2.1 Coal Prices

Figure 3-4 presents domestic coal prices from 1976 through 2006 in 2000 dollars (EIA, 2007a). Prices peaked in 1979 at $47.93/short ton (2000 dollars). From 1979 through 2003, prices show an unbroken decline. By 1993, coal prices were less than half of the 1979 value ($22.46/short ton). The price decline continued and reached its lowest point in 2003 at $16.78/short ton. Coal prices in 2003, then, were 35 percent of their 1979 values. The long run decline in real coal prices is primarily associated with interrelated industry trends toward the following (Bonskowski, 1999; see Section 3.2.2 for more discussion):

- Increased production from mines west of the Mississippi;
- A shift to production from fewer but larger mines; and
- Increased mine productivity.

With price declines as unrelenting as seen in Figure 3-4, and unable to achieve the economies of scale that would allow them to compete at such low prices, small or marginal firms can reach a point where they can no longer recover operation costs and thus leave the industry.

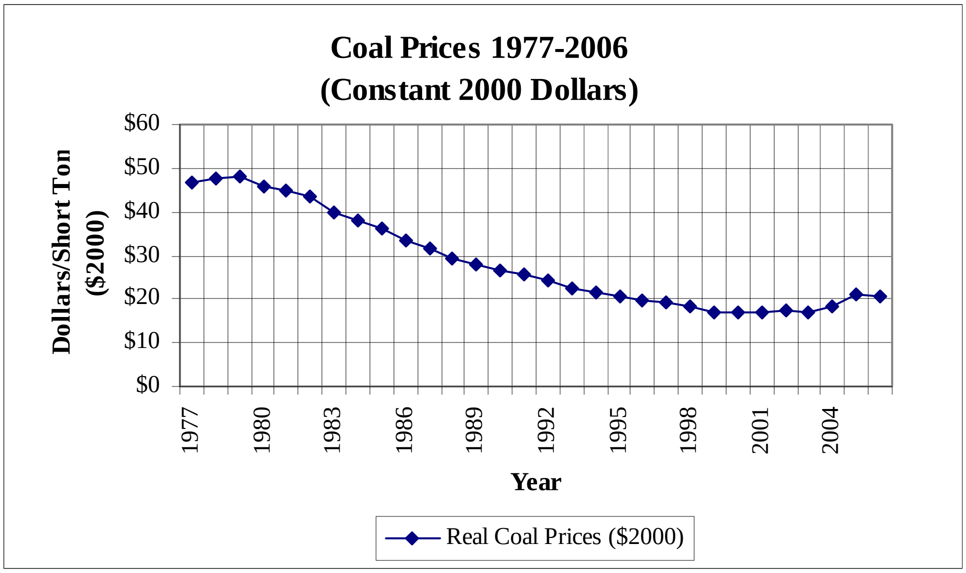

Figure 3-4. Constant Coal Prices 1997-2006
Source: Annual Energy Review 2006 (EIA, 2007a).

Figure 3-4 shows an increase in constant dollar prices beginning in 2004. EPA also examined recent price trends in current dollars (i.e., with no adjustment made for inflation) to characterize whether those price increases could be considered the beginning of a trend. Figure 3-5 presents spot market prices in current dollars from April 2005 through April 2008 for five coal-producing regions: Central Appalachia; Northern Appalachia; Illinois Basin; Uinta Basin in Colorado; and Powder River Basin in Wyoming (EIA, 2008a).[2, 3] Spot market prices fluctuate more widely than long-term contract prices because they only apply to that fraction of production available for immediate purchase; thus, as demand increases, spot prices increase more rapidly than, and tend to exceed contract prices. The prices in Figure 3-4 represent an annual value for all coal sold in the United States and is therefore a combination of all regions as well as coal sold under long-term contract and on the spot market. For these reasons, the prices shown in Figures 3-4 and Figures 3-5 are not directly comparable.

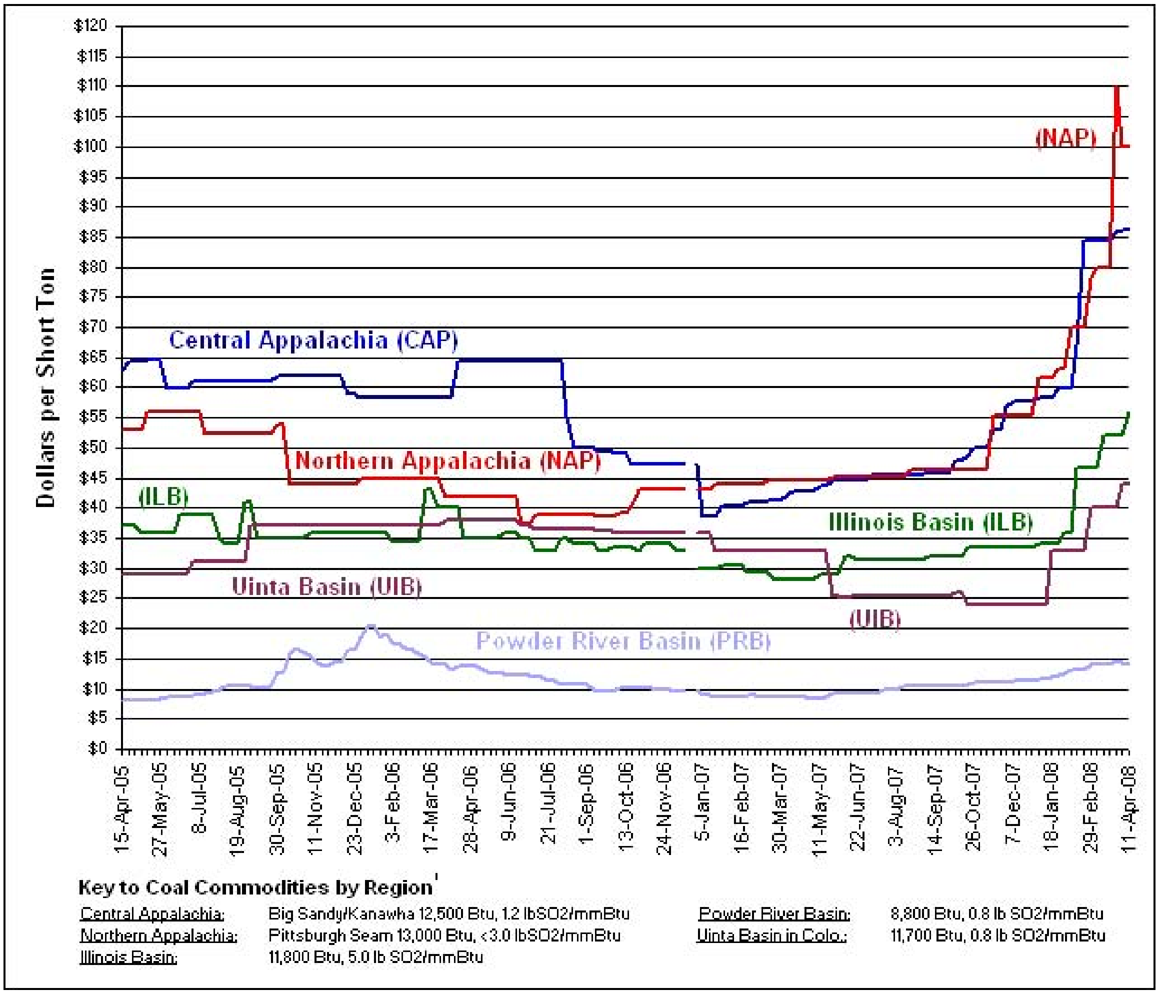

Figure 3-5. Spot Coal Prices April 15, 2005 through April 11, 2008
Source: Coal News and Markets (EIA, 2008a).

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[2] Energy prices in the EIA are indexed using the Gross Domestic Product implicit price deflator. Due to the time needed to estimate the price deflator, as well as the time to collect and compile data on long-term contract prices in addition to spot market prices, there is typically at least a one year large in generating constant dollar price estimates. Thus, at the time this report was written, price deflators were not available to deflate the time series shown in Figure 3-5 to the same basis as Figure 3-4 (2000 dollars).

[3] Spot market price applies to a one-time purchase of coal for immediate delivery at the going market price.

The regional variation in coal prices is apparent. Coal from the Powder River Basin has the lowest price even though it is lower in sulfur content, because of the transportation costs associated with getting the coal to market or export (EIA, 2008b). A slight price rise (about $5 per short ton) is seen from November 2007 through April 2008. In contrast, spot market prices for Central and Northern Appalachian coal have more than doubled during the same time period (an increase of about $55 per short ton). Prices for the Illinois and Uinta Basins coal show an increase but the increase starts about a month later and is not as pronounced as the increase in the prices for Appalachian coal basins. At this point in time, there is insufficient information to say whether the price increases seen in Figure 3-5 will be a short-term spike or a long-term change in the market. At the moment, however, the increased coal prices will enable marginal producers to remain in operation (EIA, 2008a).

Demand is high in the global coal markets for a number of reasons. Australia, the world’s largest coal exporter, has experienced infrastructure failures or production problems, resulting in lower exports. China, reduced its imports of Australian coal by 34 percent in 2007 (Marsh and McGregor, 2008). This, coupled with increasing demand for coal for power plants and manufacturers as well as for coal for steel blast furnaces in China, India, and other parts of Asia drives up demand for coal from other regions of the globe. China became a net importer of coal for the first time in early 2007 due to a mixture of increased demand and the costs and logistics of transporting coal from its inland mines to its coastal consumers. Europe imports U.S. coal for steelmaking, as well. Coal is also a substitute for oil. Therefore, high oil prices relative to coal can lead to consumers that have switching capability to change from oil to coal as a fuel. In addition, the relative weakness of the U.S. dollar makes U.S. coal more attractive to importing countries. Historically, Appalachia supplied most of the coal exported from the United States (e.g., Appalachian coal accounted for 84 percent of 2006 exports) which is a factor in the price spike seen for Appalachian coal (EIA, 2008b; Freme, 2008; Kraus, 2008).

3.2.2 Mine Counts, Mine Sizes, and Technological Changes

Table 3-11 summarizes the number of mines and mine size in Appalachia and the United States. Between 85 percent and 90 percent of U.S. mines are located in Appalachia, although Western mines produce more tons of coal (see Table 3-10). The number of mines follows the decline in prices seen in Figure 3-4, but other factors also play a role (see below). While the number of mines has decreased, the size of the remaining mines has increased; implying that the closures are concentrated in the smaller mines. Like coal prices, the number of mines hit its lowest value in 2003. The number of mines has increased slightly since then with a concomitant decrease in mine size. In Appalachia, the number of mines in 2006 was less than one-third of the number of mines in 1986.

Table 3-11. Number and Size of U.S. and Appalachian Coal Mines

Year	United States		Appalachia	
	Number of Mines	Average Mine Size (000, short tons)	Number of Mines	Average Mine Size (000, short tons)
1976	6,553	105	NA	NA
1986	4,424	201	3,990	107
1991	3,022	330	2,676	171
1994	2,354	439	2,068	215
1997	1,828	596	1,602	292
2003	1,316	814	1,124	335
2006	1,438	809	1,254	312

Source: The U.S. Coal Industry in the 1990s: Low Prices and Record Production (Bonskowski, 1999); The Changing Structure of the U.S. Coal Industry: An Update (EIA, 1993); Annual Coal Report 2004 (EIA, 2005); Annual Coal Report 2006 (EIA, 2007b).

The EIA noted several factors contributing to the decrease in the number of mines with the associated increase in mine size. With the oil price spikes of the 1970s, electric utilities turned toward coal as a less expensive fuel and looked for large coal suppliers that were capable of meeting long-term demands. Coal production thus shifted toward the thick coal seams in the West (EIA, 1993). The Clean Air Act Amendments of 1990 increased the demand for low-sulfur coal. The two major low-sulfur coal regions are the Powder River Basin (Wyoming) and Central Appalachia (southern West Virginia and eastern Kentucky) (EIA, 1993).

Bonskowski (1999) mentions several additional negative factors for small to medium operations. First, loss or renegotiation of contracts can be devastating. He notes that, in many cases, the financial problems of marginal mines stemmed from contract disputes and/or cancellations involving major customers. Second, the decline in the domestic steel industry meant a reduction in demand for coke plants. The coal used for steelmaking is produced primarily in Appalachia. In 1976, steel companies owned two of the top four coal producers in Appalachia. By 1986, steel-industry-affiliated companies had dropped out of the top four producers. By 1991, USX (formerly U.S. Steel) and Bethlehem Steel ranked 18th and 19th in central Appalachian coal production (EIA, 1993). By 1999, USX dropped to 25th place and Bethlehem Steel does not appear on the list of coal producers (EIA, 1999). These factors led to weakened financial conditions for small or marginal coal mines that were the typical coal mine in the Appalachian region.

Third, the industry underwent technological changes during the last two decades. From 1973, the coal mining industry has seen four trends:

1. Growth in surface mining accelerating at a greater pace than underground mining.
2. Surface mining techniques applied at larger and larger scales in western mines.
3. A shift in underground mining from room and pillar techniques to longwall techniques (see Section 3.1.4).
4. Continuing improvements in durability and capability in mining equipment, such as improved roof bolting systems, a shift to conveyor belt systems to carry coal out of underground mines, more powerful drill bits, and larger haul trucks and loaders.

While these changes might have begun several years ago, the trends they put in motion in the coal mining industry continue today (EIA, 2006c). One way of measuring the effect of the technological developments is the change in the number of short tons of coal mined by one employee per hour. Table 3-12 illustrates both the differences in productivity between surface and underground mining operations as well as regional differences. The Western region includes the Unita and Powder River Basins. Although western surface mining operations are five to six times more productive than Appalachian operations, the average productivity for the Powder River Basin is higher than that for the Unita Basin. During 2006, the average production per employee is 37.6 short tons per hour for the Powder River Basin (EIA, 2007b).

Table 3-12. Employee Productivity

Year	Short Tons per Employee per Hour				
	United States	Appalachian		Western	
		Surface	Underground	Surface	Underground
1986	3.01	2.54	1.90	11.49	2.82
1991	4.09	3.24	2.54	15.33	4.56
1994	4.98	3.72	2.96	17.68	5.98
1997	6.04	4.26	3.55	21.78	6.88
2003	6.95	3.83	3.64	25.01	8.42
2006	6.26	3.45	2.95	25.70	6.77

Source: The U.S. Coal Industry in the 1990's: Low Prices and Record Production (Bonskowski, 1999); The Changing Structure of the U.S. Coal Industry: An Update (EIA, 1993); Annual Coal Report 2004 (EIA, 2005); Annual Coal Report 2006 (EIA, 2007b).

3.2.3 Major Producers

Consistent with the increase in mine size over time, EIA's definition of a major producer has also changed. In 1994, a major coal producer was one that mined more than 2 million short tons that year (EIA, 1994). In 2006, a major coal producer mined more than 5 million short tons (EIA, 2007b). Table 3-13 lists the 27 major producers that accounted for 81 percent of the 2006 production. At least 81 percent of domestic coal production is in private hands.[4]

Table 3-13. Major Coal Producers in 2006

Rank	Company Name	Company Name/Parent	Public	Private	Foreign (Country)	% of Total Production (2006)	Reference
1	Peabody Coal Co.	Peabody Energy Co.	X			17.9	(Peabody, 2008)
2	Rio Tinto Energy America, Inc.	Rio Tinto		X	U.K., Australia	11.6	(Rio Tinto, 2008)
3	Arch Coal, Inc.	Arch Coal, Inc.	X			11.1	(Arch Coal Inc, 2008)

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[4] EIA (2007b) does not specify the ownership of the remaining 19 percent of production; it is likely that some of it is mined by private companies.

Table 3-13. Major Coal Producers in 2006

Rank	Company Name	Company Name/Parent	Public	Private	Foreign (Country)	% of Total Production (2006)	Reference
4	Foundation Coal Corp.	/Foundation Coal Holdings, Inc.	X			6.0	(Foundation Coal, 2008)
5	CONSOL Energy, Inc.	CONSOL Energy, Inc.	X			5.4	(CONSOL, 2008)
6	A.T. Massey Coal Co., Inc.	Massey Energy Company	X			3.3	(Massey, 2008a)
7	North American Coal Corp.	/NAACO Industries, Inc.	X			2.7	(NACC, 2008)
8	Westmoreland Coal Co.	Westmoreland Coal Co.	X			2.5	(Westmoreland, 2008)
9	Alliance Coal, LLC	Alliance Resource Partners, L.P.	X			2.0	(Alliance, 2008)
10	Peter Kiewit Sons, Inc.	Peter Kiewit Sons, Inc.		X		2.0	(Kiewit, 2008)
11	TXU Corp	Energy Future Holdings, Corp.		X		1.9	(TXU, 2008)
12	Robert Murray	Murray Energy Corp		X		1.8	(Murray, 2008)
13	International Coal Group, Inc.	International Coal Group, Inc.	X			1.7	(ICG, 2008)
14	BHP Minerals Group	BHP Billiton	X		Australia	1.6	(BHP, 2008)
15	Alpha Natural Resources, LLC	Alpha Natural Resources, Inc.	X			1.6	(Alpha, 2008)
16	Magnum Coal Co.	Magnum Coal Co.		X		1.0	(Magnum Coal, 2008)
17	James River Coal Co.	James River Coal Co.	X			1.0	(JRCC, 2008)
18	Energy Coal Resources, Inc.	Energy Coal Resources, Inc.		X		0.9	(Energy Coal Resources, 2008)
19	Pittsburg & Midway Coal Mining Co.	/Chevron		X		0.8	(Chevron, 2008)
20	PacifiCorp	/Mid American Energy Holdings Co.	X			0.8	(PacifiCorp, 2007)
21	Peter Kiewit/Kennecott	/Kennecott Minerals, Rio Tinto Group		X	U.S./ Australia	0.6	(Kiewit, 2008; Kennecott, 2008)
22	Alcoa, Inc.	Alcoa, Inc.	X			0.6	(Alcoa, Inc, 2008)
23	Andalex Resources, Inc.	Andalex Resources, Inc.		X	Canada	0.6	(Andalex Resources, 2008)
24	Western Fuels Association, Inc.	Western Fuels Association, Inc. (Cooperative)		X		0.5	(Western Fuels, 2008)

Table 3-13. Major Coal Producers in 2006

Rank	Company Name	Company Name/Parent	Public	Private	Foreign (Country)	% of Total Production (2006)	Reference
25	TECO Energy, Inc.	TECO Energy, Inc.	X			0.5	(TECO, 2008)
26	Wexford Capital LLC	Wexford Capital LLC		X		0.5	(Wexford, 2008)
27	Oxbow Carbon & Minerals, Inc.	Oxbow Corporation		X		0.4	(Oxbow, 2008)

Source: Table 10 from Annual Coal Report 2006 (EIA, 2007b).

Corporate structures in the coal mining industry can be complex and fluid. For example, in October 2007, Peabody Energy Corporation—the number one coal producer in the United States in 2006 (see Table 3-13)—spun off its coal mining subsidiaries into Patriot Coal Corporation. At the end of 2007, Patriot Coal Corporation had 57 subsidiaries (Patriot, 2007). In April 2008, Patriot Coal Corporation announced it would acquire Magnum Coal (Table 3-13, company number 16), making its structure even more complicated (Patriot, 2008). At the end of 2007, Massey Energy Company listed 109 subsidiaries in its annual financial report (Form 10-K) to the Securities and Exchange Commission (SEC) (Massey, 2008b).

3.2.4 Foreign Ownership

Coal production under foreign ownership is shown in Table 3-14. In 1976, less than 2 percent of domestic coal was produced by foreign-owned firms. The percentage slowly increased through the 1980s and showed a sharp increase in the mid-1990s. By 2006, the percentage had dropped to about 14 to 15 percent, with Rio Tinto the major foreign owner (EIA, 1994; EIA, 2006a).

Table 3-14. Percent of U.S. Coal Production by Foreign-Owned Firms

Year	Percent of U.S. Coal Production by Foreign-Owned Firms
1976	1.4
1986	1.6
1991	14.3
1994	20.9
2006	14.4

Source: Figure 2 from *Coal Industry Annual 1994* (EIA, 1994); Table 10 from *Annual Coal Report 2006* (EIA, 2007b).

3.2.5 Number of Small Entities

The Small Business Administration (SBA) sets size standards for each NAICS industry in 13 CFR 121.201. For the coal mining NAICS codes, 212111, 212112, and 212113, the size standard is 500 employees. In Appalachia, the average production per employee is 3.13 short tons per hour while in the Powder River Basin, the average production per employee is 37.6 short tons per hour (EIA, 2007b, Table 21, 2006 data). Assuming an employee works 2,000 hours per year, a single employee could produce between 6,260 and 75,200 short tons per year.

Thus, what SBA considers a small firm is still capable of producing a substantial amount of coal. Two of the major coal producers listed in Table 3-13, Western Fuels Association, Inc. and Wexford Capital LLC, have fewer than 500 employees and thus qualify to be called a small business on the basis of SBA size standards. SBA works with the U.S. Census Bureau to provide the number of firms by employment size by NAICS code. The most recent data available are 2005, presented in Table 3-15. The majority of firms are classified as small businesses by SBA.

Table 3-15. Employer Firms, and Employment by Size of Firm, 2005

Industry	NAICS	Number of Firms	Number of Firms with <500 Employees	Percent Small
Coal Mining	2121	703	660	94%
Bituminous Coal and Lignite Surface Mining	212111	383	349	91%
Bituminous Coal Underground Mining	212112	296	268	91%
Anthracite Mining	212113	56	55	98%

Source: Employer Firms, and Employment Size of Firm by NAICS Codes, 2005 (SBA, 2005).

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4.0 COAL MINING REGULATORY FRAMEWORK

Coal mining operations are governed by a complex regulatory nexus between the Clean Water Act (CWA), the Surface Mining Control and Reclamation Act (SMCRA), and state requirements. The CWA regulates discharges from coal mines; SMCRA regulates the planning, active mining, and reclamation of coal mines; and states and tribes, authorized by EPA, oversee both regulatory programs. States and tribes may add requirements that are more stringent than federal requirements.

Compared with other industries permitted under the CWA's National Pollutant Discharge Elimination System (NPDES), the coal mining industry is unique. Due to linkages between the CWA and SMCRA, state mining programs, rather than water quality programs, often issue NPDES permits for this industry.

4.1 Regulation of Coal Mining Discharges to Surface Water

States write NPDES permit requirements based on either effluent limitations and guidelines (ELGs) or water quality criteria—whichever limits are more stringent. Permit limits from ELGs for coal mining discharges are based on 40 CFR Part 434. Under the water quality criteria approach, permit writers use the designated goals of a waterbody to establish numeric pollutant concentrations and narrative requirements. Of particular relevance to this study, EPA estimates that approximately 50 percent of Pennsylvania's and 20 percent of West Virginia's coal mining permits with manganese limits are based on more stringent water quality criteria rather than ELGs (see Section 5.2.1).

4.1.1 Regulation of Coal Mine Discharges Using ELGs

EPA first promulgated ELGs for the Coal Mining Category (40 CFR Part 434) on October 9, 1985 (50 FR 41305) and revised them on January 23, 2002 (67 FR 3369). Table 4-1 presents the Coal Mining ELGs of primary importance with respect to this study. Figure 4-1 presents a flow chart describing the interaction of SMCRA and Part 434 from the time that a company develops its initial application for a mining permit, through bonding, active mining, and post-mining activity.

During active mining, discharges from both surface and underground mines are regulated by Subparts C and D: Acid or Ferruginous Mine Drainage and Alkaline Mine Drainage, respectively. Once a permitting authority determines that a mine is in the post-mining stage, coal mining discharges are regulated by Subpart E - Post-Mining Areas. Subpart F – Miscellaneous Provisions is applicable to both active mines and post-mining areas. Discharges from abandoned mines (e.g., pre-SMCRA) are not regulated by 40 CFR Part 434.

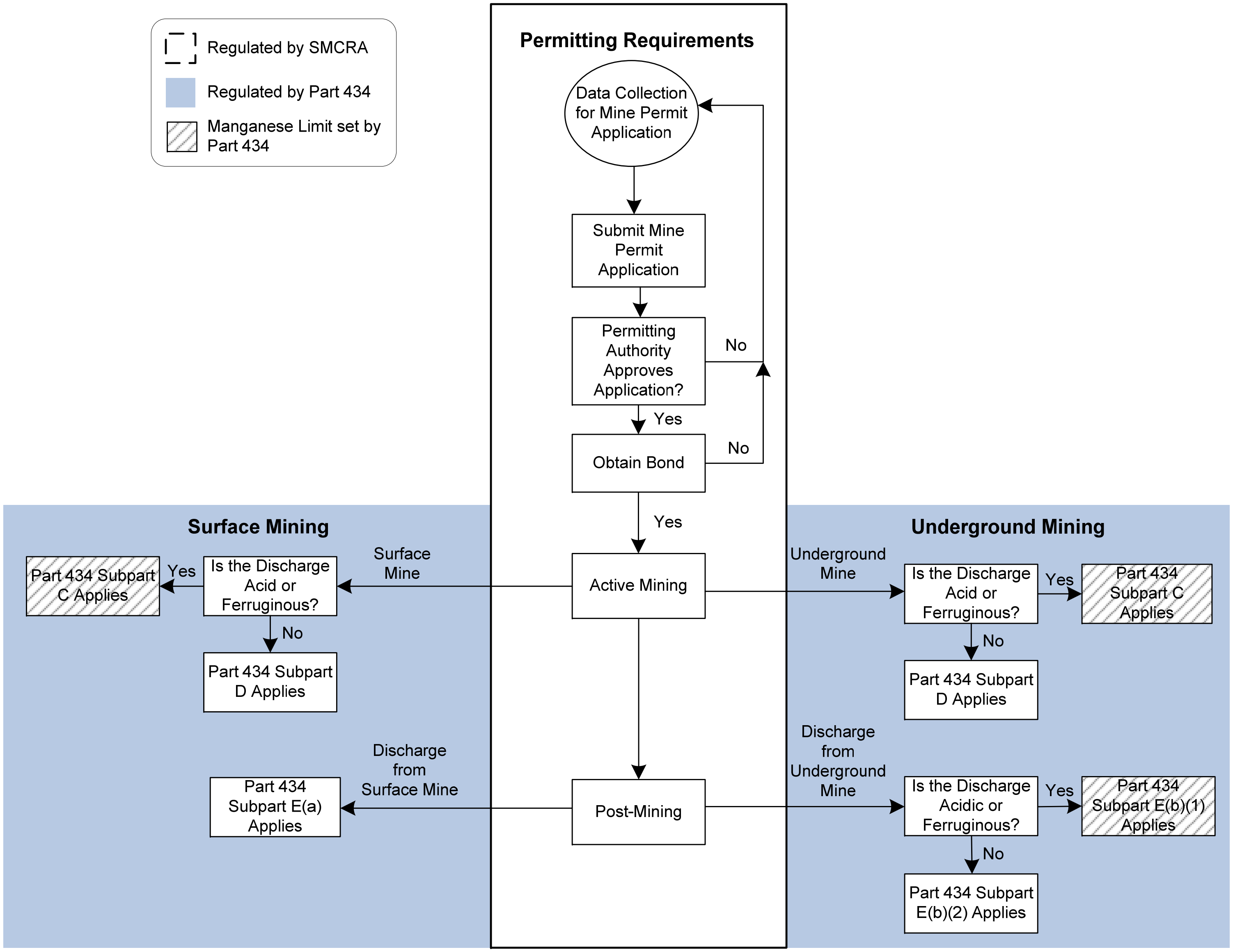

Figure 4-1. SMCRA and Part 434 Regulatory Framework

Table 4-1. Coal Mining ELGs

Subpart	Mine Status	Subcategory Name	Type of Limitation Guideline
Subpart C	Active	Acid or Ferruginous Mine Drainage [a]	BPT, BAT, NSPS
Subpart D	Active	Alkaline Mine Drainage [b]	BPT, BAT, NSPS
Subpart E	Post-Mining	Post-Mining Areas [c]	BPT, BAT, NSPS
Subpart F	Active and Post-Mining	Miscellaneous Provisions	Provisions for alternate effluent limitation for pH

Source: *Coal Mining Point Source Category BPT, BAT, BCT Limitations and New Source Performance Standards – 40 CFR Part 434*.
a – Acid or ferruginous mine drainage is mine drainage that, before treatment, either has a pH of less than 6.0 or a total iron concentration equal to or greater than 10 mg/L.
b – Alkaline mine drainage is mine drainage that has a pH equal to or greater than 6.0 and total iron concentration of less than 10 mg/L.
c – Post-mining areas are defined as reclamation areas, and the underground workings of an underground coal mine after the extraction, removal, or recovery of coal from its natural deposit has ceased or prior to bond release.
BPT – Best practicable control technology.
BAT – Best available technology economically achievable.
NSPS – New source performance standards.

Table 4-2 lists the numeric limitations for active mines (established under Subparts C and D) and Table 4-3 presents the numeric limitations for post-mining areas (established under Subpart E). Note that there are no manganese limits for surface post-mining areas.

Note that there are different limits for reclamation (surface) areas and underground post-mining areas. Subpart E further separates the regulation of drainage from underground post-mining areas into acid or ferruginous mine drainage and alkaline mine drainage.

Table 4-2. Effluent Guidelines for Active Mines Part 434, Subparts C – D

Parameter	BPT/BAT		NSPS	
	30-day Average (mg/L)	Daily Maximum (mg/L)	30-day Average (mg/L)	Daily Maximum (mg/L)
Acid or Ferruginous Mine Drainage				
Iron, Total	3.5	7.0	3.0	6.0
Manganese, Total	2.0	4.0	2.0	4.0
pH	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9
TSS	35	70	35	70
Alkaline Mine Drainage				
Iron, Total	3.5	7.0	3.0	6.0
pH	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9
TSS	35	70	35	70

Source: *Coal Mining Point Source Category BPT, BAT, BCT Limitations and New Source Performance Standards – 40 CFR Part 434*.
BAT - Best available technology economical achievable.
BPT - Best practicable control technology.
NSPS - New source performance standards.

Table 4-3. Effluent Guidelines for Post-Mining Areas Part 434, Subpart E

Parameter	BPT/BAT		NSPS	
	30-day Average (mg/L)	Daily Maximum (mg/L)	30-day Average (mg/L)	Daily Maximum (mg/L)
Reclamation (Surface) Areas [a]				
pH [b]	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9
Settable Solids	0.5 mL/L	NA	0.5 mL/L	NA
Underground Mine Drainage [c] – Acid or Ferruginous				
Iron, Total	3.5	7.0	3.0	6.0
Manganese, Total	2.0	4.0	2.0	4.0
pH [b]	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9
TSS [b]	35.0	70.0	35.0	70.0
Underground Mine Drainage [c] – Alkaline				
Iron, Total	3.5	7.0	3.0	6.0
pH [b]	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9	within range of 6 to 9
TSS [b]	35.0	70.0	35.0	70.0

Source: *Coal Mining Point Source Category BPT, BAT, BCT Limitations and New Source Performance Standards – 40 CFR Part 434*.
a - Reclamation area, which is the surface area of a coal mine that has been returned to required contour and on which revegetation (specifically, seeding or planting) work has commenced (40 CFR 434.11(l)).
b – Not included as BAT.
c - Underground mine drainage, which is the underground workings of an underground coal mine after the extraction, removal, or recovery of coal from its natural deposit has ceased and prior to bond release (40 CFR 434.11(k)).
BAT - Best available technology economical achievable.
BPT - Best practicable control technology.
NSPS - New source performance standards.

In addition to the ELGs presented in Tables 4-2 and 4-3, Subpart F – Miscellaneous Provisions includes a variance for pH:

> *Where the application of neutralization and sedimentation treatment technology results in inability to comply with the otherwise applicable manganese limitations, the permit issuer may allow the pH level in the final effluent to exceed 9.0 to a small extent in order that the manganese limitations can be achieved.*

EPA found that both West Virginia and Pennsylvania have issued permit variances for pH, allowing discharges above 9, to assist mines in meeting manganese limitations. EPA evaluated the frequency of permitting authorities issuing pH variances, presented in Section 5.2.2.

Manganese Regulations in Part 434

As shown in Tables 4-2 and 4-3 above, Part 434 establishes limitations for manganese discharges for both active mines (under Subpart C) and underground mines in the post-mining state (under Subpart E). Note, however, that Subpart E does not set limitations for manganese for discharges from surface mines in the post-mining state. Thus, manganese limitations apply to the following:

1. Active surface and underground mining areas with acid or ferruginous mine drainage discharges; and
2. Underground post-mining areas with acid or ferruginous mine drainage discharges.

There are no national manganese effluent limits for surface post-mining areas with acid mine drainage (AMD). There are also no national manganese effluent limits for AMD that may develop after SMCRA bond release has been granted. Nor are there national manganese effluent limits for AMD from abandoned coal mines (e.g., pre-SMCRA).

4.1.2 Regulation of Coal Mine Discharges Using State Water Quality-Based Limitations

Water quality standards are the foundation of the water quality-based control program mandated by the CWA. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing water quality standards to protect water quality from pollutants. A water quality standard consists of four basic elements:

1. Designated use of the water body (e.g., recreation, drinking water supply, aquatic life, agriculture);
2. Water quality criteria to protect designated use (numeric pollutant concentrations and narrative requirements);
3. An anti-degradation policy to maintain and protect existing uses and high quality waters; and
4. General policies addressing implementation issues (e.g., low flows, variances, mixing zones).

Both Pennsylvania and West Virginia established manganese water quality criteria at lower concentrations than the 40 CFR Part 434 Subpart C manganese limitations: 1.0 mg/L in both states, for certain stream designations.

Pennsylvania set the water quality criterion for manganese at 1.0 mg/L for most stream designations to protect their use as potable water sources (i.e., drinking water source) (*025 Pa. code Section 93.*7). Pennsylvania may not apply the 1.0 mg/L criterion for certain streams, such as those designated as acid impaired.

West Virginia set the water quality criterion for manganese at 1.0 mg/L for all surface water that is a possible source of drinking water. Prior to 2005, the 1.0 mg/L manganese criterion was effective for all outfalls that discharge into surface water. West Virginia Department of Environmental Protection (WV DEP) incorporated this manganese criterion into all NPDES permits, including coal mines, for final effluent outfalls. In 2005, WV DEP changed the applicability of the manganese criterion so it applies only to outfalls that are five or fewer miles upstream of a drinking water intake location (“Five-Mile Rule”) (*WV Title 47 Legislative Rules*).

Following this change, WV DEP modified NPDES manganese permit limits for discharges, including coal mine discharges that were more than five miles from a drinking water intake to the limitations in the ELGs (2.0 mg/L 30-day average and 4.0 mg/L daily maximum). The manganese permit limits for discharges, including coal mine discharges, that are five or fewer miles up-stream of a drinking water intake remained at 1.0 mg/L. WV DEP said that the majority of coal mines with NPDES permits limits for manganese that were based on the water quality criterion applied for permit modifications when the applicability was changed (U.S. EPA, 2008). The coal mine NPDES permits issued by WV DEP since 2005 are based on the revised manganese criterion.

EPA collected data on how often manganese permit limitations are based on water quality criteria instead of Part 434. Section 5.2.1 discusses this analysis in detail. Overall, the frequency of manganese water quality-based permit limits ranges from approximately 20 percent (West Virginia) to 50 percent (Pennsylvania).

4.2 SMCRA Requirements

SMCRA regulates many aspects of coal mining. Prior to SMCRA there were no federal requirements for reclamation of mine sites; therefore, reclamation was often not done. Coal mines were often left unreclaimed, with open pits, portals, and mine shafts. It is estimated that up to 90 percent of AMD is from abandoned coal mines without a responsible party treating the discharge (U.S. EPA, 2001). SMCRA was passed to promote reclamation after coal extraction to maintain the quality of the environment, prevent damage to the beneficial use of land or water resources, and avoid endangering the health or safety of the public (U.S. EPA, 2001).

SMCRA regulates surface mining operations, the surface aspects and effects of underground mining operations, and facilities associated with coal mining operations, such as coal preparation plants and refuse disposal sites. States may be delegated authority to implement a regulatory program under SMCRA. States receive delegated status by demonstrating that state laws are at least as effective as SMCRA and by showing that states have resources to enforce the laws. The Office of Surface Mining Reclamation and Enforcement (OSMRE) oversees the delegated state programs. All of the states in the Appalachian Region except for Tennessee have been delegated authority to implement SMCRA. SMCRA is implemented by OSMRE in Tennessee (U.S. EPA, 1998).

SMCRA includes requirements for coal mine operators to conduct pre-mining and post-mining activities. SMCRA also authorized taxation of coal production to fund the federal Abandoned Mine Lands (AML) Fund. The AML Fund finances abandoned mine land reclamation projects initiated by states (ERG, 2006; OSMRE, 2006).

Under SMCRA, before a permit is issued, mine operators must show how the site will be reclaimed after mining is complete. This reclamation plan includes reclamation of the mine site, evaluating the hydrologic impacts of the mining and reclamation, and assessing the impacts of the mine site on the watershed. The reclamation plan must demonstrate that the original land use has been restored, the site is revegetated, and does not have negative impacts on the watershed. Some examples of reclamation tasks include regrading, sealing shafts and portals, and removing ponds and other surface water control structures.

Mine operators must also demonstrate that the reclaimed mine will not degrade surface waters or impact groundwater hydrology (U.S. EPA, 1998). Mine operators evaluate the hydrologic impacts of mining and reclamation by conducting a “Probable Hydrologic Consequences” (PHC) evaluation. For the PHC, mine operators generally collect at least six months of baseline surface and groundwater monitoring data. These data are used to generate erosion and sedimentation control plans, predict post-mining water quality and quantity, and minimize environmental impacts.

The collected monitoring data is also used by the regulating authority to conduct a Cumulative Hydrologic Impact Assessment (CHIA). The CHIA assesses the impact of the proposed mine site on the watershed while factoring in impacts from previous mining areas (ERG, 2006). If a PHC evaluation indicates the likelihood of AMD, a permit is not issued. The ability to predict AMD has increased greatly since the passage of SMCRA in 1977.

SMCRA also requires mine operators to post a bond (monetary guarantees) covering the costs of reclamation, as determined by the permitting authority, if the company goes out of business before reclamation is complete. The bond amount is designed to reflect the probable difficulty of reclamation given geography, hydrology, climate, and other factors, and be sufficient to assure completion of reclamation if the mine operator defaults and regulatory authorities must complete reclamation. The reclamation bond is not released until the mine has been reclaimed and the permitting authority has determined the reclamation was successful.

Throughout the life of the mine, authorities review and renew permits and inspect mine activities, to ensure the use of proper erosion and sedimentation control, treatment, mitigation, and rehabilitation (ERG, 2006). The amount of the initial bond is set with the assumption that discharges (and AMD in particular) will not occur. If a discharge occurs after the mine has begun operation, the state may direct the operator to post additional bonding to treat the discharge (Pizarchik, 2008).

4.3 Coal Mining Regulatory Framework References

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5.0 COAL MINE DRAINAGE CHARACTERISTICS

This section presents the untreated and treated wastewater characteristics of Appalachian acid mine drainage (AMD), including pollutants observed in mine drainage to provide background information on coal mine drainage. EPA also compared pollutant concentrations in treated AMD to Part 434 in response to comments received from stakeholders saying mines had difficulty meeting manganese limits. This study uses data from five databases to update existing EPA data, including recent data from hundreds of coal mines. As explained in Section 2.0, EPA did not find a comprehensive source containing information to characterize pollutant concentrations in coal mine discharge. However, EPA's data collection efforts include the major sources of coal mining data at the federal level and for Pennsylvania and West Virginia.

Overall, EPA concluded the following:

- AMD has untreated manganese above the Part 434 Subpart C New Source Performance Standards (NSPS) limitations. Manganese ranges from 0.02 to 980 mg/L in untreated AMD from *ARAMD* (see Sections 5.1.2.3).
- Many National Pollutant Discharge Elimination System (NPDES) manganese limits for AMD discharges are based on water quality standards, not Part 434. The water quality standards for West Virginia and Pennsylvania are both 1.0 mg/L. Approximately 27 percent of current West Virginia NPDES permit manganese limits for coal mines are water quality-based; Pennsylvania Department of Environmental Protection (PA DEP) estimated that 50 percent of coal mine manganese NDPES permit limits are based on water quality standards (see Section 5.2.1).
- pH permit variances are issued in West Virginia to assist mines in meeting their water quality-based manganese limits. West Virginia Department of Environmental Protection (WV DEP) granted pH permit variances for 49 mines with maximum pH limits up to 10.5. PA DEP has also issued pH permit variances, but does not believe mines discharge above pH 9 even if treating for manganese. EPA found that the number of total manganese concentrations above the Subpart C NSPS limits do not increase when the effluent pH is below 9. (i.e., below the optimal pH for manganese removal) (see Section 5.2.2).
- EPA's comparison of discharge concentrations of treated wastewater with Part 434 NSPS limits indicates that compliance rates are high (see Section 5.2.3).

5.1 Wastewater Characteristics

Water discharges from coal mines result from stormwater and groundwater infiltration. The resulting runoff or groundwater eventually discharges to surface water, typically in headwater streams.

The Office of Surface Mining Reclamation and Enforcement (OSMRE) database *ARAMD* provides data from 1,264 mine outfalls in the Appalachian region. The remainder of this section examines pollutant characteristics of AMD: the pollutants of interest in mine discharges (Section 5.1.1), and the formation, location, and characterization of AMD (Section 5.1.2).

5.1.1 Pollutants of Interest

Pollutants found in AMD include acidity, metals, solids, and increased conductivity. Conductivity is measured as an indicator pollutant of total dissolved solids (TDS) which includes bicarbonate, calcium, magnesium, and sulfate (U.S. EPA, 1982). Regulators typically monitor AMD for the following parameters: metals (aluminum, iron, and manganese), acidity, alkalinity, total suspended solids (TSS), and pH (*WVDMR*; *PADEPInspector*). NPDES permits for mine drainage often include other pollutants based on water quality standards or other state requirements, as discussed in Section 4.1.2.

Metals (aluminum, iron, and manganese) can be analyzed as total metals, dissolved metals, or for valence states (e.g., ferrous versus ferric iron). Treated and untreated discharges are typically analyzed for total metals (*WVDMR*; *ARAMD*); Pennsylvania requires analysis for dissolved metals (PA Code). In addition, some coal mines analyze untreated mine drainage for certain valence state metals. The valence state of iron, ferrous or ferric, is important for determining the appropriate iron removal treatment technology, especially passive treatment of AMD. For example, anoxic limestone drains will not adequately treat AMD with high concentrations of ferric iron or dissolved oxygen (U.S. EPA, 2001). When reporting metal concentrations for AMD to permitting authorities, the majority of preparation plants report values as total metals.

Acidity measures the concentration of available hydrogen ions. It can also be described as the ability of a water sample to neutralize a base. In this report, acidity is reported as either net acidity or hot acidity. Hot acidity involves adding hydrogen peroxide and heating the sample, which degasses carbon dioxide and oxidizes any metal hydroxides, thereby liberating acidity. After this step, the sample is titrated with a standard solution of sodium hydroxide to a predetermined pH, usually 8.3. In this study, the term “net acidity” indicates that the method used to measure acidity was not identified in the data source. Both parameters are expressed in mg/L of calcium carbonate equivalent, and both can be reported as negative values. A negative value indicates that the water has a net alkalinity. Treated and untreated discharges are typically analyzed for acidity (U.S. EPA, 1982).

Alkalinity measures the ability to neutralize acid and relates the buffering capacity of the water, or the ability of the water to resist changes in pH. In this report, alkalinity is expressed as mg/L of calcium carbonate ($CaCO_3$). A negative value indicates that the water has a net acidity. Treated and untreated discharges are typically analyzed for alkalinity (U.S. EPA, 1982).

TSS is the concentration of filterable solids measured in a sample. Suspended solids are the material remaining after filtration of a sample using a standard glass fiber filter disk. The filter is weighed before filtration, dried between 103 and 105°C, and weighed again. The gain in weight is the total suspended solids. Both treated and untreated discharges are typically analyzed for TSS (U.S. EPA, 1982).

pH measures the activity of hydrogen ions in a sample. The typical pH range of coal mine discharges are from two to 12 standard units (s.u.). The pH is determined for both treated and untreated discharges (U.S. EPA, 1982).

5.1.2 Acid Mine Drainage

AMD is characterized by high metals concentrations and an acidic (low) pH, created by geochemical and microbial reactions of oxygen and water with pyrite (iron disulfide). AMD contains varying levels of iron, manganese, aluminum, and total dissolved solids (TDS), depending on the geochemistry of the coal seam and the rock surrounding the coal. Part 434 defines AMD as drainage with a pH less than 6 or an iron concentration of greater than or equal to 10 mg/L.

AMD chemistry varies by type of mine (surface vs. deep mines). Surface mining breaks apart rocks above the coal seam (i.e., overburden), greatly increasing the overburden surface area and exposure to the atmosphere. The overburden frequently contains nodules of siderite (iron carbonate) as a cementing agent in sandstones. Studies have shown that the siderite contains small amounts of manganese as replacement for the iron (Larsen, 2005). The siderite breaks down and releases manganese once exposed to the air and in contact with water infiltrating through the overburden. The resulting wastewater discharge is AMD. In deep mines, the remaining coal and the exposed rock usually contain little siderite, but considerable pyrite (Larsen, 2005). As a result, AMD from surface mines may have higher concentrations of manganese, while AMD from deep mines may have higher concentrations of sulfates and iron (ERG, 2006).

5.1.2.1 Chemistry of AMD

Exposure of pyrite to oxygen and the infiltrating stormwater produces sulfuric acid and iron (dissolved in the water). The following chemical reactions summarize the formation of AMD from stormwater and oxygen weathering pyrite (Snoeyink, 1980):

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2\ SO_4^{-2} + 2\ H^+ \qquad (5\text{-}1)$$

$$Fe^{+2} + \tfrac{1}{4}\ O_2 + H^+ \rightarrow Fe^{+3} + \tfrac{1}{2}\ H_2O \qquad (5\text{-}2)$$

$$Fe^{+3} + 3\ H_2O \rightarrow Fe(OH)_3 + 3\ H^+ \qquad (5\text{-}3)$$

$$FeS_2 + 14\ Fe^{+3} + 8\ H_2O \rightarrow 15\ Fe^{+2} + 2\ SO_4^{-2} + 16\ H^+ \qquad (5\text{-}4)$$

AMD chemistry is unique because oxygen oxidizes pyrite to produce Fe^{2+} (Equation 5-1), which is further oxidized to Fe^{3+} (Equation 5-2). The Fe^{3+} may oxidize more pyrite to form more Fe^{2+} (Equation 5-4), or Fe^{3+} may precipitate as $Fe(OH)_3$ (Equation 5-3). Additionally, *Thiobacillus thiooxidan, Thiobacillus ferrooxidan,* and *Ferrobacillus ferrooxidan* microorganisms catalyze the oxidation of ferrous ion, allowing more rapid oxidation to ferric iron, even at low pH (Snoeyink, 1980).

5.1.2.2 Locations of AMD

The formation of AMD is a problem in areas of the United States where the coal and overburden contain significant amounts of pyrite and little alkaline material (e.g., calcium carbonate). Coal mines in the Appalachian region of the United States (Western Pennsylvania, Eastern Ohio, northern West Virginia, Southwestern Virginia, and Maryland) have the highest tendencies for producing acidic discharges.

Figure 5-1 presents the potential acid mine drainage locations from surface mining in the Appalachian Region based on USGS coal drilling data. The black dots on Figure 5-1 represent the areas where USGS conducted drilling. The green areas have low potential to produce AMD; the yellow areas have intermediate potential to produce AMD; and the red areas have high potential to produce AMD. The remaining Appalachian region, including southern West Virginia, Virginia, and eastern Kentucky, infrequently produce acidic drainage (Cecil, 2005). Additional, localized acid mine drainage problems may exist in Indiana, Illinois, Iowa, Missouri, Oklahoma, Kansas, Tennessee, Alabama, and Georgia, depending on the geology of the overburden and the hydrologic setting (OSMRE, 2002).

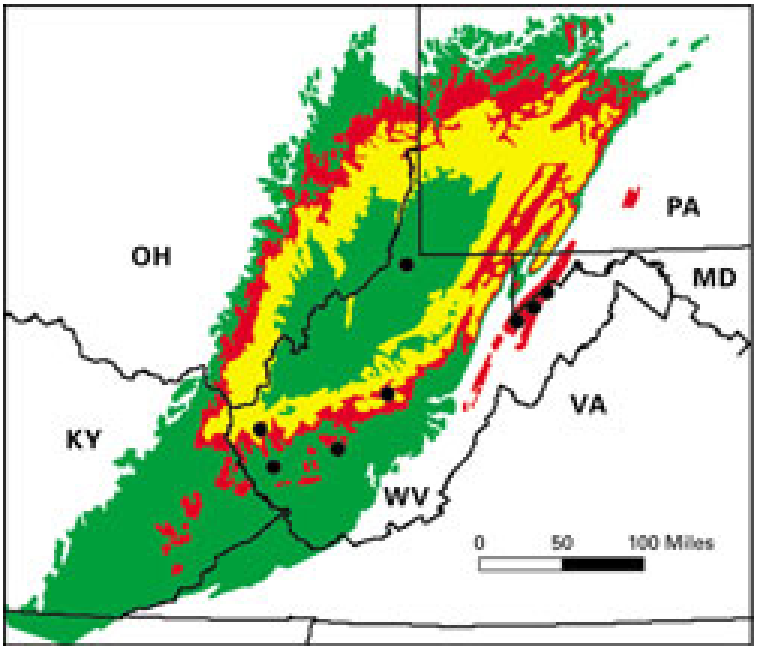

Figure 5-1. Distribution of Potential Acid Mine Drainage from Surface Mining in the Appalachian Region

Source: Coal Extraction – Environmental Prediction (Cecil, 2005).

5.1.2.3 AMD Characteristics

AMD may contain manganese, aluminum, and TDS, depending on the geochemistry of the coal seam and surrounding rock. In water bodies that receive AMD, permitting authorities usually monitor pH, iron, manganese, TSS, aluminum, sulfates, alkalinity, and acidity.

Table 5-1 presents the number of outfalls from available data sources that are classified as AMD. These data sources do not include all outfalls in the Appalachian region, and therefore the counts represent a sample of outfalls with AMD. Additionally, the data sources may overlap, and EPA may count outfalls in multiple sources more than once. EPA identified outfalls with AMD based on pH and iron concentrations.

Table 5-1. Number of Acid Mine Drainage Outfalls

Database	Number of Permit IDs	Number of Outfalls	Number of Sample Dates
Untreated			
AMD143	143	143	143
AMDI	236	376	403
ARAMD	580	971	974
BAMR	1	2	99
PADEPMDI	320	573	14,124
WVDEPSpecialRec	16	42	1,837
Treated			
PADEPInspector	234	333	4,305
WVDMR	883	3,295	46,406

Source: *AMD143*; *AMDI*; *ARAMD; BAMR; PADEPMDI; PADEPInspector; WVDEPSpecialRec*; *WVDMR*.

EPA identified the mines and outfalls with AMD and summarized the untreated water quality data from the following data sources: *ARAMD*, *AMDI*, *WVDEPSpecialRec*, *PADEPMDI*, *BAMR*, and *AMD143*. Table 5-2 presents the wastewater characteristics in untreated AMD[5] from the *ARAMD*, *AMDI*, *WVDEPSpecialRec*, and *PADEPMDI* databases for 17 parameters. Table 5-3 presents the wastewater characteristics in untreated AMD from the *BAMR* and *AMD143* databases for 17 parameters. The *BAMR* and *AMD143* databases are presented separately because *BAMR* contains sampling data for AMD discharges on abandoned mine land and *AMD143* contains sampling data for deep/underground mines with large flows that are uncharacteristic of surface mines. However, data from both databases still provides an overview of the range of pollutant values. Appendix A presents additional parameters reported in the *AMD143* and *PADEPMDI* databases.

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[5] If an outfall had an average pH less than 6 s.u. or an average iron concentration greater than or equal to 10 mg/L, EPA identified the outfall as AMD.

Table 5-2. Untreated Acid Mine Drainage Characteristics

Pollutant Parameter	*ARAMD* Database [a]			*AMDI* Database [a]			*WVDEPSpecialRec* Database [a]			*PADEPMDI* Database [a]		
	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value
Conductivity (umhos/cm) [b]	NR	NR	NR	26.70	1,839	7,600	NR	NR	NR	140.00	2,081	4,089
Dissolved Iron (mg/L)	NR	NR	NR	NR	NR	NR	1.40	45.11	239.00	NR	NR	NR
Dissolved Oxygen (mg/L)	1.80	6.42	12.60	1.90	8.04	10.70	NR	NR	NR	8.00 [c]	8.00 [c]	8.00 [c]
Ferric Iron (mg/L)	0.05	24.54	229.00	0.03	15.02	115.00	NR	NR	NR	NR	NR	NR
Ferrous Iron (mg/L)	0.01	19.83	508.00	0.01	23.05	140.50	NR	NR	NR	NR	NR	NR
Flow (GPM)	0.00	55.40	4,500	0.00	142.89	5,000	0.74	57.31	450.84	0.00	143.03	5,600
pH (s.u.) [d]	2.00	4.43	8.60	2.37	4.52	8.00	2.44	3.57	7.00	2.60	4.76	7.70
Sulfates (mg/L)	40.00	1,434	21,115	33.30	1,253	6,377	105.00	839.84	3,397	79.92	1,230	25,989
Total Acidity (mg/L)	0.00	473.91	21,455	-894.00	329.74	8,140	NR	NR	NR	17.00	200.50	650
Total Alkalinity (mg/L)	0.00	22.79	792.00	-30.00	37.47	906.00	0.00	12.96	241.00	0.00	58.10	842.33
Total Aluminum (mg/L)	0.01	30.25	558.00	0.01	17.52	354.25	5.00	51.28	196.89	0.38	19.44	447.94
Total Calcium (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR	NR	6.00	190.78	520.00
Total Hardness (mg/L $CaCO_3$)	NR	NR	NR	NR	NR	NR	NR	NR	NR	121.00	1,036	3,214
Total Iron (mg/L)	0.01	67.70	2,640	0.00	65.20	1,200	1.00	141.40	709.42	0.17	43.52	455.03
Total Magnesium (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR	NR	7.00	137.69	500.00
Total Manganese (mg/L)	0.02	25.32	980.00	0.02	22.04	165.00	1.00	13.41	68.60	0.33	23.31	140.46
Total Suspended Solids (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR	NR	118.00	2,482	6,130

Source: *ARAMD*; *AMDI*; *WVDEPSpecialRec*; *PADEPMDI*.

a – Exclude zeros except for flow (GPD), total acidity (mg/L), and total alkalinity (mg/L). The databases do not include less than signs to represent values below the detection limit.

b – Conductivity is often measured as an indicator for TDS, which includes bicarbonate, calcium, magnesium, and sulfate.

c – Below detection indicators are not reported in the *PADEPMDI* database. EPA believes these samples are the detection limit due to all of the samples having the same value.

d – pH values greater than 7 are from discharges with total iron greater than or equal to 10 mg/L.

Min – Minimum.	Max – Maximum.
Avg – Average.	NR – Not reported.

Table 5-3. Untreated Acid Mine Drainage Characteristics (Additional Databases)

Pollutant Parameter	*BAMR* Database [a]			*AMD143* Database [a]		
	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value
Conductivity (umhos/cm) [b]	1,299.20	1,455.65	1,612.10	131.00	1,356.65	3,980.00
Dissolved Iron (mg/L)	NR	NR	NR	NR	NR	NR
Dissolved Oxygen (mg/L)	NR	NR	NR	0.20	2.70	11.50
Ferrous Iron (mg/L)	NR	NR	NR	<0.50	11.79	214.00
Flow (GPM)	20.83	66.48	112.12	0.00	1,503.44	34,961.52
pH (s.u.) [c]	2.54	2.61	2.68	2.70	4.96	7.30
Phosphates (mg/L)	282.00	304.00	326.00	<0.001	0.03	2.80
Sulfates (mg/L)	365.54	405.80	446.07	36.00	600.43	2,000.00
Total Acidity (mg/L)	443.32	474.42	505.52	19.00	230.15	2,340.00
Total Alkalinity (mg/L)	0.00	2.66	5.32	0.00	58.23	510.00
Total Aluminum (mg/L)	32.71	34.62	36.52	0.01	8.18	108.00
Total Calcium (mg/L)	13.90	15.99	18.08	3.30	102.46	410.00
Total Hardness (mg/L $CaCO_3$)	119.33	127.62	135.92	NR	NR	NR
Total Iron (mg/L)	66.09	71.00	75.90	0.05	48.10	512.00
Total Magnesium (mg/L)	11.02	15.02	19.02	3.60	44.78	210.00
Total Manganese (mg/L)	1.66	2.30	2.93	0.02	5.45	74.00
Total Suspended Solids (mg/L)	13.36	775.65	1,537.93	NR	NR	NR

Source: *BAMR*; *AMD143*.

a – Exclude zeros except for flow (GPD), total acidity (mg/L), and total alkalinity (mg/L). The *BAMR* database does not include less than signs to represent values below the detection limit.

b – Conductivity is often measured as an indicator for TDS, which includes bicarbonate, calcium, magnesium, and sulfate.

c – pH values greater than 7 are from discharges with total iron greater than or equal to 10 mg/L.

Min – Minimum. Max – Maximum. < - Result below the detection limit.
Avg – Average. NR – Not reported.

Table 5-4 presents the manganese concentration ranges in untreated AMD by state, from *ARAMD*. There are 751 samples with untreated manganese concentrations more than 4.0 mg/L (daily maximum discharge limitation), while 847 untreated samples reported manganese above 2.0 mg/L (30-day average discharge limitation). In all states, the average untreated AMD concentrations of manganese are greater than the Part 434 Subpart C monthly average 2.0 mg/L manganese limit.

Table 5-4. Range of Manganese Concentrations for Untreated Acid Mine Drainage in *ARAMD*

State	Number of Samples [a]	Minimum Manganese Concentration (mg/L)	Average Manganese Concentration (mg/L)	Median Manganese Concentration (mg/L)	Maximum Manganese Concentration (mg/L)
Kentucky	17	0.60	13.14	5.34	62.00
Maryland	4	6.00	59.89	55.78	122.00
Ohio	30	1.44	69.53	50.15	350.00
Pennsylvania	293	0.02	25.86	18.00	150.25

Table 5-4. Range of Manganese Concentrations for Untreated Acid Mine Drainage in *ARAMD*

State	Number of Samples [a]	Minimum Manganese Concentration (mg/L)	Average Manganese Concentration (mg/L)	Median Manganese Concentration (mg/L)	Maximum Manganese Concentration (mg/L)
Tennessee	24	0.52	21.47	12.18	70.20
Virginia	16	0.40	7.68	2.61	28.46
West Virginia	574	0.03	23.51	10.07	980.00
Total	**958**	**0.02**	**25.32**	**13.00**	**980.00**

Source: *ARAMD*.
a – Excludes zeros. The *ARAMD* database does not include less than signs to represent values below the detection limit.

Treated Acid Mine Drainage

EPA identified the mines and outfalls with AMD and summarized the treated water quality data from the *WVDMR* and *PADEPInspector* databases. Section 6.0 discusses the treatment technologies available for treating AMD. This section presents the results of samples only after the treatment system.

Table 5-5 presents the wastewater characteristics in treated AMD[6] from the *WVDMR* and *PADEPInspector* databases for 12 parameters. Appendix A presents additional parameters reported in the databases.

Table 5-5. Treated Acid Mine Drainage Characteristics

Pollutant Parameter	*WVDMR* Database [a]			*PADEPInspector* Database [a]		
	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value
Conductivity (umhos/cm) [b]	83.29	660.34	3,800.00	1,145.00	3,302.00	9,188.33
Dissolved Iron (mg/L)	0.90	3.00	5.10	0.61	0.69	0.77
Dissolved Oxygen (mg/L)	NR	NR	NR	NR	NR	NR
Ferric Iron (mg/L)	NR	NR	NR	NR	NR	NR
Ferrous Iron (mg/L)	NR	NR	NR	<0.02	1.42	6.05
Flow (GPD)	0.00	1,549,221	1,268,436,600	0.25	201.15	3,616.13
pH (s.u.)	1.14	7.47	12.70	2.42	6.85	8.80
Sulfates (mg/L)	12.95	767.78	3,085.00	<20.00	730.23	8,437.11
Total Acidity (mg/L)	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/L)	1.00	149.75	789.31	15.00	63.21	103.80
Total Aluminum (mg/L)	0.001	0.60	181.36	0.23	4.11	441.00

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[6] In the databases with treated samples, EPA identified the outfall as AMD if the outfalls have manganese samples because Part 434 includes manganese limits. EPA realizes that this could include alkaline mine drainage that has a water quality-based manganese limitation.

Table 5-5. Treated Acid Mine Drainage Characteristics

Pollutant Parameter	*WVDMR* Database [a]			*PADEPInspector* Database [a]		
	Min Value	Avg Value	Max Value	Min Value	Avg Value	Max Value
Total Calcium (mg/L)	14.30	72.34	203.00	0.14	0.14	0.14
Total Hardness (mg/L $CaCO_3$)	0.02	355.67	2,290.00	NR	NR	NR
Total Iron (mg/L)	0.001	1.10	737.63	0.18	11.19	1,836.36
Total Magnesium (mg/L)	NR	NR	NR	4.55	38.72	88.50
Total Manganese (mg/L)	0.003	0.59	80.00 [c]	0.04	4.48 [d]	59.90 [d]
Total Suspended Solids (mg/L)	0.91	10.02	1,320.67	<3.00	37.88	1,530.00

Source: *WVDMR*; *PADEPInspector*.

a – Exclude zeros except for flow (GPD), total acidity (mg/L), and total alkalinity (mg/L).

b – Conductivity is often measured as an indicator for TDS, which includes bicarbonate, calcium, magnesium, and sulfate.

c – Less than 4 percent of outfalls in *WVDMR* have total manganese concentrations above the Part 434 Subpart C NSPS monthly average limitation.

d – PA DEP mining inspectors collect more samples from mines with historical compliance issues than from mines with consistent compliance (U.S. EPA, 2007). Therefore, the *PADEPInspector* database is skewed towards non-compliant data.

Min – Minimum.
Max – Maximum.
< - Result below the detection limit.
Avg – Average.
NR – Not reported.

5.2 Comparison of Effluent AMD Concentrations to Part 434 Effluent Limitations Guidelines and Standards

EPA received comments from stakeholders that coal mines have difficulty meeting the manganese permit limits (U.S. EPA, 2006), and that pH control is more difficult because of treating to remove manganese. As a result, EPA evaluated the following issues for coal mines that discharge AMD to receiving streams (direct discharge):

- Frequency of manganese water quality-based permit limits instead of Subpart C water quality-based limits;
- Trends in pH permit limit variances granted to enable treatment for manganese (i.e., how often permit writers provide alternative pH limits to mines, as allowed by Part 434 Subpart F);
- Effluent concentrations compared to Part 434 Subpart C - Acid or Ferruginous Mine Drainage NSPS limitations; and
- Compliance with permits and enforcement actions.

Because the majority of AMD coal mines are located in Pennsylvania and West Virginia, as presented in Section 5.1.2.2, EPA focused its review on permitting and compliance of mines in these two states.

5.2.1 Manganese Water Quality-Based Limits

Both West Virginia and Pennsylvania established manganese water quality standards at lower concentrations than the Part 434 Subpart C manganese limitations to protect the water quality of receiving streams (as described in Section 4.1.2). EPA evaluated the frequency of water quality-based manganese limits in West Virginia and Pennsylvania.

Using the *WVMnLimit* database, EPA estimated the number of outfalls with manganese limits based on water quality standards. EPA limited the evaluation to active permits because these include the 2005 WV DEP manganese standard modification. Table 5-6 summarizes the number of outfalls with manganese limits more stringent than the Part 434 Subpart C 30-day average of 2.0 mg/L for each of the West Virginia permit basis designations.

In the *WVMnLimit* database, the WV DEP denotes the permit basis as "Water Quality-Based Limits" manganese limits at 27 percent of the active permit limits (AMD and non-AMD). EPA assumed that manganese permit limits more stringent than the Part 434 Subpart C 30-day average (2.0 mg/L) were water quality-based, even if the permit basis in the database was not "Water Quality Based Limit Designation." Approximately 16 percent of the active WV DEP permits (from 2003 to 2007) have limits more stringent than the effluent limitations guidelines and standards (ELGs), and are likely based on water quality standards.

Table 5-6. WV DEP Manganese Permit Limits Summary

Permit Basis as Designated in WVMnLimit	Number of Permit Limits <2 mg/L	Number of Permit Limits ≤2 mg/L	Percent of permit Limits <2.0 mg/L [a]
Acid Technology Based, Active	336	10,816	3.01%
Post Deep Acid Technology Based, Active	11	315	3.37%
Post Surface Acid Technology Based Limit Designation, Active	40	724	5.24%
Water Quality-Based Limit Designation, Active [b]	2,295	2,256	50.43%
Total [b]	**2,682**	**14,111**	**15.97%**

Source: *WVMnLimit.*

a – EPA assumes that manganese limits set below 2.0 mg/L are based on water quality standards. The BAT and NSPS limitations for manganese in Part 434 Subpart C are 4.0 mg/L daily maximum and 2.0 mg/L 30-day average.

b – Includes AMD and non-AMD outfalls.

PA DEP does not maintain a permitting basis database tracking the number of manganese water quality-based permit limits. However, based on experience, PA DEP estimated that approximately 50 percent of the active PA permits include discharge limits for manganese based on this water quality criterion (U.S. EPA, 2007).

5.2.2 pH Variances

EPA found that both West Virginia and Pennsylvania have issued permit variances for pH, allowing discharges above 9, to assist mines in meeting manganese limitations. As discussed in Section 6.1, mines using active treatment raise the pH of the wastewater during treatment to between 9 and 10 for optimal manganese removal. Part 434 Subpart F allows for pH variances to be issued "where the application of neutralization and sedimentation treatment technology results in inability to comply with the otherwise applicable manganese limitations..." Section 4.1.1 presents additional discussion of Part 434.

In West Virginia, pH variances were primarily granted for mines that needed to meet the more stringent water quality-based standards for manganese (U.S. EPA, 2008). Prior to 2005, when water quality guidelines were revised, West Virginia issued pH variances for approximately 20 percent of the mines. After modification of the water quality guidelines, less than five percent of the mines received pH variances (U.S. EPA, 2008). From 2004 through 2007, West Virginia granted pH variances for 49 NPDES permits authorizing discharge from 101 outfalls. West Virginia raised the upper pH limitation from 9.0 to between 9.5 and 10.5:

- 51 percent of the variances raised the pH limitation to 10.5;
- 45 percent of the variances raised the pH limitation to 10.0;
- 2 percent raised the pH to between 10 and 10.5; and
- 2 percent raised the pH to 9.5. (WV DEP, 2008)

Pennsylvania has also issued pH variances to AMD coal mines. However, Pennsylvania mines do not discharge above a pH of 9 very often even if performing treatment to remove manganese (U.S. EPA, 2007).

5.2.3 Comparison with Part 434 Subpart C Limitations

For this analysis, EPA compared effluent concentrations to Part 434 Subpart C NSPS ELGs. This comparison was not a compliance analysis comparing effluent concentrations to permit limits, but rather to ELGs. EPA chose this comparison to determine whether changes to ELGs are warranted. Specifically, EPA wanted to determine whether mines were having difficulty meeting the technology-based limitations in Part 434 Subpart C, as opposed to difficulty meeting permit limits based on more stringent water quality-based or state-regulated limits.

The Subpart C NSPS limitations include four pollutant parameters: pH, total iron, total manganese, and TSS (discussed in Section 4.1.1). EPA evaluated *PADEPInspector* and *WVDMR* to compare effluent pollutant concentrations with Subpart C NSPS limitations. EPA included outfalls classified as AMD[7] that represent final effluent. EPA did not include data for non-AMD outfalls or for monitoring locations in the receiving stream. See Sections 2.3.3 and 2.4.2 for further details on the databases used.

EPA compared effluent concentrations to the Subpart C ELGs and determined the following, for each parameter:

- Number of samples, by date, and percent of samples greater than the limitation (or outside pH range);
- Number of AMD outfalls and percent of samples greater than the limitation (or outside pH range); and
- Number of NPDES IDs (*WVDMR*) or mines (*PADEPInspector*) and percent of samples greater than the limitation (or outside pH range).

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[7] EPA assumed that outfalls monitoring for total manganese were AMD.

The accuracy of this analysis is limited based on the quality of the data sources: *WVDMR* and *PADEPInspector*. *WVDMR* includes minimum, average, and maximum concentrations. For multiple concentrations reported on the same sampling date, EPA calculated the minimum, average, and maximum concentrations for each date to compare to the limitations.

PADEPInspector does not distinguish the type of value presented (i.e., minimum, average or maximum), and in most cases (at least 99 percent of the time for all parameters), only a single reading was collected. For the analysis, EPA still calculated the minimum, average, and maximum concentrations for each sample date to compare to the limitations. However, for the outfalls with single readings, only one numeric value represents the minimum, average, and maximum. Therefore, the number of concentrations greater than the 30-day average limitations will always be higher than the number of concentrations greater than the daily maximum limitations. In addition, inspectors may not collect wastewater samples at outfalls believed to be in compliance. As a result, this analysis will exaggerate the concentrations greater than the limitations at Pennsylvania mines.

WVDMR contains many more data points than the *PADEPInspector* database (25 times the number of data points). However, the *PADEPInspector* database covers a larger time period than the *WVDMR* database (five years compared to two years).

5.2.3.1 pH—Comparison with Part 434 Subpart C NSPS Limitations

EPA compared effluent pH levels to the Subpart C NSPS ELGs, which require an effluent pH between 6 and 9, and found that the vast majority of outfalls had effluent pH levels within the ELGs (more than 90 percent). For instance, 94 percent of AMD outfalls in the *WVDMR* database were in compliance with the maximum pH limit of 9. Table 5-7 presents the comparison of AMD effluent pH at West Virginia and Pennsylvania mines with Part 434 Subpart C NSPS limitations (between 6 and 9). For West Virginia, over 98 percent of the pH levels are within the Subpart C pH limitations. Only 6 percent of the outfalls and 15 percent of the NPDES IDs reported pH values greater than 9, which may result from pH variances greater than 9. A larger percentage of outfalls and mines reported pH values less than 6.

States may set pH effluent limits above 9 to allow further removal of manganese. However, the comparison of pH data with Subpart C limitations shows that a number of samples also discharge below a pH of 6. The addition of acid to adjust the pH from around 10 for manganese treatment to the 6 to 9 ELGs pH range, might explain pH discharges below the pH limit. However, the majority of treatment plants in West Virginia do not add acid to lower the pH back to within the pH range of 6 to 9 (U.S. EPA, 2008). Outfalls with pH values below 6 may be internal monitoring locations at the treatment plant; however, EPA did not have the data necessary to determine monitoring point locations.

As with the West Virginia samples, at least 88 percent of Pennsylvania pH samples are within the Subpart C pH limitations. Twenty-two percent of the outfalls and 25 percent of the mines reported pH discharges higher than 9. More mines had effluent pH above the maximum pH compared to those below the minimum pH value. Mines with pH discharges above 9 may be operating treatment plants at a higher pH to remove manganese from the discharge with pH variances granted by PA DEP. A majority of the samples, representing multiple years, were in the 6 to 9 range in the Part 434 Subpart C NSPS limitations.

Table 5-7. Summary of Effluent Discharges Compared to Part 434 Subpart C NSPS Limitations for pH

	Dates	Number of Mines [a]	Number of AMD Outfalls [b]	Number of Samples
West Virginia: Daily Maximum pH >9				
Total Number of Data Sets	Apr 2003—Mar 2005	883	3,293	64,036
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	135	191	977
Percent Above Part 434 [c]	Apr 2003—Mar 2005	15%	6%	2%
West Virginia: Daily Minimum pH <6				
Total Number of Data Sets	Apr 2003—Mar 2005	879	3,197	62,038
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	160	270	821
Percent Above Part 434 [c]	Apr 2003—Mar 2005	18%	8%	1%
Pennsylvania: Daily Maximum pH >9				
Total Number of Data Sets	Jan 2003—Dec 2007	159	229	2,467
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	39	51	308
Percent Above Part 434 [c]	Jan 2003—Dec 2007	25%	22%	12%
Pennsylvania: Daily Minimum pH <6				
Total Number of Data Sets	Jan 2003—Dec 2007	159	229	2,467
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	37	52	140
Percent Above Part 434 [c]	Jan 2003—Dec 2007	23%	23%	6%

Source: *WVDMR*; *PADEPInspector*.

a – Mines are identified as NPDES IDs in the WV DEP database.

b – Number of outfalls may include non-AMD outfalls that discharge under a permit with water quality-based manganese limitations.

c – For this analysis, comparisons were made to Part 434 Subpart C - Acid of Ferruginous Mine Drainage NSPS limitations; however, mines may have alternative limits in their NPDES permits.

5.2.3.2 Total Iron—Comparison with Part 434 Subpart C NSPS Limitations

EPA compared effluent iron concentrations to Subpart C NSPS iron ELGs and found that effluent iron levels were less than the ELGs more than 90 percent of the time. Table 5-8 presents the comparison of AMD effluent to total iron limitations in Part 434 Subpart C NSPS (3.0 mg/L 30-day average and 6.0 mg/L daily maximum). For West Virginia, 99 percent of the iron concentrations were less than total iron limitations, and at least 90 percent of the Pennsylvania iron concentrations were less than the total iron limitations.

For West Virginia, 13 percent of the facilities and four percent of the outfalls had at least one total iron concentration higher than the daily maximum limit. For Pennsylvania mines, 28 percent of the mines and 25 percent of the outfalls had at least one total iron concentration above the daily maximum limit. For both states, effluent iron concentrations were above the 30-day average limitations more often than daily maximum limitations. The number of total iron concentrations above the 30-day average concentration at Pennsylvania mines may be exaggerated, due to a majority of one-time samples.

Table 5-8. Summary of Effluent Discharges Compared to Part 434 Subpart C NSPS Limitations for Total Iron

	Dates	Number of Mines [a]	Number of AMD Outfalls [b]	Number of Samples
West Virginia: Daily Maximum Total Iron >6.0 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	882	3,293	63,239
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	116	147	397
Percent Above Part 434 [c]	Apr 2003—Mar 2005	13%	4%	<1%
West Virginia: 30-Day Average Total Iron >3.0 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	877	3,205	61,872
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	201	284	690
Percent Above Part 434 [c]	Apr 2003—Mar 2005	23%	9%	1%
Pennsylvania: Daily Maximum Total Iron >6.0 mg/L				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,457
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	65	84	235
Percent Above Part 434 [c]	Jan 2003—Dec 2007	28%	25%	7%
Pennsylvania: 30-Day Average Total Iron >3.0 mg/L [d]				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,457
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	92	116	354
Percent Above Part 434 [c]	Jan 2003—Dec 2007	39%	35%	10%

Source: *WVDMR*; *PADEPInspector*.

a – Mines are identified as NPDES IDs in the WV DEP database.

b – Number of outfalls may include non-AMD outfalls that discharge under a permit with water quality-based manganese limitations.

c – For this analysis, comparisons were made to Part 434 Subpart C - Acid or Ferruginous Mine Drainage NSPS limitations; however, mines may have alternative limits in the NPDES permits.

d – Data used for this analysis is inspector-collected data that represents a one-time sampling event. Therefore, the number and percentage of total iron concentrations above the Subpart C NSPS limitations may be exaggerated.

5.2.3.3 Total Manganese—Comparison with Part 434 Subpart C NSPS Limitations

EPA compared effluent manganese concentrations to Subpart C NSPS manganese ELGs and found that effluent manganese levels were less than the ELGs for 96 percent of samples in *WVDMR* and 67 percent of samples in *PADEPInspector*. Table 5-9 presents the comparison of AMD effluent to total manganese limitations in Part 434 Subpart C NSPS limitations (2.0 mg/L 30-day average and 4.0 mg/L daily maximum). For West Virginia, over 96 percent of the total manganese concentrations meet both the daily maximum and 30-day average total manganese limitations. For Pennsylvania, 76 percent of the total manganese concentrations meet the daily maximum limitation and 67 percent meet the 30-day average limitation for total manganese. The total manganese concentrations above the 30-day average limit at Pennsylvania mines may be exaggerated, due to a majority of one-time samples.

EPA found that a majority of the effluent total manganese concentrations were less than the Subpart C manganese limits. For example, more than 96 percent of samples in the *WVDMR* database met the manganese daily maximum and 30-day average manganese limits. This demonstrates that ELGs are achievable for a majority of mines and outfalls.

Table 5-9. Summary of Effluent Discharges Compared to Part 434 Subpart C NSPS Limitations for Total Manganese

	Dates	Number of Mines [a]	Number of AMD Outfalls [b]	Number of Samples
West Virginia: Daily Maximum Total Manganese >4.0 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	882	3,292	57,699
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	141	257	1,330
Percent Above Part 434 [c]	Apr 2003—Mar 2005	16%	8%	2%
West Virginia: 30-Day Average Total Manganese >2.0 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	870	3,120	56,301
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	229	456	2,461
Percent Above Part 434 [c]	Apr 2003—Mar 2005	26%	15%	4%
Pennsylvania: Daily Maximum Total Manganese >4.0 mg/L				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,456
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	89	134	822
Percent Above Part 434 [c]	Jan 2003—Dec 2007	38%	40%	24%
Pennsylvania: 30-Day Average Total Manganese >2.0 mg/L [d]				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,456
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	121	172	1,125
Percent Above Part 434 [c]	Jan 2003—Dec 2007	52%	52%	33%

Source: *WVDMR*; *PADEPInspector*.

a – Mines are identified as NPDES IDs in the WV DEP database.

b – Number of outfalls may include non-AMD outfalls that discharge under a permit with water quality-based manganese limitations.

c – For this analysis, comparisons were made to Part 434 Subpart C - Acid or Ferruginous Mine Drainage NSPS limitations; however, mines may have alternative limits in their NPDES permits.

d – Data used for this analysis is inspector-collected data that represents a one-time sampling event. Therefore, the number and percentage of total manganese concentrations above the Subpart C NSPS limitations may be exaggerated.

5.2.3.4 TSS—Comparison with Part 434 Subpart C NSPS Limitations

EPA compared effluent TSS concentrations to Subpart C TSS ELGs and found that more than 95 percent of the time, effluent TSS levels were less than the ELGs. Table 5-10 presents the comparison of AMD effluent to TSS limitations in Part 434 Subpart C NSPS. For West Virginia, over 98 percent of the TSS concentrations meet the TSS limitations. TSS concentrations above Subpart C NSPS limitations were more common than iron concentrations above Subpart C NSPS limitations, but occurred in a similar percent of samples. The number of manganese concentrations above the ELGs was 2.5 times as many the number of TSS concentrations above the ELGs.

Over 90 percent of all TSS concentrations were below the ELGs over the multiple years represented.

Table 5-10. Summary of Effluent Discharges Compared to Part 434 Subpart C NSPS Limitations for TSS

	Dates	Number of Mines [a]	Number of AMD Outfalls [b]	Number of Samples
West Virginia: Daily Maximum TSS >70 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	865	3,109	42,960
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	235	377	536
Percent Above Part 434 [c]	Apr 2003—Mar 2005	27%	12%	1%
West Virginia: 30-Day Average TSS >35 mg/L				
Total Number of Data Sets	Apr 2003—Mar 2005	850	2,968	41,731
Number of Results Above Part 434 [c]	Apr 2003—Mar 2005	308	535	872
Percent Above Part 434 [c]	Apr 2003—Mar 2005	36%	18%	2%
Pennsylvania: Daily Maximum TSS >70 mg/L				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,455
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	67	76	152
Percent Above Part 434 [c]	Jan 2003—Dec 2007	29%	23%	4%
Pennsylvania: 30-Day Average TSS >35 mg/L [d]				
Total Number of Data Sets	Jan 2003—Dec 2007	234	333	3,455
Number of Results Above Part 434 [c]	Jan 2003—Dec 2007	101	124	342
Percent Above Part 434 [c]	Jan 2003—Dec 2007	43%	37%	10%

Source: *WVDMR*; *PADEPInspector*.
a – Mines are identified as NPDES IDs in the WV DEP database.
b – Number of outfalls may include non-AMD outfalls that discharge under a permit with water quality-based manganese limitations.
c – For this analysis, comparisons were made to Part 434 Subpart C – Acid or Ferruginous Mine Drainage NSPS limitations; however, mines may have alternative limits in their NPDES permits.
d – Data used for this compliance analysis is inspector-collected data that represents a one-time sampling event. Therefore, the number and percentage of TSS concentrations above the Subpart C NSPS limitations may be exaggerated.

5.2.4 Comparison of pH and Manganese in West Virginia and PA Analytical Data

EPA analyzed whether facilities with higher effluent pH levels had more consistent effluent manganese concentrations, to address the comments that to meet manganese limits, mine discharges had high pH levels. From discussions with state permitting authorities, NPDES permits may contain pH maximum limitations higher than Subpart C ELGs. States have granted the pH waivers (raising pH limit to 10 or 10.5) to assist mines in removing additional manganese and meeting the total manganese limitations (see Section 5.2.2). EPA reviewed discharge monitoring report (DMR) data from West Virginia to determine whether the number of manganese concentrations above the Subpart C limitations decreased at higher pH levels.[8]

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[8] EPA did not perform this analysis for *PADEPInspector* because this database is not representative of all mines in PA. It contains data from inspectors, who collect more data from mines with poor compliance, and *PADEPInspector* is skewed towards mines having difficulty meeting NPDES permit limits.

The optimal precipitation of iron occurs at a pH of 8.3. At this pH, the iron is the least soluble in water and more easily precipitated out of the wastewater. As noted above, mines do not have difficulty achieving total iron concentrations less than the Subpart C NSPS limitations; and the optimal pH for iron removal also falls within the pH limitation range of 6 to 9. On the other hand, the optimal precipitation of manganese occurs at a pH between 9 and 10 (Means, 2004).

EPA compared the pH values to the manganese concentrations reported on the same sample date. There was no correlation between higher effluent pH and better manganese removal. That is, EPA found that the number of manganese concentrations above the Subpart C NSPS ELGs do not increase when the effluent pH is below 9 (i.e., below the optimal pH for manganese removal). Table 5-11 presents the comparison. A higher percentage of samples and outfalls have total manganese concentrations above the Subpart C NSPS limitations when the pH is above 9. Therefore, raising the limits set for effluent pH by a permit variance does not appear to correlate to a higher rate of total manganese concentrations below the Subpart C NSPS limitations.

5.2.5 Compliance with Permits and Enforcement Actions

To further assess the difficulty of mines complying with Part 434, EPA was able to collect compliance and enforcement data from Pennsylvania.

From 2003 through 2007, inspectors from Pennsylvania completed over 90,000 inspections at coal mines to ensure that permit requirements were being met. Table 5-12 summarizes the number of inspections and effluent violations noted. The data in the table are not limited to AMD outfalls (e.g., violations could be in the stream). Also, the data do not specify which pollutant was in violation. For non-administrative requirements, the mines were found in compliance at more than 99 percent of inspections.

Table 5-11. Manganese Concentrations Above Part 434 Subpart C NSPS Limitations Compared to Effluent pH (West Virginia data from April 2003 through March 2005)

Parameter and Condition	NPDES IDs		Outfalls [a]		Samples	
	Total Number	Number with Total Manganese Concentrations Above Subpart C [b]	Total Number	Number with Total Manganese Concentrations Above Subpart C [b]	Total Number	Number with Total Manganese Concentrations Above Subpart C [b]
Daily Maximum Manganese Concentration (Limit of 4.0 mg/L)						
Total number with paired effluent pH and manganese DMR data	882	140 (16%)	3,290	251 (8%)	57,439	1,290 (2%)
All pH in within Subpart C range (pH≤9)	751	123 (16%)	3,104	229 (7%)	56,452	1,235 (2%)
At least one pH above the Subpart C range (pH>9)	131	17 (13%)	186	22 (12%)	897	55 (6%)
30-Day Average Manganese Concentration (Limit of 2.0 mg/L)						
Total number with paired effluent pH and manganese DMR data	869	227 (26%)	3,171	450 (14%)	56,051	2,411 (4%)
All pH in within Subpart C range (pH≤9)	739	202 (27%)	2,988	415 (14%)	55,169	2,311 (4%)
At least one pH above the Subpart C range (pH>9)	130	25 (19%)	183	35 (19%)	882	100 (11%)

Source: *WVDMR*.

a – Number of outfalls may include non-AMD outfalls that discharge under a permit with water quality-based manganese limitations.

b – For this analysis, comparisons were made to Part 434 Subpart C – Acid or Ferruginous Mine Drainage NSPS limitations; however, mines may have alternative limits in their NPDES permits.

Table 5-12. Summary of PA DEP Inspections at Coal Mines 2003 -2007

Inspection Type	Total Number of Inspections	Number of Effluent Violations (Percent)	Type of Violation
Routine/Partial Inspection	52,599	145 (<1%)	a
		3	b
Routine/Complete Inspection	37,424	68 (<1%)	a
		2	b
Follow-Up Inspection	1,889	58 (3%)	a
		2	b
Administrative/File Review	924	157 (17%)	a
Bond Release	45	0	NA
Routine Final Inspection	11	0	NA
Complaint Inspection	4	0	NA
Joint Internal Site Inspection	1	0	NA

Source: PA Coal Mine Inspections 2003 to 2007 (PA DEP, 2007).
a – Discharging water that does not meet water quality limits.
b – Failure to meet effluent limits or failure to properly design, construct or maintain erosion and sedimentation controls.
NA – Not applicable. PA DEP did not report effluent violations for these types of inspections.

5.3 Wastewater Characteristics and NPDES Permitting References

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6.0 ACID MINE DRAINAGE TREATMENT TECHNOLOGIES

The Coal Mining Detailed Study focuses on discharges from acid mine drainage (AMD) from coal mines located in the Appalachian Region, based on comments that EPA received. This section describes treatment technologies most commonly used to treat AMD.

The goals of treating AMD are to raise pH and lower the concentrations of metals, as well as to remove solids and other pollutants, so that receiving streams support aquatic life. The optimal AMD treatment type depends on the discharge flow, iron species and concentration, acidity, and dissolved oxygen content. In general, treatment can be divided into the following:

- Active treatment in which the treatment facility actively adds chemicals to the discharge to maintain desired effluent characteristics; and
- Passive treatment in which the treatment facilities are engineered to require little to no maintenance once the facility is operational.

Based on the *ARAMD* database (described in Section 2.2.2*)*, mines most often use active chemical precipitation treatment systems, using lime and/or sodium hydroxide to adjust pH, aeration to oxidize the dissolved metals, and ponds to precipitate metal hydroxides. However, passive treatment systems minimize annual operating costs and are often preferred because of lower long-term treatment costs. Section 6.1 describes active treatment technologies and Section 6.2 describes passive treatment technologies.

6.1 Active Treatment Technologies for AMD

Active treatment technologies require chemical addition to neutralize acidity and precipitate metals. Active treatment technologies typically have higher annual operating costs than passive treatment systems but have proven performance and have been used longer. Chemical precipitation involves removing metallic contaminants from aqueous solutions by converting soluble heavy metals to insoluble salts. The precipitated solids are then removed from solution in sedimentation ponds.

Precipitation of metallic contaminants is caused by the addition of chemical reagents that increase the pH of the water to the minimum solubility of the metal. The standard reagents include the following (U.S. EPA, 2000):

- Lime (calcium hydroxide);
- Caustic (sodium hydroxide);
- Magnesium hydroxide;
- Soda ash (sodium carbonate);
- Trisodium phosphate;
- Sodium sulfide; and
- Ferrous sulfide.

These reagents precipitate metals as hydroxides, carbonates, phosphates, or sulfides. The precipitated metals form sludge which, over time, must be removed from the treatment system. The majority of coal mines treating AMD using active treatment technologies use lime or caustic for precipitation (ARAMD, Unknown).

Figure 6-1 presents an example of a chemical precipitation treatment system using caustic soda; Figure 6-2 presents an example of a chemical precipitation treatment system using hydrated lime. Both figures show the following steps of chemical precipitation:

- The AMD is aerated, often by gravity flow and sprays, to increase the dissolved oxygen in the discharge. The increased dissolved oxygen allows some metals to oxidize and form metal hydroxides, such as ferric hydroxide ($Fe(OH)_3$).
- The first settling pond removes the majority of the metal hydroxides that formed due to aeration.
- A chemical precipitant (caustic soda in Figure 6-1 and hydrated lime in Figure 6-2) is added in a channel or pond, where the remaining dissolved metals, such as manganese and magnesium, are oxidized to an insoluble form. A mixing tank or pond is sometimes required if the chemical precipitant is in a solid form, providing additional contact time to dissolve the precipitant.
- The remaining settling ponds remove the insoluble metal hydroxides, which settle to the bottom of the pond as sludge.
- Sludge is removed periodically via vacuum trucks or on-site vacuums. Operators may use the sludge as part of backfilling or reclamation material, because of its alkaline properties.

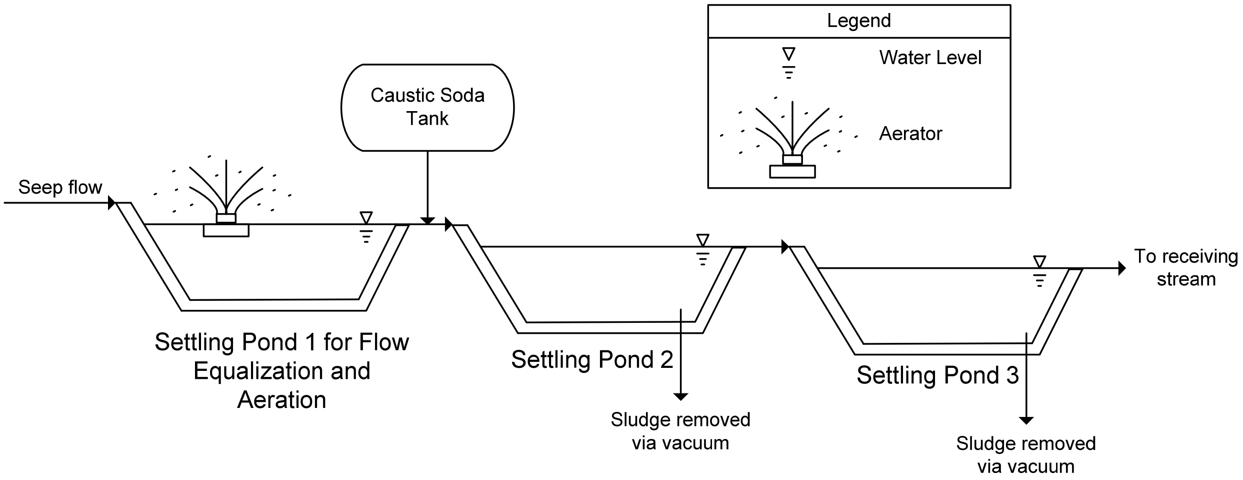

Figure 6-1. Example AMD Chemical Precipitation Treatment System Using Caustic Soda

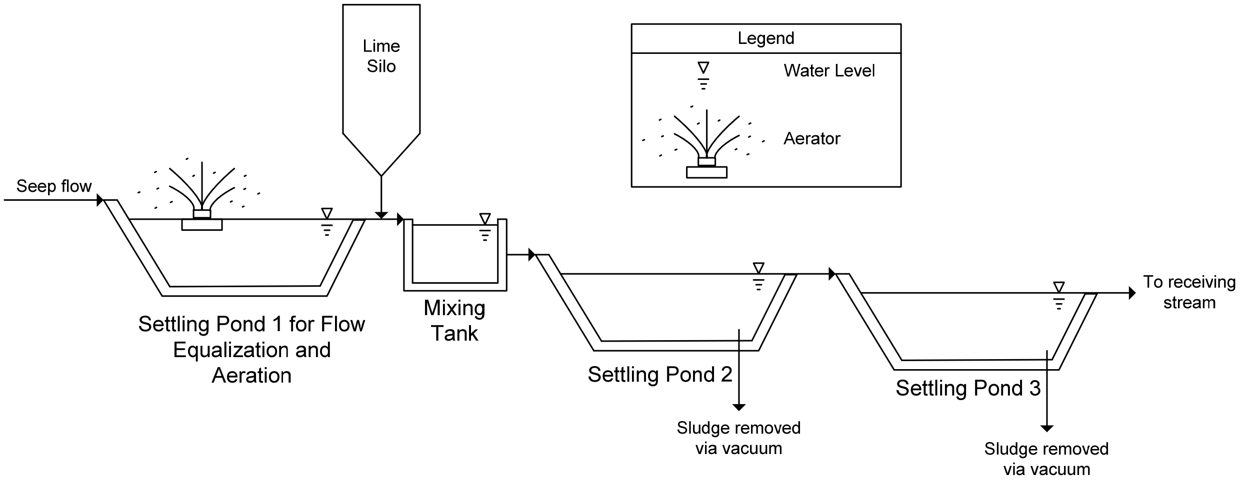

Figure 6-2. Example AMD Chemical Precipitation Treatment System Using Hydrated Lime

Hydroxide precipitation normally involves using lime ($Ca(OH)_2$) or caustic soda (NaOH) as a precipitant to remove metals as insoluble metal hydroxides. The reaction is illustrated by Equations 6-1 and 6-2 for precipitation of divalent and trivalent metals using caustic soda, and Equations 6-3 and 6-4 for precipitation using lime:

$$\text{Metal}^{++} + 2\ \text{NaOH} \rightarrow \text{Metal(OH)}_2 + 2\ \text{Na}^{+} \qquad (6\text{-}1)$$

$$\text{Metal}^{+++} + 3\ \text{NaOH} \rightarrow \text{Metal(OH)}_3 + 3\ \text{Na}^{+} \qquad (6\text{-}2)$$

$$\text{Metal}^{++} + \text{Ca(OH)}_2 \rightarrow \text{Metal(OH)}_2 + \text{Ca}^{++} \qquad (6\text{-}3)$$

$$2\ \text{Metal}^{+++} + 3\ \text{Ca(OH)}_2 \rightarrow 2\ \text{Metal(OH)}_3 + 3\ \text{Ca}^{+++} \qquad (6\text{-}4)$$

The effluent metals concentration attained by hydroxide precipitation depends on the metals present and reaction conditions. Many scientists have studied metals removal from AMD, particularly the difficulty of removing manganese. While scientists have found that iron will quickly precipitate at a pH near 8.3, manganese precipitates quickly only when the pH is raised to 9 or 10 (Means, 2004). Figure 6-3 illustrates the solubility curves from research performed by Dr. Chuck Cravotta, USGS, for metals commonly found in AMD, showing solubilities relative to pH. Section 7.3 discusses the removal of non-regulated metals based on solubilities in AMD.

6.2 Passive Treatment Technologies for AMD

Passive treatment technologies do not require chemical addition and take advantage of chemical and biological processes that occur naturally to treat AMD (Skousen, Unknown). Passive treatment technologies are preferred over active treatment to reduce operating costs (U.S. EPA, 2001). Passive treatment technologies include the following:

- Aerobic wetlands;
- Anaerobic wetlands;
- Anoxic limestone drains;

- Diversion wells;
- Open limestone channels;
- Oxic limestone drains;
- Pyrolusite® technology; and
- Vertical flow reactors (successive alkalinity-producing systems).

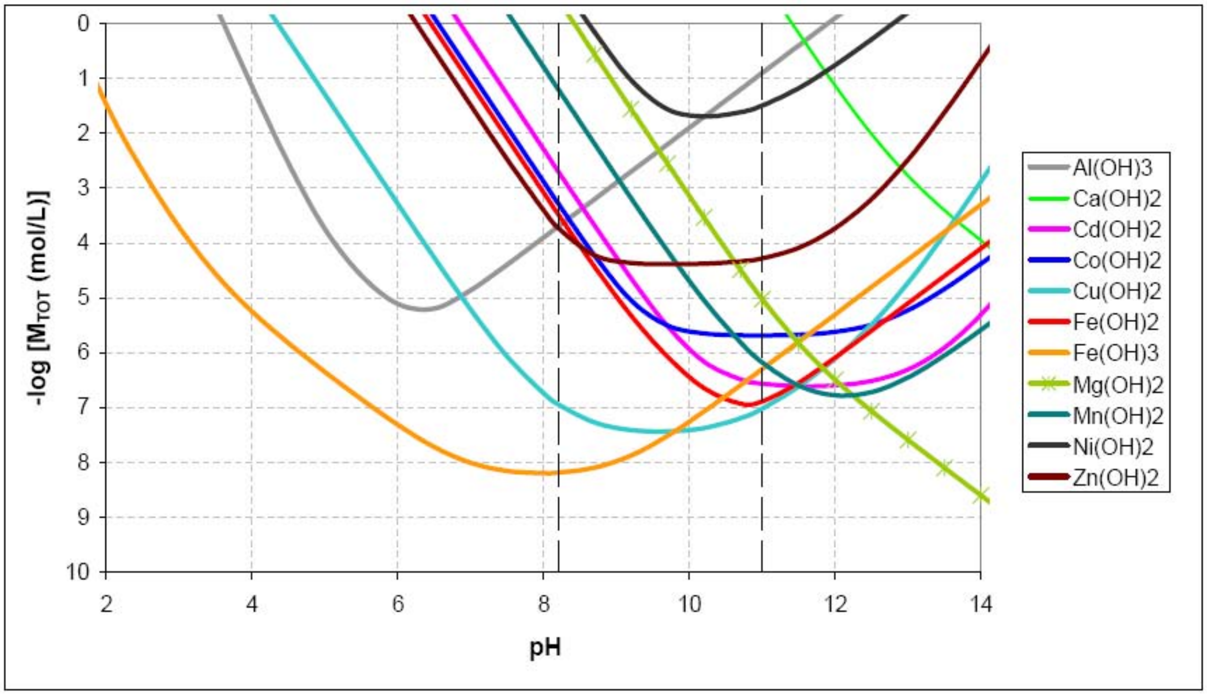

Figure 6-3. Comparison of Metal Hydroxide Solubilities for Constituents Commonly Found in Acidic Mine Drainage

Source: *Comparison of Three Methods to Measure Acidity of Coal-Mine Drainage* (Means, 2004).

Effective treatments of AMD typically involves a combination of two or more passive treatment technologies. An example treatment system could include an anoxic limestone drain to raise pH and alkalinity, followed by a settling pond to remove high concentrations of oxidized metals, followed by an aerobic wetland to remove additional metals if needed to meet permit limits and/or to impart additional alkalinity (U.S. EPA, 2001). EPA collected information about passive treatment systems as part of its 2002 revision to Part 434. EPA's *Coal Remining Best Management Practices Guidance Manual* (BMP Manual), dated December 2001, describes passive treatment technologies in detail. The remainder of this section summarizes the information in the BMP Manual (U.S. EPA, 2001).

Passive treatment systems require less maintenance than active treatment systems; however, passive treatment systems are not appropriate for all AMD. The limitations of passive treatment systems are the following (U.S. EPA, 2001):

- Finite life spans that will require rebuilding or rejuvenation to treat the discharge in perpetuity;
- Difficult to design for discharges with large flow variations;
- Require large land areas to achieve desired treatment level;

- May not be feasible if for AMD with high flows; and
- Limited use for each system based on raw water quality characterization (e.g., anoxic limestone drains are only appropriate for AMD with low or no dissolved oxygen).

6.2.1 Aerobic Wetlands

An aerobic wetland is a large, shallow pond with horizontal surface flow. The pond may be planted with typical wetlands plants such as cattails. Aerobic wetlands promote the precipitation of iron, aluminum, and manganese by oxidizing and hydrolyzing the metals into low solubility hydroxides. The removal of metals tends to release mineral acidity, which lowers the pH of the water. The amount of metals oxidization that occurs depends on the dissolved metal concentrations, dissolved oxygen content, pH and net alkalinity of the water, presence of microbes, total surface area, and detention time (Skousen, Unknown; PA DEP, Unknown).

Aerobic wetlands work most efficiently when the pH in untreated AMD is 6.0 or higher with a net alkalinity. At a pH of 6.0 or higher, the rate of iron and manganese oxidation increases. Manganese oxidation does not occur in any measurable amount when the pH is less than 6.0 (standard units). The net alkalinity is required to buffer the release of mineral acidity, to maintain a higher pH and continue metals oxidation (U.S. EPA, 2001).

The life of an aerobic wetland can be extended by diverting the AMD into a settling pond to precipitate some excess iron prior to entering the aerobic wetland. The required size of the aerobic wetland depends on the maximum flow, influent metals concentrations, and desired effluent water quality. The detention time is maximized by adding baffles in the wetlands to maximize the flow path length. For effective treatment, a low pH discharge requires a larger wetland than a higher pH discharge with the same metals concentrations. The pH is typically increased prior to the wetlands using an anoxic limestone drain (U.S. EPA, 2001). For the most effective treatment, surface loading rates of iron less than 21 g/m^2/day and manganese less than 2 g/m^2/day are recommended, if the water is net alkaline (Skousen, Unknown; PA DEP, Unknown).

6.2.2 Anaerobic Wetlands

Anaerobic wetlands are large, shallow ponds with a layer of organic material, through which the water is induced to flow down through before discharge. Common organic materials are usually available locally and include spent mushroom compost, peat moss, wood chips, sawdust, and hay. Spent mushroom compost is most common because it contains 10 percent calcium carbonate ($CaCO_3$). Limestone is typically added to the other compost materials to assist in neutralizing the acidic water. Anaerobic wetlands remove some metals by oxidization and hydrolysis in the aerobic surface layer in addition to microbial reduction reactions and limestone dissolution in the anaerobic layer, generating alkalinity. The alkalinity generated by the anaerobic layer raises the pH. Anaerobic wetlands have been successful at treating discharges with dissolved oxygen, iron in the Fe^{3+} state, aluminum as Al^{3+}, or acidity less than 300 mg/L (Skousen, Unknown; PA DEP, Unknown).

6.2.3 Anoxic Limestone Drains

Anoxic limestone drains are sealed and buried trenches of limestone designed to treat AMD under anoxic conditions. The anoxic condition limits the oxidization of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). If oxidized, the iron precipitates out of solution as iron hydroxide (yellow boy), which clogs the drain and/or coat the limestone. Maintaining the anoxic conditions is important for extending the life and maintaining the efficiency of these systems. Kepler and McCleary determined that the AMD should contain less than 1 mg/L dissolved oxygen, while Cravotta recommended that dissolved oxygen content be less than 0.3 mg/L to prevent in-situ iron oxidation (U.S. EPA, 2001).

Anoxic limestone drains generate greater concentrations of alkalinity because of increased CO_2 concentrations. As the partial pressure of CO_2 increases, the solubility of calcium carbonate (or alkalinity) increases, and the water can neutralize more acidity. The decreased acidity and increased alkalinity of the water upon discharge from the anoxic limestone drain significantly increase the precipitation rate of iron and other metals. Therefore, anoxic limestone drains are often installed prior to aerobic wetlands or settling ponds (U.S. EPA, 2001).

The design and construction of anoxic limestone drains are based on the maximum anticipated flow rate, projected life of the system (commonly 20 to 25 years), limestone purity, and effluent water quality (related to detention time). An analysis of water quality and flow data for 21 anoxic limestone drains treating AMD in Appalachia determined a detention time of at least 15 hours and as high as 23 hours was required to produce maximum alkalinity (U.S. EPA, 2001).

Anoxic limestone drains do not adequately treat AMD discharges if the dissolved iron (ferrous iron) has been oxidized prior to entering the anoxic limestone drain. Dissolved iron oxidizes if the dissolved oxygen concentration in the AMD is too high. Therefore, it is suggested that the AMD be transported from the discharge point using a sealed and buried collection and piping system. Anoxic limestone drains are not recommended for treating AMD with high concentrations of dissolved aluminum because aluminum precipitates out in the drain once the pH is raised, even if the dissolved oxygen concentration is low. Additionally, anoxic limestone drains are not recommended for treating AMD with sulfate concentrations in excess of 2,000 mg/L because gypsum ($CaSO_4 + 2\ H_2O$) may form and precipitate in the drain, clogging it (U.S. EPA, 2001).

6.2.4 Diversion Wells

Diversion wells are large cylinders constructed of reinforced concrete or other erosion resistant material (commonly manhole rings), which are then partially filled with limestone. AMD is piped down the center for introduction at the bottom of the well. The rapid movement of water upward through the well causes the limestone to maintain a fluidized state. The water then flows over the sides of the well into a settling pond or is channeled back to the stream or the remainder of the discharge. Unlike limestone in a channel or bed, fluidized limestone does not become “armored” by iron hydroxides. Dissolved iron above 0.3 mg/L should precipitate after leaving the well (U.S. EPA, 2001).

Diversion wells increase the alkalinity when the AMD reacts with the limestone. Alkalinity is released by both physical and geochemical actions in the wells. The fluidization of the limestone increases the alkalinity generation by crushing the limestone into finer particles, increasing the surface area. Alkalinity production is limited by the atmospheric levels of CO_2, because increased CO_2 allows for greater concentrations of calcium carbonate, or alkalinity. Researchers have suggested injecting CO_2 into the AMD stream prior to treatment in the diversion well to increase the alkalinity production up to 1,000 mg/L. However, the injection of CO_2 is not a passive treatment and would increase operating costs and operation complexity (U.S. EPA, 2001).

The treatment of AMD using diversion wells requires sufficient head and flow rate, low to medium acidity concentrations (high acidity concentrations require multiple diversion wells), and increased maintenance to periodically recharge the limestone. High dissolved metals concentrations requires a settling pond after the diversion well (U.S. EPA, 2001).

6.2.5 Open Limestone Channels

Open limestone channels, also called limestone beds, are trenches filled with limestone, which increases alkalinity and pH, thus precipitating metals. They are not suitable for extremely high metals concentration; however, because oxidized metals precipitate on the limestone and reduce the alkalinity yield. Oxidized metals precipitate and coat the surface of the limestone; this action is called “armoring.” Completely armored limestone will, in theory, continue to yield some alkalinity or temporarily store some acidity in a mineral form. The armored limestone rapidly reduces acidity initially, with the acidity reduction rate slowing with time in the form of a logarithmic decay curve (U.S. EPA, 2001).

Figure 6-4 shows an example limestone bed treatment system process. The limestone bed is designed to 1) increase alkalinity and raise pH to neutral (between 6 and 9), and 2) precipitate and remove metals from the AMD. As limestone dissolves, it imparts alkalinity according to the following reactions (Sibrell, 2005):

$$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^- \tag{6-5}$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca^{2+} + 2\ HCO_3^- \tag{6-6}$$

$$CaCO_3 + H_2O \rightarrow Ca^{2+} + HCO_3^- + OH^- \tag{6-7}$$

The available hydroxide ions (OH^-) then react with metals to form insoluble metal hydroxides, which form according to the following equations:

$$\mathrm{Metal}^{+2} + 2\ OH^- \rightarrow \mathrm{Metal}(OH)_2 \tag{6-8}$$

$$\mathrm{Metal}^{+3} + 3\ OH^- \rightarrow \mathrm{Metal}(OH)_3 \tag{6-9}$$

The insoluble metal hydroxides will precipitate and be removed from the water; however, over time the precipitates coat the limestone. This coating of the limestone is referred to as “armoring” and decreases the effectiveness of the limestone bed over time. High flow velocities through the bed can minimize the armoring, and the limestone beds should be made large enough to account for armoring.

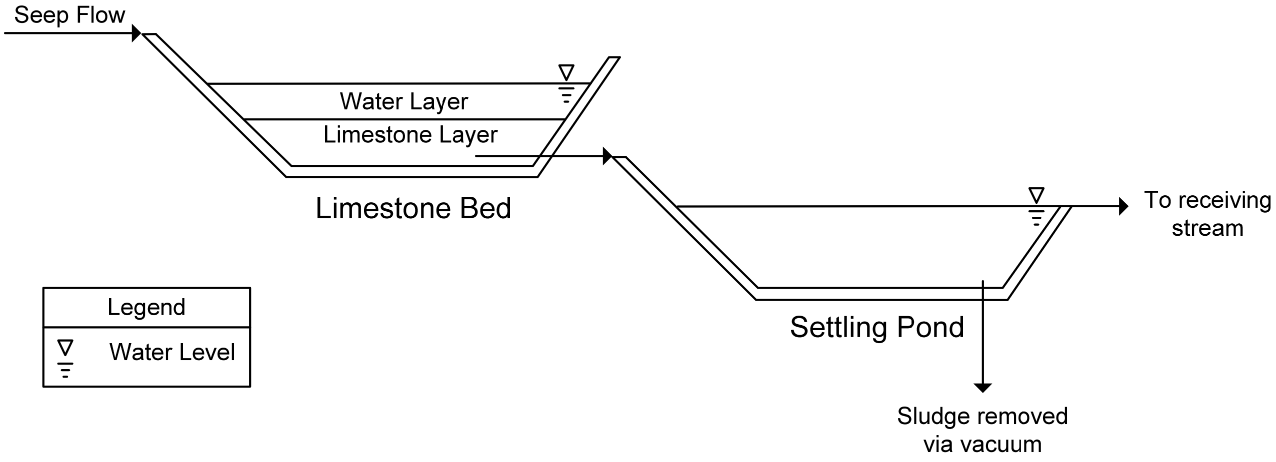

Figure 6-4. Example AMD Limestone Bed Treatment System

As the metal cations, such as Fe^{3+} and Mn^{2+}, consume the hydroxide anions in the above reactions, the pH of the water decreases. To be effective, limestone beds should be large enough to buffer the acidity liberated from metals precipitation.

Limestone channels are sized to neutralize 90 percent of the influent acidity in one hour of contact time or to neutralize 100 percent of the influent acidity in three hours of contact time. The design of limestone channels is based on the flow rate, channel slope, and acidity concentration. The slope and flow rate are important to prevent clogging of the limestone with the precipitated iron, aluminum, and manganese. Settling ponds are often constructed after the open limestone channels to allow for the precipitated metals to precipitate (U.S. EPA, 2001). The metals sludge in these ponds is periodically removed.

Limitations of open limestone channels effectiveness are mainly the dissolution rate of armored limestone, atmospheric CO_2 concentrations, and contact time. The contact time to treat relatively large discharges with considerable acidity may require trenches more than 3,000 feet (half mile) long, limiting the use of open limestone channels at space-limited mine sites. The effectiveness of the channel is also based on at least a 10 percent slope to prevent clogging (U.S. EPA, 2001).

6.2.6 Oxic Limestone Drains

Oxic limestone drains are similar to anoxic limestone drains except that they are designed to treat AMD containing high dissolved oxygen and oxidized iron. Oxic limestone drains are covered to increase the alkalinity production by increasing the partial pressure of CO_2, which allows for greater concentration of calcium carbonate (alkalinity) in the water. The limestone dissolves rapidly enough to make the surface unstable for iron armoring. Some iron hydroxide and aluminum hydroxide precipitates in the oxic limestone drain. However, metal flocs can be carried through the drain when water velocity is high (greater than 0.33 feet per minute. The oxic limestone drains can also be designed for periodic flushing to remove the metal hydroxide buildup (U.S. EPA, 2001).

A study of an oxic limestone drain treating AMD with moderate acidity (<90 mg/L), a pH less than 4.0 (standard units), and moderately low dissolved metals (iron, manganese, and aluminum concentrations 1 to 5 mg/L) found that iron and aluminum concentrations were reduced by up to 95 percent. The manganese concentrations were unaffected the first six months the oxic limestone drain was active; however, after the initial six months, the manganese concentrations were lowered by 50 percent. The increased manganese removal rate is due to the co-precipitation with iron hydroxide that is facilitated by pH greater than 5.0 (U.S. EPA, 2001).

Oxic limestone drain design is based on flow and acidity concentration. Oxic limestone drains are not effective for treating discharges with large flows or with high concentrations of acidity.

6.2.7 Pyrolusite® Technology

Allegheny Mineral Abatement, Inc. developed the patented Pyrolusite®[9] bed, which is a type of in-situ bioremediation that primarily removes manganese and raises the alkalinity. These systems can remove minor amounts of dissolved iron, but are not recommended to do so because iron can armor (coat) the limestone and reduce its efficiency. Users install a bed of crushed limestone inoculated with cultured microorganisms. In an aerobic environment, the microorganisms metabolize manganese ions, converting them to relatively insoluble oxides: manganese dioxide (todorokite (Mn, Ca, Mg) $Mn_3^{+4}O_7 \times H_2O$ or Pyrolusite®, MnO_2) (Cravotta, 1999). Pyrolusite® beds promote alkalinity because the microorganisms also "etch" or alter the surface chemistry of the limestone hosting medium, keeping the area of $CaCO_3$ reaction sites open (U.S. EPA, 2001). The flowing mine water also dissolves the limestone at a rate based on the partial pressure of CO_2, temperature and other factors. Figures 6-5 and 6-6 show a plan and profile view, respectively, of how the Pyrolusite® bed works. Figure 6-7 is a photograph of a Pyrolusite® bed from a PBS Coals, Inc. mine in Pennsylvania.

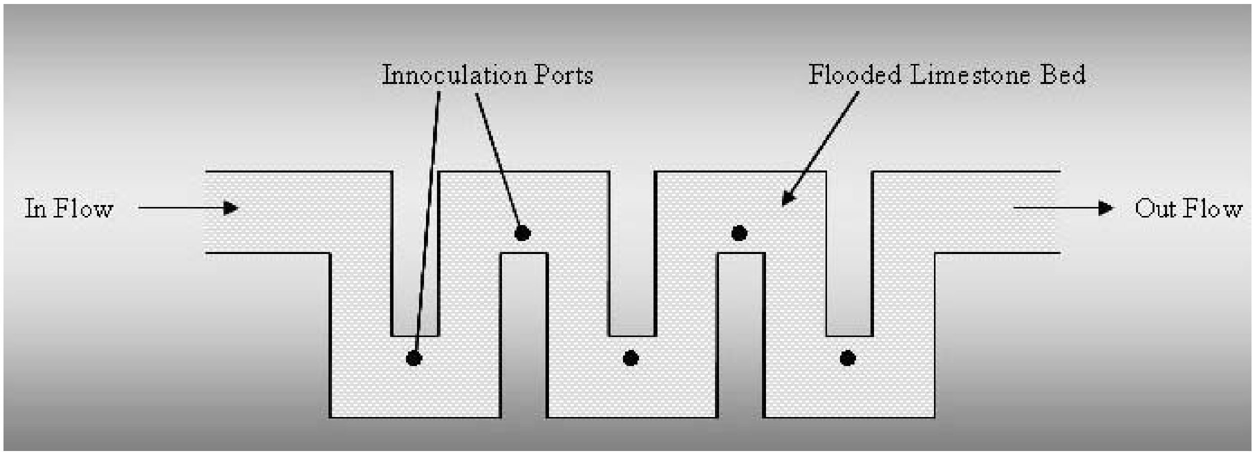

Figure 6-5. Plan View of a Pyrolusite® Bed

Source: Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems (ERG, 2006).

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[9] Mention of specific products does not constitute an endorsement by EPA.

Figure 6-5 shows baffles in the Pyrolusite® bed. Most of these beds are rectangular without baffles. The dimensions (length, width, and depth) are such that the desired retention time will be achieved. Usually a manifold or dispersion unit spreads the inflow across the front width of the bed.

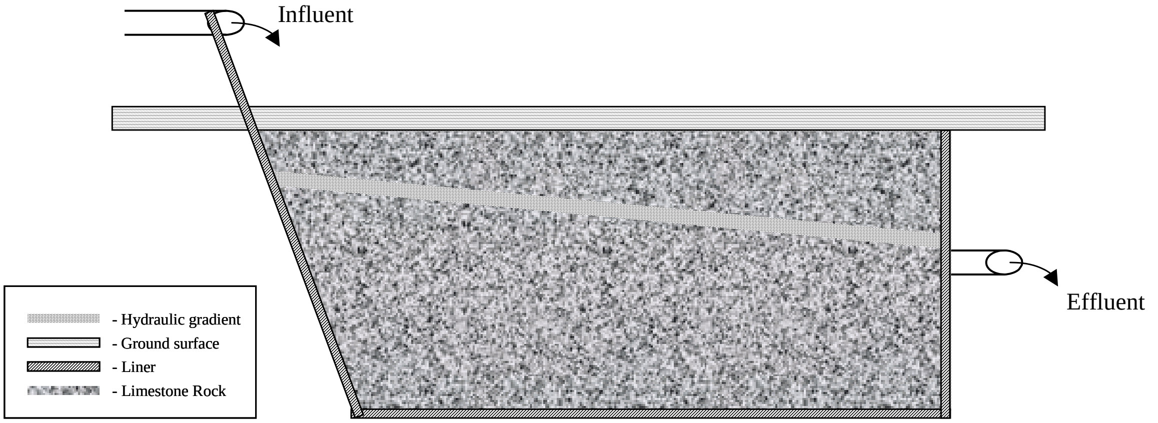

Figure 6-6. Profile View of a Pyrolusite® Bed
Source: Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems (ERG, 2006).

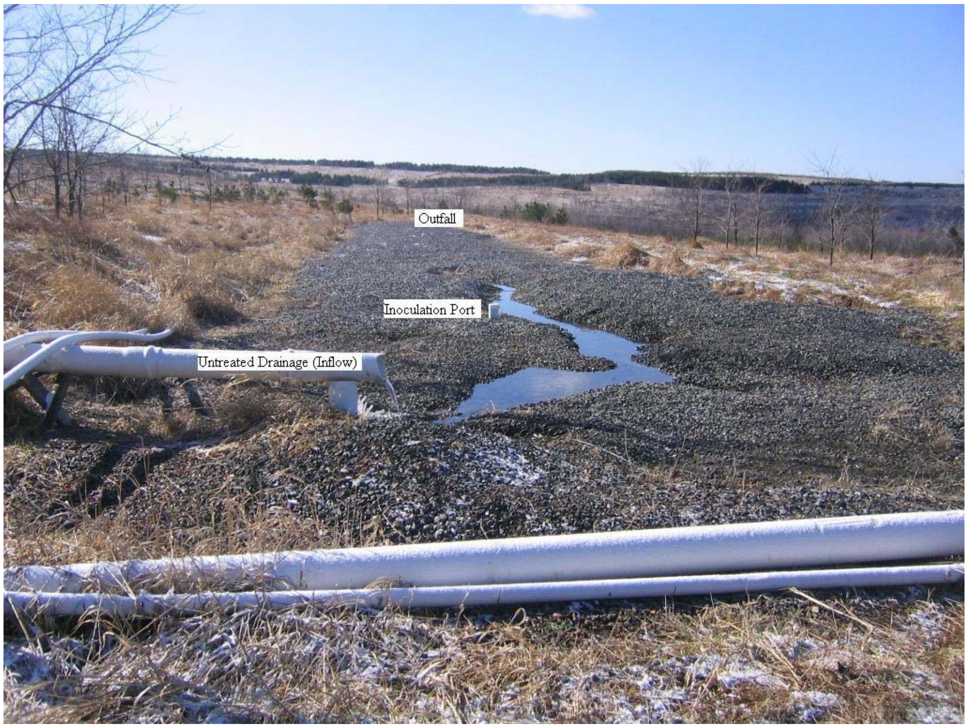

Figure 6-7. Photograph of Pyrolusite® Bed at PBS Job #5
Source: Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems (ERG, 2006).

Vail and Riley, Allegheny Mineral Abatement, Inc., recommend a residence time of 2.5 to 3.0 days, based on the projected maximum flow. The bed design should maximize reaction time and contact with the inoculated limestone. Vail and Riley also recommend a limestone purity of 87 percent $CaCO_3$ or greater (U.S. EPA, 2001).

Disadvantages of the Pyrolusite® system include long recommended residence times (2.5 to 3 days), requiring a relatively large treatment area. For example, to treat a flow of 5 gpm with 3 days residence time, the Pyrolusite® bed would cover more than a quarter acre of land (assuming a depth of 10 feet). Also, the Pyrolusite® system may not be effective for AMD with a pH less than 4. Some studies show that culturing and inoculation may not be necessary. The Pyrolusite® system has been most successful for treating AMD with low flow and low concentrations of iron (U.S. EPA, 2001).

6.2.8 Vertical Flow Wetlands

Vertical flow wetlands (also known as successive alkalinity-producing systems, or SAPS) incorporate anaerobic wetland and anoxic limestone drain technology to generate high amounts of alkalinity. AMD that is unsuitable for treatment by anoxic limestone drains because of oxic conditions or the presence of ferric iron can be treated through vertical flow wetlands (U.S. EPA, 2001).

In vertical flow wetlands, water enters the cell at the surface and drains into the underlying organic layer. In the organic layer, the dissolved oxygen content is greatly decreased by microbial action (decomposition) of organic matter, creating a nearly anoxic state. In this layer, anaerobic sulfate-reducing bacteria chemically reduce any previously oxidized metals, generate bicarbonate alkalinity, and yield hydrogen sulfide gas and low solubility metal sulfides. The reduction process increases alkalinity, neutralizing acidity and raising the pH of the water.

The metal sulfides may precipitate in the organic material. However, some of the metals remain in the dissolved state and pass through the organic layer. Below the organic layer, limestone gravel functions as an anoxic limestone drain. In the limestone gravel, the alkalinity further increases, resulting in effluent with a pH of 6.0 or higher. Aluminum may precipitate in the limestone region, which can clog this part of the system but will not greatly impact the limestone's effectiveness at increasing alkalinity. Where aluminum clogging may be a problem, underdrain systems are installed in a configuration to allow periodic flushing of the aluminum from the limestone. Vertical flow wetlands are typically followed by an aerobic wetland or settling pond to accommodate metals removal by precipitation. Because of the buffering capacity possessed by the water entering the aerobic wetland or settling pond, the remaining precipitated metals will be removed without a decreased pH (U.S. EPA, 2001).

The limitations of treating AMD with vertical flow wetlands are similar to those for anaerobic wetlands and anoxic limestone drains. The organic layer must also be kept wet to maintain the oxygen removal and sulfate reduction (U.S. EPA, 2001).

6.3 Acid Mine Drainage Treatment Technologies References

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7.0 CASE STUDIES OF TREATMENT COSTS

EPA reviewed case studies and developed model mines to determine the costs to treat acid mine drainage (AMD) after receiving comments from stakeholders stating that removing manganese is expensive and leads to mine forfeitures (EPA-HQ-OW-2004-0032-1049, 1055, 1062, 1091, 1101). In their comments, stakeholders described the expense associated with treating AMD discharges to achieve manganese limits. Stakeholders estimated that treating discharges to meet the iron and manganese limits would cost at least twice as much as treating discharges to meet only the iron limitations.

EPA also collected data on the difference in pollutant removals: which pollutants are removed when treating to meet only the Subpart C iron limits versus which are removed when treating for both the Subpart C iron and manganese limits. EPA obtained solubility data, but not actual sampling data, to characterize treatment system performance and co-removal of metals besides iron and manganese.

Overall, the three case studies show that it is less costly to operate treatment systems to meet Subpart C iron limits (6.0 daily maximum and 2.0 mg/L monthly average) than treating to meet both the iron and manganese limitations. Specifically, the three case studies show that treating to meet both the Subpart C iron and manganese limitations is approximately two to three times more expensive. Using the model costs, the estimated annualized capital and annual costs are both one to five times higher to treat the discharge to meet both the iron and manganese limitations in Subpart C compared to meeting only the Subpart C iron limitation. However, the data also show that treatment systems remove more pollutant loads when operated to meet Subpart C limits for both iron and manganese.

7.1 Treatment Cost Case Studies

PBS Coals, Inc. (PBS Coals) provided EPA with operating and maintenance costs for their RoxCoal, Inc. (RoxCoal) Outfall 003, PBS Coals Job #1, and PBS Coals Job #8 treatment systems, both chemical precipitation (ERG, 2006; Tercek, 2007). This section provides information about the three treatment systems and presents the treatment costs.

7.1.1 RoxCoal, Inc. Mine Outfall 003 Treatment

RoxCoal mined coal in an underground mine from 1992 until 2002. Stormwater and groundwater collected in the underground mine pit, and operators dewatered the pit by pumping mine drainage from the pit. After the mine was reclaimed, the mine drainage was no longer pumped from the mine pit. In 2002, Pennsylvania Department of Environmental Protection (PA DEP) identified that AMD from the PBS Coals mine was discharging near an adjacent historic landmark. In 2003, PBS Coals resumed pumping between 1,200 to 1,500 gpm from the former mine pool, to eliminate the discharge at the historic landmark (ERG, 2006). By resuming pumping, PBS Coals lowered the water table. The AMD no longer discharged near the historic landmark but rather discharged upgradient. The discharge is currently permitted under National Pollutant Discharge Elimination System (NPDES) Permit PA0213772 for Outfall 003.

The resulting pumped underground mine drainage is net alkaline, with high iron content (approximately 70 mg/L) and low manganese (approximately 14 mg/L) (ERG, 2006). Based on the high iron content (greater than 10 mg/L), Part 434 defines the discharge as AMD. Table 7-1 lists the AMD characteristics for the discharge at three stages: prior to treatment (untreated), after aeration pond, and after treatment (treated).

Table 7-1. NPDES Permit PA0213772 Outfall 003 Characteristics

Parameter [a]	Untreated Drainage Characteristics	Aeration Pond Discharge	Treated Drainage Characteristics
Alkalinity	82 – 210	152 – 210	26.0 – 222.2
Aluminum	<0.1 – 0.50	<0.1 – 0.34	<0.5 – <0.5
Flow (gpm)	1,000 – 1,200		
Hot acidity [b]	-11.8 – 11.8	Negative	-95.8 – 8.2
Iron	1.8 – 80	25.3 – 88	<0.3 – 1.42
Manganese	13.7 – 17.5	12.5 – 18.5	<0.05 – 5.002
pH (standard units)	6.3 – 8.6	6.2 – 7.3	7.4 – 9.8
Sulfate	327.4 – 2100.6	Unknown	1317.2 – 2,745.8
Total suspended solids (TSS)	38 – 100	Unknown	<3 – 40

Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* Appendix B (ERG, 2006); Personal Correspondence with Mr. Mark Tercek, PBS Coals, Inc., and Ms. Jessica Wolford, Eastern Research Group, Inc. (Tercek, 2007).
a – Units are mg/L unless otherwise noted. Untreated and treated data are from 1996 – 2005. Aeration pond only data are from November 26, 2005 to December 12, 2005.
b – Hot acidity measures the ability of water to neutralize a base. Negative values indicate net alkalinity.

PBS Coals, a sister company to RoxCoal, operates the chemical precipitation treatment system to meet the NPDES permit limits, which include Pennsylvania water quality-based limitations for manganese. The pumped AMD discharges into an aeration pond, where metals are oxidized. The oxidized metals are predominately iron and aluminum. However, some manganese oxidization can occur. The aeration pond is also designed to allow for the oxidized metals to precipitate. After the settling ponds, drainage is treated with lime and flows by gravity through a series of unlined settling ponds connected by channels. The remaining dissolved metals are oxidized into insoluble forms with the lime addition. The insoluble metals precipitate in the unlined settling ponds. Manganese, aluminum, and iron precipitate in the settling ponds, and sludge is vacuumed from the ponds as needed using vacuum trucks. Figure 7-1 is a photograph of the treatment system.

Figure 7-1. Photograph of the Outfall 003 Treatment System Aeration Pond
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

PBS Coals performed an aeration-only test in November 2005 to determine if chemical treatment was necessary, or if aeration alone was sufficient to remove iron and manganese to meet permitted limits. Because the pumped AMD at Outfall 003 is net alkaline with high iron, aerating the AMD is expected to rapidly precipitate iron. Treatment using aeration alone would reduce costs by reducing labor costs and eliminating chemical treatment costs.

During the study, pumped AMD was aerated, followed by settling of solids in Ponds 1 and 2. PBS Coals added caustic to the AMD flowing between Ponds 2 and 3, to ensure compliance with NPDES permit limits prior to discharge from Pond 3. Table 7-2 lists the metals concentrations measured in Pond 1 (aeration and precipitation), Pond 2 (aeration and further precipitation), and Pond 3 (aeration and chemical precipitation).

The data in Table 7-2 demonstrate that, after aeration and settling in Ponds 1 and 2, iron concentrations range from 2.2 to 15.3 mg/L, compared to up to 80 mg/L in the untreated, pumped AMD. The data also demonstrate that after aeration and settling in Ponds 1 and 2, manganese concentrations range from 5.25 – 15.7 mg/L, compared to up to 17.5 mg/L in the untreated, pumped AMD. However, additional retention time and/or further aeration would be required to meet Part 434 Subpart C effluent limitation guidelines and standards (ELGs) (daily maximum iron concentration of 6.0 mg/L and monthly manganese concentration of 2.0 mg/L). PBS Coals has stated that they could increase retention time by routing the treatment system through other, existing ponds (Tercek, 2007).

Table 7-2. Treatment Performance of Aeration-Only for Outfall 003

Parameter Measured [a]	Pumped AMD	Aeration Pond Discharge	Pond 1	Pond 2 (Aeration Only)	Pond 3 (Outfall 003, After Caustic)	NPDES Permit PA0213772 Limit [c]	Part 434 NSPS Limitations Guidelines [c]
Acidity [b]	Negative	Negative	Negative	Negative	Negative	Less than alkalinity	NA
Alkalinity	82 – 210	152 – 210	115 – 140	70 – 132	72 – 108	Greater than acidity	NA
Aluminum	<0.1 – 0.50	<0.1 – 0.34	ND – 0.65	<0.1 – 0.25	<0.1 – 0.20	0.5	NA
Flow (gpm)	Not Measured	800 – 1,000	75 – 850	75 – 850	500	NA	NA
Iron	1.8 – 80	25.3 – 88	1.1 – 54.0	2.2 – 15.3	0.5 – 1.5	1.5	3.0
Manganese	13.7 – 17.5	12.5 – 18.5	9.3 – 16.5	5.25 – 15.7	1.8 – 4.5	1.0	2.0
pH	6.3 – 8.6	6.2 – 7.3	7.0 – 8.5	6.3 – 7.6	8.5 – 9.2	6 – 9	6 – 9
Sulfates	ND	ND	ND	ND	ND – 1715	Monitoring Only	NA

Source: Personal Correspondence with Mr. Mark Tercek, PBS Coals, Inc., and Ms. Jessica Wolford, Eastern Research Group, Inc. (Tercek, 2007). Data collected from November 26, 2005 to December 12, 2005.

a – Units are mg/L unless otherwise noted.

b – Acidity measures the ability of water to neutralize a base. Negative values indicate net alkalinity.

c – Monthly average NSPS requirements.

ND – Not detected.

NA – Not applicable.

PBS Coals purchases approximately $160,000 of hydrated lime annually to treat the 1,500 gpm flow (Tercek, 2006). Because PBS Coals is operating chemical precipitation, or active treatment (see Section 6.1), labor costs include daily treatment system inspections by PBS Coals engineers, resulting in approximately $35,000 of annual labor costs (Tercek, 2007). Other annual costs include approximately $72,000 for pumping (Tercek, 2006). Table 7-3 lists itemized costs based on correspondence with Mr. Mark Tercek, Vice President of Engineering for PBS Coals. The aeration-only test that PBS Coals conducted could reduce the annual operating costs by up to $160,000 (the treatment chemicals cost). However, the aeration-only test did not achieve iron and manganese Subpart C limits.

Table 7-3. Annual Operating Costs of Existing Treatment System at Outfall 003

Item	Approximately Annual Cost
Treatment Chemicals	$160,000
Pumping (including power requirements)	$72,000
Labor	$35,000
Land costs (amortization)	$30,000
Total Annual Costs	**$275,000 – $297,000**

Source: Letter from Mr. Mark Tercek, Vice President of Engineering, PBS Coals, Inc. to the Honorable Kathleen McGinty, PA DEP, dated November 15, 2006 (Tercek, 2006); Personal correspondence with Mr. Mark Tercek and Ms. Jessica Wolford, Eastern Research Group, Inc (Tercek, 2007).

7.1.2 PBS Coals Job #1 Treatment

PBS Coals began mining at this location in 1984. The surface mining, covering roughly 1,800 acres, was completed in 1992 and backfilled in 1994. The seep associated with PBS Job #1 began in the 1990s after reclamation. The resulting discharge is net alkaline, but Part 434 defines it as AMD because the iron content is greater than or equal to 10 mg/L (ERG, 2006).

Under normal operations, AMD collects in a sump and is pumped up-gradient for treatment, because of property constraints. Figure 7-2 shows the lime house and aeration spray, where the aerator sprays the water to increase oxygen content and assist metals oxidation. Figure 7-3 shows the pumped AMD discharging in the lime house, where lime is added. The lime mixes by gravity, as the drainage flows through a channel. Next, water passes through a series of five unlined settling ponds, where metals precipitate, connected by channels. Sodium hydroxide is dripped, as needed, into the discharge channel between settling ponds 1 and 2 to ensure manganese levels comply with permit limitations. PBS Coals operators inspect the treatment system several times each week. Table 7-4 lists the treated and untreated AMD characteristics for the discharge (ERG, 2006).

Metals precipitate in the settling ponds, and sludge is vacuumed from the ponds as needed using vacuum trucks. Vacuumed sludge is pumped into boreholes in the reclaimed mine area. When treatment first began in approximately 1995, untreated drainage pH ranged from roughly 5.5 to 5.7. Currently, untreated drainage pH ranges from roughly 6 to 6.2. PBS believes that the alkalinity from the sludge precipitates deposited in the reclaimed mine area have helped neutralize the pH in the mine drainage (ERG, 2006).

Figure 7-2. Photograph of the PBS Job #1 Lime House and Aeration Spray
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

Figure 7-3. Photograph Inside the PBS Job #1 Lime House: AMD Flow and Lime Addition
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

Table 7-4. PBS Coals Job #1 Discharge Characteristics

Parameter [a]	Untreated Drainage Characteristics	Treated Drainage Characteristics
pH (standard units)	6.1 – 6.2	7.7 – 8.9
Alkalinity	75 – 88	47 – 100
Iron	13.5 – 15.5	0.2 – 5.25
Manganese	6.3 – 6.65	0.6 – 5.55

Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* PBS Coals, Inc. Treatment system summary handout for Job #1 (ERG, 2006).
a – Units are mg/L unless otherwise noted.

In effort to reduce treatment costs, PBS Coals researched an aeration-only alternative. Because the AMD at Job #1 is net alkaline with iron, aerating the AMD is expected to rapidly precipitate iron. PBS Coals performed an aeration-only test in March 2006 to determine if chemical treatment was necessary, or if aeration alone was sufficient to remove iron and manganese to meet permitted limits. Treatment using aeration alone would reduce costs by reducing labor costs and eliminating chemical treatment costs (ERG, 2006).

During the aeration-only study, PBS Coals shut off the chemical precipitation treatment system and used only aeration. PBS Coals mixed aerated water from treatment Pond 1 with untreated mine drainage from the sump. Drainage flowed by gravity through a series of five ponds to the outfall to Clear Run. Prior to the fifth pond, PBS Coals added sodium hydroxide to comply with effluent permit limits prior to discharge into Clear Run (ERG, 2006).

PBS Coals analyzed the Pond 4 outfall for the typical suite of mine pollutants to evaluate the performance of aeration-only. Table 7-5 lists the metals concentrations measured in the untreated AMD, Pond 4 (aeration and precipitation), and Pond 5 (aeration and chemical precipitation). After 96 hours of testing, the Pond 4 outfall was saturated with oxygen and iron levels had decreased by 55 to 60 percent. However, manganese levels did not change significantly using only aeration. PBS Coals added sodium hydroxide to precipitate the remaining iron and manganese at Pond 4 (ERG, 2006).

The data in Table 7-5 demonstrate that, after aeration and settling in Ponds 1, 2, 3, and 4, iron concentrations range from 2.6 to 6.5 mg/L, compared to up to 15.5 mg/L in the untreated AMD. The data also demonstrate that, after aeration and settling in Ponds 1, 2, 3, and 4, manganese concentrations range from 2.1 to 6.5 mg/L, compared to up to 6.65 mg/L in the untreated AMD. However, additional retention time and/or further aeration would be required to meet the Subpart C ELGs (monthly average iron concentration of 3.0 mg/L and monthly average manganese concentration of 2.0 mg/L) (ERG, 2006).

Table 7-5. Treatment Performance of Aeration-Only for Job #1

Parameter Measured [a]	**Untreated AMD**	**Pond 4 (Aeration Only)**	**Pond 5 (After Sodium Hydroxide)**	**Part 434 NSPS Limitations Guidelines [b]**
Alkalinity	75 – 88	69 – 71	47 – 100	NA
Flow (gpm)	750		NA	
Iron	13.5 – 15.5	2.6 – 6.5	0.20 – 5.25	3.0
Manganese	6.3 – 6.65	2.1 – 6.5	0.6 – 5.55	2.0
pH	6.1 – 6.2	7.1 – 7.5	7.2 – 9.0	6 – 9

Source: Personal Correspondence with Mr. Mark Tercek, PBS Coals, Inc., and Ms. Jessica Wolford, Eastern Research Group, Inc. (Tercek, 2007). Data collected from November 26, 2005 to December 12, 2005.
a – Units are mg/L unless otherwise noted.
b – Monthly average NSPS requirements.
NA – Not applicable.

PBS Coals provided EPA with information on the operating and maintenance costs of the treatment system during normal operation and during the aeration-only study. From February 1, 2005 through January 31, 2006, PBS Coals spent approximately $50,000 to operate the chemical precipitation treatment system at Job #1, presented in Table 7-6. The aeration-only test that PBS Coals conducted could reduce the annual operating costs by up to $19,417 (the treatment chemicals cost). However, the aeration-only test did not achieve iron and manganese levels below the permit limits.

Table 7-6. Annual Operating Costs of Existing Treatment System at Job #1

Item	Approximately Annual Cost
Treatment Chemicals	$19,417
Labor	$12,590
Electricity	$16,017
Repairs and Maintenance	$446
Total Annual Costs	**$48,470**

Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* PBS Coals, Inc. Treatment system summary handout for Job #1 (ERG, 2006).

7.1.3 PBS Coals Job #8 Treatment

PBS Coals found three seeps at Job #8 in 1996. The mine drainage is acidic, and the flow ranges from 2 to 400 gpm. Flow fluctuations tend to be gradual and vary with rainfall. Iron is only present at low concentrations in one of the seeps, but manganese and aluminum are present in all three seeps and require treatment to achieve permit compliance.

Under normal operations, AMD from the three seeps is collected in a basin and sump as shown in Figure 7-4. From the sump the discharge flows by gravity through a pipe where sodium hydroxide is added. The sodium hydroxide mixes as the drainage flows by gravity through a channel, and then through a series of five unlined settling ponds (connected by channels), as shown in Figure 7-5. Aluminum and manganese precipitate in the settling ponds, and sludge is vacuumed from the ponds as needed using vacuum trucks. Vacuumed sludge is pumped into boreholds in the old mine field area. Figure 7-6 shows the white color of the aluminum precipitate on the bottom of the first settling pond and the vacuum truck removing sludge. Table 7-7 lists the treated and untreated AMD characteristics for the discharge.

Table 7-7. PBS Job #8 Drainage Characteristics

Parameter [a]	Untreated Drainage Characteristics			Treated Drainage Characteristics
	Seep 1	Seep 2	Seep 3	
Alkalinity	0 – 10.8	0 – 58	6.8 – 174.0	30.0 – 1055.6
Aluminum	2.64 – 38.4	<0.5 – 48.6	0.7 – 39.2	<0.5 – 6.18
Flow (gpm)	2 – 400			
Hot acidity [b]	48 - 592	0 – 512	-40.2 – 338.0	-331.4 – 0
Iron	ND – 19.9	ND – 1.04	ND – 2.47	ND – 35.3
Manganese	5.05 – 98.6	0.7 – 100	1.93 – 62.8	<.0.05 – 21.2
pH (standard units)	3.2 – 5.0	3.8 – 6.7	4.1 – 7.7	6.6 – 11.0
Sodium	<10 – 10.2	<10	<10	11 - >300
Sulfate	350 – 2440	27.8 – 2859.5	147.2 – 1880.8	337.6 – 2429.4
Total suspended solids (TSS)	<3 - 30	<3 – 18	<3 – 32	<3 – 40

Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006).
a – Units are mg/L unless otherwise noted. Data from 1996 – 2005.
b – Hot acidity measures the ability of water to neutralize a base. Negative values indicate net alkalinity.

Figure 7-4. Photograph of the Chimney Sump and Collection Basin at PBS Coals Job #8
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

Figure 7-5. Photograph of Sodium Hydroxide Addition at PBS Job #8
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

Figure 7-6. Photograph of the Three PBS Job #8 Settling Ponds
White precipitate in Pond 1 is aluminum. The vacuum truck is removing sludge from Pond 2.
Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* (ERG, 2006)

PBS Coals provided EPA with information on the operating and maintenance costs of the treatment system. From April 1, 2004 through March 31, 2005, PBS Coals spent approximately $80,000 to operate the chemical precipitation treatment system at Job #8, presented in Table 7-8.

Table 7-8. Annual Operating Costs of Existing Treatment System at Job #8

Item	Approximately Annual Cost
Treatment Chemicals (Caustic)	$58,129
Miscellaneous	$21,262
Total Annual Costs	**$48,470**

Source: *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems* PBS Coals, Inc. Treatment system summary handout for Job #8 (ERG, 2006).

7.2 Model Costs for Passive and Active Treatment Systems

EPA developed cost modules for the following four treatment technologies using *AMDTreat® v.4.1*, along with input from the PA DEP, Mr. Brent Means of the Office of Surface Mining, Reclamation, and Enforcement (OSMRE), and Dr. Charles Cravotta of the USGS:

- Chemical precipitation with caustic soda (caustic cost module);
- Chemical precipitation with hydrated lime (lime cost module);
- Limestone bed with a clay liner (limestone bed – clay cost module); and
- Limestone bed with a synthetic liner (limestone bed – synthetic cost module).

The cost modules are presented as Appendix B (caustic cost module), Appendix C (lime cost module), and Appendix D (limestone bed – clay cost module and limestone bed – synthetic cost module).

The cost modules estimate the cost to treat AMD to achieve two effluent treatment scenarios:

1. Effluent Treatment Scenario 1. Treating the discharge to meet *all* of the NSPS limits in 40 CFR Part 434 Subpart C (TSS, pH, iron, and manganese).
2. Effluent Treatment Scenario 2. Treating the discharge to meet *only* the TSS, pH, and iron NSPS limitations in 40 CFR Part 434 Subpart C (the discharge does not meet the NSPS manganese limitations).

Each cost module then calculates the difference between the annualized costs to treat the AMD for the two effluent treatment scenarios. This cost difference (delta) represents the estimated expense required to achieve the 40 CFR Part 434 Subpart C NSPS manganese limit.

EPA used the cost modules to estimate treatment costs for four raw water quality scenarios over a range of flows. Table 7-9 lists the raw water quality inputs used. The flow range varied from 10 gpm to 1,500 gpm.

Table 7-9. Raw Water Quality Scenarios

Raw Water Quality Scenarios	Alkalinity (mg/L)	pH	Manganese (mg/L)	Iron (mg/L) [a]	Aluminum (mg/L)	Magnesium (mg/L)
Net Alkaline, Low Metals	10	6	5	10	1	10
Net Alkaline, High Metals	10	6	25	50	10	150
Net Acidic, Low Metals	0	4	5	10	1	10
Net Acidic, High Metals	0	4	25	50	10	150

a – EPA assumed all of the iron is ferric iron (Fe+3) for simplicity. This assumption may underestimate the amount of treatment necessary to remove iron from AMD, because of considerations necessary when ferrous iron is present.

The results of the cost modules for each of the raw water quality scenarios and flow ranges are summarized below:

- In terms of annualized costs, chemical precipitation using caustic soda is approximately eight times more expensive than chemical precipitation using hydrated lime and two times more expensive than using a limestone bed, both for clay and synthetic liners.
- The metals content drives the treatment expense for all four technologies considered, and it is most expensive to treat AMD containing high metals, regardless of alkalinity and pH.
- For treatment using chemical precipitation, capital costs are not the driving expense. Annual costs, especially annual labor costs at low flows and annual chemical costs at high flows, dominate the costs to treat AMD using chemical precipitation, for both hydrated lime and caustic.

- For treatment using a limestone bed, both for clay and synthetic liners, the driving expense depends on the treatment flow and raw water quality scenario. For low flows, annual costs drive the expense; whereas for high flows, capital costs drive the expense. The treatment costs for low flows are dominated either by labor or limestone bed turning costs.
- Generally, the annualized capital costs and annual costs are both one to five times higher to achieve Effluent Treatment Scenario 1 versus Effluent Treatment Scenario 2, depending on the untreated raw water quality and treatment technology in place.

Figures 7-7 through 7-10 present the estimated difference, or net delta, in costs for each treatment technology to meet Effluent Treatment Scenario 1 versus Effluent Treatment Scenario 2. The costs plotted represent the cost to achieve the 40 CFR Part 434 Subpart C NSPS manganese limit for four raw water quality scenarios over a range of flows. Note that the range of costs (on the y-axis) is different for each graph. Appendix E presents the results of the cost modules.

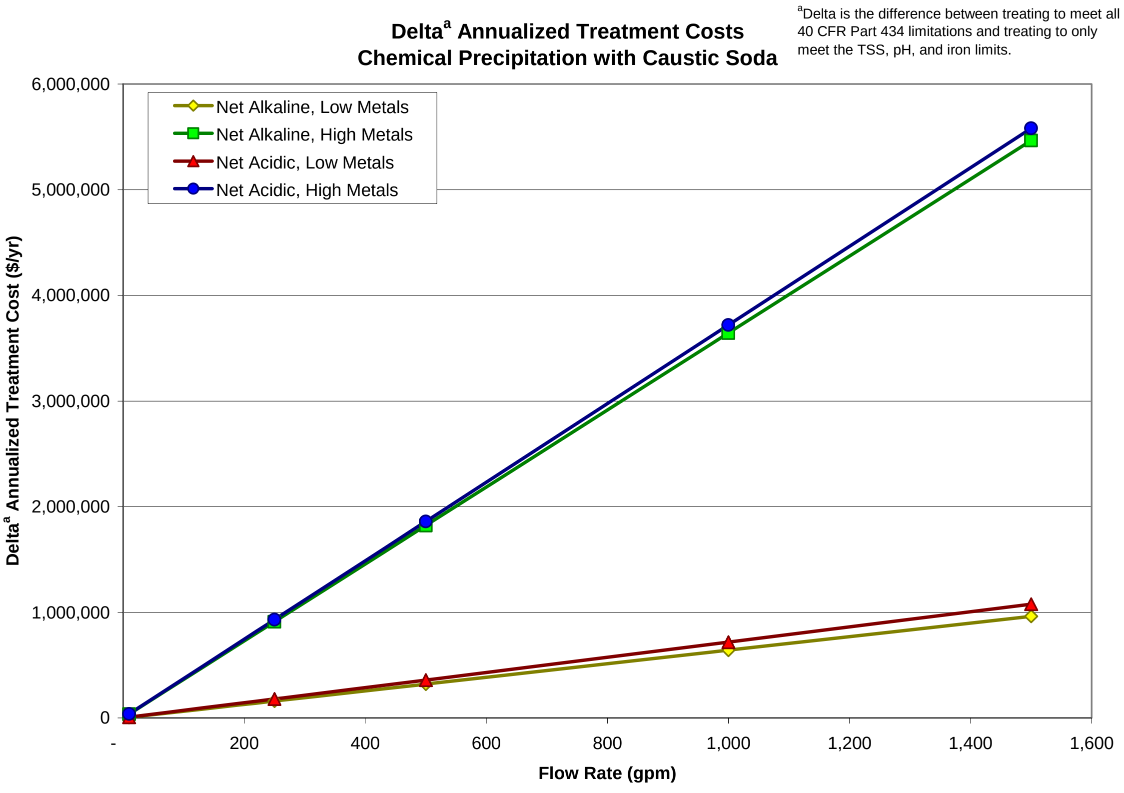

Figure 7-7. Annualized Treatment Costs for Chemical Precipitation with Caustic Soda

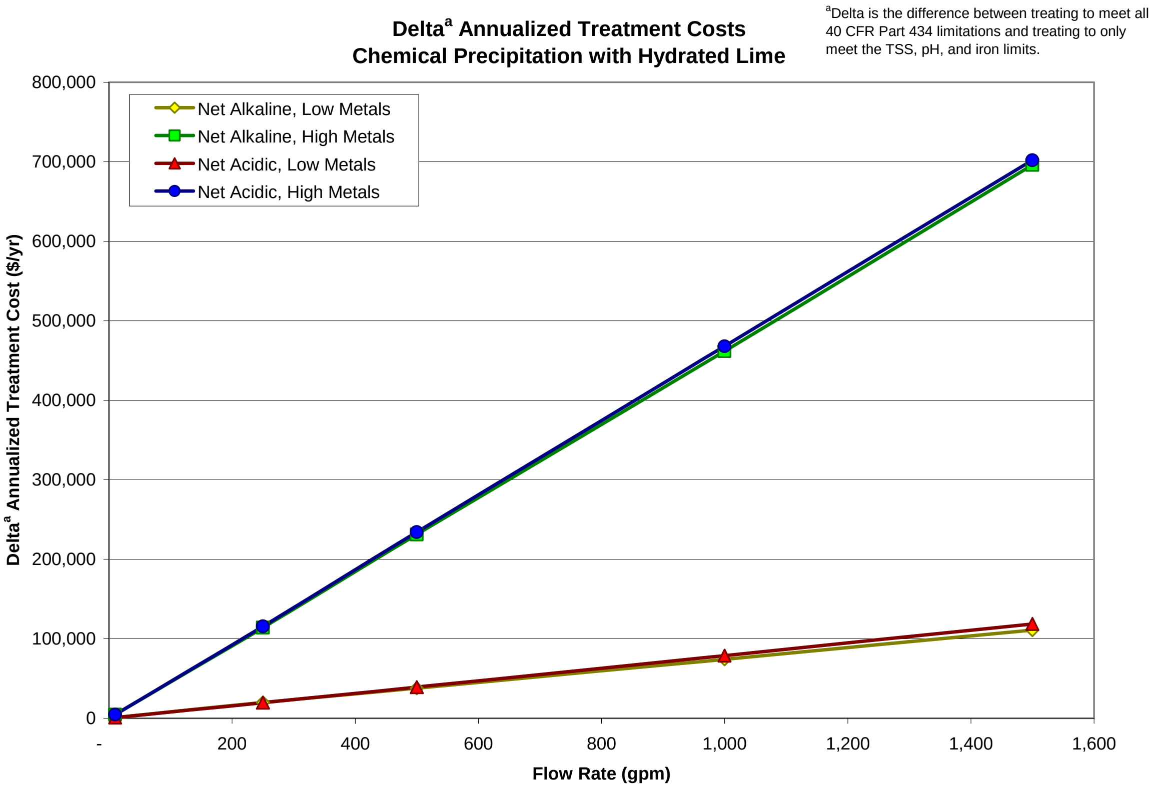

Figure 7-8. Annualized Treatment Costs for Chemical Precipitation with Hydrated Lime

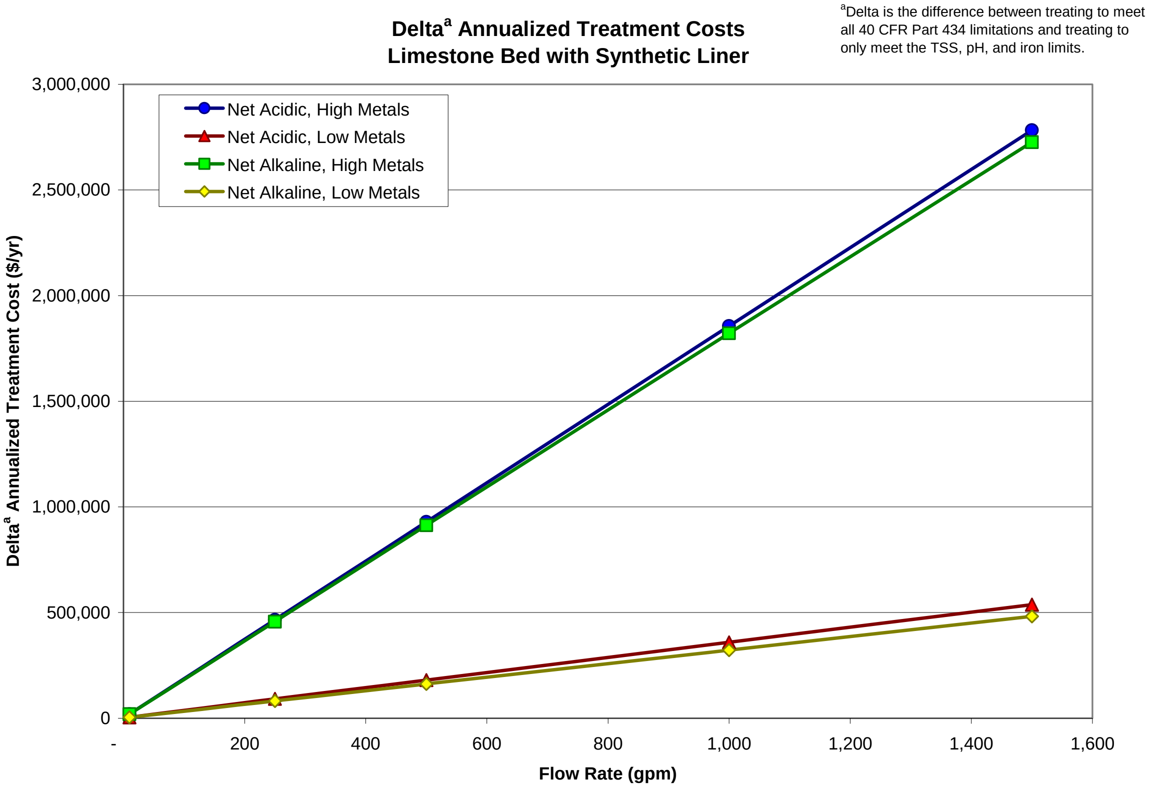

Figure 7-9. Annualized Treatment Costs for Limestone Bed Using a Clay Liner

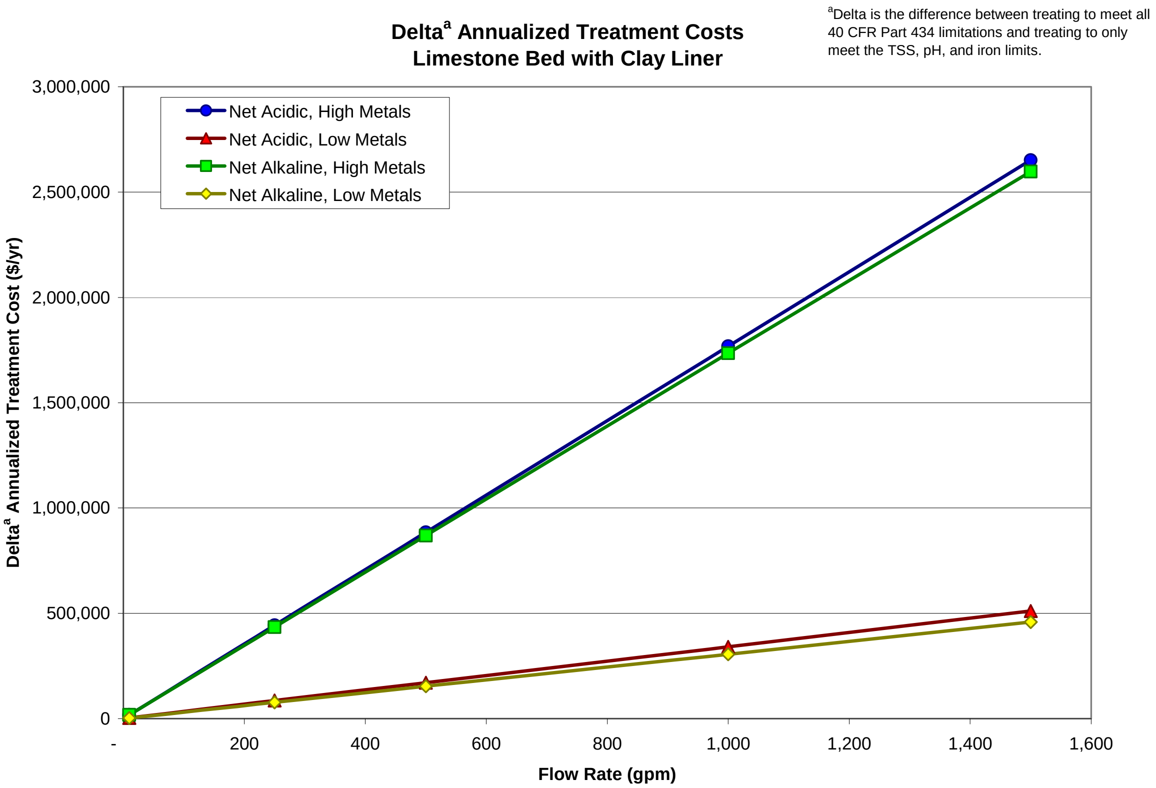

Figure 7-10. Annualized Treatment Costs for Limestone Bed Using a Synthetic Liner

7.3 Removal of Non-Regulated Metals Based on Solubility and Literature

As part of assessing the costs and pollutant removals associated with treating AMD to remove manganese, EPA used theoretical solubility curves to estimate pollutant co-removal. Metals with theoretical minimum solubilities at higher pH, for example, would be removed when treating for manganese. Treating AMD solely for iron may not remove these metals.

To evaluate the metals concentrations in untreated AMD, EPA used the *AMD143* database (see Section 2.5 for additional details on *AMD143*). The *AMD143* database includes sampling data from untreated AMD discharges from abandoned deep mines with large flows in Pennsylvania, for a wide variety of metals concentrations. Although *AMD143* represents deep mines with large flows, the database still provides an overview of the range of metals in AMD. Table 7-10 reviews the concentrations of selected metals observed in AMD prior to treatment.

Table 7-10. Untreated Acid Mine Drainage Metal Concentrations from *AMD143*

Pollutant Parameter [a]	*AMD143* Database [b]		
	Minimum Value	Average Value	Maximum Value
Aluminum (mg/L)	0.01	8.18	108.00
Cadmium (µg/L)	<0.01	0.53	16.00
Calcium (mg/L)	3.30	102.46	410.00
Cobalt (µg/L)	0.27	130.63	3,100.00

Table 7-10. Untreated Acid Mine Drainage Metal Concentrations from *AMD143*

Pollutant Parameter [a]	*AMD143* Database [b]		
	Minimum Value	Average Value	Maximum Value
Copper (µg/L)	0.40	11.07	190.00
Ferrous Iron (mg/L)	<0.50	11.79	214.00
Iron (mg/L)	0.05	48.10	512.00
Magnesium (mg/L)	3.60	44.78	210.00
Manganese (mg/L)	0.02	5.45	74.00
Nickel (µg/L)	2.60	158.45	3,200.00
Zinc (µg/L)	0.60	341.55	10,000.00

Source: *AMD143*.
a – All 143 outfalls were sampled for each pollutant. Therefore, the number of permits for each pollutant is 143.
b – Exclude zeros except for flow (GPD), total acidity (mg/L), and total alkalinity (mg/L).
< – Indicates the sample result was less than the detection limit.

Part 434 Subpart C regulates two metals: iron (6.0 mg/L daily maximum and 3.0 mg/L monthly average) and manganese (4.0 mg/L daily maximum and 2.0 mg/L monthly average). To achieve these limits, operators adjust pH to precipitate the metals. Each metal will reach minimum solubility (and maximum precipitation) at different pH levels. Scientists have determined that iron precipitates best at a pH of approximately 8.3 while manganese precipitates best at a pH around 10.0. To determine which other metals in Table 7-10 are likely removed when treating for manganese, EPA compared the theoretical solubilities.

Figure 7-11 presents the solubilities of selected metal hydroxides at 25°F (Means, 2004). These solubilities consider only pH and formation of the metal hydroxides. The removal of metals can also result from the formation of other metal precipitates, co-precipitation, and site-specific water quality characteristics.

Aluminum hydroxide and mercury hydroxide both have minimum solubilities below pH 8.3 and therefore would likely be removed in the same pH range as iron. Cobalt hydroxide, copper hydroxide, nickel hydroxide, lead hydroxide, and zinc hydroxide have minimum solubilities at a pH less than or approximately 10.0. These metals would likely have some removal in the same pH range as iron, with increasing removals at higher pH.

Stakeholders commented that EPA should review discharges of cadmium and selenium from coal mines. The minimum solubility of cadmium hydroxide occurs at a pH between 10.5 and 12.5. It is likely that cadmium hydroxide would not be removed in the same pH range as iron, but would require a higher pH for any removal. Selenium tends to exist in water as selenite (SeO_3^{-2}) and selenate (SeO_4^{-2}). Selenite will adsorb to iron hydroxides and precipitate, but neither selenite nor selenate precipitate as hydroxides (EPRI, 2006). As a result, selenium was not included in the metal hydroxide solubility curve in Figure 7-11.

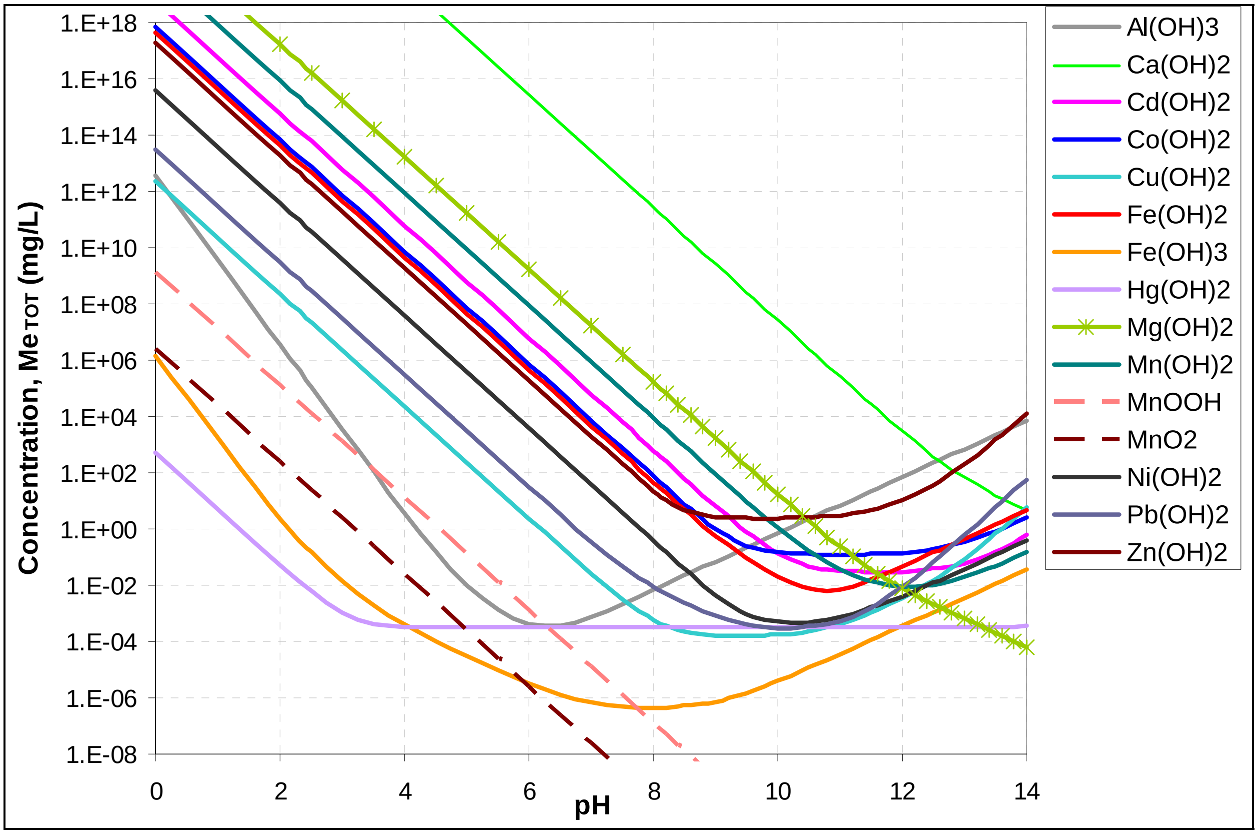

Figure 7-11. Comparison of Various Metal Hydroxide Solubilities

Source: *Comparison of Three Methods to Measure Acidity of Coal-Mine Drainage* (Means, 2004)

7.4 Case Studies of Treatment Costs References

1. AMD143. Unknown. Sampling Database from 143 Acid Mine Drainage Discharges. EPA-HQ-OW-2006-0771-0082.1.

2. EPRI. Electric Power Research Institute. 2006. *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers*. Palo Alto, CA. (December). EPA-HQ-OW-2006-0771-0081.

3. ERG. Eastern Research Group, Inc. 2006. *Site Visit Report Pennsylvania Coal Mine Acid Drainage Treatment Systems*. Chantilly, VA. (October). EPA-HQ-OW-2004-0032-02487.

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6. Tercek, Mark. PBS Coals, Inc. 2007. Personal correspondence with Mr. Mark Tercek, PBS Coals, Inc., and Ms. Jessica Wolford, Eastern Research Group, Inc. (May 2). EPA-HQ-OW-2006-0771 DCN 04272.

8.0 ESTIMATED POLLUTANT LOADINGS FOR ACID MINE DRAINAGE

As part of the Coal Mining Detailed Study, EPA estimated current pollutant loadings from coal mining outfalls that discharge acid mine drainage (AMD) to provide background for the environmental impacts from AMD. EPA limited its estimates to AMD in Pennsylvania and West Virginia, because these two states are most affected by AMD (see Figure 5-1 in Section 5.1.2).

EPA estimated pollutant loadings for AMD using two databases: *PADEPInspector* and *WVDMR*. To limit the analysis to AMD, EPA excluded loadings from outfalls discharging alkaline mine drainage. EPA's estimates for Pennsylvania are likely minimum estimates due to the data limitations presented below. Therefore, EPA estimates that AMD from coal mines in Pennsylvania discharge at least 0.45 million pounds per year of manganese into surface water, based on available data. EPA estimates that AMD from coal mines in West Virginia discharge 2.4 million pounds per year of manganese into surface water.

PADEPInspector includes Pennsylvania Department of Environmental Protection (PA DEP) mining inspector-collected pollutant concentration measurements representing wastewater discharges from coal mining treatment plants (effluent discharge). PA DEP said that the mining inspectors collect more samples from mines they suspect are not meeting their permit requirements rather than they do from other mines (U.S. EPA, 2007). For the purposes of the estimated pollutant loadings, limitations of the data contained in *PADEPInspector* include the following:

- More samples may be collected for outfalls that have difficulty meeting the permit requirements than for compliant outfalls;
- The pollutants measured were not consistent, sample to sample;
- Discharge type is not included—EPA assumed outfalls with manganese analytical data were AMD (see Section 2.3.3); and
- Database may not represent all AMD outfalls (e.g., if data for an AMD discharge does not include analytical data for manganese, EPA did not include the outfall in the pollutant loadings analysis).

The *WVDMR* database contains the reported pollutant concentrations or quantities from the discharge monitoring reports (DMRs) for coal mines located in West Virginia (WVDMR, 2007). For the purposes of the estimated pollutant loadings, limitations of the data contained in *WVDMR* include the following:

- Discharge type is not included—EPA assumed outfalls with manganese analytical data were AMD (see Section 2.4.2).

Based on the data limitations, EPA concluded that the total effluent loadings and average pollutant loadings per outfall for West Virginia presented in this section represent pollutant loadings for the entire state.

8.1 Pollutant Loadings Methodology

EPA obtained detailed data on coal mining discharges for West Virginia and Pennsylvania. EPA describes the data sources used in detail in Section 2.0 of this study. EPA used DMR data submitted to West Virginia (*WVDMR* database) and inspector-collected data from Pennsylvania (*PADEPInspector* database) to estimate the mass of pollutants directly discharged to surface waters. EPA estimated the pollutant loadings for four pollutants that coal mines routinely monitor at outfalls with AMD:

- Total aluminum;
- Total iron;
- Total manganese; and
- Total suspended solids (TSS).

Coal Mines with AMD are required by 40 CFR Part 434 Subpart C to monitor and meet effluent limitations for total iron, total manganese, and TSS (see Section 4.1.1 for additional discussion on ELG limitations). Mines may also have National Pollutant Discharge Elimination System (NPDES) permit limits for aluminum. Mines also must meet pH limitations in their NPDES permits; however, pollutant loadings cannot be calculated for pH.

This section describes how EPA used the DMR and inspector-collected data for AMD discharges to estimate the mass and toxicity of pollutants discharged for two scenarios:

- Current effluent loadings (Section 8.2). The estimated amount of pollutants in coal mining wastewater currently discharged to surface waters (baseline).
- Estimated loadings if all outfalls meet 40 CFR Part 434 Subpart C NSPS Limitations (ELG Scenario Loadings) (Section 8.4). The estimated amount of pollutants in coal mining wastewater discharged to surface waters if 40 CFR Part 434 limits are being met. In this scenario, any pollutant concentration above the 40 CFR Part 434 New Source Performance Standards (NSPS) limitation is set at the limit. For example, if the reported monthly manganese concentration was 3.0 mg/L, EPA calculated the manganese load using the 30-day average manganese limit of 2.0 mg/L.

The two databases used do not differentiate outfalls by alkaline versus acid discharges; therefore, EPA identified outfalls representative of AMD discharges at treatment plant effluent in both databases.

8.1.1 Outfalls Identified as AMD at Pennsylvania Coal Mines

PADEPInspector includes 1,809 state primary facility IDs (state permit ID) and 4,624 outfalls. EPA identified 333 outfalls (at 234 state IDs) as AMD representing the treatment plant effluent (i.e., excluding monitoring locations with no flow rate). The *PADEPInspector* database is a compliance database that only includes samples collected by inspectors and may not include sampling data for all mines and outfalls. In addition, if manganese samples were not collected by the inspector at an outfall with AMD, that outfall would not be included in the pollutant loadings analysis. EPA does not have the data available to identify the total number of outfalls with AMD in the state; therefore, EPA's estimated pollutant loadings represent a minimum discharge amount. The number of outfalls with AMD in Pennsylvania may be greater than 333; EPA identified over 3,000 outfalls with AMD at West Virginia mines.

8.1.2 Outfalls Identified as AMD at West Virginia Coal Mines

WVDMR represents 1,289 NPDES IDs and 8,934 outfalls. EPA identified 3,295 outfalls (at 883 NPDES IDs) as AMD representing the treatment plant effluent (i.e., excluding surface water monitoring locations). As described above, the *WVDMR* database includes 24 months of data (April 2003 through March 2005) compared to five years of data in *PADEPInspector*. However, *WVDMR* provides more details on discharges (e.g., 30-day average and daily maximum values, multiple months of data for all outfalls).

8.1.3 Results of Identifying Outfalls with AMD

Table 8-1 summarizes the number of permit IDs, 2006 production, and number of outfalls with AMD included in the pollutant loadings analysis. Note that a single Surface Mining Control and Reclamation Act (SMCRA) permitted mine may operate under more than one state permitting ID.

Table 8-1. Number of SMCRA Permits and 2006 Total Production for All Mines And Number of Permit IDs and Outfalls with AMD Represented by *WVDMR* and *PADEPInspector*

	West Virginia		**Pennsylvania**	
	Number of Permits	**Number of Outfalls**	**Number of Permits**	**Number of Outfalls**
SMCRA Permits (Surface and Underground) [a]	626	—	737	—
2006 Total Production (tons) [a]	148 million	—	75 million	—
State Permit IDs Represented by Database [b]	1,289 [d]	8,934	1,809 [e]	4,624
Outfalls with AMD and Corresponding State Permit IDs in the Database (Included in the Pollutant Loadings Analysis) [b,c]	883 [d]	3,295	234 [e]	333
Percent of State Permit IDs Classified as AMD and Included in Analysis [b,c]	69%	37%	13%	7%

Source: Coal Production Index (OSMRE, 2006); *WVDMR*; *PADEPInspector*.
a – From the Coal Production Index (OSMRE, 2006).
b – From the *WVDMR* or *PADEPInspector* databases.
c – EPA classified an outfall as AMD if the sampling data included manganese. EPA also limited the number of outfalls in the analysis to those that represent effluent at the treatment plant. EPA identified treatment plant effluent outfalls by the flow parameter in *WVDMR* and by inclusion of only outfalls with flow rates (>0) in *PADEPInspector*.
d – Number of NPDES IDs in WVDMR. A mine may discharge under more than one NPDES permit.
e – Number of primary facility IDs in *PADEPInspector*. A mine may operate under more than one state permitting ID.

EPA was able to identify 37 percent of the outfalls as AMD in *WVDMR* and seven percent of the outfalls as AMD in *PADEPInspector*.

8.2 Current Effluent Loadings

For each set of analytical data, EPA calculated annual pollutant loadings using the following steps:

- Select the measurement value (Section 8.2.1);
- Calculate the monthly load (Section 8.2.2); and
- Calculate the annual load (Section 8.2.3).

8.2.1 Measurement Value Selection

WVDMR included multiple measurement value fields for each pollutant representing the same sampling month. These include: minimum quantity, average quantity, maximum quantity, minimum concentration, average concentration, and maximum concentration. EPA selected a measurement value to use for the loadings analysis based on the following sequence, or hierarchy:

1. Average Quantity;
2. Maximum Quantity;
3. Average Concentration; and
4. Maximum Concentration.

The *PADEPInspector* database includes inspector-collected samples at one-day sample events (i.e., not monthly data). Therefore, all the data collected are maximum concentration values.

Appendix F provides the annual average measurement values for each pollutant parameter (total aluminum, total iron, total manganese, and TSS) and annual average effluent flow rate by outfall with AMD in *WVDMR*. Appendix G provides the annual average concentration values for each pollutant parameter and annual average effluent flow rate by outfall with AMD in *PADEPInspector*.

In a few instances, EPA updated flow rate unit of measurements from the *WVDMR* database to correspond with the units listed for the same outfall for other reporting months. However, EPA did not perform any systematic checks of the data for either database.

Non-Detect Concentration Measurements

Non-detect samples are monitoring concentrations analyzed to be below the detection limit. For reporting purposes, a less than sign (<) and the detection limit are included in the analytical databases.[10] For samples below the detection limit (indicated by a less than sign "<"), EPA assigned one of two values for the concentration:

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[10] Only two outfalls included a non-detect quantity sample in the *WVDMR* database. For each outfall, the non-detect "reading" applied to one month of TSS sampling. Therefore, EPA did not modify quantities reported based on non-detect samples.

1. If all samples for the outfall, parameter, and loadings year were below the detection limit, EPA set the concentration (and pollutant loading) for non-detect months to zero.
2. If at least one sample for the outfall, parameter, and loadings year was above the detection limit, EPA multiplied all non-detect sample detection limits (i.e., numerical value reported) by ½.

8.2.2 Monthly Load Calculation

To calculate the monthly load for each outfall and pollutant parameter, EPA used Equation 8-1 for quantity load measurements and Equation 8-2 for concentration measurements.

$$\text{Monthly Load (lb/mo)} = \text{Quantity (lb/day)} \times 30 \text{ (days/mo)} \tag{8-1}$$

$$\begin{aligned}\text{Monthly Load (lb/mo)} = \text{Conc (mg/L)} \times \text{Flow (MGD)} \times 3.785 \text{ (L/gal)} \\ \times 2.2046 \text{ (lb/kg)} \times 30 \text{ (days/mo)}\end{aligned} \tag{8-2}$$

The data for West Virginia mines include monthly DMR data; however, the data for Pennsylvania mines include only one-day sample events. EPA used the Pennsylvania one-day sample event measurements to represent the entire month. Therefore, the monthly loadings from Pennsylvania outfalls with AMD may be higher than actual monthly discharges. In addition, PA DEP said inspectors tended to collect samples more often at outfalls suspected to be out of compliance (U.S. EPA, 2007). However, for the total pollutant loadings estimated for AMD discharges at Pennsylvania coal mines, EPA concluded the calculated loadings are a minimum value—additional outfalls with AMD may not be included in this analysis.

Sensitivity Analysis for Pollutant Loading Outliers

EPA reviewed the concentration and flow rate values for outfalls and months where the pollutant loading exceeded 10,000 pounds per month. Flow rates for the discharges were higher than average, but were determined to be reasonable. EPA expects variations in flow rate from one outfall to another; therefore, the flow rates were used as reported.

EPA found that a high pollutant loading did not necessarily correlate with a high pollutant concentration. However, some high concentrations may be due to incorrect units measured or reported. For example, concentration values included in the databases may have been measured as micrograms per liter (µg/L) rather than mg/L. In those cases, the concentration value included in the database would be 1,000 times higher than expected. Table 8-2 presents the effluent median concentrations using monthly average data from *WVDMR* and data from *PADEPInspector*.

Table 8-2. Effluent Median Monthly Average Concentrations

Pollutant	Median Concentration (mg/L)	
	WVDMR	*PADEP Inspector*
Total aluminum	0.21	<0.50
Total iron	0.23	0.30
Total manganese	0.12	0.71
TSS	4.75	8.00

Source: *WVDMR; PADEPInspector.*

To adjust for potential concentration units reporting errors, EPA assumed concentrations in the database exceeding 100 were in units of μg/L rather than mg/L. For *WVDMR*, 81of the monthly concentrations used to estimate pollutant loadings were greater than 100 mg/L. Appendix F provides the list of outfalls and concentrations in *WVDMR* where EPA assumed the concentration units of measurement were μg/L. For *PADEPInspector*, 37 of the monthly provides the list of outfalls and concentrations in *PADEPInspector* where EPA assumed the concentration units of measurement were μg/L.

EPA did not perform any additional systematic checks of the concentration data for either database.

8.2.3 Annual Load Calculation

To calculate the annual load for each outfall and pollutant parameter, EPA normalized the monthly loads (or each sample event) to a 12-month year using Equation 8-3.

$$\text{Annual Load (lb/yr)} = \frac{\sum \text{Monthly Load (lb/mo)} \times 12}{\text{No. of Months with Sampling Data}} \qquad (8\text{-}3)$$

For example, if an outfall included only six months of sampling data for manganese, EPA summed the manganese loads for those six months and assumed the average monthly manganese load applied to the six months without measurement values.

EPA also estimated toxic-pound equivalent (TWPE) pollutant loadings. To calculate TWPE, EPA multiplies the annual load (lb/yr) by a toxic weighting factor (TWF). EPA has developed TWFs for more than 1,900 pollutants based on aquatic life and human health toxicity data, as well as physical/chemical property data. TWFs account for differences in toxicity across pollutants and provide the means to compare mass loadings of different pollutants on the basis of their toxic potential. EPA multiplies a mass loading of a pollutant in pounds per year (lb/yr) by a pollutant-specific weighting factor to derive a "toxic-equivalent" loading (lb-equivalent/yr), or TWPE. EPA calculated the TWPE for total aluminum, total iron, and total manganese using Equation 8-4. TWPEs do not apply to conventional pollutants or bulk parameters, including TSS.

$$\text{TWPE (lb-eq-yr)} = \text{Annual Load (lb/yr)} \times \text{TWF} \qquad (8\text{-}4)$$

For West Virginia outfalls with AMD, EPA calculated pollutant loadings for two loadings years (April 2003 through March 2004 and April 2004 through March 2005). For

Pennsylvania outfalls with AMD, EPA calculated pollutant loadings for five loadings years (annually for 2003 through 2007).

If a mine did not report any pollutant data for an outfall with AMD during a loadings year, EPA set the annual pollutant loading equal to the average annual pollutant loading from the other reporting year(s). EPA determined this was appropriate because once AMD occurs at a location it typically occurs in perpetuity. For example, if an outfall with AMD for Pennsylvania has TSS sampling data for 2003, 2005, 2006, and 2007, but does not have any data for 2004. EPA would assume the TSS loadings for 2004 equals the average TSS loadings for 2003, 2005, 2006, and 2007.

For some West Virginia outfalls, no data were reported for a particular pollutant for all loadings years. EPA calculated the median annual loadings for each pollutant using the annual loadings (see Equation 8-3) for the outfalls that reported a particular pollutant. For the mines that did not report any pollutant data for an outfall with AMD for all loadings years (e.g., no total aluminum data in *WVDMR*), EPA used the following median annual loadings:

- Total aluminum: 38.24 lb/yr;
- Total iron: 31.18 lb/yr;
- Total manganese: 19.95 lb/yr; and
- TSS: 789.20 lb/yr.

For the outfalls with AMD in Pennsylvania, all outfalls had at least one month of monitoring data for all four pollutants.

Appendix H presents the annual pollutant loadings for outfalls with AMD included in *WVDMR*. Appendix I presents the annual pollutant loadings for outfalls with AMD in *PADEPInspector*.

8.3 Current Effluent Loadings Results

After calculating the annual pollutant loadings, EPA determined the average annual pollutant loadings for each state. Table 8-3 presents the average annual effluent loadings for each pollutant, along with the TWPE. EPA used the average annual effluent loadings in Table 8-3 to estimate the average loadings per outfall. Table 8-4 presents the average annual pollutant loadings per outfall with AMD.

Table 8-3. Current Annual Effluent Loadings at Mine Outfalls with AMD Located in West Virginia and Pennsylvania

Pollutant	Number of State Permit IDs and Outfalls	Current Annual Effluent Loadings [a] (lb/yr)	TWF	TWPE (lb-eq/yr)
Annual Loadings for AMD Outfalls in West Virginia				
Aluminum, total	883 state permit IDs (3,295 outfalls)	4.80 million	0.0647	310,210
Iron, total		4.59 million	0.0056	25,718
Manganese, total		2.36 million	0.0704	166,523
TSS		33.0 million	NA	NA
WV Total		**44.8 million**		**502,451**
Annual Loadings for AMD Outfalls in Pennsylvania				
Aluminum, total	234 state permit IDs (333 outfalls)	0.24 million	0.0647	15,753
Iron, total		0.54 million	0.0056	3,035
Manganese, total		0.45 million	0.0704	31,448
TSS		3.95 million	NA	NA
PA Total		**5.2 million**		**50,236**

Sources: *WVDMR*; *PADEPInspector*.

a – Prior to adjustment for monthly loadings outliers, the total effluent loadings from West Virginia were 5.16 million lb/yr for total aluminum, 9.36 million lb/yr for total iron, 2.36 million lb/yr for total manganese (no change), and 34.4 million lb/yr for TSS. Prior to adjustment for monthly loading outliers, the total effluent loadings from Pennsylvania were 0.24 million lb/yr for total aluminum (no change), 0.73 million lb/yr for total iron, 0.45 million lb/yr for total manganese (no change), and 4.90 million lb/yr for TSS.

TWF – Toxic weighting factor.

TWPE – Toxic-weighted pound equivalent.

TSS – Total suspended solids.

NA – Not applicable. TSS does not have a TWF because it is not considered a toxic pollutant. Therefore, EPA can not calculate the toxic-weighted pound equivalent of TSS.

Table 8-4. Current Average Annual Effluent Loadings Per Outfall with AMD

Pollutant	Current Annual Effluent Loadings (lb/yr)	TWPE (lb-eq/yr)
Average Annual Loadings Per WV AMD Outfall		
Aluminum, total	1,455	94.1
Iron, total	1,393	7.8
Manganese, total	718	50.5
TSS	10,007	NA
Total	**13,573**	**152**

Table 8-4. Current Average Annual Effluent Loadings Per Outfall with AMD

Pollutant	Current Annual Effluent Loadings (lb/yr)	TWPE (lb-eq/yr)
Average Annual Loadings Per PA AMD Outfall		
Aluminum, total	731	47.3
Iron, total	1,628	9.1
Manganese, total	1,341	94.4
TSS	11,859	NA
Total	**15,559**	**151**

Source: *WVDMR*; and *PADEPInspector*.
TWPE – Toxic-weighted pound equivalent.
TSS – Total suspended solids.
NA – Not applicable. TSS does not have a TWF because it is not considered a toxic pollutant. Therefore, EPA can not calculate the TWPE.

8.4 Estimated Effluent Loadings if All Outfalls Meet 40 CFR Part 434 Subpart C NSPS Limitations (ELG Scenario Loadings)

EPA's comparison of effluent concentrations and 40 CFR Part 434 Subpart C NSPS limitations (Tables 5-7 through 5-10 in Section 5.2) shows that there are outfalls that discharge above the ELG limitations. As part of the loadings analysis, EPA estimated the annual pollutant loadings expected if all outfalls met the NSPS 30-day average limitation for all months during the year. To estimate the ELG Scenario Loadings, EPA followed the same steps as described in Section 8.2.

8.4.1 Measurement Value Selection

EPA reviewed the measurement values selected as part of the current effluent loadings analysis. If a quantity load measurement was used, EPA assumed the concentration value met the NSPS limits at 40 CFR Part 434 Subpart C. Less than one percent of the monthly samples were represented by quantity load measurements. If a concentration measurement was used, EPA compared the value to the limitation and did one of the following:

1. If the concentration was below or equal to the limitation, the measurement value was used.
2. If the concentration exceeded the limit, EPA set the measurement value for the *ELG Scenario Loadings* analysis equal to the 30-day average limitation: 3.0 mg/L for total iron, 2.0 mg/L for total manganese, and 35 mg/L for TSS.

8.4.2 Monthly and Annual Load Calculation

EPA calculated the monthly and annual pollutant loadings as outlined in Sections 8.2.2 and 8.2.3. A sensitivity analysis did not need to be performed on the ELG Scenario Loadings monthly load calculations. The concentrations for total iron, total manganese, and TSS used for the ELG Scenario Loadings are already adjusted to be no greater than the 40 CFR Part 434 Subpart C NSPS limitations.

As discussed in Section 8.2.3, some West Virginia outfalls did not report data for a particular pollutant for any month. For those outfalls EPA used the following median annual loadings for the ELG Scenario Loadings calculation:

- Total iron: 30.93 lb/yr;
- Total manganese: 19.71 lb/yr; and
- TSS: 757 lb/yr.

8.4.3 ELG Scenario Loadings Results

Table 8-5 presents the estimated ELG Scenario Loadings for each pollutant, along with the TWPE. Table 8-6 presents the average ELG Scenario Loadings per outfall with AMD.

Table 8-5. Estimated ELG Scenario Loadings at Mine Outfalls with AMD Located in West Virginia and Pennsylvania

Pollutant	Number of State Permit IDs and Outfalls	ELG Scenario Loadings (lb/yr)	TWF	TWPE (lb-eq/yr)
Annual Loadings for AMD Outfalls in West Virginia				
Aluminum, total	883 state permit IDs (3,295 outfalls)	4.80 million	0.0647	310,210
Iron, total		3.84 million	0.0056	21,514
Manganese, total		1.81 million	0.0704	127,356
TSS		32.05 million	NA	NA
WV Total		**42.5 million**		**459,080**
Annual Loadings for AMD Outfalls in Pennsylvania				
Aluminum, total	234 state permit IDs (333 outfalls)	0.24 million	0.0647	15,753
Iron, total		0.27 million	0.0056	1,500
Manganese, total		0.16 million	0.0704	11,085
TSS		3.2 million	NA	NA
PA Total		**3.9 million**		**28,338**

Sources: *WVDMR*; *PADEPInspector*.
TWF - Toxic weighting factor.
TWPE - Toxic-weighted pound equivalent.
TSS - Total suspended solids.
NA - Not applicable. TSS does not have a TWF because it is not considered a toxic pollutant. Therefore, EPA can not calculate the toxic-weighted pound equivalent of TSS.

Table 8-6. Estimated ELG Scenario Loadings Average Annual Effluent Loadings Per Outfall with AMD

Pollutant	ELG Scenario Loadings (lb/yr)	TWPE (lb-eq/yr)
Average Annual Loadings Per WV AMD Outfall		
Aluminum, total	1,455	94.1
Iron, total	1,166	6.5
Manganese, total	549	38.7
TSS	9,726	NA
Total	**12,896**	**139.3**
Average Annual Loadings Per PA AMD Outfall		
Aluminum, total	731	47.3
Iron, total	804	4.5
Manganese, total	473	33.3
TSS	9,693	NA
Total	**11,701**	**85.1**

Sources: *WVDMR*; *PADEPInspector*.
TSS - Total suspended solids.
TWPE - Toxic-weighted pound equivalent.
NA - Not applicable. TSS does not have a TWF because it is not considered a toxic pollutant. Therefore, EPA can not calculate the TWPE.

8.5 Pollutant Loadings Summary

EPA does not have the data available to identify the total number of AMD outfalls for each state, therefore the total state annual loadings presented may not include all AMD discharges. EPA identified 3,295 AMD outfalls in the West Virginia database (*WVDMR*) and 333 AMD outfalls in the Pennsylvania database (*PADEPInspector*).

EPA found that the average pollutant loading for total aluminum, total iron, total manganese and TSS at an AMD outfall falls between 13,000 and 16,000 pounds per year (151 to 152 lb-eq/yr). Discharges from all the AMD outfalls in *WVDMR* (3,295 outfalls) total 44.8 million lb/yr (502,451 lb-eq/yr). The number of AMD outfalls in *PADEPInspector* is about one-tenth of those in *WVDMR* (333 outfalls). The pollutant loadings from all the AMD outfalls in *PADEPInspector* total 5.2 million lb/yr (50,236 lb-eq/yr). Most of the pounds discharged are TSS; however the TWPE discharges (lb-eq/yr) include only the three metal parameters: total aluminum, total iron, and total manganese because TSS does not have a TWF.

Table 8-7 presents the current annual effluent loadings, ELG Scenario Loadings, and the difference between the two data sets.

Table 8-7. Comparison of Current Effluent Loadings and ELG Scenario Loadings at Mine Outfalls with AMD

Pollutant	Current Effluent Loadings		ELG Scenario Loadings		Difference in Pollutant Loadings if All Outfalls Met 40 CFR Part 434 Subpart C NSPS Limitations	
	Lbs/Yr	TWPE, lb-eq/yr	Lbs/Yr	TWPE, lb-eq/yr	Lbs/Yr	TWPE, lb-eq/yr
Average Annual Loadings for AMD Outfalls in West Virginia						
Aluminum, total	4.80 million	310,210	4.80 million	310,210	0	0
Iron, total	4.59 million	25,718	3.84 million	21,514	0.75 million (16%)	4,204
Manganese, total	2.36 million	166,523	1.81 million	127,356	0.55 million (23%)	39,167
TSS	33.0 million	NA	32.05 million	NA	0.95 million (3%)	NA
WV Total	**44.8 million**	**502,451**	**42.5 million**	**459,080**	**2.3 million (5%)**	**43,371 (9%)**
Average Annual Loadings for AMD Outfalls in Pennsylvania						
Aluminum, total	0.24 million	15,753	0.24 million	15,753	0	0
Iron, total	0.54 million	3,035	0.27 million	1,500	0.27 million (50%)	1,535
Manganese, total	0.45 million	31,448	0.16 million	11,085	0.29 million (64%)	20,363
TSS	3.95 million	NA	3.2 million	NA	0.75 million (19%)	NA
PA Total	**5.2 million**	**50,236**	**3.9 million**	**28,338**	**1.3 million (25%)**	**21,898 (44%)**

Source: *WVDMR; PADEPInspector*.
TWPE - Toxic-weighted pound equivalent.
TSS - Total suspended solids.
NA - Not applicable. TSS does not have a TWF because it is not considered a toxic pollutant. Therefore, EPA can not calculate the TWPE.

EPA's ELG Scenario Loadings (i.e., discharges assuming all outfalls equal or fall below 40 CFR Part 434 Subpart C NSPS 30-day average limitations) indicates that 2.3 million lb/yr from *WVDMR* outfalls with AMD and 1.3 million lb/yr from *PADEPInspector* outfalls with AMD are a result of discharges with concentrations higher than the ELGs. In terms of TWPE, the amount of baseline discharges resulting from discharges with concentrations higher than the ELGs are 43,371 lb-eq/yr for *WVDMR* outfalls with AMD and 21,898 lb-eq/yr for *PADEPInspector* outfalls with AMD.

8.6 Estimated Pollutant Loadings for Acid Mine Drainage References

1. OSMRE. U.S. Department of Interior. Office of Surface Mining Reclamation and Enforcement. 2006. Coal Production Index. Washington, DC. (November 4). Available online at: http://www.osmre.gov/coalprodindex.htm. Date accessed: March 5, 2007. EPA-HQ-OW-2006-0771-0044.

2. PADEPInspector. Pennsylvania Department of Environmental Protection. 2008. Treatment Facility Monitoring Data for Coal Mining Inspectable Units. (January 14). EPA-HQ-OW-2006-0771 DCN 05981A1.

3. U.S. EPA. 2006. *Technical Support Document for the 2006 Effluent Guidelines Program Plan*. EPA-821R-06-018. Washington, DC. (December). EPA-HQ-OW-2004-0032-2782.

4. U.S. EPA. 2007. Conference Call between Bob Agnew, Keith Brady, and Mike Smith, Pennsylvania Department of Environmental Protection, Tom Born, U.S. EPA, and Jill Lucy and Jessica Wolford, Eastern Research Group, Inc. (December 11). EPA-HQ-OW-2006-0771 DCN 05983.

5. WVDMR. West Virginia Department of Environmental Protection. 2006. Discharge Monitoring Reports for Coal Mines from April 2003 through March 2006. Charleston, WV. (Unknown). EPA-HQ-OW-2006-0771-0074.

9.0 POTENTIAL ENVIRONMENTAL IMPACTS FROM ACID COAL MINE DRAINAGE

Due to data limitations, EPA was able to conduct only a very limited analysis of potential impacts from total dissolved solids (TDS) (e.g., sulfates and chlorides), mercury, cadmium, manganese, and selenium in order to respond to comments that more stringent controls on these pollutants may be warranted.

EPA reviewed readily available literature and analyzed coal mine drainage information provided by Pennsylvania and West Virginia in order to better understand the potential for human health and aquatic life effects of these pollutants. EPA found limited information concerning documented environmental impacts. The discharge data provided by the states was difficult to use for the purpose of assessing potential impacts because of the small sample sizes for certain pollutants and inconsistencies across the data sets due to different collection purposes.

Moreover, EPA found no evidence in its literature review or through conversations with Pennsylvania and West Virginia state agencies to support comments that over-dosages or spills of treatment chemicals have caused fish kills or other significant stream damage.

9.1 AMD Environmental Impacts

AMD forms as stormwater and groundwater flow in mined areas, eventually discharging to surface water, typically headwater streams (U.S. EPA, 2001). Section 5.1.2 of this study describes AMD formation and wastewater characteristics in more detail. As a result of AMD, surface water throughout Appalachia is impaired (U.S. EPA, 2001), and even groundwater is impaired (McAuley, 2006).

In stream waters with low pH and elevated[11] iron concentrations, streambeds are typically coated with ferric iron (“yellow boy”) and aquatic life is limited or not present (U.S. EPA, 2001). Scientists have documented the impacts of acidity and iron on surface water throughout the United States (U.S. EPA, 2006a). Acidity mobilizes metals and causes the most aquatic toxicity and fish kills in streams impacted by coal mine drainage (U.S. EPA, 2005).

As discussed in the U.S. EPA 2006 Wadeable Streams Assessment, 2 percent of U.S. stream length (14,763 miles) is impacted by anthropogenic acidification. In Appalachia (the Eastern Highlands region), 3.4 percent (9,396 miles) of stream length is impacted (U.S. EPA, 2006a). Figure 9-1 shows the streams impacted by AMD in EPA Region 3 as of 1995. The red lines are streams with no fish, while the blue lines are streams with reduced quantity of fish due to AMD discharges. Additionally, in 1996 the West Virginia Department of Environmental Protection identified 17 of 51 priority streams in the state that were impacted by AMD, while 469 non-priority streams were identified as impacted by AMD (Faulkner, 1998).

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[11] Above the 40 CFR Part 434 NSPS limitations (3.0 mg/L 30-day average and 6.0 mg/L daily maximum).

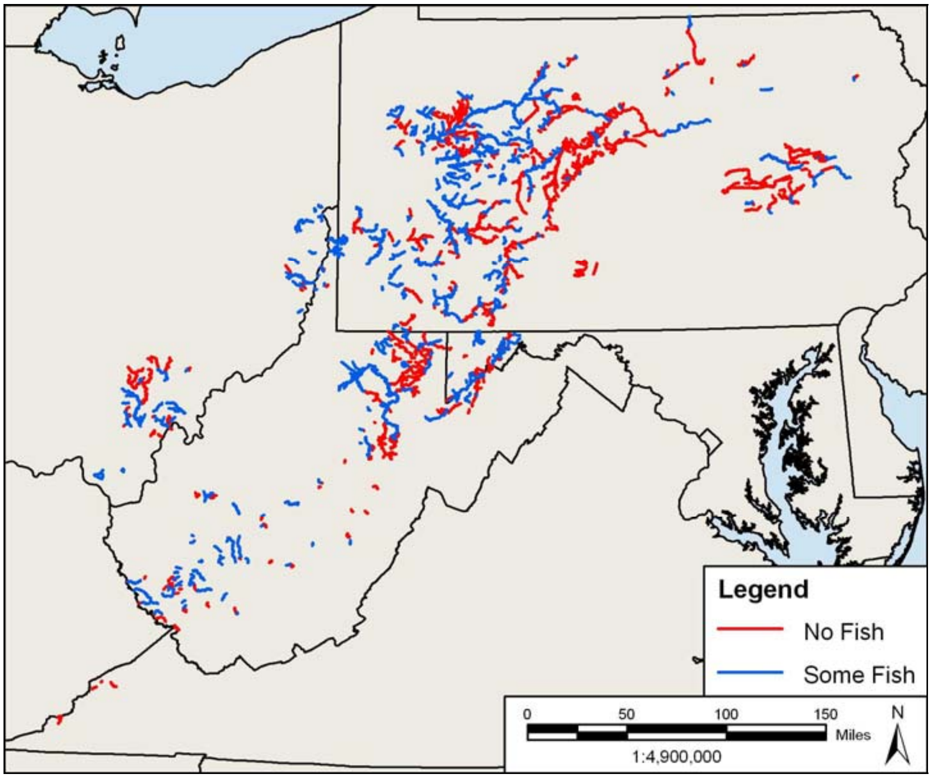

Figure 9-1. Distribution of Streams Impacted by Acid Mine Drainage in EPA Region 3
Source: Acid Mine Drainage Inventory in West Virginia (Faulkner, 1998).

9.2 Water Quality Criteria

In this study, EPA compared concentrations of pollutants in AMD to national and state water quality criteria. The water quality criteria are used in conjunction with the Coal Mining Effluent Limitations Guidelines and Standards (ELGs) in Part 434 to determine permit limits for coal mines, as described in Section 4.1. EPA establishes National Regional Water Quality Criteria (NRWQC) as required by Section 304(a)(1) of the Clean Water Act (CWA). The NRWQC are based on data and scientific judgments on pollutant concentrations and environmental or human health effects. The CWA requires numeric water quality criteria for priority toxic pollutants and any pollutant that would interfere with or degrade a water body's use. For each pollutant, EPA recommends criteria for the following (U.S. EPA, 2006b):

- Freshwater: acute and chronic;
- Saltwater: acute and chronic; and
- Human health for the consumption of:
  - Water plus organism; and
  - Organism only.

States are also required to establish water quality criteria by Section 303(c)(2)(B) of the CWA for the pollutants that EPA has published criteria. States can establish water quality criteria by completing the following:

- Adopting the criteria that EPA publishes under Section 304(a) of the CWA;
- Modifying the Section 304(a) criteria to reflect site-specific conditions; or
- Adopting criteria based on other scientifically-defensible methods.

For each pollutant, states can choose to adopt EPA's criteria for one environmental impact but establish a criterion for the other impacts. For example, a state may adopt EPA's freshwater criteria for a pollutant but determine a criterion for human health consumption based on other scientific data. States also have the option of establishing criteria for pollutants that EPA has not published criteria. Pennsylvania and West Virginia established their own water quality criteria, some of which are based on the NRWQC.

As part of this review of AMD environmental impacts, EPA compared the effluent pollutant concentrations for five pollutants to federal and state water quality criteria for Pennsylvania and West Virginia, where available. Table 9-1 lists the simplified water quality criteria while Table 9-2 presents the effluent AMD concentrations for the five pollutants raised in stakeholder comments. Table 9-1 presents federal and state water quality criteria in a simplified form: it presents only the lowest criteria for each pollutant to compare them to the concentrations in the effluent AMD.

9.3 Potential Impacts from Manganese in Coal Mine Drainage

EPA was able to find only very limited peer-reviewed information on the aquatic toxicity of manganese. EPA did not identify studies of the long-term effects of manganese concentrations on the diversity of the aquatic organism population.

In general, manganese discharges to surface water may have varying effects depending on the hardness of the receiving water body. The State of Colorado, for example, considers hardness when determining water-quality based limits for manganese (5 CO State Code §1002-31). Aquatic species' manganese uptake has been shown to increase with temperature and decrease with pH, relating toxicity to pH and temperature (WHO, 2004). These varying water chemistry factors make it difficult to draw conclusions about the overall potential for manganese impacts without considering the chemistry of individual receiving water bodies.

EPA identified three studies which documented the following human health effects from manganese:

- Time to Re-evaluate the Guideline Value for Manganese in Drinking Water? (Ljung and Vahter, 2007): Inhalation and ingestion can have neurological effects.
- *Effect of Enhanced Manganese Oxidation in the Hyporheic Zone on Basin-Scale Geochemical Mass Balance* (Hafeman *et al*., 2007): In Bangladesh, manganese in groundwater possibly increases infant mortality.

Table 9-1. Water Quality Criteria for AMD Pollutants of Concern [a]

Pollutant	Federal		West Virginia		Pennsylvania	
	Criteria	Basis	Criteria	Basis	Criteria	Basis
Cadmium	0.00025 mg/L	Aquatic	Depends on hardness.	Aquatic	0.0005 mg/L	Aquatic
Manganese	0.05 – 0.1 mg/L	PWS (organoleptic effects)	1 mg/L	Human Health	1 mg/L	PWS
Mercury	0.00077 mg/L	Aquatic (0.3 mg/kg human health)	0.00014 – 0.00015 mg/L	Human Health	0.000005 mg/L	Human Health
Selenium	0.005 mg/L	Aquatic (0.17 mg/L human health)	0.005 mg/L	Aquatic	0.0046	Aquatic
Total Sulfates [b]	No federal or West Virginia water quality criteria established				250 mg/L	PWS

Sources: National Recommended Water Quality Criteria (U.S. EPA, 2006b); 25 PA Code §93.7; 47 WV Code §2-8.

a – Only the lowest (most stringent) criteria are shown for each pollutant. See 25 PA Code §93.7 and 47 WV Code §2-8 for the full list, including the basis and values for acute, chronic, aquatic, and human health criteria.

b – The total sulfates concentration is an indicator for total dissolved solids.

PWS – Potable water supply.

Table 9-2. Effluent AMD Concentrations for AMD Pollutants of Concern [a]

Pollutant	*PADEPInspector* Database					*WVDMR* Database				
	Total Number of Data Points	Number of Data Points BDL	Minimum Result (mg/L)	Average Result (mg/L)	Maximum Result (mg/L)	Total Number of Data Points	Number of Data Points BDL	Minimum Result (mg/L)	Average Result (mg/L)	Maximum Result (mg/L)
Cadmium	7	1	0.0064	0.0095	0.013	39	3	0.000001	0.0013	0.01
Manganese	4,317	403	0.01	4.96	114.00	41,859	4,166	0.001	0.60	80.50
Mercury	7	7	NA	NA	NA	236	9	0.0000001	0.15	1.00 [b]
Selenium	7	6	0.0013	0.0013	0.0013	1,290	166	0.0000004	0.59	35.37
Total Sulfates [c]	4,321	24	20.10	889.91	11,349.20	164	0	7.72	444.93	4,507.00

Sources: *PADEPInspector*; *WVDMR*.

a – Concentrations observed in effluent AMD (after treatment, just prior to discharge to streams).

b – This range excludes an outlier of 5 mg/L.

c – The total sulfates concentration is an indicator for total dissolved solids.

BDL – Below detection limit.

NA – Not applicable. All of the results were BDL.

- Toxicological Profile for Manganese (ATSDR, 2000): Manganese in drinking water (as low as 0.241 mg/L in drinking water) can have adverse neurological effects in children.[12]

The NRWQC for total manganese for the consumption of water and organisms is 0.050 mg/L, which is the National Secondary Drinking Water Regulation limit.[13] This recommended limit is not based on toxic effects, but rather is intended to minimize objectionable organoleptic effects (U.S. EPA, 2006b). In addition, the NRWQC also lists a human health limit of 0.100 mg/L for the consumption of organisms only (see Table 9-1). The NRWQC does not provide any recommendation for acute or chronic criteria for salt or freshwater (U.S. EPA, 2006b). Pennsylvania and West Virginia have each set their water quality criteria for potable water supplies at 1 mg/L total recoverable manganese (25 PA Code §93.7; 47 WV Code §2-8). However, both states are flexible in considering the distance from potable water intakes in determining their permit limitations (see Section 4.1.2).

The data provided to EPA by Pennsylvania and West Virginia indicate varying concentrations of manganese in AMD discharges, with manganese concentrations ranging from below the detection limit to 114 mg/L in treated drainage, and from below the detection limit to more than 500 mg/L in untreated drainage (*PADEPInspector*; *WVDMR*; *ARAMD*). In typical streams without mine drainage influence, the manganese concentration is generally less than 0.2 mg/L (WHO, 2004). Toxic effects have been shown to start occurring around 2 mg/L (WHO, 2004).

9.4 Potential Impacts of Cadmium in Coal Mine Drainage

EPA found no documentation of impacts from cadmium in Appalachian coal mine drainage. Concentrations of cadmium that can cause acute toxicity in aquatic organisms range from 0.001 mg/L to 135 mg/L according to EPA's NRWQC. For freshwater aquatic plants, the range is from 0.002 to 7.4 mg/L. Chronic cadmium exposure can result in declines in growth and reproduction or death of aquatic organisms (U.S. EPA, 2006b).

The cadmium NRWQC are based on the following (U.S. EPA, 2006b):

- Human health protection from ingestion of water and contaminated organisms: 0.01 mg/L.
- Four-day average concentration (in mg/L) in freshwater is not to exceed (0.0007852 [ln(hardness)]-3.490) more than once every three years.
- One-hour concentration (in μg/L) in freshwater is not to exceed (0.001128 [ln(hardness)]-3.828) more than once every three years.

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[12] EPA also reviewed the Concise International Chemical Assessment Document 63: Manganese and Its Compounds: Environmental Aspects (CICAD 63) by the World Health Organization (WHO, 2004). The CICAD 63 refers readers to the Concise International Chemical Assessment Document 12: Manganese and Its Compounds (CICAD 12) for information on the human health effects from manganese (WHO, 1999). EPA reviewed the CICAD 12 and determined that the information contained within and references were the same as provided in the Toxicological Profile for Manganese (ATSDR, 2000).

[13] National Secondary Drinking Water Regulations set limits above which cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) may occur in drinking water. However, secondary regulations are not enforceable.

- Four-day average concentration in saltwater is not to exceed 0.0093 mg/L more than once every three years.
- One-hour concentration in saltwater is not to exceed 0.043 mg/L more than once every three years.

As presented in Table 9-2, the limited data provided to EPA by Pennsylvania and West Virginia indicate that total cadmium concentrations in treated AMD ranged from below the detection limit to 0.01 mg/L. Pennsylvania and West Virginia, however, rarely sample for cadmium in coal mine discharges.

9.5 Potential Impacts of Mercury in Coal Mine Drainage

EPA found no documentation of impacts from mercury in Appalachian coal mine drainage. EPA requires mercury concentrations in drinking water to be less than 0.002 mg/L (40 CFR Part 141). Concentrations of mercury that can cause acute toxicity in aquatic organisms range from 0.0022 mg/L to 2 mg/L according to EPA's NRWQC. The most toxic form of mercury is methylmercury, which is formed when microorganisms bind non-biologically available forms of mercury with organic molecules in the environment to convert it to a biologically available form. Methylmercury can bioconcentrate, leading to severe chronic human health and aquatic impacts (U.S. EPA, 2006b).

The dissolved mercury NRWQC are based on the following (U.S. EPA, 2006b):

- Human health protection from ingestion of water and contaminated organisms: 0.000144 mg/L.
- Human health protection from consumption of contaminated aquatic organisms alone: 0.000146 mg/L
- Four-day average concentration in freshwater is not to exceed 0.000025 mg/L more than once every three years.
- One-hour concentration in freshwater is not to exceed 0.0024 mg/L more than once every three years.
- Four-day average concentration in saltwater is not to exceed 0.000012 mg/L more than once every three years.
- One-hour concentration in saltwater is not to exceed 0.0021 mg/L more than once every three years.

As presented in Table 9-2, the data provided to EPA by Pennsylvania and West Virginia indicate that total mercury concentrations in treated AMD range from below the detection limit to 1 mg/L. Pennsylvania and West Virginia, however, rarely sample for mercury in coal mine discharges.

9.6 Potential Impacts from Selenium in Coal Mine Drainage

Recent United States Geological Survey studies indicate that selenium in varying concentrations has the potential to occur with coal seams throughout the Appalachian region (USGS, 2005; USGS, 2007). The 2003 *Draft Programmatic Environmental Impact Statement* for mountain top mining and valley fills concluded that there is the potential for selenium from valley fills to impact the aquatic environment and possibly to effect higher organisms that feed on aquatic organisms (U.S. EPA, 2003).

Selenium affects both aquatic life and human health. Concentrations above the draft NRWQC for selenium (0.005 mg/L) for aquatic organisms could impact fish reproduction and birds that prey on fish. Selenium may not impact macroinvertebrates directly, but will bioaccumulate in the food chain in both lentic (running water) and lotic (standing water) aquatic systems (U.S. EPA, 2005). Although essential to mammals in small amounts, it rapidly becomes toxic (Bryant et al., 2002).

The draft selenium NRWQC are based on the following (U.S. EPA, 2006b):

- 0.005 mg/L for chronic aquatic toxicity. This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996- CMC or 0.922- CCC) that was used in the GLI to convert this to a value that is expressed in terms of dissolved metal.
- 0.17 mg/L for human health for both water and organism consumption.

Pennsylvania established water quality criteria for selenium of 0.00461 mg/L, as well (25 PA Code §16.61).

As presented in Table 9-2, data provided to EPA by Pennsylvania and West Virginia indicate that total selenium concentrations in treated AMD range from below the detection limit to 35.37 mg/L, though the Pennsylvania database is very limited.

9.7 Potential Impacts from Total Dissolved Solids in Coal Mine Drainage

Recent research conducted by EPA Region 3 and EPA's Office of Research and Development have concluded that surface mining with valley fills has impaired the aquatic life of numerous streams in the Central Appalachian Mountains due to high levels of common constituents of TDS such as bicarbonate, calcium, magnesium, and sulfate. TDS can disrupt water balance and ion exchange processes causing stress or death of aquatic organisms. TDS concentrations tend to be higher downstream of valley fills in mountaintop mining. More specifically, the research found that in streams receiving valley fill mine drainage, entire orders of aquatic organisms, such as mayflies which are common indicator of aquatic health, were nearly eliminated. Further studies are being conducted to better understand the geographic extent, magnitude, and aquatic life impacts of TDS in coal mining discharges (Pond et al., 2008)

For the purpose of this study, EPA reviewed information about sulfates because it is a potential component of TDS in Appalachian coal mining areas. Ambient fresh water sulfate concentrations range from 5 to 20 mg/L. Sulfates concentrations in mining areas can range from 50 to thousands of mg/L, depending on oxidation rates, amounts of sulfide materials present in overburden material, and the extent of mining disturbance (U.S. EPA, 2003). EPA has not developed NRWQC for sulfates. Pennsylvania, however, set water quality standards of 250 mg/L, based on impacts to streams serving as potable water supply (25 PA Code §93.7). As presented in Table 9-2, data provided to EPA by Pennsylvania and West Virginia indicate that total sulfate concentrations in AMD ranged from below the detection limit to 11,349 mg/L.

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10.0 THE ROLE OF MANGANESE TREATMENT COSTS IN BOND FORFEITURES

EPA reviewed trends in coal mine bonding to respond to comments that coal mining operators have forfeited reclamation bonds because of the cost of long-term acid mine drainage (AMD) treatment to meet manganese permit limits. EPA focused on forfeiture trends in Pennsylvania and West Virginia because they are the states in which AMD is most prevalent. EPA reviewed technical literature and asked the mining personnel within Pennsylvania Department of Environmental Management (PA DEP) and West Virginia Department of Environmental Management (WV DEP) for their best estimates of the extent to which manganese treatment costs played a role in past bond forfeitures. EPA also discussed the potential for future bond forfeitures with personnel in PA DEP and WV DEP.

Based on information received from PA DEP and WV DEP, EPA concluded that only a small percentage of coal mine bond forfeitures are due to the cost of manganese treatment. Overall, EPA found forfeitures are largely a legacy of the first decade of the Surface Mining Control and Reclamation Act (SMCRA) implementation during the 1980s and early 1990s. EPA's analysis indicates that there is little potential for future bond forfeitures on SMCRA permits that have been granted during the past five years. Similarly, EPA believes that current trends will continue, making it unlikely that companies will forfeit bonds on permits that will be issued in the future. As described in Section 4.2, SMCRA requires a Probable Hydrologic Consequence (PHC) analysis prior to approval of the SMCRA permit. The PHC includes a determination of the impact the proposed mining will have on these baseline conditions of the site. When potential adverse impacts are identified (e.g., AMD) through use of the PHC, appropriate protection, mitigation, and rehabilitation plans are developed and included in mining and reclamation permit requirements. If the potential adverse impacts cannot be sufficiently mitigated the SMCRA permit may be denied. The ultimate goal of using the PHC in the SMCRA permit review is to prevent AMD after land reclamation is complete and the SMCRA bond is released. Neither PA DEP and WV DEP issue SMCRA permits if the PHC identifies AMD as a potential adverse impact. PHC analytical techniques have evolved over time due to increasing knowledge. The current methods for PHC analysis are more advanced and can adequately predict AMD formation, where as in the past predictions were not as accurate. Based on the advancements in the PHC analysis, PA DEP anticipates that less than one percent of recently SMCRA permitted mines will develop AMD after reclamation.

10.1 <u>Mine Reclamation Bonds and Bond Forfeiture</u>

Under the SMCRA of 1977, coal mine operators must apply for a mining permit before mining activities may start. Although SMCRA sets the minimum requirements for obtaining a permit, permitting authority is generally delegated to each state if the state regulations are at least as stringent as SMCRA (see Section 4.2).

For permit approval, the operator must show how the mine site will be reclaimed after mining is complete. Reclamation includes regrading and revegetating the site to a degree equivalent to its pre-mining use, sealing mine shafts and portals, removing ponds and other surface water control structures, and other similar activities. In addition to demonstrating how the site will be reclaimed, the mine operator must post a "performance bond" to cover the reclamation cost if the operator fails to adequately complete reclamation. The bond, often called a reclamation bond, is a financial guarantee that the site will be reclaimed.

The permitting authority determines if the site has been adequately reclaimed. If reclamation is complete, then the bond is "released," or returned to the operator (or the operator's guarantor). If the operator fails to complete reclamation, then the bond is forfeited and the proceeds from the bond are used by the permitting authority to complete site reclamation.

States stipulate that if AMD occurs bonds cannot be released until treatment is no longer necessary to comply with permit limits. This has resulted in permits where land reclamation is complete, but bonds cannot be released because long-term treatment of AMD is required. Operators must renew their bonds every five years. In the comments that EPA received from state mining agencies and through discussions, States indicated that they are concerned that at some point in the future operators may default rather than renew their bonds. States reasoned that if manganese limits were less stringent, and thus less expensive to meet, then operators would be less likely to default.

10.1.1 Bond Types

The size of the reclamation bond is determined by the permitting authorities. Although the bond amount is based on the reclamation plans and cost estimates of the permit applicant, authorities are not limited to those estimates (30 CFR 800.11). The bond amount is designed to reflect the probable difficulty of reclamation given geography, hydrology, climate, and other factors, and must be sufficient to assure completion of reclamation if the operator defaults on the bond (30 CFR 800.14).

Regulatory agencies have the authority to adjust required bond amounts periodically to account for changes in mining operations and the projected cost of future reclamation (30 CFR §800.15). Although not required by SMCRA, the Office of Surface Mining Reclamation and Enforcement (OSMRE), the SMCRA regulatory authority, states that mine discharge is one reason for increasing the bond amount (67 FR 35070, May 17, 2002). In Pennsylvania and West Virginia, regulatory authorities will not issue a mining permit if the PHC of mining evaluation shows that AMD will result. Therefore, in these two states, the initial bond requirement does not include any costs for treating AMD. Thus, if AMD occurs during mining, the authorities will increase the bond amount.

Performance bonds can take one of three forms (30 CFR 800.12):

- Surety bonds;
- Collateral bonds; and
- Self-bonding.

10.2 Trends in Bond Forfeitures

EPA obtained data on all coal mining permits with forfeited bonds from the OSMRE, Applicant/Violator System Office for 1977 through 2007. The office hosts the Applicant/Violator System (AVS) to which states report mining violations. Section 501(c) of SMCRA prohibits the issuance of new permits to applicants who own or control operations with outstanding violations. A violation includes a forfeited bond on a permit. The database includes the date when the bond was forfeited (AVS, 2007a; AVS, 2007b), but does not include the reason for the forfeiture, the bond amount, or the acreage of the site (DeVinney, 2007).

Based on the information in the AVS database, the Appalachian region is the area most affected by bond forfeitures. As shown in Figures 10-1 and 10-2, forfeitures peaked in the mid- to late 1980s.[14]

10.3 Reasons for Forfeitures

EPA received information from Pennsylvania and West Virginia mining agencies concerning estimates of the extent to which manganese treatment costs played a role in the forfeitures during the past five to 10 years.

10.3.1 Pennsylvania

Table 10-1 summarizes the PA DEP list of 227 mine permits for which bond forfeiture actions were initiated after January 1, 1998. Overall, the PA DEP list shows that manganese treatment played a major role in 125 cases (55 percent) of defaults.

In its review of data associated with these defaults, however, EPA believes that this count may be overstated. There is no easy and objective way to determine the exact influence of the cost of manganese treatment. In some cases, companies declared bankruptcy due the cost of manganese treatment at one site and thus forfeited permits (and, therefore, the associated bonds) at other sites where treatment was not required. In other cases, the bankruptcy of one company resulted in the bankruptcy and forfeitures of permits and bonds by its subsidiaries. In such instances, the state classified all forfeited permits and bonds as due to the cost of manganese treatment. The information from Pennsylvania presented in Table 10-1 thus shows a higher proportion of bond forfeitures due to manganese treatment costs than if an analysis were done on a permit specific basis. Of the 125 sites where manganese treatment costs were considered to play a major role in the forfeiture, 42 sites have no discharge (PA DEP, 2008).

Table 10-1. Role of Manganese Treatment Costs in Bond Forfeiture by Site - Pennsylvania

Role of Manganese Treatment Costs in Bond Forfeiture	Count	Percent (%)
Major	125	55
Minor	7	3
None	95	42
Total	**227**	

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[14] In 1987, Kentucky changed mining regulations, requiring the closure of all mines smaller than two acres. This regulatory change likely influenced the high number of bond forfeitures in that state in the late 1980s. As noted earlier, AMD and manganese treatment are much less likely to occur in Kentucky due to its geography.

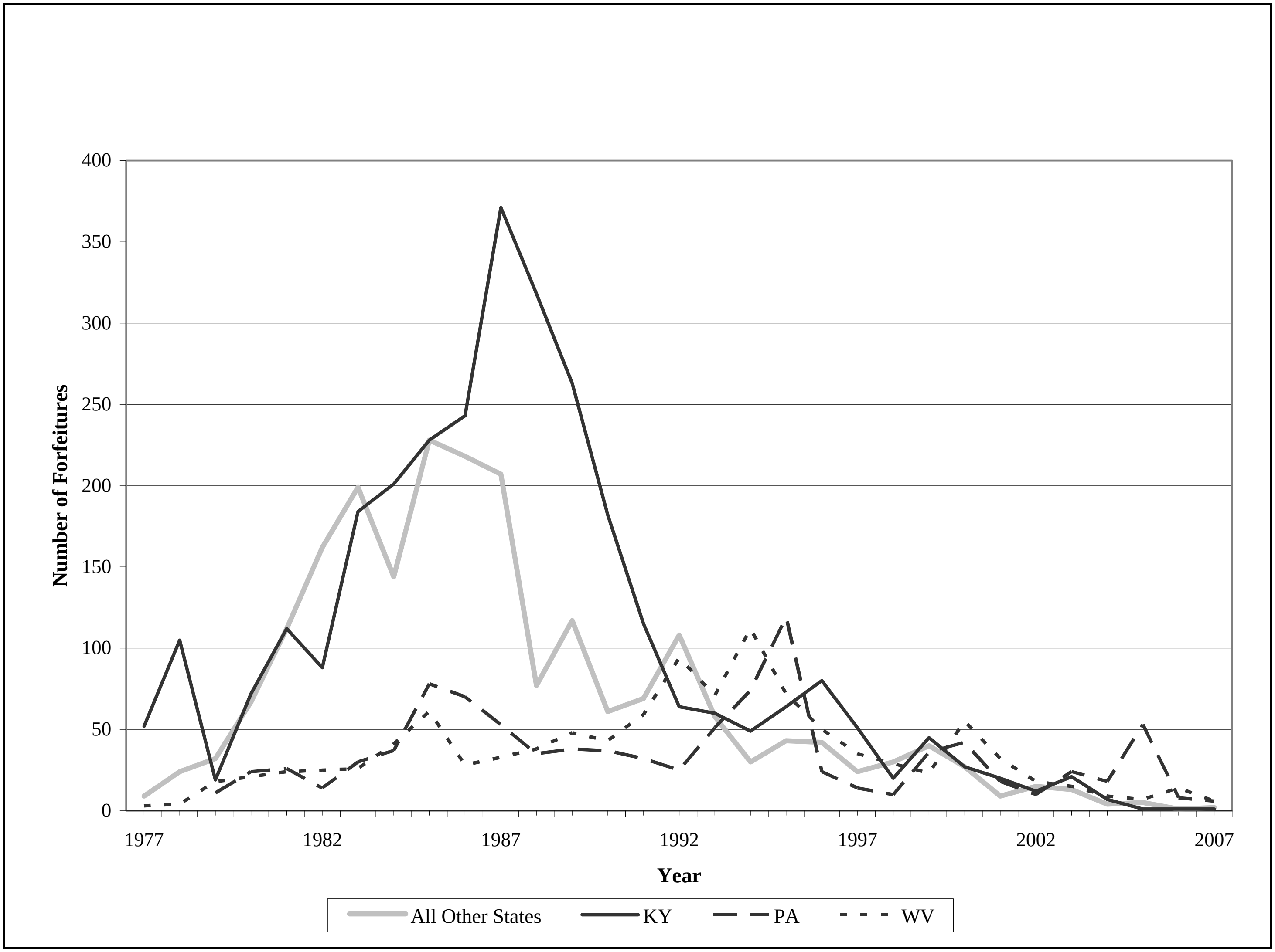

Figure 10-1. Number of Permits with Bond Forfeitures: Appalachian States, 1977-2007

Source: Personal communication with Charles DeVinney, Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Applicant/Violator System Office, and Maureen F. Kaplan, Eastern Research Group, Inc. (DeVinney, 2007).

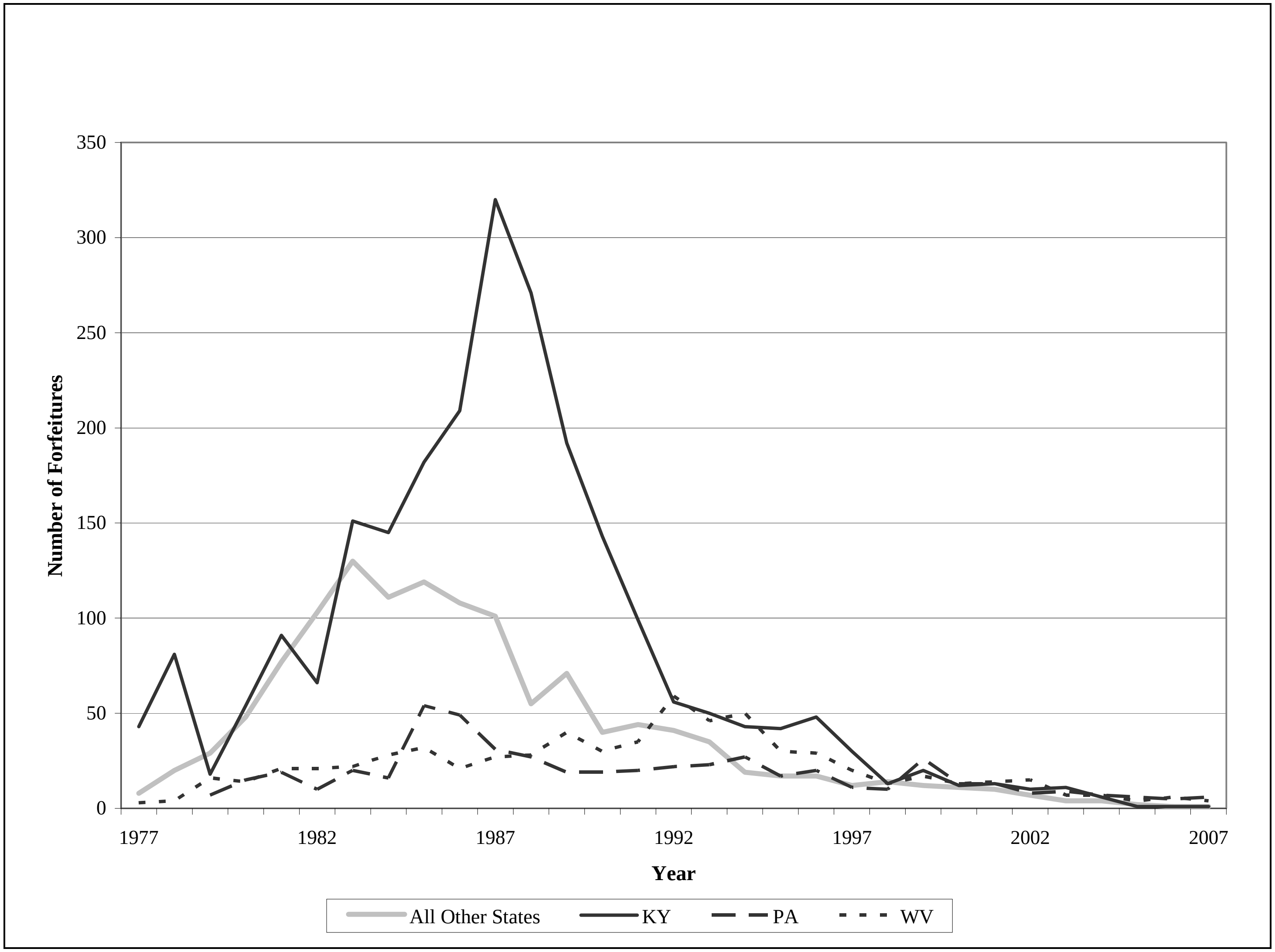

Figure 10-2. Number of Companies with Bond Forfeitures: Appalachian States, 1977-2007

Source: Personal communication with Charles DeVinney, Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Applicant/Violator System Office, and Maureen F. Kaplan, Eastern Research Group, Inc. (DeVinney, 2007).

10.3.2 West Virginia

The WV DEP provided EPA with summary information about forfeitures (Halstead, 2008). West Virginia has more than 1,800 mining permits as of 2008. Since June 30, 2001, there were 127 forfeitures, 23 of which have discharges that require treatment. WV DEP considered the cost of manganese treatment to have played a major role in four of those forfeitures (17 percent), while WV DEP considered the cost of manganese treatment to have played a minor role in eight of the forfeitures (35 percent).

10.4 Potential for Future Bond Forfeitures

States do not issue permits to mining operations if there is a likelihood of AMD. As a result of discussions with states and underwriters, EPA examined the predictability and likelihood of AMD and how they have changed over time.

The long-term downward trends in the number of forfeitures seen in Figures 10-1 and 10-2 are consistent with an improving ability to predict AMD in the pre-SMCRA permitting PHC analysis. The influence of improved PHC analysis on bond forfeiture rates will not be seen until the recently permitted mines complete coal extraction in 20 or more years. In Pennsylvania, approximately 15 to 20 percent of the permits issued in the early 1980s resulted in post mining discharges. Due to advances in PHC analysis, Pennsylvania now believes that less than one percent of the permits issued have the potential for long-term post mining discharges that do not meet 40 CFR Part 434 (PA DEP, 2000; Pizarchik, 2008).

10.5 The Role of Manganese Treatment Costs in Bond Forfeitures References

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